EC4MACS
Modelling Methodology

The EU-FASOM Land Use Model

European Consortium for Modelling of Air Pollution and Climate Strategies - EC4MACS

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Contents

Aim of the project

Aim of the EC4MACS project is to bring together most of the widely used policy assessment models in Europe in the areas of pollutant emissions. The long-term objective is to develop the links between the models in order to perform consistent policy impact assessments and scenario evaluations.
This report describes the methodologies/models that are planned to be used in the framework of EC4MACS by the FOR Program at IIASA. The aim is that these methods are reviewed by national experts, in order to make projections which are consistent with those designated by the member states.

Background on the available tools

The IIASA/FOR Modeling cluster for EC4MACS consist of 2 central models (EUFASOM and EPIC) and 3 accompanying models (G4M, BEWHERE, FORMICA) that are all interlinked.

The inter-linkage between the IIASA/FOR model cluster and the IIASA/APD models (Rains/Gains) where EUFASOM serves as a hub for Gains is described previously. This report concentrates on the methodology description of the IIASA/For model cluster as applied for EC4MACS. Figure 1 describes the IIASA/FOR modeling tree for GHG mitigation through land-use. The following section provides an overview on the single models included in this cluster, starting with EUFASOM and EPIC as the major modeling platforms. Detailed papers describing the models are attached as annexes.

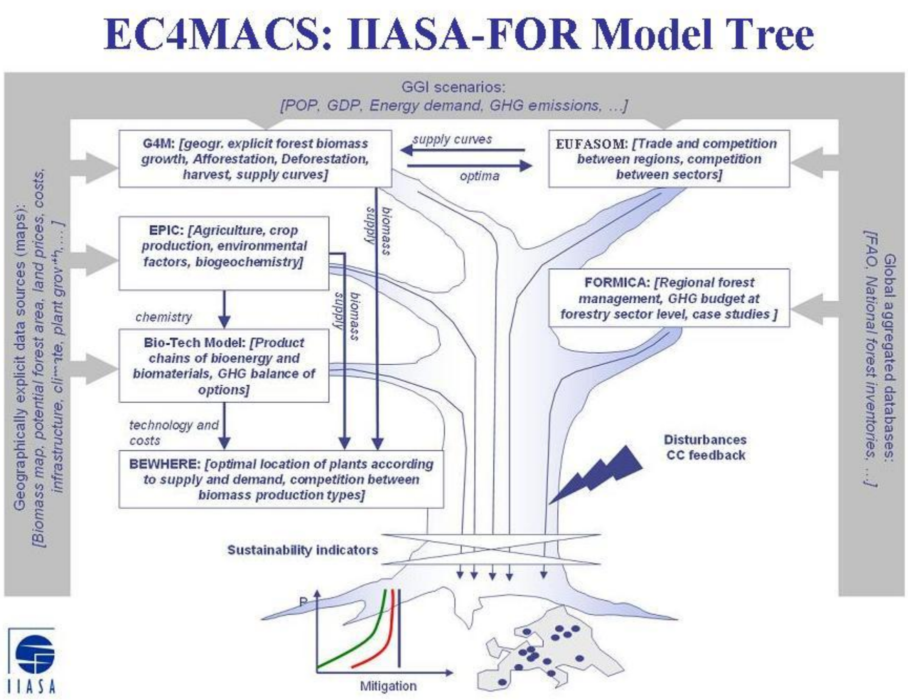

Figure 1: IIASA Forestry Modeling Tree: Modeling Mitigation of GHGs through Land-Use

EUFASOM

The European Forest and Agricultural Sector Optimization Model (EUFASOM)

Objective

EUFASOM explores welfare maximizing total land-use strategies, including greenhouses gas emission control and carbon sink strategies that meet wider environmental objectives on inter alia soil, water and biodiversity protection.

Model characteristics

EUFASOM is a bottom-up, dynamic partial equilibrium model of the agricultural – forestry – biomass for energy sectors, which simulates land use management under environmental, political, and technical change. EUFASOM uses constrained welfare maximization to simulate the market equilibrium in the forest, bioenergy and agricultural markets. The EUFASOM integrates a wide spectrum of environmental impacts for each land management option by integrating results from biophysical simulation models.

