Smart Agriculture: Transforming Agriculture with Technology

Chapter · October 2023

DOI: 10.1007/978-981-99-7240-1_29

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Abstract. The widespread adoption of digital technologies has brought momentous changes to all economic sectors, and the agriculture sector is no exception. As one of the oldest and most vital professions, agriculture and farming in Chanthaburi, the East of Thailand are also being transformed by the digital revolution. The digital revolution in agriculture, often referred to as "smart farming" or "smart agriculture" involves the integration of various digital tools and technologies into traditional farming practices. These technologies are aimed at enhancing productivity, efficiency, and sustainability in agricultural operations. This study conducts comprehensive various technologies proposed for the agriculture sector. Some of the technologies that could have been included in the study are: Data Center in Chanthaburi (DCC), Internet of Things (IoT), Unmanned Aerial Vehicles (UAVs)) and Smart Agriculture Management System (SAMs). The study also aims to showcase the potential of integrating DCC, and SAMs in agriculture and how these technologies can revolutionize farming practices. The findings could have significant implications for the agricultural industry, encouraging the adoption of these technologies to optimize agricultural processes, increase productivity, and contribute to sustainable farming practices.

Keywords: Smart Agriculture · Internet of Things · Big Data

1 Introduction

According to the Food and Agriculture Organization (FAO), it has been projected that the global population would reach 9.73 billion by the year 2050, with a further growth expected to reach 11.2 billion by the year 2100. Food scarcity and population growth are the greatest obstacles to global sustainable development. Advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), UAVs and mobile internet can offer practical solutions to the

Supported by Burapha University Chanthaburi Campus.

F. Hassan et al. (Eds.): AsiaSim 2023, CCIS 1911, pp. 362–376, 2024.
https://doi.org/10.1007/978-981-99-7240-1_29

global problems [1]. The potential of smart agriculture lies in its utilization of AI, IoT, UAVs and cyber-physical systems in farm management. This integration of advanced technologies can lead to transformative outcomes in agricultural practices, enabling farmers to optimize their operations for enhanced productivity and sustainability. Moreover, smart agriculture tackles numerous crop production challenges through the monitoring of climate factors, soil characteristics, and soil moisture. IoT technology plays a vital role by seamlessly linking various remote sensors, including robots, ground sensors, and drones [2]. These interconnected devices operate automatically, facilitating efficient and real-time data collection and analysis [3].

Over the past few years, farming has witnessed several technical revolutions, leading to increased industrialization and reliance on technology. With the adoption of intelligent agricultural technologies, farmers now have enhanced control over crop cultivation, resulting in greater predictability and efficiency. The integration of smart farming practices has been driven by the growing consumer demand for farm products, contributing to the global proliferation of these advanced technologies in agriculture [4]. The drive is built upon a diverse range of digital technologies, encompassing Big Data, and digital behaviors like collaboration, mobility, and open innovation [5]. These technological components work together to create a dynamic and innovative approach, fostering the effectiveness in achieving its goals. As a result, the data-driven approach empowers farmers to optimize their agricultural practices, leading to improved overall productivity while ensuring sustainability and environmental stewardship.

Farmers can completely use relevant data sources to extract significant insights, regularities, patterns, and knowledge from accumulated data in order to create qualitative goods, enhance revenues, and make well-informed judgments. Big data is important in smart farming because it allows us to properly exploit this abundance of information. Agricultural practices are currently utilizing comprehensive data analysis tools to intelligently and cost-effectively utilize smart farming data. Therefore, the adaptability of big data in smart farming analytics is demonstrated by a variety of common smart-farming applications [6]. These examples show how big data may help farmers acquire useful insights and improve their farming methods.

In addition, big data encompasses vast amounts of information characterized by its high volume, generated at high velocity, and exist in a variety of formats and types [7]. It is difficult to handle and analyze agricultural data using traditional procedures because the sheer volume of data exceeds the capabilities of standard data processing technologies. Specialized technology and cutting-edge analytical techniques like data mining, machine learning, and artificial intelligence are used to extract valuable insights and value from farming data. With the help of these technologies, businesses and industries can turn raw data into useful knowledge, improve processes, and gain a competitive edge in the current data-driven environment [8]. Despite the extensive number of data mining-related studies published, there is a notable scarcity of literature reviews specifically focusing on smart farming. Hence, it is imperative to address the significance of big data in the field of agriculture.

