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# An academic analysis with recommendations for water management and planning at the basin scale: A review of water planning in the Segura River Basin

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## Abstract

Water resources management is particularly challenging in water-scarce basins, where low water availability is combined with a potential water demand exceeding the supply capacity of the natural system. This is the case of the Segura River Basin in south-eastern Spain. This paper aims at analysing the usefulness of incorporating new hydrological data and perspectives to improve the understanding of water availability and management and help promote more integrated water planning in the Segura Basin. In this basin, agriculture amounts to approximately 1366 $hm^3$/year and accounts for 80% of the total blue water use. The forest and agriculture use of soil water amounts to 3065 and 1962 $hm^3$/year, respectively. The unaccounted virtual water trade is also relevant and helps in mitigating water scarcity in the basin. The basin is a net virtual water-exporting region, with an average export of 1598 $hm^3$/year, mainly in the form of fruits and vegetables, and imports approximately 1253 $hm^3$/year, mainly related to feed for pig farms. Virtual water imports are four times larger than the disputed water transfer rate to the Segura Basin from other river basins. Water productivity analyses by sub-sectors are useful in understanding the economic rationale of the basin activities. Two types of agriculture coexist in the basin, namely, intensive industrial agriculture and occupational farming, which maintain the territory and landscape. From a Mediterranean country perspective, the analysis recommends considering climate fluctuations and temporal variability and trends of water availability and use, moving beyond the average values considered in river basin management plans. Groundwater reserve depletion continues to occur at a rate of 231 $hm^3$/year, as water from wells is currently cheaper than using desalinated water in farms, and it does not cause boron-related water quality problems for irrigation. If socially costly administrative measures are not taken, groundwater reserve depletion will continue.

**Keywords**

Water planning; integrated water resources management; green water; virtual water trade; groundwater depletion; Segura River Basin.

## 1. Introduction

Water resources management is prone to different types of conflicts related to addressing multiple and conflicting water demands, relationships between users and the environment, and compliance with regulations (Vollmer et al., 2018). This effect is especially acute in arid or semi-arid regions, such as the Segura River Basin, with an areal average rainfall of 375 mm/year (CHS, 2015; Morote et al., 2017; Senent and García-Aróstegui, 2013; Zimmer, 2010). To solve these conflicts, it is essential to know the main factors that influence good water governance. Many are already considered in current water planning. This paper identifies and broadly analyses some key aspects that hitherto have not been taken into account or have been considered in water planning in a limited way.

Water planning at the river basin level in Spain was established as a requirement for the first time in the 1985 Water Act (BOE, 1985). Subsequently, the Water Act was modified to incorporate the requirements of the European Water Framework Directive (WFD) (EC, 2000), approved in the year 2000. It was transposed into the Spanish legislation in 2001 and 2003 as the Rewritten Text of the Water Law (BOE, 2011; 2013).

The Ministry responsible for the Environment of Spain, through its Water Planning Instruction (BOE, 2008), introduced the requirement to analyse the water footprint and virtual water trade. This requirement has been officially applied, but it is out of focus and, consequently, has little influence on planning (Aldaya and Llamas, 2012).

A period of revision of the Water Framework Directive has currently begun in the European Union, which, by regulation, will replace the current one from 2000 in 2027.

Both the Spanish legislation and European directives do not consider in depth a set of new concepts on water resources introduced to better understand the interactions between the anthroposphere and the hydrosphere. These include virtual water trade, the water used to produce traded goods (Allan, 2011); blue water, water stored in surface or groundwater bodies; green water, soil water (Falkenmark, 2000); the water footprint (Hoekstra, 2003); or the economic and social productivity of water uses (Garrido et al., 2010). Hitherto, studies on these concepts focused at the river basin level and have not provided a comprehensive analysis of all of the elements. Some miss the trade component (Dumont et al., 2013), others neglect the environmental water requirements (Aldaya and Llamas 2008) and others do not consider the economic and social productivity (Government of Spain, 2011; Zeng et al., 2012; Salmoral et al., 2017; Pellicer-Martínez and Martínez-Paz, 2018). The integration of these concepts, as in the current research, may help in better understanding the interrelations between the different policies, particularly those on water and land management, consumption and trade, showing the relevance of a global perspective on water use and scarcity.

This paper analyses the usefulness of incorporating new data and perspectives into the Segura River Basin water management plan 2015-2021 (CHS, 2015). More generally, it assesses the interest of more explicitly taking into account these concepts in future water plans and in the European WFD reform process. Many water experts consider that the current WFD is mainly designed to cope with the problems of the more humid central and northern member states, without giving due consideration to concerns in the dry areas in southern member states, such as Spain, Italy or Greece (Boeuf and Fritsch, 2016). Comparative data can be found in EEA (2018). This paper analyses the influence of land use changes on basin water balances, the economic and social productivity of the different water uses, the relevance of imported and exported virtual water in each basin, the problems of intensive use of aquifers and depletion (mining) of groundwater reserves, which are often inappropriately defined as overexploitation of aquifers, and ways to improve participation and transparency in hydrological planning processes.

## 2. General concepts

### 2.1. Green water, blue water

There are two types of water, and their corresponding uses are not explicitly considered either in the Segura River Basin management plan or in the Spanish and European water planning guidelines (CHS, 2015; WFD, 2000).

The blue water, or water that can be mobilized, is defined as the fresh water stored in surface and groundwater bodies such as lakes, rivers and aquifers. Brackish waters are considered groundwater and are therefore part of blue water. Desalinated water comes from seawater, and consequently, its consumption does not have a blue water footprint, unless the saline water is captured from an inland or a coastal saline aquifer that incorporates a fraction of continental water (Aparicio et al., 2017; SASMIE, 2017).

Green water refers to the soil water of the root (edaphic) zone, defined as the water that comes from rainfall, snowmelt and horizontal rain from fog and is stored temporarily in the upper part of the soil or in vegetation. It is not part of the surface runoff nor does it recharge aquifers. It returns to the atmosphere as vapour though evapotranspiration, except for a small part that is incorporated into the vegetation mass and the vegetal products removed from the area.

The grey water footprint has not been considered in this paper, since several indicators and models are needed to address its various potential impacts on water quality (e.g., eutrophication, acidification, and aquatic eco-toxicity), and this is outside the scope of the current work.

### 2.2. Virtual water trade

Virtual water refers to the volume of water that has been consumed in the production of a certain good or service along its process chain (Allan, 2011). Virtual water trade, also called virtual water flow, refers to the volume of virtual water transferred from one area to another as the result of the trade of products. If a particular nation, region or area exports or imports a certain product, it also exports or imports water in virtual form.

## 3. The study area: the Segura River Basin

### 3.1. Territorial framework

The semiarid Segura River Basin is located in the south-eastern area of the Iberian Peninsula in the Mediterranean Sea basin. It has a surface area of 19,025 km² and is located in parts of four Spanish Autonomous Regions: 59% in Murcia, which it is almost inside, 25% in Castilla-La Mancha, 9% in Andalucía and 7% in the Community of Valencia (Figure 1). The population in the basin was 2,009,533 inhabitants in the year 2012 (CHS, 2015).

The basin has the lowest percentage of renewable water resources in Spain and is the region with the lowest rainfall in continental Europe (Vera, 2005). The average rainfall is 375 mm/year, which is highly variable in time and space, creating sub-humid conditions in the headwaters to semiarid conditions in the middle and lower basin (CHS, 2015). The area presents great contrasts: from severe droughts to torrential rains, floods, heat waves and heavy frosts, which increases the risk of desertification (Miró et al., 2018). Temperatures also present notable space variations, e.g., the mean annual values are 10ºC in the north-west mountain ranges and 18ºC on the coast.

**Figure 1.** Segura River Basin location within the four Spanish Autonomous Regions and the percentages of total surface within each region. Source: CHS (2015).

The main land uses are 50.6% forest and 40.6% agricultural. Urban land accounts for 4.7%, watercourses and surface water represent 1.8% and unproductive land accounts for 2.3% of the total land area of the basin (CHS, 2015).

There are 120 wetlands in the Segura River Basin, occupying a surface area of 230 km$^2$, which is approximately 1.6% of the total area of the basin. Of these wetlands, 70 have been declared subject to special protection based on the European Habitats directive (92/43/EEC) and Birds directive (79/409/EEC) (CHS, 2015). The Mar Menor is the largest saline lagoon in Spain and is surrounded by wetlands (salt marshes and reeds), with an area of 135 km$^2$. It is an almost-closed coastal lagoon in which the dominant seawater influence and evaporation are tamed by surface and groundwater contributions, which produce a unique water environment. In 1994, the Mar Menor was included on the Ramsar Convention list for the conservation and sustainable utilization of wetlands. It is also part of a Specially Protected Area of Mediterranean Importance and a Special Protection Area for bird life. The Mar Menor ecosystem is extremely fragile. In recent years, environmental problems in the lagoon have been aggravated by the loss of transparency, the proliferation of algae, clogging and pollution, among others. Water use and management and the intensive agriculture in the surrounding area play great roles in affecting the Mar Menor conditions (Jiménez-Martínez et al., 2016; García-Oliva et al., 2018).

The Segura River Basin is highly regulated by reservoirs, 33 of them with dams more than 10 m in height and 72 between 2 and 10 m in height.

