The EPRECOT modelling study

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This handout provides some basic information about the modelling „experiment“ that was performed for the EPRECOT project. Details on the simulation protocol and the full range of results will be presented in three talks at the workshop, but it is recommended to look through this document prior to the meeting in order to get an overview of the structure of the simulations. It may also serve as a reference during the workshop.

The goal of the modelling is to simulate for a selection of well-studied sites potential changes in key ecosystem properties in response to predefined scenarios of climate and CO_2 change. According to the focus of EPRECOT, effects of precipitation changes will be emphasised, but their interaction with changing temperature and CO_2 will also be analysed. Albeit preliminary – the selection of sites and scenarios is not yet definitive, and the models may require some fine-tuning based on thorough validation datasets – the presented results are indicative of ecosystem changes that are to be expected under the defined scenarios. The discussions at the workshop are thought to help define the final model setup and sharpen the research questions.
Analysis was focused on simulated changes in net primary production (**NPP**), heterotrophic soil respiration (**Rh**), and net ecosystem exchange (**NEE** = NPP – RH). Changes in soil moisture (**Wr**), plant water stress (water limitation on NPP, defined in LPJ as the ratio of water-limited over maximum canopy conductance **gcgp** and in DayCent based on relative moisture of the wettest soil layer), transpiration (**AET**), and **runoff**, as well as other relevant processes that influenced the changes in the above (e.g. nutrient limitation) were also taken into account.

Scenarios

The following scenarios were defined (note their abbreviations):

Precipitation changes	
Doubled precipitation	**2P**
Halve precipitation	**0.5P**
Doubled intensity, halved frequency of precipitation	**dihf**
Halve intensity, doubled frequency of precipitation	**hidf**
Changes seasonality of precipitation (Jan/Feb exchanged with Jun/Jul)	**P_seas**
CO_2 change	
CO2 concentration elevated (720 ppm)	**2CO2**
Temperature change	
Temperature plus 2 Kelvin	**T2**
Combinations of the above	
Temperature plus 2 K *and* elevated CO2	**T2_2CO2**
Temperature plus 2 K *and* doubled precipitation	**T2_2P**
Temperature plus 2 K *and* halved precipitation	**T2_0.5P**
Temperature plus 2 K *and* changed seasonality of precipitation	**T2_Pseas**
Elevated CO_2 *and* doubled precipitation	**2CO2_2P**
Elevated CO_2 *and* halved precipitation	**2CO2_0.5P**
Elevated CO_2 *and* changed seasonality of precipitation	**2CO2_Pseas**
Temperature plus 2K *and* elevated CO_2 *and* doubled precipitation	**T2_2CO2_2P**
Temperature plus 2K *and* elevated CO_2 *and* halved precipitation	**T2_2CO2_0.5P**
Temperature plus 2K *and* elevated CO_2 *and* changed seasonality of precipitation	**T2_2CO2_Pseas**

The dihf and hidf scenarios were not combined with the others, because their isolated effects turned out to be small.

Sites

All scenarios were computed for the following five sites, which represent a preliminary suite of different climatic/hydrologic regimes and vegetation types.

The **Jasper Ridge** Biological Preserve (37°24'N, 122°13'W) is a low ridge in the eastern foothills of the Santa Cruz Mountains at the base of the San Francisco Peninsula, 7 km west of the main Stanford University campus, CA. The preserve encompasses remarkable geologic, topographic, and biotic diversity within its 481 hectares. The preserve has been focus of numerous research projects; e.g. since 1997, researchers affiliated with the Jasper Ridge Global Change Experiment have tested the response of a California grassland to climate change, elevated CO_2, and increased nitrogen pollution.

