Chapter 21

Intensively irrigated agriculture in the north-west of Doñana

Jerónimo Rodríguez[1] *& Lucia De Stefano*[2]
[1] *Humboldt University, Berlin, Germany*
[2] *Water Observatory of the Botín Foundation; Department of Geodynamics, Complutense University of Madrid, Madrid, Spain*

ABSTRACT: The Doñana region in southwestern Spain is one of the largest and most complex natural systems in western Europe. Groundwater resources constitute a key component of its natural processes and a fundamental input for the intensive irrigated agriculture that began in the 1970s and it is now one of the most important economic drivers in the region. This agricultural activity and its associated groundwater use affects the hydrological cycle of the Doñana both in terms of quality and quantity and puts pressure on its sensitive ecosystems. Since the 1990s, several initiatives were undertaken to find a balance between socio-economic development and nature conservation and avoid reaching a deadlock situation. The complex nature of the resource system, the presence of unauthorized extractions, unsolved ownership issues and a fragmented institutional structure hinder the establishment of a sustainable resource use regime.

Keywords: groundwater, institutional structure, irrigation district, strawberries, Doñana

1 INTRODUCTION

With a total area of 2,700 km^2, one third of it under some level of protection, the Doñana region constitutes one of the richest natural systems in western Europe (Oñate *et al*., 2003). Located on the Atlantic coast of Andalusia between the estuary of the Guadalquivir River on the east, the Odiel and Tinto Rivers on the west (Figure 1), the Doñana region boasts the largest wetland system in the European Union.

The term Doñana is usually associated with marshes, sand dunes, beaches, and protected natural areas, as part of the Doñana region is a National Park created in 1969, surrounded by a Natural Park. However, from an ecological perspective, Doñana goes much further, including the territory of 14 municipalities in the provinces of Cádiz, Huelva and Seville, and can be classified into 4 eco-districts (Montes *et al*., 1998). The system known as Aquifer 27 or Doñana aquifer is the main source of water for human activities and for the maintenance of a rich system of wetlands and streams.

The region offers a key point on the route of migratory birds, a nesting site for waterfowl, and the last stronghold for heavily endangered fauna, including the emblematic Iberian lynx and the Spanish imperial eagle. The wetlands system provides important environmental services like the regulation of the local hydrologic