### 3.2. Available water resources in the Segura River Basin

The water resources available in the Segura River Basin are composed of the following:

1). Conventional resources, which include surface and groundwater. The headwaters of the basin (Segura and Mundo Rivers above their confluence) represent the main source of water resources in the basin (CHS, 2015). The second main source of water resources are the flows of the tributaries of the right-hand river basin (Moratalla, Argos, Quipar and Mula Rivers), which have permanent hydrological regimes but low water flow (65 $hm^3$/year approximately). They are locally consumed and do not generate significant return flows to the Segura River. The total rainfall of 7132 $hm^3$/year (375 mm/year) precipitated in the basin under the natural regime resulted in an average annual total runoff of 854 $hm^3$/year (43 mm/year) for the 1980/1981-2011/2012 series, which represents 11% of the total rainfall. Of this total runoff, 207 $hm^3$/year (11 mm/year) is surface runoff and 647 $hm^3$/year (32 mm/year) is groundwater and deferred runoff (CHS, 2015: 134-135). These data does not include groundwater transfers between different planning areas inside the basin. As is common, most of the precipitation in the basin becomes green water in agricultural and forested land, at 5030 $hm^3$/year (264 mm/year), which represents 71% of the total rainfall.

Groundwater is intensively used to irrigate cash crops and, increasingly, to supply water for tourism. This produces continuous groundwater storage depletion (mining), as abstraction often exceeds recharge. The remaining usable reserves are grossly estimated approximately 25 $km^3$, which, under non-sustainability conditions, would allow the current exploitation to continue for several decades, although in some aquifers, depletion may be produced within a shorter term and with a much more extended term in others (Custodio et al., 2016; MASE 2015).

2). External resources consist of the Tajo-Segura water transfer from the Tajo River basin, which amounts to an average of 305 $hm^3$/year, and the Negratín-Almanzora water transfer from the Guadalquivir River Basin, at 17 $hm^3$/year (see Figure 2) (CHS, 2015). These transfers are not permanent and depend on the year. The Tajo-Segura transfer is highly debated in the Spanish water policy. The autonomous government of Castilla-La Mancha strongly opposes transfer from the Tajo Basin, which is in the area it administrates.

3). Unconventional resources in the basin are composed of the following:

a) seawater desalination, which amounted to 139 $hm^3$ in the year 2015 and is expected to increase to near 200 $hm^3$/year in the year 2021, for both urban water supply and irrigation (CHS, 2015).

b) water reuse, in which 96% of the urban water is reclaimed to be used in agriculture. In this process, 86 $hm^3$/year is directly reused from urban and industrial tertiary treated water before being incorporated into the public water domain, and 50 $hm^3$/year is indirectly reused after being discharged into the water courses (CHS, 2015). Twenty years ago, the Segura River Basin was one of the most polluted rivers in Europe and a pestilent open-air sewer in its course through Murcia, but later, the Segura Water Authority effectively cleaned wastewater from its populations and industries. Today, the inhabitants of Murcia can practice water sports in a clean river. This achievement received the 2016 European Riverprize award.

Irrigation return flows in the basin amount to 125 hm$^3$/year, while the amount collected in irrigation canals (drains), the so-called "azarbes", reaches 60 hm$^3$/year. This traditional irrigation network located in the fertile plains of the basin, the so-called "Vegas del Segura", facilitates water reuse, drains the aquifer to avoid waterlogging, and keeps the water flow in the old channel of the Segura River mouth constant (CHS, 2015). Traditional irrigation systems are also located in the plains ("vegas") of the Guadalentín and Mula River areas and are of great agricultural and socioeconomic relevance, but they are largely linked to intensive groundwater use and mining.

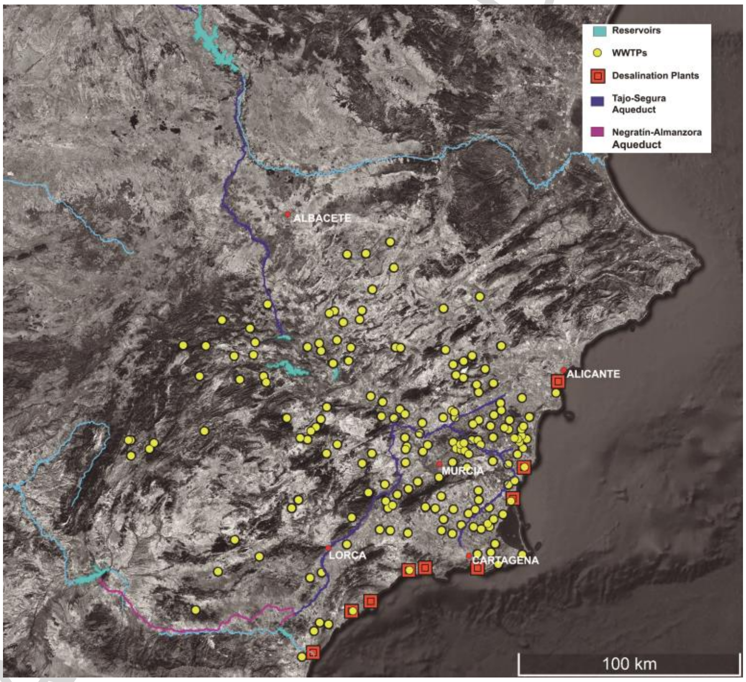

**Figure 2.** Wastewater treatment plants (WWTPs), desalination plants, and the Tajo-Segura and Negratín-Almanzora aqueducts. Source: Own elaboration based on data from CHS (2015).

### 3.3. Agricultural management in the Segura River Basin

The Segura River Basin agriculture is some of the most productive in Spain, together with that in the Southern Mediterranean Water District and some areas of the province of Huelva in the south-western Atlantic coast area (Maestu and Gómez, 2008). In fact, the Region of Murcia is known as the “orchard of Europe” because of the relevance of its regional production and effective international commercialization of fruits and vegetables.

The agricultural area in the basin (7720 $km^2$) is approximately 50% rain-fed and 50% irrigated (CHS, 2015). Part of the irrigated area uses "support" irrigation with low allocations, such as in the case of cereals, grapevines, olive trees and almond trees. The agricultural sector in Murcia is characterized by an important irrigation technology development producing very efficient irrigation systems: 72.5% is drip irrigation, 25% is gravity irrigation and 2.6% is sprinkler irrigation (CHS, 2015). Highly efficient large-scale irrigation systems coexist with traditional irrigation systems.

From a European perspective, the water management structure has evolved to adapt to new ways of management and planning in relation to the European Common Agricultural Policy, which, after the 2003 reform, has become more oriented toward production according to market rules and environmental preservation. The agriculture has become more specialized towards delicacy agriculture, with early varieties benefiting from the climatic advantage at times when there is no competition from other agricultural areas. Assuming a certain risk for the possibility of frost, crops from colder climates, such as cherries, are being incorporated. Farmers have moved from being producers to distributors and depend on distribution chains.

## 4. Methods

### 4.1. Blue water availability and use

The blue water availability and use for different activities in the Segura River Basin were obtained from the Segura River Basin management plan 2015-2021 (CHS 2015). The evaluations in this report are taken as acceptable for the current purposes and assumed to be inside the expectable uncertainty range. Therefore, no new assessments have been done, and only complements to existing data have been added when not available in the report.

### 4.2. Crop and forest green water use

The green water use of rain-fed crops and irrigated crops ($CWU_{g,\alpha}$) ($L^3 \cdot T^{-1}$) is estimated as the monthly evapotranspiration ($ET_g$) ($L \cdot T^{-1}$) over the entire growing period multiplied by the area occupied by the rain-fed crops and irrigated crops ($A_\alpha$) ($L^2$), following the method described by Garrido et al. (2010).

$$CWU_{g,\alpha} = \sum_i ET_{g_i} A_{\alpha_i}$$

Here, the subscript $\alpha$ stands for rain-fed and irrigated crops. The green water evapotranspiration ($ET_g$) ($L \cdot T^{-1}$) is calculated as the minimum value between the total crop evapotranspiration ($ET$) ($L \cdot T^{-1}$) and effective rainfall ($P_{eff}$) ($L \cdot T^{-1}$).

$$ET_g = min\ (ET, P_{eff})$$

The effective rainfall ($P_{eff}$) ($L \cdot T^{-1}$) is here considered to be the portion of the total precipitation ($P_t$)($L \cdot T^{-1}$) retained by the soil so that it is available for crop production. $P_{eff}$ was estimated as a first approximation from Pt, assuming a threshold and a factor taken from knowledge in other areas, as no local soil water balances were available. This is a point for refinement, as the parameters vary spatially, and it is not certain that a simple linear relationship will hold in the semiarid areas.

The green water use of different forest uses was estimated following the method proposed by Zhang et al. (2001).

### 4.3. Economic and social analysis of water use

The water apparent economic productivity ($WAP$) ($€ \cdot L^{-3}$) is calculated as the market price of the commodity ($P_c$) ($€ \cdot M^{-1}$) divided by the water required to produce the commodity ($WF$) ($L^3 \cdot M^{-1}$), following the method described by Garrido *et al.* (2010).

$$WAP = \frac{Pc}{WF}$$

In an analogous way, the water social productivity (*WSP*) (Job·L$^{-3}$) is calculated as the total number of jobs (*E*) (Job·M$^{-1}$) related to the water required to produce the commodity (*WF*) (L$^{3}$·M$^{-1}$).

$$WSP = \frac{E}{WF}$$

### 4.4. Virtual water trade

The virtual water trade (*V*)(L$^{3}$·T$^{-1}$) is estimated by multiplying the quantity of the traded commodity (*T*) (M·T$^{-1}$) by its estimated water use at the production site (*WF*)(L$^{3}$·M$^{-1}$).

$$V = T * WF$$

## 5. Water use analysis in the Segura River Basin

When examining blue water, the agricultural sector is the main user in the Segura River Basin, amounting to approximately 80% of the total. The Segura Basin has a blue water deficit. That is, the total blue water demand for the maintenance of the productive model exceeds the basin net available and usable renewable blue water resources: 1870 hm$^{3}$/year versus 1319 hm$^{3}$/year in average values. Currently, balance between the system inputs and outputs is achieved both by increasing the available water based on the exploitation of groundwater reserves (which can be performed according to needs) and by reducing the irrigated area, which varies from year to year in an unpredictable way (Custodio et al., 2016). Agriculture is largely the cause of intensive exploitation of resources, but, above all, it is part of the solution and is key to reaching a balance between the water demand and the available water through using a mixture of water from different sources, including desalinated and reused water.

