39th IAHR WORLD CONGRESS GRANADA, SPAIN 2022 From Snow to Sea 19-24 June 2022

Proceedings of the 39th IAHR World Congress
19–24 June 2022, Granada, Spain
doi://10.3850/IAHR-39WC2521716X20221855

Hydro-economic Analysis of Wastewater Reuse Opportunities in Agriculture Under Climate Uncertainties in Spain

Irene Blanco-Gutiérrez[(1)], Paloma Esteve[(2)], Marina RL Mautner[(3)], Marisa Escobar[(4)], and Samaneh Seifollahi-Aghmiuni[(5)]

[(1,2)]Research Centre for the Management of Agricultural and Environmental Risks (CEIGRAM),Universidad Politécnica de Madrid,Madrid, Spain, irene.blanco@upm.es

[(1,2)] Department of Agricultural Economics, Statistics and Business Management, ETSIAAB, Universidad Politécnica de Madrid, Madrid, Spain

[(3,4)] Stockholm Environment Institute U.S., Davis, USA, marina.mautner@sei.org

[(5)] Stockholm University, Stockholm, Sweden, samaneh.seifollahi@natgeo.su.se

Abstract

Growing pressure on water sources from diverse water demands and uses threatened by uncertain regional climate conditions have increased the use of unconventional water resources (e.g. reclaimed water) to compensate water deficit in Spain. Specifically, recycled urban wastewater has become an attractive, reliable, and safe alternative to regulated groundwater pumping in over-drafted aquifers for agricultural irrigation. However, wastewater reuse for irrigation still lags behind stated national goals, that may even conflict with environmental and recreational water uses in this high water stress region. This study uses a hydro-economic model to explore the potential for reclaimed water reuse in agriculture and effective water resource management under climate uncertainties for water availability. Management alternatives include different levels of reclaimed water reuse from urban wastewater treatment plants in the region, while climate uncertainty is represented by projected precipitation and temperature changes from a selection of global climate models under different representative concentration pathways. We evaluate the quantity of groundwater abstraction averted, area of crops irrigated with reclaimed water, impact on farmers' income, and streamflow available for environmental uses under the combined climate and management scenarios. Such evaluations are subject to reclaimed water availability and groundwater pumping restrictions determined for drought conditions. Our results provide valuable insights on economic and environmental implications of reclaimed water reuse, and can support responsible decision and policy options to maximize the uptake of such alternatives for integrated and sustainable water resource management in semi-arid regions.

Keywords: Wastewater reuse; Planning and management; Climate uncertainty; Agriculture; Spain

1 INTRODUCTION

Years of increasing irrigated agriculture demands paired with other increasing demands in the European Union (EU)have led to increasing stress on water sources, particularly in the Mediterranean region. The water supply capacity of the natural systems will be further strained by climate uncertainty going forward, with temperatures expected to increase, and droughts to become more frequent and more extreme. In some Mediterranean areas, total water demand each year greatly exceeds the long-term freshwater resources available, indicating unsustainable future supply (EEA, 2018). Irrigation supply has traditionally consisted of surface water from reservoirs and groundwater from pumping wells. However, as these sources have been threatened, EU countries facing conflicts between water users have turned to unconventional water supply sources, including treated wastewater.

Recycled urban wastewater has become an attractive, reliable, and safe alternative to regulated groundwater pumping in over-drafted aquifers for agricultural irrigation (Voulvoulis, 2018). The use of reclaimed water for irrigation of agricultural fields located near urban and peri-urban areas is two-fold, potentially decreasing demand on surface and groundwater, while decreasing effluents discharged to water bodies (Gil-Meseguer et al., 2018). Additionally, excess nutrients that can be expensive to treat in wastewater are often welcomed by farmers because of their positive impact on crop yields (Salgot and Folch, 2018).Recent policies (e.g., the EU Circular Economy Action Plan) are encouraging circular approaches to water reuse in agriculture. However, wastewater reuse for irrigation still lags behind stated policygoals in most areasand may even conflict with environmental and recreational water uses in high water stress regions.