Thus, the primary focus of this study is on the implementation and utilization of smart agriculture techniques. In current smart farming scenarios, academics are progressively directing their attention towards comprehending and executing agricultural data-oriented methodologies in conjunction with data center in Chanthaburi, Thailand. The provided material possesses significant worth for practitioners seeking to include and use big data within their smart farming solutions with farming application. Futhermore, the primary aim of this study is to address the existing gap and provide a comprehensive examination of modern technology and applications that focus on big data in the field of smart farming such as IoT and drone. The contributions of this study are as follows:

1. Filling the Knowledge Gap: By providing a detailed review of agricultural data techniques in smart farming, the study addresses the existing lack of comprehensive information in this area.
2. Insights for Practitioners: The study equips practitioners with valuable insights and knowledge, enabling them to make informed decisions when implementing big data technologies in their smart farming endeavors.
3. State-of-the-Art Analysis: Through a thorough examination of current practices and applications, the study presents the latest advancements and trends in big-data-focused smart farming data analysis.

Therefore, this study serves as a valuable resource for those interested in the intersection of data and smart farming, offering a comprehensive overview of the techniques and applications that drive innovation and efficiency in modern agriculture. The research questions considered as the main criteria for the selection of the research are as follows: What are the various types of data generated by smart agriculture? What are the favored agricultural data applications in smart agriculture? What are the techniques used for smart agriculture big data analysis? By investigating these research questions, the study aims to provide comprehensive insights into the use of big data in Data Center in Chanthaburi (DCC) and Smart Agriculture Management System (SAMs) in Chanthaburi, Thailand, contributing to a better understanding of how data-driven technologies can transform modern agriculture and improve overall agricultural management.

2 Methodology

In the methodology employed for the agricultural data analysis and smart farming practices, the initial step is to gain a comprehensive understanding of the data that will be utilized in the process. This involves exploring the nature of the data, its sources, and the technologies that can be leveraged for effective data management and analysis.

2.1 Types of Data and Data Resources

The objective of this inquiry is to investigate the different data resources and types of data generated within smart farming practices. The focus is on identifying various categories of data collected, encompassing:

Environmental Data: This category includes information related to climate conditions, soil properties, and water characteristics [9]. Data on temperature, humidity, rainfall, soil nutrients, and water availability are some examples that fall under this category [10]. Environmental data is crucial for making informed decisions about irrigation, fertilization, and pest control.

Sensor Data: Derived from IoT devices, robotics, satellite and drones, sensor data provides real-time information on various aspects of the farm [11]. This data can include measurements of soil moisture, temperature, crop growth, and atmospheric conditions. IoT sensors play a significant role in monitoring and managing the farm environment efficiently.

Agricultural Data: This category involves data concerning both crop and livestock aspects of the farm. It includes information on plant growth, crop health, soil characteristics, as well as data related to animal well-being, weight, activity levels, and feeding patterns [12]. Monitoring agricultural data helps optimize crop management practices, detect early signs of crop diseases, ensure proper nutrient management, and improve overall animal husbandry practices. Integrating and analyzing both crop and livestock data enables farmers to make well-informed decisions, enhance productivity, and achieve sustainable and efficient agricultural practices.

Crop Data: This category involves data specifically related to the cultivation and management of crops on the farm. It includes information on plant growth, crop health, soil characteristics, weather conditions, irrigation schedules, fertilization practices, and pest control measures. Monitoring crop data helps farmers optimize planting schedules, assess soil fertility, detect and address crop diseases and pests, and make data-driven decisions to enhance crop yields and overall agricultural productivity [13]. Analyzing and utilizing crop data play a crucial role in implementing precision agriculture practices, conserving resources, and achieving sustainable crop production.

Other Relevant Information Streams: Smart farming may involve the collection of additional data from diverse sources. This can include data from market trends, supply chain logistics, financial records, and other relevant data streams that impact farm operations and decision-making [14].

Indeed, as the volume of data in agriculture continues to grow, proper categorization becomes essential to manage and make sense of the vast amounts of information generated [15]. Categorization helps organize the data in a structured manner, making it easier to access, analyze, and derive meaningful insights.

2.2 Network Organization

The concept of the network organization pertains to how stakeholders within the agricultural ecosystem interact and collaborate to achieve data process objectives effectively. The behavior of stakeholders within the network organization can significantly impact the success of data center processes and the overall outcomes of data-driven agriculture. Understanding and influencing this behavior are crucial for optimizing data center operations and achieving the objectives of data-driven initiatives in agriculture [16]. In this context, stakeholders can include farmers, researchers, data center operators, technology providers, policymakers, and other relevant entities involved in the collection, management, and analysis of agricultural data. The emergence of Big Data and Smart Farming has led to significant technical changes in the agricultural sector, prompting a need to comprehend the stakeholder network surrounding the farm [17].