When including green water in the assessment, the agricultural sector, both irrigated and rain-fed, and the natural vegetation, mainly forests, are the two main water users in the basin, with an average green and blue water requirement of 3328 and 3065 $hm^3$/year, respectively (Figure 3, Table 1). The adequate choice of crop types that are adapted to the actual availability of green water offers the possibility of reducing the pressure on blue water resources, although it entails an economic risk in relation to the high climatic variability in the basin. It is relevant to achieve good water management in harmony with the natural environment and the rural social values, that is, coordination with the territory through the integrated planning and management of land-use and water policies, as well as agricultural, energy, environmental, social and trade policies.

Other relevant water flows in the basin are the virtual water flows. The Segura River Basin is a net virtual water-exporting region, with an average export of 1598 $hm^3$/year, mainly related to fruits and vegetables, and an import of 1253 $hm^3$/year, mainly related to livestock feed for pigs, as estimated for Murcia during the period 2005-2015 (see section 7).

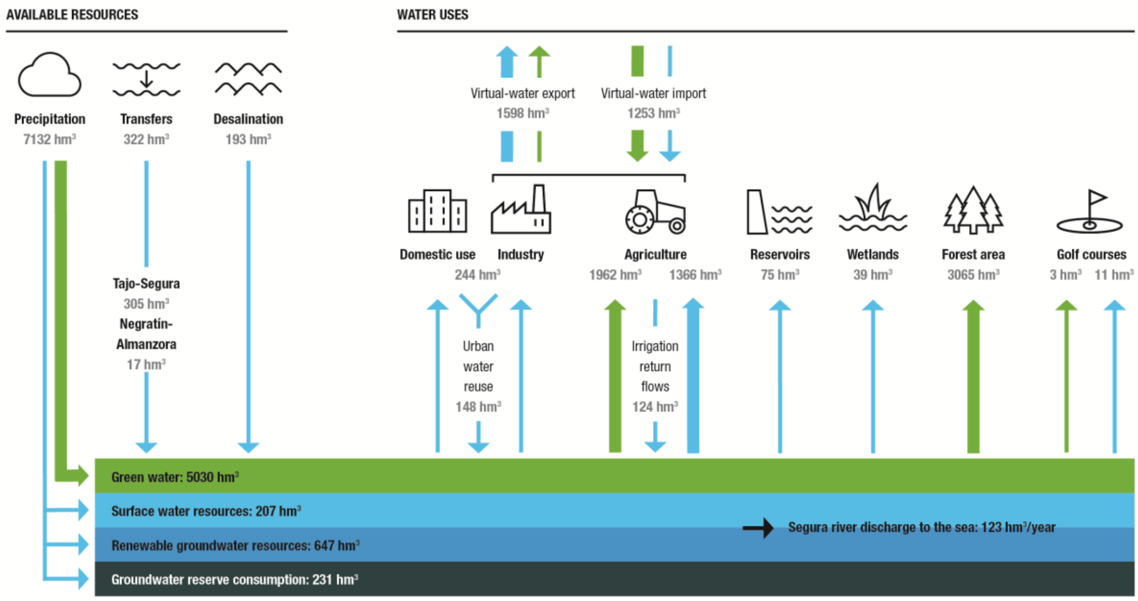

**Figure 3.** Average green and blue water balance and virtual water trade in the Segura River Basin over 10 $hm^3$. Available resources are shown versus water uses (gross demand). The reference volume is the aquifer-river

system. Source: Blue water in the natural regime for series 1980/81-2011/12 (CHS, 2015); green water, own elaboration. The figures provided have some degree of uncertainty.

**Table 1.** Average green and blue water balance and virtual water trade in the Segura River Basin. Available resources are shown versus water uses (gross demand). The reference volume is the aquifer-river system. Source: Blue water in the natural regime for series 1980/81-2011/12 (CHS, 2015); green water, own elaboration. The figures provided have some degree of uncertainty, so they represent the order of magnitude, and probably, only the two first digits in the values are significant.

| **Inflow to the system** | hm$^3$/year | **Outflow from the system** | hm$^3$/year |
|---|---|---|---|
| **Blue water** | **1870** | **Blue water** | **1870** |
| Surface runoff and interflow | 207 | Domestic and connected water use | 235 |
| Groundwater and delayed flow | 647 | Non-connected industrial use | 9 |
| Tajo-Segura water transfer | 305 | Served agriculture irrigation[3] | 1366 |
| Negratín-Almanzora water transfer | 17 | Direct use by livestock | 9 |
| Desalination | 193 | Golf courses | 11 |
| Groundwater reserve depletion | 231 | Thermo-solar energy use | 3 |
| Direct and indirect reclaimed urban water | 148 | Wetlands and coastal outflow to control freshwater-seawater interface | 39 |
| Irrigation returns from groundwater | 67 | Evaporation from the surface water system | 75 |
| Irrigation returns from surface water, so-called “azarbes” | 57 | Surface and ground outflow to the sea | 123 |
| **Green water** | **5030** | **Green water** | **5030** |
|  |  | Agriculture use | 1962 |
|  |  | Golf courses | 3 |
|  |  | Forest area | 3065 |
| **Available blue water** |  | **Blue water for human use** | 1783 |
| Usable renewable own resources | 1319 |  |  |
| Water for wetlands | 39 |  |  |
| Bulk available own renewable resources | 1280 |  |  |

| **Virtual water import**[1] | **1253** | **Virtual water export**[2] | **1598** |
|---|---|---|---|
| Blue water | 143 | Blue water export | 491 |
| Green water import | 1110 | Green water export | 1107 |

[1] Murcian virtual water import for the period 2005-2015, related to virtual water used in the basin as feed for the livestock sector (CHS, 2015; MINECO, 2017).

[2] Murcian virtual water export for the period 2005-2015 (CHS, 2015; MINECO, 2017).

[3] Only includes the irrigation fraction that can be currently met from a total water requirement of 1546 $hm^3$/year.

## 6. Economic analysis of water use

The European Water Framework Directive (WFD) states that water users must pay for all the costs of the water supply, including environmental and resource costs. Nevertheless, this situation hardly happens (EC, 2012). The analysis of the economic and social productivity of different water uses provides complementary information that might be useful in understanding the socio-economic rationale of water uses in the basin.

In social and economic terms, the services sector accounted for 64% of the gross value added (GVA) and 64% of the total employment in the basin during the period 2000-2013 (see Table 2). During this period, industry (excluding construction and services) was 16% of the GVA and 15% of the employment. Construction accounted for 13% of the GVA and 12% of the employment. Although it is not generally disaggregated, agro-industry is an important part of the overall industry. In the Region of Murcia, the agro-food system as a whole contributed 21% of the regional GDP (5% in relation to the primary sector, 5% in relation to the agro-food industry and 11% in relation to auxiliary activities, such as transport, energy and lubricants, and other goods and services) and 28% of the regional wage employment (UCAM, 2016). Agro-industry raw material and its associated virtual water content seem to correspond to locally produced goods, except for livestock feed. Finally, the strict agricultural sector represented approximately 5% of the total gross value added (GVA) of the basin and 8% of the total employment in the period 2000-2013.

**Table 2.** Economic value (million euros, M€) and employment for the period 2000-2013 by branch of activity in the Segura River Basin. Source: CHS (2015).

| | **Total economic value** | | **Total employment** | | **Average blue water economic productivity** | **Average blue water social productivity** |
|---|---|---|---|---|---|---|
| | **M€** | **%** | **Thousands of people** | **%** | **€/m$^3$/year** | **employment/m$^3$/year** |
| Agricultural use[1] | 1801 | 5 | 60 | 8 | 2 | 0.1 |
| Forest area[2] | 1 | 0.0 | - | - | - | - |
| Domestic use[3] | 270 | 0.8 | - | - | 3 | - |
| Total industry[4] | 31,530 | 93 | 657 | 91 | 909 | 19 |
| *Construction* | *4309* | *13* | *87* | *12* | - | - |
| *Industry*[5] | *5509* | *16* | *111* | *15* | - | - |
| *Services* | *21,712* | *64* | *460* | *64* | - | - |
| Wetlands[6] | 53 | 0.2 | - | - | 2 | - |
| Golf courses[7] | 164 | 0.5 | 4 | 1 | 14 | 0.4 |
| Energy use[8] | 9 | 0.0 | - | - | 3 | - |
| Total | 33,828 | 100 | 721 | 100 | | |

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[1] The economic value refers to the gross value added (GVA) at constant prices for the period 2000-2013 (CHS, 2015). GVA and employment refer to all primary activity.

[2] Own estimate of the economic value considering exports of € 360,000 during the year 2010 (Statistical Yearbook of the Region of Murcia) and € 360,000 in 2010, mainly from hunting and recreational uses in the mountains of Murcia (Compensaforest, Ministry of Agriculture, Food and Environment, 2016).

