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The model of root spreading and belowground competition in boreal mixed forests

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Highlights: New model of belowground competition is proposed. The model is operating on simulation grid and can simulate growth of root systems in mixed stands taking into account the irregularity in horizontal and vertical distribution of roots' biomass. The main outputs are the density of roots in each cell and amount of nutrients captured by each tree.

Keywords: belowground competition, root systems, mixed forests

The model is spatially-explicit. It allows describing the competition between trees for soil nutrients. The area of simulation is represented as two-dimensional grid consisting of cells of equal size. Each tree has exact spatial location, and its zone of nutrition is represented as array of cells. The tree-specific area of nutrition is calculated on the basis of average (*l_avg*) and maximal (*l_max*) root spreading distance. These two parameters, in turn, are calculated on the basis of stem diameter at breast height using logistic equation $l=a/(1+b*e^{-c*DBH})$. The coefficients *a*, *b*, *c* of equation were calculated from the experimental data using regression analysis. Since maximal and average root spreading distances decrease with increasing soil fertility and moisture, these parameters have site-specific modifiers: $l=l*m_{moist}*m_{fert}$. In the first stage of simulation, potential area occupied by rooting system is calculated based on average root spreading distance as square of circle with radius equal to *l_avg*: $S_{n\_zone}=Pi*l\_avg^2$. The next stage is the determination which cells are occupied by rooting system of the tree. To calculate the preferability of including of each cell into the area of nutrition the parameter *p* is used. It is calculated as $p=d^{-1}*m^{-1}*n$, where *d* is the distance between current cell and the rooting cell of focal tree, *m* is the mass of roots of other species, and *n* is the amount of available nutrients (nitrogen etc.) in the current cell. Parameter *p* is calculated for all cells inside the potential zone of nutrition (circle with *R*=*l_max*) but not included into the actual zone of nutrition yet. Therefore, the cells with the highest values of *p* will be included first. There are two restrictions which should be taken into account: (1) the distance from each cell included into the nutrition area to the rooting cell cannot be more than maximal root spreading distance for the given tree and (2) all cells, forming the area of nutrition of the given tree, must be arranged in continuous connected contour. Nutrition zones of different trees can overlap. The horizontal distribution of biomass of roots is depended on the distance from the stem. Vertical distribution (implemented as independent calculation of root portion for forest floor and mineral soil) depends on species-specific features, soil characteristic and strength of belowground competition (amount of roots of other plants). Model independently calculates distribution for coarse and fine roots. The nutrients from each cell are distributed between competing trees proportionally to the biomass of their fine roots in given cell with species-specific modifiers. The main outputs from the model are the spatial distribution of biomass of roots and the amount of nutrients captured by each tree. This will allow simulating asymmetric competition between different species, which gives comprehensive facilities for realistic modelling of mixed forests. The value of uptake of nutrients can be used as driving variable for calculation of annual increment of biomass of tree. The model also can be used for simulation of vegetative propagation of trees. This work was supported by the Russian Foundation for Basic Research, grant number 12-04-31635 and the Academy of Finland, project numbers 140766 and 257845.