Spain in particular has become a leader in wastewater reuse, accounting for nearly half of the total volume of recycled water in the EU (Deloitte, 2015). In 2007, Royal Decree 1620/2007 and the National Plan for Sanitation and Treatment created a new framework for promoting and improving water recycling in Spain. Despite relatively significant advances in some areas, particularly in coastal regions, total share of water supply by reclaimed water has been stalled at approximately 10% over the last decade and uptake has been limited in water-stressed inland regions such as the Upper Guadiana Basin (INE, 2018).

While many technical aspects of irrigation with recycled water have been examined, such as treatment quality and distribution, other aspects, such as integrated planning and economic implications, have been largely overlooked. On the one hand, lack of public understanding may lead farmers and consumers to be resistant to such proposals (Smith et al., 2017). While on the other hand, extremely limited supply in water-stressed regions may mean that diversion of wastewater discharge will lead to unintended impacts on ecological flows (Bolinches et al., 2022). In addition, pricing policies and other long-term economic considerations have yet to be properly developed, all of which create a need for more research that integrates diverse modeling analyses (Beveridge et al., 2017).

Integrated research in this area must consider surface and groundwater supplies, climate uncertainty, crop yields, farmers' income infrastructure requirements, environmental demands, and wastewater potential to provide meaningful decision-making support and promote sustainable management of water resources.This study uses a hydro-economic model to explore the potential for reclaimed water reuse in agriculture and effective water resource management under climate uncertainties for water availability. We explore wastewater reuse as a reliable tool to help alleviate groundwater overexploitation in La Mancha Occidental Aquifer, in the Upper Guadiana Basin in the southern central plateau in Spain. Specifically, if there are policies that avoid compromising environmental flows, particularly those that feed the Tablas de Daimiel wetlands. Most importantly, how do these policies allow for robust supply options under climate change.

This study provides valuable insights on economic and environmental implications of reclaimed water reuse and can support responsible decision and policy options to maximize the uptake of such alternatives for integrated and sustainable water resource management in semi-arid regions.

2 THE STUDY REGION

The Mancha Occidental aquifer is located in the Upper Guadiana Basin (see Fig. 1). It has been the objective of many previous works as it constitutes a paradigmatic case in which groundwater resource mismanagement leads to severe environmental, social and institutional concerns (e.g., Varela-Ortega et al 2011). In this area, the great development of irrigation in the last decades of the 20th century led to the overexploitation of the Mancha Occidental aquifer and provoked the degradation of the highly valuable wetlands of the National Park of Las Tablas de Daimiel.This "agricultural development / nature conservation" conflict resulted in intense social conflicts among farmers, environmental NGOs, regional administration departments (agriculture and environment) and the River Basin Authority.