The landscape of agriculture is evolving, with stakeholders from diverse backgrounds collaborating to leverage data-driven approaches for enhanced efficiency, sustainability, and productivity in agriculture. Indeed, open data sets in the agricultural domain are typically owned and managed by government institutes responsible for collecting and generating the data. In addition, government organizations and corporations, particularly those in the technology and data sectors, have acknowledged the significant opportunities presented by agricultural data center. Consequently, they are making substantial investments in the exploration, advancement, and application of big data technologies within this field. These organizations possess significant resources and specialized knowledge, which empowers them to create advanced data analytics platforms, Internet of Things (IoT) solutions [18], and cloud-based services specifically designed for the agriculture industry [19].

2.3 Data Center

The surge in demands for data processing, data storage, and digital telecommunications has resulted in a significant expansion of the data center industry [20]. Data centers play a crucial role in modern information technology (IT) infrastructure, serving as specialized facilities designed to house and operate IT equipment used for data processing, storage, and communication networking [21]. As depicted in Fig. 1, the data process commences with identifying the sources from which valuable data is extracted [22]. Subsequently, the data is stored in a suitable data model based on its structure - either structured or unstructured (primary data, secondary data, real time data). The next step involves classifying and filtering the data, depending on the specific type of analysis required [23]. The method of processing is then determined, whether it be data cleaning, data transformation, data integration, or data aggregation. Once the data is classified, appropriate tools are employed for analysis. These tools encompass machine learning (ML), regression, deep learning and other data science techniques. The insights obtained from the analysis are then presented using visualization tools. Lastly, precision agriculture involves the application of various technologies such as crop management software and Irrigation systems.

In addition, the ability of data center networks is determined by the effective communication between devices and the responses from data center networks. Data centers serve as critical industrial infrastructure for dynamic computing and storage needs. The Data Center network is tasked with managing an enormous number of elements within the network. This robust infrastructure enables the storage and processing of large amounts of data in a highly efficient and reliable manner. Furthermore, cloud computing facilitates data accessibility and collaboration. Stakeholders in different locations can access, analyze, and share agricultural data seamlessly through cloud-based platforms [24]. This fosters collaboration between farmers, researchers, and other industry players, leading to innovative solutions and improved agricultural practices.

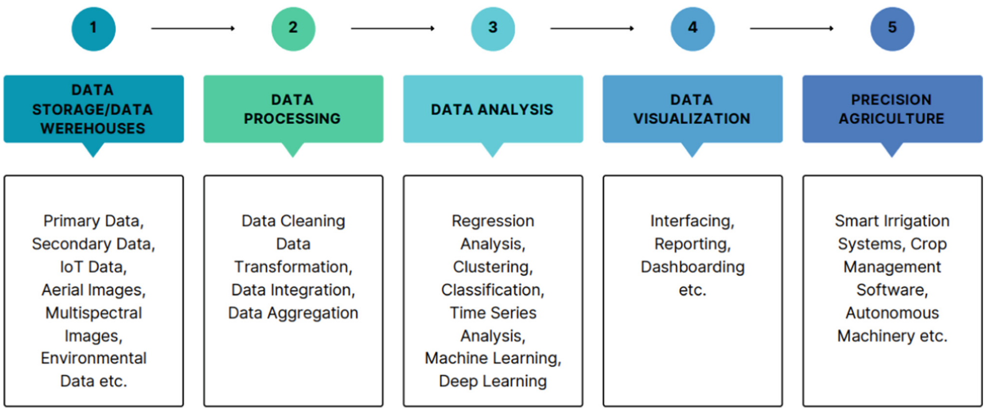

Fig. 1. The framework architecture of data center.

