environmental sciences proceedings

MDPI

Proceeding Paper

Digital Twin Greenhouse Technologies for Commercial Farmers †

Kainat Fatima [1,*], Saddam Hussain [2,3,4], Shahid Ali Khan [5], Muhammad Azam Khan [1,6], Shoaib Rashid Saleem [1,7] and Sehrish Kanwal [1]

1 Data-Driven Smart Decision Platform (DDSDP), PMAS-Arid Agriculture University, Rawalpindi 46000, Pakistan
2 Department of Irrigation and Drainage, University of Agriculture Faisalabad, Faisalabad 38000, Pakistan
3 Department of Biological and Agricultural Engineering, University of California Davis (UC Davis), Davis, CA 95616, USA
4 National Center of Industrial Biotechnology (NCIB) Project, PMAS-Arid Agriculture University, Rawalpindi 46000, Pakistan
5 Directorate of Planning & Development, PMAS-University of Arid Agriculture, Rawalpindi 46000, Pakistan
6 Department of Horticulture, Faculty of Crop and Food Sciences, PMAS-University of Arid Agriculture, Rawalpindi 46000, Pakistan
7 Department of Farm Machinery and Precision Engineering, Faculty of Agricultural Engineering and Technology, PMAS-Arid Agricultural University, Rawalpindi 46000, Pakistan
* Correspondence: kainatfatima@uaar.edu.pk
† Presented at the 1st International Precision Agriculture Pakistan Conference 2022 (PAPC 2022)—Change the Culture of Agriculture, Rawalpindi, Pakistan, 22–24 September 2022.

Abstract: Technology integration between the farm and the consumer is at the heart of digital agriculture. New technologies for developing countries, such as vertical indoor farming that uses automation and robots, might speed up the elimination of rural poverty and hunger worldwide. Significant technical developments include state-of-the-art greenhouse techniques, laser-guided precision farming, AI, and blockchain. Connected farm machinery collects data that may then be used to research the soil and climate of a given area, allowing experts to offer advice on seed selection and the optimal timing for applying pesticides and fertilizers. One of the most widely used innovations of the previous century was the mobile phone. The use of digital technology will improve communication between consumers and farmers. The public now has more accessible access to information on farming because of the wealth of data collected on crops and livestock. Smart farming's impact on crop yields will be seen in the long term.

Keywords: digital twin; greenhouse horticulture; smart farming

Citation: Fatima, K.; Hussain, S.; Khan, S.A.; Khan, M.A.; Saleem, S.R.; Kanwal, S. Digital Twin Greenhouse Technologies for Commercial Farmers. *Environ. Sci. Proc.* **2022**, *23*, 33. https://doi.org/10.3390/environsciproc2022023033

Academic Editor: Tahir Iqbal

Published: 3 January 2023

1. Introduction

As a result of concerns about food security, safety, sustainability, and health, the production of horticultural goods is becoming increasingly industrialized. Greenhouses are rapidly transforming into high-tech factories that utilize a great deal of machinery and a vast variety of goods in extremely large quantities [1]. This transformation is a result of the increased use of advanced sensors and control systems for climate management, irrigation, fertigation, lighting, crop monitoring, disease scouting, harvesting, internal transportation, sorting, and packaging. On the other hand, greenhouse horticulture is becoming increasingly cutting-edge and data-driven. This phenomenon has accelerated due to technological developments such as cloud computing, the Internet of Things (IoT), big data, machine learning, augmented reality, and robots [2]. Growers now can remotely monitor and control innovative and data-driven greenhouse horticulture activities by utilizing digital information in (near) real-time. They receive notifications for potential concerns and can view a rich visual image of the plants or equipment in the greenhouse from their desk or smartphone. Growers can simultaneously mimic corrective and preventive activities on the digital depiction. Finally, the farmer can remotely implement the recommended treatments and use digital representation to confirm that the problem is solved. Without the grower's manual intervention, this intelligent management cycle will become increasingly autonomous. Finally, plants, containers, greenhouse sections, and equipment can be virtualized and remotely managed through digital twin development. It simulates the behavior of real-life objects in a virtual world [3]. The digital twin concept is new and could advance intelligent greenhouse horticulture. However, it is uncertain how much greenhouse horticulture uses digital twins. There is little expertise in creating and using digital twin-based systems for greenhouse horticulture.

