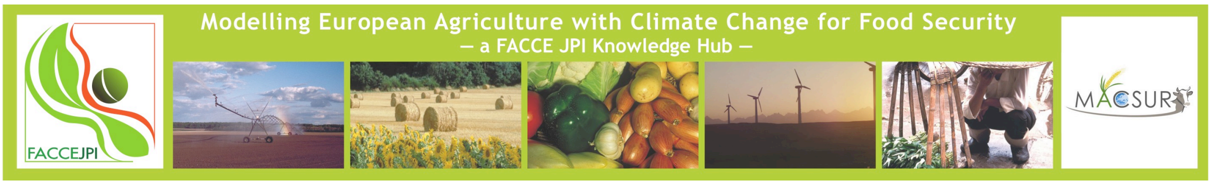

FACCE-MACSUR

Results of uncalibrated grassland model runs

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Abstract/Executive summary

This deliverable focuses on the some illustrative results obtained with the grassland models selected (D-L2.1.1) to simulate biomass and flux data from grassland sites in Europe and peri-Mediterranean regions (D-L2.1.1 and D-L2.1.2). This is a blind exercise, carried out without model calibration. The complete set of results will include simulations from calibrated models.

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Introduction

Grassland simulation models are a major part of integrated agro-ecosystem models, which are applied to support decision making at different spatial and temporal scales. Applications range from field to global scales, targeting the evaluation of management and policy options. With increasing spatial extent of the area under investigation, input data for mechanistic grassland models are scarce and uncertain and data to test relevant state variables are insufficiently available. There is also an increasing demand by both model users and decision makers for analysis of the robustness of models and the uncertainties of model results in climate change impact studies. However, grassland models have seldom been inter-compared to assess the uncertainties in estimates that can also be large. Supporting climate change impact studies includes an up-to-date geographical coverage of climate, soil and vegetation data, and access to secondary information (e.g. soil information obtained via transfer functions from the primary data), as associated with changes in management options. A protocol based on the principles laid down by the Agricultural Model Intercomparison and Improvement Project (AgMIP, http://www.agmip.org) was developed in LiveM WP2 (M L2.2: Protocol for model evaluation), which includes: evaluation of uncalibrated (blind) and calibrated model simulations against observations, and sensitivity tests of models to changes of CO_2, temperature and precipitation. This deliverable illustrate the results obtained with nine grassland models, which are an inventory of modelling approaches made available through the MACSUR consortium (D L2.1.1) and applied at nine sites across Europe and peri-Mediterranean regions (D L2.1.1and D L2.1.2).

Grassland datasets

Long-term (five to 31 years of data) grassland sites were identified (D L2.1.1, D L2.1.2), covering a gradient of geographic and climatic conditions (Figure 1, left) and a variety of management practices. Four of them (Laqueuille, France, Klumpp et al., 2011; Monte Bondone, Italy, Wohlfahrt et al., 2008; Grillenburg, Germany, Prescher et al., 2010; Oensingen, Switzerland, Amman et al., 2007), equipped with eddy covariance systems to determine the net ecosystem exchange of CO_2, are semi-natural grasslands in place for a long time including vegetation types representative of the zone (with the exception of Oensingen, established in 2001). Other sites (Kempten, Germany, Schröpel and Diepolder, 2003; Lelystad, The Netherlands, Schils and Snijders, 2004; Matta, Israel, Golodets et al., 2013; Rothamsted, United Kingdom, Silverston et al., 2006; Sassari, Italy, Cavallero et al., 1992) from experimental research focus on biomass production. The limits of the De Martonne-Gottmann index (*b*, De Martonne, 1942) discriminate between aridity conditions (Figure 1, right): $b<5$: extreme aridity; $5 \le b \le 14$: aridity; $15 \le b \le 19$: semi-aridity; $20 \le b \le 29$: sub-humidity; $30 \le b \le 59$: humidity; $b>59$: strong humidity (Diodato and Ceccarelli, 2004).

