
FACCE-MACSUR

# Task C2.3: Guidelines on extending on-going experiments with additional measurements to support crop modelling - Field experimental protocol

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Deliverable type: Report
File name: Report WP2 task C2.3.docx
Deliverable reference num.: C2.3


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|---|---|
| Instrument: | Joint Programming Initiative |
| Topic: | Agriculture, Food Security, and Climate Change |
| Project: | Modelling European Agriculture with Climate Change for Food Security (FACCE-MACSUR) |
| Due date of deliverable: | month 6 |
| Submission date: | 2013-05-10 |
| Start date of project: | 1 June 2012 |
| Duration: | 36 months |
| Deliverable lead partner: | Global Change Research Centre |
| Revision: | 1.0 |
| Work Package: | CROPM 2.3 |
| Document ref number: | C2.3 v1.0 |

## Abstract

The input data necessary for crop model simulations and data for their calibration/validation (and thus requirements for observations and measurements in suitable experiments) are listed. A list of possible seasonal observations/measurements that could be carried out in existing experiments to increase their potential for crop modelling studies is also provided. The general methodology suitable to be used is outlined, but in all cases the selected method depends strongly on the experimental set-up and facilities/instruments at the disposal of the experimentalists. Such methodologies needs to be documented and preferably benchmarked against standard methods.

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## Introduction

At present crop models represent one of the few tools available for complex studies assessing the potential climate change impacts and available adaptation options. The goal of MACSUR is ensure further development of the crop models which cannot be realized without significant use of new experimental data. However, experiments designed for crop model calibration and validation are still scarce as recent studies (e.g. Palosuo et al., 2011; Rötter et al. 2012) have revealed. However, there is still need for new information to inform crop modelling on aspects not well covered in the models (Craufurd et al., 2013) or to extend the spectrum of crops covered by the models. Outlines to link experimental data and model calibration and validation procedures are described exemplarily e.g. by Kersebaum 2011. There are on-going experiments that have been set-up for different purposes, which can be used for crop model calibration and validation, expecially if additional and complemetary measurements are carried out. In this way for relatively small cost high quality datasets could be obtained in relatively short time. This protocol attempts to define which observations/measurements in existing trials would be particularly helpful for crop-modelling studies and a simple protocol that would ensure robustness of data is provided. As each experiment is specific we strongly advise partners willing/planning/considering to carry out such updates of existing experiments to discuss it with the WP2 leaders who would provide feedback of the crop modelling community.

## Methods

### *Required data set*

Any dataset that is to be considered for crop model development, improvement or validation must include good quality data in these areas:

- Daily weather data typically at least:
  - Global radiation that might be measured directly or calculated from daily sunshine duration hours or cloud cover estimates;
  - Maximum and minimum temperatures measured at 2 m height
  - Precipitation
  - Mean air humidity and daily mean wind speed (optional)
- Soil data should include detailed description of the soil profile at the experimental site, especially
  - Description of the main horizons, their thickness and the soil type
  - Soil texture data for each horizon in the soil profile. Texture information should contain data on the percentage of stone and gravel content as well as clay, silt and sand.
  - Bulk density of individual horizons.
  - Carbon (or organic matter content) and content of total nitrogen (optional) in individual profiles (mainly for tillage layer).
  - Depth of the water table and with information on seasonal variation, if needed.
- Initial condition data should contain "start" conditions for the experiment (optional)
  - $NO_3$ and $NH_4$ content in individual soil horizons at the time preceding sowing
  - Water content in individual soil horizons at the time preceding sowing
- Crop information should include
  - Name of the crop species and name of cultivar and ideally its origin and type
  - Dates of sowing, emergence, anthesis, maturity and harvest
  - Grain yield (as dry matter) and grain N content
  - Number of grains and ears per area for cereals (optional)
- Management information should include
  - Information on the layout and technology used in the experiment
  - Previous crop
  - Dates, amounts and types of fertilization, in particular for nitrogen (if not given as pure nutrient amount, nutrient content per application unit has to be given, e.g. for slurry)
  - Seed density (or seed rate) and depth of seeding
  - Soil tillage, including type, dates and depth
  - Date and amounts of irrigations (optional: if relevant nutrient content)
  - Other operations (e.g. application of pesticides), which have affected crop growth
- Meta-data should include as detail assessment of the experimental season as possible including reports on the positive and negative factors influencing yield especially
  - Occurrence of extreme meteorological events (hail, drought, floods, etc.)
  - Lodging or other direct damage to the experiment
  - Occurrence of weeds, pests and diseases especially in cases which could influence significantly the yield level or phenology

If the conditions mentioned above are fulfilled then such experiment could be potentially used in the crop modeling studies. Clearly experiments with multiple seasons and treatments are preferable, especially if they include factors as irrigation, different fertilization doses, different timing of sowing, elevated $CO_2$ or drought levels. The listed parameters can be classified as "minimum data-set" although requirements differ between models. If your existing experiments meet such criteria then additional measurements from the list in the next section can be considered to be included in the measurement programme for supporting modeling.