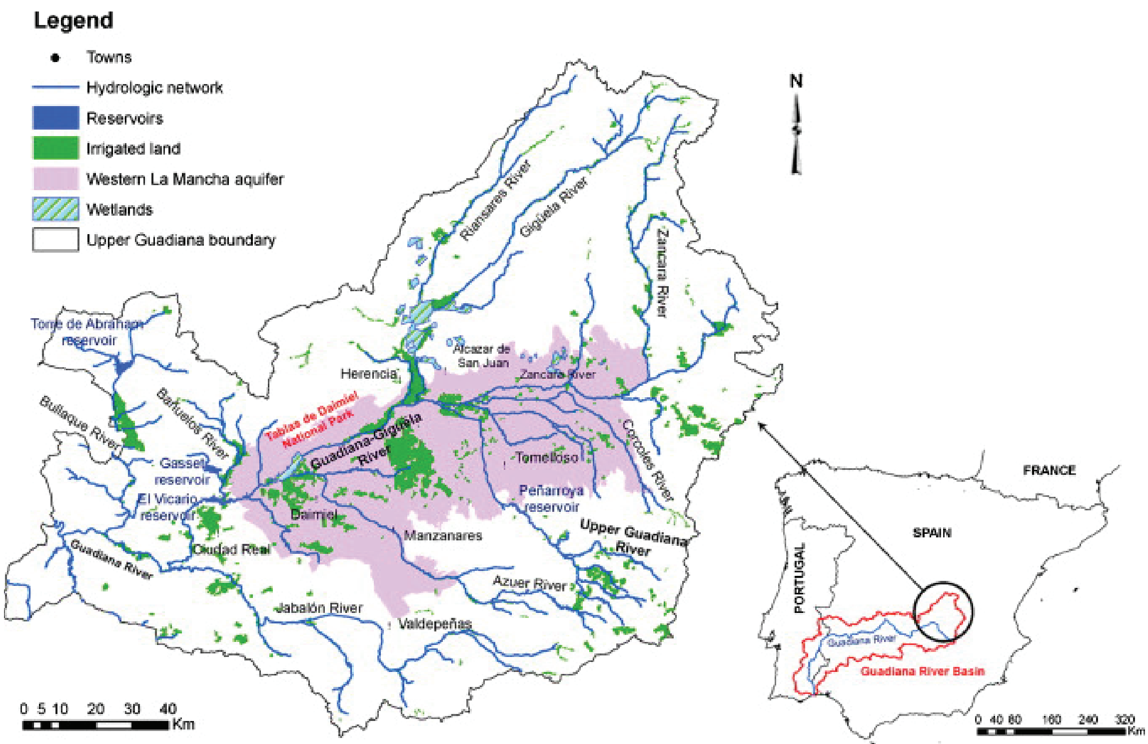

Figure 1. Upper Guadiana basin. Mancha Occidental I and II depicted as one body "Western La Mancha Aquifer". Source: Varela-Ortega et al. (2011)

The legal declaration of overexploitation of the Mancha Occidental Aquifer in the early nineties triggered the constitution of groundwater user associations and the implementation of a Water Abstraction Regime that forbade drilling new wells or deepening the existing ones, restricted water abstraction and re-defined the previously established water allotment rights of the private irrigators by reducing substantially their entitled water allotments.Enforcement of this legal provision has not been without difficulties, mainly related to strong legal and practical opposition form the irrigators and the consequent high transaction costs involved for control and administration, and has not reverted the overexploitation of the aquifer.

The Water Abstraction Regime restricted water allotments to 2000 m3/ha for herbaceous crops and to 1500 m3/ha for woody crops. However, in the most recent years, and due to the continued degradation of groundwater levels, these allotments have been further reduced (Table 1).

Table 1. Water allotments according to the annual water abstraction regime published by the River Basin Authority.

Crop type	Water quota (m3/ha)		
	2012 to 2019	**2020**	**2021**
Herbaceous	2,000	1,900	1,800
Woody	1,500	1,400	1,350

In this conflictive context, the search for new approaches to water management and use triggered the start of wastewater reuse in the region, even though it remains a very limited use.The Guadiana River Basin Management Plan (CHG 2016) states that, “in the deficit areas, and especially in the Upper Guadiana Subsystem, water reuse will exclusively be allowed to substitute irrigation or industrial water rights”. That is, that water reuse should be a relief to the existing abstraction, and not a net increase in the water offer.

Still, even if the potential for wastewater reuse is small in the area, some initiatives have emerged. The most important one is the case of Los Auriles, a wastewater user association, located in the municipality of Tomelloso, that reuses reclaimed water for irrigating 800 hectares of vineyards. This alternative water source has at least three clear advantages:

i. The reclaimed water allotment is 1500 m3/ha, and this amount has not been reduced even if for groundwater users the water allotment was reduced from 1500 m3/ha to 1400m3/ha in 2020 and 1350 m3/ha in 2021.
ii. Nutrient concentration in reclaimed water (mainly phosphorus and nitrogen) reduces crop fertilization needs in the field.
iii. Treated water is continuously produced, so farmers need not worry about droughts or water shortages.

The potential advantages of reclaimed water reuse call for an in depth assessment of the potential contribution of reclaimed water reuse for irrigation in agriculture to help alleviate groundwater overexploitation and to improve efficiency in water management and use in this conflicting region.