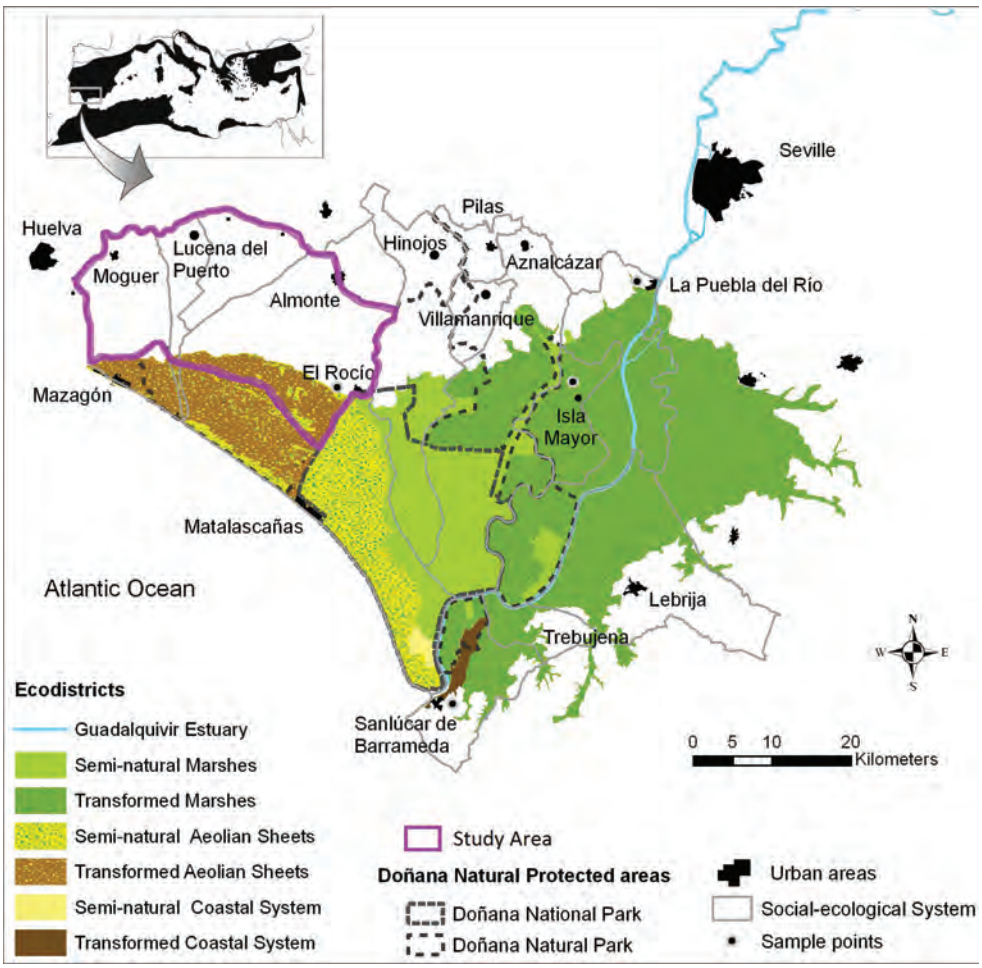

Figure 1 The Doñana region and the location of the study area. (Source: Adapted from Palomo *et al.* (2011)).

cycle, the production of biomass and provision of landscape and other aestetic goods (Martín-López *et al.*, 2011). Today, the Doñana National Park belongs to the RAMSAR Convention, the Man and Biosphere Programme of the UNESCO, the EU Natura 2000 Network, and is catalogued as a UNESCO World Heritage Site.

Historically, the region remained underdeveloped and sparsely inhabited for long time and land uses were limited to extensive cattle breeding, traditional lumbering activities, rain-fed crops, and hunting campaigns of the nobility. By the end of the 19th century, projects to transform areas into farmland, and promote land colonization began to be implemented to foster local development (Ojeda & del Moral, 2004; Swyngedouw, 1999). In the 1960s, supported by the developmentalist vision of the time, Doñana is perceived as an important economic opportunity, where commercial forestry, irrigated agriculture, beach tourism and natural beauty provide the means to help improve the

local hard living conditions (Ojeda & del Moral, 2004). In this context, one of the most important changes was the increasing use of groundwater to irrigate the zone located in the western part of the Doñana region. Two main categories of crops developed: a capital-intensive rice sector around the town of Villamanrique de la Condesa on the east, and a labour-intensive fruit and horticultural sector in the west.

Water became the driver of a spectacular socio-economic development and, at the same time, a factor of conflict. The development of intensive irrigated agriculture brought about drops in the groundwater levels, contamination by leaked agrochemicals, and territorial fragmentation due to the creation of new arable land (Corominas, 1999; Manzano & Custodio, 2005; Custodio *et al*., 2008). All these activities have affected the hydrological dynamics of the aquifer system (Rodríguez *et al*., 2008) and the long-term evolution of the Doñana aquatic and terrestrial ecosystems (WWF/Adena, 2009). Since the 1990s the debate has focused on how to achieve harmony between the agricultural sector and the natural values of the area (Ojeda & del Moral, 2004), but no long-term solution has been found so far.

This chapter aims at shedding light on the factors that determine the complex interaction between human activity and nature conservation in areas devoted to intensive irrigated berries[1], citrus and other fruits, located north-west of the Doñana area. The interest of this area lies in the significant economic value of the agricultural production – mainly strawberries for export to the European markets – and in the complexity of the factors that determine the success (or the failure) of any policy action in the area.

The chapter is based on fieldwork carried out between January and May 2011. It included a survey among horticulture producers; semi-structured interviews with local stakeholders; and a review of the local socio-economic conditions, the regulatory framework and the biophysical characteristics of the system. The study looks at the area considered in the Farmland Reorganization Plan published in 2010 (Junta de Andalucía, 2010b) as a social-ecological system (Ostrom, 2009), where interactions of the resource system, the users and the governance structure build a complex structure of nested subsystems and crossed interdependences.

