#7645 MONITORING IRRIGATION WATER USE AT LARGE SCALE IRRIGATED AREAS USING REMOTE SENSING IN WATER SCARCE ENVIRONMENT

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ABSTRACT

Increasing pressure on available water resources in semi-arid region will affect the availability of water for irrigated agriculture. In this context, adoption of innovative and cost-effective tools for water management and analysis of water use patterns in irrigated areas is required for an efficient and sustainable use of water resources. This study aims to evaluate a remote sensing-based approach which allows estimation of the temporal and spatial distribution of crop evapotranspiration and irrigation water requirements over large irrigated areas. The method consists of an adaptation of the daily step FAO-56 Soil Water Balance model combined with time series of basal crop coefficient (Kcb) and the fractional vegetation cover (fc) derived from high resolution satellite NDVI imagery (Normalized Difference Vegetation Index). The model was first calibrated and validated at plot scale using evapotranspiration measured by eddy-covariance systems over wheat fields and olive orchards which represents the main crops grown in the study area of Haouz plain located around Marrakesh city. Then, the model was used to compare remotely sensed estimates of irrigation water requirements and observations of irrigation water use at plot scale over an irrigation district in Haouz plain along three agricultural seasons. At plot scale, the results showed that the model provides good estimates of evapotranspiration for wheat and olive trees, given specific calibration of crop and soil related parameters that control transpiration and evaporation processes. At the irrigation district scale, the comparison of spatialized irrigation water requirements and irrigation water use showed great discrepancies indicating a temporal and spatial varying demand and supply of irrigation water over the seasons. In addition to the model and the observed data uncertainties, the variability observed could be influenced by different biophysical factors and the farmer’s behaviour and management practices. Also, some differences between observations and estimates were spatially correlated at some extent with the distribution of wells in the area, which shows a potential use of the method for monitoring groundwater withdrawals. These results suggested that the water supplied within the studied irrigation district needs to be improved for a better performance of irrigation. The findings demonstrate the potential interests for irrigation managers of using remote sensing-based models to assess irrigation water requirements and monitor irrigation water use for efficient and sustainable use of water resources.

INTRODUCTION

Irrigated agriculture is the main water consumer worldwide, accounting for about 70% of all available fresh water (FAO, 2016). However, increasing pressure on available water resources, particularly in semi-arid region, due to population growth, climate change and competition from other economic sectors will affect the availability of water for irrigated agriculture in the future. In this context, assessing irrigation performance and improving irrigation water management using innovative and cost-effective tools is necessary for an efficient and sustainable use of water resources.

One key information useful for irrigation managers to evaluate irrigation performance is the temporal and spatial distribution of crop water use or evapotranspiration (ET) over large irrigated areas. Recently, research has demonstrated the potential for remote sensing to monitor crop development and to assess the spatial and temporal variability in crop water use (Tasumi and Allen, 2007; Zhang et al., 2016).

In this study, we evaluated the reliability of an approach based on a soil water balance model assisted by remote sensing data for assessing crop irrigation requirement and monitoring spatialized irrigation water use. This approach was used to compare remotely sensed estimates of crop irrigation requirements and in situ observations of irrigation water use in the Haouz irrigated plain (Morocco). Our goal is to demonstrate the operational application of a remote sensing-based water balance model to monitor irrigation water use at field level over large irrigated areas.

MATERIALS AND METHODS

The irrigation district evaluated in this study, during three agricultural seasons (2002-03, 2005-06 and 2008-09), is located in the Haouz plain around Marrakesh city (Morocco) which is a part of the Tensift watershed characterized by a semi-arid climate (Figure 1).