The Mancha Occidental aquifer can be split into two subregions within the model area: Mancha I and Mancha II. Various details of the two subregions, representing 44% and 56% of the model area, respectively, can be found in Table 2below.

Table 2. Basic data for the two subregions of the Mancha Occidental aquifer. Source: Own elaboration based on CHG (2021).

	Available groundwater resources (hm3/year)	**Water extraction permits (hm3/year)**	**Exploitation index**	**Balance (hm3/year)**	**Population(inhabitants)**	**Irrigated area (ha)**
Mancha Occidental I	91.2	327.39	3.59	-236.19	80,024	83,564
Mancha Occidental II	106.2	337.53	3.18	-231.33	109,891	90,000

3 METHODOLOGY

Integrated biophysical and economic models have been largely used to analyze interactions between water and agricultural systems and to assess the impacts of climate and socio-economic scenarios.In this paper, we use a modular hydro-economic model based on the integration of a hydrologic simulation model, Water Evaluation and Planning (WEAP), and an economic optimization model, written using the General Algebraic Modeling System (GAMS).

Previous studies have developed integration approaches based on WEAP combining it with different types of socioeconomic models (e.g. Purkey et al. (2008) combine WEAP with econometric methods; Kemp-Benedict et al. (2010), combine WEAP with Knowledge Elicitation Tools (KnETs)). In this research, we follow the approach adopted by Varela-Ortega et al. (2011), Blanco-Gutiérrez et al. (2013) and Esteve et al. (2015) that link WEAP with farm-based economic mathematical programming models (MPM)for the simulation and optimization of conventional surface and groundwater-supplied irrigation systems. Hence, we propose an advanced integrated framework that integrates WEAP and farm-based mathematical programming economic model to study reclaimed water management and use for agricultural irrigation, as a key alternative water resource that may contribute to alleviate water conflicts in water-scarce basins.

3.1 Economic Model

Farm-basedeconomic models have been widely applied in the analysis of agricultural management of resources and crop decision-making (Graveline, 2016). In this research we apply a non-linear, risk-based, single-year mathematical programming model that represents farmers' decision-making at the farm system scale, under a set of constraints including agronomic, economic, resource (water and land) and policy-driven (e.g. water allotments). The proposed model simulates farmers' behavior to identify optimal cropping patterns and agricultural techniques, and resource use, providing indicators on water consumption, labor use, land use changes and farm revenue.

The objective function [1] maximizes farmer's utility (U). This utility is defined as the farm's expected revenue (Z) and a risk component, in which *Æ*is the farmer's risk aversion coefficient and *Ã(Z)* is the Standard deviation of farm's revenue due to naturevariability (yield) and market variability (price).

$$MaxU = Z_p - \phi \times \sigma(Z_p) \quad [1]$$

where, U is the utility to be maximized, Z_p is the expected revenue (€) of farming system p, ϕ is the risk aversion coefficient, andσ is the standard deviation of the expected revenue (€).

The farm revenue per farm type, Z_p, is defined as the difference between the value of production (product sold for final consumption or processed) and variable and fixed costs. It is defined by the following equation:

$$Z_p = \sum_{c,i,q} Pr_c \times Y_{c,q} \times X_{c,i,q,p} - \left(Vcost_c \times X_{c,i,q,p}\right) - Fcost_p - \sum_q \left(PrWat_q \times QWAT_{q,p}\right) - \sum_q \left(TarWat_q \times Irrland_{q,p}\right) \quad [2]$$

where, c is crop type, q is water source, i is irrigation technique, $X_{c,i,q,p}$ is crop activity level (ha), Pr_c is average crop price (€/ql), $Y_{c,q}$ is crop yield (ql/ha), $Vcost_c$ are variable costs (€/ha), $Fcost_p$are fixed costs (€),, $PrWat_q$ is water tariff per m^3 by water source, $QWAT_{q,p}$ is annual water use (m3) by water source, $TarWat_q$ is water tariff per ha by water source, and $Irrland_{q,p}$ is irrigated land (ha) by water source.