2. The Present Need for Digital Agricultural Practices

The agricultural technology industry is evolving in line with other markets and becoming more knowledge-intensive. Production methods have evolved from their old forms into more efficient and creative models as a result of this shift. The farmers have been going through it recently. All of these changes may be achieved via the use of digital agriculture [4]. The concepts of "precision agriculture," which centers on agricultural production processes, and digital agriculture, which [5] characterize as an application of the digital world idea established in the 1990s, are crucial to the development of this field. When we talk about digital agriculture, we are referring to the practice of using digital and communication technology to boost agricultural productivity and longevity. The growing use of innovative, interconnected, and data-intensive computing technologies is collectively referred to as the Industry 4.0 revolution, which has brought digital agriculture and a slew of new possibilities to the agricultural sector [6]. The Global Institute of Food Security (2015) states that only approximately 20% of the world's agricultural areas are being managed using digital agriculture technology.

3. Digital Twin Concept

The idea of a digital twin has its roots in product management. There was a demand in this field for a centralized repository of product data that anybody could access at any point in the product lifecycle. As such, it was planned for the digital representation of the product to include all the necessary data for the planning, production, and upkeep of the product [7].

The IoT is predicated on the idea of interaction between digital and physical items. Every real-world item has a detailed digital counterpart that can be accessed from anywhere in the world that details the item's history, provenance, ownership, and sensory context. As IoT-based systems evolve, these digital artifacts often serve as the foundation for smart systems with highly sophisticated control features like monitoring and prediction as mentioned in Table 1. Among other reasons, the novelty of the notion leads to such intelligent systems not being presented as digital twins.

Table 1. Essential traits of digital twin technology.

Qualities	Findings	Reference
Timeliness	A digital twin represents its physical twin in (near) real-time, identifying and synchronizing state changes of the physical object and vice versa.	[8]
Fidelity	Digital twins must be unquestionably reliable and secure to be trusted for decision-making.	[8]
Integration	A digital twin integrates data from all aspects of the physical object in a unified format.	[2]
Intelligence	Digital twins can replicate products, resources, components, and processes. The digital twin can also show multiple interdependent items.	[2]

4. Digital Twins in Greenhouse Horticulture

Horticulture is characterized by a great variety and variability in production. It involves living, perishable products and production dependent on natural conditions such as weather, diseases, soil condition, seasons, and climate. This makes horticulture one of the world's most dynamic and exciting industries. To mitigate these risks, many farmers are turning to greenhouses for year-round indoor production, which provides a better-managed production environment in which temperature, fertigation, light, and moisture can all be optimized. By enabling farmers to take quick action in the face of (anticipated) deviations and to simulate treatments based on real data, digital twins may considerably boost the required control skills. Furthermore, greenhouse horticulture has become more widespread in recent years, as shown in Figure 1. Large-scale manufacturing makes the manual tracking of the growing process impossible. The growing shortage of "green labor," or skilled workers in the field of horticulture, only adds fuel to the fire.