Konza Prairie is located in the Flint Hills region of NE Kansas, approximately 10 km south of Kansas State University and the city of Manhattan (39°05'N, 96°35'W). The Flint Hills are steep-sloped and overlain by shallow limestone soils unsuitable for cultivation. This region contains the largest remaining area of unploughed tallgrass prairie in North America. Vegetation is dominated by the perennial, warm-season grasses big bluestem, little bluestem, Indian grass, and switchgrass. A highly diverse mixture of other species includes warm-season and cool-season grasses, composites, legumes, and other forbs. A few woody species are locally common. The Konza site is burned every 4 years typically, thus the border between the tallgrass prairie and decidious forest is controlled by the fire management practices.

Oak Ridge/Walker Branch: The Walker Branch watershed (35°58'N, 84°17'W) is located on the U.S. Department of Energy's Oak Ridge Reservation near Oak Ridge, Anderson County, Tennessee. The forest soils are acidic, very cherty, infertile, and permeable. They are formed over dolomitic bedrock, but retain little evidence of their carbonate parent material. The forest vegetation is primarily oak-hickory with scattered pine on the ridges and mesophytic hardwoods in the valleys. Many projects conducted at this site have contributed to a more complete understanding of how forest watersheds function and have provided insights into the solution of energy-related problems associated with air pollution, contaminant transport, and forest nutrient dynamics. This is one of a few sites in the world characterized by long-term, intensive environmental studies.

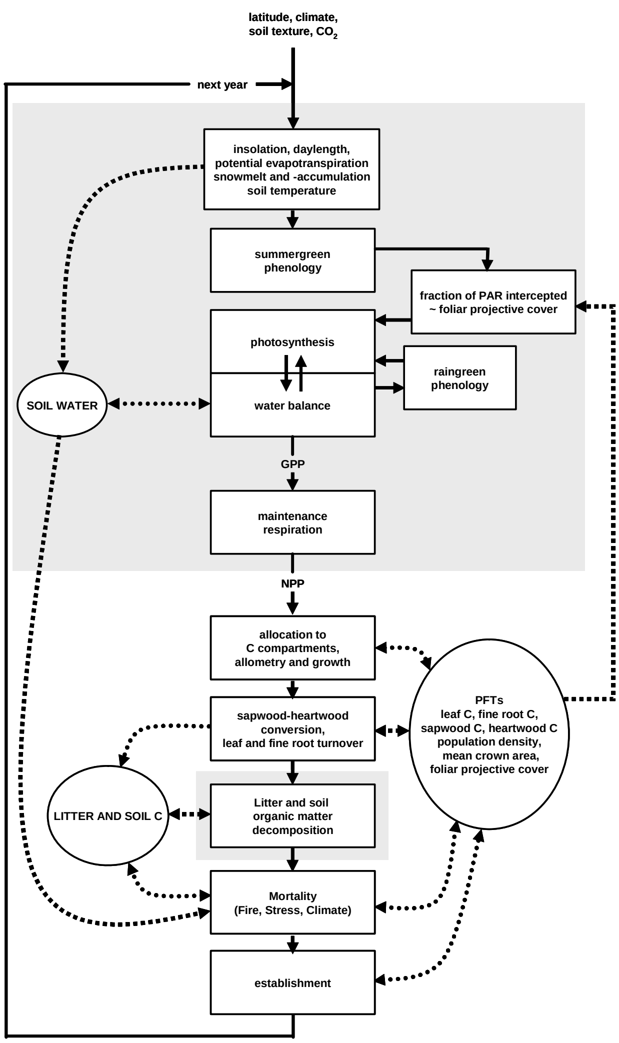
The **Flakaliden** long-term nutrient optimisation experiment (64°07'N, 19°27'E) was laid out 1986 in a young Norway spruce (*Picea abies* (L.) Karst.) stand, planted in 1963 with four-year-old seedlings of Norway spruce of a local provenance, after clear-felling, prescribed burning and soil scarification. The soil at Flakaliden is a podzolic, glacial, loamy till with an average depth of approximately 1.2 m and a mean humus layer depth of 30-40 mm. Understorey vegetation is of the low-herb type, with dwarf shrubs, mainly bilberry (*Vaccinium myrtillus* L.) and cowberry (*Vaccinium vitis-idaea* L.).

