

The Role of Precision Irrigation in Environmentally Sensitive Areas

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Introduction

High value crops are usually highly dependent on irrigation in Southern Europe areas because the climate in the region is predominantly Mediterranean, with rainfall concentrated mainly in autumn and spring, and dry spells in summer. However, good irrigation practices are particularly important in high environmentally sensitive areas where poor irrigation management may have a large impact on water resource availability and pollution. This is the case of strawberry production in the vicinity of Doñana National Park (Southwest of Spain).

Strawberries are an example of a water-intensive crop that is highly demanded in both the European fresh market and the food industry. It represents the largest concentration of strawberry production in Europe (and the second largest globally) and nearly all (>90%) production from this region is exported to the international market, which demands premium-quality strawberries produced under environmentally sustainable conditions. Strawberry cultivation provides huge economic and social benefit to the region, representing a strategic sector that generates more than 700 work days per ha and supports over 55000 jobs per year [1].

However 73% of total strawberry production in Huelva is located in the surroundings of Doñana National Park [1]. The Doñana National Park wetland is a valued wildlife refuge that belongs to the UNESCO World Heritage list and it is also a Ramsar site, a Biosphere Reserve and a European Community Special Protection Area [2]. Therefore the ecological sensitivity of Doñana is recognized worldwide, and in this case, water is the most affected resource by the interaction between the irrigated agriculture and the environment, where water dynamics play a crucial role. Several water regulations affect the park and its surrounding areas: the Guadalquivir and the Tinto, Odiel, Piedras hydrological basin plans [3,4]. But despite the strawberry contribution to the rural economy and employment, it has been identified as being a water-intensive activity due to its high dependency on fresh water. There are thus growing concerns regarding the environmental sustainability of strawberry production in the region, relating mainly to over-abstraction and groundwater pollution [5].

Precision agriculture is defined as a “set of technologies that combines sensors, information systems, enhanced machinery, an informed management to optimize production by accounting for variability and uncertainties within the agricultural systems”[6]. Precision irrigation (PI) involves the accurate assessment of plant water requirements and precise application of the required volume at the required time. Therefore, it is also important to determine the appropriate irrigation frequency/strategy in order to avoid leaching of the soils (typically very sandy) towards deeper layers and the possibility of aquifers contamination. This can be achieved through PI technologies which certainly would increase Water Use Efficiency (WUE) for strawberry production and its environmental sustainability [7].

Strawberry cropping in Huelva has specific traits that make irrigation scheduling (timing) difficult. One of the main reasons for the high levels of water demanded for production is the high sand content in most of the local soils. These soils have a very low water-holding capacity; consequently, the soil water dynamics move very quickly, involving high losses through deep percolation, causing important pollution problems due to the dissolved fertilizers, when water is applied inefficiently. Accurate irrigation management is thus essential and water should be applied in short pulses to avoid percolation losses. The most common irrigation emitters used in strawberry production are 1-year low density polyethylene tapes which are not pressure compensating. This type of product is both cheap and easy to install. Despite these advantages, plastic tapes are not the most suitable system to irrigate crops by pulsing, a process that is essential on these sandy soils. Based on uniformity evaluations carried out between 2011 and 2014, the distribution uniformity dropped dramatically to around 50% during the middle-final period of the season. One of the reasons for these low values was the increasing occurrence of emitter clogging due to back suction when the system drained down between each irrigation event. System malfunctioning is common in the region as the irrigation units are usually too large, so most of the emitters do not work within the right pressure range. Farmers do not detect the cause of the problem as they do not regularly check the working pressure. To exacerbate the situation, management of the systems is based mainly on farmer experience instead of relying on more objective methods using agroclimatic and soils data.

The inefficiencies in farm water management have resulted in the development of a comprehensive irrigation system for strawberry production. Based on precision irrigation principles, irrigation should be an activity that involves both the accurate assessment of crop water requirements and the adequate application of the right amount of water applied at the right time, using hydraulic elements with high volumetric efficiencies and a system that allows spatially uniform applications [8].

A precision irrigation system has been developed to reduce the inefficiencies detected in the current irrigation systems in strawberry cultivation. The precision system operates following a three stage procedure. Firstly, at the beginning of the growing season, a gross daily irrigation scheduling is carried out based on estimations of crop water requirements that require the historical data recorded in the closest weather station [9,10]. This schedule takes into account crop and soil local conditions as well as the topology of the irrigation network (size of irrigation sectors) that have a significant influence when low quality water emitters were installed. The impact of the hydraulic network on the application efficiency was analyzed using EPANET as hydraulic simulator and the pulses duration are corrected according to this in order to consider the irrigation distribution uniformity [11]. On the contrary, for high quality water emitters (no pressure dependent), the influence of the irrigation network in the irrigation efficiency is very low. Then, the irrigation timing was

established according to the optimum duration of the irrigation pulses that minimize percolation losses. The duration of the pulses varies during the cropping season. Thus to maximize WUE, the crop-soil-water system was modeled using the numerical model Hydrus 2D to estimate the optimum pulse durations along the season.

Finally the control of the daily amount of water applied was performed using new irrigation technologies that also provided information to support farmer decision making. The irrigation sector operation was controlled with an electro-valve, a pressure regulator, a smart water meter and an irrigation controller. The initial irrigation schedule and timing (number of daily pulses and their duration) were weekly updated by an ad-hoc application fed with the actual information recorded at the local weather station and by the soil water sensors.

This system was installed on commercial strawberry farms for seasons 2013/2014 and 2014/2015. The farmers' concern over improving the sustainability of the strawberry promoted a strong engagement between growers and researchers to develop and implement this precision irrigation, involving directly more than 20% of the production area. Additionally, an intensive dissemination campaign has extended the advisory service on precision irrigation up 70% of the total area. Thus, for season 2014/2015 water use reductions between 11% and 33% in total gross water applied were achieved in relation to the volume of water typically applied, whilst maintaining yield and fruit quality. The total water savings achieved are over 2300 ML.

Precision irrigation involves both the irrigation system and water management and its generalization should be an important objective for water intensive crops like strawberries. The implementation will help farmers to use water more efficiently, reducing water abstraction, percolation and groundwater pollution and therefore minimizing the environmental impact of strawberry production in this very sensitive area.

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