Catena 155 (2017) 127–134

Contents lists available at ScienceDirect

Catena

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

# Evaluation of alternatives for flood irrigation and water usage in Spain under Mediterranean climate

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ARTICLE INFO

*Article history:*
Received 6 June 2016
Received in revised form 14 February 2017
Accepted 20 February 2017
Available online 22 March 2017

*Keywords:*
Irrigation water management
Irrigation efficiency
Water balance
Water deficit
Ebro river basin

ABSTRACT

Evaluation of water management has been progressively more necessary to determine the availability of water resources, especially in the Mediterranean environment where competition for these resources is maximum.
This work evaluates the irrigation management and evolution of hydric needs for the main crops implemented in the Ebro basin (Spain), through the monitoring of a pilot experimental basin between 1998 and 2012. This 15-year period comprehends changes in irrigation implemented by the Irrigation District as well as climate and agronomic variabilities of the region.
Changes in water management (implementation of an on-demand irrigation system with annual water allowances and payment per surface and consumption, in opposition to an irrigation system in shifts) and crops contributed to reduce irrigation by 40% and drainage by 72%. This occurred due to better adjustments between the water volumes applied and the hydric needs of the crops, achieving flood irrigation efficiencies of 80%. However, small negative trends were detected in the water deficit evolution of corn and sunflower, which should be addressed and improved.
Improvements in water management by farmers have enabled the increase of irrigation efficiency up to values found in pressurized irrigation systems, especially in initial stages of the irrigation campaigns. However, specific water deficit episodes were detected that should be remediated.



## 1. Introduction

Evaluation of water management in arid regions is becoming increasingly necessary to determine the availability of water resources, as competition for this resource is maximum and is predicted to increase during the XXI century. In fact, climate studies developed up to date predict a lower availability of water resources in the Mediterranean environment: decreases in precipitation and increases in temperatures (IPCC, 2007, 2008) will have strong consequences on the regional water balance.

In this sense, considering that the agricultural sector is the greatest consumer of water in the world (FAO, 2006), it is necessary to rethink and evaluate the use and management of water in this sector. The bottom line is to obtain adequate agrarian efficiencies without causing simultaneous negative impacts to the natural environment.

Therefore, although irrigation enables the increase and maintenance of agricultural productions (FAO, 2003), it is also the responsible for soil (Tanji and Kielen, 2002; Liu et al., 2012; García-Garizábal et al., 2014a; Gkiougkisa et al., 2015) and water degradation due to salts (Causapé et al., 2004b; Isidoro et al., 2006; Thayalakumaran et al., 2007; Duncan et al., 2008; Abrahao et al., 2011a; García-Garizábal et al., 2014a) and other agrochemicals (Causapé et al., 2004b; Thayalakumaran et al., 2008; Abrahao et al., 2011b; Petrovic et al., 2011; García-Garizábal et al., 2012b, 2014b), being nitrate and phosphorus the main issues associated with the occurrence of anoxic zones and eutrophication of aquatic environments (Diaz, 2001; Scavia and Bricker, 2006; Wang, 2006).

Up to now, studies on agricultural usage and contamination of soil and water have been carried out using lysimeters in small experimental plots (Roman et al., 1999; Caballero et al., 2001; Spalding et al., 2001; Isla and González, 2006; Feng et al., 2005; Gehl et al., 2005; Bustos et al., 2006; Li et al., 2007). More recently, monitoring of irrigation hydrological basins has been utilized (Tedeschi et al., 2001; Cavero et al., 2003; Causapé et al., 2004a; Isidoro et al., 2004; García-Garizábal and Causapé, 2010; Abrahao et al., 2011a; Barros et al., 2011; García-Garizábal et al., 2011), which is a methodology

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http://dx.doi.org/10.1016/j.catena.2017.02.019
0341-8162/

considered to be highly appropriate to evaluate water management at plot and irrigation district levels.

Nevertheless, although the work carried out in previous studies provided knowledge on water management in the agricultural sector, the studies approached a low temporal resolution. This hindered the drawing of adequate conclusions on irrigation management for agricultural districts, mainly due to the high annual climate variability that exists in the Mediterranean area.

The objective of the work herein presented is to evaluate water management in a pilot basin with traditional irrigation, with Mediterranean climate conditions in the Ebro valley, between1998–2012. This work extends the study period developed by García-Garizábal et al. (2011; 2001–2008) and better accommodates the climate and agronomic variabilities of the region.

## 2. Description of the study zone

The study zone corresponds to the superficial hydrological basin D-XIX-6 at the Bardenas Irrigation District (BID, Fig. 1). The network of canals that surround D-XIX-6 acts as a surface water divider, limiting a 95 ha basin that is flood-irrigated.

Annual reference potential evapotranspiration by Penman-Monteith ($ET_0$) during 1998–2012 was 1382 mm with low inter-annual variability (3%). Associated with higher temperatures, 45% of $ET_0$ occurred in Summer (June–July–August), while only 9% of annual $ET_0$occurred in Winter (December–January–February; Fig. 2).

Precipitation reaches an average value of 374 mm and is the most irregular climate component, with a 30% inter-annual variability. In years with low precipitations, only 165 mm of rain was registered while rainy years reached values close to 600 mm, with maximums in Spring (March–April–May) and Autumn (September–October–November; Fig. 2).

Regarding the soil that constitutes the zone, two lithologic units can be distinguished (Lecina et al., 2005; García-Garizábal et al., 2011). The higher areas of the basin correspond to glacis levels where layers of gravel with loamy matrix (11–43%) develop with average water retention capacity of 111 mm (Calcixerollic Xerochrept).

