ExpeER

Distributed Infrastructure for EXPErimentation in Ecosystem Research

Grant Agreement Number: 262060

SEVENTH FRAMEWORK PROGRAMME

Capacities

Integrating activities: Networks of Research Infrastructures(RIs)

Theme: Environment and Earth Sciences

DELIVERABLE 9.2

Assessment/review of model strengthens and weaknesses

Abstract:

The report summarises the work to provide Biogeochemical models potentially applicable at the EXPEER sites will be identified and evaluated with respect to strengths and weaknesses for modelling specific ecosystems, key ecosystem compartments as well as key drivers of change (e.g. climate and land use change). Also the ability to model vegetation change will be evaluated.

Due date of deliverable: M24

Actual submission date: M30

Start date of the project: December 1st, 2010

Duration: 48 months

Organisation name of lead contractor: DTU

Contributors: Claus Beier, Per Erik Jansson, Michael Michurov, Elianor Blyth

Revision N°: Final

Dissemination level:

PU Public (must be available on the website)	**[X]**
PP Restricted to other programme participants (including the Commission Services)	**[]**
RE Restricted to a group specified by the consortium (including the Commission Services) (precise to whom it should be addressed)	**[ ]**
CO Confidential, only for members of the consortium(including the Commission Services)	**[ ]**

1 Executive summary

Three Biogeochemical models have been selected to be included in the EXPEER model toolbox. The model characteristics and specific features in terms of compartments and drivers are summarized in tables below.

2 Model selection

Three models have been identified and selected. These are COUP, LPJ-GUESS and JULES.

COUP model

Purpose: To quantify and increase the understanding concerning basic hydrological and biological processes in the soil-plant-atmosphere system.

Brief Description : The model simulates soil water and heat processes in many type of soils; bare soils or soils covered by vegetation. The basic structure of the model is a depth profile of the soil. Processes such as snow-melt, interception of precipitation and evapotranspiration are examples of important interfaces between soil and atmosphere. Two coupled differential equations for water and heat flow represent the central part of the model. These equations are solved with an explicit numerical method. The basic assumptions behind these equations are very simple:

- (i) The law of conservation of mass and energy and
- (ii) flows occur as a result of gradients in water potential (Darcy's Law) or temperature (Fourier's law).

The calculations of water and heat flows are based on soil properties such as: the water retention curve, functions for unsaturated and saturated hydraulic conductivity, the heat capacity including the latent heat at thawing/melting and functions for the thermal conductivity. The most important plant properties are: development of vertical root distributions, the surface resistance for water flow between plant and atmosphere during periods with a non limiting water storage in the soil, how the plants regulate water uptake from the soil and transpiration when stress occurs, how the plant cover influences both aerodynamic conditions in the atmosphere and the radiation balance at the soil surface.
All of the soil-plant-atmosphere system properties are represented as parameter values. Meteorological data are driving variables to the model. Most important of those are precipitation and air temperature but also air humidity, wind speed and cloudiness are of great interest. Results of a simulation are such as: temperature, content of ice, content of unfrozen water, water potential, vertical and horizontal flows of heat and water, water uptake by roots, storages of water and heat, snow depth, water equivalent of snow, frost depth, surface runoff, drainage flow and deep percolation to ground water.
In addition to the water and heat conditions also the plant dynamics and related turnover of nitrogen and carbon may be simulated. The abiotic and biotic processes may be linked in

different ways also to handle the feedback between the physical driving forces and the plant development.

A full technical description of the model is available as an Acrobat file.
ftp://amov.ce.kth.se/CoupModel/CoupModel.pdf

Contact: Prof. Dr. Per-Erik Jansson, KTH Royal Institute of Technology, Stockholm, Sweden; Per-Erik.Jansson@aom.kth.se

References:

Eckersten, H., Gärdenäs, A. & Jansson, P-E. 1995. Modelling Seasonal Nitrogen, Carbon, Water and Heat Dynamics of the Solling Spruce Stand. Ecological Modelling, 83: 119-129 .

Jansson, P-E. & Thoms-Hjärpe, C. 1986. Simulated and measured soil water dynamics of unfertilized and fertilized barley. Acta Agric Scand 36:162-172.

