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Towards improved modeling of forest management in land surface models employed in climate research

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Forest management alters both the spatial distribution of tree species and the temporal development of forest structural attributes that influence surface fluxes. The large variability in forest structure is not sufficiently represented in land surface models because the underlying land cover maps have a limited number of forest types which are not fully representative of the diversity in species and structural attributes. Here, we show how national forest inventory (NFI) data can be used to enhance forest classifications of existing land cover products to improve the spatial variability in forest structure and facilitate the modeling of forest temporal development in climate model simulations of forest management activities. Novel semi-objective clustering approach was developed to obtain a Land Cover (LC) -dependent Look-Up Table (LUT) of forest structure which reflects the transient nature of the key forest structural attributes in a managed forest. The forests were first divided into three species groups based on the most abundant species, and the optimal number of structural groups within each species group was determined based on a trade-off curve between total within-cluster sum of squares (i.e. variability) and number of clusters. Given the optimal number of clusters, k-medoids clustering was used to form the clusters in 4D-space of forest structural attributes (i.e. leaf area index, stand total stem volume, Lorey's height and crown length) obtained from NFI data. Mahalanobis distance was used to determine class-memberships of the 4D clusters and form 2D class membership grids to allow classifying the forests using two of the most common forest variables obtained from NFIs. Medians of the clusters were selected to form a LUT of forest structural attributes. Classification was applied spatially for NFI map data to allow application of the LUT, and the classified forest classes were fused with the most recent ESA CCI LC-product (v.2.0.7) to obtain a complete surface representation. To forecast the development of forests, a set of rules was developed, based on NFI data and environmental data, to allow simulation of future structural development via changes to the forest class. Transitions between different forest classes (i.e. growth) were modeled based on transition matrix using air temperature and soil data as covariates. The impact of 'business-as-usual' harvests on distribution of forest classes was estimated based on NFI data. The distribution of forest classes can be predicted by employing a growth transition matrix and class-harvest probabilities iteratively. Simulation of the impacts of different harvesting intensities on forecasted forest structural attributes can be investigated by adjusting the harvest-class probabilities. In essence, our framework describes the current state of forests in the form of a land cover map with corresponding LUT of key forest structural attributes, which can be used to prepare surface data in a land surface model. Simulating the change in structure over time is done by updating the forest classification through application of a simple transition matrix-based approach that allows for regional calibration according to local management practice (i.e. harvest intensity) and environmental conditions (soil, temperature).