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Water pricing following rainfall distribution and its implications for irrigation agriculture
A case study from Vélez Blanco, Andalusia (1967–2006)

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ABSTRACT

This study uses data from water auctions, conducted by the traditional irrigation community of Vélez Blanco. Water prices are comprehensively compared and statically correlated with local precipitation data on different temporal scales; the data analyzed reach back to 1967. The local prevailing Mediterranean climate is characterized by a mean annual precipitation amount of 419 mm, while effective rainfall (≥1 mm) occurs averagely at 37 days per year. The rainfall distribution data used were of daily, seasonal and annual resolution and are assessed on their influence on the local water price formation. The results were validated with information about local agricultural practices and subjective perceptions of the *vega's* status, gained from interviews with local farmers. Results show that high correlation coefficients are achieved when water prices and precipitation data are correlated on a monthly scale. The highest correlation coefficients are achieved with a temporal offset of one month throughout the spring and summer season. Interestingly, neither short term water surplus, nor long term water deficit (consecutive drought years) are clearly reflected. Based on the given data-base, annual rainfall distribution has proven to be a significant factor that influences water price formation in the Vega of Vélez Blanco.

1. Introduction

Within Europe, the country of Spain is a prime example to study traditional water management with a long history. Throughout history, the water management schemes and cultures of Roman, Moorish, Iberian and other Mediterranean civilizations influenced the technical advancement and administrational management of irrigation on the Iberian Peninsula (Brunhes, 1902; Fröhling, 1965; Glick, 1970; Kress, 1968; Ostrom, 1990). Especially in the dry-sub-humid south of the country, traditional water management structures and irrigation governance systems date back to Medieval times and most likely originate from Moorish cultures who conquered Spain in the 8th century BCE. In general, modern Spanish water law defines water as a public good, meaning that it has no monetary value at all. Only costs for its distribution, administration and the maintenance of regulation infrastructure can be charged for (Arriaza et al., 2002). Therefore, in the following, the term *water price* always refers to the costs of water allocation.

At present, the agricultural sector is the largest water consumer in Spain. Its water consumption for irrigation totals annually 14,535 hm^3, which is about 75 % of the national available water resources (INE, 2015). Overall, 3.6 million hectares of Spain's agricultural land is equipped for irrigation of which 1.3 million hectares (47%) are supplied by groundwater, while 2.3 million hectares (63%) are irrigated by surface water (FAO, 2017). These numbers demonstrate that groundwater irrigation is vitally important for agricultural production and hence an important factor for the local-, regional- and national economy.

Thinking of the significance of water at these various levels, the question always arises: What does the water cost? The restriction of water costs and the social equity of different water pricing methods is a frequently discussed issue to which there is no universal answer (Gleick, 1997; Johansson et al., 2002; Molle and Berkoff, 2007). Worldwide, numerous studies on the pricing of water used for irrigation agriculture are available (Johansson et al., 2002; Molle and Berkoff, 2007; Abu-Zeid, 2001). The wide variety of water pricing implementations encompasses volumetric, non-volumetric and quote systems, as well as market-based and user-based mechanisms, in which water is distributed by e.g. quotas, applications or water auctions (Johansson et al., 2002).

Historically, water auctioning was a well-known instrument for several irrigation communities in south-eastern Spain to locally

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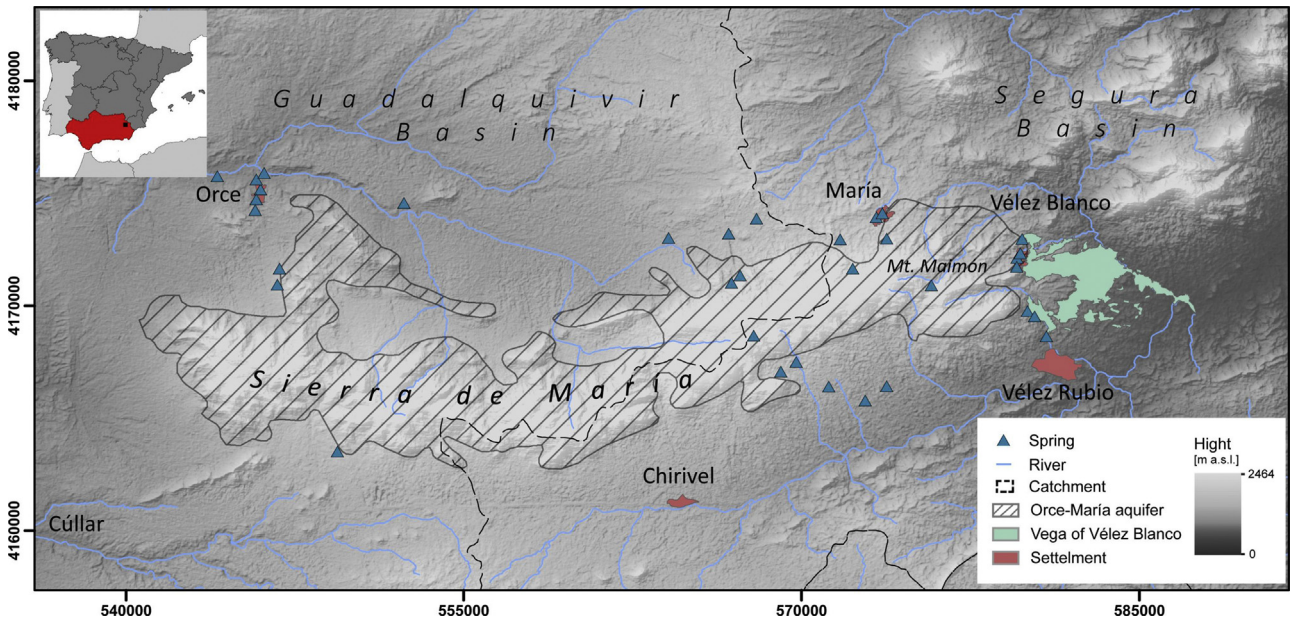