2.4 IoT in Smart Agriculture

In Fig. 2 shows that smart Agricultural Applications concentrate on conducting a thorough examination of current agricultural applications, encompassing a wide range of aspects, including irrigation management, soil quality assessment, weather forecasting, price prediction, and monitoring plant health. For examples, smart irrigation systems are designed to optimize water usage in agriculture by providing the right amount of water to crops at the right time [25]. These systems use soil moisture monitoring devices to measure the moisture content in the soil. Based on the readings, the irrigation system can automatically adjust the irrigation schedule, ensuring that crops receive the appropriate amount of water without overwatering or underwatering [26]. The data collected from smart agriculture applications can be shared with a data center, creating a symbiotic relationship between smart agriculture and data centers. The integration of data centers in smart agriculture allows for centralized storage, management, and analysis of the vast amount of data generated by various IoT devices, sensors, and other smart farming technologies. For fertilization, the data center takes into account factors like soil nutrient levels and crop growth stage. Based on this information, it determines the appropriate amount of fertilizer and other supplements required to support healthy plant growth. The data center then instructs the system to mix and distribute the specified amount of fertilizers to the crops [27].

Therefore, the collaboration between smart agriculture and data centers results in improved agricultural practices, increased productivity, resource efficiency, and enhanced sustainability. By harnessing the power of data analytics and advanced technologies, farmers can make informed decisions to optimize their operations and contribute to the transformation of the agricultural industry.

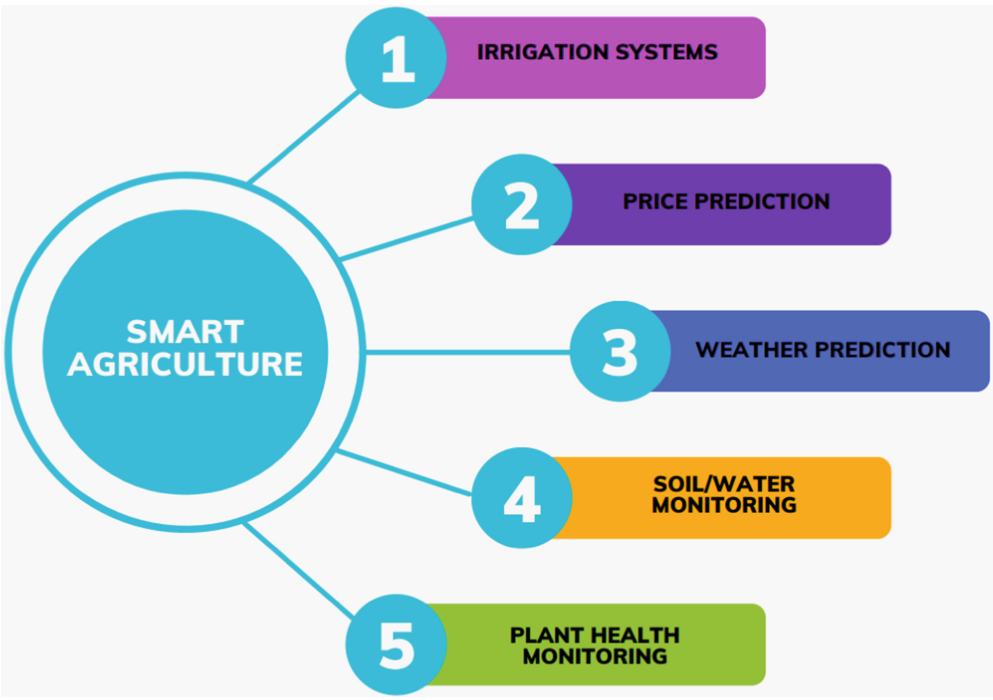

Fig. 2. The implementation of IoT technology in the agricultural sector.

2.5 Machine Learning Models

In the field of smart agriculture, machine learning (ML) algorithms have emerged as powerful tools for analyzing the vast amounts of agricultural data generated today. These techniques have been widely applied to analyze various types of smart farming data, including environmental data, sensor data, and crop data, among others. For example, linear regression is a fundamental ML technique used for predicting numerical values based on input features. In smart agriculture, it can be applied to analyze climate data and predict crop yields, helping farmers make informed decisions about irrigation, fertilization, and pest control [28]. Similarly, time series analysis techniques are used to analyze data that changes over time. In smart agriculture, time series analysis can be employed to study weather patterns, monitor crop growth, and predict market trends. Artificial Neural Networks (ANNs) and their variants have indeed become one of the most widely utilized techniques in the field of smart agriculture. In smart agriculture, ANNs have been applied to various applications, and one of the significant areas of use is yield prediction [29]. Yield prediction models based on ANNs take into account various factors such as climate data, soil characteristics, crop variety, and management practices [30]. They are also used for image recognition in precision agriculture, enabling identification of pests, diseases, and weed species from images captured by drones or cameras. The machine learning algorithm and applications are listed in Table 1.

