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Editorial

Modelling and Management of Irrigation System

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Abstract: Nowadays, irrigation is becoming an activity of precision, whereby it is necessary to combine information collected from various sources to manage resources in an optimal way. New management strategies, such as big data techniques, sensors, artificial intelligence, unmanned aerial vehicles (UAV) and new technologies in general, are becoming more relevant every day. Related to this, modeling techniques, both at the water distribution network and at farm level, will be essential to gather information from various sources and offer useful recommendations for decision-making processes. In this Special Issue, ten high-quality papers were selected that cover a wide range of issues that are relevant to the different aspects related to irrigation management: water source and distribution network, plot irrigation systems and crop water management.

Keywords: water-energy nexus; decision support systems; soil-water-plant-atmosphere models; optimization

1. Introduction

Agricultural irrigation is the main water user, accounting for more than 70% of all water withdrawals worldwide [1] and plays an essential role of feeding the world population since, representing 20% of the total cropped area, it produces 40% of the global food production (rainfed agriculture produces 60% with 80%). However, irrigated agriculture will face important challenges in the coming decades and must feed, in a climate change context, a growing population with less soil and water resources. For this reason, it will be increasingly important to use water as efficiently as possible.

Seeking to increase water use efficiency, in recent decades, many water conveyance networks and irrigation systems have evolved to pressurized ones, making energy another key resource for the irrigation sector, which represents a growing percentage of the total water costs and increases the carbon footprint of irrigation activities [2].

Nowadays, agriculture in general is in a technological revolution involving the use of sensors, unmanned aerial vehicles (UAV), satellite images, renewable energy sources and new technologies in general. This new technology offers a huge amount of information that must be processed, analyzed and made available to users in a friendly way. In all this, concepts such as big data, ICTs and, of course, decision support systems that facilitate irrigation management and efficient use of resources will play an increasingly important role.

Given this situation, it is essential to use modeling techniques that, collecting information from the wide variety of sources currently available, allow to analyze the different systems in depth and facilitate decision-making processes. Better control of the irrigation process, as well as better management of pressurized irrigation networks, are essential to convert irrigation to a precision activity, where the efficiency of the use of the involved resources is maximized. These facts highlight the need to improve efficiency in the water–energy nexus, which is essential for economic, social and environmental development of the sector [3].

However, irrigation systems modeling is somewhat complex given that many factors are involved, such as the water distribution network, the hydraulic configuration of the on-farm irrigation system and the soil-water-plant-atmosphere system. For this reason, it is necessary to model the different levels of the whole irrigation system since all of them are relevant for the efficient use of resources.

The selected papers included in this special number cover a wide range of issues that are relevant to the three abovementioned levels: the water distribution network, on-farm irrigation system engineering, and irrigation management at field level.

2. Summary of the Papers

2.1. Water Distribution Network

In this regard, four papers are presented that address topics such as the optimal allocation of resources, the optimal management of water distribution networks and the efficient use of energy in pressurized networks.

Ehteram et al. (2018) [4] presents a heuristic method based on an improved weed algorithm for reservoir operation aimed at reducing the irrigation deficits. The result is a useful tool for solving complex problems in water management.

The management of open channels water distribution networks is especially complex. It is necessary to analyze, on the one hand, the offtake and flowing discharge in the canal, and on the other hand, the water users and the peculiarities of the water demand. This topic is addressed by Luppi et al. (2018) [5] who combined agronomic and hydraulic aspects thanks to the tools IRRINET management Decisional Support System (DSS) and the SIC2 (Simulation and Integration of Control for Canals) hydraulic software. The methodology is applied in the open-canal Canale Emiliano Romagnolo (CER), which is one of the major irrigation infrastructures in Northern Italy.

The optimization of the water-energy is essential in pressurized irrigation systems. Related to this, two papers are included. Córcoles et al. (2018) [6] presents a decision Support System tool useful to reduce the energy consumption of water abstraction from wells. It is based on the installation of variable speed drives and results shows potential energy savings of up to 23% with payback periods ranging from 4.5 to 10 years.

