7 *Env. Biodiv. Soil Security*, **Vol. 6**, pp: 81 - 90 (2022)

Environment, Biodiversity & Soil Security

http://jenvbs.journals.ekb.eg/

Applications and Challenges of Smart Farming for Developing Sustainable Agriculture

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Agriculture is the backbone of any nation, which supplies with the needed foods, feeds, fiber and fuel. The crucial sector has become more flexible and advanced due to the enormous progress in the bioinformatics, which penetrates all fields in our life. Smart agriculture is an important page in the history of global agriculture, which already used several advanced technologies during different agricultural practices starting from the pre-cultivation, cultivation, seedling, fertilization, weed detection, irrigation, spraying pesticides, till harvesting and also pot-harvest. Many sectors have been involved in smart farming like smart irrigation, and all precision farming practices for improving and management of the agriculture especially in the developing countries, which need more supporting from their governments even at the private sector and the small farms level. This short communication is a call for submitting articles on smart farming and its applications in different agricultural practices including irrigation, fertilization, and etc. Due to smart agriculture mainly depends on the bioinformatics, this technology has several open questions particularly their applications, models, and security, which need further investigations.

Keywords: Smart irrigation, Smart agriculture, Bioinformatics, Fertilization, Sustainability.

1. Smart agriculture: and its applications

Agriculture is the main source for supplying the human and animal with their needs from foods, feeds, fiber and sometimes fuel as fundamental pillar for achieving the economic and social development (**Fig. 1**). Based on the high and advanced technologies (e.g., artificial intelligence 'AI', the Internet of Things 'IoT', and the mobile internet) in our life, the agriculture also improved due to this revolution (Mohamed et al. 2021). The advanced agriculture practices based on technology of information is called smart agriculture. Smart farming or smart agriculture is a kind of agriculture, which several modern technologies are used in both agricultural and livestock sectors in order to increase the quantity of production, and its quality through making maximizing usage of the resources and minimizing the environmental impacts (Monteiro et al. 2021). So, smart agriculture has the ability to establish a great future due to the modern agriculture depends on all available bioinformatics (**Fig. 2**). There are 6 main components should be achieved for the concept of smart agriculture including (1) collecting data and their analyzing, (2) artificial intelligence powered robots, (3) wireless sensor networks, (4) using drone technology, (5) using the internet of things and cloud computing, and (6) software applications (Abbasi et al. 2022).

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Received: 25/04/2022; Accepted: 26/05/2022
DOI: 10.21608/JENVBS.2022.135889.1175

Fig. 1. The agriculture sector is very important source for our life to supply with the necessary foods, feed for our animals, fiber and fuel. The pictures are presenting different sectors in the agriculture including sector of vegetables, fruits, and agricultural drainage water. All photos were taken by El-Ramady from the experimental farming, faculty of agriculture, Kafrelsheikh university and El-Hamoul City, and Kitchener drain. All photos by El-Ramady.

Fig. 2. Smart agriculture or farming has a great future due to the modern agriculture depends on all available bioinformatics in many fields. Source: https://www.oda-agri.fr/introduction-to-agricultural-science/ 10.3.2022, https://saiard.co.in/centre-for-studies-in-smart-agriculture/

https://www.iot83.com/smart-farming-the-future-of-agriculture/
https://www.shutterstock.com/search/agriculture

Smart agriculture is also called agriculture 4.0, which was also termed digital farming or smart farming due to almost agriculture practices are smart. What is the difference between agriculture 4.0 and industry 4.0? The agriculture 4.0 was generated from the industrial agriculture, and based on the 4^{th} industrial revolution, which led to reshaping every industry (Abbasi et al. 2022). The digital agriculture has priority research, which may include the following topics data management, governance, enabling use of data and technologies, understanding benefits and uptake of data and technologies, new collaborative arrangement, optimizing data and technologies for performance, and impacts of digital agriculture (Ingram et al. 2022). What are the most important emerging disruptive digital technologies? They include artificial intelligence (AI), additive manufacturing (AM), big data and analytics (BDA), cloud computing (CC), Internet of Things (IoT), system integration (SI), simulation, autonomous robotic systems (ARS), augmented reality (AR), wireless sensor networks (WSN), cyber-physical system (CPS), and digital twin (DT) (Kalyani and Collier 2021; Abbasi et al. 2022). There are several applications of smart farming such as water management (using sensors for crop specific irrigation, crop water requirements), animal care (monitoring of animal health, animal tracking), farmer helpline (solving problems by experts, and farm management (climatic specific suggestion, maintain crop growth till harvest), and crop care (protecting crop from pests and animals, and solving problem of excess water) (Nawandar and Satpute 2019; Azadi et al. 2021). Day by day, new publications on smart agriculture could be found in the scientific journals as presented in Table 1.

