HOLISTIC APPROACH TO THE ECONOMIC BENEFITS OF USING RECLAIMED WATER IN AGRICULTURE

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ABSTRACT

Implementing water alternatives to ensure its supply is crucial in a worldwide context where water scarcity is a daily problem that is anticipated to intensify in the upcoming years. In this context, reclaimed water has proved to be a viable option for ensuring water availability for such a water-demanding and critical sector as agriculture is. Nevertheless, its use is too often seen as a last-resource alternative desired mainly by farmers facing water scarcity or a lack of water alternatives. Despite the pressing need to look for reasons that justify the profitability of its implementation over other water alternatives, and in light of there being gap research when analyzing all the benefits of using reclaimed water from a holistic economic approach, the overall objective of this study is to evaluate the economic impact generated by the use of tertiary water in agriculture to irrigate crops. To reach this ambitious objective, the economic value of a large list of positive externalities derived from the implementation of reclaimed water in agriculture is going to be calculated. Some of the aspects that are going to be evaluated are: its fertilizer value affecting crop productivity, soil quality and plant growth and its capacity of being a source of organic carbon. Furthermore, these others relevant aspects that too often go unnoticed due to the difficulty in their measurement are going to be evaluated: its contribution to protect water bodies and promote water resources quality and recovery, its capacity of enhancing and boosting marine ecosystem services and its leverage effect in promoting agriculture in new areas and in fostering different crop varieties in other areas where, because of salinity levels or water scarcity, only some crop varieties may be grown. Results will show through economic data and results the urge of implementing reclaimed water in agriculture worldwide.

Keywords: water reuse, reclaimed water, sustainability, circular economy, agricultural water contamination, wastewater management.

1 INTRODUCTION

Even distribution of a finite resource like water is today a serious concern, given that over 4 billion people experience severe water scarcity for at least a month each year [1], [2]. In light of this, agriculture's importance should be highlighted, as it is the world's largest water consumer, consuming up to 90% of total water supplies in some areas and predicted to worsen in many others [3]–[7]. Agriculture is also critical in terms of climate change, which is one of the greatest threats to both humans and the environment, because, in addition to its high vulnerability due to extreme and unpredictable weather conditions that exacerbate water scarcity, agriculture contributes up to 14% of global greenhouse gas emissions. [8]–[12]. Considering this, and because of the natural relationship between water and land use, agriculture plays a critical part in the worldwide job of ensuring sustainable water supply [13]–[16]. The quest for the implementation of a successful, long-lasting, and sustainable water source to irrigate crops is critical to agriculture satisfying the need of an ever-growing population [17]. This irrigation option should also be capable of ensuring economic, environmental, and social development [18]. To combat this alarming scenario, tertiary water use has been bolstered in recent decades, and even more so in recent years, as it is a resource that, in addition to being apparently inexpensive, helps to preserve important water supplies when utilized for irrigation [19], [20]. Another aspect of using treated wastewater to irrigate

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crops in agriculture that merits special attention due to its importance and potential is its contribution to the circular economy (CE), as the treatment process facilitates the transformation of wastewater from waste to resource through reuse and recycling. [21], [22]. Even though it is becoming more frequently used due to its well-documented environmental, social, and economic benefits, reclaimed water irrigation is still at a low level due to a lack of social acceptance [23]–[25].

2 AREA OF STUDY

Because of its representativeness, the current study was conducted in the province of Almeria, which is a Mediterranean region in southeastern Spain. This area, shown in Fig. 1, is a semi-arid terrain with significant solar radiation due to its low annual rainfall of less than 200m and a mean annual temperature of 18°C [26]. Furthermore, irrigation water availability influences productivity and is one of the key limiting factors in one of Europe's driest regions [27], [28]. This region is well-known for its important agricultural role, having the world's highest concentration of greenhouses and being the largest exporter of fruits and vegetables in the European Union [29]–[32]. Due to localized irrigation, automated fertigation, and the use of tensiometers, the system used to irrigate crops in the region has undergone a significant upgrade in recent years, all of which have improved the efficiency of the water in the area [30]. Irrigated regions are split geographically into irrigation villages, each of which has its own water source. This semi-arid region needs special attention since its case study can be applied to other countries in comparable situations, particularly those with arid and semi-arid climates and water resource constraints [33]–[37]. The province is divided into six primary sub-areas, two of which hold more than 77% of the province's greenhouse gas concentration [38]. These two areas, Campo de Dalias and Bajo Andarax (which includes Almeria City), are crucial to this research because in Campo de Dalias tertiary water is not used for irrigation because the main water resource is groundwater, whereas in Bajo Andarax, treated

