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Editorial

Agricultural Practices to Improve Irrigation Sustainability

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1. Introduction

Water is the main limiting factor in agricultural production in regions where the annual or seasonal rainfall is insufficient for the water requirements of crops. Agriculture and water use are intricately related. Globally, around 70% of all water extracted from water supplies is used in irrigation. Irrigated agriculture plays a key role in feeding the world's population, being responsible for 40% of the global food production while taking up only 20% of the global cultivated land [1,2].

Data from FAOSTAT (2024) [3] on the evolution of world agricultural and irrigation-equipped areas from 2011 to 2021 show an increase in the amount of land used for irrigation, while the global area of agriculture has slightly decreased (Figure 1). When looking at global values regarding the area and yield of three major groups of crops (cereals, fruit, and vegetables) from 2011 to 2021, it is clear that production growth was not accomplished due to an increase in the crops' area (Figure 2) [4]. On the other hand, an increase in crop productivity in recent years has been achieved thanks to the technological evolution of agriculture, no doubt including advances in the efficiency of irrigation water use, soil, water, and biodiversity conservation practices, and smart agricultural practices. However, pressures on soil and water resources have also grown: e.g., the increasing use of chemical inputs or farm mechanization; the expansion of soil degradation due to salinization, erosion, or contamination; and the rising of polluting processes in surface or groundwater resources [5,6]. Therefore, although productivity developments have been driving growth, the environment remains under pressure and inadequate agricultural practices affect ecosystems and the services they provide [6–11].

Taking the above into consideration, it is crucial to address water scarcity due to climate change while ensuring food security, enhancing water use efficiency in crop production, and minimizing the negative environmental impacts associated with intensive agricultural practices [12–16]. This editorial provides an overview of the Special Issue "Agricultural Practices to Improve Irrigation Sustainability", which focuses on agroecological practices, advances in agronomic technology, and effective management actions to promote sustainable irrigated agriculture.

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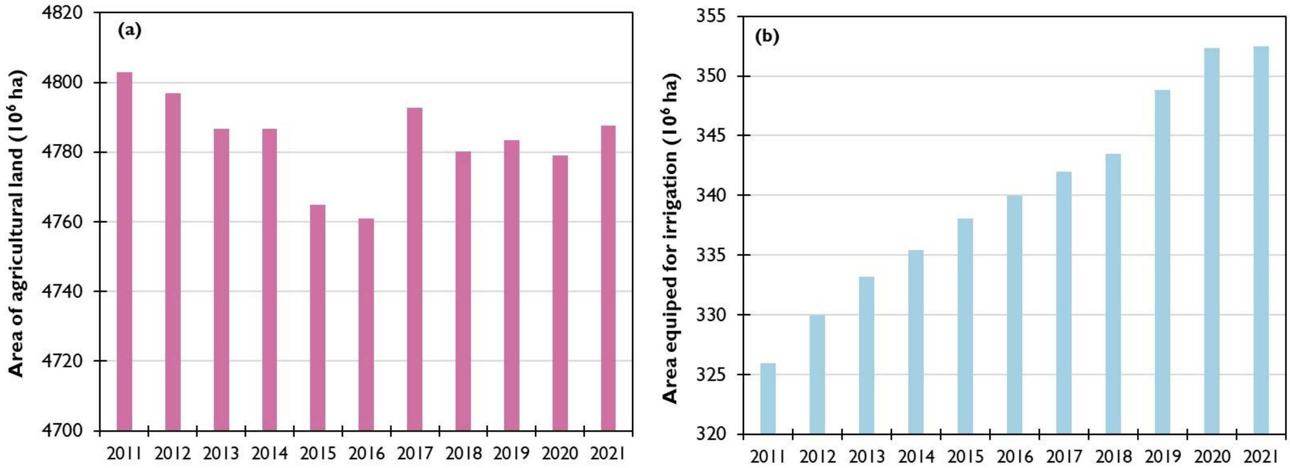

Figure 1. Evolution of (**a**) agricultural land area and (**b**) irrigation-equipped area during the period 2011–2021 (data from FAOSTAT [3]).