Variable costs, include temporary labor and machinery use, seeds, fertilizers and pesticides, fuel, insurance, and electricity. Costs of irrigation water are calculated as the volume of water used multiplied by the price of water per cubic meter for each type of water, and/or a fixed water tariff to be paid per hectare of irrigable land.

The standard deviation of farm revenue is calculated by equation [3]:

$$\sigma(Z) = \sqrt{\sum_k \frac{\left(Z - ZK_{sn,sm}\right)^2}{N}} \quad [3]$$

where, ZK is random income (€), N is the number of states of nature for price/yield variability ($N = 50$), Z is expected farm income (€), sn is the state of nature, and sm is the state of the market.

Water use, $QWAT_{q,p}$ is defined as follows:

$$QWAT_{q,p} = \sum_{c,i} \left(\frac{NIR_c}{htech_{i,p}} \right) \times X_{c,i,q,p} \qquad [4]$$

where, NIR_c is net irrigation requirement by crop type (m^3/ha), $htech_{i,p}$ is technical efficiency of the irrigation system.

Farmers' utility maximization is constrained by a number of factors such as quantity and quality land and water, as well as by water policies. The land constraint is defined by equation [6]:

$$\sum_{c,i,q} X_{c,i,q,p} \leq Land_p \qquad [5]$$

where, $Land_p$ is agricultural land availability for each farming system (ha). The total land constraint asserts that the set of crops grown, including uncultivated land and no-tillage, does not exceed the available land.

The water constraint [7] asserts that the sum of the water requirement for irrigated crops over the year cannot exceed the yearly water availability per type of water:

$$QWAT_{q,p} \leq WATav_{q,p} \qquad [6]$$

where, $WATav_{q,p}$ is water availability (m^3) per type of water source.

Crop decisions based on the economic model are then input into the hydrologic model to determine the effects on water stress in the region.Then, water availability and climate impacts (e.g., yields) based on the hydrology model are input into the economic model.

3.2 Hydrologic Model (WEAP)

The overarching objective is to model the two hydrologic catchments of Mancha I and II using the Water Evaluation and Planning System (WEAP) software, and evaluate water availability for various demands including environmental requirements under different scenarios of climate change and management options (i.e., wastewater reuse) (Sieber and Purkey, 2015).The Upper Guadiana Basin WEAP Model is a monthly time-step model that incorporates groundwater and treated wastewater quantities, root zone processes, and a representation of the reservoir and irrigation system within the watershed. The model is calibrated over the historical period 2000 to 2015.The following section describes the input data and assumptions behind the model development for the historical period.

The model includes local tributaries of the Guadiana River fitting the following criteria: 1) sources of supply for any demand site in the region, 2) those that receive outflow from wastewater treatment plants (WWTP), 3) those that connect and interact with tributaries that meet the previous criteria, and 4) a river branch without human influence for calibration purposes. These criteria resulted in a selection of 8 tributaries feeding into the main river: Ciguela, Cañada de la Urraca, Córcoles. Azuer, Valdecañas, Amarguillo, Záncara, and Guadiana.For the historical scenario, headflows are input from gauge data available during the historical period, except for Cañada de la Urraca and 'Rio Valdecañas', where data were not available and headflows are calculated manually using the curve number method and the expression of hourly rainfall intensity of the road drainage standard (CEDEX, 2022).

As indicated in the following descriptions of irrigation and municipal demands, and groundwater use, the hydrologic model is generally represented at the municipal and other subregional scale. Specifically, municipalities with a wastewater treatment plant with potential for reuse are represented individually, while all other municipalities are assigned the subregional aggregation of either Mancha I or Mancha I, or split evenly between the two (Table 3). The municipalities that are represented individually are Alcázar de San Juan and Campo de Criptana (ASJ_CC), Almagro and Bolaños de Calatrava (AB), Argamasilla de Alba (AMDA), Daimiel (DLM), Herencia (HRA), Manzanares and Membrilla (MMB), Socuellamos (SCM), Tomelloso (TMS), and Villarrubia de los Ojos (VRDO).