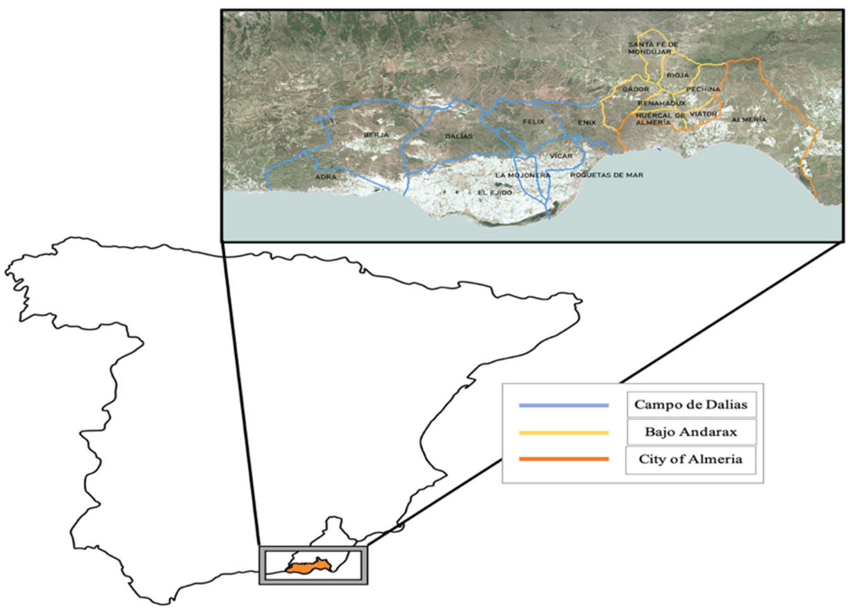

Figure 1: Area of study.

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wastewater has been used for irrigation since 1997 [39]. These singularities make the area ideal for a comparison of the consequences of using reclaimed water for more than 20 years with others where it has never been used before.

After previous analyses in many geographical points, two farm plots with very similar soil structure, nearly identical level of precipitation and average temperatures have been chosen for this research. These two chosen farm plots are not adjacent because water filtration of both water sources may bias the results of the aspects analyzed.

3 METHODOLOGY

All the benefits of using reclaimed water are going to be analyzed from a holistic economic approach with the main objective of evaluating the direct and indirect economic impact generated by the use of tertiary water in agriculture to irrigate crops.

The following aspects are going to be measured through different methodologies individually adapted for each one:

- Fertilizer capability: Soil levels of potassium (K), nitrogen (N) and phosphorus (P) are going to be analyzed in both samples. Results are going to be evaluated monetarily with the difference in terms of euros spent in fertilizer to reach ideal levels for crops growth by a non-user of reclaimed water farmer compared with a reclaimed water user since a great part of these costs are avoided by reclaimed water users because of the fertilizer capability of this water resource.
- Crop productivity: Kilograms of production per hectare are going to be measured in the same period of the year during 8 weeks within open season. In both farms is grown the same crop variety under same irrigation conditions in terms of quantity of water used to irrigate. Then, medium prices at which the product grown have been sold during crop season are going to be used to know in economic terms how differences in crop productivity influences farmers' profits.
- Soil quality: Two analyses in each farm are going to be carried out to evaluate the soil quality (macro and micronutrients and soil microbial communities) after being exposed during a long period of time to different water sources. The economic value will be measured using the results of the reclaimed water farm analyses and calculating how much would it cost to buy everything needed to reach the same levels for the other plot.
- Plant growth: Volumes and mass from plants grown from the same variety of seeds are going to be measured. Formation of new structures such as cells, organs or tissues are also going to be considered. Last but not least, plant development (directly related to cell and tissue specialization) and reproduction (understood as the production of new individuals) are also going to be taken into account. The economic value will be measured using the results of the reclaimed water farm analyses and calculating how much would it cost to reach same plant growth levels for the other plot.
- Source of organic matter: It is a viable and valuable source of organic carbon for soils because it provides energy to join soil particles into aggregates, promoting plant growth and enhancing soil stability. Furthermore, the organic matter also increases the good aeration of the soil and water infiltration which may not only reduce, but also even prevent a flood in the farm in case a heavy rainfall happens. Samples from both farm plots are going to be analyzed and differences between them in terms of organic matter are going to be economically measured using the market price of organic matter.
- Contribution to protect water bodies and capacity of enhancing and boosting marine ecosystem services: These two positive aspects derived from the use of reclaimed water in agriculture are inextricably linked. Treating wastewater and channeling it into new