Johnsson, H. & Jansson, P-E., 1991. Water balance and soil moisture dynamics of field plots with barley and grass ley. Journal of Hydrology, 129:149-173.

Stähli, M., Jansson, P.-E. & Lundin, L.-C. 1999. Soil moisture redistribution and infiltration in frozen sandy soils. Water Resources Research, 35 (1): 95-103.

LPJ-GUESS model

Purpose: LPJ-GUESS is a computer model that simulates the responses of land vegetation and ecosystems to climatic and environmental variation..

Brief Description: LPJ-GUESS model (Smith et al. 2001) employs forest-gap method to model dynamics of natural vegetation. Its implementation represents forest stand as a mosaic of independent patches each 1000 sq. m that are at different successional stages and follow independent hydrological and biogeochemical histories. The difference between the patches originates in explicitly-formulated processes of establishment, mortality and competition for resources under probabilistic disturbance regime. Overall state of the forest is obtained by averaging the patch variables. Establishment of new tree individuals occurs in age groups (“cohorts”), i.e. newly established individuals have similar characteristics; however, the age-dependent and growth-stress mortality of individual trees is modelled stochastically as is patch-destroying mortality due to a disturbance (e.g., storms, fire). Typically model is run with a daily time step, meaning that daily meteorological forcing data are required and most of the physiological processes are parameterised for this time scale. Establishment, growth, mortality and disturbances are calculated annually. Vegetation is organised into groups, referred to as plant functional types (PFTs), which have specific static parameters describing their ecological niches. List of PFTs is designed to represent most relevant and common plant species and live forms; it can be expanded or adjusted as necessary to account for site-specific vegetation.

The model was successfully applied to a variety of environments and a particular attention has been paid to European conditions with a more detailed parameterisation of the relevant PFTs (Wramneby et al. 2010; Smith et al. 2011). It was used with both historical meteorological datasets as well as various climate projections. Data from manipulation experiments were successfully used to evaluate obtained results at a wider regional or global scale (Hickler et al. 2008). Therefore, LPJ-GUESS is uniquely suitable to possible wide range of applications for ecosystem research in Europe.

Availability and documentation: The model is well documented and has a number of configuration parameters that can be adjusted by the users, including duration of the simulation and optional disturbance regime. The model, including a detailed description of the model is available at http://www.nateko.lu.se/lpj-guess

Contact: Prof. Ben Smith, Dept of Physical Geography and Ecosystem Science, Lund University Geocentrum II. ben.smith.lu@gmail.com

References

Hickler, T., B. Smith, I. C. Prentice, K. Mjöfors, P. Miller, A. Arneth and M. T. Sykes (2008). "CO2 fertilization in temperate FACE experiments not representative of boreal and tropical forests". Global Change Biology 14(7): 1531-1542, doi: 10.1111/j.1365-2486.2008.01598.x.

Smith, B., I. C. Prentice and M. T. Sykes (2001). "Representation of vegetation dynamics in the modelling of terrestrial ecosystems: comparing two contrasting approaches within European climate space". Global Ecology and Biogeography 10(6): 621-637, doi: 10.1046/j.1466-822X.2001.t01-1-00256.x.

Smith, B., P. Samuelsson, A. Wramneby and M. Rummukainen (2011). "A model of the coupled dynamics of climate, vegetation and terrestrial ecosystem biogeochemistry for regional applications". Tellus A 63(1): 87-106, doi: 10.1111/j.1600-0870.2010.00477.x.

Wramneby, A., B. Smith and P. Samuelsson (2010). "Hot spots of vegetation-climate feedbacks under future greenhouse forcing in Europe". J. Geophys. Res. 115(D21): D21119, doi: 10.1029/2010jd014307.

JULES model

Purpose: The Joint UK Land Environment Simulator (JULES) is a process-based model that simulates the fluxes of carbon, water, energy and momentum between the land surface and the atmosphere.

