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Preliminary planning for reclaimed water reuse for agricultural irrigation in the province of Girona, Catalonia (Spain)

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ABSTRACT

The province of Girona (Catalonia, Spain) is not an area where there is a structural deficit of water. There are certain problems and restrictions connected with climatic conditions and with special seasonal factors related to tourism, particularly in summer. Hence reusing reclaimed water for agricultural irrigation in the province would help to reduce the effect of these restrictions. Despite the apparent benefits of reclaimed water its use for agricultural irrigation, is not yet a widespread practice. This is the background against which a province-wide study has been carried out using a geographic information system (GIS) to set up a digital database containing details of current agricultural reclaimed water reuse in the area. In addition, a visual presentation of the current situation in the province has been developed to make data update easier over time. A questionnaire has been drawn up to determine the views of irrigation communities and farmers that use reclaimed water for agricultural irrigation in the study area. Further, a preliminary plan to reuse reclaimed water for agricultural irrigation in the province has been proposed to achieve a more sustainable water management. The plan was made on the base of Spanish Royal Decree 1620/2007, which regulates reclaimed effluents reuse. The study shows that the reuse of this non conventional water resource represents a viable method of reducing the competition between urban and agricultural water demands. Implementation of the plan would save about 20% of the conventional water consumed by agriculture, which could be redirected towards satisfying the urban sector's demand for water.

Keywords: Reclaimed water reuse; Planning; Irrigation; Girona

1. Introduction

Agriculture is the main user of water resources in most regions of the world, and in Spain—as a part of the Mediterranean region—about 68% of water resources are consumed by this sector [1]. About 70% of water resources in Catalonia, a region located in the northeast of Spain, are used for irrigation [2]. Like other Mediterranean regions where it is difficult to satisfy agricultural water demand with conventional resources, reclaimed water reuse can be considered as a viable water resource option. The most commonly accepted goal of wastewater reclamation and reuse projects is to produce water of sufficient quality for all potential uses that do not have to meet drinking water quality standards [3]. There are certain restrictions on water usage in Girona province, which is one of the four provinces of Catalonia, connected with climatic conditions and with special seasonal factors related to tourism, especially in summer. These restrictions could be simply pointed out in the elevated urban water demand related to tourism activity in summer season that coincides with high agricultural water requirement. In recent years, there have been repeated scenarios in the province of water supply restrictions.

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For example, in the summer of 1999, no water was supplied to irrigation communities of Muga basin. Further in 2000, they faced some water supply restrictions. Therefore, the government promulgated some exceptional decrees related with water resources use. These exceptional decrees provide a reduction of irrigation water doses and support the usage of reclaimed water for irrigation in drought episodes [4].

According to Calvo [5], any failure to meet reasonable water demand for territorial development could result in significant economic damage. Castillo [6] and Gómez-Lama et al. [7] concluded that the highest wastewater production coincides with elevated tourism activity. However, other factors must also be considered when we talk about the mentioned restrictions on water usage in the province of Girona. Among them, there are the social issues (such as public perception about using reclaimed water for irrigation) and the importance of the food produced by agricultural activity, given that the increase in food demand is partly generated by tourism. Therefore, in terms of water consumption, it is important to look at the existing interrelationship between the agriculture and urban sectors, and determine if the reuse of reclaimed water for irrigation, is the best solution to the conflicting demands of these two sectors.

The Costa Brava, the coastline zone of the entire province within the districts of Alt Empordà, Baix Empordà and La Selva, attracted about five million tourists in 2007. The number of tourists that visited the other areas of Girona province was not considered in this study, because it was considerably smaller with regard those who visited Costa Brava. Visitors stayed an average of ten days [8] and their daily average water consumption was 166 l per tourist [9]. As a result, the annual water consumption by tourists was about 8.3 hm^3. The total domestic demand for water in the province in 2008 was estimated to be at least 43 $hm^3\ y^{-1}$ for 709,150 inhabitants [9]. This means that the total urban demand, taking both domestic and tourist consumption into account, was about 51 $hm^3\ y^{-1}$. Another factor to consider is that the summer season coincides with the maximum irrigation water requirement. Water consumed by golf irrigation in the province was estimated to be about 4.1 $hm^3\ y^{-1}$, for the irrigation of 500 ha of golf courses [10]. This coincides with the average water consumption for irrigating golf courses in Spain that has been estimated by Rodríguez-Díaz et al. [11] to be 8,200 $m^3\ ha^{-1}\ y^{-1}$. This is also consistent with the estimates of Sanz Magellón [12] and Morell [13] of about 7,563 and 8,000 $m^3\ ha^{-1}\ y^{-1}$ respectively.