Table 1. Machine learning models and applications in smart agriculture.

Machine learning Algorithm	Application	Reference
Linear Regression	Minimization of fertilizer and water	[28]
Linear Regression	Prediction of yield	[31]
Gaussian	Detection of leaves	[32]
ANN	Prediction of yield	[29]
ANN	Optimization of water	[30]
Random Forest	Prediction of yield	[33]
Support vector machines	Detection of fruit	[34]

3 Application of Smart Agriculture

Chanthaburi, being one of the agricultural provinces in the east, is an excellent starting point for the smart agriculture, considering its significance in the agricultural sector. By starting with Chanthaburi and gradually expanding to cover other provinces, smart agriculture will play a crucial role in transforming the agricultural landscape in the region. It will empower farmers with data-driven tools and knowledge, fostering a culture of continuous learning and improvement in the agricultural community.

3.1 Data Center in Chanthaburi

Having a dedicated agricultural data center in Chanthaburi, Thailand, in the east of the country, will reflect a commitment to harnessing the power of data and technology to drive agricultural advancements, sustainability, and productivity. It will serve as a vital resource for the entire agricultural community, helping them adapt to the challenges of modern farming and contribute to the growth and development of the region's agricultural sector.

The data center will also foster collaboration and knowledge-sharing among different stakeholders within the agricultural ecosystem. This data center will be a valuable repository of time series data, particularly secondary data, obtained from various government organizations. This data will encompass a wide range of agricultural-related information, including crop yield data, labor statistics, economic indicators, weather data, and more.

As the data center evolves and expands its scope to cover more provinces in the east of Thailand, it can become a regional hub for agricultural information and innovation. Farmers across the region will have access to valuable insights and historical data, aiding them in adapting to the challenges posed by modern farming and making informed choices for their agricultural operation.

After classifying the data, a variety of appropriate tools are employed for analysis, such as data visualization, machine learning, and other data science techniques. The data can be exported as a csv file, enabling users to select and visualize the information. The results and insights derived from this analysis are then presented through visualization tools, as depicted in Fig. 3, facilitating users' comprehension and interpretation of the data effectively.

Fig. 3. Functions of data center in Chanthaburi.

For primary data, IoT will continuously capture and store the data in real-time. IoT devices and sensors are equipped to gather data directly from the source, such as agricultural fields, livestock, weather conditions, and other relevant aspects. The data collected by IoT devices is transmitted in real-time to a centralized system or data center, where it is processed, analyzed, and made available for further use. Moreover, the data collected by drones is then stored in the data center for future analysis. As the data center accumulates a significant amount of image data over time, it becomes a valuable repository for assessing crop yield, monitoring changes in vegetation health, and conducting comprehensive analyses to improve agricultural practices. By combining the real-time data collected by IoT devices with image data from drones, the data center can provide a comprehensive view of the farm's performance. This integrated approach to data collection and analysis empowers farmers to make informed decisions, optimize resource allocation, and enhance overall crop yield and farm productivity. Additionally, it facilitates research and innovation in the agriculture sector, leading to the development of more efficient and sustainable farming practices.

3.2 Smart Agriculture Management System (SAMs)

SAMs, which stands for "Smart Agricultural Management System" is a blockchain-based solution designed to enhance traceability, transparency, and security in the agricultural supply chain [35]. By integrating blockchain technology into the data center, SAMs can significantly improve the management and sharing of agricultural data. Figure 4, the context of SAMs application demonstrates that the traceability of durian refers to the capability of tracking the journey of durian fruits from their point of origin (e.g., the farm where they were grown) through various stages in the supply chain until they reach the end consumer or market [36]. Therefore, the traceability of durian through SAMs empowers stakeholders along the supply chain, including farmers, distributors, retailers, and consumers, to have greater confidence in the origin, quality, and

Fig. 4. Traceability of durian of SAMs application.

safety of durian products. This enhanced transparency and trust contribute to a more efficient and sustainable agricultural ecosystem.

SAMs will initially be implemented and tested with durian farms. How SAMs can enhance the traceability of durian? Information about the durian variety, harvest date, farming practices, and quality control measures can be documented on the blockchain. Consumers can access this data by scanning a QR code on the product packaging, gaining insight into the product's authenticity and quality. In addition, each durian's origin, handling, processing, and transportation details are securely recorded on the blockchain. By providing transparent information about the durian's journey from farm to table (Fig. 5), SAMs fosters consumer trust. Consumers can make informed decisions, supporting sustainable and ethical practices in the agriculture sector.

