Conceptual design of albedo output extension

**Purpose**: produce maps of albedo (earth surface reflectance) based on the vegetation on each cell.

**Background**: Land cover produces an important feedback between the earth system and atmosphere system by determining how solar radiation is reflected or absorbed. Absorbed solar energy typically is re-radiated as heat, contributing warmth to the global atmospheric system. Reflected solar energy is generally lost to space, and does not contribute warmth to the global atmospheric system. Albedo is the common measure of this reflectance, with higher values representing greater reflectance. In forested landscapes where forest covers large territories, changes in albedo can influence climate by altering how much solar radiation is re-radiated as heat. Albedo varies by forest type (deciduous, conifer, mixed), leaf area and canopy structure, forest floor characteristics (snow cover, plant ground cover), so dynamic forest composition and age can result in dynamic albedo.

**Algorithm**: Uses empirical data of Lukes et al 2013, which measured albedo in pure stands as a function of leaf area. Lower LAI means more of albedo is driven by the forest floor. Thus, approach here is to compute albedo for cumulative LAI of all three forest types to control for effect of forest floor. Then compute cell albedo as weighted average, weighting by proportion of leaf area in each canopy type. Compute at middle of growing season. Provide option to also compute and map winter albedo? Albedo units: DHR (directional hemispherical reflectance (black sky (shortwave) albedo), which is a ratio of reflected solar radiation to incoming solar radiation, often measured in W/m2.

*Generate Maps*

For each month

For each cell

1. Calculate each cohort’s albedo from its LAI (x) and cover type (dark, light, decid, ground) and the site snow pack (see spreadsheet):
   1. Dark conifer: y = -0.067ln(x) + 0.2095 (Lukes et al 2013). Snow (>25mm), add 80% (Betts and Ball 1997). Constrain x to be no less than 0.7 for computations.
   2. Light conifer: y = -0.054ln(x) + 0.2082 (Lukes et al 2013). Snow, add 75% (Betts and Ball 1997). Constrain x to be no less than 0.7 for computations.
   3. Deciduous: y = -0.0073x + 0.231 (Lukes et al 2013). Snow, add 35% (Betts and Ball 1997)
   4. Grass or moss or open: y = 0.24 (Betts and Ball 1997). Snow, add 212.5% (y = 0.75) (Betts and Ball 1997)
2. Calculate each layer’s (biomass-weighted) average albedo from the cohorts that make up the layer
3. Calculate each layer’s (biomass-weighted) average LAI from the cohorts that make up the layer
4. Calculate the site albedo as the albedo of the top-most layer with LAI >= 1. If not layer has LAI >= 1, then use the top-most layer albedo as the site albedo.

End cell loop

Write map

*Tables*

Write mean cell albedo for landscape for month

Write mean cell albedo for ecoregions for month

End month loop

*Required input parameters*

Canopy type of each species (dark conifer, light conifer, deciduous, ground cover). We may ultimately need another deciduous type (Shade-tolerant?), but not for Siberia.

Equations (making them user-defined)?

**Literature Cited**

Betts and Ball. 1997. Albedo over the boreal forest. J. GEOPHYSICAL RESEARCH 102(D24):28901-28909.

Lukeš Petr, Pauline Stenberg, Miina Rautiainen. 2013. Relationship between forest density and albedo in the boreal zone. Ecological Modelling 261–262:74-79. <https://doi.org/10.1016/j.ecolmodel.2013.04.009>.

**Coding Notes:**

Monthly albedo output can follow the same structure as the other monthly outputs: MonthlyNetPsn, MonthlyFolResp, MonthlyGrossPsn, MonthlyMaintResp.

The monthly values are tracked as an array in SiteCohorts.cs, where the array is filled with the values for each month. Calculations across cohorts to represent the site value (as outlined above) might occur within the AllCohorts loop at SiteCohorts.cs Ln 1154.

Each species will need a way to designate which canopy type they fit into. This could possibly use the Lifeform parameter, if additional options were added. We still need a way to designate trees versus others for use in the layering algorithm (SiteCohorts.cs Ln 567 and 1405). One possible path would be to make the designated canopy types include “tree” for the tree types, so that the checks in the layering algorithm could instead be a search whether the string contains “tree”. So those options could be something “dark\_tree”, “light\_tree”, “decid\_tree”, “other”. That way users could still just designate “tree” as the lifeform if they are not using albedo outputs.