Fig. 1. Topographical map of the Sierra de María and the location of the study area. The Orce-María aquifer is highlighted by the *striped* signature and the area of the Vega of Vélez Blanco is marked *turquoise*. Elevation data is based on SRTM1 data (based on data from Gobierno de España, 2016; Jarvis et al., 2008). In the overview map the location of the study site is marked by the *black dot* and autonomous region of Andalusia is colored *red*.

organize the allocation of irrigation water. In modern times, most of these systems have been abolished, e.g. the *Huerta de Lorca* where water was auctioned until its abandonment in 1960 (Capel, 1968), hence the operating water sharing system of *Vélez Blanco*, presented in this study, is a rarity. In this study water prices, originating from the water auctions of the irrigation community of Vélez Blanco, and daily precipitation records from the local weather station are used to evaluate the influence of rainfall distribution on the water requirements for irrigation agriculture on different temporal scales. Based on the isolation of the local water sharing system, it is locally possible to carry out an independent analysis of the local water market and with this of the formation of water prices. Data from the water auctions used in this study show that there is a certain willingness of the local landowners to pay high prices for irrigation water. This leads to the following central research question: *What impact does the local rainfall distribution have on the local water requirements and irrigation schemes?*

Hence this study tests the statistical significance of correlations between precipitation patterns and archived local water prices, on a daily, seasonal and annual scale. The results are interpreted in the context of irrigation schemes, historical events and socio-economic conditions.

2. The vega of Vélez Blanco

Embedded in the mountainous landscape of the Sierra de María, situated at a height of 1070 m a.s.l., the town of Vélez Blanco and its vicinity is a fertile spot of intensive agricultural cultivation. The irrigated agricultural terraces are located east of the town, adjacent to the municipal boundaries. Locally this area is called vega. Based on information about similarly structured systems in the region of south-eastern Spain, it is assumed that the water management structures that can be found in the Vega of Vélez Blanco date back to at least the Muslim period (8th cent. BCE), whereas written evidences only exist for the last 500 years approximately (Roth, 2015; Roth et al., 2015).

Today, cultivation within the Vega of Vélez Blanco is dominated by almond and olive groves, fruit orchards, vegetable gardening and grain farming. Almond trees, which are predominantly cultivated in the upper part of the vega are rarely irrigated, whereas vegetable gardening, practiced all over the vega, has a significantly higher water demand that necessitates irrigation, particularly during spring and autumn. Olive groves are also occasionally irrigated during summer months.

2.1. Irrigation structures

The technical water management facilities that are deployed within the Vega of Vélez Blanco predominantly include traditional structures such as concrete channels (*acequias*) to *transport*, sluice gates to *divert* and reservoirs (*balsas*) to *store* the irrigation water. Within the parcels of land, maintained by the individual landowners, traditional techniques like furrow irrigation still dominate, while modern irrigation installations, such as drip irrigation systems, are becoming increasingly important.

The administration of the water allocation is traditionally managed by the local irrigation community that consists of farmers, elected during the general assembly of all farmers owing irrigated land in the Vega of Vélez Blanco. The task of the irrigation community is to maintain the irrigation network, to organize and execute the irrigation rotations and to host the regular water auctions at the *Alporchón*. The term *Alporchón* is defined as a traditional law body that has existed in Vélez Blanco since time immemorial. It is responsible for the local regulation of water sharing and observation of the hydrological regime[1] (Navarro Sánchez, 2010; Roth et al., 2015). In principle, the water allocation between owners of irrigated land within the Vega of Vélez Blanco is organized in a mixed system of irrigation rotations and water auctions (Navarro Sánchez, 2010). The rotational system is based on the subdivision of the irrigated land into irrigation units that are usually named after the respective water source (spring, river, reservoir or channel). The five largest of these subunits are *Balsa Alara*, *Hila de la Unión*, *Hilas de Conceje*, *Hilas de Turruquena* and *Río de Argan*[2] (Fig. 1). Within those

[1] Alporchón – "una entidad jurídico-consuetudinaria e inmemorial, de base corporative, en material de aguas y de regimen hidráulico" (Navarro Sánchez, 2010)

[2] Hila (plural: Hilas) – The terms hila, hilo or fila are defined as an abstract unit that represents a share of the entirety of available irrigation water from a river, spring or canal (Glick, 1970)