[3] Own elaboration of the economic value, considering a weighted average rate for urban water supply and sanitation services of 1.72 €/m$^3$ for the year 2004 (http://hispagua.cedex.es/sites/default/files/especiales/Tarifas_agua/precios_costes_servicios_%20agua.pdf).

[4] Including construction, industry and services. Economic value refers to the gross value added at constant prices for the period 2000-2013 (CHS, 2015).

[5] Extraction industries, manufacturing industry, conditioning, water supply, sanitation activities, waste management and remediation, food industry, beverage manufacturing and tobacco industry and supply of electric power, gas, steam and air.

[6] Own elaboration of the economic value of wetland ecosystem services, considering an average value of 14,785 US US$/ha/year (13,950 €/ha/year) (Costanza et al., 1997) and a land use of 0.2% (3774 ha) of the Segura River Basin total (CHS, 2016).

[7] Estimated income of 6.08 M€$_{2012}$/year for a typical golf course (18 holes), of which 2.03 M€$_{2012}$/year would correspond to income for golf tickets and € 4.05 M€$_{2012}$/year to income derived from tourism activity (CHS, 2015). This would generate 150 jobs per golf course (CHS, 2015). There are 27 golf courses used in 2012 (CHS, 2015).

[8] Production value of the estimated hydroelectric use based on energy production data in 2006 (prices in € of 2012).

Within the agricultural sector, the quantity of rainwater used by rain-fed and irrigated agriculture (1962 hm$^3$/year) is larger than that used by irrigation (1366 hm$^3$/year). Rain-fed agriculture implies greater risk and vulnerability to climate variability and has a significantly lower economic value than that of irrigated agriculture: 400 M €/year compared to 2700 M €/year.

The water economic productivity of traditional crops (cereals: wheat, barley, oats, rice and corn, and oilseeds, such as sunflower) and industrial crops (cotton) vary between 0.1 and 0.3 €/m$^3$, reaching up to 0.5 €/m$^3$ in the case of almond trees and 1.4 €/m$^3$ for citrus trees. The value approaches 2 €/m$^3$ for wine vineyards, fleshy fruit trees (peaches and apricots) and potatoes, 4 €/m$^3$ for olive trees and vineyards of table grapes and almost 7 €/m$^3$ for protected (under plastic cover) vegetable crops, such as tomatoes, melons and peppers (Figure 4) (Aldaya et al., 2017).

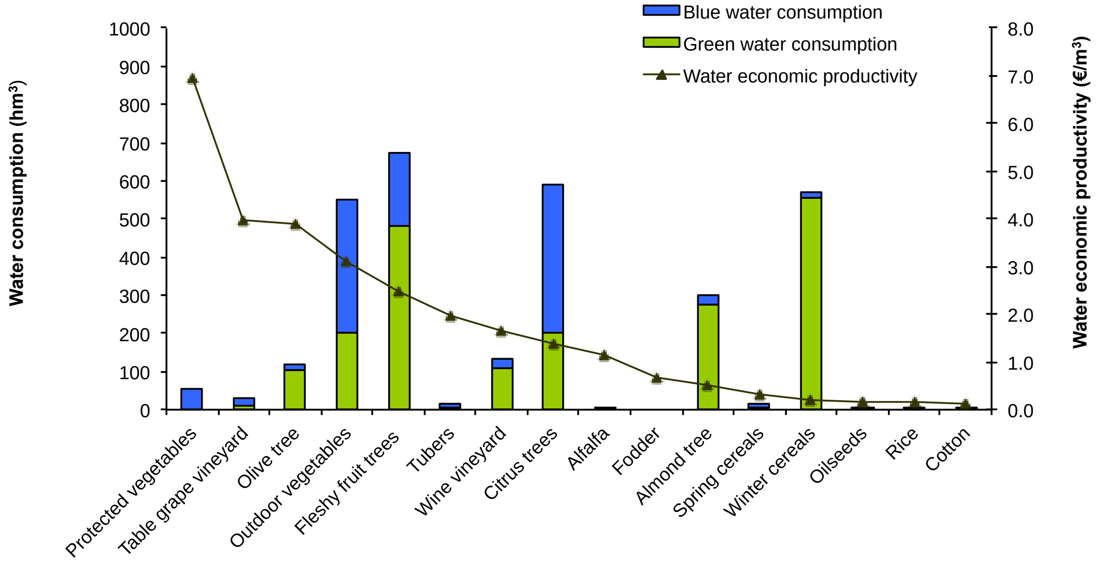

**Figure 4.** Blue and green water consumption and blue water economic productivity in the Segura River Basin. Source: Own elaboration based on data on irrigation water consumption and area (CHS, 2015), yield and historical series of the index of prices received by farmers (average 2004-2014) (Government of Spain, 2015) and the green water footprint (Aldaya et al., 2017).

In many cases, the choice of water source by farmers is a function of the crop type and the benefit generated. For instance, desalinated water, with an average production cost of approximately 0.8 €/m$^3$ in plants, can only be afforded by those who grow medium/high-economic value crops. For irrigation, farmers in the Segura Basin often use a mixture of water from different origins to produce a salinity and chemical composition that meets the plant water quality needs. In the case of desalinated water, this is also done to alleviate the high boron content of desalinated water (approximately 1 mg/L B), which makes it unsuitable for direct irrigation of certain crops, such as citrus trees. The increasing presence of boron in sewage water due to enhanced use of desalinated water for the urban supply is also a new growing concern that necessitates water mixing.

In total, the three main irrigation water-consuming products are citrus trees (35%), outdoor vegetable crops (32%) and fleshy fruit trees (17%), having an average economic water productivity of 1.4, 3 and 2.5 €/m$^3$ and an economic value of 530, 1080 and 470 M€, respectively (20, 41 and 18% of irrigated agriculture) (Aldaya et al., 2017). These three crops consume 3.5 times more water than do all other crops combined.

The protected vegetable crops only consume 5% of the blue water and have a very high economic productivity, at approximately 7 €/m$^3$, with an economic value of 14% of the irrigated agriculture (380 M€/year), and they occupy 3% of the total irrigated area in the basin (approximately 7800 ha). Something similar happens in the coastal Campo de Dalías (Almería, Spain), to the south of the Segura Basin, where the productivity of protected vegetable crops reaches 10 €/m$^3$ (Dumont, 2015). There, greenhouse crops have a significantly larger area, at 24,700 ha (Dumont, 2015). In the Segura River Basin, citrus trees and outdoor vegetable crops extend over 29% and 28% of the cultivated area with irrigation in the basin, respectively, followed by 16% for fleshy fruit trees. In total, 40% of the economic value in the Segura Basin is produced with 60% of the water (Figure 5).

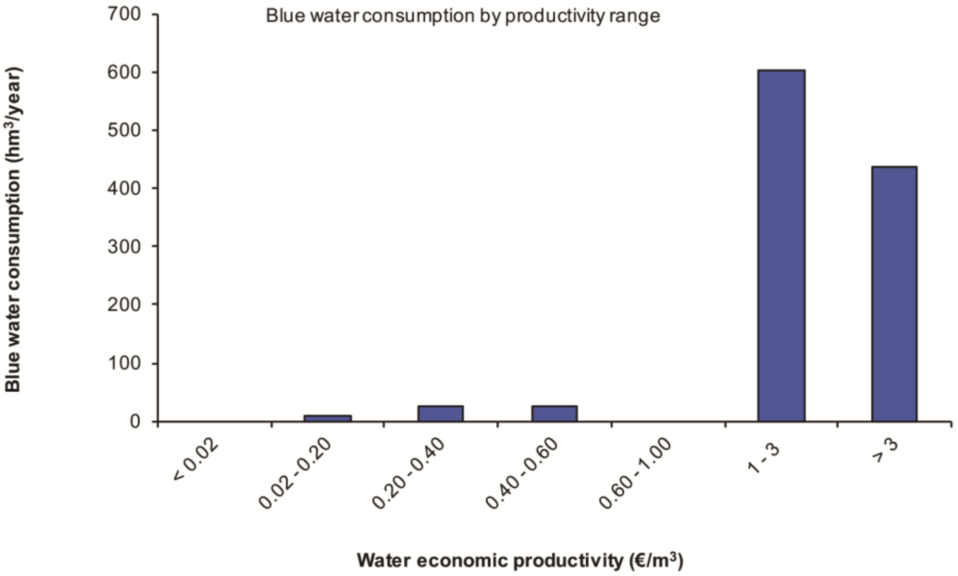

**Figure 5.** Blue water consumption by productivity range in irrigated agriculture in the Segura River Basin for the entire irrigated area. Source: Prepared by the authors based on data on irrigation water consumption and the area of the CHS (2015), as well as yield data and historical series of the price index perceived by farmers (average 2004-2014) of the Government of Spain (2015). Economic values refer to net income (net margin).

## 7. Virtual water balance: inputs and outputs

In the Segura River Basin, trade is key for the economy, particularly the exports of the agro-food sector (see Figure 6). In total, 20% of the weight of Spanish exports of fruit and vegetables originates in the Region of Murcia. For vegetables, the percentage reaches 24% (UCAM, 2016). During the last ten years (2005-2015), the Region of Murcia has been a net exporter of lettuce (42% of all vegetables and legumes) and citrus fruits (49% of total fruits, with 63% of them lemons). The produced fruits and vegetables are mainly sold fresh.