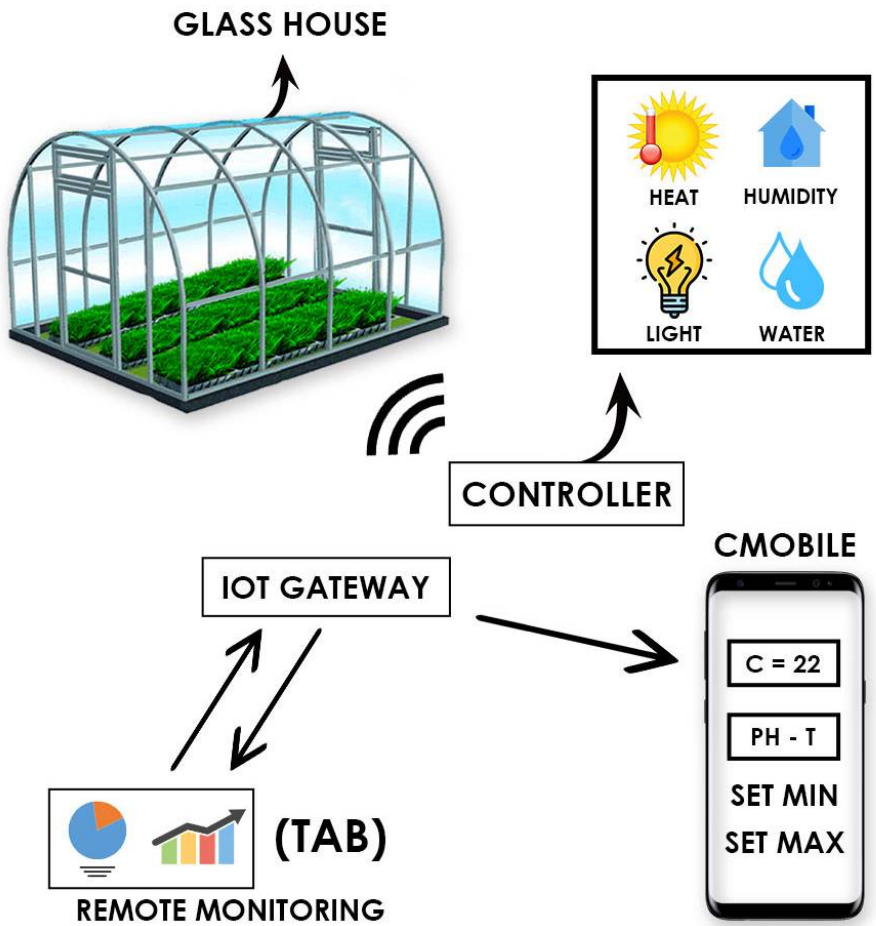

Figure 1. Design and Implementation of Integrated Control System—Sensors for "Smart" Greenhouses based on the Internet of Things (IoT) Technologies (Picture Credit: Kainat Fatima).

Digital twins may help to solve these problems by removing location, time, and human observation restrictions [9]. Remote and automated greenhouse horticulture would allow stakeholders to remotely execute, monitor, control, and coordinate greenhouse activities. This separates physical and information processes in horticulture. Sensor and energy data and data from other information owners may augment digital twins (e.g., weather data), as shown in Figure 1. Digital twins in greenhouse horticulture may also analyze past states and anticipate future behavior in terms of crop growth and yields. Thus, correctly linked digital twin apps may help farmers and stakeholders make decisions, respond instantly to predicted deviations, and remotely regulate greenhouse operations. Intelligence lets digital twins collect the implicit "green" knowledge of experienced horticulturists and learn from data. This will improve production, yields, and quality at the right moment while reducing the demand for experienced workers.

5. Conclusions

Many intricate steps work together to make agriculture. Everything needs to be broken down into manageable steps to increase productivity. How well a product does in the market depends on the farmer, technology, service and consultancy idea. As with the rest of the economy, agriculture will be digitized. The government should allocate time and money to spreading the word about the advantages of digitization among the general public. The rapid growth of e-agriculture is hindered by inadequate connectivity in rural regions, exorbitant service rates, and a lack of fundamental computer literacy and comprehension. Substantial funding is essential for developing physical infrastructure, electrical networks, broadband internet, and transportation.

Author Contributions: Conceptualization, K.F., S.H., S.A.K. and S.R.S.; methodology, K.F., S.H., and S.R.S.; validation, S.R.S., M.A.K. and S.K.; formal analysis, S.H. and K.F.; investigation, S.R.S.; resources, S.H. and S.R.S.; data curation, S.R.S.; writing—original draft preparation, S.H., K.F. and S.H.; writing—review and editing, S.H. and K.F.; visualization, S.R.S. and S. K.; supervision, S.H. and S.R.S.; project administration, S.H., S.R.S. and S.K.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Verdouw, C.; Tekinerdogan, B.; Beulens, A.; Wolfert, S. Digital Twins in Smart Farming. *Agric. Syst.* **2021**, *189*, 103046. [CrossRef]
2. Grieves, M.; Vickers, J. Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In *Transdisciplinary Perspectives on Complex Systems*; Kahlen, F., Flumerfelt, S., Alves, A., Eds.; Springer: Cham, Switzerland, 2018; pp. 85–113.
3. Sundmaeker, H.; Guillemin, P.; Friess, P.; Woelfflé, S. *Vision and Challenges for Realising the Internet of Things*; EU Publications: Luxembourg, 2010.
4. Zude-Sasse, M.; Fountas, S.; Gemtos, T.; Abu-Khalaf, N. Applications of precision agriculture in horticultural crops. *Eur. J. Hortic. Sci.* **2016**, *81*, 78–90. [CrossRef]
5. Shen, S.; Basist, A.; Howard, A. Structure of a Digital Agriculture System and Agricultural Risks Due to Climate Changes. *Agric. Agric. Sci. Procedia* **2010**, *1*, 42–51.
6. Deichmann, U.; Goyal, A.; Mishra, D. Will Digital Technologies Transform Agriculture in Developing Countries? *Agric. Econ.* **2016**, *47*, 21–33. [CrossRef]
7. Pylianidis, C.; Osinga, S.; Athanasiadis, I.N. Introducing Digital Twins to Agriculture. *Comput. Electron. Agric.* **2021**, *184*, 105942. [CrossRef]
8. Yane, D. Research and Analysis about System of Digital Agriculture Based on a Network Platform. In Proceedings of the International Conference on Computer and Computing Technologies in Agriculture, Nanchang, China, 22–25 October 2010; pp. 274–282.
9. Zhai, Z.; Martínez, J.F.; Beltran, V.; Martínez, N.L. Decision support systems for agriculture 4.0: Survey and challenges. *Comput. Electron. Agric.* **2020**, *170*, 105256. [CrossRef]