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Temporal dynamics of alfalfa water use efficiency under hyper arid conditions of Saudi Arabia

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*A field study was carried out to investigate the seasonal variations in alfalfa (*Medicago sativa *L.) water use efficiency (WUE) using Eddy Covariance (EC) measured CO_2 and H_2O fluxes, aiming at optimizing the use of irrigation water under hyper arid conditions. The EC system used for this study was installed on a center pivot-irrigated 50 ha alfalfa field. Results revealed that the net EC estimated CO_2 uptake ranged from 65,00 kg ha^{-1} (in winter) to 21,500 kg ha^{-1} (in summer). While, H_2O flux was 4,147 m^3 ha^{-1} (in winter) and 20,157 m^3 ha^{-1} (in summer). This resulted in an estimated alfalfa WUE of 1.57 and 1.07 kg m^{-3} for winter and summer seasons, respectively. However, the actual WUE of harvested alfalfa was calculated at 0.70 and 0.71 kg m^{-3} for winter and summer, respectively. Therefore, attaining an actual crop WUE of 33–55% lower than the EC measurement (i.e. more water losses were due to leaching and deep-percolation processes, as the EC system could only estimate evapotranspiration over agricultural fields) emphasizes the need of precision irrigation practices, which will enable farmers to apply irrigation water and agrochemicals more precisely and site-specifically to match soil and plant status and needs.*

Keywords: Center pivot irrigation, Eddy Covariance, energy fluxes, hyper-arid region, water use efficiency

Introduction

Due to the limited availability of water and fluctuating and extreme evapotranspiration patterns, there is a need to improve irrigation efficiency through modern agricultural practices such as Precision Agriculture (PA). Proper scheduling of irrigation is crucial for efficient water management in crop production, particularly under conditions of water scarcity (Pereira *et al*., 2002). Water Use Efficiency (WUE) is one of the key parameters which provide information on irrigation efficiency (Montazar and Sadeghi, 2008). Accurate WUE of crops can be modeled based on crop water requirement, available water resources, soil water infiltration rate and variability of agro-meteorological information such as energy fluxes and evapotranspiration (Bezerra *et al*., 2015). On the other hand, proper documentation of irrigation scheduling practices is essential for improving crop yield and/or WUE with respect to irrigation times and amounts of water applied per growth season (Qiu *et al*., 2008; Al-Ghobari *et al*., 2013).

The Eddy Covariance (EC) technique to measure CO_2, water and energy fluxes between the biosphere and the atmosphere is widely used in various agricultural monitoring studies (Ji *et al*., 2011; Gilmanov *et al*., 2014). WUE, the rate of carbon uptake per unit of water lost, precisely quantifies how much water an ecosystem uses relative to the gained carbon. In general, WUE of agricultural crops differ from each other with respect to their contribution to CO_2 and H_2O fluxes (Gilmanov *et al*., 2014). Continuous observations of carbon and water fluxes using EC system can be used to characterize the variability in WUE as the ratio of the productivity (i.e. gross primary productivity – GPP, net primary productivity – NPP, net ecosystem productivity – NEP, etc.) to the evapotranspiration (ET), Tang *et al*. (2015).

In Saudi Arabia, alfalfa (*Medicago sativa* L.) is one of the major fodder crops cultivated under center pivot irrigation systems. As water management under hyper-arid, arid and semi-arid regions is a challenging aspect, optimum irrigation scheduling to agricultural crops is critical for improving irrigation efficiency (i.e. WUE). In order to achieve optimum irrigation schedules and patterns, seasonal dynamics of WUE of alfalfa was monitored with respect to the changing agro-meteorological conditions in the Eastern region of Saudi Arabia. Therefore, this study was carried out, during the period from June 2013 to May 2014, to understand the temporal dynamics of net ecosystem productivity (NEP), ET and WUE of alfalfa, by analyzing the EC measured CO_2 and H_2O fluxes, in order to optimize the use of irrigation water. The specific objectives of this study were: (i) to explore the temporal dynamics of alfalfa CO_2 assimilation and

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