

Smart Farming and Sustainable Agriculture Application, Issues and the Way Forward

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Abstract

Sustainable Agriculture is described as a system that improves the quality of environment and the base of resources on which agriculture depends, meets the basic needs of humans for food and fibre, economically viable, improve the quality of life for farmers and the society as a whole over the long term. This paper explores smart farming for promoting sustainable agriculture, its application, issues and the way forward. The review was organized under the concepts of smart farming, smart farming techniques, smart farming applications in agriculture, influence of smart farming techniques on sustainable agriculture, challenges to effective smart farming applications. The findings from the review revealed that the application of smart farming techniques is effective in crop and livestock management, soil health monitoring, big data analytics for farming insights, real-time livestock monitoring, and smart irrigation system. In conclusion, the review emphasizes the transformative potentials of smart farming techniques for sustainable agriculture in Nigeria. It recommends the need for the Governments and development partners to provide training and educational programs on smart farming technologies to help farmers adopt new technologies through seminars, workshops and conferences, smart farming technologies tools should be inculcated into Nigeria's farming system to increase productivity and enhance food security. Provision of financial and incentives support programs such as grants, subsidies, low-interest loans, and tax credits specifically, for farmers to adopt changes from traditional farming to smart farming and the new technologies to fully harness the benefits of smart farming.

Keywords: Smart Farming, Sustainable, Agriculture, Application and Way-Forward

Introduction

The word “sustainable” is the process of maintaining changes in the environment. Sustainable Agriculture is the measures in which it should emphasize long-term support in producing food and beverages and also at the same time in an eco-friendly mannered (Srisruthi, *et al.*, 2016). Sustainable agriculture plays a significant role in preserving natural resources, halting biodiversity loss, caring valued landscapes and reducing greenhouse gas emissions. The term “sustainable agriculture” refers to an agricultural system that is continuously productive in the future (Feenstra, 2020). Sustainable agriculture and food production is expected to be economically feasible and maintains soil quality, reduces soil erosion and degradation, saves water resources, improves land biodiversity, and ensures a natural and healthy environment (Brodt *et al.*, 2011; Obaisi *et al.*, 2022).

Srisruthi *et. al.* stated that sustainable Agriculture is applied to farming in order to preserve nature without compromising the equality of the future generation basic needs and thus enable smartness in farming. The common practices included in smart farming for sustainable Agriculture are crop rotations that mitigate weeds, disease, insect and other pest problems, thus it leads a way to make the hazardless environment. The researcher also stated that sustainable Agriculture comprises of sustainability of farmers, the productivity of Agricultural resources, environment – friendly, recycling and harvesting of water is the milestone to form sustainable agriculture in other to preserved sufficient food to meet with the demand of the society.

Living organisms are dependent on the nature of biodiversity, this has been contaminated slowly by emitting wastes, degraded dead plants, use of fertilizers and pesticides, dilution of water etc. more- over , because of this desecration of an environment and emission of greenhouse gases actually affects the plants, animals as well as human beings. So, it is very pertinent or important to sustain and make a better environment for plants, animals and for human beings. Thus, smart farming is a primary key to meet better Agricultural systems and make better sustainable agriculture for the future.

Concepts of Smart Farming

Smart farming is defined as a system where smart and cutting-edge technologies are integrated with traditional farming approaches to improve quality and quantity of agricultural products, while at the same time lowering applied inputs significantly (Panchasara *et al.*, 2021). Smart farming enables the farmers to monitor and control over plant remotely and satisfy the necessary requirements of the plants and animals, and Internet of Things (IoT) is the new technology that enables the devices to connect remotely in order to achieve (Patil & Kale, 2016) smart farming is the incorporation of information and communication technologies into machinery, equipment, and sensors for use in agricultural production systems. (Pivoto *et al.*, 2018) The goal of smart farming is to boost production, yields, and profitability while reducing environmental impact by applying various approaches such as effective irrigation, and targeted and exact application of pesticides and fertilizers for crops, among others. The availability and accessibility dimension of food security can be strengthened through smart farming techniques.

