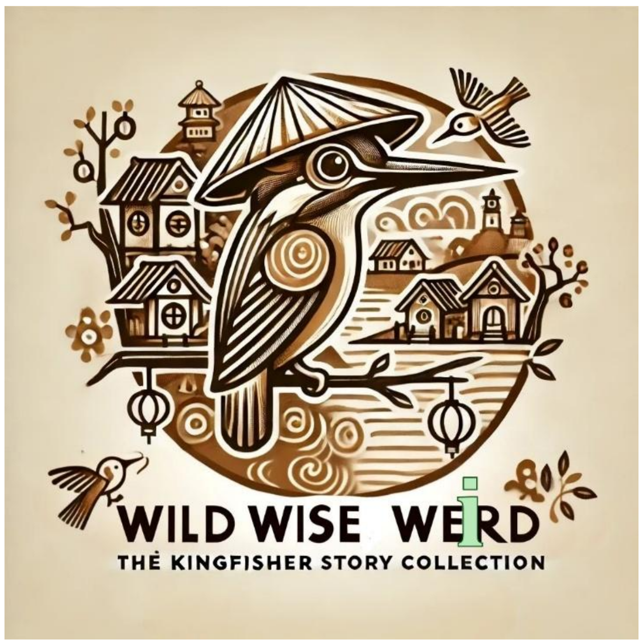
Balancing Agriculture, Water, and Energy: A Pathway to Sustainability

Vàng Anh

24-03-2025



"The fish, indeed, grow very fast. If there isn't enough feed, the two birds will bring back any suitable grass and veggies. Occasionally there might be crickets and worms, giving the fish some much-needed protein. In no time, the fish multiplied several times."

In "Joint Venture"; *Wild Wise Weird* [1]

ஓ • ஓ

• • • • •

Agriculture is fundamental to global food security, accounting for approximately 72% of worldwide freshwater withdrawals [2]. As the global population grows, so does the demand for agricultural water, creating complex interactions with regional water-energy balances. The Budyko framework—a widely used hydrological model—has revealed agriculture's substantial influence on the water cycle, demonstrating how aridity affects the partitioning of rainfall into evapotranspiration and streamflow [3]. Notably, agricultural practices in temperate and snowy climates significantly alter the relationship between precipitation and streamflow, necessitating adaptive water management strategies.

The impact of agricultural water use varies across climatic regions. In temperate zones, agricultural expansion weakens the relationship between precipitation and streamflow, amplifying deviations from natural water-energy balances [2]. Conversely, in snowy climates, agricultural activities strengthen this relationship, underscoring the need for climate-specific water resource management. These findings highlight that a one-size-fits-all approach to agricultural water use is inadequate.

Irrigation, a key component of agricultural water use, has traditionally focused on maintaining soil moisture levels. However, sustainable irrigation requires a more integrated approach that accounts for both soil water supply and atmospheric evaporative demand [4]. A plant-centric irrigation management approach, which considers these factors, has been proposed as a solution to improve water sustainability. Integrating soil moisture and vapor pressure deficit (VPD) reduces water consumption while maintaining crop yields, increasing economic profitability, and enhancing irrigation efficiency [4].

Groundwater resources add another layer of complexity to the water-energy nexus in agriculture. In many arid and semi-arid regions, groundwater reserves consist of non-renewable "fossil" aquifers, which were formed under past, more humid climatic conditions and replenished extremely slowly. While these aquifers provide a temporary solution to water scarcity, their overexploitation can lead to irreversible depletion, threatening regional water security and agricultural sustainability [5].

Recognizing the critical role of groundwater, UNESCO's International Hydrological Programme (IHP) has emphasized the need for sustainable management of non-renewable groundwater resources [5]. A comprehensive approach to water resource management—one that integrates economic, social, and environmental dimensions—is essential to address the challenges associated with groundwater depletion.

Achieving sustainability in agriculture requires a nuanced understanding of the interplay between water availability, atmospheric conditions, and groundwater resources. The adoption of improved water management strategies, informed by scientific frameworks such as the Budyko hypothesis and plant-centric irrigation models, will be essential for securing global food production while preserving vital water-energy systems. By taking a holistic and climate-responsive approach, agriculture can sustainably meet growing demands while safeguarding essential water resources for future generations [6].

References

[1] Vuong QH. (2024). *Wild Wise Weird*. https://www.amazon.com/dp/B0BG2NNHY6/

[2] Zaerpour M, et al. (2025). Agriculture's impact on water–energy balance varies across climates. *PNAS*, 122(12), e2410521122. https://www.pnas.org/doi/10.1073/pnas.2410521122

[3] Berghuijs WR, et al. (2020). Unanswered questions on the Budyko framework. *Hydrological Processes*, 34(26), 5699-5703. https://doi.org/10.1002/hyp.13958

[4] Zhang J, et al. (2021). Sustainable irrigation based on co-regulation of soil water supply and atmospheric evaporative demand. *Nature Communications*, 12, 5549. https://www.nature.com/articles/s41467-021-25254-7

[5] Margat J, et al. (2006). *Concept and importance of non-renewable resources*. UNESCO-IHP.

[6] Nguyen MH. (2024). How can satirical fables offer us a vision for sustainability? *Visions for Sustainability*. https://ojs.unito.it/index.php/visions/article/view/11267