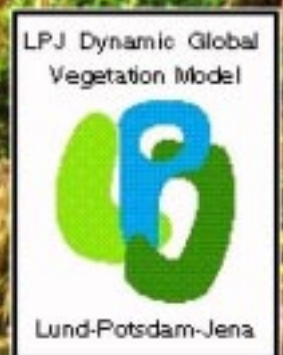


*The LPJ Dynamic Global Vegetation Model
- short description -*



2003



Short description of the LPJ Dynamic Global Vegetation Model (for further explanations and implementations turn to the basic paper: Sitch et al. 2003)

Introduction and methods

The Lund-Potsdam-Jena Model (LPJ) has been developed as a DGVM with a broad range of potential applications to global problems. Three major considerations have guided its development:

1. Process-based yet computationally efficient representation of land-atmosphere coupling.
2. Explicit inclusion of the major processes of vegetation dynamics, including the role of the natural fire regime, and growth, competition and demographic processes.
3. An emphasis on comprehensive evaluation, using the widest possible range of data sets from atmospheric science as well as ecosystem science.

The LPJ-DGVM has adopted many features from the BIOME family of models. In LPJ we define 10 PFTs, of which eight are woody (two tropical, three temperate, three boreal) and two herbaceous. In addition to the attributes controlling physiology and dynamics, each PFT is assigned bioclimatic limits, which determine whether it can survive and/or regenerate under the climatic conditions prevailing in a particular grid cell at a particular time in the simulation. Unlike previous models in the BIOME family, LPJ also includes explicit representation of vegetation structure, dynamics, competition between PFT populations, and soil biogeochemistry. The figure below shows the model logic.

Average individual properties The fundamental entity simulated in LPJ is the average individual of a PFT. This concept provides a simple way for process acting at the level of the plant individual to be scaled up to the “population” over a grid cell. For survival and regeneration bioclimatic limits are applied to 20-year running means. Each PFT “population” is characterized by a set of variables describing the state of the average individual, and by the population density.

Four scaling rules define individual physiognomy and constrain biomass allocation among the three living tissue pools (leaves, fine roots and sapwood) in woody plants.

Grid cell properties The grid cell is treated as a mosaic divided into fractional coverages of PFTs and bare ground. It is assumed that the physical environment of the plants is well mixed, i.e., the PFTs do not occupy discrete blocks, but compete locally for resources.

Annual vegetation and carbon dynamics The number of new individuals established annually is the product of the PFT-specific potential establishment rate and the fraction of the grid cell currently devoid of woody vegetation, i.e., areas sufficiently illuminated to allow sapling growth. Additional mortality can