The crop irrigation water requirements over the irrigated area were obtained by a remote sensing-based Soil Water Balance model which consists in coupling the FAO-56 dual crop coefficient model with time series of high resolution NDVI imagery (Normalized Difference Vegetation Index) providing estimates of the actual basal crop coefficient (Kcb) and the fractional vegetation cover (fc). The FAO-56 model was modified by adding a deep soil layer below the root compartment to account for deep water storage and capillary rise (Zhang and Wegehenkel, 2006). A series of Landsat TM (in 2002-03, 2008-09) and Formosat (in 2005-06) images of the studied area were acquired and used to provide a NDVI time series and a land cover map (Simonneaux et al., 2008; Duchemin et al., 2008). The latter shows a predominance of annual crops (mainly cereals), and trees (mainly olive trees) over the irrigated areas (Figure 1).

Calibration and validation of the model were performed at plot scale using evapotranspiration (ET) measured by eddy-covariance systems over wheat fields and olive orchards during experiments conducted in the studied area (Er-Raki et al., 2007, 2010). Then, the model was used to compare spatialized estimates of irrigation water requirements with observations of irrigation water use at plot scale over the R3 irrigation district in Haouz plain along the three agricultural seasons.

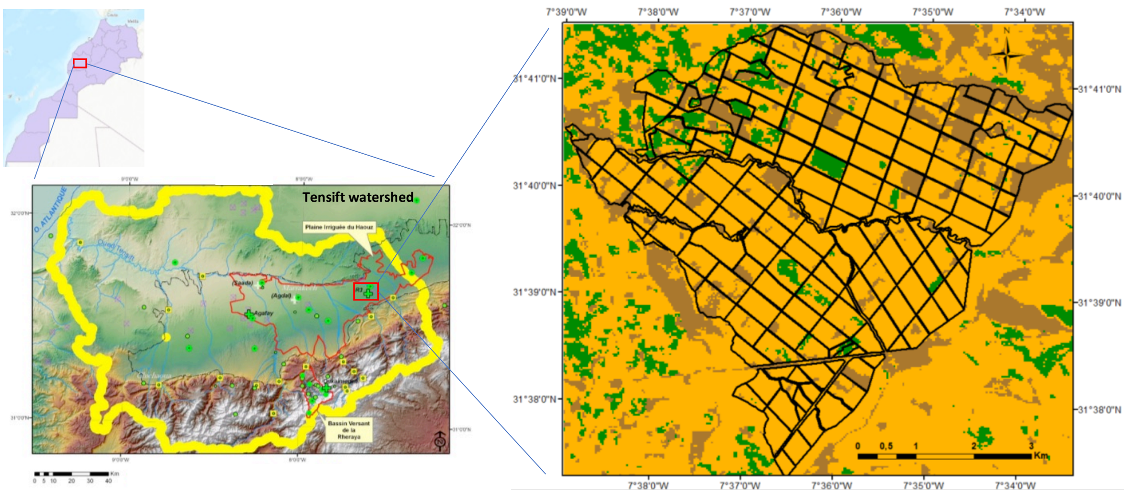

Figure 1. Location of the studied area and land cover map (2008-09). Land cover: trees in green, cereals in orange and bare soil in brown. Bold line: plot boundaries in R3 irrigation district.

RESULTS AND DISCUSSION

The calibration was performed for the parameters controlling the processes of transpiration (Kcb mid-season, root zone depth max, diffusion coefficient between deep and root zone layers and maximum soil depth) and evaporation (diffusion coefficient between root zone and evaporation layers, Readily evaporable water, soil surface layer depth). The Kcb and fc profiles were estimated from satellite data using linear Kcb-NDVI and fc-NDVI relationships and the other parameters (soil moistures at field capacity and wilting point, fraction of soil surface wetted by irrigation, initial soil moisture) were obtained from ground observations.

The parameters values obtained allowed a good adjustment between the ET estimated by the model and the measured ET. The validation of the model was performed using the same set of calibrated parameters over other wheat and olive fields. The results showed a good performance of the model in estimating actual ET with average Nash-sutcliff efficiency (NSE) and Root Mean Square Error (RMSE) respective values of 0.67, 0.56 mm/day for wheat and 0.64, 0.52 mm/day for olive tree. The dynamic of actual ET estimated by the model followed reasonably well the time course of observed actual ET (Figure 2).