According to Sala and Mujeriego [14], agriculture and livestock breeding are two of the main nutrient sources responsible for some environmental problems such as water eutrophication. The reclamation and reuse of this water could be a suitable strategy not only for preserving the quality of natural water resources by reducing effluent discharges to receiving waters but also, for using the content of nutrients of the effluents for saving fertilizers.

This paper proposes a preliminary plan strategy for the reuse of reclaimed water from wastewater treatment plants (WWTPs) in the province of Girona to help meet water requirements of both the agriculture and urban sectors. Also, this work provides figures for some of the maps developed by using the ArcView program [15] to manipulate Crop and Soil Use map 1:50,000 at level 5 [16] in order to give an idea about the actual circumstances in the province of Girona that related to reclaimed water and agriculture activity.

2. The current situation

Fig. 1 identifies the location and the administrative districts of the province of Girona, an area included in the Catalan inner river basins (Spain).

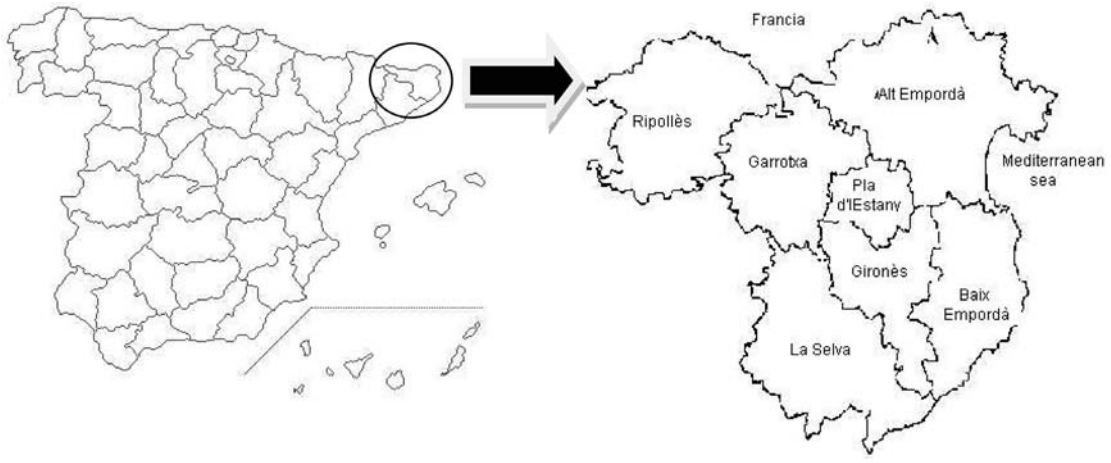

Fig. 1. Administrative districts and location of the province of Girona in Catalonia, Spain.

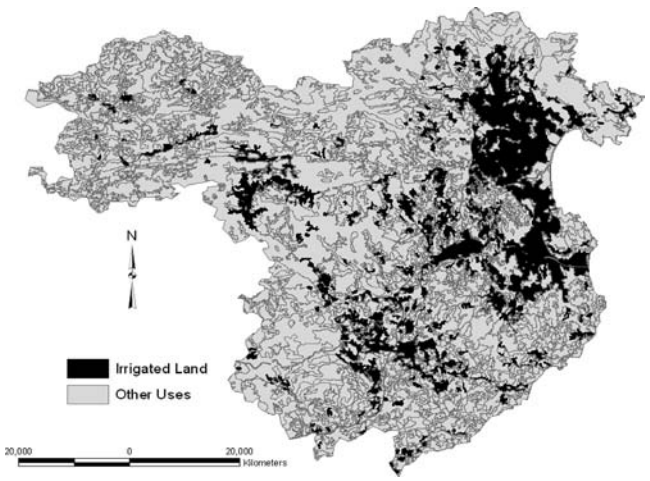

Fig. 2. GIS developed map that shows the distribution of irrigated areas in the province of Girona (Catalonia, Spain).