2 WATER USE IN THE NORTH-WEST OF DOÑANA

The region under study lies on north-western part of Doñana, on the semi-transformed aeolian sheets of the deltaic unit of the Doñana aquifer (Figure 1, location of the study area) and includes the territories of the municipalities of Moguer, Rociana del Condado, Lucena del Puerto, Bonares, Almonte (including the village of El Rocio) and a part of Palos de la Frontera of the Huelva Province. Some of these areas were part of the Almonte-Marismas Agricultural Transformation Plan (PTAAM) launched during the 1970s by the Spanish government and intended to transform 38,000 ha into irrigated land using up to 150 hm^3/year [hm^3 = cubic hectometre = million m^3 = 10^6 m^3] of groundwater. Finally the area affected by the Plan was reduced, because it could severely affect water-related ecosystems inside and outside of the National Park.

1 The area produces many red berries, strawberry being the dominant one.

The study area is located on the Doñana aquifer, which extends over 3,400 km^2 and is composed of a series of connected unconfined or semi-confined hydrogeological units (Manzano & Custodio, 2007). The diffuse boundaries of the resource system, the temporal gap between abstraction affections and the moment they can be measured, and the inter-annual oscillations of the precipitation regime (Custodio *et al*., 2008), make it difficult to forecast the behaviour of the system and predict its hydrogeological evolution.

Agriculture is the main water user: groundwater abstraction from the whole aquifer is estimated to be 45–60 hm^3/year, equalling almost one third of the total aquifer recharge (through precipitation, an average of 200 hm^3/year, with large inter-annual variability) (Manzano & Custodio, 2007; Rodríguez *et al*., 2008; CIED, 1992). In the area, the main irrigated crops are 5,800 ha of red berries and 1,700 ha of citrus (Junta de Andalucía, 2010b; Fuentelsaz *et al*., 2011). Other uses of groundwater are urban supply for the local towns (5.3–7 hm^3/year), some of which are important tourist destinations. A small amount of surface water is imported from the Chanza-Piedras dam and is used for strawberry irrigation and urban supply.

Intensive use of land and groundwater is affecting the Doñana ecosystem and its biodiversity. In the strawberry area visible impacts are: the fragmentation of the territory with negative impacts on some mammals like the Iberian lynx, the alteration of the river-aquifer dynamics of La Rocina, Cañada, del Partido and other creeks (with the associated drops in the flow, the feeding of the wetlands, the transformation of permanent ponds and lagoons into temporary ones and the disappearance of others), localized groundwater pollution by agrochemicals and salinization, increased soil erosion rates, and the retreat of the phreatophytic vegetation, replaced by vegetation characteristic of more arid environments (Custodio *et al*., 2008; Manzano & Custodio, 2007; Rodríguez *et al*., 2008).

3 THE SOCIO-ECONOMIC VALUE OF GROUNDWATER USE

With an annual production value of 250 M€, 1,700 farmers, 12,000 permanent and 50,000 temporary employees in the province of Huelva, from which the largest part is located in the area of Doñana (Junta de Andalucía, 2010b), horticulture has transformed a formerly economically deprived region into one of the largest strawberry producers in the world. The sector produces around 25% of the strawberries in the EU15, and employs between 24% and 48% of the active population in the towns of the study area (Junta de Andalucía, 2009; 2010b).

In terms of the economic value of water use, the apparent productivity of strawberries in this area has been estimated to be 8.50 €/m^3 for blue water (irrigation) and 5.90 €/m^3 for both blue and green water (total water consumption) (Aldaya *et al*., 2010).

In the area, horticultural production is a highly mechanized and competitive activity, deploying modern irrigation systems and high productive early varieties. Specialized in supplying northern Europe during the first months of the year, the sector is very sensitive to the decisions of distributors and consumers in those markets. Hence, most of the producers have good production practices certifications awarded by third party organizations. These certifications focus on traceability, agrochemical