Fig. 5. SAMs application on mobile.

4 Discussion

The research questions formulated in the Introduction and provide answers to each of them based on the discussion presented: What are the various types of data generated by smart agriculture? The data center and SAMs will serve as a central repository for storing agricultural data collected from various organizations and stakeholders in the agricultural sector [37]. Initially, the focus of data storage and management will be on Chanthaburi, and subsequently, it will expand to cover other provinces in the east of Thailand. This approach ensures a systematic and scalable implementation of data storage and analysis capabilities to cater to the agricultural needs of the entire region Data center and SAMs will generate a wide variety of data [38], including environmental data (climate factors, soil characteristics), crop health data (disease, pests, nutrient levels), farm equipment data (operational status, fuel consumption), market and price data, satellite, drone and remote sensing data, energy consumption data, water usage data, farm operations data, and financial data. This diverse range of data enables precision agriculture, efficient resource utilization, and informed decision-making for optimal agricultural practices [39].

What are the favored agricultural data applications in smart agriculture? In smart agriculture, various agricultural data applications are favored for optimizing farm management, increasing productivity, and ensuring sustainability. The integration of a data center and Smart Agricultural Management System (SAMs) further enhances the capabilities of these applications. Some of the favored agricultural data applications in smart agriculture, empowered by the data center and SAMs, include: precision agriculture, crop monitoring, weather and climate prediction, market analysis and price prediction, and sustainable farming practices [40]. It highlights how data center-supported data applications play a pivotal role in promoting sustainable farming practices by enabling farmers to monitor and optimize resource usage. Specifically, IoT-based irrigation systems efficiently manage water usage, leading to reduced water wastage and minimizing environmental impacts [41].

What are the techniques used for smart agriculture big data analysis? Smart agriculture utilizes various techniques for big data analysis to derive meaningful insights and optimize agricultural practices such as machine learning, data visualization and internet of things (IoT) analytics. Together, data center and SAMS create a robust ecosystem that empowers smart agriculture big data analysis. By harnessing the power of advanced technologies, they drive agricultural advancements, optimize resource utilization, and contribute to sustainable and data-driven farming practices [42].

Therefore, the integration of a data center and SAMs application will plays a crucial role in facilitating the successful implementation and operation of this advanced agricultural technology. First of all, the data center acts as a central hub for managing, storing, and processing the vast amount of agricultural data collected. The data center enhances the efficiency, reliability, and effectiveness of the entire agricultural ecosystem. Secondly, the SAMs application complements the data center by providing specialized functionalities and insights tailored to the unique needs of smart agriculture. SAMs serves as an intelligent decision support system that leverages the data center's data resources to offer real-time monitoring, analysis, and recommendations for farm management. Thirdly, SAMs plays a vital role in tracking and ensuring traceability throughout the agricultural supply chain. By integrating data center capabilities with SAMs' tracking functionalities, smart agriculture can achieve enhanced traceability and transparency in various stages of the agricultural process.

5 Conclusion

In conclusion, the agriculture sector's importance in the global economy cannot be overstated, as it drives economic growth and employment opportunities, especially in rural regions. In developing countries like Thailand, agriculture holds a pivotal role in poverty reduction and economic advancement, contributing to the overall prosperity of the nation. The continuous development and enhancement of the agricultural sector in Thailand, fueled by technological advancements and data-driven approaches, further strengthen its potential for sustainable growth and improved livelihoods. Embracing smart agriculture practices, facilitated by the integration of data center and Smart Agricultural Management System (SAMs), empowers farmers with valuable insights, real-time monitoring, and efficient resource management.

The data center acts as a central hub for storing and processing vast amounts of agricultural data, while SAMs offers intelligent decision support and automation, enabling precise and sustainable farming practices. Together, they foster a more productive, resilient, and environmentally conscious agricultural ecosystem, addressing modern challenges and ensuring the well-being of farmers and communities. By making a plan for the future and putting it into action, Chanthaburi's agriculture industry will be able to reach its full potential and become a model of data-driven, sustainable, and resilient agriculture. Integrating new technologies, building more data centers, and using smart farming methods will help create a prosperous and environmentally friendly agricultural setting in the future.

Acknowledgements. We would like to express our heartfelt gratitude to the dedicated and hardworking teams at the Data Center and UAVs (Unmanned Aerial Vehicles) in Chanthaburi, Thailand. Their unwavering support and collaboration have been instrumental in the success of our endeavors in the field of smart agriculture.