In terms of the virtual water trade, Murcia exported 494 hm$^3$/year related to fruit and vegetable trade during the period of 2005-2015 (see Figure 6). This figure, which is rather low compared to the high economic value generated, was largely related to the blue water resources coming from the basin. The virtual water export associated with fruits and vegetables accounted for 7% of the total precipitation (7132 hm$^3$/year), 8% of the actual evapotranspiration (6373 $hm^3$/year) and 34% of the renewable blue water resources available in the basin.

At the same time, during the 2005-2015 period, Murcia was an importer of raw materials with high virtual water contents, such as oilseeds and cereals, mainly soybeans (54% of seed imports), of which 70% came from Brazil, and corn (49% of cereal imports), of which 47% came from Ukraine. In hydrological terms, this import contributed approximately 3000 $hm^3$/year of green water and 120 $hm^3$/year of blue water to the region (the latter was related to corn imports). However, the total virtual water imported should not be attributed to the basin, since part of the imports received in the harbour of Cartagena (the fourth at the national level in freight traffic) are redistributed to the rest of the Iberian Peninsula.

Fruit and vegetable exports and oilseed imports have been increasing during the last 10 years (Figure 7). Similarly, exports by the livestock sector have grown, with a very small direct water footprint within the basin and a high economic value (€ 145 million/year in the period 2005-2015) (Figure 8). Cereal imports present peaks that can be associated with dry hydrological years in the basin (2009; 2012; 2015), while canned fruit, vegetable and juice exports have remained relatively stable (Figure 7).

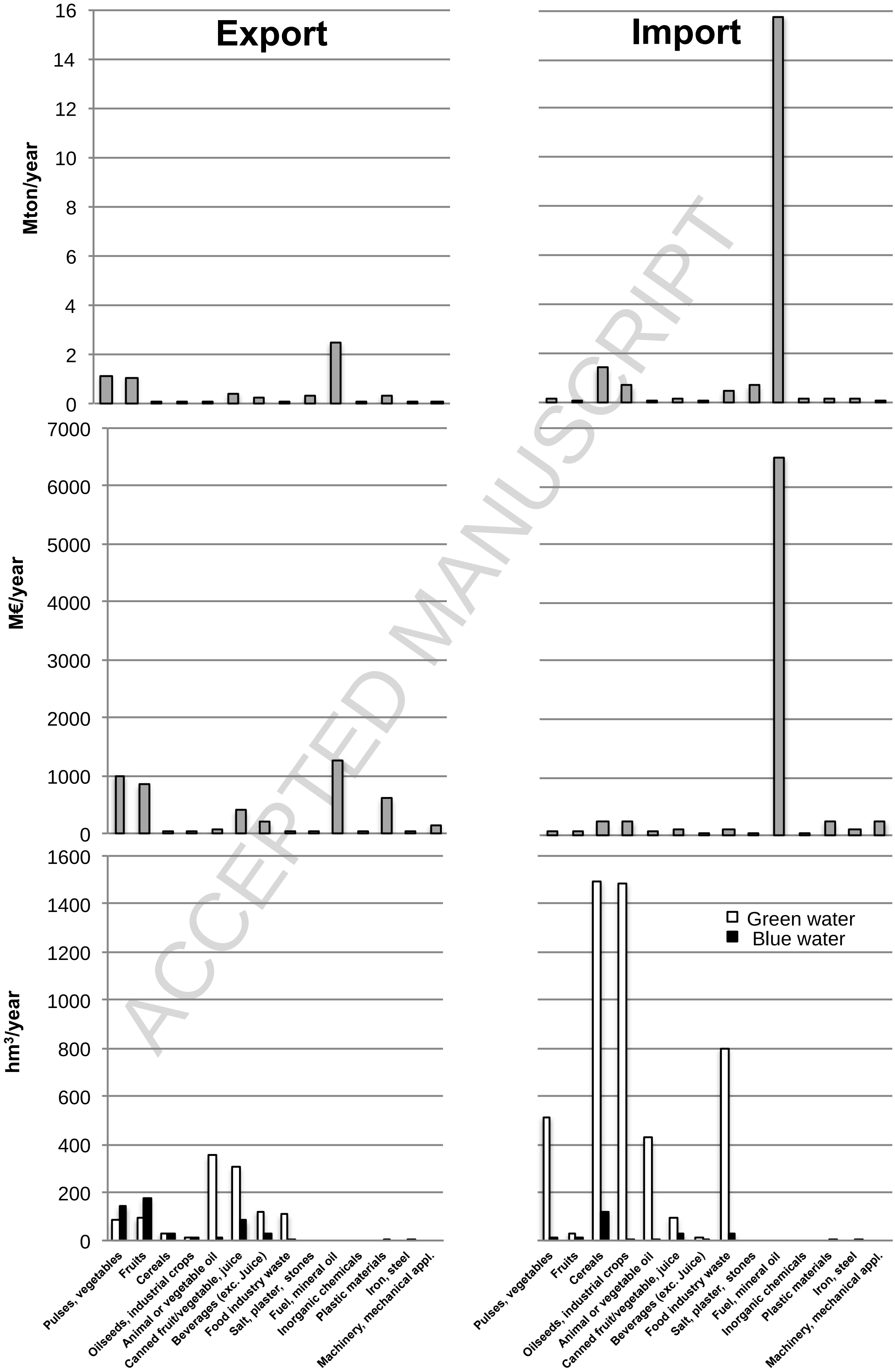
Export
Import
Mton/year
0
2
4
6
8
10
12
14
16
M€/year
0
1000
2000
3000
4000
5000
6000
7000
hm³/year
0
200
400
600
800
1000
1200
1400
1600
Green water
Blue water
Pulses, vegetables
Fruits
Cereals
Oilseeds, industrial crops
Animal or vegetable oil
Canned fruit/vegetable, juice
Beverages (exc. Juice)
Food industry waste
Salt, plaster, stones
Fuel, mineral oil
Inorganic chemicals
Plastic materials
Iron, steel
Machinery, mechanical appl.

**Figure 6.** Annual international export and import of agricultural products in million tonnes (Mton), million euros (M€) and million cubic metres ($hm^3$) for Murcia during the period 2005-2015. Values above 2000 M€/year and 2 Mton/year are represented. Source: Own elaboration based on trade data (tonnes and euros) of the Ministry of Economy, Industry and Competitiveness (MINECO, 2017); exported blue virtual water from the CHS (2015); exported green virtual water from Aldaya et al. (2017); global imported blue and green water average (Mekonnen and Hoekstra, 2010); and global blue and green water average related to exported and imported non-agricultural products (Ercin et al., 2011).

* No data was found on the quantity of re-exported products or inter-regional trade in Spain.

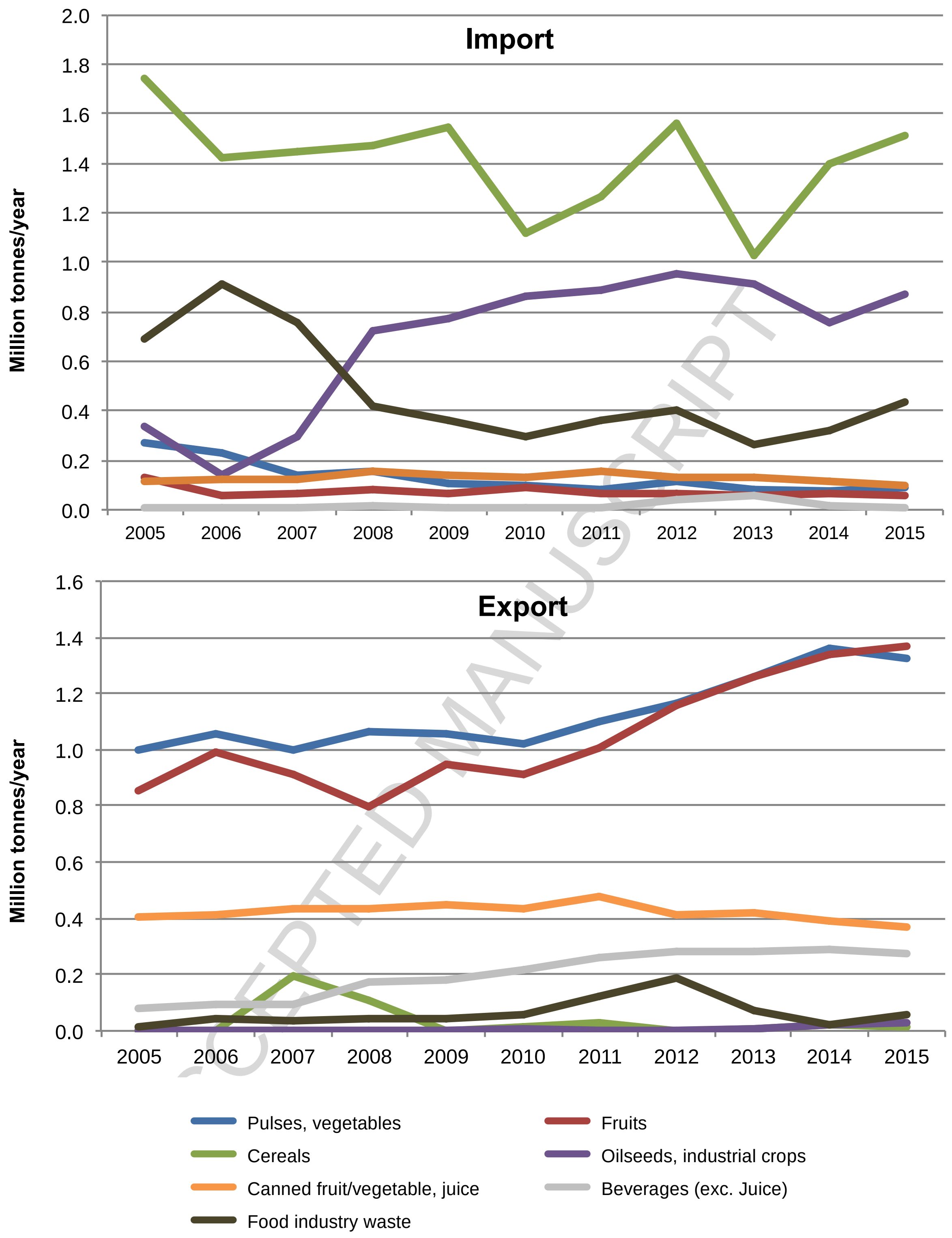

**Figure 7.** Temporal evolution of agricultural trade over the last 10 years. Source: Own elaboration based on trade data (tonnes) of the Ministry of Economy, Industry and Competitiveness (MINECO, 2017).