water resources avoid sea dumping thus protecting water bodies and marine ecosystem services by reducing the amount of pollutants spilled into the sea that pollutes the underwater flora and fauna. Furthermore, as the use of reclaimed water reduces the use of fertilizers, water pollution caused by fertilizers would also be reduced. Methodologies used will be:

- Chromophoric dissolved organic matter (CDOM) monitoring: As while it is being discomposing it releases tannin which reduces the pH of the water and depletes the oxygen levels.
- Conductivity, salinity and total dissolved solids (TDS) monitoring to see if levels may jeopardize marine ecosystem services.
- Chlorophyll fluorescence analysis: As phosphorus and nitrogen (both fertilizers used in agriculture) may lead into an uncontrolled growth of algae which results in oxygen depletion at levels that may be toxic to the fauna and flora.
- Biochemical oxygen demand test to see how much sewage is found in the water by counting decomposer bacteria in the water.

Using a sample of water from an area where wastewater is dumped, the economic evaluation will be done calculating the cost of cleaning and purifying the water analyzed artificially until reaching same levels as in the non-polluted water sample.

- Promote water resources quality and recovery: When wastewater is properly treated and used for the irrigation of agricultural crops it enhances water bodies recovery since using reclaimed water means that pressure put under already overexploited wells or aquifers will be reduced so there will be a higher chance of its regeneration. Furthermore, reclaimed water will help in the improvement of the quality of water resources since reducing the level of water extraction would reduce salinity and conductivity. As if local wells or aquifers had enough quantity of quality water transfers from other water alternatives would not be necessary, using reclaimed water would avoid the cost of distribution channels from other locations and the energy cost so this is how the economic value of the reclaimed water in promoting water resources quality and recovery will be calculated.
- Promoting agriculture: The area of study, where agriculture has an important value in terms of the contribution to the total revenues will be compared with another geographical location with very similar area (km^2), soil structure and climatic conditions (temperature, humidity, and rainfall) but with a high scarcity of water resources which impede the implementation of the agricultural sector. Then, the economic value generated in the area by the agriculture sector using reclaimed water to irrigate crops would be compared with the scenario without tertiary water.
- Escherichia coli control: Since wastewater is a possible source of some bacteria as Escherichia coli, different concentrations of this bacteria are going to be measured in samples of treated wastewater with the minimum conditions required by European legislation for sea dumping and treated wastewater after minimum conditions needed for its use to irrigate agricultural crops. Differences in the cost of the two treatments are going to be used to see how the farmer ends up bearing the total cost of a process that if it was not done for irrigation of his crops should be covered by the government to comply with the regulations.

Furthermore, for this research reclaimed water samples will be compared with different of surface water samples from rivers which are surrounded by industries, and which are used to irrigate adjacent crops.