There is a notable shortage of renewable water resources in the province, which depends mainly on groundwater. This is especially so in the districts of Alt and Baix Empordà, where the available surface water resources are insufficient [2]. In addition, it is predicted that the hydrological resources in the interior river basins of Catalonia will decrease as a result of climate change [17]. A desalination plant located in the south of the province supplies an annual volume of 10 hm^3 (that will be doubled in 2010) for supporting urban water demand at the time that helps to stabilize water intrusion of the Tordera Aquifer, in the south of the district of La Selva [18].

The province of Girona has 106,059 ha of cultivated land, 46.4% of which was irrigated in 2006 [19]. Fig. 2 is a geographic information system (GIS) developed map that shows the distribution of irrigated areas in the province. Wheat, barley, maize, rice, sunflowers, rapeseed, sorghum, rye grass, alfalfa, apples, pears, peaches and olives are the most important crops in the province (Table 1). The yearly amounts of conventional water required for these crops were determined by computing crop evapotranspiration (ET_c) to calculate their irrigation water demand using the crop coefficient approach [20]:

$$ET_c = ET_o \cdot K_c \quad (1)$$

where ET_c is crop evapotranspiration [mm mo^{-1}]; ET_o is reference crop evapotranspiration [mm mo^{-1}]; and K_c is the crop coefficient [dimensionless].

Data going back an average of six to ten years from district meteorological stations in the province of Girona were used to calculate ET_o and represent environmental conditions. The K_c values for sub-humid zones where the study area is included were obtained by Allen et al. [20].

Table 1
Crop surface (in 2006) and water requirements in the province of Girona (Crop surface was obtained by DARP [19]

Crop	Area, ha	CWR, $m^3\ ha^{-1}\ y^{-1}$
Wheat	12,456	1,993
Barley	8,631	2,499
Maize	8,759	3,417
Rice	821	5,070
Sunflowers	4,388	2,383
Rapeseed	548	1,851
Sorghum	2,034	1,922
Rye grass	1,952	3,477
Alfalfa	7,270	3,850
Apples & Pears	5,391	3,384
Peaches	1,699	3,397
Olives	1,804	2,797

The water requirement for each crop was then obtained in accordance with Allen et al. [19] as follows:

$$CWR_m = ETc - EP \quad (2)$$

where CWR_m is the crop water requirement [mm mon^{-1}]; and EP is effective precipitation [mm mo^{-1}].

Effective precipitation was calculated as 85% of total precipitation as recommended by Smith [21].

The sum of CWR_m (mm mo^{-1}) equals CWR_y (mm y^{-1})

$$\sum_{x}^{y} CWR_m(\mathrm{mm/mo}) = CWR_y(\mathrm{mm/y}) \quad (3)$$

where x is the initial planting month; y is the final harvesting month.

A probability not exceeding 80% of a normal distribution was adopted to compute the CWR_y.

Finally, irrigation water demand (IWD) was calculated by dividing the CWR_y by the efficiency of the irrigation system (EIS) as follows

$$IWD = \frac{CWR_y}{EIS} \quad (4)$$

where IWD is irrigation water demand [mm y^{-1}]; and EIS is efficiency of the irrigation system [%].

Since more than 77% of water used for agriculture is consumed by gravity irrigation [9], the efficiency of the surface irrigation system was on average 60% according to Brouwer et al. [22]. Tables 1 and 2 show, respectively, the calculation results of the annual crop water requirement for each crop and the annual irrigation water demand for each district in the province. These results show that water demand for irrigating the most important crops in the province of Girona is 283 $hm^3\ y^{-1}$.