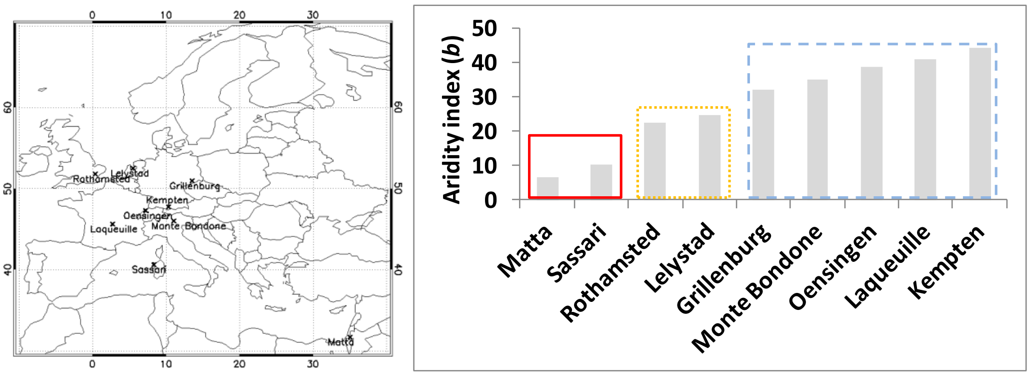

Figure 1. Geographic location (left) and classification (right) of grassland sites with respect to De Martonne-Gottmann aridity index (*b*). The solid box, dotted box and hatched box represent arid, sub-humid and humid sites, respectively.

Grassland models

Nine models were selected for the intercomparison (D L2.1.1). Three of them are **grassland-specific models**. **AnnuGrow** (Köchy, 2008) quantifies the effect of daily rainfall distributions and compares it to the effect of a change in mean annual amount on vegetation. **PaSim** (Ma et al., 2014) simulates water, carbon and nitrogen cycles in grassland plots at sub-daily time step via modules of climate, soil biology and physics, vegetation and management (including grazing animals). **SPACSYS** (Wu et al., 2007) is a multi-dimensional, field-scale, daily time-step model of carbon and nitrogen cycles between plants, soils and microbes, with fine representation of the root system. The following are **crop models** with grassland options. **ARMOSA** (Perego et al., 2013) estimates nitrogen dynamics in soil-crop-atmosphere continuum and evaluates the impact of management on shallow and groundwater quality via modules of energy, water, carbon and nitrogen balances, and plant development and growth. **EPIC**, originally developed to estimate soil productivity as affected by erosion (Williams et al., 2008), is designed to allow simulation of a large variety of crops and grasses with unique parameter values. **STICS** (Brisson et al., 2003) is a generic, daily-step, patch-scaled model covering many crops and conditions of climate, soil and management, being set to simulate either sown or established mowed grasslands. Three **dynamic vegetation models** include grasslands as biome type. **Biome-BGC MuSo** (Hidy et al., 2012) implements a multilayer soil module, improved grassland phenology and management routines into the Biome-BGC, originally developed to simulate undisturbed ecosystems, with allometric relationships used to initialize carbon and nitrogen pools. **CARAIB** (Warnant et al., 1994), a process-based vegetation model of carbon assimilation in the biosphere, implements a range of plant functional types including C_3 and C_4 grasses. Based on the LPJ-Dynamic Global Vegetation Model, **LPJmL** simulates vegetation composition and distribution as well as stocks and land-atmosphere exchange flows of carbon and water (Waha et al., 2012) using generic crop functional types to represent plant prototypes.

Illustrative results from uncalibrated simulations

Harvested biomass

Blind simulations of harvested biomass at Rothamsted (United Kingdom), a multi-year experimental site (with cuts in June and November and fertilized with 48 kg N ha^{-1} yr^{-1} in April), show that some models (grassland model 4, crop models 6 and 8) approach the observations with far less bias than others (Figure 2).