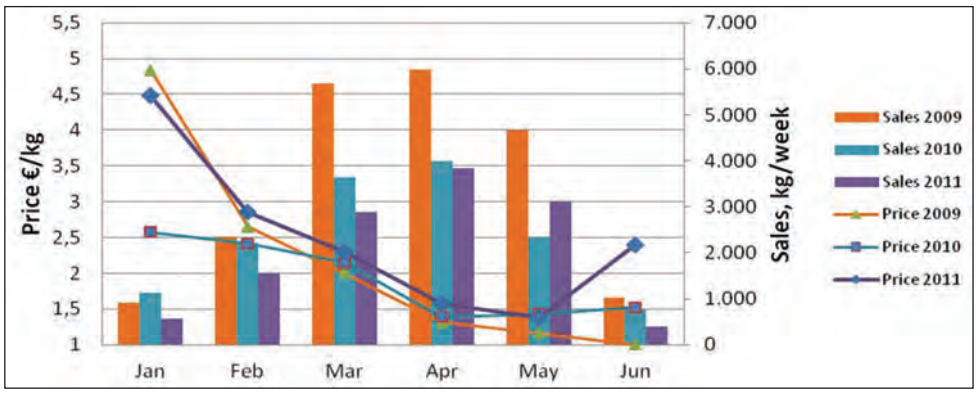

Figure 2 Price and volume traded of Huelva strawberries in the Madrid wholesaler market 2009–2011. (Source: Adapted from Mercamadrid Price Information System).[2]

management and labour issues. Main drivers of innovation in water use are profitability and risk hedging. Production and prices have an important seasonal component and are negatively correlated (Figure 2), with prices starting at high levels in January and falling constantly until May.

Between June and the beginning of the following season, production is marginal and, given the high specificity of the assets (knowledge, infrastructure), there are few chances to recover eventual losses during the rest of the year. Given this short window, the priority is to start harvesting and reach the production peak as soon as possible. To achieve this, a sufficient and timely water supply is fundamental. Thus water saving considerations become secondary, reinforced by the relatively small share of irrigation in the total production cost (only 4% to 8%). Producers say they use between 5,300 and 7,500 m^3/ha and consider that further reductions in water consumption are difficult to achieve.

4 THE STRAWBERRY PRODUCING AREAS: A MIRROR OF A COMPLEX SOCIO-ECOLOGICAL SYSTEM

The red berry-producing area can be divided in three main sectors, depending on the relation with the resource (land and water) and the level of institutional development of water users: the most western one (here called *Sector 1*) includes the cultivated areas of Moguer and a part of Palos de la Frontera municipality; the second one (*Sector 2*) includes Rociana del Condado, Bonares, Lucena del Puerto and the northern part of Almonte; and a third sector (*Sector 3*) surrounds El Rocío (see Figure 1).

Sector 1 is where greenhouses were first established and is the most advanced in institutional terms. Producers are of medium scale (7–12 ha), and mostly managing their own private farms and associated in large cooperatives. Producers in this area started their activity using unlicensed wells and in a second stage some of them accepted

2 [http://www.mercamadrid.es/index.php?option=com_estadisticas&task=mensuales&Itemid=159].

Table 1 Main characteristics of the three sectors of the study area.

	Sector 1:	*Sector 2:*	*Sector 3:*
	Palos, Moguer	*Lucena, Bonares, Rociana, North of Almonte*	*El Rocío (Almonte)*
Sector size (ha)	2,017	2,288	4,647
Main water source	Surface water	Groundwater. Pumping from local creeks (Arroyos del Horcajo, del Fresno, del Avispero Hondo)	Groundwater
Main crops	Redberries	Redberries and citrus	Redberries and citrus
Average well depth (m)	15	20–30	90
Land ownership	Private	Public concession	Public concession, Private
Average farm size (ha)	Mid (7.7)	Small (2–5.4)	12–38; >100
Role of ICs and other cooperatives	Surface water supply. Infrastructure provision. Commercialization	Groundwater supply. Commercialization and input procurement	Limited
Legal situation	ICs are registered legal entities. Most of the farms are licensed	Numerous unauthorized land or water uses	Larger users, unlicensed extractions. Some derived from the PTAAM, have officially granted licenses
Main environmental problems	Effects on the landscape, territorial fragmentation, pollution through agrochemicals	Unauthorized occupation of public forests, reductions in the piezometric level	Links to La Rocina Creek. Leaks of agrochemicals

Source: Own elaboration.

to switch to publicly provided surface water. Surface irrigation water conducted from the Chanza-Piedras dam is supplied by Irrigator Communities (ICs), which charge a fixed rate per unit of area plus a volumetric rate. The Communities are organized under a public-private structure with mandatory membership, and have become strong organizations since their creation at the beginning of the present century.