Brief Description: JULES has a tiled model of sub-grid heterogeneity with separate surface temperatures, short-wave and long-wave radiative fluxes, sensible and latent heat fluxes, ground heat fluxes, canopy moisture contents, snow masses and snow melt rates computed for each surface type in a grid-box.
Nine surface types are normally used: five Plant Functional Types (PFTs) - broadleaf trees, needleleaf trees, C3 (temperate) grass, C4 (tropical) grass and shrubs - and four non-vegetation types - urban, inland water, bare soil and land-ice. Except for those classified as land-ice, a land grid-box can be made up from any mixture of the other surface types.
Fractions of surface types within each land-surface grid-box are read from an ancillary file or modelled by TRIFFID.
Air temperature, humidity and wind-speed above the surface and soil temperatures and moisture contents below the surface are treated as homogeneous across a grid-box.

The model runs on an hourly timestep with the incoming radiation energy being allocated to either sensible or latent heat fluxes from the land to the atmosphere as well as warming up the soil. Soil moisture dynamics are calculated using the Darcy-Richards equations with flow going across four vertically layered soils. If the soil moisture falls below a critical threshold, the transpiration is reduced and the photosynthesis is also reduced. The soil moisture also affects the surface and sub-surface runoff through a simple hydrology model. In this way, the carbon, water and energy cycles are linked.

Availability and documentation: The model is freely available upon acceptance of the terms of conditions. Available at: https://jules.jchmr.org/

Contact: Eleanor Blyth - emb@ceh.ac.uk

References:

Best, M. J., Pryor, M., Clark, D. B., Rooney, G. G., Essery, R .L. H., Ménard, C. B., Edwards, J. M., Hendry, M. A., Porson, A., Gedney, N., Mercado, L. M., Sitch, S., Blyth, E., Boucher, O., Cox, P. M., Grimmond, C. S. B., and Harding, R. J.: The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes, Geosci. Model Dev., 4, 677-699, doi:10.5194/gmd-4-677-2011, 2011.

Clark, D. B., Mercado, L. M., Sitch, S., Jones, C. D., Gedney, N., Best, M. J., Pryor, M., Rooney, G. G., Essery, R. L. H., Blyth, E., Boucher, O., Harding, R. J., and Cox, P. M.: The Joint UK Land Environment Simulator (JULES), Model description – Part 2: Carbon fluxes and vegetation, Geosci. Model Dev. Discuss., 4, 641-688, doi:10.5194/gmdd-4-641-2011, 2011.