4 HIGHLY PREDICTABLE RESULTS

Although this study is getting going and the time to fully carry out the research will take years in order to guarantee different sampling periods under different weather conditions to avoid a bias in the results, using already existing research about some of the parameters here studied some results may be predicted with some certainty. Reclaimed water capacity of being a source of organic matter (OM) is expected to almost triple the initial samples parameters after being irrigated with reclaimed water while values of soil samples after being irrigated with well water are predicted to remain stable without relevant variations or even certain decreases in the OM concentration [40]–[42]. Conversely, another of the many benefits derived from the implementation of tertiary water to irrigate crops directly that is expected to be shown in this study is a great increase in the growth of the crops, which affects the growing process potentiating the growth in the yields of some crop varieties up to 61% [43]. Productivity also goes through relevant variations since the implementation of reclaimed water to irrigate crops may double crop production in terms of kilograms produced by the same crop variety during the same period and under same external conditions [44], [45]. Last but not least, important reductions in the use of fertilizers are expected since previous research in the area of study proved a decrease in amount of nitrogen (N) needed up to 60%, in the amount of phosphorus (P) up to 80% and in the amount potassium (K) up to 25% using as a reference the total quantities of fertilizers needed to provide crops the optimum amount to peak performance [46]–[49]. Despite that the parameters mentioned before have already been studied in other previous research, our thorough methodology will refine existing data within the same area of study so all the data can be used to study interconnections and direct relationships. Moreover, after this research different economic values will be assigned for each positive aspect derived from the use of reclaimed water in agriculture to irrigate crops which since it has not been done before it will strengthen with real and comparable data the value of such a sustainable alternative as reclaimed water is. Furthermore, there are other aspects that are going to be studied in this research for the first time ever since they have not been considered before. This make our research groundbreaking as some parameters as reclaimed water capacity of boosting marine ecosystem or its contribution on controlling e.coli concentration and distribution might show for the first time and with certain confidence the relevancy of the economic benefits derived from all the benefits of using reclaimed water to irrigate crops. Furthermore, as this research will show economic and therefore quantifiable results, all the stakeholders will take part in the boosting of the implementation of this alternative water resource in agriculture. At last, results from surface water samples might show how while this water can be used to irrigate crops without any minimum requirements or parameters and its use is widely accepted by farmers and consumers, levels of pollution are potentially way higher than in treated wastewater while farmers and consumers tend to undervalue it rejecting its use in agriculture because of the yuck factor and wrong beliefs. Feedback from highly experienced researchers after the Air and Water Pollution 2022 Conference is also a great opportunity that would provide significant added value to this research since all the suggested improvements given will be considered.

REFERENCES

[1] UNESCO World Water Assessment Programme (WWAP), The United Nations World Water Development Report 2019: Leaving no one behind. UNESCO: Paris, 2019.

[2] Deviller, G., Lundy, L. & Fatta-Kassinos, D., Recommendations to derive quality standards for chemical pollutants in reclaimed water intended for reuse in agricultural irrigation. *Chemosphere*, **240**, 2020. DOI: 10.1016/j.chemosphere.2019.124911.