Smart Farming Techniques

1. **Precision Farming** this is also known as precision agriculture or site – specific crop management, is a modern approach to farm management that utilizes advanced technology to optimize crop production .by collecting and analyzing detailed data on soil characteristics, crop health, and environmental conditions, farmers can make informed decisions about planting, fertilization, irrigation, and pest control at a highly localized level. This enables them to maximize yields, reduce costs, and minimize environmental impacts (Finger *et al.*, 2019)

2. **Geographic Information Systems (GIS)** is a system of computer hardware, software, and procedures designed to support the compelling, storing, retrieving, analyzing, and display of spatially referenced data for addressing planning and management problems. Geographical Information System (GIS) uses feature attributes and location data to produce maps. The modern precision farming system is an amalgamation of several techniques including Global Positioning System, sensor technologies, geographic information system, variable rate technologies, grain yield monitors for mapping, and crop management (Roy & George 2020).
3. **Autonomous Farming Machinery:** Autonomous farming machinery is a revolutionary aspect of smart agriculture, transforming traditional farming practices and improving efficiency on the farm. These machines, equipped with advanced sensors and artificial intelligence (AI) capabilities, can operate and perform tasks without human intervention. This technology includes autonomous tractors, harvesters, seeders, and more. Autonomous machinery plays a crucial role in increasing productivity and efficient resource management. These machines navigate fields with precision, applying fertilizers and pesticides only where necessary. With AI-powered systems, they can adapt their actions based on real-time data, ensuring crops receive the right care at the right time. (Subeesh, & Mehta. 2021):
4. **Sensors and Data Collection Systems:** Sensors and data collection systems are essential tools in modern agriculture, often referred to as smart agriculture. It is small helpers placed in different parts of the farm, such as fields, machinery, and even on animals (Bauer & Nils, 2018). These sensors act like eyes and ears, gathering crucial information about the farm's environment. They measure things like soil moisture, temperature, humidity, weather conditions, crop health, and even the behavior of animals, all the data collected by these sensors is then sent to a central system, like a computer or smart phone, where farmers can access and analyze it. This real-time information allows farmers to make smart decisions about their crops and livestock (Mishra, and Sunil, 2023)

Smart Farming Applications in Agriculture

There are several applications of smart farming stated by (Nawandar and Satpute 2019; Azadi *et al.*, 2021).

1. Smart soil cultivation system to include preparing the soil for cultivation, weeding , phoughing, preparing of seedbeds and sowing
2. Smart irrigation systems to be automatized to supply the required water irrigation requirement in controlled manner
3. Smart fertilizers system 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 field efficiency
7. Smart farm management system by providing analytics and evaluation recording data to improve the productivity of cultivated crops in the field.
8. Smart groundwater quality management system by monitoring and maintaining proper levels of groundwater for the crop and livestock production.
- 9.

Influence of Smart Farming Techniques on Sustainable Agriculture

Soil Health Monitoring: An important factor in increasing the output agricultural products is the condition of the soil, the examination of soil composition has become more efficient and economical with the use of sensors based soil health monitoring. Smart farming techniques through smart sensing help in the estimation of nitrates and phosphates concentration, soil moisture detection, determining soil compaction, developing nutrients recommendation system, detecting capsaicin concentration, classifying soil fertility, and land classification (Wu *et al.*, 2020; Vincent *et al.*, 2019).

Big Data Analytics for Farming Insights: Big data analytics serves as a game-changer for farmers in smart agriculture; it functions like a superpower providing them with the capability to make intelligent decisions by harnessing vast amounts of data from sensors, drones, and weather stations. Big data analytics in smart agriculture reveals hidden patterns and trends from various data sources. It helps farmers keep crops healthy, detect problems early, and predict challenges like bad weather or pests. (Chergui & Mohand, 2022). Big data analytics in smart agriculture having these insights at their fingertips allows farmers to plan better, optimize their resources, and run their farms more efficiently. They can adjust irrigation schedules, apply the right amount of fertilizers and pesticides, and make sure their crops get the care they need at the right time. This saves resources and also leads to higher crop yields and better results.

In a way, big data analytics is like a secret tool that gives farmers a competitive edge. It empowers them to tackle farming challenges with confidence and make data-driven decisions that lead to success. With this powerful tool in their hands, farmers can take their farming practices to a whole new level, making agriculture smarter, more sustainable, and more rewarding for everyone involved. (Steup *et al.*, 2019)

Real-time livestock monitoring: Some drones are equipped with thermal imaging cameras that enable a single pilot to manage and monitor livestock. This allows farmers to keep track of livestock a much greater frequency, and with less time and staff investment.