Table 3. Spatial designations for hydrologic modeling.

	Municipalities
Mancha I	Fernán Caballero, Fuente el Fresno, Las Labores, Malagón, Miguelturra, Puerto Lápice, San Clemente, Torralba de Calatrava, Valdepeñas, Villarta de San Juan, and AB, DLM, HRA, MMB, and VRDO
Mancha II	Arenas de San Juan, El Pedernoso, El Provencio, La Solana, Las Mesas, Las Pedroñeras, Mota del Cuervo, Pedro Muñoz, San Carlos del Valle, Villarrobledo, and ASJ_CC, AMDA, SCM, and TMS
Mancha I and II	Alhambra, Carrión de Calatrava

Simulation of the irrigation demand is done using a native catchment process simulation to WEAP that determines evapotranspiration, runoff, and infiltration based on crop and climate parameters (Sieber and Purkey, 2015).Simulation of non-irrigated vegetative demands, including rainfed agriculture, forest, grass, and semi-natural land, is done at the other subregional scale using WEAP's soil-moisture method to calculate rainfall-runoff, which represents the root zone with two buckets (Sieber and Purkey, 2015).Non-vegetativewater demands in the system are represented at the municipal scale. Specifically, municipal demands are calculated using a per capita annual water use rate of 48.5 m^3/person, which is then multiplied by the population and divided over the year according to the number of days in each month. Municipal demands are taken from the groundwater system, described below. A return flow of 80% is assumed, which can be routed either to irrigation using treated wastewater or, in the case of historical use, back to the river. Finally, the Tablas de Daimiel wetland requires 12,222 m^3 of water per hectare with an extent of 1,800 ha, resulting in a total annual requirement of 22 Hm^3, divided over the year according to the number of days in each month (Varela-Ortega et al., 2011). The wetland demand is taken directly from the river.

Groundwater is represented using a bucket system separated into the two subregions mentioned earlier: Mancha I and Mancha II.All demands in the system except rainfed and wetlands are taken from the two groundwater buckets. All infiltration excess from irrigated and rainfed vegetation is routed to the two groundwater buckets according to Table 3. In the future scenarios described below, any wastewater reuse is applied in lieu of groundwater use, resulting in a net zero change in total water use.

Climatic data is taken from seven meteorological stations in the model area that are part of the SIAR network (http://www.siar.es). The variables utilized in the model are precipitation (p_mm), minimum temperature (tma), maximum temperature (tma), dew point, minimum humidity (hrmin), maximum humidity (hrmax), wind speed(v), and solar radiation (RS_MJ/m2). Data is averaged between those stations within Mancha I and Mancha II, respectively, and applied to the appropriate municipalities.CO2 is used to calculate the effect on stomatal conductance, leaf area, and radiation use efficiency; the constant value of 410 ppm is used for all municipalities in the model.

4 EXPECTED RESULTS

We will evaluate the quantity of groundwater abstraction averted, area of crops irrigated with reclaimed water, impact on farmers' income, and streamflow available for environmental uses under the combined climate and management scenarios. Such evaluations are subject to reclaimed water availability and groundwater pumping restrictions determined for drought conditions. Our results will provide valuable insights on economic and environmental implications of reclaimed water reuse, and can support responsible decision and policy options to maximize the uptake of such alternatives for integrated and sustainable water resource management in semi-arid regions.

Analysis will include representation of water use source by crop type and municipality, as well as comparison of water availability for different uses under the various scenarios. Particularly, the integrated modelling framework will be used to evaluate supply side and demand side water management policies under different socio-economic and climate scenarios (Table 4).

Table 4. Scenario setup and expected simulation results.