Table 1. List of the most important published articles on smart agriculture this year (2022).

The main title or topic of the published article	References
The digitization of agricultural industry – a systematic literature review on agriculture 4.0	Abbasi et al. (2022)
Smart irrigation monitoring and control strategies for improving water use efficiency in precision agriculture: A review	Bwambale et al. (2022)
Towards smart farming: fog-enabled intelligent irrigation system using deep neural networks	Cordeiro et al. (2022)
Wireless sensor deployment scheme for cost-effective smart farming using the ABC-TEEM algorithm	Dananjayan et al. (2022)
Smart farming technologies adoption and their factors which play a role in the digital transition	Giua et al. (2022)
Classification and yield prediction in smart agriculture system using the IoT system	Gupta and Nahar (2022)
What is the priority research question for digital agriculture?	Ingram et al. (2022)
Design and deployment of a practical IoT-based monitoring system for protected cultivations to help farmers by increase farm-efficiency	Hernández-Morales et al. (2022)
Real-time and IoT-based cloud-enabled service for smart agriculture decision-making system	Raju and Vijayaraghavan (2022)
IoT enabled mushroom farm automation with machine learning to classify toxic mushrooms in Bangladesh	Rahman et al. (2022)
IOT based smart irrigation management system for environmental sustainability in India	Sangeetha et al. (2022)
A survey on recent advancements and challenges of Internet of Things in smart agriculture	Sinha & Dhanalakshmi (2022)
Using internet of things and artificial intelligence for the smart greenhouse monitoring system	Soheli et al. (2022)
Review of agricultural IoT technology	Xu et al. (2022)
Developments, applications, and challenges on few-shot learning in smart agriculture	Yang et al. (2022)
Autonomous application controls on smart irrigation	Veerachamy et al. (2022)
Increasing productivity of rice plants based on IoT (Internet of Things) to realize smart agriculture using system thinking approach	Wicaksono et al. (2022)

There are many IoT applications in the agricultural sector as follows:

1– Smart soil cultivation system to include preparing the soil for cultivation, weeding, ploughing, preparing of seedbeds and sowing,

2– Smart irrigation systems to be automatized to supply the required water irrigation requirements in a controlled manner,

3– Smart fertilizer systems through the automatized spraying of fertilizers to the field under control the quantity and quality of fertilizer as well as controlling the period of spraying,

4– Smart pest detection and control systems by monitoring and detecting the infestation of pests on cultivated crops using different techniques for controlling this infestation,

5– Smart livestock farming using smart technologies for breeding livestock,

6– Smart harvesting system using IoT-based techniques to reap the harvest of a field efficiently,

7– Smart farm management system by providing analytics and evaluation recording data to improve the productivity of cultivated crops in the field, and

8– Smart groundwater quality management system by monitoring and maintaining proper levels of groundwater for on the crop and livestock production (Vangala et al. 2022).

2. Precision farming and its components

The concept of precision agriculture (PA) was emerged for the first time and introduced by the United States House of Representatives in 1997. Precision agriculture could be defined as an integrated information and production-oriented farm system, which designated and aims to improve site-specific, long-term, and whole farming production, typically in productivity, efficiency, and profitability, while at the same time minimizing un-wanted impacts on the environment and wildlife (Tan et al. 2022). Many distinctive elements could be identified from the main definitions of PA in **Table (2**) including the application, technology, and sustainability. The PA term also focuses on (*i*) adoption of technologies to recognize (e.g., detect, monitor, analyze, and predict) temporal and spatial site-specific information, (*ii*) incorporation of application-oriented technologies, and (*iii*) maximization the available resources and minimization waste and their negative impacts on the environment (Tan et al. 2022).

