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Editorial

Impact of Climate and Socio-Economic on Irrigation Water Management and Agricultural Water Productivity

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1. Introduction to the Special Issue

Water security and food security are fundamental pillars of sustainable social and economic development [1]. As the human activity with the greatest water requirement, agricultural production consumes 70% of total water use worldwide and intensifies global pressure on water resources [2]. Therefore, improving agricultural water productivity is an important measure to ensure global water security and food security. Among all agricultural inputs, irrigation plays the most important role in ensuring stable agricultural production. However, increasing water demand leads to further strain on irrigation systems, while growing water scarcity poses a serious threat to food security and sustainable development in agricultural regions, endangering the livelihood of 3.2 billion people [3]. Without appropriate measures, freshwater use may soon reach its limit, underlining the urgent need for sustainable irrigation water management practices [4].

Climate change, human activities, and economic development pose serious threats to agricultural water productivity and irrigation water management due to changes in water supply and demand. These factors alter the spatial and temporal distribution of rainfall, impact water availability and allocation, and affect various other aspects of agricultural production [5,6]. For example, as global warming continues, extreme weather events such as severe droughts and floods are intensifying, negatively impacting global agricultural production and irrigation management [7]. Additionally, enhanced human activities, including land use and land cover changes, groundwater overexploitations, and stream flow regulations, have altered the hydrological cycle and water allocation for agricultural irrigation use [8]. Furthermore, socio-economic growth, driven by a rising global population, creates a persistent need for food production, increased urban and industrial water supply, suitable water quality, and environmental protection, leading to significant pressure on water resources and management [9]. Therefore, understanding the impact of climate change, human activity, and socio-economic development on agricultural water productivity and irrigation water management, along with pursuing targeted improvements, is a key challenge for ensuring water and food security and enhancing agriculture resilience against future challenges.

To this end, in this Special Issue, we attempted to publish related research papers on the following topics: (1) the impacts of climate change, human activities, and socio-economic development—including increasing temperature, extreme weather events, flooding, irrigation management, cropping patterns, water conservation measures, economic growth, infrastructure development, mining, governance and policy support, etc.—on the agricultural system; (2) management strategies and assessment approaches to help improve the sustainability of the agricultural and hydrological system under the challenging environment. We have collected eleven high-quality papers and summarize them in the following section.

2. A Summary of the Special Issue

Alternate wetting and drying (AWD) technology is an innovative and effective way to save water and improve agricultural water productivity. The study by Suwanmaneepong et al. [Contribution 1] explores the adoption of AWD among suburban rice farmers in Thailand. The findings indicate that variable cost is positively associated with higher AWD adoption intention in the short-run, while a higher fixed cost lowers the probability of AWD adoption. It is essential for farmers to apply the AWD method safely and correctly, together with the assistance of crop insurance, to encourage efficient water use in agriculture.

While the AWD method in rice farming may cause mild soil moisture stress, the use of zeolite could improve crop growth and yields due to its strong ion exchange capacity and high affinity for water and fertilizer. The study by Sun et al. [Contribution 2] examines the role of zeolite in improving rice cultivation, particularly under AWD conditions. The results indicate that zeolite application increased rice dry matter and grain yield, while both AWD and zeolite improved water productivity. Combining AWD and zeolite could offer several benefits, especially under water stress conditions.

In addition to AWD technology, plastic film mulching is another crucial technique to prevent water evaporation and improve agricultural water productivity. Xu et al. [Contribution 3] conducted a meta-analysis to quantify the effect of mulching properties, different levels of natural conditions, fertilizer application, and cultivation measures on potato yield and its water productivity. The results show that plastic film mulching significantly increased yield and water productivity, especially under less favorable natural and fertilizer conditions, which provides valuable reference for improving agricultural water management.

Sustainable agriculture goes beyond improving agricultural water productivity; it is also highly related to irrigation water management. In areas with limited surface water availability, well drilling and placement are essential to maximize groundwater resources. Li et al. [Contribution 4] developed two-stage stochastic mixed-integer programming models to optimize groundwater well placement for agricultural irrigation in Ethiopia. Their study highlights that well layouts vary slightly in different scenarios and that the model achieves lower costs in out-of-sample tests—11% and 4% lower than in deterministic cases—making it a robust strategy for sustainable groundwater management in irrigation.

As a vital resource for crop production, agricultural water is both affected by the environment and has significant environmental impacts. It plays a crucial role in maintaining ecosystem balance, affecting river flows, water quality, and aquatic life. Kang et al. [Contribution 5] evaluated agricultural return flow effects on downstream rivers using reservoir data, the SWAT model, and the PHABSIM model. Their findings show that agricultural return flow significantly increases river flow during non-rainy seasons, but fails to meet optimal ecological flow rates. Additionally, the impact on river water quality is minimal, except during rice paddy drainage. Overall, agricultural water contributes positively to downstream aquatic ecosystems.