The drone operator can quickly check in on herd to see if there are any injured or missing livestock, as well as see livestock who are giving birth. Drones are used to keep an eye on the heard at all times, a once costly and time-intensive task. Plus, thermal imaging will also help to keep an eye out for any livestock predators, which can be a huge advantage for some farm owners (Basso and Antle, 2020)

Smart Irrigation Systems: Smart irrigation systems are innovative technologies that are set to revolutionize agriculture by optimizing water use and improving irrigation efficiency. These advanced systems use data from a variety of sources, including soil moisture sensors, weather forecasts and evaporation rates, to deliver the exact amount of water needed by crops at the right time (Vallejo-Gómez *et al.*, 2023). By adopting smart irrigation, farmers can ensure that their crops get enough water without over-watering, thereby reducing water wastage and the risk of water stress, these systems can be automated or remotely controlled, allowing farmers to adjust irrigation schedules and settings based on real-time data. As a result, Smart irrigation contributes to water conservation and sustainability in agriculture, promotes efficient water use and supports environmental protection. Smart irrigation systems are a game-changer in modern agriculture, increasing crop yields, optimizing resource efficiency, and contributing to a more sustainable and eco-friendly approach to irrigation practices (Obaideen *et al.*, 2022)

Challenges to Effective Smart Farming Applications

Educational Level of Farmers: Technologies in smart farming must be handled by skilled workers including up-to-date farm managers (Fountas *et al.*, 2015). Finding highly skilled and experienced labour, with the ability to operate in extremely specific work conditions, has also been identified as a relevant challenge in the domain (Johnson, 2014). The skills required to operate the tools include both technical and academic expertise. A farmer's ability to analyzed information and use farming technology to make decisions depends on their level of education. Most farmers in developing countries lack education and skills due to a lack of interest in learning new things or awareness of emerging technologies. As a result, it is a factor in why farmers prefer traditional farming over smart farming. Farmers have considered that usage is too complex, sometimes incapable of recognizing the icons used in a mobile application as the farmers use general icons based on traditional understanding (Dhanaraju *et al.*, 2022).

Data Management: Farmers are facing problems in organizing and manipulating data obtained by the sensors. The weather stations are generating data; however, farmers do not recognize how to use the information and how to change the data into a more available form (Dhanaraju *et al.*, 2022). Its complex systems, alongside issues of acceptability and usability, lead to incorrect calculations. Farmers, consultants, and others involved in the production process must provide greater accessibility to data and farming uses the internet to connect field-based sensors and farmer-smart communication devices. However, most rural

communities and villages do not always have access to the Internet. This makes it challenging for smart farming to adapt. Smart farming relies on a robust technological infrastructure, including sensors and high-speed internet connectivity.

Regulatory and Policy Constraints: Regulatory and policy constraints, such as outdated agricultural regulations or zoning restrictions, can hinder the adoption of smart farming practices

(Mahesh, and Verma, 2018). These constraints may not align with the innovative nature of smart farming technologies.

High cost of Technology: Many of the smart farming technologies currently available on the market are designed for larger commercial farms and may not be suitable for small-scale family farms due to their higher acquisition and maintenance costs. (Mizik, 2023)

Lack of Financial Resources: Many farmers, especially smallholders in developing countries, lack access to financial support for acquiring smart farming equipment. The heterogeneity of cropping systems and land fragmentation makes it infeasible for small landholding farmers to invest in smart farming technologies, thus, the movement of machinery is restricted by small land holdings (Idoje *et al.*, 2021)

Lack of knowledge: Traditional farming practices have a strong connection with farmers, and the transition to smart farming may not be easy for them. Farmers and other farm workers require proper knowledge, information, and skills to effectively use of smart farming tools, (Jellason, *et al.*, 2021)

Conclusion

Smart farming is a shift from traditional methods of farming to more innovative and strategic methods that demand high level of technology to address the issues of food insecurity to a sustainable food security in Nigeria. However, several challenges such as the educational level of farmers, data management, high cost of technology, regulatory and policy constraints, lack of financial resources and knowledge among others hinder the application of smart farming techniques agriculture. Smart farming has the potential of soil health monitoring, big data analytics for farming insights, real-time livestock monitoring, and smart irrigation systems by farmers to management water and other natural resources, and increased both crops and livestock agricultural output. in Nigeria. If these challenges are addressed, smart farming techniques will have the potential in contributing to sustainable agricultural production.