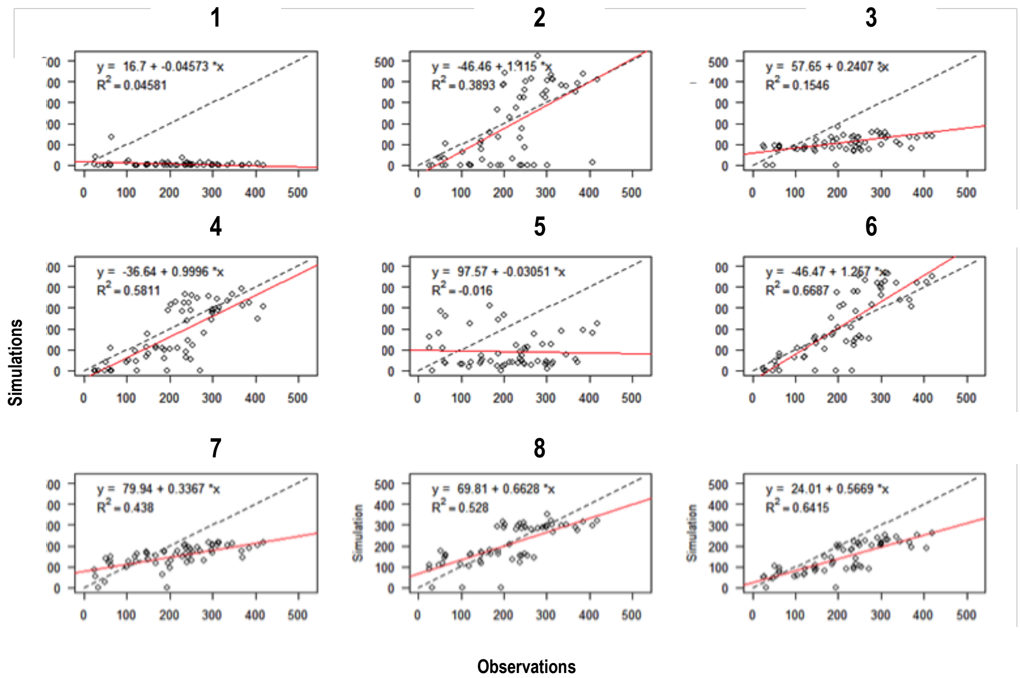

Figure 2. Blind tests: simulated (eight models - 1 to 8 - and the mean output from all models) versus observed harvested above ground biomass (g DM m^{-2}) at Rothamsted (1981-2011), United Kingdom (solid line: linear regression between simulations and observations; hatched line: 1:1 line).

Gross primary productivity

Another example (Figure 3) refers to gross primary production (GPP, monthly values), blindly simulated by five models and compared to observations at the Swiss site of Oensingen, where the grassland is mowed 3-4 times each year and highly fertilized (more than 200 kg N ha^{-1} yr^{-1} split into four events).

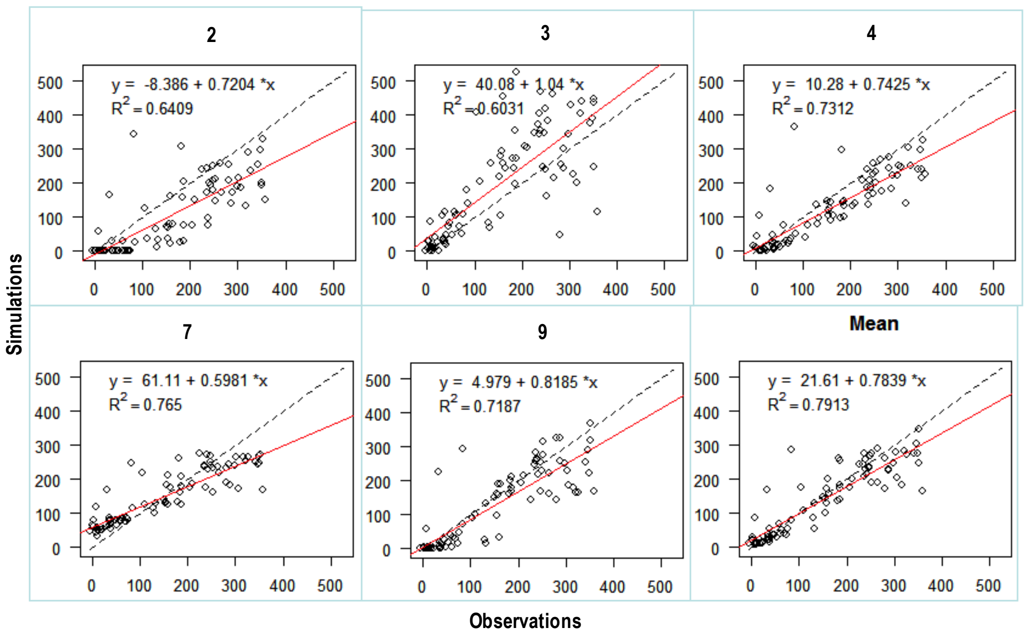

Figure 3. Blind tests: simulated (five models – 2, 3, 4, 7, 9 - and the mean output from all models) versus observed gross primary production (g C m^{-2} month^{-1}) at Oensingen (2002-2009), Switzerland (solid line: linear regression between simulations and observations; hatched line: 1:1 line).

Regression lines (Figure 3) indicate that blind parameterizations roughly match GPP observations for all models (slope and intercept near 1 and 0, respectively; adjusted R^2>0.6), although some calibration might help to improve performances. The uncertainty envelope obtained with the ensemble of model estimates (Figure 4) shows that the influence of extreme events such as the hot and dry summer 2003 can lead to an amplification of uncertainties.