Summary

Models for plot-scale testing (WP9)	COUP	LPJ-GUESS	JULES
Main Contacts	Per Erik Jansson - pej@kth.se	Ben Smith - ben.smith.lu@gmail.com	Eleanor Blyth - emb@ceh.ac.uk
Documentation	A full technical description of the model is available as an Acrobat file. ftp://www.lwr.kth.se/CoupModel/CoupManual.pdf or http://www2.lwr.kth.se/CoupModel	Full reference list and demonstration version: http://www.nateko.lu.se/lpj-guess	https://jules.jchmr.org/ + references below
Purpose - features	The model quantifies basic hydrological and biological processes in the soil-plant-atmosphere system. The model simulates soil water and heat processes in many type of soils; bare soils or soils covered by vegetation. The basic structure of the model is a depth profile of the soil. Processes such as snow-melt, interception of precipitation and evapotranspiration are examples of important interfaces between soil and atmosphere.	Dynamic global vegetation model for simulation of interactions between climate, atmospheric burdens of trace gases and vegetation, biogeochemical cycles and trace gas exchange. Vegetation dynamics based on neighbourhood-scale interactions between plant individuals.	The Joint UK Land Environment Simulator (JULES) is a process-based model that simulates the fluxes of carbon, water, energy and momentum between the land surface and the atmosphere. Simulation of the fluxes of energy, water, carbon and momentum between the land surface and the atmosphere. It is a process based model.
Scale / spatial unit (grid cells, polygons, etc)	Spatial resolution: plot.However model can be run in distributed model representing any region	Spatial resolution depends on climate and land cover input. Typically 10 minutes (Europe) or 0.5 degree (globe) but may also be applied at stand or plot scale, basic spatial unit is a 0.1 ha vegetation patch	Single point, country and global scale, resolution dependent on the available input data; usually 50km on the global scale, and 1 km on the country scale
Time units	Time resolution: hourly to daily	Shortest time-step daily; can be applied to past, present-day and 21st century simulations	be run with available data – up to 100 years in practice and for future climate scenarios. Temporal coverage and resolution
Inputs summary	Climate (hourly or daily radiation, precip, temperature (average), windspeed and CO2 concentration)	Climate (monthly or daily radiation, precip, temperature (average), CO2 concentration	Meteorological forcing data, soil, topography and vegetation data
Outputs summary	Ecosystem hydrology and energy, ecosystem NPP, and carbon exchange components, soil and biomass C and N), N deposion and N inputs for managed ecosystems	Ecosystem NPP, and carbon exchange components, soil and biomass C and N pools, population demography and size structure, potential natural species composition (Europe, major tree species)	LAI, canopy height, GPP, soil moisture, leaf litter, soil carbon, runoff, evaporation, heat, soil temperature, respiration, momentum
Ecosystem impact indicators	Any related to hydrology, energy and/or C and N cycling	Any that can be deduced from the previous column.	Any that can be deduced from the previous column.
Strengthes	Hydrology & energy. High degree of flexibility with respect to feedback between various components and integrated methods for calibration of model.	Dynamic vegetation	Simulation of the fluxes of energy, water, carbon and momentum between the land surface and the atmosphere
References (add full reference below table)	Jansson, 1991; Stähli et al., 1999 Gustafsson et at, 2004; Hollesen et al 2011, Jannson et al, 2008, Jansson, 2012, Norman et al, 2008, Svensson et al 2007, Wu et al, 2011, Wu et al 2012	Smith et al., 2001, 2008, 2011; Sitch et al., 2003; Hickler et al. 2004, 2008, 2012; Zaehle et al. 2005; Arneth et al., 2007; Lehsten et al., 2009; Tang et al. 2010, 2012	Best et al., 2011; Clark et al., 2011

3 Model requirements, strengths and weaknesses

Data inputs

Entity/ Group	Quantity or parameter	Type	Freq.	COUP		LPJ-GUESS		JULES	
		In = input, Va=validation		Units	Importance	Units	Importance	Units	Importance
				Importance - 0 low, 1 medium, 2 high					
Basics	Site name	ID	once	text	2	text	2	text	2
	Treatment name	ID	once	text	2	text	2	text	2
	Site Latitude	In	once	decimal degree	2	decimal degree	2	decimal degree	2
	Site Longitude	In	once	decimal degree	2	decimal degree	2	decimal degree	2
	Elevation	In	once		0		0		0
	Vegetation Type	In	once		0	text (PFT)	1	text (PFT or species)	1
	Management history (description)	In	annual	text	1	text	1		0
	Start/end plant growing season/fumigation period	In	Annual		0		0		0
Climate	Soil temperature - mean annual	In	Annual		0		0		0
	Air temperature - mean annual	In	Annual		0		0		0
	Air temperature - daily / monthly	In	Daily/monthly	daily, oC	2	daily, oC	2		0
	Air temperature - hourly	In	hourly	oC	2		0	oC	2
	Air temperature minimum - daily	In	Daily		0	oC	2		0
	Air temperature maximum - daily	In	Daily		0	oC	2		0
	Air temperature - July maximum	In	Annual		0		0		0
	Air temperature - January minimum	In	Annual		0		0		0
	Leaf temperature	In	hourly		0		0		0
	Precipitation flux - annual	In	Annual		0		0		0
	Precipitation flux - daily	In	Daily		0	mm/d	2		0
	Precipitation flux - hourly	In	hourly	mm/hr	2		0	mm/hr	2
	Runoff flux (precipitation surplus) - annual	In	Annual		0		0		0
	Relative humidity	In	Daily		0		0		0
	Vapour pressure deficit	In	hourly		0		0	kg/kg	2
	PAR flux	In	daily/monthly	W/m2	2	W/m2	2		0
	Heat flux density	In	hourly		0		0	W/m2	2
	Air pressure	In	hourly		0		0		0
	Wind speed - hourly	In	hourly	m/s	2		0	m/s	2
	Wind speed - daily	In	Daily		0		0		0
	Turbulent Stress	In	hourly		0		0		0
Deposition	Ozone concentration - daily	In	daily		0	surface, ppb	2		0
	Ozone concentration - hourly	In	hourly		0		0		0
	CO_2 concentration - daily	In	daily	ppm	2	ppm	2	ppm	2
	CO_2 concentration - hourly	In	hourly		0		0		0
	NH_y deposition flux	In	annual	gN/m2/yr	2	gN/m2/yr	2		0
	NO_x deposition flux	In	annual	gN/m2/yr	2	gN/m2/yr	2		0
	NH_3 atmospheric concentration	In	daily		0		0		0
Soil	Soil depth above which properties & stocks are recorded - e.g. solution sampling depth	In	once	m	2		0		0
	Organic horizon thickness	In	once	m	2		0		0
	Soil bulk density	In	annual		2		0		0
	Soil texture	In	once	pF/soil layer	2		1		1
	Soil water content	In	annual mean		0		0		0
	Cation exchange capacity	In	once		0		0		0
Veget	Canopy height	In	annual		0	m	1	m	1
	Max rooting depth	In	annual		0	m	1	m	1