[3] Becerra-Castro, C., Lopes, A.R., Vaz-Moreira, I., Silva, E.F., Manaia, C.M. & Nunes, O.C., Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. *Environment International*, **75**, pp. 117–135, 2015. DOI: 10.1016/j.envint.2014.11.001.
[4] Martínez-Alvarez, V., Maestre-Valero, J.F., González-Ortega, M.J., Gallego-Elvira, B. & Martin-Gorriz, B., Characterization of the agricultural supply of desalinated seawater in Southeastern Spain. *Water (Switzerland)*, **11**, 2019. DOI: 10.3390/w11061233.
[5] Contreras, J.I., Roldán-Cañas, J., Moreno-Pérez, M.F., Gavilán, P., Lozano, D. & Baeza, R., Distribution uniformity in intensive horticultural systems of Almería and influence of the production system and water quality. *Water (Switzerland)*, **13**, pp. 1–15, 2021. DOI: 10.3390/w13020233.
[6] Wang, X., Müller, C., Elliot, J., Mueller, N.D., Ciais, P., Jägermeyr, J., Gerber, J., Dumas, P., Wang, C., Yang, H., Li, L., Deryng, D., Folberth, C., Liu, W., Makowski, D., Olin, S., Pugh, T.A.M., Reddy, A., Schmid, E., Jeong, S., Zhou, F. & Piao, S., Global irrigation contribution to wheat and maize yield. *Nature Communications*, **12**, pp. 1–8, 2021. DOI: 10.1038/s41467-021-21498-5.
[7] Kourgialas, N.N., A critical review of water resources in Greece: The key role of agricultural adaptation to climate-water effects. *Science of the Total Environment*, **775**, 145857, 2021. DOI: 10.1016/j.scitotenv.2021.145857.
[8] Melián-Navarro, A. & Ruiz-Canales, A., Evaluation in carbon dioxide equivalent and chg emissions for water and energy management in water users associations: A case study in the southeast of Spain. *Water (Switzerland)*, **12**, 2020. DOI: 10.3390/w12123536.
[9] Ashu, A.B. & Lee, S.I., The effects of climate change on the reuse of agricultural drainage water in irrigation. *KSCE Journal of Civil Engineering*, **25**, pp. 1116–1129, 2021. DOI: 10.1007/s12205-021-0004-2.
[10] AL-Agele, H.A., Nackley, L. & Higgins, C.W., A pathway for sustainable agriculture. *Sustainability*, **13**, p. 4328, 2021. DOI: 10.3390/su13084328.
[11] Arellano-Gonzalez, J., Aghakouchak, A., Levy, M.C., Qin, Y., Burney, J., Davis, S.J. & Moore, F.C., The adaptive benefits of agricultural water markets in California. *Environmental Research Letter*, **16**, 2021. DOI: 10.1088/1748-9326/abde5b.
[12] Xin, Y. & Tao, F., Have the agricultural production systems in the North China Plain changed towards to climate smart agriculture since 2000? *Journal of Cleaner Production*, **299**, 126940, 2021. DOI: 10.1016/j.jclepro.2021.126940.
[13] Pretty, J. et al., The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, pp. 219–236, 2010. DOI: 10.3763/ijas.2010.0534.
[14] Hoang, L.T., Roshetko, J.M., Huu, T.P., Pagella, T. & Mai, P.N., Agroforestry: The most resilient farming system for the hilly northwest of Vietnam. *International Journal of Agriculture System*, **5**, p. 1, 2017. DOI: 10.20956/ijas.v5i1.1166.
[15] Cabello Villarejo, V. & Madrid Lopez, C., Water use in arid rural systems and the integration of water and agricultural policies in Europe: The case of Andarax river basin. *Environment, Development and Sustainability*, **16**, pp. 957–975, 2014. DOI: 10.1007/s10668-014-9535-8.
[16] Runhaar, H., Four critical conditions for agroecological transitions in Europe. *International Journal of Agricultural Sustainability*, **19**, pp. 227–233, 2021. DOI: 10.1080/14735903.2021.1906055.

[17] Fields, C.M., Labadie, J.W., Rohmat, F.I.W. & Johnson, L.E., Geospatial decision support system for ameliorating adverse impacts of irrigated agriculture on aquatic ecosystems. *Agricultural Water Management*, **252**, 106877, 2021. DOI: 10.1016/j.agwat.2021.106877.

[18] Hristov, J., Barreiro-Hurle, J., Salputra, G., Blanco, M. & Witzke, P., Reuse of treated water in European agriculture: Potential to address water scarcity under climate change. *Agricultural Water Management*, **251**, 106872, 2021. DOI: 10.1016/j.agwat.2021.106872.

[19] Tociu, C., Ciobotaru, I.E., Maria, C., Déak, G., Ivanov, A.A., Marcu, E., Marinescu, F., Savin, I. & Noor, N.M., Exhaustive approach to livestock wastewater treatment in irrigation purposes for a better acceptability by the public. *AIP Conference Proceedings*, p. 2129, 2019. DOI: 10.1063/1.5118074.

[20] Dhiman, J., Prasher, S.O., ElSayed, E., Patel, R.M., Nzediegwu, C. & Mawof, A., Heavy metal uptake by wastewater irrigated potato plants grown on contaminated soil treated with hydrogel based amendments. *Environmental Technology and Innovation*, **19**, 100952, 2020. DOI: 10.1016/j.eti.2020.100952.

[21] Morales, M.E. & Belmonte-Urena, L.J., Theoretical research on circular economy and sustainability trade-offs and synergies: A bibliometric analysis. *2021 IEEE International Conference on Technology and Entrepreneurship, ICTE 2021*, 2021. DOI: 10.1109/ICTE51655.2021.9584537.

[22] Preisner, M. et al., Indicators for resource recovery monitoring within the circular economy model implementation in the wastewater sector. *Journal of Environmental Management*, **304**, 2022. DOI: 10.1016/j.jenvman.2021.114261.

