Agricultural Water Management 202 (2018) 183–194

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Influence of soil hydraulic variability on soil moisture simulations and irrigation scheduling in a maize field

Mouna Feki*, Giovanni Ravazzani, Alessandro Ceppi, Marco Mancini

Department of Civil and Environmental Engineering (D.I.C.A.), Politecnico di Milano, Piazza Leonardo da Vinci, 32, 20133 Milano, Italy

ARTICLE INFO

Keywords:
Soil water content
Soil hydraulic properties
Stress index
Irrigation scheduling
Soil temporal variability

ABSTRACT

Hydrological models play a crucial role for their ability to simulate water movement from soil surface to groundwater and to predict onset of stress conditions within agricultural fields. However, optimal use of mathematical models requires intensive, time consuming and expensive collection of soil related parameters. Typically soils to be characterized exhibit large variations in space and time as well during the cropping cycle, due to biological processes and agricultural management practices: tillage, irrigation, fertilization and harvest. This paper investigates the variability of soil hydraulic properties over a cropping cycle between April and September 2015, within a surface irrigated maize field (6 ha) located in northern Italy.

To this aim, undisturbed and disturbed soil samples were collected from different locations within the study area and at different depths, during three measuring campaigns, at the beginning, in the middle of the cropping season and after the harvest. For each soil sample, several parameters were monitored: organic matter and bulk density together with soil hydraulic parameters. Soil parameters of Soil water retention curve parameters were measured following the evaporation method, while the saturated hydraulic conductivity was determined in the laboratory using the well-known falling head method. Results show that soil properties, mainly the saturated hydraulic conductivity, are subjected to significant variations. The variability of these parameters was taken into consideration when simulating soil moisture using FEST-WB model. An improvement in soil water content simulations was observed as compared to field measurements with implications on prediction of water stress conditions that is fundamental for irrigation scheduling.

1. Introduction

Over the last decades, many advances had been made in terms of development of more sophisticated irrigation techniques. Modern irrigation systems with high efficiency have been suggested (sprinkler, drip, subsurface irrigation) as alternatives to low efficient ones (like surface irrigation). These irrigation techniques allowed increasing the water use efficiency for crop production (Levidow et al., 2014). In spite of this success, still many agricultural lands are irrigated through gravity-fed irrigation systems. According to the Spanish experience, the modernization of irrigation schemes was coupled with infrastructures and energy costs (Rodríguez-Díaz et al., 2011). Thus, the improvement of water management practices is considered as more cost-effective than the modernization of irrigation schemes (Lozano and Mateos, 2008).

Nowadays, "smart agriculture" based on the combination of monitoring and modelling has been widely implemented for producing "more crop per drop". In fact, a better irrigation planning, which allows optimizing water use to maximize crop production, is a precondition to reduce water use in agriculture (Rallo et al., 2011; Mun et al., 2015). Many models exist and they have been mainly developed to better manage water for irrigation such as the Aquacrop model (Steduto et al., 2009).

Implemented as decision support tools, these models should provide accurate information about the timing and amount of irrigation water in order to meet the crop water requirements. This should be reached without developing water stress or surplus conditions. Agro-hydrological models represent a powerful tool to enhance the effectiveness of irrigation scheduling (Rallo et al., 2010). The implementation of these models for irrigation scheduling is constrained by many sources of uncertainties due to: meteorological data, field measurements and the formulation of some processes such as infiltration, and evapotranspiration (Chaubey et al., 1999; Allen et al., 2011; Pereira et al., 2015 Mun et al., 2015). Understanding the controlling factors of water movement within the root zone is essential not only for irrigation scheduling, but also for the design of irrigation and drainage systems

* Corresponding author.
E-mail address: mouna.feki@polimi.it (M. Feki).

https://doi.org/10.1016/j.agwat.2018.02.024
Received 23 August 2017; Received in revised form 9 February 2018; Accepted 21 February 2018
0378-3774/

(Kourgialas and Karatzas, 2015).

The vadose zone, considered as the interface between surface and groundwater, controls key processes such as (infiltration, drainage, evapotranspiration) which determine the water availability (Kourgialas and Karatzas, 2015). In fact, a better characterization of the field conditions, and in particular the soil hydraulic parameters, is important for a better understanding and modeling of water and solute transport in the vadose zone. These later are also required to calculate the water availability for crops.

To be characterized, soils, particularly in the vadose zone, exhibit large variations in space and occasionally in time, due to biological processes and agricultural management practices: tillage, wheel-traffic, irrigation, fertilization and roots development (Cameira et al., 2003; Shirmohammadi and Skaggs, 1984; Iqbal et al., 2005). Therefore, soil properties are subjected to diverse physical and chemical changes that lead to a non-stability in terms of water and solutes movements within the soil as well as to the groundwater. In this context, many researchers have focused their studies on quantifying the effect of tillage on soil properties (Green et al., 2003, Mapa et al., 1986). Others tried to assess the effect of wheel traffic on infiltration (Ankeny et al., 1990; House et al., 2001 Richard et al., 1999 Défossez et al., 2003). While fewer studies were carried out to evaluate the impact of agronomic practices on soil properties and on soil water movement within the vadose zone (Ndiaye et al., 2007).