The experimental study site at **Mols** in Denmark (56°23’N, 10°57’E) is dominated by the ericaceous shrub *Calluna vulgaris* and the grass *Deschampsia flexuosa* on podzolic soil with a shallow organic layer. The site is a semi-natural ecosystem formerly subject to low-intensity grazing with no management activities during the last 15 years.

Models

Three ecosystem models were used to run the scenarios: LPJ, DayCent, and TECOS (see below for brief model descriptions). For each site, we performed a control run using observed daily climate and annual CO_2 concentrations (the length of the observation periods differed among sites, depending on the climate data that were initially available). From these datasets the above-defined scenario time series were created by manipulating the daily climate data; the models were then forced with these time series, and their results compared. All simulations were preceded by a spinup period to bring the models into equilibrium.

LPJ is a process-based biogeography–biogeochemistry model of intermediate complexity that simulates the spatio-temporal dynamics of terrestrial vegetation together with land–atmosphere carbon and water exchanges in a single framework. To account for functional differences among vegetation types, 9 plant functional types are distinguished. Their annual presence, coexistence, and fractional coverage is adjusted dynamically by competition for water and light, as well as by individual bioclimatic, physiological (C3 or C4 photosynthesis), physiognomic (woody or herbaceous), phenological (deciduous or evergreen), and flammability characteristics (however, in this study changes in vegetation cover were suppressed).
Core of the model is a modified Farquhar photosynthesis scheme coupled with a transpiration scheme, based upon which gross primary production (GPP), NPP, Rh, as well as carbon assimilation and transpiration rates are calculated. Assimilated carbon is allocated to four vegetation carbon pools (leaves, sapwood, heartwood and fine roots) following a set of allometric and functional rules; leaf and root turnover redistribute carbon to a litter and a slow and a fast decomposing soil carbon pool. Decomposition of litter and soil organic matter is computed based on soil temperature and moisture. The latter is updated daily according to evapotranspiration (soil evaporation, interception loss from canopies, and transpiration as dependent on rooting depth), runoff, snowmelt, precipitation, and percolation through two soil layers of 50 and 100 cm depth. Besides, LPJ is now the first DGVM that incorporates a process-based representation of the major crop types of the world.

