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Modeling a wheat–maize double cropping system in China using two plant growth modules in RZWQM

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Abstract

Agricultural system models are potential tools for evaluating soil-water–nutrient management in intensive cropping systems. In this study, we calibrated and validated the Root Zone Water Quality Model (RZWQM) with both a generic plant growth module (RZWQM-G) and the CERES plant growth module (RZWQM-C) for simulating winter wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) double cropping systems in the Northern China Plain (NCP), China. Data were obtained from an experiment conducted at Yucheng Integrated Agricultural Experimental Station (36°57′N, 116°36′E, 28 m asl) in the North China Plain (NCP) from 1997 to 2001 (eight crop seasons) with field measurements of evapotranspiration, soil water, soil temperature, leaf area index (LAI), biomass and grain yield. Using the same soil water and nutrient modules, both plant modules were calibrated using the data from one crop sequence during 1998–1999 when detailed measurements of LAI and biomass growth were available. The calibrated models were then used to simulate maize and wheat production in other years. Overall simulation runs from 1997 to 2001 showed that the RZWQM-C model

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simulated grain yields with a RMSE of 0.94 Mg ha^{-1} in contrast to a RMSE of 1.23 Mg ha^{-1} with RZWQM-G. The RMSE for biomass simulation was 2.07 Mg ha^{-1} with RZWQM-G and 2.26 Mg ha^{-1} with RZWQM-C model. The RMSE values of simulated evapotranspiration, soil water, soil temperature and LAI were 1.4 mm, 0.046 $m^3 m^{-3}$, 1.75 °C and 1.0 for RZWQM-G and 1.4 mm, 0.047 $m^3 m^{-3}$, 1.84 °C and 1.1 for RZWQM-C, respectively. The study revealed that both plant models were able to simulate the intensive cropping systems once they were calibrated for the local weather and soil conditions. Sensitivity analysis also showed that a reduction of 25% of current water and N applications reduced N leaching by 24–77% with crop yield reduction of 1–9% only.
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Keywords: Agricultural system; Crop growth model; Evapotranspiration; Soil water; Soil temperature; Wheat; Maize; North China Plain

1. Introduction

The North China Plain (NCP) is the largest region of agricultural importance in China. It lies in Northeastern China between 32–40°N and 114–121°E, covering about 18 million hectares of farm lands (18.3% of the national total) and producing about 21.6% of the total grain yield of edible crops and more than 36.2% of the total cotton yield of the country. In the NCP, wheat grain yield increased from 2.27 Mg ha^{-1} in 1980 to 4.69 Mg ha^{-1} in 2000, and maize grain yield from 3.18 to 5.27 Mg ha^{-1}, while fertilizer application increased from 102 kg ha^{-1} yr^{-1} in 1980 to 612 kg ha^{-1} in 2000 (China Statistics Bureau, 2001). Climatically, there are marked interannual and seasonal variations in precipitation and temperature in this area. While 80% of the annual precipitation is concentrated in the summer months (from June to September), spring is typically dry. Precipitation decreases from 900 mm yr^{-1} near the Huaihe river in the south to 480 mm yr^{-1} in the northern part of the NCP. Winter wheat–maize double crop rotations (two crops harvested in a year) dominate cropping systems in the region. Due to sparse rainfall and associated soil water deficit, winter wheat crops are usually irrigated. Since the 1970s, the NCP has been confronted with serious challenges associated with increased water deficit and water quality degradation. More than 50% of the irrigated land uses groundwater, causing groundwater levels to decline at an average rate of about 1 m yr^{-1} in the past two decades in the NCP (Hu et al., 2005). In order to meet the increasing need for grain and fiber, intensive agricultural management prevails in the region with over-application of fertilizer and increased crop water needs. Nitrogen fertilizer plays a critical role in producing high yields; however, its over-use results in decreased economic returns and declines in surface and groundwater quality. Continuation of the current agromanagement practices can pose a big challenge to sustainable agricultural production in the NCP (Hu et al., 2005).

Agricultural scientists and planners in the area are being confronted with the task of developing timely and viable alternative soil-water–crop management systems to counteract the current downward trends in environmental degradation and agricultural productivity. To address these emerging challenges in agriculture, there is an

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