Table 2
Total volumes of reclaimed water adequate for agriculture and irrigation water demand in the province of Girona

District	Irrigation water demand, $hm^3 y^{-1}$	Reclaimed water adequate for agriculture, $hm^3 y^{-1}$
Alt Empordà	109	7
Baix Empordà	93	19
Pla de l'Estany	22	1
Garrotxa	19	7
Gironès	28	1
Ripollès	0	6
Selva	13	18
TOTAL	283	59

The annual IWD of these calculations is higher than the IWD of 207 $hm^3 y^{-1}$ determined by Rodríguez Díaz et al. whom covered in their study more than 71,000 ha of the total surface of Andalucía (south of Spain) [23] This difference between both calculations is due that part of the winter cereals was considered as irrigated crops in Girona province according to Government classification although in reality it was rainfed.

3. Planning the reuse reclaimed water in the province of Girona

3.1. Legislative framework

From the legislative standpoint, wastewater reuse in Spain must be in accordance with Spanish Royal Decree 1620/2007 [24]. This Royal Decree classifies the adequacy of reclaimed water for different activities according to its biological, physical and chemical characteristics, e.g. the presence of intestinal nematode, *Legionella spp.*, *Escherichia coli*, suspended solids and turbidity. Under Spanish regulations, water quality for agricultural activity is divided into three categories: a) quality 2.1, which is the highest quality for agricultural activity and can be used for irrigation technologies that allow a direct contact between the effluent and fresh edible parts of the plant; b) quality 2.2, which has restrictions related to the end use of the crop and is only allowed to be used on crops that will not be consumed fresh; and c) quality 2.3, which cannot be used with irrigation methods that allow direct contact between the reclaimed water and the crop. Effluents under quality 2.1 are suitable for irrigating golf courses.

As additional comments in the Royal Decree 1620/2007, farmers and irrigation communities must notice the presence of some dangerous substances in the reclaimed effluent before using it for irrigation, e.g. heavy metals, organochlorines, fluorides and total cyanide. In case of existing any of these dangerous substances, they must be sure that they do not exceed the limits provided by the European Environmental Quality Standards in the field of water policy. Further, this Royal Decree established limits values for salinity and heavy metals. These limits are a maximum of 3.00 dS m^{-1} of electrical conductivity, 6.00 mg l^{-1} of sodium adsorption ratio, 0.50 mg l^{-1} of boron and cobalt, 0.20 mg l^{-1} of copper, manganese, nickel and selenium, and 0.10 mg l^{-1} of arsenic, beryllium, cadmium, chromium, molybdenum and vanadium. When effluent's parameters exceed the values provided by the Royal Decree, farmers must provide more additional information such as crop and soil type to the government to authorize whether or not the effluent can be used.

According to Sheikh et al. and Hamilton et al. [25,26], the concentration of heavy metals in reclaimed water is markedly smaller than in raw sewage. Therefore, most concern over the potential effects of heavy metals on plant production and human health relates to raw sewage irrigation rather than irrigation with reclaimed effluents [27,28]. According to the Royal Decree 1620/2007, the European Environmental Quality standards in the field of water policy must be respected in case of that those dangerous substances are present in reused effluent. Further studies should be carried out in order to determine whether the widespread reuse applications of reclaimed water for agricultural use according to qualities defined by the Royal Decree 1620/2007 contributes to the distribution of these compounds in the environment or not.

Fig. 3 shows the distribution and quality classification of WWTPs for the agricultural irrigation use in the province of Girona according to Spanish Royal Decree 1620/2007. This figure is a part of the geographic information system (GIS) developed by ArcView program [15] for the strategic management plan.

The water framework directive (WFD) is another important piece of legislation that member states of the European Union have to use to convert the "new water culture" into a definitive policy that has been coordinated with all political sectors [29]. The directive is designed to be a clear and integrated regulatory framework based on a specific management plan, drawn up to promote the participation of institutions and citizens in the process. The catalan water agency (ACA) [30] is currently responsible for the application of this directive and is working to achieve better quality water through the diverse and proactive participation of different groups, and to draw up a hydrological plan for Catalonia.

3.2. Wastewater and conventional water availability

The province of Girona has 90 WWTPs located near irrigated fields (Fig. 4), excluding those in the district of Ripollès which are located away from cultivated areas [31].