Table 2. Definition of precision agriculture (PA) over the last years from different sources.

The definition	Reference
'Precision agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.'	Journal of Precision Agriculture (2022)
Precision Agriculture (PA) is calling site-specific farming or the develop of the high-quality agricultural production using a technological approach through modern data technology and knowledge	Akhter and Sofi (2022)
PA is defined as an integrated information and production-oriented farm system, which designated for improving site-specific, long-term, and whole farming production, as well as improving the efficiency, productivity, and profitability with minimum impacts on the environment at the same time	Tan et al. (2022)
Precision farming is an emerging field, which includes the communication technologies (ICT), and information, aims at real-time monitoring and management of the smallest production units to improve the farming process	Mahmud et al. (2021)
Precision agriculture is a new technology that utilizes satellite technology, Information Technology (IT), Geographical Information System (GIS), and remote sensing for enhancing all functions and services of the agriculture	Torky and Hassanein (2020)
Precision farming or precision agriculture (PA) is one such instrument which is effective in making agriculture more 'climate smart' by reducing its impact on the environment	Roy and George (2020)
Precision agriculture is a management strategy, which utilizes information technologies in collecting useful data from distinct sources, with the aim of supporting the decisions associated to the production of crops	Cisternas et al. (2020)
PA is a contemporary farming management concept that uses digital tools to track and optimize agricultural production processes.	STOA (2016)
PA's applicability is based on the utilization of technology to identify and determine what is correct	Pierpaoli et al. (2013)
PA is a crop management method that takes into account field variability as well as site-specific variables. PA technologies are any technology that can be used alone or in combination to achieve PA.	Tey and Brindal (2012)
That type of agriculture that increases the number of (right) judgments per unit area of land per unit time with related net benefits	McBratney et al. (2005)
PA can assist in the ecologically responsible management of agriculture production inputs.	Bongiovanni and Lowenberg-Deboer (2004)
PA is based on a system approach to reorganizing the entire agriculture system toward low-input, high-efficiency, and long-term sustainability.	Zhang et al. (2002)
PA is a discipline designated to improve the efficiency of agriculture management. It involves the development of new technologies, the modification of old technologies, and the integration of monitoring and computing at the farm level for a specific purpose.	Kirchmann and Thorvaldsson (2000)
PA is the use of technologies and techniques to control the spatial and temporal variability in all elements of agricultural production to improve crop performance and environmental quality. PA is made possible by technological advancements.	Pierce and Nowak (1999)

Nowadays, the precision farming depends upon Artificial Intelligence (AI), blockchain, mobile applications, drones, cloud computing, smart sensors, and internet of Things (IoT) (Torky and Hassanein et al. 2020). Based on the previous technologies, it is become possible to process and access real-time data about the conditions of the soil, crops, food safety, weather along with other relevant services such as crops and fruits supply chain, and animal grazing (Torky and Hassanein 2020). Precision agriculture can often maximize the long-term supply of soil and water, due to them consider as inexhaustible or plentiful resources, as well as minimizing losses and waste of other resources (Cisternas et al. (2020). Many benefits could be achieved also by following the system of precision farming such as increase the crops yield, reduce the variability and input costs. The hardware devices and software systems are technologies could be utilized by PA, which process the data captured by the devices, providing the necessary information for the decision-making processes (Cisternas et al. (2020).

The main components of precision farming are mainly related to capturing the on-farm variability for better management. The main steps in precision farming include (1) precision soil preparation through soil survey, (2) precision seeding through crop scouting, (3) precision crop management, (4) precision harvesting through yield monitoring and (5) database analyses through networking and evaluation to get precise results (Roy and George 2020). The modern precision farming system is an amalgamation of several techniques including (a) global positioning system, (b) sensor technologies, (c) geographic information system, (d) variable rate technologies, (e) grain yield monitors for mapping, and (f) crop management (Roy and George 2020). Several agricultural practices or management of activities could be improved using the precision farming such as irrigation (fertigation) using Internet of Things (Lin et al. 2020), crop disease detection (Yang 2020; Jiao et al. 2022), the desert agriculture (Garg et al. 2022), improving water use efficiency (Bwambale et al. 2022), forecasting the crop yield like sugarcane (Han et al. 2022), exploring strategies for balance agricultural production (Wang et al. 2022), and precision seeding (Chen et al. 2022).