Typical features and results

The spatial resolution of the EUFASOM includes European countries (EU27) and up to 28 international regions. Natural variation e.g., with respect to altitudes, soil textures and farm types within European countries is accounted through integration of relative shares of aggregated homogenous response units. The model currently covers carbon, methane and nitrous oxide fluxes. Crop growth, soil erosion, nutrient leaching, and agricultural soil carbon levels for annual and perennial crops are estimated with the EPIC model. IIASA's forest model simulates forest biomass growth and carbon balances under different planting and thinning regimes. In addition to farms and a large number of crop, livestock, and timber processing options, explicitly modeled activities include biorefinery options to produce several bioenergy and biomaterial products.

Input from other EC4MACS models:

- Projections of agricultural activities (from the CAPRI model)
- Biophysical management responses in agricultural production (from EPIC/DNDC model)
- Biophysical management responses in forest production (from OSCAR/DNDC model)
- Scale dependent cost functions of second generation power plants / refineries (from the BEWHERE model)

Output to other EC4MACS models:

- Costs of emission control measures (to the GAINS model)

Documentation:

The model code and input data is available under
https://lists.zmaw.de/mailman/listinfo/eufasom upon registration.

Developed by:

University Hamburg and International Institute for Applied Systems Analysis (IIASA)

For a detailed description: see Annex

EPIC

The Environmental Policy Integrated Climate Model

General description

The Environmental Policy Integrated Climate (EPIC) integrates a large number of biophysical processes and allows assimilation of EO products allowing for global calibration of environmental impact assessments. The major components in EPIC are weather simulation, hydrology, erosion-sedimentation, nutrient and carbon cycling, pesticide fate, plant growth and competition, soil temperature and moisture, tillage, cost accounting, and plant environment control.

EPIC operates on a daily time step, and is capable to simulate hundreds of years if necessary. The optional Green and Ampt infiltration equation simulates rainfall excess rates at shorter time intervals (0.1h). Different options for simulating several processes with different algorithm – five PET equations, six erosion/sediment yield equations, two peak runoff rate equations, etc., which allow reasonable model applications in very distinct natural areas will be performed.

EPIC will be used to compare management systems and their effects on water, nitrogen, phosphorus, pesticides, organic carbon, and sediment transport, on organic carbon sequestration, and eventually on green house gas emissions. The management components (e.g. latest Crop maps from IFPRI) that will be analyzed include crop rotations, crop/grass mixes, tillage operations, irrigation scheduling, drainage, furrow diking, liming, grazing, burning operations (e.g., on prairies), tree pruning, thinning and clear cut harvest or regeneration cuts, manure handling (e.g., lagoons), and fertilizer and pesticide application rates and timing. The Epic model is already today operational on global scales and is continuously improved. The linkage to EU-FASOM Model and GLOBIOM Model is operational.

Scope

Simulation of spatially and temporally explicit bio-physical impacts (e.g. crop yields, nutrient fate, carbon sequestration, sediment transport) of observed and alternative land use and management systems at regional and global scale.

Resolution

spatial: Homogeneous Response Units (HRUs) and Individual Simulation Units (ISU) that delineate representative weather-soil-topography-management systems at regional and global scales. *temporal:* daily time steps over hundreds of years if necessary.

Processes included

- crop growth
- hydrology
- weather simulation
- nutrient cycling (NPKC)
- pesticide fate
- erosion

Input

- regional and global weather/climate change data (statistics)
- regional and global soil data
- regional and global land use data and representative crop rotations
- regional and global topography data
- regional and global crop management data (e.g. fertilization, irrigation, tillage)

Output

- crop yields
- hydrology (PET, runoff, percolation)
- sediment transport
- N-leaching
- green house gases
- soil carbon sequestrations

Current status

- delineation of HRUs at global scale
- developing and testing a prototype of the global data-modeling infrastructure for Europe
- building the global database (weather, soil, topography, crop management) for global EPIC simulations at HRU scale

Planned development

- linking with Global FASOM /EUFASOM and BEWHERE Model by providing spatially and temporally explicit bio-physical impact vectors.
- analyze the bio-physical impacts of alternative agricultural management systems (e.g. tillage systems, precision farming, etc.).
- simulation of climate change impacts using a statistical approach.

Developer

Erwin Schmid, BOKU

BEWHERE

The optimal sizing and positioning of plant model

General description

The BEWHERE model calculates the optimal spatial distribution and size of bioenergy plants, pulp and paper mills and sawmills given the spatial biomass supply distribution from biophysical models. Together with a demand estimated from a geographically explicit driver maps and aggregate demand from EU-FASOM Model or GLOBIOM Model, BEWHERE calculates the optimal positions of plants and mill, such that economies of scale and scope under polyproduction of spatial explicit bioenergy systems can be assessed.