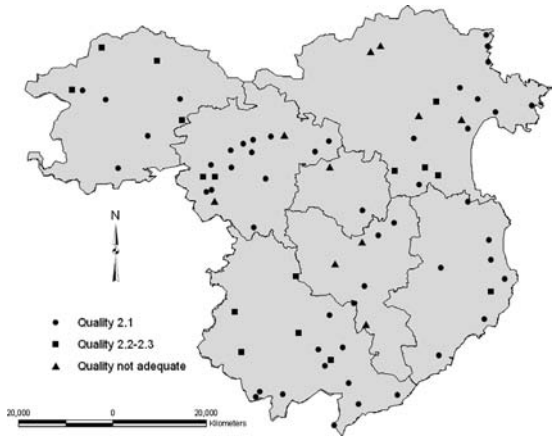

Fig. 3. GIS map that shows the distribution and quality classification of WWTPs for agricultural use in the province of Girona according to Spanish Royal Decree 1620/2007.

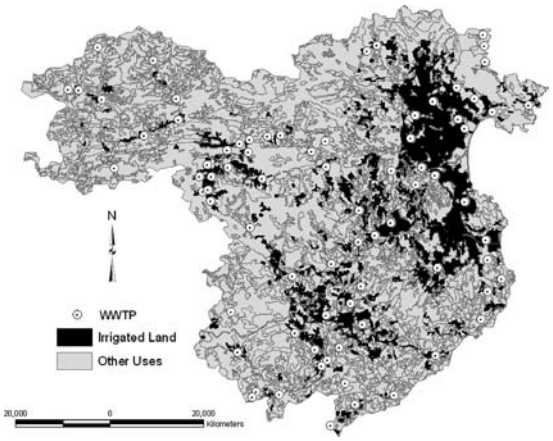

Fig. 4. GIS developed map that shows the distribution of WWTPs on irrigated land in the province of Girona.

Each WWTP has its own effluent's characteristics and also, has its goals from the purifying process according to the expected use of the effluent. Table 3 presents the average and standard deviation for WWTPs' effluent characteristics in the province after classifying them according to qualities defined by Royal Decree 1620/2007 [24].

A considerable amount of the resulting effluents are discharged into the sea or used to increase river flow [32]. Table 4 shows the number of WWTPs by district and the quality of their effluents for agricultural irrigation use according to Royal Decree 1620/2007. The data demonstrates that about 87% of the reclaimed water from WWTPs is suitable for agricultural use, with 50% of it being of the highest quality (category 2.1). This quantity of reclaimed water is about 20% of the IWD, for the Girona province, previously calculated.

Reclaimed effluents from 14 WWTPs were analysed for the presence of protozoa and parasites in 2008 and had no restrictions for agricultural irrigation use according to WHO standards and with a maximum of only one intestinal nematode egg for every 10 litters of reclaimed water [33]. Further, and after taking into consideration the physical parameters as total suspended solids and turbidity, it was found that 9 of them were of quality 2.1 according to Royal Decree 1620/2007 [24].

On this basis, up to 58 $hm^3\ y^{-1}$ of reclaimed water are available for agricultural use in Girona (Table 4). Treated effluents from WWTPs in the district of Ripollès were excluded from this calculation despite they are adequate for agriculture use. This is due to the mountainous topography of this district and its null irrigation water demand. Transporting these effluents to closer districts like La Garrotxa is not possible from a practical point of view, because the nature of the topography would considerably increase the cost of the infrastructure. These effluents are now discharged into the river Ter.