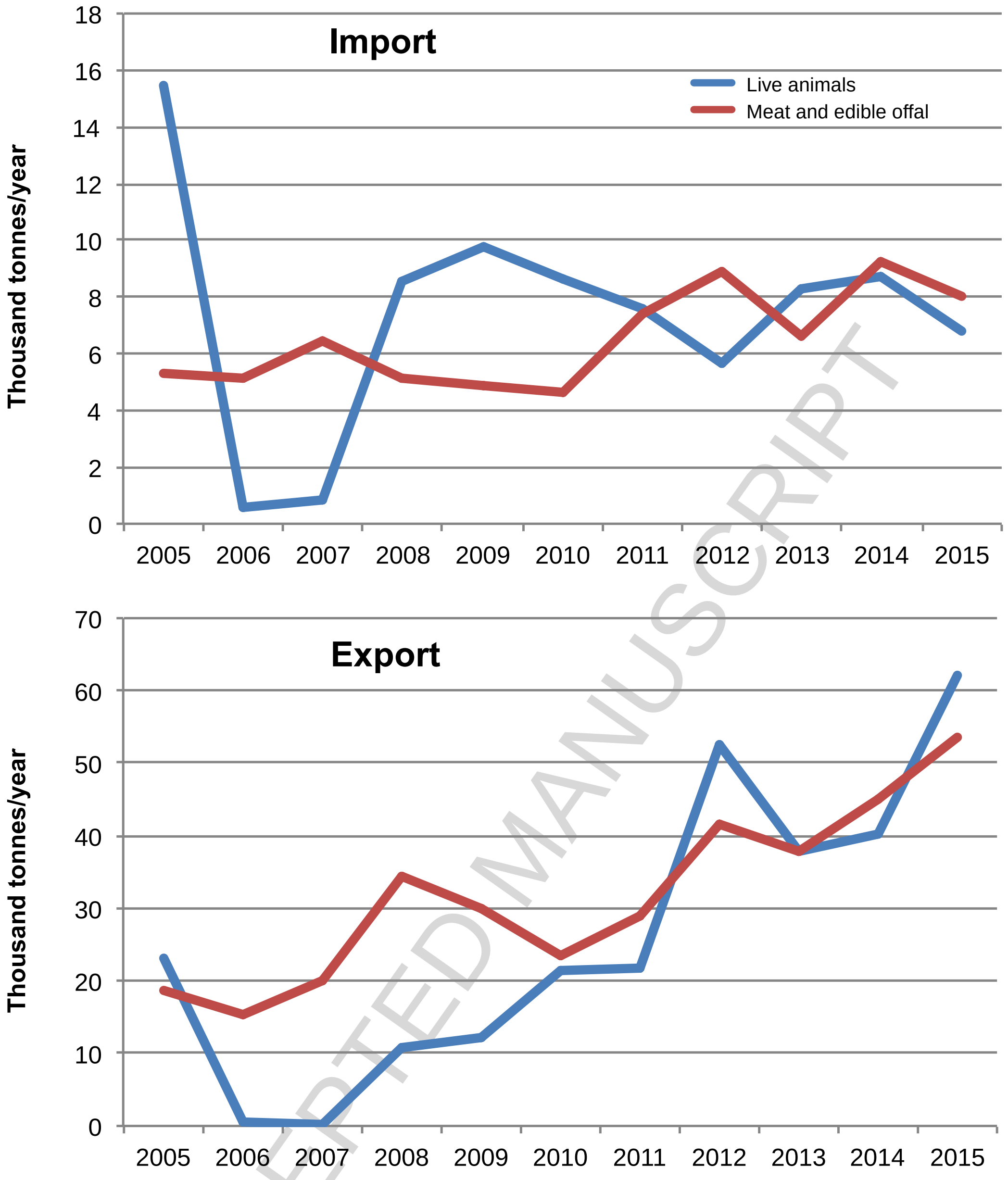

**Figure 8.** Temporal evolution of trade in the livestock sector over the last 10 years. Source: Own elaboration based on trade data (tonnes) of the Ministry of Economy, Industry and Competitiveness (MINECO, 2017).

## 8. Temporal variability and trends of rainfall

The figures in the present study are average values in line with the Segura River Basin management plan (1980/1981-2011/1912) (CHS, 2015). Dynamic values are not considered due to time and data limitations. Figure 9 represents the rainfall cumulative deviation curve for the historical period of 1933-2017, showing relatively wet and dry periods, including a

1950-1966 dry period, 1966-1996 average period, 1996-2013 wet period, and 2013-2017 dry period. The large climate variability of the Segura River Basin and the contributions of water from the outside require dynamic analysis that values the hydrological, economic and social roles of the different sources of water, especially that of groundwater reserves. Adequate water planning is influenced strongly by this variability.

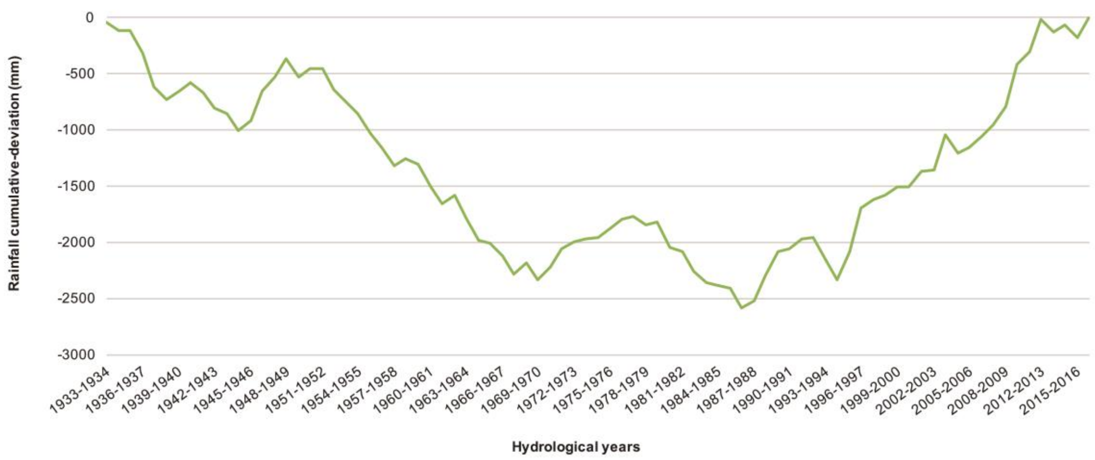

**Figure 9.** Average accumulated deviations of rainfall compared to the average over the period 1933-2017 in the hydrological year in the Fuensanta reservoir. Average precipitation, 385 mm/year.

## 9. Improving participation and transparency in water planning processes

Particularly in water-scarce regions, water is an essential part of tangible and intangible heritage. The European Water Framework directive implementation in Spain, along with its requirements of social transparency and accountability in public action (recitals 14 and 16 and Art. 14), is gradually transforming decision-making models in relation to water planning and management, ensuring the involvement of the general public, including water users (all stakeholders). While transparency and participation have improved in the Segura River Basin in recent years, there is still room for improvement.

Regarding the transparency of access to information, according to the Transparency International's Water Management Transparency Index (INTRAG), the Segura River Basin

Authority (Confederación Hidrográfica del Segura) obtained overall intermediate scores of 60% in 2010, 68% in 2011, 66% in 2013, and 51% in 2015, with a worsening trend in the last two editions. The lowest scores, and therefore, the aspects susceptible to improvement, were in the sections related to transparency in resources management and water uses, economic-financial information, and contracts and tenders. Almost all of the data on the Segura River Basin Authority website are available only for online viewing or for downloading in pdf format, but they are not available in formats that make them reusable. Additionally, the available information is not always updated.

## 10. Intensive exploitation and mining of groundwater in the Segura Basin

The aquifers of the Segura Basin, except for the western ones, are generally subjected to intensive exploitation and, in many cases, suffer groundwater mining. The accumulated reserve consumption is estimated at approximately 15 km$^3$, with a current rate of 231 hm$^3$/year compared to the total extraction of groundwater at 800 hm$^3$/year. The most intensively exploited aquifers due to water mining are those of the Altiplano, the Guadalentín Valley and some of the Campo de Cartagena. The remaining usable reserves are uncertain, but it is reasonable to expect them to be between 20 and 30 km$^3$, which, under non-sustainability conditions, would allow the current exploitation to continue for several decades, although in some aquifers, the depletion may be faster and in others, much more extended (Custodio et al., 2016; MASE 2015).