Scenarios	Patterns of change	Representation	Expected impacts
Climate scenarios	Current climate	2000-2015	Decreased inflows
	Moderate climate change	RCP4.5	Decreased inflows, lower yields
	Severe climate change	RCP8.5	Decreased inflows, lower yields, environmental flows at risk
Socio-economic scenarios	Current trends	Moderate population decrease by 2050	Decline of urban water demand Decline of treated wastewater flows
	Economy first	Population increase by 2050	Increase of urban water demand, increase of treated wastewater flows
	Environment first	Strong population decrease by 2050	Strong decline of urban water demand, strong decline of treated wastewater flows
Water-supply scenarios	Current trends	No reclaimed water use	Overexploitation of the aquifer, limited farmer income
	Water reuse	Reclaimed water reuse up to total treated quantity	Lower overexploitation of the aquifer, increased farmer income (fertilizer savings), unprotected environmental flows
	Limited water reuse	Reclaimed water reuse limited to respect ecological flows	Win-win solution (lower overexploitation of the aquifer, increased farmer income, protected environmental flows)
	Diversification of water sources	Mix of different water sources (groundwater + water reuse)	Overexploitation of the aquifer, maximum gain from fertilizer savings& absence of salinity problems)
Water-demand scenarios	Current trends	Water quotas aimed at resource saving (GW and reclaimed water)	Social unrest
		Reclaimed water is partly subsidized	Full cost not recovered
	Cost recovery through water pricing	Reclaimed water is no longer subsidized	Full cost recovery, viability of small farms challenged

5 CONCLUSIONS

This research contributes to Integrated Water Resource Management (IWRM) by addressing the role of all different water sources, with a specific focus on reclaimed water reuse, and by considering different interrelated processesthat take place at crop, farm and sub-basin levels.The integrated modelling approach that has been applied can support water management decision-making, especially when addressing confronting goals such as the protection of watercourses and ecosystems while ensuring rural socio-economic development through irrigation agriculture.

The developed hydro-economic modelling framework allows reflectionon the interconnectedness of hydrologic, agronomicand socio-economic dimensions, and allows the consideration of new strategies involving unconventional water resources, such a reclaimed water reuse.

The economicmodel explains farmers' behavior and water demand, and deliversan improved understanding on the impact of circular economy and water management policies,providing economic indicators. TheWEAP hydrology model represents the supply side of water management and it is crucial for understanding the physical context andspatial dimensions of water resources and climate.

Although unconventional resources such as reclaimed water may represent a small part of the available resources, their exploitation may present advantages and contribute to a more efficient use of water resources as well as nutrients. Even if it is not very relevant in quantitative terms, reclaimed water reuse can contribute to increasing supply security and farm income, and adapts very well to certain farming systems in the La Mancha Occidental aquifer.

6 ACKNOWLEDGEMENTS

This work was supported by the Spanish Ministry of Science and Innovation, State Research Agency, as part of the National Plan for Scientific and Technical Research and Innovation 2017–2020. Project R&D&i - Challenges 2019: The contribution of water REuse to a resourCe-efficient and sustainabLe wAter manageMent for irrigatiOn (RECLAMO) [grant number PID2019-104340RA-I00].

7 REFERENCES

Beveridge R, Moss T, Naumann M, et al. (2017) A socio-spatial understanding of water politics: Tracing topologies of water reuse. *Water Alternatives*, 10(1), 22-40.

Blanco-Gutiérrez, I., Varela-Ortega, C., Purkey, D.R., 2013. Integrated assessment of policyinterventions for promoting sustainable irrigation in semi-arid environments: ahydro-economic modeling approach. *Journal of Environmental Management*128, 144–160.

Bolinches, A., Blanco-Gutiérrez, I., Zubelzu, S., Esteve, P., Gómez-Ramos, A. (2022). A method for the prioritization of water reuse projects in agriculture irrigation. *Agricultural Water Management* 263, 170435 doi:10.1016/j.agwat.2021.107435.

Centro de Estudios Hidrográficos (CEDEX). (2022). Anuario de aforos (Streamflow guage yearbook). https://ceh.cedex.es/anuarioaforos/default.asp

CHG (2016). Plan Hidrológico del segunndo ciclo de planificación: 2015–2021. (Available at: https://www.chguadiana.es/planificacion/plan-hidrologico-de-la-demarcacion/plan-hidrologico-2015-2021)

CHG (2021). Anejo 3. Inventario de recursos hídricos. Plan Hidrológico del tercer ciclo de planificación: 2022–2027. Anejos a la Memoria. (Available at: https://www.chguadiana.es/sites/default/files/2021-06/A03_Inv_Recursos.pdf)

Deloitte (2015) Optimising water reuse in the EU – Public consultation analysis report prepared for the European Commission (DG ENV). Part I. In collaboration with ICF and Cranfield University. Luxembourg.