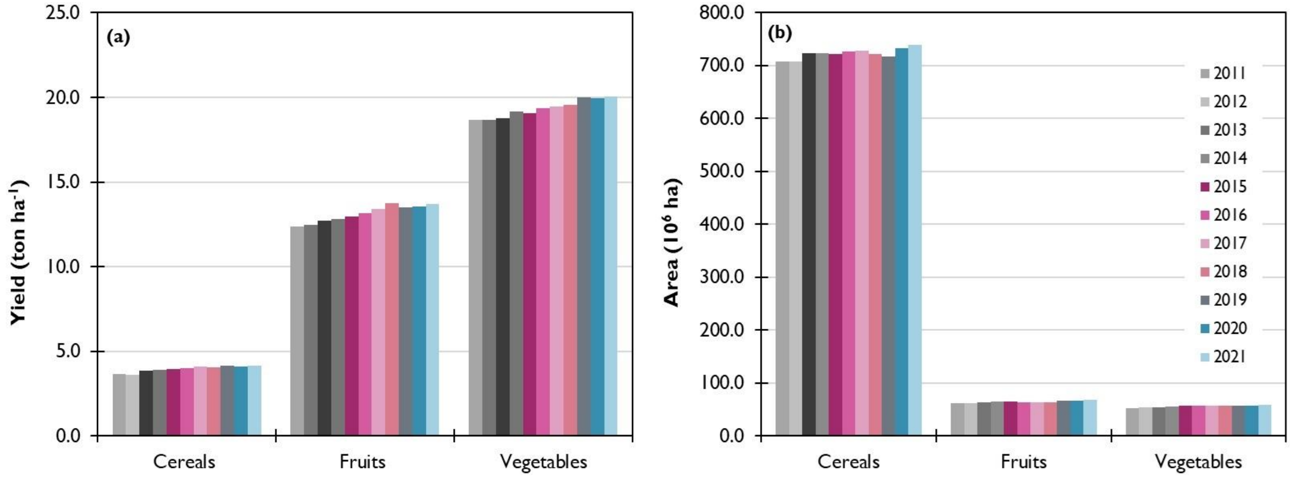

Figure 2. Evolution of average values of global cereal, fruit, and vegetable (**a**) yields and (**b**) area during the period 2011–2021 (data from FAOSTAT [4]).

2. Brief Description of the Selected Articles

The articles selected for publication, including research articles and one review, cover a wide range of topics related to irrigation sustainability, from the assessment of soil quality to the evaluation of management techniques and options, to the examination of indicators of agroecosystem sustainability.

Tomaz et al. (Contribution 1) carried out a study in irrigated farm fields in southern Portugal to evaluate the spatial and temporal variability of soil properties and their correlations with management practices, using multivariate statistical methods (factor analysis and discriminant analysis). The most influential factors and variables in temporal discrimination (sampling dates) were those related to chemical composition, with electric conductivity as the preponderant indicator. As for the spatial differentiation, the dominant factor in the surface layer (0–20 cm) was texture, and in the sub-surface layer (20–40 cm), the dominant factor was nutrient availability. The most important discriminant indicators of spatial variability were the proportion of fine sand and the available potassium, respectively, for the surface and sub-surface layers. The results showed that the multidimensional and integrated assessment of patterns of temporal and spatial variation in soil functions from agricultural practices or soil degradation processes can be valuable in improving crop productivity and soil health.

Moghbel et al. (Contribution 2) studied the well-known HYDRUS-1D numerical model, which can facilitate the exploration of management scenarios to mitigate the consequences of irrigation with poor quality water, especially soil salinization. Their research focused on calibrating the model and analyzing its parameters and the uncertainty of its outputs, using the generalized likelihood uncertainty estimation (GLUE) algorithm for simulating soil salinity in corn root zones under saline irrigation with a linear-moving sprinkle irrigation system. The results showed lower uncertainty in parameters related to water flow and solute transport compared to others and a higher level of uncertainty for the diffusion coefficient, which the authors attributed to the minor contribution of diffusion to the solute transport process in the soil compared with advection and hydrodynamic dispersion under saline water irrigation conditions. The calibrated model performed well in simulating soil water content and electrical conductivity at the corn root zone, thus providing a methodology to help manage poor-quality irrigation water and its effect on plants and soil.

A comparison between different geo-resistivity methods was carried out by Aziz et al. (Contribution 3) to evaluate the performance of mole drains in salt-affected clay soils in the Nile Delta region of Egypt. Geo-electrical surveys were conducted on three newly reclaimed farms to image the subsurface soil drainage conditions and to evaluate the efficiency of using traditional mole drain systems in these types of soils. The results showed that the proximity of buried mole drainage layers to topsoil reduced their effectivity for soil drainage and prevented deep-rooted plant growth. These results suggest that integrated models can be used to improve soil conditions and, thus, agricultural practices in these areas.

