Retrieving the forest species composition from remote sensing data using a three-dimensional radiative transfer model

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A three-dimensional model was developed to derive the reflection, absorption and transmission of photosynthetically active radiation (PAR) by a non-uniform forest canopy with a multi-species structure (Levashova et al., 2018). The model algorithm describing solar radiation transfer through a forest canopy considers direct and diffuse radiation penetrating through gaps in the canopy, transmitted by leaves and reflected from leaves, bark and soil surface. To estimate the canopy the reflection, absorption and transmission the model uses external data about 3D structure of each tree species in the forest stand, about the spectral properties of photosynthesizing and non-photosynthesizing parts of the different trees species, and about spectral reflectance of soil surface. Moreover it uses also information about incoming solar radiation, sun elevation, the ratio of incoming direct and diffuse solar radiation, and surface topography. The model is based on steady-state transport equations initially suggested by Ross (Ross, 1981) and further developed and described by Myneni and Knyazikhin (Myneni et al., 1990; Knyazikhin et al., 2005). Calculation of the direct solar radiation fluxes within the canopy is based on estimation of the probability that a ray of light passing through the foliage reaches a given location within the canopy without interception. Diffuse solar radiation is calculated taking into account both diffuse solar radiation from the sky penetrating through foliage gaps and direct and diffuse radiation scattered by canopy foliage and woody components. The numerical scheme for solving the integro-differential equations is based on the discrete ordinates method.

The model was used to describe the spatial patterns of solar radiation reflection and transmission by non-uniform mixed forest canopy and to develop an algorithm that allows to retrieve the proportion of different tree species in a mixed forest stand from measured canopy reflection coefficients for blue, green, red and near-infrared spectral bands (obtained from e.g. the Landsat satellite imagery). This approach allowed us to quantify the proportion of different tree species (both coniferous and deciduous) in a forest stand in case if their spectral reflection properties of the leaves are not the same. The accuracy of assessing the proportion of vegetation species using this method depended on the number of reflection measurements under various solar conditions (e.g. different sun elevations) that can reached by several measurements during the growing seasons. An increase of the input data volume (determined by the number of the measurements) resulted in higher accuracies for prediction of the proportions of different tree species.

References

Knyazikhin Y., Marshak A., Myneni R.B. Three dimensional radiative transfer in vegetation canopies. In: Three Dimensional Radiative Transfer in the Cloudy Atmosphere, Marshak, A., Davis, A.B., Eds., Springer Verlag: Berlin, Heidelberg, 2005, 617-652.

Levashova N., Lukyanenko D., Mukhartova Y., Olchev A. Application of a three-dimensional radiative transfer model to retrieve the species composition of a mixed forest stand from canopy reflected radiation. Remote Sensing, 2018, 10 (10), 1661.

Myneni R.B., Asrar G., Gerstl S.A.W. Radiative transfer in three dimensional leaf canopies. Transport Theory and Statistical Physics, 1990, 19, 205–250.

Ross J. The radiation regime and architecture of plant stands; Dr. W. Junk Publishers: The Hague, Netherlands, 1981, 390 p.

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