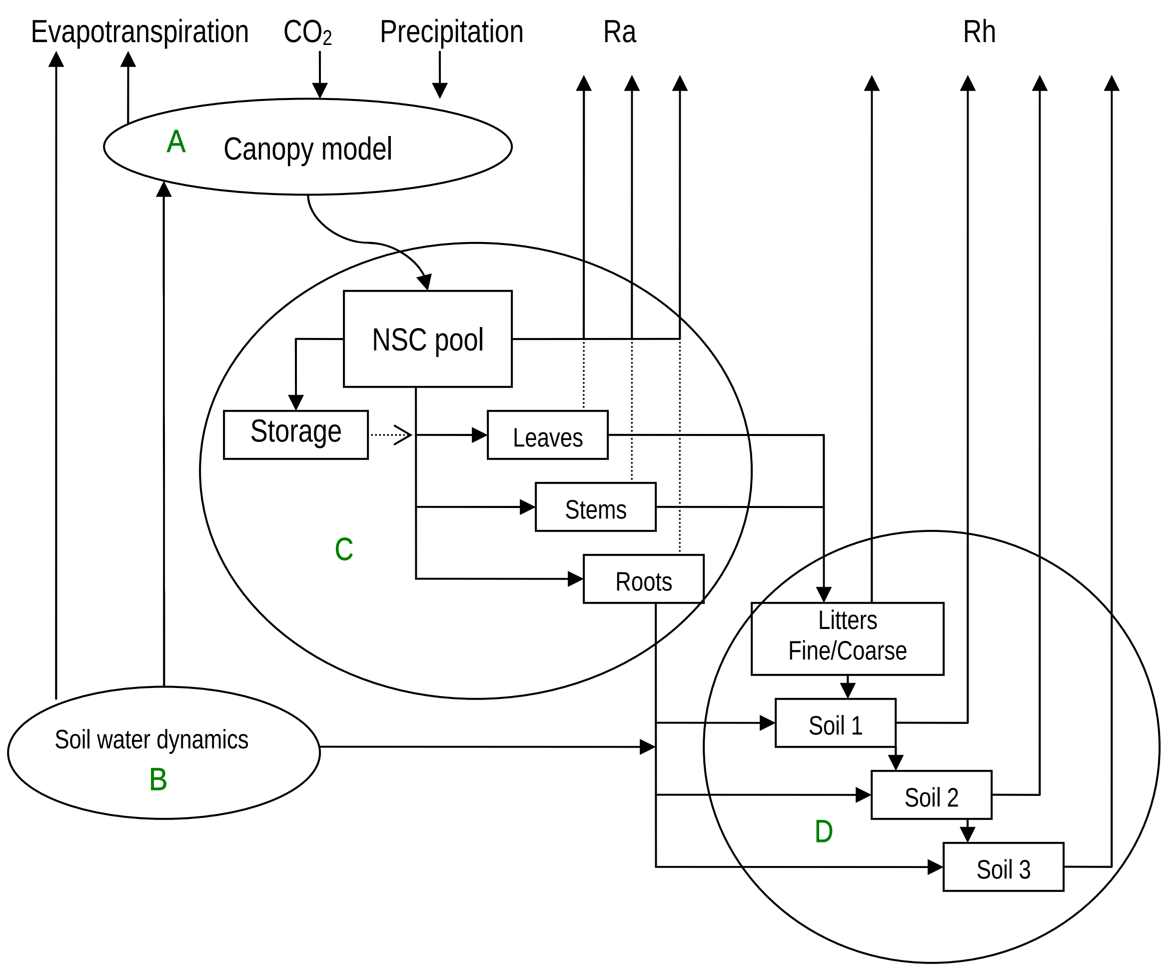


Scheme of the LPJ model

TECOS is designed to examine critical processes in regulating interactive responses of plants and ecosystems to precipitation and other global change factors. TECOS has four major components: a canopy photosynthesis model, a soil water dynamic model, and a C dynamic model which consists of a plant growth model and a soil C transfer model.

The canopy model is a multi-layer process-based model that calculates radiation transmission based on Beer's law. For each layer, foliage is divided in sunlit and shaded LAI. Leaf photosynthesis is estimated based on the Farquhar photosynthesis model and the Ball and Berry stomatal conductance model. The soil water model simulates soil moisture dynamics based on precipitation, evapotranspiration, and runoff. The two components run at the hourly temporal scale.

The C dynamic model considers plant growth, plant respiration and soil C transfers among pools. Allocation of assimilates over the plant components depends on the growth rate of leaves, stems and roots, and varies with phenology. A soil profile is divided into three layers with water and carbon movement between the layers. Carbon inputs to the soil from plant residues are partitioned into these three layers. The plant growth and the soil carbon model run at daily step.