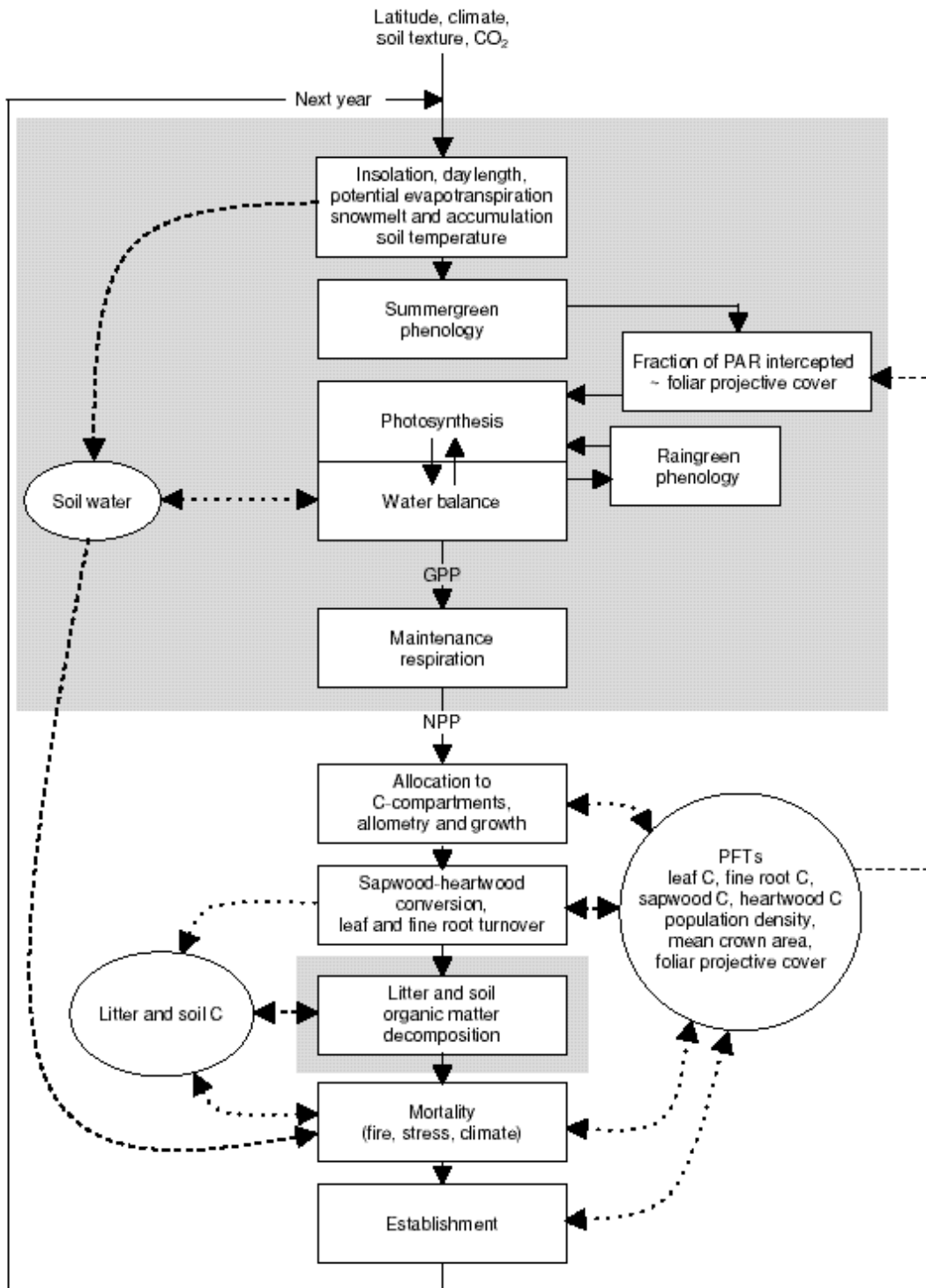


Figure: A flowchart describing the order individual process representations (in boxes), known as modules, are performed (solid lines) in all grid cells, during one simulation year. The dashed lines represent exchange of information between vegetation and soil state variables and the individual modules, with arrows representing the direction of information flow. Modules with a shaded background are called on a daily or monthly time step, the remainder called annually.

result from depressed growth efficiency, heat stress and negative net primary production (NPP). Whether a particular PFT can establish depends also on available soil moisture and bioclimatic limits.

Phenology

Each woody PFT is assigned an evergreen, summergreen or raingreen phenology. Leaf senescence occurs if the water stress factor falls below a certain point. Under water- or temperature-limited conditions herbaceous PFTs adopt a raingreen or summergreen phenology, respectively.

Production

Water availability Soil hydrology is modelled following the semi-empirical approach of Haxeltine & Prentice, which was simplified from the model developed by Neilson. Two soil layers are defined, the upper layer with 0.5m and the lower one with 1m. PFTs differ in their rooting strategy with woody PFTs having a smaller fraction of their roots in the upper layer compared with herbaceous plants.

Photosynthesis The Farquhar photosynthesis model as generalized for global modelling purposes by Collatz et al. underlies the model. The “strong optimality” hypothesis is assumed to apply. The resulting model has the form of a “light-use efficiency” model. Photosynthesis by plants adopting the C₃ vs. C₄ biochemical pathways are modelled in slightly different ways.

Autotrophic respiration Here the maintenance respiration is calculated following the approach of Ryan (1991) and Sprugel et al. (1995). After maintenance respiration is subtracted from gross primary production (GPP), 25% of the remainder is taken as growth respiration leaving the annual net primary productivity (NPP).

Average individual growth

Tissue turnover Each living tissue is assigned a PFT-specific tissue turnover rate, which is transferred either into litter or from living sapwood to heartwood. A yearly update of the above- and below-ground litter is computed.

Reproduction As a simple approximation a fixed fraction of 10% of the annual NPP is deducted to account for allocation to reproduction.

Allocation After reproduction costs have been accounted for, the remaining fraction of annual NPP is allocated to the tissue pools in such a way as to satisfy the four scaling rules (see above), governing plant physiognomy. Years with stress or drought situations are treated differently than years with sufficient remaining NPP. For herbaceous plants the biomass is distributed among leaves and fine roots. Relocation of carbon is allowed from the fine roots to leaves, i.e. the existence of below-ground carbon reserves is assumed, which can be mobilized in times of stress.

Mortality

For the different aspects of mortality, as already mentioned above, different rules are applied.

Disturbance regime Fire is the most important natural disturbance at a global scale, and is the only form of disturbance explicitly represented in LPJ. A full description of the fire module is given by Thonicke et al. (2001).

Establishment

Each year, new woody PFT individuals and herbaceous PFTs are established, available space permitting. Woody PFT saplings can establish in the proportion of the grid cell not currently occupied by woody PFTs; shading reduces establishment as summed woody FPC approaches its limit of 1. Establishment of both woody and herbaceous PFTs is inhibited under extreme heat or water stress. A major simplification arising from the average-individual approach is that only one age-height class for each woody PFT is explicitly defined for a grid cell at any particular time.

Soil and litter biogeochemistry

Each PFT has an associated above- and below-ground litter pool. As litter decomposes a fraction is respired as CO₂ directly into the atmosphere. The remainder is divided between the two soil organic matter (SOM) pools. Decomposition is soil temperature- (for above-ground litter) and moisture-dependent (for below-ground litter).

Input data

Monthly fields of mean temperature, precipitation and cloud cover were taken from the CRU05 (1901-1998) monthly climate data on a 0.5° × 0.5° global grid. A data set of historical global atmospheric CO₂ concentrations extending from 1901-1995 was obtained from CCMLP. Soil texture data are from the FAO soil data set.

Modelling protocol

A typical simulation with LPJ starts from “bare ground” and “spins up” for 1000 model years until approximate equilibrium is reached with respect to carbon pools and vegetation cover. The model can then be driven with a transient climate. The standard LPJ simulation is run with the transient CRU data for 1900-1998.