At the irrigation district scale, the model was used to estimate the spatial and temporal distribution of ET and irrigation water requirement. The cumulated seasonal ET values were 470 mm, 420 and 400 mm on average respectively for the 2002-03, 2005-06 and 2008-09 seasons with a great heterogeneity inside the R3 district. The same was true for irrigation requirement with average values of 163, 156 and 103 mm respectively for the 2002-03, 2005-06 and 2008-09 seasons. This seasonal variability could be explained by the differences in climatic conditions characterized by high climatic demand (reference evapotranspiration, ETo) and low rainfall in 2002-03 compared with the other seasons.

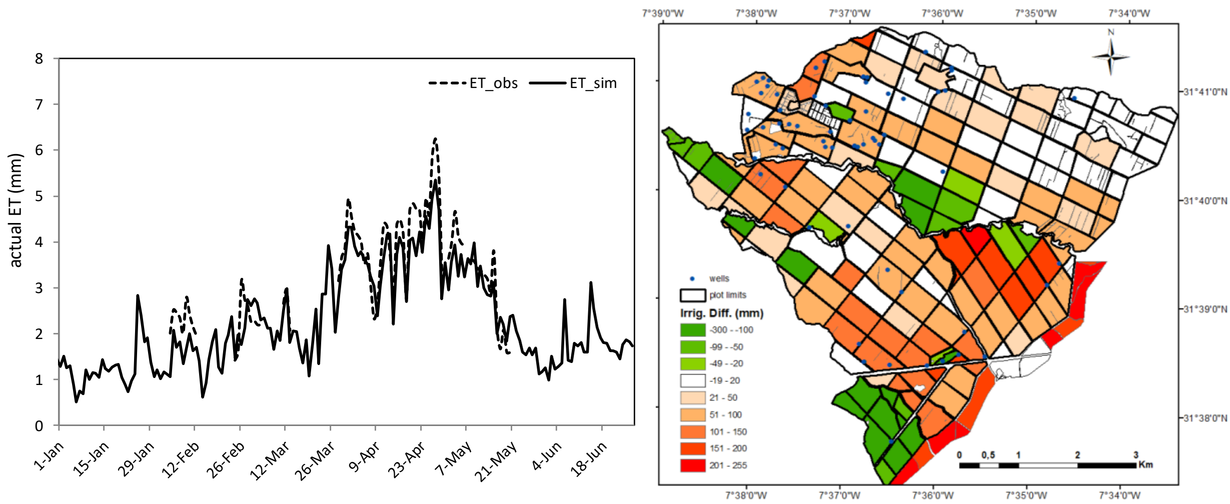

Figure 2. Time course of observed and simulated actual ET over a validation wheat field in 2002-03 season (left), and map of difference between simulated and observed irrigation at plot scale for 2002-03 season over R3 irrigation district (right).

The differences between irrigation water needs and irrigation water supplied at farm level showed great spatial variations in each season and across seasons (Figure 2). This suggest that large proportion of farms were either over-irrigating or under-irrigating regardless the seasonal water availability. The spatial distribution of farms whose irrigation water needs exceeded observed supply were located to some extent close to the wells suggesting groundwater extractions to meet crop water needs (Figure 2). In addition to the model and the observed data uncertainties, the variability observed could be attributed to different biophysical factors, irrigation supply conditions which depends on water availability, the farmer's behaviour (inadequate irrigation scheduling, financial considerations, …) and management practices (cultivar, sowing date, fertilizers, weed control…etc) as previously reported (Duchemin et al., 2008; Kharrou et al. 2013). These results revealed that this approach could provide an interesting framework for irrigation managers to monitor irrigation water use for efficient and sustainable use of agricultural water.

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