

Modelling for Water Management: First Calibration of Yield-SAFE for irrigated maize in Mediterranean regions

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Abstract: In the Mediterranean region, careful management of water and nitrogen utilization is required to achieve high crop yields in a sustainable and economic way. Prediction models are useful tools for deriving site/region-specific optimum management strategies for irrigation and nitrogen use. Yield-SAFE, a simple and robust model for growth and resource use in agroforestry systems, simulates crop yields under rainfed and irrigated conditions. This paper represents a refined calibration with respect to the fluxes of water, based on, data from an irrigation/fertilisation experiment with maize in the South-East of Turkey. The model performs satisfactorily and further development will include nitrogen leaching calibration and validation.

1 Introduction

Presently, innovation for sustainable resource use as well as increasing its efficiency are getting wide attention. There are several reasons for this: an increasing demand for conservation of resources to achieve better sustainability; mitigation of drought problems that might result in some areas, especially on regions from climate change; the environmental problems due to excess of nutrient in soils; and the expected increase of demand for bio-energy and agriculture-derived raw products for industrial processing. Models for resource utilization in agricultural systems can help to explore - for different regions - locally adapted resource-efficient farming systems like precision farming, mixed cropping system or innovative irrigation systems [1]. Mixed cropping systems can include systems that mix crops and trees, i.e. agroforestry. Long term predictions are

needed to assess the long term economic profitability and environmental sustainability of such farming systems.

In water-scarce regions, it is necessary to save irrigation water and, thereby, increase crop water-use efficiency to maintain production [2]. In addition, nitrogen leaching, as a result of inappropriate fertilizer and irrigation management is a problem. Prediction models can be used to optimize the application rate and timing of water and fertilizer specific to the crop species, production aims and local conditions. In the present study the water module of the prediction model Yield-SAFE (Yield Estimator for Long term Design of Silvoarable AgroForestry in Europe) [3] was calibrated and tested against data of an irrigation experiment with maize in the Mediterranean region.

2 Material and Methods

2.1 Model description

Yield-SAFE [3] is a simple biophysical model for predicting long term crop and tree yields in monoculture and mixed systems. The model comprises few equations and parameters to attain sufficient model robustness for prediction purposes under constrained data availability. For the simulation of a monoculture crop four state equations are involved: biomass, leaf area, heat sum, available soil water. The model simulates growth and yield as a function of resource capture and resource use efficiency. Available soil water is computed considering precipitation, irrigation, drainage and soil evaporation. Nutrient dynamics are not included in the model because the involved processes are complex and would require heavy parameterization. Instead, the nitrogen demand corresponding to the water-limited yields is computed using the “Triple Quadrant-approach” [4, 5] which estimates the effect of fertilizer application on crop yields, based on two relations: 1) between nitrogen application and uptake and 2) between uptake and crop yield (invariable per crop species). Finally, nitrogen leaching can be quantified from model predictions on nitrogen recovery and water flow to the groundwater [6]. The model has been evaluated in terms of biomass production of summer and winter cereals and four tree species in Atlantic and Mediterranean regions [7].

2.2 The experimental data

The experimental data were obtained from an irrigated maize field during the growing seasons of 2001, 2002, 2004 and 2005 at the Research Fields of Cukurova University, Adana, Turkey [2]. The area has a typical Mediterranean climate with an average annual rainfall of 650 mm. Soils are with fine textured soils. In 2002, the irrigation water use efficiency was about $27 \text{ kg ha}^{-1} \text{ mm}^{-1}$ for the irrigation treatment in which soil-water content in the root zone was replenished to field capacity at each irrigation event. The planting density of hybrid maize was $79000 \text{ plants ha}^{-1}$. The data used for the calibration were derived from a well fertilized treatment. The measurements comprise: daily

weather, weekly soil water contents, and relevant soil physical characteristics, plant physiological measurements, crop yields and leaf area development. The crop and soil parameters were adapted for maize, the Mediterranean climate and the soil type. The simulation runs were performed for the water limited production level.

3 Results and Conclusions

The simulation results of the year 2002 are presented in Figures 1 and 2, showing the crop development (Figure 1) and the course of the soil water content (Figure 2) during the growing season 2002, respectively. The simulation slightly overestimated the total aerial dry matter, but there was a good agreement between simulated and observed growth pattern of biomass and Leaf Area Index (LAI). The simulated values of soil water content were close to the measured values. Moreover, the alternating drying and wetting cycles of the soil, i.e. the sudden change of soil water content after irrigation (replenishing to field capacity in the root zone) followed by drying of the soil till the following irrigation event, was well simulated (Figure 2).

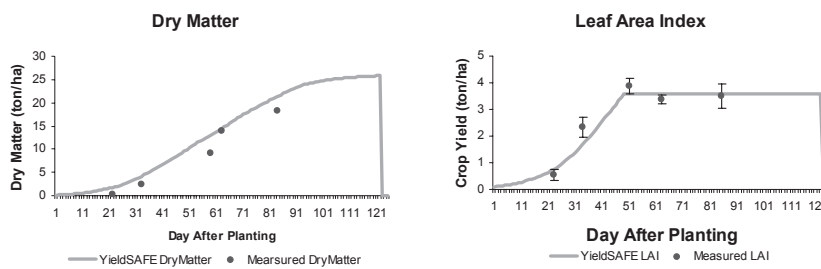


Figure 1: Simulated (line) and measured (dots) dry matter and Leaf Area Index (LAI) of hybrid maize, in 2002 at the Cukurova Research Fields, Turkey.

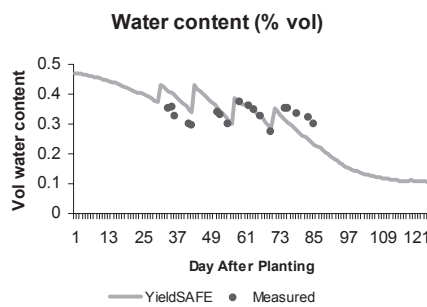


Figure 2: Simulated (line) and measured (dots) volumetric soil water content in 1 m depth of a maize field, in 2002 at the Cukurova Research Fields, Turkey

This paper describes the first calibration of the water module of Yield-SAFE using data of an irrigated maize field under semi-arid conditions. The model satisfactorily describes the water dynamics in a soil of the experimental maize field at the Cukurova research station. Improved quantification of water capture and losses allows more accurate yield predictions (Figures not shown). For generic use the model has to be tested for many different growing conditions. In a next step the belowground module will be calibrated and validated for the Atlantic region (Stuttgart, Germany) including nitrogen leaching.

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