References

1. Mohamed, E.S., Belal, A.A., Abd-Elmabod, S.K., El-Shirbeny, M.A., Gad, A., Zahran, M.B.: Smart farming for improving agricultural management The Egyptian. J. Rem. Sens. Space Sci. **24**(3), 971–981 (2021)
2. Adamides, G., et al.: Smart farming techniques for climate change adaptation in Cyprus. Atmosphere **11**(6), 557 (2020)
3. AlMetwally, S.A.H., Hassan, M.K., Mourad, M.H.: Real time internet of things (IoT) based water quality management system. Proc. CIRP **91**, 478–485 (2020)
4. Javaid, M., Haleem, A., Singh, R.P., Suman, R.: Enhancing smart farming through the applications of Agriculture 4.0 technologies. Int. J. Intell. Netw. **3**, 150–164 (2022)
5. De Alwis, S., Hou, Z., Zhang, Y., Na, M.H., Ofoghi, B., Sajjanhar, A.: A survey on smart farming data, applications and techniques. Comput. Ind. **138**, 103624 (2022)
6. Othman, M.M., Ishwarya, K.R., Ganesan, M.: A study on data analysis and electronic application for the growth of smart farming. Alinteri J. Agric. Sci. **36**(1), 209–218 (2021)
7. Wolfert, S., Ge, L., Verdouw, C., Bogaardt, M.J.: Big data in smart farming-a review. Agric. Syst. **153**, 69–80 (2017)
8. De Mauro, A., Greco, M., Grimaldi, M.: A formal definition of Big Data based on its essential features. Libr. Rev. **65**(3), 122–135 (2016)
9. Sun, J., Zhou, Z., Bu, Y., Zhuo, J., Chen, Y., Li, D.: Research and development for potted flowers automated grading system based on internet of things. J. Shenyang Agric. Univ. **44**(5), 687–691 (2013)

10. Li, P., Wang, J.: Research progress of intelligent management for greenhouse environment information. Nongye Jixie Xuebao= Trans. Chin. Soc. Agric. Mach. **45**(4), 236–243 (2014)
11. Faulkner, A., Cebul, K., McHenry, G.: Agriculture gets smart: the rise of data and robotics. Cleantech Agriculture Report (2014)
12. Cole, J.B., Newman, S., Foertter, F., Aguilar, I., Coffey, M.: Breeding and genetics symposium: really big data: processing and analysis of very large data sets. J. Anim. Sci. **90**(3), 723–733 (2012)
13. Bauer, J., Aschenbruck, N.: Design and implementation of an agricultural monitoring system for smart farming. In: 2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany), pp. 1–6. IEEE (2018)
14. Miller, H.G., Mork, P.: From data to decisions: a value chain for big data. It Professional **15**(1), 57–59 (2013)
15. Hartmann, P.M., Zaki, M., Feldmann, N., Neely, A.: Capturing value from big data-a taxonomy of data-driven business models used by start-up firms. Int. J. Oper. Prod. Manag. **36**(10), 1382–1406 (2016)
16. Glaroudis, D., Iossifides, A., Chatzimisios, P.: Survey, comparison and research challenges of IoT application protocols for smart farming. Comput. Netw. **168**, 107037 (2020)
17. Carolan, M.: Acting like an algorithm: Digital farming platforms and the trajectories they (need not) lock-in. In: Desa, G., Jia, X. (eds.) Social Innovation and Sustainability Transition, pp. 107–119. Springer Nature Switzerland, Cham (2022). https://doi.org/10.1007/978-3-031-18560-1_8
18. Navarro, E., Costa, N., Pereira, A.: A systematic review of IoT solutions for smart farming. Sensors **20**(15), 4231 (2020)
19. Idoje, G., Dagiuklas, T., Iqbal, M.: Survey for smart farming technologies: challenges and issues. Comput. Electr. Eng. **92**, 107104 (2021)
20. Ren, J., Zhang, D., He, S., Zhang, Y., Li, T.: A survey on end-edge-cloud orchestrated network computing paradigms: transparent computing, mobile edge computing, fog computing, and cloudlet. ACM Comput. Surv. (CSUR) **52**(6), 1–36 (2019)
21. Huang, P., et al.: A review of data centers as prosumers in district energy systems: renewable energy integration and waste heat reuse for district heating. Appl. Energy **258**, 114109 (2020)
22. Santos, M.Y., et al.: A big data analytics architecture for industry 4.0. In: Rocha, Á., Correia, A.M., Adeli, H., Reis, L.P., Costanzo, S. (eds.) WorldCIST 2017. AISC, vol. 570, pp. 175–184. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-56538-5_19
23. Cravero, A., Pardo, S., Sepúlveda, S., Muñoz, L.: Challenges to use machine learning in agricultural big data. Syst. Lit. Rev. Agron. **12**(3), 748 (2022)
24. Bo, Y., Wang, H.: The application of cloud computing and the internet of things in agriculture and forestry. In: 2011 International Joint Conference on Service Sciences, pp. 168–172. IEEE (2011)
25. Alex, N., Sobin, C.C., Ali, J.: A comprehensive study on smart agriculture applications in India. Wirel. Pers. Commun. **129**(4), 2345–2385 (2023)
26. Shock, C.C., Pereira, A.B., Feibert, E.B., Shock, C.A., Akın, A.İ., Ünlenen, L.A.: Field comparison of soil moisture sensing using neutron thermalization, frequency domain, tensiometer, and granular matrix sensor devices: relevance to precision irrigation (2016)