Table 3
Average and standard deviation for WWTPs' effluent characteristics in the province of Girona after classifying them per quality for agricultural irrigation purpose according to Royal Decree 1620/2007 [21]

Characteristic	SS, g m^{-3}	BOD, g m^{-3}	COD, g m^{-3}	t N, g m^{-3}	t P, g m^{-3}
Quality 2.1	12 ± 4	11 ± 3	45 ± 9	11 ± 5	3 ± 1
Quality 2.2 & 2.3	25 ± 5	19 ± 8	74 ± 25	17 ± 11	4 ± 3
Not adequate for agricultural use	200 ± 88	218 ± 93	464 ± 197	44 ± 15	8 ± 3

SS: total suspended solids in the effluent; BOD: biological oxygen demand; COD: chemical oxygen demand; t N: total nitrogen; t P: total phosphorus.
Quality 2.1: adequate for crop irrigation with a water application system that allows direct contact between the reclaimed water and edible parts for fresh human consumption.
Quality 2.2: adequate for a) irrigation of products for human consumption with an application system that does not prevent direct contact between the reclaimed water and edible parts – no fresh consumption; b) irrigation of pasture lands for milk and animal meat consumption; c) aquaculture.
Quality 2.3: adequate for a) tree irrigation that prevents contact between the reclaimed water and consumable fruit; b) irrigation of ornamental flowers, nurseries and greenhouses without direct contact between the reclaimed water and the plants; c) irrigation of industrial crops which not for food, e.g. nurseries, forages, silage, grains and oilseeds.

Table 4
Number of WWTPs per district in the province of Girona and their water quality for agricultural irrigation purposes according to Royal Decree 1620/2007 [21]

District	Number of WWTPs				Total flow, $hm^3 y^{-1}$		Total annual reclaimed water adequate for agriculture, $hm^3 y^{-1}$
	Total	Quality 2.1	Quality 2.2 & 2.3	Not adequate for agricultural use	Quality 2.1	Quality 2.2 & 2.3	
Alt Empordà	18	10	3	5	7.0	0.2	7.2
Baix Empordà	8	7	0	1	19.0	0.0	19.0
Garrotxa	17	12	2	3	7.0	0.1	7.1
Gironès	7	3	0	4	1.0	0.0	1.0
Pla de l'Estany	2	1	0	1	1.0	0.0	1.0
Osona	1	1	0	0	0.5	0.0	0.5
Ripollès	9	5	2	2	5.0	0.4	5.4
Selva	16	10	5	1	18.0	4.1	22.1
Total	78	49	9	17	58.5	4.8	63.1

Quality 2.1: adequate for crop irrigation with a water application system that allows direct contact between the reclaimed water and edible parts for fresh human consumption.
Quality 2.2: adequate for a) irrigation of products for human consumption with an application system that does not prevent direct contact between the reclaimed water and edible parts – no fresh consumption; b) irrigation of pasture lands for milk and animal meat consumption; c) aquaculture.
Quality 2.3: adequate for a) tree irrigation that prevents contact between the reclaimed water and consumable fruit; b) irrigation of ornamental flowers, nurseries and greenhouses without direct contact between the reclaimed water and the plants; c) irrigation of industrial crops which not for food, e.g. nurseries, forages, silage, grains and oilseeds.

3.3. Wastewater reuse and public perception

Spain has recently begun to pay more attention to the subject of reclaimed water reuse. However, the quantity of reused wastewater of agricultural use is still low. For example, according to the Consortium of the Costa Brava [32], the total volume of reclaimed water from the Consortium's WWTPs is about 5.5 $hm^3 y^{-1}$, but only 0.5 $hm^3 y^{-1}$ is used for agricultural irrigation. This is less than 10% of the total reclaimed water, with the rest going to rivers and lakes [33].

Public perception is an important issue in any discussion about the reuse of reclaimed water for agriculture. It is obvious that from both the community and the institutional perspective that the major concerns about water reuse schemes are driven by the potential risks. These risks are perceived differently by individuals, communities and institutions (both public and private) [34]. According to Jeffrey [34], the main elements of risk regarding to reuse for agriculture are the possible infections during irrigation water application, product handling or consumption; damage to the final product quality or land productivity; risk that people will not purchase the final product; and financial risk of investment in the system. For this reason, a survey of user opinion about reclaimed water reuse for irrigation in the province of Girona has been carried out by interviewing the farmers and irrigation communities that use reclaimed water [35]. Table 5 summarises the main characteristics of these irrigation communities and farmers.