Scope

Calculation of the size, costs and optimal location of biofuel (methanol, ethanol), sawnwood or pulp for paper plants, given the biomass and demand distribution, and international trades.

Side products are also considered. The residual heat can be delivered to district heating networks. The model includes calculation of infrastructure costs of the heat distribution, and estimates the heat demand regarding the housing infrastructure.

Trades with other countries can also be considered, such as imports/exports of the raw material or the final product

Resolution

Spatial: Biomass input can vary from $1km^2$ (regional level) to half a degree (country level). Demand input varies from the exact location of the demand (regional level) to half a degree (country level).
Time: Depending on the forecast data.

Processes included

- Location and yield of available biomass
- Location of demand grid points
- Transportation cost (truck, train or ship)
- Plants technology and economy
- Competing product price

Input

- Biomass grid points
- Demand grid points
- Amount of biomass
- Amount of demand
- Economical and technological characteristics of the possible plants
- Logistic network map (roads, railways, ports)
- Side products prices
- Products import price

Output

- Spatial explicit location of plants
- Spatial explicit location of used biomass by each plant
- Spatial explicit location of demand spots delivered by each plant
- Size of the plants
- Final product cost
- Amount of by-product produced

Current status

- Integrate more detailed maps (raod, railways, ports)
- Combine with a heat demand model

Planned development

- Extend to Europe
- Extend to different products (Bio-diesel, FT, DME...)
- Use of a wider range of raw material (Sugar cane, corn...)
- Linking to other models

Developers

- Sylvain Leduc, IIASA
- Erik Dotzauer, Fortum
- Johannes Schmidt, BOKU
- Dagmar Schwab, ex-IIASA, now BOKU

FORMICA

The Forest management for Climate Change mitigation Model

General description

The model FORMICA aims to calculate carbon pool trajectories under current and changing forest management in existing forests at a regional scale. FORMICA considers forest biomass to be an entity of mass in different compartments and it ignores single trees or layers. The model captures the development of the current annual stem wood increment and the allocation of biomass to branches, foliage and roots. Biomass harvest can be parameterized to various forest management activities like planting, thinning and final harvest as clear cutting, shelter wood or continuous cover forestry. Treatment is simulated by removing fractions of stem biomass and channeling material that is left in the forest to according litter pools.

Soil and litter pools are important components of the forest ecosystem balance and are included in the FORMICA frame through an implementation of algorithms of an existing model (Liski et al., 2005).

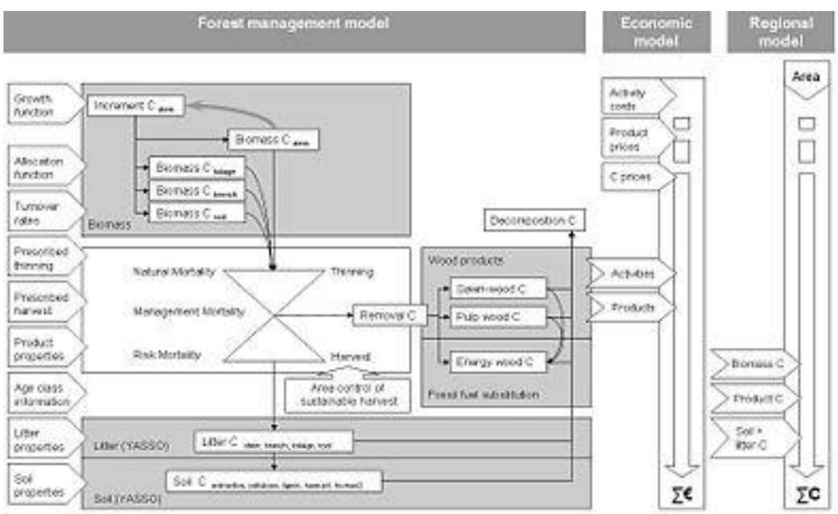

Figure 2: FORMICA overview

The lifetime of wood products and possible substitution effects of wood by other materials has a strong feedback on the C balance of the forestry sector. Therefore, the model offers options to transfer C from biomass to different product pools characterized by mean residence times in a forest product module.