[23] Chhipi-Shrestha, G., Hewage, K. & Sadiq, R., Fit-for-purpose wastewater treatment: Testing to implementation of decision support tool (II). *Science of the Total Environment*, **607–608**, pp. 403–412, 2017. DOI: 10.1016/j.scitotenv.2017.06.268.

[24] Michetti, M., Raggi, M., Guerra, E. & Viaggi, D., Interpreting farmers' perceptions of risks and benefits concerning waste water reuse for irrigation: A case study in Emilia-Romagna (Italy). *Water (Switzerland)*, **11**, 2019. DOI: 10.3390/w11010108.

[25] Baawain, M.S., Al-Mamun, A., Omidvarborna, H., Al-Sabti, A. & Choudri, B.S., Public perceptions of reusing treated wastewater for urban and industrial applications: Challenges and opportunities. *Environment, Development and Sustainability*, **22**, pp. 1859–1871, 2022. DOI: 10.1007/s10668-018-0266-0.

[26] Toro Sánchez, F., El uso del agua en Nijar: implicaciones ambientales del modelo actual de gestión. *Revista de Estudios Regionales,* **7585**(83), pp. 145–176, 2008.

[27] Aznar-Sánchez, J.A., Belmonte-Ureña, L.J. & Valera, D.L., Perceptions and acceptance of desalinated seawater for irrigation: A case study in the Níjar district (southeast Spain). *Water (Switzerland)*, **9**, 2017. DOI: 10.3390/w9060408.

[28] Jiménez-Buendía, M., Soto-Valles, F., Blaya-Ros, P.J., Toledo-Moreo, A., Domingo-Miguel, R. & Torres-Sánchez, R., High-density wi-fi based sensor network for efficient irrigation management in precision agriculture. *Applied Sciences (Switzerland)*, **11**, pp. 1–20, 2021. DOI: 10.3390/app11041628.

[29] Egea, F.J., Torrente, R.G. & Aguilar, A., An efficient agro-industrial complex in Almería (Spain): Towards an integrated and sustainable bioeconomy model. *New Biotechnology*, **40**, pp. 103–112, 2018. DOI: 10.1016/j.nbt.2017.06.009.

[30] Aznar-Sánchez, J.A., Belmonte-Ureña, L.J., Velasco-Muñoz, J.F. & Valera, D.L., Farmers' profiles and behaviours toward desalinated seawater for irrigation: Insights from south-east Spain. *Journal of Cleaner Production*, **296**, 2021. DOI: 10.1016/j.jclepro.2021.126568.

www.witpress.com, ISSN 1743-3541 (on-line)