3. Smart agriculture challenges

Agricultural industry is considered a promising industry because several vital industries derive their raw materials from agriculture beside its contribution to the economy (Vangala et al. 2022). Smart farming also can use the new technology of 5G "5G-enabled IoT-based smart agriculture", which means the 5th generation mobile network and is defined as "*a new wireless communication technology that has the capability to connect a million devices per square kilometer with about a 100 times more uploading and downloading speeds compared to the fourth generation of mobile technology* (4G) *and fourth generation long-term evolution* (4GLTE) *technologies and latencies as low as* 1 ms" (Vangala et al. 2022). Based on the global water crisis, the management of smart agriculture in irrigation is very important as reported by many recent reports such as Cáceres et al. (2021), Karmakar and Sarkar (2021), Liu et al. (2022), and Sami et al. (2022).

Concerning the benefits of smart agriculture, there are several benefits that are achieved through smart agriculture including the following issues:

1– Increase production quantity by applying smart technologies in the agricultural sector, which can support the increased production,

2– Increase production quality by improving the quality of produced foods to be healthier,

3– Efficiency of agricultural process and usage of resources by using smart technologies during the regular agro-processes, which can improve the efficiency of execution of these agro-processes,

4– Optimal cultivation cost by using highly efficient processes to reduce the overall costs of cultivation, at the same time, with increasing the benefits of the obtained agro-outputs,

5– Reduction of wastages by reducing wastes of food and other intermediate resources in the agriculture sector,

6– Time efficiency by following smart agriculture due to its high capability for timing nearly all required agro-practices like application of fertilizers, pesticides, and other chemicals, which can produce with minimal losses, and

7– Eco-friendly agricultural processes by reducing the agricultural wastage, which will direct decrease the environmental carbon footprint (Vangala et al. 2022).

The proposed challenges in smart farming man be linked to the architecture of smart farming and its layers (**Fig. 3**).