Entity/ Group	Quantity or parameter	Type	Freq.	COUP		LPJ-GUESS		JULES	
		In = input, Va=validation		Units	Importance	Units	Importance	Units	Importance
				Importance - 0 low, 1 medium, 2 high					
Soil	Soil C stock	Va	once	gC/m2	2	gC/m2	1	gC/m2	1
	Soil N stock	Va	once	gN/m2	2	gN/m2	1	gN/m2	1
	Soil solution pH	Va	annual		0		0		0
	Soil slurry pH	Va	annual		0		0		0
	Soil respiration C flux	Va	Bi-weekly	any	1		0		0
	Mineral N leaching flux	Va	Monthly	gN/m2/yr	1	gN/m2/yr	1		0
	Dissolved organic N flux	Va	annual		0		0		0
	Dissolved organic C flux	Va	annual		0		0		0
	Annual runoff flux (precipitation surplus)	Va	annual	mm/yr	1	mm/yr	1		0
	Soil water content	Va	Daily	%	2		0		0
	soil water status (volumetric or potential)	Va	Hourly		0		0		0
	Soil surface evaporation	Va	hourly		0		0		0
Vegetation	Transpiration	Va	hourly	any	1		0		0
	Stomatal conductance	Va	Hourly	any	1		0		0
	Sap flow data	Va	Hourly		0		0		0
	Leaf water potential	Va	Hourly	any	1		0		0
	Pre-dawn leaf water potential	Va	Hourly		0		0		0
	Litter production C flux	Va	annual		1	gC/m2/yr	1		0
	Litter production N flux	Va	annual	gN/m2/yr	1	gN/m2/yr	1		0
	Litter C content	Va	annual	gC/g dm	1	gC/g dm	2		0
	Litter N content	Va	annual	gC/g dm	1	gC/g dm	2		0
	Photosynthesis net C flux - daily / monthly	Va	Daily/monthly	gC/m2/yr	0	gC/m2/yr	2		0
	Photosynthesis net C flux - hourly	Va	Hourly	any	1		0		0
	Plant respiration	Va	Hourly	any	1		0		0
	Shoot biomass	Va	Hourly		0		0		0
	Shoot total peak C stock	Va	annual	any	1		0		0
	Shoot total peak C stock, by plant functional type	Va	annual		0		0		0
	Shoot total peak N stock	Va	annual	any	1		0		0
	Crop yield	Va	annual	gC/m2/yr	1	gC/m2/yr	2		0
	Wood C stock	Va	annual	gC/m2	2	gC/m2	2		0
	Wood C/N	Va	annual	ratio	1	ratio	2	ratio	2
	Leaf biomass	Va	Hourly		1		0		0
	Leaf C stock	Va	annual max	gC/m2	2	gC/m2	2		0
	Leaf C/N	Va	annual	ratio	1	ratio	2	ratio	2
	Root biomass	Va	Hourly	gC/m2	1		0		0
	Root C stock	Va	annual max	gC/m2	2	gC/m2	2		0
	Root N stock	Va	annual	gN/m2	1	gN/m2	1		0
	Root C/N	Va	annual	ratio	2	ratio	2	ratio	2
	Evaporation	Va	daily or yearly	mm/yr	2	mm/yr	2		0
	Evaporation over grass	Va	annual		0		0		0
	Canopy height	Va	annual	m	1	m	1		0
	LAI	Va	annual		2		2		2
Floristics	Species present	Va	annual		0		0		0
	Cover of present species	Va	annual		0		0		0
	Tree type/ composition	Va	once		0	e.g., relative LAI cover	1	PFT	1

