Assessing the sustainability of wheat-based cropping systems using APSIM: model parameterisation and evaluation

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Abstract. Assessing the sustainability of crop and soil management practices in wheat-based rotations requires a well-tested model with the demonstrated ability to sensibly predict crop productivity and changes in the soil resource. The Agricultural Production Systems Simulator (APSIM) suite of models was parameterised and subsequently used to predict biomass production, yield, crop water and nitrogen (N) use, as well as long-term soil water and organic matter dynamics in wheat/chickpea systems at Tel Hadya, north-western Syria. The model satisfactorily simulated the productivity and water and N use of wheat and chickpea crops grown under different N and/or water supply levels in the 1998–99 and 1999–2000 experimental seasons. Analysis of soil-water dynamics showed that the 2-stage soil evaporation model in APSIM’s cascading water-balance module did not sufficiently explain the actual soil drying following crop harvest under conditions where unused water remained in the soil profile. This might have been related to evaporation from soil cracks in the montmorillonitic clay soil, a process not explicitly simulated by APSIM. Soil-water dynamics in wheat–fallow and wheat–chickpea rotations (1987–98) were nevertheless well simulated when the soil water content in 0–0.45 m soil depth was set to ‘air dry’ at the end of the growing season each year. The model satisfactorily simulated the amounts of NO\textsubscript{3}-N in the soil, whereas it underestimated the amounts of NH\textsubscript{4}-N. Ammonium fixation might be part of the soil mineral-N dynamics at the study site because montmorillonite is the major clay mineral. This process is not simulated by APSIM’s nitrogen module. APSIM was capable of predicting long-term trends (1985–98) in soil organic matter in wheat–fallow and wheat–chickpea rotations at Tel Hadya as reported in literature. Overall, results showed that the model is generic and mature enough to be extended to this set of environmental conditions and can therefore be applied to assess the sustainability of wheat–chickpea rotations at Tel Hadya.

Additional keywords: wheat, chickpea, Mediterranean, model evaluation, soil water, soil nitrogen.

Introduction

Crop production in the semi-arid regions bordering the Mediterranean is inherently constrained by variable, often deficient, rainfall (Cooper et al. 1987), fragile soil (Le Houérou 1981), and limited renewable water resources (Araus 2004). Today, the sustainability of crop production systems is at stake because of the degradation of agriculturally productive soil (Lal 2002) and water resources (Varelía-Ortega and Sagardoy 2002). For agricultural production in the West Asia–North Africa (WANA) region to meet the demand imposed by today’s demographic developments requires the more efficient use of water within cropping systems, and crop management techniques that maintain or improve soil quality (Araus 2004; Lal 2006).

In such water-limited environments, the long-term consequences of agricultural practices on crop productivity, water-use efficiency, and soil quality are difficult to assess because rainfall variability may mask existing trends. A complement to traditional field experimentation is cropping-systems analysis using simulation techniques that integrate long-term climatic records, and consequently allow the outcomes of agricultural interventions to be quantified across the observed rainfall variability (Meinke and Stone 2005).

The cropping-systems model APSIM (Agricultural Production Systems Simulator) is designed to simulate, on a daily basis, the dynamics of crop growth, soil water, soil carbon, and nitrogen (N) as a function of climate, cropping history, and the crop/soil management in either individual seasons or crop sequences (Keating et al. 2003).

APSIM has proven suitable for the analysis of the complex issues arising in cropping systems. Jones et al. (1996), for example, assessed the N contributions of a legume ley to...