The results of the survey show that all the participants believe that water supply safety is the principal advantage of and main reason for using reclaimed water for irrigation, especially in drought periods. They also confirm that health problems have never been an issue, and that the WWTPs conduct regular analyses to ensure that water quality is adequate for agricultural use. Saving fertilizer is considered another very important advantage of using this type of water for irrigation. Due to nutrient content of these effluents, one of the two farmers who use reclaimed water from the Castell-Platja d'Aro WWTP saves almost 100% of the nitrogen fertilizer and a significant amount of phosphorous and potassium fertilizers on his farms, which cultivated with maize. The nitrogen content of this reclaimed water was about 200 kg N $ha^{-1} y^{-1}$ and maize requires between 250 and 270 kg N $ha^{-1} y^{-1}$, so use of the reclaimed water together with a small contribution from livestock manure represents a considerable saving on fertilizers costs.

According to Mujeriego [36], the cost of water used for irrigation varies significantly depending on its origin, crop water requirements, the irrigation system used and local water allocation rights. The cost typically ranges between 0.03 and 0.24 € m^{-3} for conventional water and 0.06–0.38 € m^{-3} for reclaimed water. Farmers in the area pay between about 0.00 and 0.10 € m^{-3} for reclaimed water. At present, public administrations can cover a maximum of about 70% of the operation costs related to conveying water from the WWTP to the irrigation fields and about 10% of the total cost of installing the irrigation system used. The cost of reclaimed water is low in the province of Girona thanks to this subsidy

Table 5
Principal characteristics of the farming and irrigation communities that use reclaimed water for irrigation in the province of Girona

Location	WWTP where the effluents originate	Irrigation community and farmer type	Irrigation start date	Irrigated area, ha	Crops	Irrigation method	Irrigation water dose, l m^{-2} d^{-1}
Blanes	Blanes	Private (2 farmers)	2005	30	Maize and palm trees	Sprinkle	2.2 (reclaimed water)
Santa Cristina d'Aro	Castell-Platja d'Aro	Private (1 farmer)	2003	50	Maize	Sprinkle	5-7 dependant on climate and crop development (reclaimed water)
Castell-Platja d'Aro	Castell-Platja d'Aro	Private (2 farmers)	1988	50	Vegetables and landscape gardening plants	Microsprinkle, drip and surface irrigation	24 in summer season (reclaimed water)
Colera	Colera	Society	1997	12	Vineyard	Drip	1 (reclaimed water)
Torroella de Montgrí	Torroella de Montgrí	Irrigation community	2004	1000	Maize, alfalfa and orchard	Surface (drip irrigation by 2009)	6.6 (mixed water)

and the other advantages previously mentioned. Under the terms of the WFD, the real cost of reclaimed water should be paid by the user, but this is not yet the case in Spain [37].

The survey revealed some problems related to the complicated process of installing infrastructure that faced by those using reclaimed water for irrigation. There is an absence of adequate irrigation networks to transport reclaimed water from WWTPs to irrigated land and it was difficult to convince neighbours and stakeholders to allow installation of the necessary pipe work on their land.

Farmers, in general, do not favour high quality treated effluents as they have a low nutrient content and it will be necessary to apply fertilizers. Farmers who face salinity problems solve them by mixing reclaimed water with conventional water. It is noteworthy that farmers who use reclaimed water from Castell-Platja d'Aro have been selling vegetables and landscape gardening plants at markets without any problem for over 20 y. Such experiences can change farmers' beliefs about negative impacts of reclaimed water [29] and present these effluents as an optimal water resource which, if applied widely, will save a huge amount of conventional water that can be redirected to satisfying domestic and tourism demands.

3.4. A summary of the suggested plan for reusing reclaimed water for agricultural irrigation in the province of Girona

Taking all the factors introduced in the previous sections, it could be figured out that the study area: a) recently faced repeated scenarios of water supply restrictions for agricultural irrigation; b) in summer season, the tourism activity reaches its top and increases water consumption for about 20% which coincides with elevated agricultural water necessities; c) study area needs 283 hm^3 y^{-1} of water for agricultural irrigation; d) up to 58 hm^3 y^{-1} of reclaimed water in the study area (about 20% of IWD) meets the requirements for agricultural use according to Royal Decree 1620/2007; e) reusing reclaimed water is not yet a widespread practice in the province; and f) farmers and irrigation communities that applied reclaimed water for agricultural irrigation were satisfied from both of economic and health point of views.