Model structure, key processes and drivers

	Feature/Proces	COUP	LPJ Guess	JULES
Model structure	Model structure	Modular with "switches" making exclusion/inclusion of various processes or ecosystem components possible	Modular with switches for a number of ecosystem processes and configurable parameters, extensible interface for dealing with plant functional types (vegetation). Custom input/output module is a responsibility of the user.	Modular, with switches for processes and ecosystem components. Switches to select variables to output.
	Parameter setting support and guidance	Described in manual. Support for ranges embedded in model	Parameter setting guidelines included in text file embedded in the model	Described in manual. Input parameters (eg for PFTs) can be easily specified and varied spatially and temporally.
	Validation and uncertainty	Uncertainty based methods are available as integrated parts of the model based both on general Monte Carlo Methods and more formal probabilistic methods	No internal validation tools included. Analysis of the model performace (modelled vs. observed values) needs to be done externally.	Validation must be carried out externally.
	Model documentation	Pdf manual and as integrated part of the model	Full reference list and demonstration version: http://www.nateko.lu.se/lpj-guess	Documentation available on website: https://jules.jchmr.org/software-and-documentation/jules-v3.2
Processes	Plant growth and carbon uptake	GPP driven by by light, water, Nitrogen availability. Optionally use of Farquahar approach, light use efficiency or water use efficiency approach. Plant development calculated with different dynamic approaches assuming stage of development with different seasonality for allocation and litter fall. Carbon assimilation allocated to the different parts of depending on growth stage and water and N stress of plant.	Growth is annual, based on accumulated NPP over the previous year. Carbon uptake is daily based on plant requirements vs. available resources.	GPP driven by light, water, CO2 on timestep scale. Growth and vegetation competition on timescale of several days. GPP calculated in terms of three limiting rates: N, light and rate of product transport. GPP reduced by soil moisture stress and ozone effects. Several options for leaf to canopy scaling, with the option of including multi-layer radiation interception, sunfleck penetration, and differing reactions to diffuse and direct radiation.
	Nutrient dynamics	The model includes major nitrogen transformation processes in the soil. No treatment of other nutrients (e.g. P and base cations)	The model includes description of N dynamics in ecosystem, including photosynthesis limitation, accumulation in plant tissues. CENTURY-like soil pools and SOM dynamics for both N and C.	N concetration can vary through canopy.
	Carbon and nutrient interactions	The model consider the major carbon componentes (above and below ground plant, SOM, microbes, and DOC) which are directly interacting with macronutrients (especially nitrogen), plant nutrient re-allocation is also considered in the model.	C/N ratios constrained to a certain extent, N leaf content limits C assimilation, C/N ratios affect maintenance respiration.	Nitrogen cycle follows C cycle. N limits photosynthesis and affects respiration.
	Soil organic matter dynamics and microbiology	Dynamic soil organic matter from different pools is considered. Soil microorganisms are covered and accounted for the fluxes between different compartments in the soil.	Two microbial pools exist for both C and N.	Q10 and RothC soil carbon model both implemented with one soil pool. RothC can also be used with four (decomposable plant, resistant plant, microbial biomass, long-lived humidified) soil carbon pools.
	Vegetation change and biodiversity	The model does not include explicit species and biodiversity. However a number of functional plant types can be specified with various degrees of interactions.	Vegetation is dynamic, based on pre-defined set of plant functional types (PFTs). PFT parametrisation is static. Nitrogen, water and light competition simmulated on individual or PFT basis. Mortaliy includes both an age and a growth-stress related components that are modelled stochastically.	Vegetation is dynamic, using five PFTs. PFT parameterisation is static except LAI and canopy height, which respond to growth. Competition hierarchy trees-shrub-grass. Two types of trees compete with each other based on relative height, same for the two types of grass.
	Soil physics, hydrology and energy	The model simulates in details exchanges of water and energy in a vertical profile from the atmosphere through the vegetation to the underlying soil.	Soil hydrology is represented by a simple 2.5-layer bucket model. Otherwise soil profile is not differentiated. No lateral flow. Temperature at 25 cm is calculated, based on water content in the top layer. Soils are separated into texture groups. Energy balance is not calculated.	Soil hydrology represented by layers (default 4). Soil moisture and temperature calculated for each of these layers, along with Darcian flow between them and surface exchange of H20, CO2 and energy in the top layer, including vegetation effects. Sub-surface runoff is drainage from the bottom of the lowest layer. Energy balance is calculated.
Drivers	Climate change	The model simulate climate change (and different climate scenarios), because meteorological data are used as driving forces. The importance of vegetation and snow conditions on the local soil climate is considered.	The model has been used with a wide variety of forcing data sets including various climate projections for the XXI century. There is no fundamental differens between simulations driven by historical climate or a scenario.	Meteorological data used to drive the model, therefore will respond to climate change.
	Land use change	The model can describe land use change as respond to climate and management. The competition between the different plant functional types are not developed as part of the model.	Land-use change could be simulated by regulating establishment and mortality.	Land use can be provided as an input, so could be changed and the model will respond. If vegetation competition is switched on, then vegetation cover can change in response to changing climate.
	N deposition	Both dry and wet nitrogen deposition are considered in the model.	Both forms (reduced and oxydised) of dry and wet deposition can be considered, along with the fertilisers.	Not included
	Management	The model includes some options of soil management including fertilization , tillage and irrigation. Many options for plant management with respect to clearing, thinning and harvest.	Fertilisation is available, other management options are not included in this version of the model.	Not included
	Extreme events	Continous response functions for soil moisture and temperature are considered for a wide range of climate conditions.	Stochastic formulation of generic patch-destroying disturbances. Simple fire scheme included.	Continous response to soil moisture and temperature