Renewable energy sources will play an important role in the water supply. There are several options, such as photovoltaic energy or windmills, but another option is energy recovery from excesses of pressure. It is useful to recover part of the energy used in the pumping station but also to have energy in the farms when there is no other source available. This is especially important for the supply of programmers, fertigation equipment or filters. This aspect is addressed by Crespo Chacón et al. (2019) who analyses the potential of microhydropower and pumps working as turbines (PATs) in pressurized water distribution networks [7]. They developed a methodology for optimum selection of PATs that maximizes the energy production and minimizes the payback period. The methodology was tested in Sector VII of the right bank of the Bembézar River (BMD), in Southern Spain. Five potential sites for PAT installation were found with an energy recovery potential of 93.9 MWh and an annual energy index of 0.10 MWh year^{-1} ha^{-1}.

2.2. On-Farm Irrigation System Engineering

Two papers are presented that address on-farm irrigation system modelling. Robles Rovelo et al. (2019) [8] characterized and simulated the behavior of a Low-Pressure Rotator Spray Plate Sprinkler frequently used in center pivots. The experiments were performed under two pressures (69 kPa and 103 kPa) and in calm and windy conditions. The energy losses due to the impact of the out-going jet with the sprinkler plate were measured using an optical technique. They satisfactorily analyzed water distribution and estimated energy losses over 16,500 droplets.

Buono da Silva Baptista el al. (2019) [9] analyze also center pivots but from an energy efficiency point of view. They analyze the effect of variable speed drives to adjust the pumping pressure to that which is strictly needed. They developed the VSPM model (Variable Speed Pivot Model) to perform hydraulic and energy analyses of center pivot systems in an integrated manner. The application in a real case study of maize cropped in Albacete (Spain) offered reductions in energy consumption of 12% with annual economic savings of €2821.47.

2.3. Irrigation Management at Field Level

Finally, in the last section, agronomy and optimal irrigation scheduling are considered. In this sense, there are four papers that can be divided into two groups, on the one hand, the estimation of the real crop irrigation needs and on the other, in soil-water-plant-atmosphere models useful to facilitate irrigation scheduling. There are two papers in each subcategory.

Li and Ma (2019) [10] validated the dual crop coefficient approach experimentally for drip irrigated summer maize in Aksu, Xinjiang (China). Evapotranspiration and transpiration are validated with a root mean square error (RSME) of 10 mm and 20 mm respectively. They also compare the results with those obtained for partially mulched maize in terms of evapotranspiration and water consumption.

In the second paper about crop water requirements, Benson and Chen (2018) [11] quantify the daily water requirements of container-grown Calathea and Stromanthe produced in shaded greenhouse. To address water requirements of greenhouse-grown plants, this study adapts a canopy closure model and investigated actual evapotranspiration (ETA) of Calathea G. Mey. 'Silhouette' and Stromanthe sanguinea Sond. from transplanting to marketable sizes in a shaded greenhouse.

Regarding the soil-water-plant-atmosphere models, firstly we have a calibration and application of the well known Aquacrop model but for sugarbeet production in central Spain [12]. Using data from a single deficit irrigation experiment and from eight different commercial farms, the model is calibrated and validated for simulating canopy cover, biomass and final yield with accurate results (RMSE = 11.39%, 2.10 t ha^{-1}, and 0.85 t ha^{-1}, respectively). Finally, they use the validated model to simulate different irrigation water allocations in the two main production areas of sugar beet in Spain.

In the last paper, Alcaide Zaragoza et al. (2019) developed the REUTIVAR model for precision fertigation of olive orchards using reclaimed water [13]. This crop is particularly relevant in Southern Spain, it usually receives deficit irrigation but fertilization is commonly imprecise, which causes over-fertilization, especially nitrogen. This problem is aggravated when using reclaimed water, which carries a significant amount of nutrients. A new model for optimum precision fertigation scheduling is developed which combines weather information, both historical and forecast data, soil characteristics, hydraulic characteristics of the system, water allocation, tree nutrient status, and irrigation water quality.

3. Conclusions

The optimum management of irrigation systems is very complex given that many factors are involved, structured in clearly differentiated levels (water distribution, on-farm irrigation system and agronomy). To adequately address the optimal management of each of these levels, it is necessary to use a large amount of information, which is usually found in unfriendly formats that are not too useful to extract useful recommendations for the decision-making processes. In this context, the objective of this Special Issue was to show the latest advances in the modeling of irrigation systems at each of those levels. Thus, ten high-quality papers related to the modeling of irrigation systems were included corresponding to the three levels abovementioned. The results show the possibilities that the models offer for the optimal management of irrigation systems, focusing each of the works on a particular aspect of them.