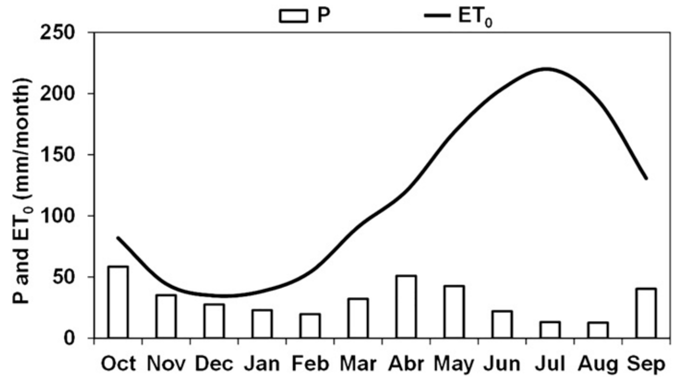


**Fig. 2.** Monthly average precipitation (P) and reference evapotranspiration ($ET_0$) values in the study zone, for the period 1998–2012.

The topographically more depressed zones are developed on tertiary impermeable substrate, providing the soils with thin limestone and gypsum levels interbedded (4–18%) as well as higher water retention capacity (158 mm; Typic Xerofluvent).

The main implemented crops were corn, alfalfa, winter cereal and sunflower, with annual distribution varying significantly during the study period (Fig. 3). While alfalfa and corn predominated in the period 1998–2001, after 2002 the farmers opted for crops with lower hydric needs such as winter cereal and sunflower.

In this sense, the 2006 change in the subsidy system of the Community Agricultural Policy (which allocated grants independently of production; Alvarez-Coque, 2006) motivated an extension of the surface destined to winter cereal.

The employed irrigation system is flood irrigation, which underwent changes during the study period. While between 1998 and 2001 (before changes) flood irrigation was applied in shifts (12–14 day irrigation intervals), after 2002 (after changes) the BID implemented an on-demand

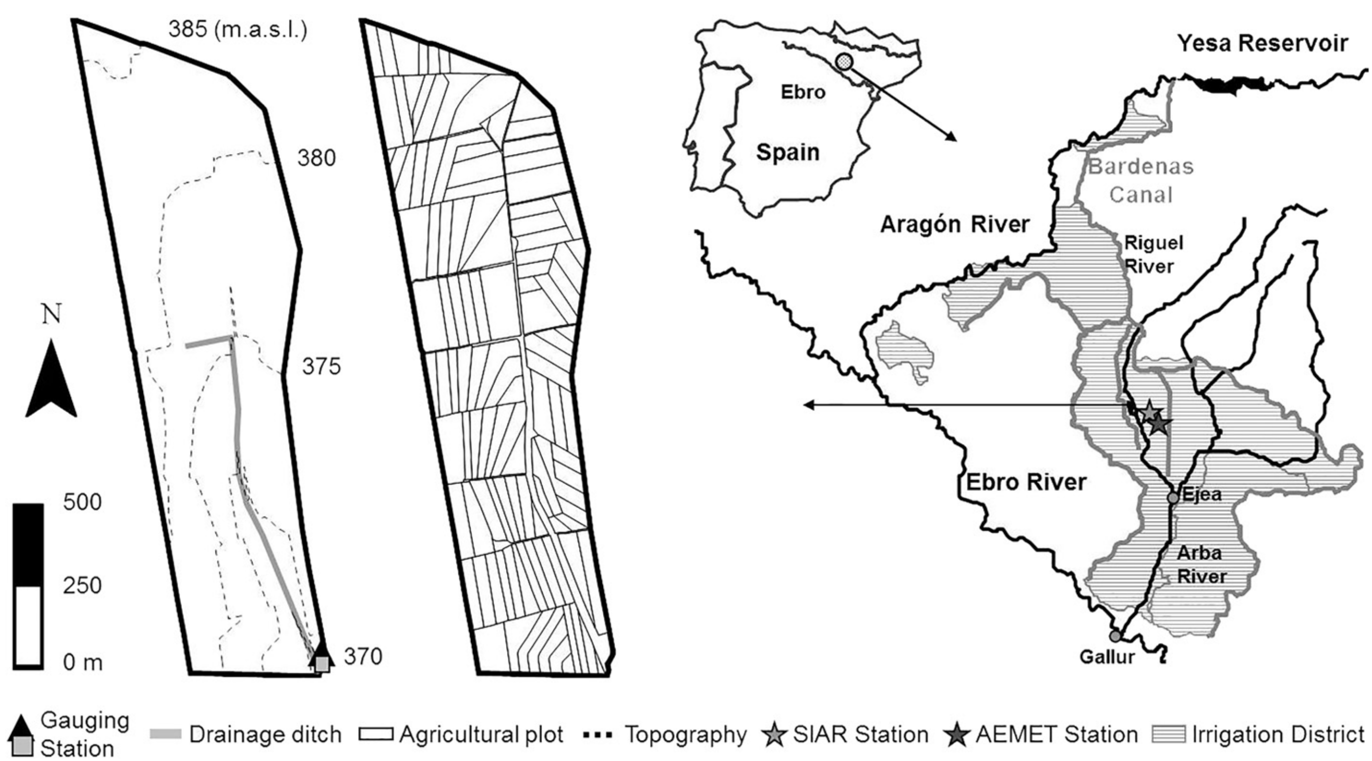


**Fig. 1.** Location of the experimental basin D-XIX-6 within the Bardenas irrigation system and weather stations employed in the study.