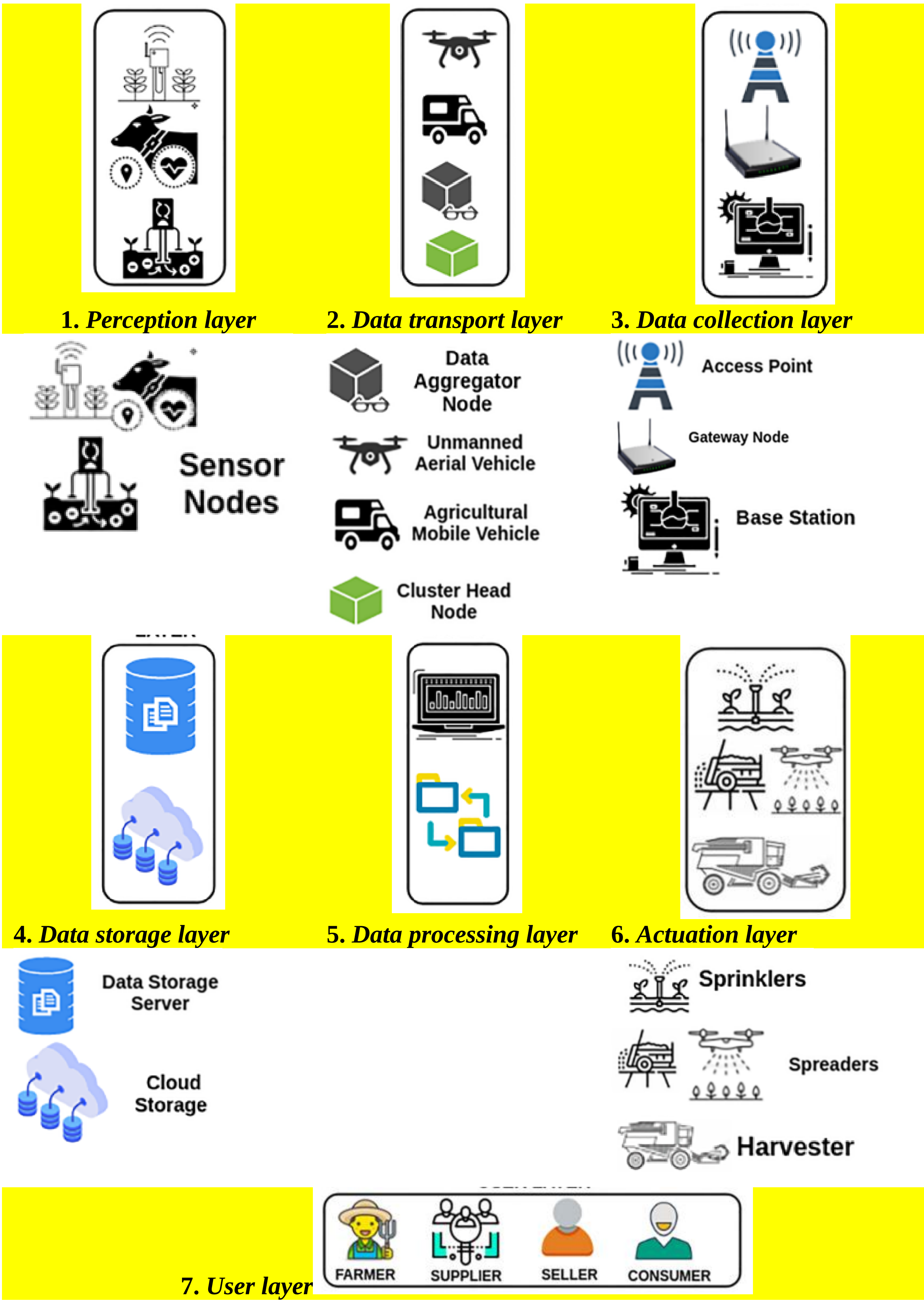

Fig. 3. General layered architecture for smart agriculture (Source: Vangala et al. 2022).

Many published articles have been issued on different challenges facing the smart farming as follows:

1- The challenges that face the few-shot learning in smart agriculture. These challenges may include (*i*) the current agricultural few-shot learning work is just only theoretical research, (*ii*) the lack of robustness of the trained model and cannot effectively identify the objects in the real scene, (*iii*) the images collected based on the natural environment will have uneven illumination due to lighting, weather and other reasons, (*iv*) increases in the difficulty of implementation of this technology, which needs to be adjusted to local conditions, (*v*) very few studies on applied few-shot learning in agriculture and plants, and (*vi*) few-shot learning itself is a challenge (Yang et al. 2022),

2- The challenges related to security in IoT-enabled smart agriculture (Vangala et al. 2022),

3- Challenges face the security and privacy issues in smart cities/industries (Rao and Deebak 2022),

4- Many challenges may face Internet of Things in smart agriculture including IoT standardization, IoT data, regulatory and market issues, security, reliability, scalability, localization, networking issue, and resource optimization (Sinha and Dhanalakshmi 2022),

5- Challenges of smart farming technologies, which may include AI for early disease detection, detection of leaf water stress in crops, the computational power of IoT devices used in smart farm, detection of soil conditions, livestock illness, and behavior pattern within the farm (Idoje et al. 2021), and

6-. Many barriers and hurdles or challenges of smart farming have been reported based on the interview on different level including farmers level (too expensive investments, lack of technical education, technical systems not connected, difficulties understanding and acting on data, unpredictable consumer market, and lacking cybersecurity), companies (lacking cybersecurity, and data ownership is unclear), research institutes (research not matching market demand), and governmental authorities (unclear role in transition, and lacking cybersecurity) (Jerhamre et al. 2022).

Ethics approval and consent to participate: This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication: All authors declare their consent for publication.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

Contribution of Authors: All authors shared in writing, editing and revising the MS and agree to its publication.

Acknowledgments: H. El-Ramady thanks the Central Department of Mission, Egyptian Ministry of Higher Education (Mission 19/2020) and also the Hungarian Tempus Public Foundation (TPF), grant no. AK-00152-002/2021 for financializing and supporting this work.

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