EEA (European Environmental Agency) (2018).European waters. Assessment of status and pressures 2018. ISBN: 978-92-9213-947-6.

Esteve, P., Varela-Ortega, C., Blanco-Gutiérrez, I., Downing, T.E. ,2015. A hydro-economic model for the assessment of climate change impacts and adaptation in irrigated agriculture. *Ecological Economics* 120, 49-58.

Gil-Meseguer E, Bernabé-Crespo MB, Gómez-Espín JM (2018) Recycled Sewage – A Water Resource for Dry Regions of Southeastern Spain. *Water Resources Management* 33 (2), 725 737. https://doi.org/10.1007/s11269-018-2136-9

Graveline N., 2016. Economic calibrated models for water allocations in agricultural production: A review. *Environmental Modelling and Software* 81, 12-25.

INE (2018) Estadística sobre el suministro y saneamiento del agua. Serie 2000-2016. Instituto Nacional de Estadística. Madrid, Spain.

Kemp-Benedict, E.J., Bharwani, S., Fischer, M.D., 2010. Methods for linking social andphysical analysis for sustainability planning. *Ecology and Society* 15 (3), 4.

Pieri, P., & Gaudillère, J.P. (2015). Sensitivity to training system parameters and soil surface albedo of solar radiation intercepted by vine rows. *Vitis:Journal of Grapevine Research*, 42, 77-82.

Piggin, I., and Schwerdtfeger, P. (1973). Variations in the albedo of wheat and barley crops. *Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie B*, 21, 365-391.

Purkey, D., Joyce, B., Vicuna, S., Hanemann, M.W., Dale, L.L., Yates, D., Dracup, J.A.,2008. Robust analysis of future climate change impacts on water for agricultureand other sectors: a case study in the Sacramento Valley. Climate Change 87,109e122.

Salgot M, Folch M (2018) Wastewater treatment and water reuse. *Current opinion in Environmental Science and Health*, 2, 64-74. https://doi.org/10.1016/j.coesh.2018.03.005

• erban, G., Cotfas, D.T., and Cotfas, P.A. (2011). Significant differences in crop albedo among romanian winter wheat cultivars. *Romanian Agricultural Research*, 11-15.

Sieber, J., and Purkey, D. (2015). User Guide for WEAP 2015 (WEAP: Water Evaluation and Planning System). Stockholm Environmental Institute (SEI). http://www.weap21.org/WebHelp/index.html

Smith HM, Brouwer S, Jeffrey P, Frijns J (2017) Public responses to water reuse - Understanding the evidence. *Journal of Environmental Management*, 207, 43-50. https://doi.org/10.1016/j.jenvman.2017.11.021

Sociedad Española de la Ciencia del Suelo (SECS). (2013). Suelos representativos de España (Representative soils of Spain). https://www.secs.com.es/suelos-representativos/

Sütterlin, M., Stöckli, R., Schaaf, C.B., & Wunderle, S. (2016). Albedo climatology for European land surfaces retrieved from AVHRR data (1990–2014) and its spatial and temporal analysis from green-up to vegetation senescence. *Journal of Geophysical Research: Atmospheres*, 121, 8156-8171.

Varela-Ortega, C., Blanco-Gutiérrez, I., Swartz, H.S., & Downing, T.E., 2011. Balancing groundwater conservation and rural livelihoods under water and climate uncertainties: a hydro-economic modeling framework. *Global Environmental Change*, 21, 604–619.

Voulvoulis N (2018) Water reuse from a circular economy perspective and potential risks from an unregulated approach. *Current Opinion in Environmental Science & Health*, 2, 32–45.