[31] Aznar-Sánchez, J.A., Belmonte-Ureña, L.J., Velasco-Muñoz, J.F. & Valera, D.L., Aquifer sustainability and the use of desalinated seawater for greenhouse irrigation in the Campo de Níjar, southeast Spain. *International Journal of Environmental Research and Public Health*, **16**, 2019. DOI: 10.3390/ijerph16050898.
[32] Lo-Iacono-Ferreira, V.G., Viñoles-Cebolla, R., Bastante-Ceca, M.J. & Capuz-Rizo, S.F., Transport of Spanish fruit and vegetables in cardboard boxes: A carbon footprint analysis. *Journal of Cleaner Production*, **244**, 2020. DOI: 10.1016/j.jclepro.2019.118784.
[33] Rodríguez Martín, J.A., Ramos-Miras, J.J., Boluda, R. & Gil, C., Spatial relations of heavy metals in arable and greenhouse soils of a Mediterranean environment region (Spain). *Geoderma*, **200–201**, pp. 180–188, 2013. DOI: 10.1016/j.geoderma.2013.02.014.
[34] Reca, J., Trillo, C., Sánchez, J.A., Martínez, J. & Valera, D., Optimization model for on-farm irrigation management of Mediterranean greenhouse crops using desalinated and saline water from different sources. *Agricultural Systems*, 166, pp. 173–183, 2018. DOI: 10.1016/j.agsy.2018.02.004.
[35] Honoré, M.N., Belmonte-Ureña, L.J., Navarro-Velasco, A. & Camacho-Ferre, F., Profit analysis of papaya crops under greenhouses as an alternative to traditional intensive horticulture in Southeast Spain. *International Journal of Environmental Research and Public Health*, **16**, 2019. DOI: 10.3390/ijerph16162908.
[36] Thompson, R.B., Padilla, F.M., Peña-Fleitas, M.T. & Gallardo, M., Reducing nitrate leaching losses from vegetable production in Mediterranean greenhouses. *Acta Horticulturae*, **1268**, pp. 105–117, 2020. DOI: 10.17660/ActaHortic.2020.1268.14.
[37] Cajamar, Análisis de la Campaña Hortofrutícola de Almería, Campaña 2019/2020, 2020. https://www.plataformatierra.es/detalle/analisis-campana-hortofruticola. Accessed on: 19 Jun. 2021.
[38] Consejería de Agricultura, Ganadería, Pesca y Desarrollo Sostenible de la Junta de Andalucía. Secretaría General de Agricultura y Alimentación. Cartografía de Invernaderos en Almería, Granada y Málaga, 2019. https://www.juntadeandalucia.es/export/drupaljda/producto_estadistica/19/06/Cartografia%20_inv_AL_GR_MA_190926.pdf. Accessed on: 19 Apr. 2021.
[39] Garcia-Caparros, P., Contreras, J.I., Baeza, R., Segura, M.L. & Lao, M.T., Integral management of irrigation water in intensive horticultural systems of Almería. *Sustainability (Switzerland)*, **9**, pp. 1–21, 2017. DOI: 10.3390/su9122271.
[40] Mohammad Rusan, M.J., Hinnawi, S. & Rousan, L., Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination*, **215**, pp. 143–152, 2007. DOI:10.1016/j.desal.2006.10.032.
[41] Yasmeen, T., Ali, Q., Islam, F., Noman, A., Akram, M.S. & Javed, M.T., Biologically treated wastewater fertigation induced growth and yield enhancement effects in Vigna radiata L. *Agricultural Water Management*, **146**, pp. 124–130, 2014. DOI: 10.1016/j.agwat.2014.07.025.
[42] Bernier, M.H., Levy, G.J., Fine, P. & Borisover, M., Organic matter composition in soils irrigated with treated wastewater: FT-IR spectroscopic analysis of bulk soil samples. *Geoderma*, **209–210**, pp. 233–240, 2013. DOI: 10.1016/j.geoderma.2013.06.017.
[43] Wang, Z., Li, J. & Li, Y., Using reclaimed water for agricultural and landscape irrigation in China: A review. *Irrigation and Drainage*, **66**, pp. 672–686, 2017. DOI: 10.1002/ird.2129.

[44] Paul, M., Negahban-Azar, M. & Shirmohammadi, A., Assessing crop water productivity under different irrigation scenarios in the mid-Atlantic region. *Water (Switzerland)*, **13**, 2021. DOI: 10.3390/w13131826.
[45] Palese, A.M., Pasquale, V., Celano, G., Figliuolo, G., Masi, S. & Xiloyannis, C., Irrigation of olive groves in southern Italy with treated municipal wastewater: Effects on microbiological quality of soil and fruits. *Agriculture, Ecosystems and Environment*, **129**, pp. 43–51, 2009. DOI: 10.1016/j.agee.2008.07.003.
[46] Athamenh, B.M., Salem, N.M., El-Zuraiqi, S.M., Suleiman, W. & Rusan, M.J., Combined land application of treated wastewater and biosolids enhances crop production and soil fertility. *Desalination and Water Treatment*, **53**, pp. 3283–3294, 2015. DOI: 10.1080/19443994.2014.933037.
[47] Mohammad Rusan, M.J., Hinnawi, S. & Rousan, L., Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination*, **215**, pp. 143–152, 2007. DOI: 10.1016/j.desal.2006.10.032.
[48] López-Serrano, M.J., Velasco-Muñoz, J.F., Aznar-Sánchez, J.A. & Román-Sánchez, I.M., Economic analysis of the use of reclaimed water in agriculture in southeastern Spain, a Mediterranean region. *Agronomy*, **11**, 2021. DOI: 10.3390/agronomy11112218.
[49] Segura Pérez, M.L., IFAPA, Centro La Mojonera. Jornada de presentación de las actividades de Investigación y Trasnferencia relacionadas con la Reutilización de Aguas Regeneradas en Cultivo de Pimiento. Proyecto INIA. RTA2006-00032-00-00, Almería, 2010.

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