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Editorial

The Use and Management of Agricultural Irrigation Systems and Technologies

Gerard Arbat [1,*] and Daniele Masseroni [2]

1 Department of Chemical and Agricultural Engineering and Technology, University of Girona, C/de Maria, Aurèlia Capmany 61, 17071 Girona, Spain
2 Department of Agricultural and Environmental Sciences, University of Milan, Via Celoria 2, 20133 Milan, Italy; daniele.masseroni@unimi.it
* Correspondence: gerard.arbat@udg.edu; Tel.: +34-972-418-400

1. Introduction

Agricultural irrigation systems help provide food to meet the growing demands of the global population. As a result of climate change, irrigated agroecosystems face threats such as excessive runoff, soil erosion, salinization, water pollution, over-irrigation, and water shortages, among others. These challenges can be met at multiple levels, but mainly through the use of technology that provides instruments and methodologies to deal with major environmental challenges, saving water and increasing crop yields. Tailored water resource management approaches for irrigation based on the application of agro-hydrological models and decision support tools at different scales are effective in maintaining reliable and flexible water allocation during periods of water shortage, preserving water for environmental requirements, and decreasing conflicts between water users.

In semi-arid and arid regions, where irrigated agriculture is threatened by water scarcity, saline or treated wastewater has become a resource; nonetheless, potential hazards to the environment/humans are a concern. This requires further research, as well as the application of innovative technologies and decision tools to provide secure solutions, promoting resilient irrigation management now and in the future.

It is necessary to promote water management research and the dissemination of its results for different irrigated agroecosystems where advanced technologies and innovative methodologies are used for efficient irrigation management and soil and water conservation.

Within this framework, this Special Issue offers an opportunity to gather studies and multidisciplinary approaches related to advanced technologies and innovative methodologies for irrigation management. It includes eleven original research papers that cover a broad range of advances in using alternative irrigation-water sources (five research papers (RPs)), modeling the soil water distribution and water quality (two RPs), modernizing surface irrigation systems (two RPs), and assessing the economic and environmental sustainability of irrigation practices and technologies (two RPs). In the following sections, there is a summary of each research paper belonging to each one of these four categories.

2. Using Alternative Irrigation-Water Sources

In this category, this Special Issue includes the work of Cymes et al. [1], which deals with the possibility of using infiltration intakes using wells that collect water from the first aquifer. This research was carried out in Braniewo poviat (Poland), which can be considered representative of the conditions of Central and Eastern Europe. Due to climate change, the intensity of the evapotranspiration process has increased and, on average, water shortages of up to 160 mm can occur with a probability of 20% and shortages of up to 120 mm can occur with a probability of 50%, affecting potato and sugar beet, which are the main crops in the area. This clearly indicates the need for irrigation of these crops. The results of this study showed that in more than 72% of the agricultural surface area of

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Braniewo poviat, the potential capacity of the wells is greater than 30 m^3 h^{-1}, which would cover the irrigation water needs.

Palacios-Diaz et al. [2] explored the feasibility of using reclaimed water together with subsurface drip irrigation and drip irrigation to produce sorghum forage in Santiago Island (Cape Verde), which is characterized by a warm, semi-arid climate. The best irrigation-water use efficiency was obtained with reclaimed water in combination with subsurface drip irrigation, at 200 L kg^{-1} of dry matter. The same irrigation water in combination with drip irrigation needed 34% more water to produce a kilogram of dry matter. An additional result from this study was that a high nitrate elimination rate in wastewater treatment plants might not be desirable if agricultural reuse is planned to irrigate high-N-demanding crops such as sorghum.

Another alternative source of reclaimed water and fertilizer is effluents from biogas treatment plants, often associated with intensive livestock and poultry production. The effluent from treatment plants is often mixed with conventional water and applied through a drip irrigation system. However, this may generate clogging problems in drip irrigation emitters. Qiu et al. [3] highlighted the need for chemical treatment to reduce the clogging problems in the emitters and studied the optimal acid and chlorine additions to minimize them.

Together with chemical treatments, pressurized media filters are used in drip irrigation systems to prevent emitter clogging, especially when using reclaimed water. Duran-Ros et al. [4] stated that the performance of these filters may be improved with more information about the retention of solids at different bed depths under different filter operation conditions and irrigation-water sources. In their study, experiments in a scaled sand medium filter were conducted to clog the filter at two different filtration velocities (30 and 60 m h^{-1}) and two particle types (coarse sand dust and organics from a reclaimed effluent). The suspended solids retained in slices of 5 mm (in the first 20 mm of the bed) and 20 mm (from 20 to 200 mm depth) thicknesses were determined. The results showed that the solids retained in each slice per mass of media were significantly ($p < 0.05$) affected by the interaction between the filtration velocity, the bed depth, and the particle type. There were significantly more solids retained in the first 5 mm of the bed than at other depths. Moreover, inorganic solids were retained more in upper slices than organic ones. Therefore, media depths can be adjusted depending on the irrigation-water source to optimize media use.

The recovery of rainwater by promoting infiltration near the root system may be an alternative source of irrigation water. Nenciu et al. [5] proposed a method involving compartmentalizing micro-basins to increase infiltration and soil water storage as one of the most promising water conservation solutions, particularly for sloping terrains. This research study aimed to improve the process of building soil-compartmentalized segments using furrow diking technology by designing and testing the optimal geometry of the active soil modeling component. Three constructive designs of a furrow dike were built and tested. In accordance with the considered quality indicators, the most efficient constructive shape was the curved rotor blade due to the higher volume of managed soil and fewer soil losses. Furthermore, the technology applied on three non-irrigated sunflower experimental crops grown on sloping land showed very good effectiveness in the studied climatic and pedological conditions in southern Romania. When compared with non-compartmentalized crops, the most efficient rotor geometry design increased seed production by 11–13%. The water storage efficiency contributed the most to the yield increase, with moisture retention from the root zone improving by an average of 20%.