27. Dai, B., Xu, G., Huang, B., Qin, P., Xu, Y.: Enabling network innovation in data center networks with software defined networking: a survey. J. Netw. Comput. Appl. **94**, 33–49 (2017)
28. Muhammed, S.E., Marchant, B.P., Webster, R., Whitmore, A.P., Dailey, G., Milne, A.E.: Assessing sampling designs for determining fertilizer practice from yield data. Comput. Electron. Agric. **135**, 163–174 (2017)
29. Akbar, A., Kuanar, A., Patnaik, J., Mishra, A., Nayak, S.: Application of artificial neural network modeling for optimization and prediction of essential oil yield in turmeric (Curcuma longa L.). Comput. Electron. Agric. **148**, 160–178 (2018)
30. Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., Nillaor, P.: IoT and agriculture data analysis for smart farm. Comput. Electron. Agric. **156**, 467–474 (2019)
31. Lobell, D.B.: The use of satellite data for crop yield gap analysis. Field Crop Res **143**, 56–64 (2013)
32. Motokura, K., Takahashi, M., Ewerton, M., Peters, J.: Plucking motions for tea harvesting robots using probabilistic movement primitives. IEEE Robot. Autom. Lett. **5**(2), 3275–3282 (2020)
33. Bocca, F.F., Rodrigues, L.H.A.: The effect of tuning, feature engineering, and feature selection in data mining applied to rainfed sugarcane yield modelling. Comput. Electron. Agric. **128**, 67–76 (2016)
34. Ramirez-Paredes, J.P., Hernandez-Belmonte, U.H.: Visual quality assessment of malting barley using color, shape and texture descriptors. Comput. Electron. Agric. **168**, 105110 (2020)
35. Zhang, Y., et al.: Blockchain: an emerging novel technology to upgrade the current fresh fruit supply chain. Trends Food Sci. Technol. **124**, 1–12 (2022)
36. Yang, X., Li, M., Yu, H., Wang, M., Xu, D., Sun, C.: A trusted blockchain-based traceability system for fruit and vegetable agricultural products, pp. 36282–36293. IEEE (2021)
37. Coble, K.H., Mishra, A.K., Ferrell, S., Griffin, T.: Big data in agriculture: a challenge for the future. Appl. Econ. Perspect. Policy **40**(1), 79–96 (2018)
38. Weersink, A., Fraser, E., Pannell, D., Duncan, E., Rotz, S.: Opportunities and challenges for big data in agricultural and environmental analysis. Ann. Rev. Resour. Econ. **10**, 19–37 (2018)
39. Weiss, M., Jacob, F., Duveiller, G.: Remote sensing for agricultural applications: a meta-review. Remote Sens. Environ. **236**, 111402 (2020)
40. Wu, B., et al.: Challenges and opportunities in remote sensing-based crop monitoring: a review. Natl. Sci. Rev. **10**(4), p.nwac290 (2023)
41. Martínez, R., Vela, N., El Aatik, A., Murray, E., Roche, P., Navarro, J.M.: On the use of an IoT integrated system for water quality monitoring and management in wastewater treatment plants. Water **12**(4), 1096 (2020)
42. Yousif, J.H., Abdalgader, K.: Experimental and mathematical models for real-time monitoring and auto watering using IoT architecture. Computers **11**(1), 7 (2022)