For all the previously mentioned motivations, a preliminary plan has been developed to reuse reclaimed water produced by WWTPs in the province of Girona with a sufficient quality for agricultural irrigation use according to Royal Decree 1620/2007. Under this plan, part of the conventional water used for irrigation purpose will be saved to meet urban water demands, with no negative effect on agricultural water demand even in summer. A digital database was set using Geographic Information System developed with the ArcView program [15] to record the actual circumstances related to reclaimed water and agriculture activity in the province of Girona. Further, the digital database provides a visual presentation for these circumstances. In addition, this database permits to manage and update the collected data over time.

As it is presented in Fig. 4 the existence of WWTPs near the irrigated lands will reduce the economic costs and the environmental impact of the installation

processes for conveying reclaimed water to irrigation lands. WWTPs of the district of Ripollès are excluded from the plan for having a null crop water requirement and also, for its mountainous topography.

Awareness campaigns should be carried out as a try to convince farmers and irrigation communities to accept reclaimed water as an alternative water resource instead of conventional water for irrigation.

If this plan was applied, it is estimated that up to 100% of the total conventional water used for irrigation in the district of La Selva, 37% in La Garrotxa, 20% in Baix Empordà, 18% in Pla de l'Estany, 6% in Alt Empordà and 3.5% in Gironès would be saved. All of this could be redirected to satisfying the urban sector. This means that about 20% of the total conventional water used in the province (about 58 hm^3 y^{-1}), which is almost equal to the urban water demand, would be redirected towards satisfying global demand, thereby reducing competition with agricultural use. In addition, applying this plan would help farmers and irrigation communities to face drought periods, especially when the government give the priority to accomplish the urban water demand at first.

4. Conclusions

Large amounts of wastewater generated from urban areas and livestock farms often become an environmental problem. However, they can also be considered as secure water resources if they are reclaimed and reused for irrigation. When this type of water used, it can reduce the pressure on conventional water resources (surface and groundwater), a subject which is of increasing interest in most developed countries.

The province of Girona (Catalonia, Spain)—as a Mediterranean region—is facing certain water problems and restrictions connected with climatic conditions and with special seasonal factors related to tourism. These problems lead to a competition between urban and agricultural water demand especially, in summer.

A plan was developed using geographic information system to reduce the mentioned competition between urban and agricultural water demands in the province of Girona. The plan consists of using about 58 hm^3 y^{-1} of reclaimed water produced by WWTPs located in the province of Girona with a quality suitable for agricultural irrigation use according to the Spanish regulations. Public perception would affect negatively when applying the plan. Thus, awareness campaigns are required to provide a new vision to farmers and irrigation communities about the benefits of reusing reclaimed water for irrigation.

In case of applying this plan, it is estimated to save up to 100% of total conventional water used for irrigation in the district of La Selva. Further, 37% of conventional water in Garrotxa, 20% in Baix Empordà, 18% in Pla de l'Estany, 6% in Alt Empordà and 3.5% in Gironès would be saved. This is equal to 20% of the conventional water used for irrigation in the province of Girona. Water saved could be redirected towards meeting other human water demands and thereby reducing the pressure on natural water resources. However, it will be necessary to carry out an assessment of the effects on environment and crops. Besides, public education and communication programs should be developed for preventing a negative image of reclaimed water reuse and emphasising the advantages and benefits of this alternative, drought-proof resource.

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Symbols

WWTP	—	wastewater treatment plant
ET_c	—	crop evapotranspiration [mm mo^{-1}]
ET_o	—	reference evapotranspiration [mm mo^{-1}]
K_c	—	crop coefficient [dimensionless]
CWR_m	—	crop water requirement [mm mo^{-1}]
CWR_y	—	crop water requirement [mm y^{-1}]
EP	—	effective precipitation [mm mo^{-1}]
x	—	initial planting month
y	—	final harvesting month
IWD	—	irrigation water demand [mm y^{-1}]
EIS	—	efficiency of irrigation system [%]

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