3. Modeling Soil Water Distribution and Water Quality

There are two research papers in this category. Liang et al. [6] proposed an algorithm called regulated sparse autoencoder–niche particle swarm optimization (RSAE-NPSO) to calculate the uniformity of the soil water distribution under drip or sprinkler irrigation using an index called the sprinkler drip infiltration quality (SDIQ). The results of this study showed that the SDIQ can be accurately calculated using soil characteristics and specific irrigation parameters.

The research paper of Romic et al. [7] applied multivariate statistics (PCA) coupled with a time-series analysis and a vector autoregression (VAR) model to forecast temporal changes in water salinity in a polder-type agricultural floodplain within the Neretva River Delta (NRD), Croatia. The results of this study revealed a mutual influence between stream water and shallow groundwater in terms of their chemical composition. The results of the PCA showed that the exchange of water between these two water bodies is a significant factor affecting their hydrochemistry. However, not all water classes had the same impact on the dominant patterns of ionic species. Differences in land use and agricultural practices in the different polders resulted in uneven water chemistry and a greater influence of certain ions, particularly nutrients. The VAR models accurately calculated the two surface water locations, but not the two groundwater locations. The developed VAR model may be useful for watershed management authorities and agricultural producers in the two polders with more than 3000 ha of agricultural land in the NRD to make future production and irrigation plans.

4. Modernizing Surface Irrigation Systems

The modernization of surface irrigation systems on the field scale is based on the use of sensors and automated flow gates together with a wirelessly connected network architecture. Automated gravity surface irrigation systems have shown the potential to reduce labor; however, their adoption is not widespread. In this Special Issue, the work of Champness et al. [8] evaluated the performance of an automated irrigation system for aerobic rice cultivation and analyzed the opportunity cost of time (the value of other on- or off-farm activities that could be conducted within that time) associated with automated irrigation. The main findings of this study showed that the system was able to dynamically control water in ponded-rice fields with the ability to strategically apply the required water depth. Labor savings of 82–88% were achieved during flush-irrigation events, with a 57% reduction in labor achieved during permanent flooding. Considering the opportunity cost of time saved as opposed to cash costs, the payback period was reduced from seven to four years in the traditional ponded-rice system. At the aerobic rice site, the payback period could be reduced from three years to less than one year when considering the opportunity cost of time. Although the costs will vary between sites and cultivation strategies, this research demonstrates the ability of gravity surface irrigation to enable novel water-saving rice practices, which result in substantial economic labor savings and likely water-saving benefits.

The modernization of surface irrigation systems requires improving the water-use efficiency in canals, which is greatly limited by the performance of the management systems responsible for controlling the flow and delivering water when needed. Recent studies demonstrate the significant sensitivity of the results obtained from irrigation canal control algorithms with respect to Manning's roughness coefficient value, thus highlighting the importance of its correct estimation to ensure an accurate and efficient water delivery service. In this Special Issue, Bonet et al. [9] developed an algorithm to estimate Manning's roughness coefficient to monitor the real behavior of irrigation canals. The friction coefficient algorithm was conceived as a powerful offline tool that can be integrated into the control system of any irrigation canal as an optimization control algorithm. This mean that can canal gates can be reconfigured according to the current crop water demands and the real Manning roughness coefficient values. The friction coefficient algorithm was applied in several irrigation canals and different scenarios, with the findings demonstrating an average Manning coefficient between 2×10^{-4} and 4.5×10^{-4}.

5. Assessing the Economic and Environmental Sustainability of Irrigation Practices and Technologies

The adoption of new irrigation practices and technologies may require additional investments compared to conventional techniques; however, this increase in cost may be compensated for by the water or energy savings and/or increased obtained crop yields. A life cycle assessment (LCA) is a standard method used to analyze the environmental sustainability of a process or system throughout its entire life cycle and plays an important role in the environmental assessment of water use efficiency measures. In this Special Issue, Pujol et al. [10] analyzed the environmental impact of three media filters used in drip irrigation (a prototype with a porous media underdrain and two commercial filters with an inserted dome and a collector arm underdrain, respectively) at different bed heights, filtration rates, and medium materials via an LCA. This work shows that filter design criteria should be chosen to minimize the energy consumption during the operation phase. Among the three filter designs, the inserted dome design had the lowest overall impact. The adoption of alternative irrigation systems in crops irrigated by traditional methods may often save water; however, it can affect the crop yield or quality. In this Special Issue, Ghazzawy et al. [11] studied the effect of drip and sprinkler irrigation on date palm production and how it affects the fruit quality. The main results showed that drip irrigation reduces the water demand by 20% compared to sprinkle irrigation; moreover, this reduction in water improved the sugar content in the fruit and therefore their quality.

6. Conclusions

The use and management of agricultural irrigation systems and technologies involve many different aspects such as the use of alternative irrigation-water sources, the application of models to calculate the soil water distribution and water quality, the modernization of traditional surface irrigation systems, and assessments of the economic and environmental sustainability of irrigation practices and technologies. The eleven papers contributed to this Special Issue offer updated discussions, providing insights into a range of innovative approaches and the emerging concerns within the broader theme. These works delve into diverse environments, methodologies, and case studies, emphasizing the ongoing need to deepen our understanding, share experiences, and promote the fair utilization of water resources. The collective effort of this Special Issue shows that the protection and conservation of the environment and its resources must be comprehensive and include a wide range of water management strategies.

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