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Quantifying the missing link between albedo and productivity of boreal forests

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Albedo and fraction of absorbed photosynthetically active radiation (FAPAR) determine the shortwave radiation balance and productivity of forests. Several studies have examined the relation between forest structure and albedo in the boreal zone. Studies regarding FAPAR are fewer and the relations between albedo and FAPAR are still poorly understood. To study these relations we simulated shortwave black sky albedo and canopy FAPAR, using the FRT forest reflectance model. We used two sets of field plots as input data. The plots were located in Alaska, USA (N = 584) and in Finland (N = 506) between Northern latitudes of 60˚ and 68˚, and they represent naturally grown and more intensively managed (regularly thinned) forests, respectively. The simulations were carried out with sun zenith angles (SZA) typical to the biome, ranging from 40˚ to 80˚. The simulated albedos in coniferous plots decreased with increasing tree height, whereas canopy FAPAR showed an opposite trend. The albedo of broadleaved plots was notably higher than that of coniferous plots. No species differences in canopy FAPAR were seen, except for pine forests in Finland that showed lowest FAPAR among species. Albedo and canopy FAPAR were negatively correlated (r ranged from -0.93 to -0.69) in coniferous plots. The correlations were notably weaker (r ranged from -0.64 to 0.05) if plots with broadleaved trees were included. To show the influence of forest management, we further examined the response of albedo and FAPAR to forest density (basal area) and fraction of broadleaved trees. Plots with low basal area showed high albedos but also low canopy FAPAR. When comparing the sparse plots to dense ones, the relative decrease in canopy FAPAR was larger than the relative increase in albedo. However, at large SZAs the basal area could be lowered to approx. 20 m^2 ha^{-1} before FAPAR was notably reduced. Increasing the proportion of broadleaved trees from 0% to 100% increased the albedos to approximately twofold, with only minor changes in canopy FAPAR. The effect of broadleaved trees was largest in dense forest. The results indicate that increasing the proportion of broadleaved trees in coniferous forests is the most important means to maximize forest albedo without compromising productivity. Because of SZA dependencies, studies that take into account seasonal and diurnal courses of SZA will further explain which forest management practices should be favored in order to maximize the climate cooling effects of boreal forests.