Surface water costs are higher than for groundwater, but the better physico-chemical properties of water resources and other technical advantages[3] allow users to

3 Water is already pressurized when delivered, sparing pumping costs, and there is a complete monitoring infrastructure, including water meters in good conditions.

Figure 3 Redberry greenhouses (left); groundwater extraction and storage facilities in public forest area (right). (Photo credits: J. Rodríguez (2011)).

avoid additional costs and annoyances. Despite the availability of surface water, some producers, mainly in Moguer, keep their wells operative, as they consider groundwater access as an acquired right and a risk hedging asset.

In the second strawberry sector (Sector 2), farmers are small-scale producers who work independently or are associated in cooperatives, in some cases gathering up to 200 ha. These cooperatives coordinate the provision of technical assistance services, the procurement of inputs and the commercialization process. An important share of the production is located on public forest land given under concession (*parcelas en canon*) by the municipalities or the province.

Irrigator Communities play a minor role here: in this area water is obtained from private wells or is pumped directly from small streams. The high density of water abstraction points – both authorized and unauthorized – increases the difficulty of the already complicated monitoring task by the competent Water Authority.

For the producer, water-related costs are represented by the drilling of the well, associated infrastructure and pumping. Given the large share of the fixed costs and the relatively low variable costs (energy and maintenance), once the well is open there are few incentives to minimize water use, besides saving on the fertilizers that are applied through irrigation. Moreover, extending the cultivated area – even with unauthorized plantations – translates into lower unit costs. The land property regime also has an effect on farmers' behaviour: as many users do not own the land, and are uncertain about the future administrative and legal viability of their activity, the intertemporal discount rate is affected and present benefits are preferred over uncertain future benefits.

The sector of El Rocío (Sector 3) corresponds to ICs associated with the Almonte-Marismas Agricultural Transformation Plan. These farms, with areas between 12 and 38 ha, rely on groundwater supplied by the ICs and from private wells. In this region the presence of Los Mimbrales and Alamillo farms, which cultivate irrigated citrus and olive trees, also constitute important players. The high expectations associated with the initial goals of the Transformation Plan, the presence of weak ICs, the proximity to the Doñana National Park and the fragile ecosystem of La Rocina creek,

make water management in this sector particularly complex. This area displays the largest registered drop of the piezometric levels (Manzano & Custodio, 2007).

5 GOVERNING GROUNDWATER IN AN UNCERTAIN INSTITUTIONAL SETTING

For long time, water management in the study area has been under the jurisdiction of the Spanish central government through the Guadiana River Basin Organization (RBO) in the west and the Guadalquivir RBO in the east. The whole area belongs to the Andalusia region, whose regional government is responsible for land use planning (including agriculture), with some intervention of the provincial and municipal authorities. The lack of coordination between the intervening administrative levels, the limited human and financial resources available to monitor and enforce regulations, and, more importantly, the politicians' reluctance to take unpopular decisions, have negatively affected the institutional credibility of the involved authorities. In 2006, water resources management of the portion of the study area belonging to the Guadiana basin was transferred to a newly created Andalusian Water Agency, with the associated uncertainty that occurs in institutional transitions. Moreover, since 2007 the disputes over the decentralization of water management and planning of the Guadalquivir river basin (see Chapters 3 and 4) have resulted in a situation of increased institutional uncertainty also in the area traditionally managed by the Guadalquivir RBO, making it even more difficult to implement long term water policies.

Since the 1990s, when a severe drought made evident the impact of intensive land use on the Doñana system (Ojeda & del Moral, 2004), several public initiatives

Table 2 Public initiatives related to the organization of the strawberry producing area.

	Main focus	*Mapped irrigated land (horticulture)*	*Water transfer as possible solution*
International Commission of Experts (1992)	Build sufficient knowledge about the situation in the area	4,500 ha	No
Plan de Ordenación Territorial de Doñana (2003)	Re-organization of land use	7,963 ha	Yes
Plan de Desarrollo Sostenible de Doñana (2010)	Diagnosis of land use in Doñana and building a vision for the future	Not specified	No
Plan Especial de la Fresa, PECN (2010)	Harmonize environmental protection with irrigated agriculture; Regularize irrigated areas	8,952 ha	Yes

Source: Own elaboration with data from CIED (1992); WWF (2009); Junta de Andalucía (2010a; 2010b).

have tried to conciliate economic development and nature conservation. Even with different focus and nature, some common elements have to be pointed out: the need to map the existing irrigated land and its temporal evolution; and the importance of improving knowledge about the dynamics of the aquifer and the groundwater extractions, as necessary conditions for the design of policy interventions. The transfer of surface water resources from the Guadiana basin as a means to release pressure from the Doñana aquifer has also been considered as an option.

