Land-Use Land-Cover Change (LULCC) in CABLE

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Brief Algorithm Description

1. Potential Vegetation Cover

Potential vegetation cover is prescribed using the BIOME1 (Prentice et al., 1992) climate-envelope approach to construct global spatial distribution of biomes according to CABLE's own climate drivers, which are accumulated from 30 years of meteorological inputs. Biomes are mapped to a single CABLE pft, or in the case of savannas and shrublands, to two CABLE pfts (one woody and one herbaceous) with fixed relative areal proportions.

2. Land-Use Forcing

The land-use data (LUH2 V1.0h) is pre-processed by re-gridding to the required resolution (here 0.5 degree) and the required quantities are extracted, aggregated, and re-chunked for optimum reading efficiency in CABLE.

We make use of the following states (areal coverage):
'primf' : an aggregation of all primary vegetation states
'secdf': an aggregation of all secondary vegetation states
'grass': an aggregation of all pasture, cropland and grassland
The above three states sum to 1 for each grid-cell.

We make use of the following aggregated transitions (fraction annual area change):
'ptos': conversion of primary vegetation to secondary vegetation (also equivalent to primary forest harvested area)
'ptog': conversion of primary vegetation to cleared land (i.e. 'grass' in our state definition above)
'stog': conversion of secondary vegetation to cleared land
'gtos': conversion of open land ('grass') to secondary vegetation (e.g. cropland abandonment, reforestation)

3. Static Land-Use

A static Land_Use simulation requires tile fractions to be set according to land-use for a particular year. The current set up has three possible tiles:

a. Primary woody vegetation
b. Secondary woody vegetation
c. Open vegetation (crops, pasture or grassland: primary and secondary not distinguished)

The "open vegetation tile" could readily be replaced by more than one tile (eg grassland, cropland, pasture, but for parsimony, we have started with a single open vegetation tile per grid-cell).

The pft for each of (a) and (b) are assumed the same, and for (c) we prescribe either C3 grassland or C4 grassland depending on climate.

Tile area fractions are initialized using LUH2 data. First, the entire data set of 'ptos' and 'ptog' (i.e. transitions from primary forest) are read from a user-specified start year. Any grid-cells where the sum of these transitions is always zero is classified as 'primary-only', meaning that it is not subject to land-use change. Grid-cells where the potential vegetation does not include a woody pft are also considered 'primary-only'. Primary-only grid-cells only contain active tiles corresponding to potential vegetation cover: either one tile (one single pft) or two tiles (two pfts) for biomes where woody and grassy vegetation co-exist, i.e. shrublands and savanna biomes. For the latter, the relative fraction of each is set according to biome.

Those grid-cells that are not classified as primary-only are subject to land-use transitions and have three active tiles ((a), (b) and (c) above). The initial tile fractions are set according to the 'primf', 'secdf' and 'grass' states in the LUH2 data (see section 2 above for definitions) in the year of interest, with adjustment of tile areas to account for the grassy component of savanna and shrubland biomes.

A static land-use simulation then proceeds with fixed tile area fractions. Such a simulation would be used e.g. for a full model run with static land-cover, or to initialize the states for a model run with dynamic land-use and land-cover.

4. Dynamic Land-Use

Initialisation

A dynamic land-use simulation is initialized using the states generated in a static land-use simulation, to ensure that tiles with potential vegetation are spun-up. In addition, secondary vegetation tiles are initialized by setting plant carbon stocks to zero and the POP age-distribution to be one in the zero-year age class and zero elsewhere. (POP is the demography model, which represents the landscape of each wooded tile as a distribution of patches distinguished by time since last disturbance).

Land-use dynamics

The model is then run forward in time, as usual, except that at the end of each simulated year, land-use change is executed by the following steps:

a. Read the LUH2 transitions and secondary forest harvested area for the current year.
b. Re-initalise secondary forested tiles where secondary forest area is zero.
c. LUH2 transtions 'ptos','ptog','stog','gtos' (See Section 2 above) are converted to changes in tile area fraction (generally these are equivalent, but a correction is required in cases where prescribed the transition requires more land than is available). Simultaneously, transitions to and from secondary forest are used to update the age frequency distribution in secondary forested tiles:
    i. Primary to secondary 'ptos' forest conversions increase the area in the lowest (0-y) age class.
    ii. Open to secondary 'gtos' transitions also increase the area in the lowest (0-y) age class.

iii. Secondary forest clearing ('stog') removes forested area from the youngest age classes first, until the total cleared area is achieved.

d. Adjust secondary age distribution for secondary mature forest harvest area and for natural disturbance.

e. The POP demography model is called, with the updated secondary age distribution. This produces an updated biomass age distribution in both primary and secondary wooded tiles, as well as turnover rates for woody biomass, and structural variables (sapwood area and fraction of woody biomass that is sapwood) which in turn affect the relative allocation of carbon between leaves and stems, and the autotrophic respiration of woody biomass.

f. State variables in each tile and tile area fractions are updated according to the current year's land-use transitions and secondary forest harvest:

    i. Biomass density (i.e. biomass per unit area) change due to disturbance in secondary forest tiles (an output from POP) is partitioned between natural disturbance, secondary forest expansion, secondary forest harvest and secondary forest clearance.

    ii. Gross transfers of mass (carbon, nitrogen and phosphorous) (should also include here water and energy, but not yet done) between tiles are evaluated, based on the area change associated with each transition, and the C- N- and P- mass densities in each of the donor tiles. Parameters values (Houghton 1983, Hansis et al. 2015) are prescribed for the fractions of harvest and cleared biomass remaining in the landscape after harvest and clearing events).

    iii. Mass densities in each tile are updated according to gross transfers, and allowing for more than one transition type to affect a tile simultaneously.

g. Harvest and Clearance product pools (distinguished by turnover times of 1, 10, 100 y) are updated according to harvest and clearance fluxes, and loss rates from these pools.
h. Tile areas are updated at the beginning of the next year.

Prentice, I. C., Cramer, W., Harrison, S. P., Leemans, R., Monserud, R. A., and Solomon, A. M.: Special Paper: A Global Biome Model Based on Plant Physiology and Dominance, Soil Properties and Climate, Journal of Biogeography, 19, 117-134, 1992.