Cappelluti et al. (Contribution 4) reported a field experiment in a 5-year-old peach orchard in a Mediterranean environment to study the effect of mixed composed amendments, applied in different amounts, on the dynamics of soil water status, seeking to improve the use of rainwater and irrigation water in Mediterranean environments. The soil water balance indicators, soil water content, and relative extractable water showed that the soil storage capacity increased with the addition of amendment. Improved soil storage capacity was associated with higher values of stem water potential and stomatal conductance, while shoot and fruit growth observations were consistent with the soil water content dynamics.

Sobreiro et al. (Contribution 5) carried out a keywords-based search of peer-reviewed publications, using the following as primary keywords: irrigated olive orchards, high density/intensive/hedgerow olive orchards/groves, irrigation strategies, and soil management. Framed by the concerns about possible negative impacts of modern olive orchard production that have arisen in recent years and putting into question the trade-offs between the production benefits and the environmental costs, these authors performed a review to research the progress made regarding agronomic options that preserve ecosystem services in high-density irrigated olive orchards. They found several studies reporting that intermediate irrigation levels linked to the adoption of deficit irrigation strategies can be effective options to increase water use efficiency. Additionally, with irrigation, it is possible to implement agroecosystems with cover crops, non-tillage, and recycling of pruning residues. These practices reduce soil erosion and nutrient leaching, improve the soil organic carbon by 2 to 3 t C ha^{-1} $year^{-1}$, and increase the biodiversity of plants and animals.

Mullen and Niu (Contribution 6) developed a new methodology for comparing the cost-effectiveness of sustainable agricultural water policies during times of drought. They compared two policy options for consideration by the state of Georgia in the lower Flint River basin: namely, irrigation buyout auctions and source switching. The results of their study demonstrated, on one hand, the importance of modeling uncertainty associated with both the frequency and timing of drought and the hydrologic effects of source switching, and, on the other hand, that the cost-effectiveness of irrigation buyout auctions decreases as the frequency of drought increases.

Esenarro et al. (Contribution 7) evaluated different water management techniques in ancient hydraulic systems located in arid climate regions of Peru, Morocco, and Iran. They analyzed climatic and water supply data, as well as the structure and operation of the systems, having observed that the techniques employed in different civilizations are responses to contextual realities, offering an adaptive solution to environmental and physical challenges.

In the study by Naher et al. (Contribution 8), exploratory data analysis techniques were employed to examine historical changes in wheat and corn cropping patterns in the Texas High Plains from the perspective of geographical concentration and spatial autocorrelation, from 1978 to 2017. The results regarding the temporal changes indicated that the harvested acres of corn and wheat tended to decrease throughout the study period. Also, the total and irrigated harvested corn and wheat areas were concentrated in a smaller number of counties over time, while wheat production was mainly concentrated in the northern part of the region.

Sezen et al. (Contribution 9) assessed changes in the development parameters of *Salvia splendens* L., a commonly used plant in seasonal floriculture in urban green spaces, through the implementation of deficit irrigation practices. Their study evaluated the effect of four irrigation treatments—100% (control), 75%, 50%, and 25% of the pot's water-holding capacity—on plant parameters (number of flowers, flower stem thickness, flower diameter, flower height, leaf chlorophyll value, leaf area, and root length) at two stages of the development, cycle as well as fresh and dry weight measurements of the flowers, vegetative parts, and roots. The results revealed that, in comparison to 100% water application, *Salvia splendens* L. plants exhibited positive effects in the assessed parameters when subjected to 75% water application, except for the flower diameter parameter. Therefore, it is expected that reducing the water application by 25% when cultivating *Salvia splendens* L. can yield substantial water conservation benefits while maintaining good levels of plant development.

3. Conclusions

This Special Issue highlights the diversity and complexity of irrigation systems and the related challenges faced in different regions and contexts. It offers valuable insights into irrigation sustainability in the face of climate change and growing water demands and we expect that it will encourage more research and efforts in addressing this crucial issue. The selected papers also demonstrate the interdisciplinary and multi-scale nature of irrigation sustainability, involving different disciplines, methods, and stakeholders.

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