These works establish a framework of options to continue advancing in the different aspects started here. Future works should be directed towards the integration of the different models included in each of these levels. Thus, new aspects such as advanced artificial intelligence, incorporation of new communication networks, integration of the models in friendly applications particularly in mobile devices, integration UAV and satellite images, renewable energy sources for water supply and the optimization of the water energy nexus in general should be integrated in the news tools that will be developed in the coming years.

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References

1. FAO. *The Future of Food and Agriculture: Trends and Challenges*; FAO: Rome, Italy, 2017; ISBN 9789251095515.
2. Daccache, A.; Ciurana, J.S.; Rodriguez Diaz, J.A.; Knox, J.W. Water and energy footprint of irrigated agriculture in the Mediterranean region. *Environ. Res. Lett.* **2014**, *9*, 124014. [CrossRef]
3. Tarjuelo, J.M.; Rodriguez-Diaz, J.A.; Abadía, R.; Camacho, E.; Rocamora, C.; Moreno, M.A. Efficient water and energy use in irrigation modernization: Lessons from spanish case studies. *Agric. Water Manag.* **2015**, *162*, 67–77. [CrossRef]
4. Ehteram, M.; Singh, V.P.; Karami, H.; Hosseini, K.; Dianatikhah, M.; Hossain, M.S.; Ming Fai, C.; El-Shafie, A. Irrigation Management Based on Reservoir Operation with an Improved Weed Algorithm. *Water* **2018**, *10*, 1267. [CrossRef]
5. Luppi, M.; Malaterre, P.O.; Battilani, A.; Di Federico, V.; Toscano, A. A Multi-disciplinary Modelling Approach for Discharge Reconstruction in Irrigation Canals: The Canale Emiliano Romagnolo (Northern Italy) Case Study. *Water* **2018**, *10*, 1017. [CrossRef]
6. Córcoles, J.I.; Gonzalez Perea, R.; Izquiel, A.; Moreno, M.Á. Decision Support System Tool to Reduce the Energy Consumption of Water Abstraction from Aquifers for Irrigation. *Water* **2019**, *11*, 323. [CrossRef]
7. Crespo Chacón, M.; Rodríguez Díaz, J.A.; García Morillo, J.; McNabola, A. Pump-as-Turbine Selection Methodology for Energy Recovery in Irrigation Networks: Minimising the Payback Period. *Water* **2019**, *11*, 149. [CrossRef]
8. Robles Rovelo, C.O.; Zapata Ruiz, N.; Burguete Tolosa, J.; Félix Félix, J.R.; Latorre, B. Characterization and Simulation of a Low-Pressure Rotator Spray Plate Sprinkler Used in Center Pivot Irrigation Systems. *Water* **2019**, *11*, 1684. [CrossRef]
9. Buono da Silva Baptista, V.; Córcoles, J.I.; Colombo, A.; Moreno, M.Á. Feasibility of the Use of Variable Speed Drives in Center Pivot Systems Installed in Plots with Variable Topography. *Water* **2019**, *11*, 2192. [CrossRef]
10. Li, F.; Ma, Y. Evaluation of the Dual Crop Coefficient Approach in Estimating Evapotranspiration of Drip-Irrigated Summer Maize in Xinjiang, China. *Water* **2019**, *11*, 1053. [CrossRef]
11. Beeson, R.C., Jr.; Chen, J. Quantification of Daily Water Requirements of Container-Grown *Calathea* and *Stromanthe* Produced in a Shaded Greenhouse. *Water* **2018**, *10*, 1194. [CrossRef]
12. Garcia-Vila, M.; Morillo-Velarde, R.; Fereres, E. Modeling Sugar Beet Responses to Irrigation with AquaCrop for Optimizing Water Allocation. *Water* **2019**, *11*, 1918. [CrossRef]
13. Alcaide Zaragoza, C.; Fernández García, I.; González Perea, R.; Camacho Poyato, E.; Rodríguez Díaz, J.A. REUTIVAR: Model for Precision Fertigation Scheduling for Olive Orchards Using Reclaimed Water. *Water* **2019**, *11*, 2632. [CrossRef]