In the Segura Basin, the drop of groundwater levels has involved a decrease of natural spring flows, from between 40 and 90 hm$^3$/year (excluding the headwaters, which are not affected) to around half of this figure. The groundwater abstraction control in the aquifers of the "vegas" (plains in the river valleys) limits the reduction of the river base flow. The discharges to the sea are not significant at the basin level, although they may have local relevance. The discharges to the Mar Menor, although moderate, have a significant influence on the water balance and solutes in the lagoon and especially, on near-shore ecology. They have an important anthropic load, which is the combination of irrigation returns and the infiltration of saline water from the numerous brackish water small desalination plants of the farmers. Currently, there is an increase in the discharge of brackish water accumulated in the aquifer due to the increased recharge related to the increment in irrigation return flows after the Tajo-Segura Transfer water arrived in the area (Jiménez-Martínez et al., 2016).

Despite the Segura Basin semi-arid conditions, there is no significant proportion of brackish water due to evapoconcentration, except in the more clayey soils of Campo de Cartagena. There are also no generalized processes of marine intrusion, except in small coastal aquifers, such as Mazarrón and Águilas and in the Torrevieja-Cabo Roig area. The salinity of the Campo de Cartagena upper aquifer water is mainly due to irrigation returns. In different areas, there are manifestations of thermal waters (Mula, Fortuna, Archena) that indicate deep discharges through important fractures, but they are not quantitatively significant (MASE, 2015).

## 11. Discussion

### 11.1. Water and land resources in the Segura River Basin

Agriculture and forests are the main land and water users in the Segura Basin. They amount to 40.6% and 50.6% of the land use, respectively, and 48% of the green and blue water use each. The adequate choice and management of crops and forests offers the possibility of reducing the pressure on blue water resources. Land-use planning has an influence on the basin water availability and water balance (MEDACC, 2017; Garcia-Prats et al., 2016; Senent-Aparicio et al., 2018). This is a step forward in the alignment of water and territorial planning.

From a social point of view, there are two types of agriculture in the basin. First, there is industrial agriculture aimed at maximizing production for commercial purposes for large national or international markets, as well as for large commercial areas, particularly for specialized intensive agriculture such as that under cover and hydroponic crops. Second, there is occupational agriculture providing living means and employment, in which the maximization of production is not the main objective.

Both types of agriculture should be treated in different ways and evaluated through different economic principles and tools. The first kind of agriculture, the industrial type, must cover all its costs, including negative externalities, as much as possible, paying for the total cost of water. It is generally not eligible for direct subsidies. Otherwise, the subsidies go to buyers outside the area. The second activity has a value of social support and value through its services of the occupation and maintenance of the territory and landscape. Organic agriculture in Murcia alone amounted to 59,000 hectares in 2012, which is 3.7% of the total organic farming area in Spain (Government of Spain, 2018). This is an added value that society must compensate, and therefore, it is an activity that can be subsidized to a certain extent in exchange for meeting environmental objectives as "gardeners of the territory” under well-defined conditions. This is an aspect in which there is very little experience worldwide. As is often the case, notable and targeted public intervention is often ineffective and discouraging, with possible effects contrary to those sought. It is necessary to develop new formulas that allow the achievement and checking of objectives, but with freedom of action.

### 11.2. Environmental objectives and the intensive exploitation and mining of groundwater in the Segura Basin

The natural recovery times of intensively exploited aquifers, after exploitation is ceased, can range from decades to more than a century (Custodio et al., 2016; MASE 2015). For this reason, it does not seem to make sense to limit extractions, nor to force the recovery by artificial recharge, which would be very expensive, and the results are only noticeable in the long-term. Forcing recovery would require disproportionate measures. Where there are no linked surface water bodies, a transitory situation could be considered in the long term that allows the use of the remaining groundwater reserves to achieve a non-traumatic and socially planned transformation of water use.

The possibility of recovery is problematic in the case of aquifers with a large proportion of poor-quality water resulting from anthropic activities, particularly considering that part of the pollution may not yet have appeared in the wells, as the pollutants may still be slowly moving downwards through the unsaturated zone (MASE 2015). This could be the case in Campo de Cartagena. The current salinization and high nitrate content in groundwater need, in most cases, decades to recover. In such situation and in similar cases, it is possible to propose less-rigorous quality objectives for the aquifer (groundwater body) and even declare it as only suitable for agricultural use, with the due controls to maintain a certain stationary situation agreed upon by the water administration, stakeholders and civil society. This approach needs monitoring of the related environment and uses, as well as actions to correct the associated negative effects, such as the discharge of waters with an excess of nutrients in the Mar Menor.

### 11.3. Actual water costs in the Segura River Basin

In the Segura River Basin, the average cost of agricultural water is 0.05 €/m$^3$ (200 €/ha) for surface water of the basin and 0.2 to 0.3 €/m$^3$ (800 €/ha) for local groundwater. If environmental costs were added, payments would increase between 0.05 and 0.3 €/m$^3$ (Garrido and Calatrava, 2009). The standard costs of water for horticulture vary between 0.15 and 0.75 €/m$^3$ (Calatrava and Martínez-Granados, 2012).

In regard to external water transfers, the irrigation water prices are on the order of 0.3 €/m$^3$ for the Tajo-Segura aqueduct supply through the central irrigation syndicate managing this transfer and of 1.2 €/m$^3$ for the Taibilla Canals Association supply. The respective resource prices are 0.2 and 0.3 €/m$^3$. The charge for reclaimed water is on the order of 0.15 €/m$^3$.

Desalinated seawater has a total cost in plants on the order of 0.8 €/m$^3$ (for a modern optimized plant), of which approximately 0.6 to 0.7 €/m$^3$ pertains to operation at nominal capacity. If the plant operates at a fraction of the nominal capacity, the costs increase depending on the load and can reach and exceed 1.0 €/m$^3$.

To make comparisons, one must consider the costs to bring the water to the place of use. In the Segura River Basin, groundwater has clear economic advantages over industrial water (desalinated seawater and reclaimed wastewater) when the place of use is remote or in relatively high areas, even when deep-groundwater pumping is needed. This explains why groundwater is used in many areas of the highlands (Altiplano) of Murcia, despite the high extraction costs. Other resources would be more expensive in these places of use, even in cases in which pipelines, elevation machinery and reservoirs are available.

For instance, the average and extreme groundwater costs are: 1) extraction, 0.20 €/m$^3$ (between 0.15 and 0.35 €/m$^3$); 2) distribution and application, 0.25 €/m$^3$ (between 0.15 and 0.65 €/m$^3$); and 3) total, 0.5 €/m$^3$ (between 0.3 and 0.9 €/m$^3$). The total average cost in the most intensively exploited aquifers with water mining is 0.5 €/m$^3$ (between 0.3 and 0.9 €/m$^3$). In the aquifer of Ascoy-Sopalmo, which is the most intensely exploited aquifer, the cost of water is among the lowest in the Altiplano region due to cost-efficient pumping (Aldaya et al., 2017).

In areas of intensive irrigation with groundwater, water is relatively expensive because of the generally deep groundwater level. Abstraction costs are close to those of the desalination plant operation but are clearly below the total cost that includes amortization and transportation to the place of water use. Thus, if socially costly administrative interventions are not implemented, groundwater reserves consumption will continue at a rate of approximately 200 hm$^3$/year, at least until the year 2027. Hitherto, as previously stated, 15 km$^3$ of the groundwater reserves have been consumed in the basin, and there is still at least a similar reserve volume left. Although, in some areas, reserves could last some decades, in others, there will be faster depletion, most of the time related to the deterioration of water quality, mainly due to increasing salinity (Custodio et al., 2016; MASE 2015).

The water regenerated in wastewater treatment plants is available and used for irrigation in many parts of the basin. The final cost is reasonable, since it is the user who pays the cost of treatment. The farmer has to bear the additional cost of making the water available at the place of use, which partly depends on the available transport and storage infrastructures. In low-lying areas, where the proportion of desalinated water in urban wastewater is significant, there is the additional problem of the high boron content for sensitive crops, such as citrus, which is even greater if direct desalinated water use takes place. To mitigate this effect, it is necessary to turn into water mixtures or to use sequential applications, which requires other water sources and water mixtures adapted to the irrigation systems and crop types.

In places where groundwater complements surface water use, as in the Campo de Cartagena, groundwater is insurance against variations in water availability. In cases where the groundwater is brackish, generally due to the accumulation of irrigation returns or the mobilization of natural saline groundwater by exploitation, brackish water treatment should be avoided if no adequate brine evacuation and treatment is in place, which ensures that the problem is not transferred to other inland or coastal water bodies. The accumulation of nitrates of agricultural origin in aquifers and, consequently, in drainages constitutes part of the problem, which some experts consider to be related to the temporary loss of water quality in the Mar Menor (CHS, 2015; Baudron et al., 2015).

### 11.4. Virtual water trade

In today's globalized world, the concept of virtual water trade could be very relevant for this region. The incorporation of the notion of virtual water trade in water planning, through the exchange of goods or crop limitation actions, could help reduce the pressure on local water resources and mitigate water scarcity and drought periods in the basin (Aldaya, 2017; Aldaya and Llamas, 2008). In turn, this trade could ideally add value to the economy of the region, as it currently does with exports of fruits and vegetables and the livestock sector, which are on the rise. Nevertheless, the potential spill-over effects should be carefully assessed to avoid negative socio-economic and environmental consequences.

Irrigated agriculture in the basin has a privileged position in the European market. In recent decades, this has led to specialization towards delicacy agriculture with early and competitive varieties. In many cases, local farmers have to compete with other remote farmers who are producing with cheaper water and, especially, lower labour costs. Summer vegetables are moving towards areas where there is a greater abundance of water, leaving the areas of milder climate for early and extra-early winter varieties. The trade of crops or derived products using groundwater reserves for irrigation could be considered unfair competition.