***Additional measurements in existing experiments***
In order to improve crop model performance high quality data are required. While the experiments that would contain all information listed above are helpful they represent "minimum data-set" and additional measurements are highly desirable. Some of the suggested measurements require extensive sampling and therefore it is recommended to devote sampling plots in order to provide sufficiently large undisturbed harvest area. Measurement methods and sampling proceedures should follow standard practice of plant physiological ecology as listed e.g. in Pearcy et al. (1991).

**Above ground biomass sampling and analysis**

*Above ground biomass*
Sampling of above ground biomass at least two times during season (anthesis and maturity) and if possible regularly conducted every 10-14 days is relatively inexpensive. We recommend to carry out these measurements on area of least 0.5 $m^2$ per replicate for cereals and appropriately larger area for crops as maize, tuber crops or oil seed rape. Please ensure to limit the harvested area at the middle between two rows to allow a proper extrapolation of the area. The biomass should be cut as close as possible to the ground and weighted. Then the dry matter of the sample must be determined either using the whole sample or a representive subsample.

*Yield components*
In particular for cereals the analysis of the crop stand at maturity provides high value information. In this case the major yield components are assessed. In case of small grain cereals this includes number of productive tillers per square meter, number of grains per ear and mean weight of the grain. It is recommended that such analysis would be carried at least at 2-3 random spots in each replicate with at least 2 times $0.5m^2$ area being assessed and at least 50 ears analyzed per replicate to provide sufficiently large sample. The ears for analysis must be chosen randomly to represent the canopy and to avoid selecting the most dominant ones which leads to significant overestimation of the production.

*Below-ground biomass*
The information about rooting depth and root density in different depths is another extremely useful parameter for crop modeling. However, it requires either a root sampler or excavation of a soil profile which both lead to considerable disturbance within the experiment.

*Leaf area index (LAI)*
Many of the crop models use the leaf area in order to estimate interception of photosynthetic radiation and also to estimate transpiration by plant and thus comparison of measured and modeled values is of particular importance. Green leaf area index can measured from the sampled above-ground plant material, or non-destructively using using commercially available instruments (e.g. produced by Li-cor or Delta Instruments). The LAI measurements should be carried out at anthesis, but preferably more frequently ideally in parallel with the above ground biomass sampling.

*Soil-water dynamics*
Measurements of soil water content are critical for evaluating ability of any model to reproduce water balance correctly. The numerous methods available which differ both in the frequency of sampling, price but also the disturbance they caused. One of the simplest and most accurate procedures is to use the gravimetric methods. In the most optimum case the minimally disturbed sample of soil is collected in the container of known volume and its water content determined. Simpler approach includes collecting sufficiently large sample (at least 50 g), determining its water content and then using the know bulk density of the soil to estimate volumetric water content. Both methods allow for sampling even in subsoil but lead to significant disturbance on the sampling plot. Therefore sampling should not be taken over the same area of the plot. In order to achieve representative sample at least 3 samples per replicate are recommended.

Indirect method of assessing of the volumetric soil water content (e.g. CS616 or TDR) or water potential (gypsum blocks) allows for continuous collection of soil moisture values (e.g. in hourly time step). When these indirect methods are used they have to be calibrated at least twice per season preferably at contrasting water contents by gravimetric method.

It is recommended to carry out measurements in representative soil depths ideally 0-10 cm, 10-30 and 30-60 cm. However, as the extraction of the soil probes especially in the annual crops is laborious and difficult alternatively the probes can be place vertically to sample at least the top-soil allowing for easy extraction at the time of harvest.

*Nitrogen sampling*
Content of total nigronge in soil should be assessed once per year. Mineral nitrogencontent in the soil and N-content in the above-ground biomass should be assessed regularly during the vegetation season and at least at anthesis and at maturity. Ideally the content mineral nitrogen (both as $NO_3$ and $NH_4$ forms) should be measured at the time of model initialization (before sowing) in depths of 0-10 cm, 10-30 cm and 30-60 cm together with the soil water content (if possible also for 60-90 cm). The same sampling should be repeated at least for to 30 cm part of the profile also in the anthesis and maturity and if possible always when soil and above ground biomass sampling is carried out. Due to the relatively small variation in the total N content the more frequent sampling is desirable especially for mineral N. Sampling shortly after fertilizer application should be avoided. The N content assessment in the above-ground biomass should be carried out every time when above-ground biomass is sampled. Care must be taken of proper storage of collected samples with special stress being put on immediate cooling of the samples assigned for mineral N content analysis.

The recommended sequence of sampling is to carry out indirect measurements of soil moisture and LAI on the harvest plots. On the sampling plots, at first the above ground biomass should be collected (and sampled for the nitrogen), then soil sampling for nitrogen (total and mineral) is conducted with the gravimetric and eventually root density sampling being carried as the last in order to minimize the damage to the crop and thus influencing measuments.

## Acknowledgements
This paper is a contribution to the FACCE MACSUR knowledge hub.

The work was funded by the project of the National Agency for Agricultural Research of the Czech Republic (Crop modelling as a tool for increasing the production potential and food security of the Czech Republic under Climate Change, QJ1310123) and by the Danish Strategic Research Council.

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