Scheme of the TECOS model

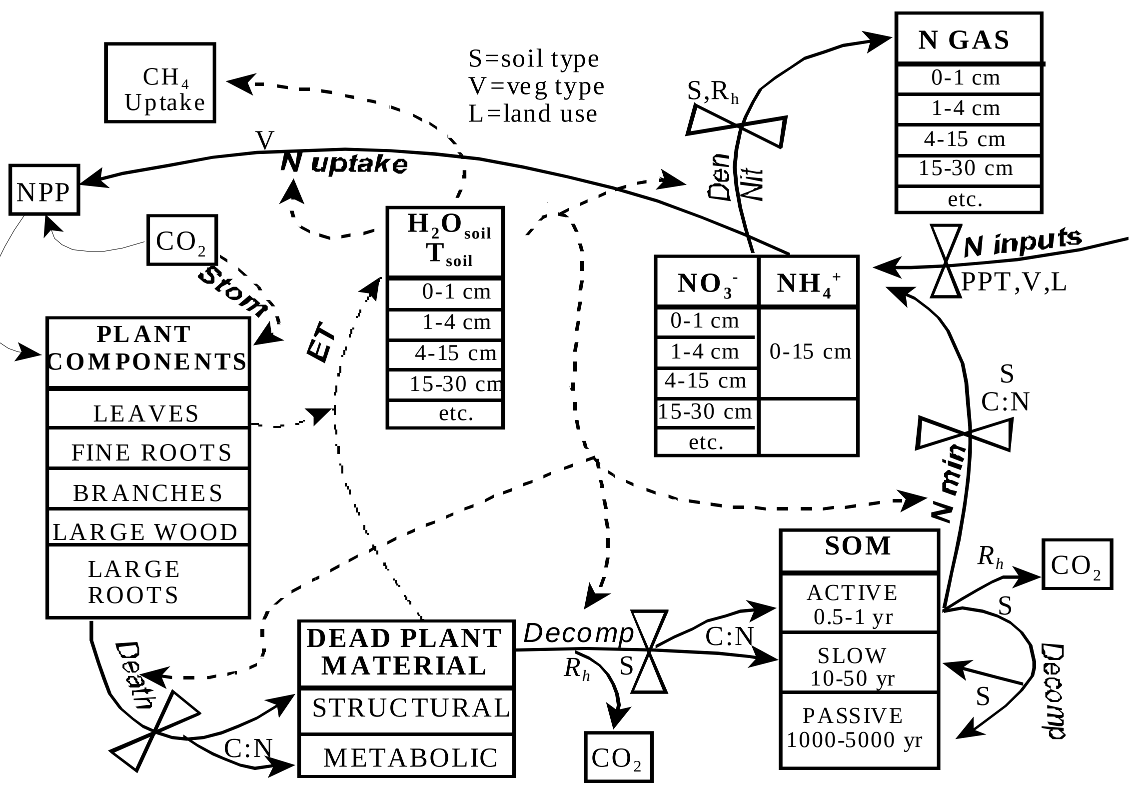
The **DayCent** ecosystem model is a daily time step version of the Century soil organic matter model, used to investigate the effects of changes in land use and climate on C and N fluxes. The key components of the model include the plant production model, the nutrient cycling model, the trace gas submodel, and the soil organic matter model. DayCent thus simulates daily soil temperature and water dynamics, trace gas fluxes (N_2, N_2O, NO_x and CH_4), soil organic matter dynamics, nutrient cycling (N, P , S), plant nutrient uptake, and plant production.

Plant production and photosynthesis rates are a function air temperature, intercepted solar radiation, soil water content (plant water stress) and available nutrients for plant growth (radiation use efficiency type of model).

The soil temperature and water flow model simulates temperature and soil water content for 10 layer model that can be set up for different soil layer depths and work for deep soils with roots greater than 2 m depth.

Soil NO_3 and NH_4 are simulated as function of depth, and inorganic soil P variables are simulated for the 0-20 cm depth. Soil organic matter dynamics are usually simulated for the 0-20 cm and can be parameterized for deeper soil depths (0-50 cm).

The model has been run for detailed agricultural plots and also for US national and global assessments.



Scheme of the DayCent model

Key results

The following graphs provide a summary of the key findings, i.e. changes in NPP (% from control run for the years under investigation) and NEE (ditto, g C m^{-2} yr^{-1}) under the different scenarios for each site. Shown are the average response of the models (error bars indicate the range of model projections).

We found that model agreement is generally high (at least in terms of the sign of change). But, there are major deviations among individual models for individual sites and/or scenarios, which can be traced back to differences in model design and parameterisation. Detailed results will be presented and discussed during the workshop. See above for scenario definitions.