### 11.5. Potential solutions for the unsatisfied demands in the Segura River Basin

The collective of farmers in the Segura River Basin has been pressing for years to increase the external water resources and eliminate the current deficit in the basin. The annual water volume needed corresponds to that necessary to avoid the extraction of groundwater reserves and requires adequate attention to the currently irrigated area in the basin. It is generally accepted that any action undertaken must involve the recovery of all of its associated costs. Potential solutions might include the following:

A. increasing the volume of desalinated water. The problem with this solution is partly the high cost of water, which is higher than 0.6 €/m$^3$ (approximately 0.80 to 0.90 €/m$^3$ if all the associated costs are recovered). This cost exceeds the payment capacity (payment willingness) of many of the basin crops. In addition, the high boron content of this kind of water makes it unsuitable for certain crops and irrigation types, which requires mixing with water of different origins and would not be possible without the current transfers. On the other hand, the fact that it is a resource incorporated into the system at zero elevation requires the construction of new infrastructure and the assumption of additional energy costs as a consequence of the need to pump the flows produced to higher levels and, where appropriate, the establishment of trade with other users, which makes it difficult to manage the unique exploitation system of the basin.

B. continuation of pumping groundwater reserves. Currently, reserve depletion is estimated at approximately 200 $hm^3$/year. This volume could possibly be maintained for some time, although not in all aquifers, since some show clear indications of depletion and a significant decrease in quality. This action is contrary to the concept of sustainability of the Water Framework Directive and the provisions of the river basin management plan, which establishes that the exploitation of reserves should not go beyond the year 2027.

C. turning to an increase in the basin resources based on new external transfers. In addition to analysing the viability of these transfers, their actual economic and environmental conditions must be clearly described. Its associated difficulty can be great in view of the territorial conflicts generated but is not insurmountable in the medium term.

D. analysing the possibility of reallocating irrigation water to activities with greater economic and social performance which are environmentally reasonable, such as tourism, profitable crops or agro-industry. The latter case would require importing additional virtual water in the form of raw materials, mainly feed. The related social and environmental problems, as well as the effects on water quality and the environment, should be assessed. These changes need a long period of time, which requires planning, acceptance and good governance. The opinions of society as a whole must be heard in order to reach a balance that benefits the economy of the basin under ethical norms of use and damages, as well as respect for the natural environment and human occupation of the territory.

E. promoting the association of better water management and governance. There is great development of irrigation communities that share and manage common water systems, but this is not the case for groundwater. This is because private water rights holders have a comparative advantage over those who do not have them. The figure of the irrigation community, which only applies to public waters, is not appropriate for these cases. Groundwater user communities for the defence and management of the aquifer would be more appropriate, similar to other cases existing in Spain.

Greater transparency is needed in the basin in view of the territorial conflicts generated by the publication of the report “The water plot in the Segura Basin, 10 years later” (Turrión, 2017), which, with little technical rigour and few conceptual errors, has generated expectations that translate into frustration, as they cannot be met. The report points at renewable groundwater flow from the headwaters of the Segura Basin to the sea. This is not hydrogeologically possible due to the tectonic compartmentalization that occurs in the Segura Basin, with 235 catalogued aquifers generally confined by impermeable lateral barriers, as well as hydrodynamic reasoning.

## 12. Conclusions

This paper provides an overview of the different types of **water resources available** in the basin, including concepts that are not considered in the current river basin management plans by the European Water Framework Directive, such as the following points. 1) The green or soil water amounts to 71% of the total rainfall in the Segura Basin and is essential for more integrated water and land-use planning. 2) The virtual water ins and outs from the Segura Basin related to the trade of food, feed and other products, are 1253 and 1598 $hm^3$/year, respectively, with a similar order of magnitude to that of the total renewable blue water resources available (1319 $hm^3$/year), and these numbers are useful to put into perspective the current water uses in the basin and to find solutions.

The paper moves beyond an economic sectoral approach and analyses **water use and demands** in a disaggregated way. In particular, the agricultural sector, as the main user in the basin, is disaggregated by crop type, the related green and blue water requirements and the social and economic elements and social performance analysed. The social, territorial and landscape interests of rural activities, which are not necessarily profitable, are considered, so that their inhabitants, as "nature gardeners", perform the necessary functions, are sufficiently remunerated and are under clear rules and that their own human environment can assess and sanction. This requires enabling the necessary funds from the community and from those who receive the benefit of conservation.

The renewable blue water resources available in the basin, at approximately 1319 hm$^3$/year, are not enough for the maintenance of the current productive model, which requires approximately 1870 hm$^3$/year. There is no single solution but a combination of several possibilities to achieve an appropriate balance between the water demand and supply. Aspects to be taken into account are desalinated water, groundwater pumping linked to community-based management, external transfers, reallocating irrigation water, generating greater socio-economic and environmental value, and virtual water imports as an option to attenuate the effects of droughts.

The figures provided by the river basin management plan are stationary average values. However, public management, good governance and adequate water planning are greatly influenced by the variability that characterizes the Mediterranean area. To go beyond and improve the status quo, the dynamic values associated with the climatology of each year, as well as technological, economic and social developments, should be considered. The reality is complex, and the inevitable uncertainties should be dealt with in water planning. Assessing the temporal variability and trends and flexible approaches to planning help in understanding and balancing the problems of water availability and uses, together with compliance with the ecological flow regimes, especially in terms of climatic fluctuations and extreme situations of floods and droughts.

In some cases, in the Segura Basin, the time frame of groundwater body recovery is estimated to be many decades and even centuries, both in terms of quantity and quality. Even upon assuming that the action and pressure ceases, the deterioration would continue, as in the case of the nitrates currently in transit through thick unsaturated zones or due to long transient evolutions of medium- and large-sized aquifer systems. The recovery attempts can have a high cost, possibly disproportionate to the benefits. These situations should be specifically addressed in a context that allows externalities which are not currently considered in the river basin management plan to be included. In groundwater bodies disconnected from surface watercourses and with no dependent springs or wetlands, the feasibility of establishing less-stringent objectives should be assessed.

## Acknowledgements

The project “Análisis académico del Plan Hidrológico de la demarcación hidrográfica del Segura 2015-2021 a la luz de modernos conceptos de la ciencia de los recursos del agua” (Academic analysis of the Segura Water District Water Plan from the point of view of water resources modern concepts) provided the ideas and data for this work. This project has been carried out by the Royal Academy of Exact, Physical and Natural Sciences of Spain with the support of the Segura Water Authority, the Botin Foundation, Obra Social La Caixa and Caja Navarra Foundation. Many experts have contributed to its development, and all of them are credited in Aldaya et al. (2017).

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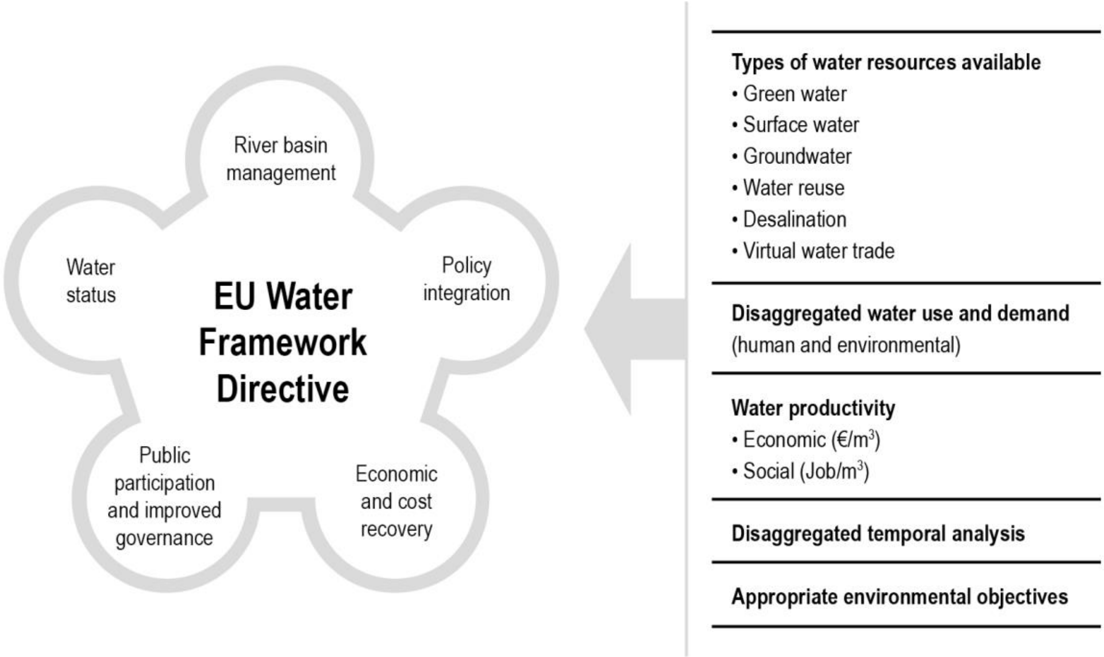
Graphical abstract



**Highlights**

- EU WFD does not address land ecosystems, rainfed agriculture nor virtual water trade
- Analysing all types and origins of water provides insight on impacts and solutions
- The temporal variability and trends analysis helps comply with environmental flows
- Virtual water imports, 1250 hm$^3$/year in the Segura basin, mitigate water scarcity
- Integrating trade, land-use and water planning helps anticipate and solve problems