The temporal variability of soil hydraulic properties was rarely assessed or taken into consideration when modeling soil water movement (Angulo-Jaramillo et al., 1997). Some researchers tried to include within their simulations this temporal variability by measuring soil parameters at different periods of the cropping cycle (Xu and Mermoud, 2003; Schwen et al., 2011). Others tried to assess the effect of irrigation practices on temporal changes of soil properties (Mubarak et al., 2009). To our knowledge, implications of the space and time variation of soil properties on irrigation scheduling were never assessed before. It has been proven that this variability affects the soil moisture simulation results (Schwen et al., 2011). Hence, in a context of precision agriculture and smart farming practices the variability of soil hydraulic properties should be taken into consideration also within decision support tools for irrigation.

This study aimed at: (i) assessing the temporal and spatial variability of soil hydraulic properties over a cropping cycle, (ii) quantifying their effect on the simulations of soil water movement using the FEST-WB model (Rabuffetti et al., 2008) and (iii) evaluating previous irrigation schedule implemented for a maize field in the Po Valley accounting for temporal and spatial variability of soil hydraulic parameters.

In this study, the variability of measured parameters was assessed as the effect of agronomic practices and biological activities on soil properties.

2. Materials and method

2.1. Experimental site

The study site is a maize field (45°13′31.70″ N, 9°36′26.82 E) located in Secugnago, a small town in the Lombardy Region, northern Italy, within the irrigation consortium of the Muzza Bassa Lodigiana (MBL). It is a surface irrigated field that covers an area of 6 ha. Although water resources in northern Italy, and in particular in the Po Valley, are considered abundant, cultivated crops are still subjected to high evaporative demand and water stress conditions during the summer season due to the Mediterranean climate (Ceppi et al., 2014)

To compensate evapotranspiration depletion, irrigation is mandatory during the summer season. However, the irrigation scheduling in northern Italy is constrained by the non-flexibility of water delivery system with a rotation irrigation scheme (typically 14 days); turns, the consortium fixes discharges and durations according to ancient negotiated water rights.

In this paper, we used both meteorological and soil moisture data, monitored from 21st of April until 16th of September 2015. During the monitoring period, the recorded cumulative rainfall for the study site was around 195 mm with a minimum temperature of 8.7 °C and a maximum temperature of 35.4 °C. The maize in this field was sown on 08/04/2015 and 09/04/2015. During the cropping season of 2015, the field was irrigated twice: 30 of June and 14 of July.

The field was equipped with an eddy covariance and meteorological stations. Rainfall was measured by a pluviometer (AGR100 by Campbell Scientific) for the quantification of rain amounts. Within the soil, both the temperature and water content were monitored at different depths. Soil was equipped with two thermocouples (by ELSI) and a heat flux plate (HFP01 by Hukseflux) for the measurement of the specific energy flux leaving the surface layer (G). As well, three TDR probes (Time Domain Reflectometry) (CS616 by Campbell Scientific) for volumetric soil moisture measurement at different depths (10 cm, 30 cm, 65 cm). For the same purpose an FDR (Frequency Domain Reflectometry) (EnviroSMART Sentek probe) was used to measure the soil moisture profile up to a depth of 1 m. Data, stored into an internal logger memory (by Campbell), are daily downloaded with a GPRS connection. For this study, only TDR measurements were considered to compare field measurements with model simulations.

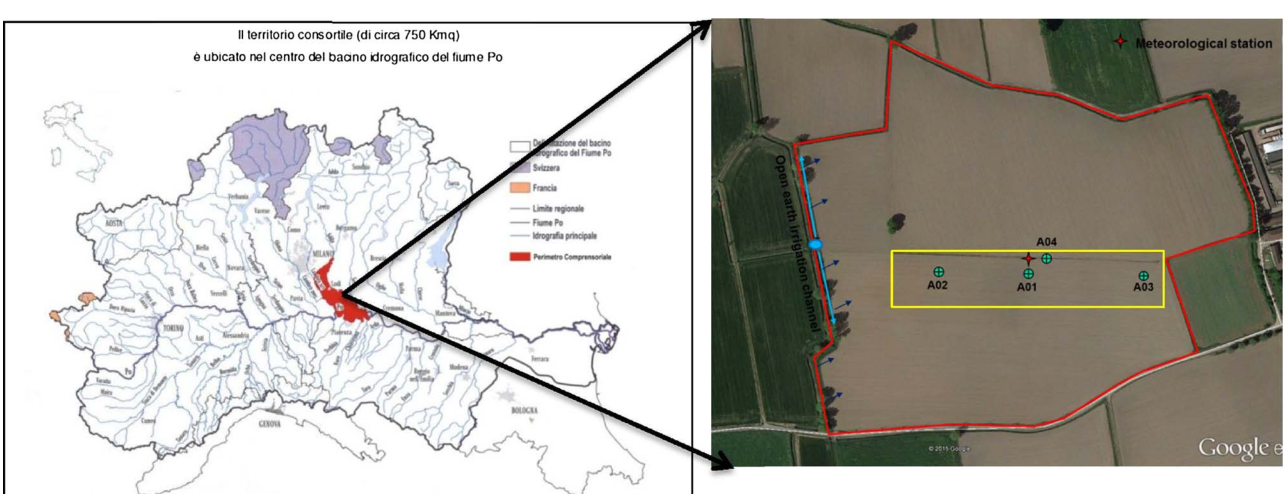

Fig. 1. Study site and sampling point locations.