An economic module was introduced to investigate economic implications of different forestry options. The algorithms that were implemented sum revenues and costs of forestry activities and allow for the calculation of a discounted net present value (NPV) of each option.

Calculations are based on an annual time step. The programming language is Matlab.

Scope

C budget model of managed forests and adjacent forestry sector

Resolution

- Spatial: not geographically explicit, adjustable, plot level to regional scale
- Time: 1 year

Processes included

- Biomass, products, soil (YASSO), substitution
- Forest growth species specific, derived from yield tables, transformed to relative growth curves
- Standing volume from national forest inventories
- Age class information from inventories
- Forest Management (FM): different thinning regimes, harvest after prescribed schedule; sustainable forestry (annual allowable cut)
- Simple economic model to calculate NPV
- Calculation on plot level for different strata (age-class, species type, management), regional aggregation by multiplication with area of each stratum

Literature

- Böttcher, H., A. Freibauer, M. Obersteiner and E.-D. Schulze (in press). Uncertainty analysis of climate change mitigation options in the forestry sector using a generic carbon budget model. Ecological Modelling doi:10.1016/j.ecolmodel.2007.11.007.
- Böttcher, H. (2008). Forest management for Climate Change mitigation - Modeling of Forestry Options, their Impact on the Regional Carbon Balance and Implications for a Future Climate Protocol. Fakultät für Forst- und Umweltwissenschaften. Freiburg, Albert-Ludwigs-Universität: 157. Available for download here

Input

- Turnover rate
- Non-woody litter
- Fine-woody litter

- Coarse-woody litter
- Management mortality
- Max volume
- Thinning first year
- Thinning interval
- Thinned fraction
- Harvest age
- Harvested fraction
- Fraction to slash
- Fraction to sawn-wood
- Fraction to pulp wood
- Fraction to energy wood
- Product MRT
- Recycling rate
- Energy substitution factor
- Product substitution factor
- Costs
- Revenue
- Stem volume
- Soil
    - soluble
    - holocellulose
    - lignin-like
    - humus1
    - humus2
- Products
    - sawn-wood
    - pulp wood
    - energy wood

Output

- carbon stocks
    - biomass
    - soil
    - products
    - other C services (C substituted)
- revenues
- costs of FM options
- NPV of FM options
- age-class distribution

Current status

Parameters and other input currently available for Thuringia, Germany, Europe (not economic part)

Planned development

Model applications

- calculation of plot and regional level mitigation potential of various FM and land-use options (including land-use change)
- global technical/biological potential of FM to mitigate Climate Change

Technical development

- strengthen economic part of the model
- include disturbances (like in CBM-CFS, Canada)

Developer

Hannes Böttcher, IIASA

G4M

The Global Forest Model

General description

The Global Forest Model (G4M) estimates the annual above ground wood increment and harvesting costs. It takes track on the above ground forest biomass. By comparing the income of managed forest (difference of wood price and harvesting costs, income by storing carbon in forests) with income by alternative land use on the same place, the decision of afforestation or deforestation is made. As G4M is spatially explicit (currently on a 0.5°x0.5° resolution which is planed to bring down to 30"x30") the different deforestation pressure at the forest frontier can also be handled.