4 Summary

Model selection

The model toolbox will contain three biogeochemical models. These were chosen among many possible obtions based on the following criteria:

- Flexibility in terms of ecosystems and drivers
- Documentation (manuals, user friendliness, access and references)
- Complementarity (the three components of the model toolbox should ideally complement each other in terms of processes, drivers, ecosystems etc.)
- Competences among the WP partners

Other models exist that could have fitted in as well, but no models have been identified which would have clear advantages over the ones chosen. Some ecosystem specific models for forests, grasses or agriculture might have advantages for those specific ecosystems, but would loose on the flexibility.

Parameter inputs

The models require a range of driving variables as well as characterising parameters and validation parameters. The driving variables are mostly climatic variables and management/treatments, which can be substantial, but which are required by any biogeochemical model, and they are more or less identical across the models.

Site characteristics and soil and plant parameters differ across models. These include quite many of which not all may be available at each site. Site specific solutions will have to be taken to obtain the parameters needed. The toolbox will provide guidelines for this.

Validation parameters will typically depend on the scientific question raised in a given project, and should therefore not be difficult to get from a given project. The toolbox will provide guidelines to more elaborate validation parameters.

Strengths

The different models are generally quite flexible with respect to terrestrial ecosystem types, they operate at slightly different scales and have different strengths. In combination this means that the model toolbox will provide models that together will provide useful model tools to cover most relevant ecosystem types and land uses, address key questions related to biogeochemical cycling and address questions at different time and spatial scales.

Key strengths are:

- COUP – plot scale, soil hydrology & energy, C and N
- LPJ-guess – Plot-regional scale, vegetation dynamics, atmospheric feedback
- JULES – Landscape scale, hydrologic and carbon flows and feedbacks

Weaknesses

None of the models address other elements (like P and nutrients) or acidity