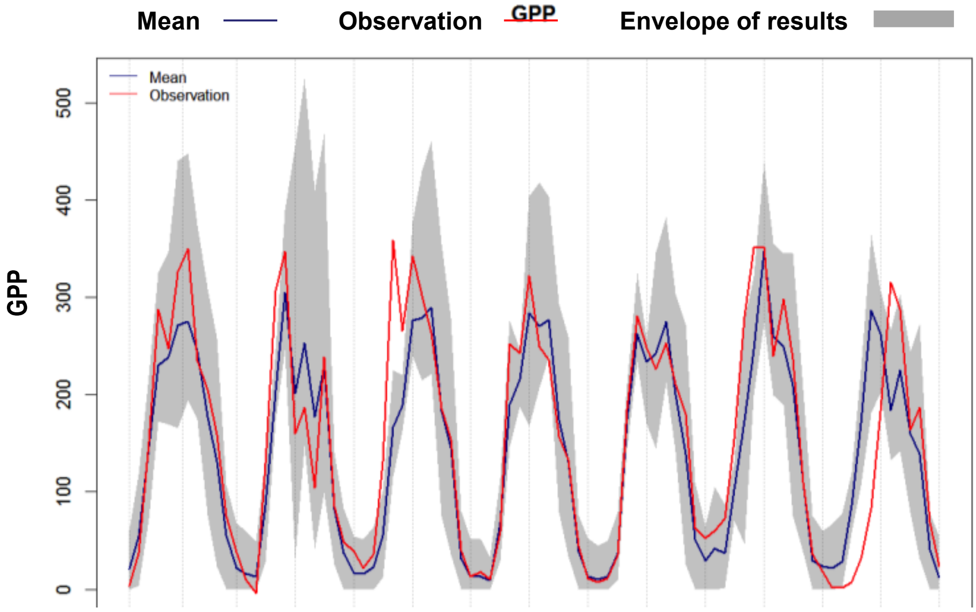

Figure 4. Blind tests: fluctuations of simulated (mean of five models) and observed gross primary production (GPP, g C m^{-2} $month^{-1}$) at Oensingen (2002-2009), Switzerland, with the envelope of results from the ensemble of models.

Ecosystem respiration

Figure 5 shows regression lines for ecosystem respiration (RECO, daily values), blindly simulated by four models and compared to observations at the French site of Laqueuille, intensively grazed with from May to October (about 1 LSU ha^{-1} yr^{-1}) and highly fertilized (200 kg N ha^{-1} yr^{-1}).

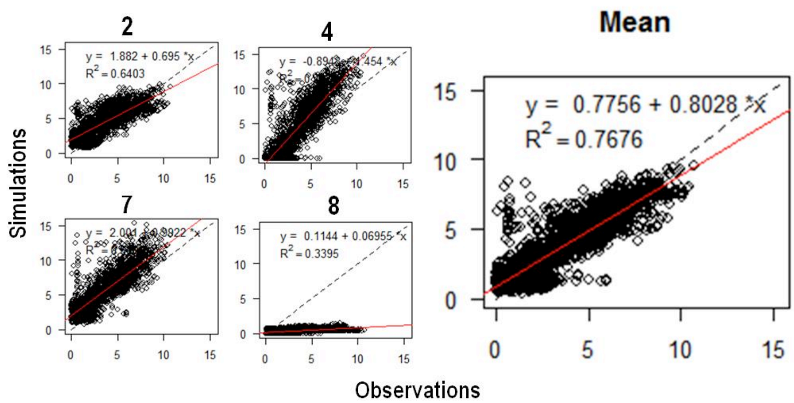

Figure 5. Blind tests: simulated (four models – 2, 4, 7, 8 - and the mean output from all models) versus observed harvested above ground biomass (g C m^{-2} d^{-1}) at Laqueuille (2004-2010) intensive paddock, France (solid line: linear regression between simulations and observations; hatched line: 1:1 line).

In this case, blind parameterizations roughly match RECO observations (slope and intercept near 1 and 0, respectively; adjusted R^2>0.6) with all but one model (model 8). The latter is a crop-specific model, not specifically designed to simulate RECO from permanent grassland systems, for which an intensive calibration work is necessary in order to achieve reasonable results.

Concluding remarks

This blind test, focused on various sites across Europe and peri-Mediterranean regions, extends parallel initiatives on the comparison of grassland models worldwide, such as AgMIP and other international projects (https://colloque.inra.fr/workshop_gra_jpi_facce_eng/2-Model-Intercomparison). The results shown are illustrative of the methodology adopted for grassland model intercomparison in MACSUR. The insights gained from this ongoing study are relevant for some crop and vegetation models, which in some cases proved comparable to grassland-specific models to simulate biomass data from managed grasslands. The results reported here cannot be considered conclusive. Additional results will be published as they become available together with calibration results, as well as the comprehensive evaluation of models with fuzzy logic-based indicators.

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