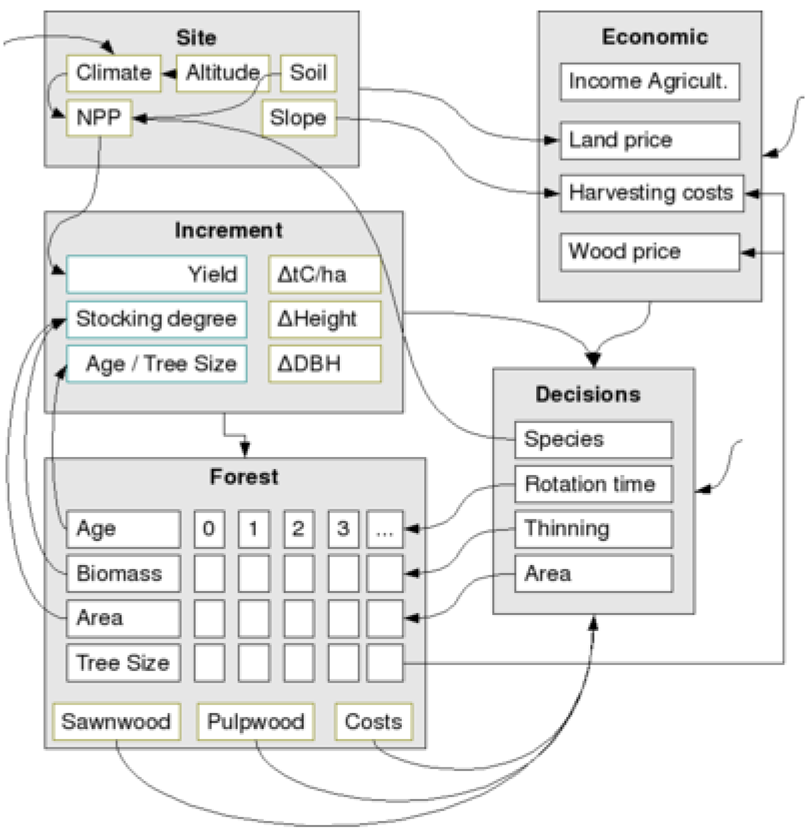

Figure 3: G4M flowchart

Increment is determined by a potential NPP map. At present this NPP map is static but can be changed to a dynamic NPP model which reacts to changes of temperature, precipitation, radiation or CO_2 concentration. Main forest management options are species selection, application of thinning and choice of rotation time. G4M does not distinguish between species but a change of species can be emulated by adapting NPP, wood price and harvesting costs. The rotation time can be individually chosen but the model can estimate optimal rotation times to maximize increment, maximize stocking biomass or maximal biomass at harvest time. The model handles age classes with one year width.

Afforestation and disasters cause an uneven age-class distribution over a forest landscape. The model is doing final cuts in a manner, that all age classes have the same area after one rotation time. During this age class harmonization time the standing biomass, increment and amount of harvest is fluctuating due to changes in age-class distribution and afterwards stabilizing.

The model can use external information from other models or data bases like wood prices, prescribed land-use change which guarantee food security and land for urban development or account for disturbance. As outputs, G4M produces forecasts of land-use change, carbon sequestration/emission in forests, impacts of carbon incentives (e.g., avoided deforestation), and supply of biomass for bioenergy and timber.

Scope

- Afforestation/Deforestation
- Forest Biomass
- Harvestable Wood

Resolution

Spatial: Global 30’×30’ Time: 1 year

Processes included

Decision of afforestation or deforestation based on Net Present Value of forestry and alternative land use, Increment based on NPP

- G4M_increment
- G4M_economic

Literature

- Kindermann, G. E., M. Obersteiner, E. Rametsteiner and I. McCallum (2006). Predicting the deforestation-trend under different carbon-prices. Carbon Balance and Management 1 (1). available online

Input

- Net Primary Production
- Development of population density

- Development of the buildup land
- Minimum of agricultural land which is needed for food
- production
- Agricultural suitability
- Price-level of the region
- Initial forest biomass
- Initial forest area
- Discount rate
- Protected land area
- Current amount of fuel wood production
- Corruption of the region
- Discount rates
- Prices of land, afforestation, carbon and wood

Output

- forest biomass
- forest area
- deforested area and carbon from these deforestation
- afforested areas
- harvestable wood
- current rotation time
- increment optimum rotation time
- age-class distribution of forests

Current status

Model core from DIMA Age/Size dependent increment more or less ready

Planned development

- bring it to a stable “user friendly” version
- increasing resolution to 30”×30”
- include slope
- dynamic NPP–Model

Source

You can download the source code at Google Code.

Developer

Georg Kindermann, IIASA

Annex 1

Erwin Schmid, Juraj Balkovic, Elena Moltchanova, Rastislav Skalsky, Katarina Poltarska, Brigitte Müller, and Radoslav Bujnovsky. BIOPHYSICAL PROCESS MODELING FOR EU25: CONCEPT, DATA, METHODS, AND RESULTS

Annex 2

SCHNEIDER, U., BALKOVIC, J., DE CARA, S., FRANKLIN, O., FRITZ, S., HAVLIK, P., HUCK, I., JANTKE, K., KALLIO, A., KRAXNER, F., MOISEYEV, A., OBERSTEINER, M., RAMOS, C., SCHLEUPNER, C., SCHMID, E., SCHWAB, D. and SKALSKY, R. (2008). The European Forest and Agricultural Sector Optimization Model EUFASOM. Working paper FNU-156, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany. http://www.fnu.zmaw.de/Working-papers.5675.0.html.