

Soilless farming: a key tool of precision agriculture for reducing environmental footprints, increasing water-use efficiency and crop yield under climate change

Imran Ali Lakhari¹, Haofang Yan¹, Chuan Zhang², Tabinda Naz Syed³, Run Xue², Rui Zhou¹, Rongxuan Bao¹
¹Research Center of Fluid Machinery Engineering and Technology, Jiangsu University, Zhenjiang 212013, China
²School of Agricultural Equipment Engineering, Jiangsu University, Zhenjiang 212013, China
³College of Engineering, Nanjing Agricultural University, Nanjing 210031, China

INTRODUCTION & AIM

Climate change (CC) poses significant challenges to global agriculture, impacting land availability, water resources, and food security. Rising temperatures and erratic weather patterns lead to soil degradation, reduced arable land, and increased water scarcity [1]. Traditional farming methods often struggle to adapt to these CCs, resulting in lower crop yields and heightened food insecurity. Soilless farming (SF), including hydroponics and aeroponics, emerges as a sustainable solution that minimizes environmental footprints, optimizes water use, and enhances crop productivity, making it a critical component of precision agriculture (Figure 1) in the face of CC [2].



Figure 1: Climate change issues

METHOD

This study synthesizes scientific information on soilless farming as a tool for precision agriculture, focusing on its impact on environmental footprints, water-use efficiency, and crop yield. We addressed the following key questions:

- What soilless farming systems are utilized in agriculture?
- How do these systems affect water-use efficiency and crop productivity?
- Can modern soilless technologies enhance sustainability in farming practices?
- What is the current state of research on soilless farming techniques?

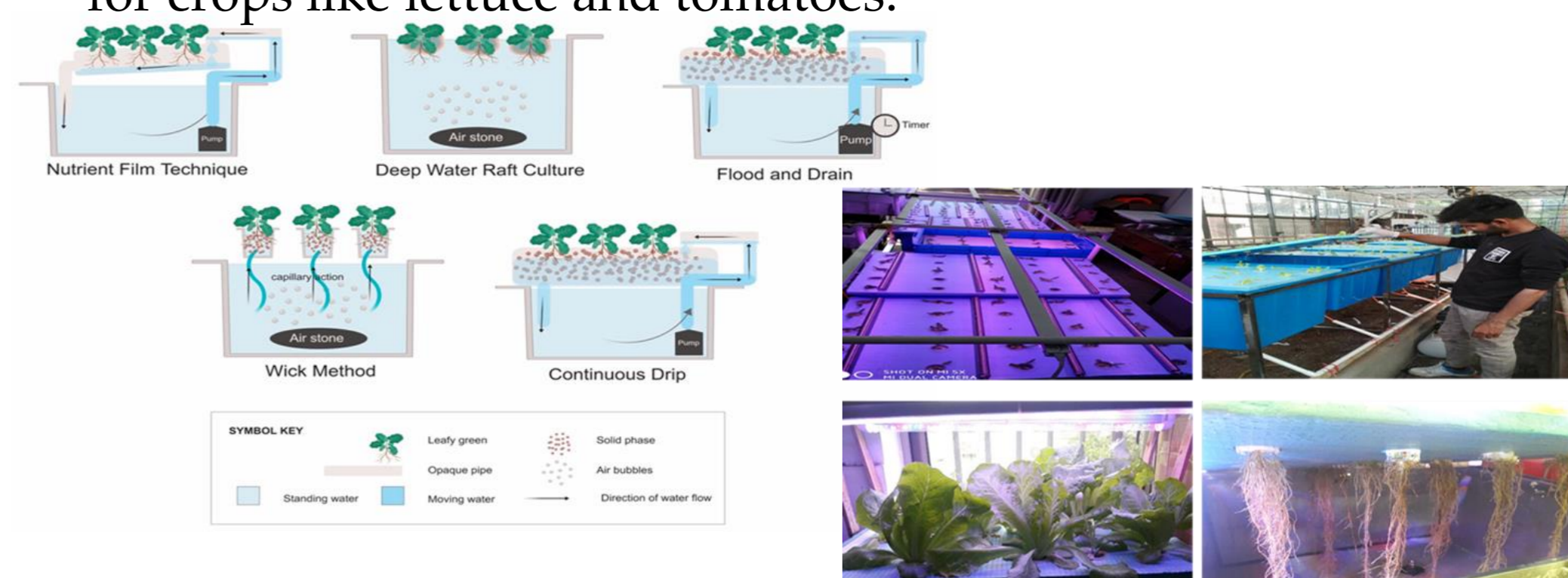
To answer these questions, we analyzed existing literature on traditional and modern soilless farming methods, linking them to precision agricultural practices. A systematic literature search (Figure 2) was conducted using keywords such as "soilless farming," "hydroponics," and "aeroponics" across major scholarly databases, including Google Scholar, Web of Science, and Scopus.



Figure 2: Review methodology

RESULTS & DISCUSSION

- SF, encompassing systems like hydroponics, aeroponics, and aquaponics, offers transformative potential in precision agriculture by ensuring efficient resource use, enhancing crop yields, and minimizing environmental impacts.
- SF can mitigate the adverse effects of extreme climate events by reducing land use. The absence of soil also reduces the risk of soil-borne diseases and pests, thereby decreasing the reliance on chemicals, lowering GHGs, minimizing nutrient runoff, and mitigating the effects of land degradation.
- These systems eliminate soil-related variability, enabling precise nutrient and water management and significantly reducing resource wastage. Studies demonstrate that soilless methods use up to 90–95% less water and 40–50% fewer chemical inputs than traditional agriculture while achieving yield increases of 20–30% for crops like lettuce and tomatoes.



Lettuce cultivated in Aeroponics system

Figure 3: Soilless farming systems [2,3].

- However, challenges remain, including high initial investment costs, reliance on energy, and the need for technical expertise, particularly in developing countries. Overcoming these barriers will require technological innovation, government support, and policies promoting accessibility and affordability.
- In summary, SF is a critical tool for sustainable, climate-smart agriculture, aligning with precision farming principles to optimize resource efficiency and ensure food security in the face of CC. Further advancements are needed to enhance its scalability and affordability for broader adoption.

CONCLUSION

- As CC intensifies, traditional farming faces increasing challenges. SF techniques provide a resilient alternative that can help ensure food security in a volatile environment.
- SF uses less water and input resources than open farming.
- It can take place in controlled environments like greenhouses or indoor vertical farms in a variety of locations, including urban areas, arid regions, and even rooftops.
- This adaptability allows for food production closer to consumption centers, reducing transportation costs and emissions.

REFERENCES

1. Toromade, A. S., Soyombo, D. A., Kupa, E., & Ijomah, T. I. (2024). Reviewing the impact of climate change on global food security: Challenges and solutions. *International Journal of Applied Research in Social Sciences*, 6(7), 1403-1416.
2. Lakhari, I. A., Gao, J., Syed, T. N., Chandio, F. A., Tunio, M. H., Ahmad, F., & Solangi, K. A. (2020). Overview of the aeroponic agriculture—An emerging technology for global food security. *International Journal of Agricultural and Biological Engineering*, 13(1), 1-10.
3. Riggio, G. M., Jones, S. L., & Gibson, K. E. (2019). Risk of human pathogen internalization in leafy vegetables during lab-scale hydroponic cultivation. *Horticulturae*, 5(1), 25.