INTEGRATED ECOSYSTEM AND CROP MODELLING FOR GLOBAL CARBON CYCLE ASSESSMENT

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Introduction

The Lund-Potsdam-Jena (LPJ) model is one of the most recent Dynamical Global Vegetation Models (DGVM) designed to simulate natural potential vegetation and the C cycle on a global scale. The use and development of this model is part of the ECOBICE project for the design of an Integrated Earth System Model that interlinks economy sectors, climate and biosphere compartments using several scenarios of climate and land use change. Crops play an important role in the carbon cycle and crop-yields are an important part of economic sustainability. We present an improved version of the LPJ model which includes crop growth and it can study and simulate C and water dynamics globally without model-dependent discontinuities when changing from natural vegetation to crops. As an outlook on the future application of the model we also describe here some preliminary result of the interaction between the land use model KLUM and the LPJ.

Materials and Methods

The real world huge variety of plants can't be simulated in detail on a global scale, so the vegetation in the model is represented as plant functional types (PFTs) differentiated by physiological, morphological, phonological, bioclimatic and fire-response attributes. Three vegetation typologies are available: trees, grasses and crops. The first two correspond to natural vegetation and compete dynamically for the resources, on the contrary crops are excluded from the competition. Indeed, if a crop is present on a grid point any natural vegetation is allowed to survive. The growth of population PFTs and the individual-level processes over the proportional area occupied are simulated for each grid cell and for each PFT, including vegetation dynamics and their feed-backs on plant C assimilation, allocation and mortality.

The main differences between natural and crop vegetation are in the C allocation scheme, LAI calculation and the mortality dynamics. In other words the optimized daily C assimilation scheme (Haxeltine and Prentice 1996a, 1996b, Farquhar and von Caemmerer 1982, Collatz et al. 1991,1992) is the common baseline, then two directions are followed depending on the vegetation allowed to grow. Therefore C is daily allocated in the plant compartments for crops and annually for natural vegetation, the consequent C balance and LAI calculation follow the same scheme. The crop scheme and the allocation procedure is actually derived and adapted from the WOFOST crop growth model (Boons-Prins et al. 1993, Supit et al. 1994) in which the development stage (DVS) depends on the mean daily temperature. The DVS basically drives the biomass allocation during the whole growing period into four plant compartments (stems, leaves, roots and storage organs). The new biomass allocated into the leaves will then produce a new LAI that will influence in turn the assimilation for the daily next time step.

Calibration and results

The model is able to perform simulation of both natural and crop vegetation using the same assimilation scheme, but different carbon and vegetation dynamics within PFTs. I order to test and validate the model, two strategies are currently used and still in development. The first is based on the comparison between the model output and experimental crop field data. Crop productions and LAI data have been gathered for corn and wheat for 10 stations in the EU using literature (Boons-Prins et al. 1993) and direct access to data (Istituto Agronomico Speriementale in Modena). The LPJ model has been forced using the CRU TS 2.0 climate observation data set of the Tydall Center (Mitchell et al. 2003). The main idea of this first calibration attempt is to find the best combination of crop parameters that minimize the errors as deviation from the observed LAI, Total Above Ground Production (TAGP) and the maturity day. A second strategy is to compare regional or national aggregated crop yield data against the model output. Several elements suggest that this validation option can be used mainly on sensitivity analysis rather then a calibration procedure. The calibration procedure is still under development, but some interesting results are already available. The model is strictly dependent on temperature and the first calibration results show that the best combination of crop parameters depend on the regional climate regime. In this work we used only EU crop data, the consequent calibration optimizes the parameter set for Europe and similar climate regime. The biomass production are on the same order of magnitude of observed mean in Europe and some region of North America, but they are far away in other regions of the World. Those result implies that at least a "warm" parameterization for tropical regions and a "cold" one for mid-latitudes is needed for wheat and corn. A first attempt of linking the LPJ model to a land use model was also performed using the KLUM model from the University of Hamburg.

Outlook

The LPJ model will be used under future climate scenarios to perform simulations and studies on the global carbon cycle, rather then predictions of crop yields. It will be part of a larger Integrated Assessment Model in which also the KLUM model will play an primary role. The latter has been already connected in an "off-line" version to the LPJ and the system was tested for 3 small regions in the world, Schleswig-Holstein in Northern Germany, Obion and and Tehama in the USA. The KLUM model allocates the land to agricultural land use as a function of the potential crop production, the prices and profit variability. In this framework the LPJ feeds the potential crop production directly to KLUM which in return allocates the land. The allocated land was compared against the observations. So far no feed-back to the crop-vegetation model where applied, but this will be the next step in the ECOBICE project.

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