The most recent policy elements are the POTAD (Ordination Plan for the Doñana Area), approved in 2003, and stemming from it, the PECN (Special Plan for the Regulation of Irrigation in the Northern Part of Doñana), which was published at the end of 2010 and whose official approval is still pending. While POTAD has a regulatory value only, PECN also includes a specific budget of 4.5 M€ over a 12-year period and specific actions to reorganize water use in Doñana.

The PECN foresees the creation of ecological corridors to reconnect Doñana with Sierra Morena, in the north, and this requires some strawberry plantations, both authorized and unlicensed, to be relocated or dismantled. For this, decided political will as well as financial means to pay compensations are necessary. Besides the budgetary uncertainty, the PECN implementation faces legal difficulties. As many illegal greenhouses are located on public property, occupiers do not formally own the land. Thus it is not possible to buy the land back, and it will be necessary to design specific legal mechanisms to execute this operation.

In terms of user-based governance, only 32% of the irrigated land in the area belongs to an Irrigation Community (Junta de Andalucía, 2010b). A marked characteristic of the area is the atomization of water users' associations. Agricultural water users cooperation in most of the cases has been limited to specific lobbying activities (e.g. regularization of unlicensed wells, requests for surface water transfer), the provision of technical assistance services, and the coordination of the procurement and commercialization processes.

6 THE WAY AHEAD: IN SEARCH OF A SUSTAINABLE BALANCE

The contribution of intensive irrigated agriculture to the local economy, together with the central role that water issues play in an arid country like Spain, makes control over water resources a major political issue (see Chapter 4). As in the rest of Spain, in Doñana a water policy favourable to local economic interests linked to agriculture brings important electoral revenues, while limiting water use for environmental reasons is often perceived as an economically and politically costly burden that responds to external illegitimate interests.

During the past decade, the enforcement of administrative constraints to the expansion of irrigated land and improvements in the irrigation efficiency have contributed to limit the pace of land use change and to stabilize groundwater consumption. This trend has been uneven, though, with consumptions oscillating between more than 10,000 m^3/ha/year and 5,000 m^3/ha/year. In 2003, the POTAD delimited the areas where irrigated agriculture was permitted, any posterior expansion being

illegal. Nevertheless, even if slower, the greenhouse area has kept growing,[4] as a result of the limited enforcement capacity of the competent authorities.

The importance of building up users' associations and the positive effects of their existence can be appreciated in the western sector of the strawberry area, where ICs are active in improving technical standards and formalizing and coordinating efforts and resources. Nonetheless, the heterogeneity of water users, the irregular legal situation of part of them and possibly the lack of a pressing need to cooperate so far have hampered the development of effective user based-resource management structures.

Signs of progress in the collective awareness about the need to reach a compromise between economic welfare and nature can be observed, but the system is still under intense pressure. The study of the strawberry-growing areas as a social-ecological system sheds light on the complexity of the interactions between socio-economic development and nature conservation, thus confirming that there is no *one size fits all* solution not even within the Doñana region.

In Doñana, the inclusion of water and land use-related requirements in the certification systems, the transfer of best practices to improve irrigation efficiency and, more importantly, raising awareness of the benefits – even economic ones – of having well-functioning ecosystems are ways worth exploring in the search for a balance between socio-economic development and nature conservation.

In any case, the development of a higher level of cooperation and trust between users, authorities and other stakeholders, including formal communication and participation mechanisms, seems to be a necessary condition if effective robust and long lasting improvements of water and land governance in the area are to be achieved.

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4 The POTAD established prohibition or limitations to transform rain-fed land into irrigated plots. In the period 2003–2009, however, the greenhouse area increased by 18.5% relative to the POTAD baseline. The land transformed into greenhouses included forest area (41% of the transformed land) and even highly protected public land (11%) (Fuentelsaz *et al*., 2011).

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