In addition to agricultural water, agricultural production systems also exert pressure on aquatic ecosystems. The study of Troian et al. [Contribution 6] used a participatory approach, utilizing a multidimensional model to evaluate land use, soil management, and agricultural waste disposal based on 7 criteria and 25 sub-criteria, applied across 14 farms in a large watershed in southern Brazil. The results highlight that key factors influencing environmental risks include the fragility of cultivated areas and the lack of conservation practices, contributing to 73% of the risks. Their study suggests incorporating a cost-effectiveness analysis to better manage environmental conflicts in future research.

Water management is important in cold alpine regions. However, traditional models often neglect cryosphere elements such as frozen ground and snow cover, which significantly impact hydrological processes and lead to inaccurate estimates. Zhao et al. [Contribution 7] incorporated these elements into the Seasonal Water Yield model to better assess water yield in the Three-River Headwaters Region of the Qinghai–Tibetan Plateau. Frozen ground reduces water infiltration by acting as a low-permeability layer, while snow cover influences water yield through melting and sublimation. The improved model helps in making more reliable water resource management decisions in cold alpine regions, especially in the context of climate change.

Mining provides significant benefits to society but can also pose environmental risks. Hunter et al. [Contribution 8] investigated the impact of the Cuajone copper mine on water resources in the hyper-arid region of Southern Peru, focusing on the Torata river catchment. Based on water chemistry analyses from 16 sites over three seasons, they found that the mine does not significantly affect water quality. Instead, urban effluents and agricultural runoff are identified as the primary contributors of water contamination, especially in the lower catchment. However, elevated levels of total dissolved solids still pose risks for agricultural use and domestic consumption.

Runoff is one of the key water resources for irrigation, and irrigation practices, as a major human activity, can significantly affect the volume and quality of runoff. Miao et al. [Contribution 9] investigated the factors of declining runoff in the Xiliugou basin, a semi-arid region in northern China. By using six methods, including statistical and hydrological models, they found that human activities, particularly water conservation and land use changes, are responsible for 76% of the decline, while climate change contributes to only 24%. Their study highlights the significant role of soil and water conservation projects in altering runoff patterns, offering valuable insights for water resource management and sustainable development in the region.

Drought has become a major climatic concern affecting ecology and agriculture. Liu [Contribution 10] examined the sensitivity of vegetation growth to drought in the Yellow River Basin from 2003 to 2020, using the Standardized Precipitation Evapotranspiration Index and the Normalized Difference Vegetation Index. The results show that vegetation in arid and semi-arid areas is positively correlated with drought, while humid regions exhibit negative correlations, especially in high-altitude areas where vegetation is more sensitive to heat than water. Vegetation responds strongly to short-term (1 to 3 months) droughts, with sensitivity peaking in summer. The study provides insights into vegetation's response to drought and informs strategies for ecological protection in the Yellow River Basin under climate change conditions.

With the rapid growth of agricultural production, the amount of crop straw has significantly increased, making its decomposition a key challenge in agricultural production management. Wang et al. [Contribution 11] reviewed the literature on straw returning and decomposition processes, focusing on improving soil fertility through the use of straw decomposition agents. Utilizing bibliometric analysis via the CiteSpace software, their study visualized research trends and progress from 2002 to 2022, highlighting the importance of microorganisms, such as Pseudomonas, in enhancing decomposition rates. Their study also explored how returning straw to the soil can improve crop yields and mitigate environmental issues, such as heavy metal pollution. Their findings emphasize the growing interest in improving nutrient release from straw using bacterial agents to accelerate the decomposition process for sustainable agricultural development.

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List of Contributions:

1. Suwanmaneepong, S.; Kultawanich, K.; Khurnpoon, L.; Sabaijai, P.E.; Cavite, H.J.; Llones, C.; Lepcha, N.; Kerdsriserm, C. Alternate Wetting and Drying as Water-Saving Technology: An Adoption Intention in the Perspective of Good Agricultural Practices (GAP) Suburban Rice Farmers in Thailand. *Water* **2023**, *15*, 402. https://doi.org/10.3390/w15030402.
2. Sun, Y.; Xie, J.; Hou, H.; Li, M.; Wang, Y.; Wang, X. Effects of Zeolite on Physiological Characteristics and Grain Quality in Rice under Alternate Wetting and Drying Irrigation. *Water* **2023**, *15*, 2406. https://doi.org/10.3390/w15132406.
3. Xu, J.; Wang, Y.; Chen, Y.; He, W.; Li, X.; Cui, J. Identifying the Influencing Factors of Plastic Film Mulching on Improving the Yield and Water Use Efficiency of Potato in the Northwest China. *Water* **2023**, *15*, 2279. https://doi.org/10.3390/w15122279.
4. Li, W.; Finsa, M.M.; Laskey, K.B.; Houser, P.; Douglas-Bate, R.; Verner, K. Optimizing Well Placement for Sustainable Irrigation: A Two-Stage Stochastic Mixed Integer Programming Approach. *Water* **2024**, *16*, 2715. https://doi.org/10.3390/w16192715.
5. Kang, T.; Shin, Y.; Shin, M.; Lee, D.; Lim, K.J.; Kim, J. Evaluation of the Effect of Agricultural Return Flow on Water Quality, Water Quantity and Aquatic Ecology in Downstream Rivers. *Water* **2024**, *16*, 1604. https://doi.org/10.3390/w16111604.
6. Troian, A.; Gomes, M.C.; Tiecher, T.; Piccin, M.B.; Rheinheimer, D.d.S.; Reichert, J.M. Participatory Analysis of Impacts of Agricultural Production Systems in a Watershed Depicting Southern Brazilian Agriculture. *Water* **2024**, *16*, 716. https://doi.org/10.3390/w16050716.
7. Zhao, L.; Chen, R.; Yang, Y.; Liu, G.; Wang, X. A New Tool for Mapping Water Yield in Cold Alpine Regions. *Water* **2023**, *15*, 2920. https://doi.org/10.3390/w15162920.
8. Hunter, M.; Perera, D.H.N.; Barnes, E.P.G.; Lepage, H.V.; Escobedo-Pacheco, E.; Idros, N.; Arvidsson-Shukur, D.; Newton, P.J.; de los Santos Valladares, L.; Byrne, P.A.; et al. Landscape-Scale Mining and Water Management in a Hyper-Arid Catchment: The Cuajone Mine, Moquegua, Southern Peru. *Water* **2024**, *16*, 769. https://doi.org/10.3390/w16050769.
9. Miao, P.; Dagula; Li, X.; Naeem, S.; Kumar, A.; Ma, H.; Ding, Y.; Wang, R.; Luan, J. Runoff Decline Is Dominated by Human Activities. *Water* **2023**, *15*, 4010. https://doi.org/10.3390/w15224010.
10. Liu, W. The Response of NDVI to Drought at Different Temporal Scales in the Yellow River Basin from 2003 to 2020. *Water* **2024**, *16*, 2416. https://doi.org/10.3390/w16172416
11. Wang, Y.; Shan, Q.; Wang, C.; Feng, S.; Li, Y. Research Progress and Application Analysis of the Returning Straw Decomposition Process Based on CiteSpace. *Water* **2023**, *15*, 3426. https://doi.org/10.3390/w15193426.

References

1. Huntington, H.P.; Schmidt, J.I.; Loring, P.A.; Whitney, E.; Aggarwal, S.; Byrd, A.G.; Dev, S.; Dotson, A.D.; Huang, D.; Johnson, B.; et al. Applying the food–energy–water nexus concept at the local scale. *Nat Sustain.* **2021**, *4*, 672–679. [CrossRef]
2. D'Odorico, P.; Chiarelli, D.D.; Rosa, L.; Bini, A.; Zilberman, D.; Rulli, M.C. The global value of water in agriculture. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 21985–21993. [CrossRef] [PubMed]
3. FAO. *The State of Food and Agriculture 2020: Overcoming Water Challenges in Agriculture*; FAO: Rome, Italy, 2020. [CrossRef]
4. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; De Vries, W.; De Wit, C.A.; et al. Planetary boundaries: Guiding human development on a changing planet. *Science* **2015**, *347*, 1259855. [CrossRef] [PubMed]
5. Alcamo, J.; Dronin, N.; Endejan, M.; Golubev, G.; Kirilenko, A. A new assessment of climate change impacts on food production shortfalls and water availability in Russia. *Glob. Environ. Chang.* **2007**, *17*, 429–444. [CrossRef]
6. Hanjra, M.A.; Qureshi, M.E. Global water crisis and future food security in an era of climate change. *Food Policy* **2010**, *35*, 365–377. [CrossRef]
7. El-Nashar, W.; Elyamany, A. Adapting Irrigation Strategies to Mitigate Climate Change Impacts: A Value Engineering Approach. *Water Resour. Manag.* **2023**, *37*, 2369–2386. [CrossRef]
8. Wang, R.; Xiong, L.; Xu, X.; Liu, S.; Feng, Z.; Wang, S.; Huang, Q.; Huang, G. Long-term responses of the water cycle to climate variability and human activities in a large arid irrigation district with shallow groundwater: Insights from agro-hydrological modeling. *J. Hydrol.* **2023**, *626*, 130264. [CrossRef]
9. Cetinkaya, C.P.; Gunacti, M.C. Multi-criteria analysis of water allocation scenarios in a water scarce basin. *Water Resour. Manag.* **2018**, *32*, 2867–2884. [CrossRef]