Way Forward

1. Governments and development partners should provide training and education programs on smart farming technologies to help farmers adopt new technologies through seminars, workshops and conferences

2. Smart farming technologies tools should be inculcated into Nigeria's farming system to increase productivity and enhance food sustainability.
3. There is need for policy support from the government and agro-tech industries
4. Government should develop tailored financial products (e.g., green loans, agriculture loans, pay-per-use models for technology)
5. Provision of financial and incentives support programs: such as grants, subsidies, low-interest loans, and tax credits specifically for farmers adopt changes from traditional farming to smart farming and the new technologies.
6. Farmers need training to enhance them with adequate skills and understanding of smart farming technologies and their implications.

References

- Azadi, H., Movahhed M. S., Burkart, S., Mahmoudi, H., Van, P. S., Kurban, A., & Lopez-Carr, D. (2021). Rethinking resilient agriculture: From Climate-Smart Agriculture to Vulnerable-Smart Agriculture. *Journal of Cleaner Production*, 319, 128602. <https://doi.org/10.1016/j.jclepro.2021.128602>
- Basso, B., & Antle, J. (2020) Digital Agriculture to design sustainable agricultural systems *Nature Sustainability*.3 (4) , 254- 256
- Bauer, J., & Nils A.(2018) "Design and implementation of an agricultural monitoring system for smart farming." In *IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany)*, pp. 1-6.IEEE.
- Basso, B., & Antle, J. (2020) Digital Agriculture to design sustainable agricultural systems *Nature Sustainability*.3 (4), 254- 256
- Brodt, S., Six, J., Feenstra, G., Ingels, C., & Campbell, D. (2011). *Sustainable Agriculture. Natural Educational Knowledge*, 3(1).
- Chergui, N., & Mohand T. K (2022). "Data Analytics for Crop Management: A Big Data View." *Journal of Big Data* 9 (1), 1-37.
- Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, S., & Kaliaperumal, R. (2022). Smart Farming: Internet of Things (IoT)- based sustainable agriculture. *Journal of Agriculture*, 12, 1745. <https://doi.org/10.3390/agriculture12101745>
- Feenstra, G. (2020). What is Sustainable Agriculture? University of California. <https://sarep.ucdavis.edu/sustainable-ag>
- Finger, R., Swinton, S. M., Elbenni, N., & Walter, A., (2019) Precision farming at the nexus of agricultural production and the environment. *Annual Review of Resources Economics*, 11, 313- 335

- Fountas, S., Carli, G., Sørensen, C.G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., & Tisserye, B. (2015). Farm management information systems: Current situation and future perspectives. *Computers and Electronics in Agriculture*, 115, 40-50
- Idoje G, Dagiuklas T, Iqbal, M (2021) Survey for smart farming technologies: challenges and issues. *Journal of Computer Electronic Engineering*. 92:107104. <https://doi.org/10.1016/J.COMPELENG.2021.107104>.
- Jellason, N. P, Robinson, E. J. Z, Ogbaga, C. C. (2021) Agriculture 4.0:.. <https://doi.org/10.3390/APP11125750>. Is Sub-Saharan Africa Ready *Journal of Applied Science* 11 (12), 5750.
- Johnson, David M., (2014). *An assessment of pre-and within-season remotely sensed variables for forecasting corn and soybean yields in the United States. Journal of Remote Sensory Environment*. 141, 116–128.
- Kalantari, F., Tahir, O. M., Joni, R. A., & Fatemi. E. (2017) A review of vertical farming technology: A guide for implementation. *Renewable and Sustainable Energy Review* 67, 241- 254
- Mahesh, G., & Verma, R. (2018). Smart farming: Agriculture using IoT. *In proceedings of the international conference on inventive research in computing applications*. 1399- 1404.
- Mishra, S., & Sunil, K. S.,(2023) "Advanced contribution of IoT in agricultural production for the development of smart livestock environments." *Journal of Internet of Things* 22 100724.
- Mizik T. (2023) How can precision farming work on a small scale? A Systematic Literature Review. *Journal of Precision Agriculture*. 24(1):384–406. <https://doi.org/10.1007/S11119-022-09934-Y>.
- Nawandar N. K., & Satpute V. (2019). IoT based intelligent irrigation support system for smart farming applications. *Advances in Distributed Computing and Artificial Intelligence Journal* 8(2), 75-85. <https://doi.org/10.14201/ADCAIJ2.019827385>.
- Obaisi, A. I., Adegbeye, M. J., Elghandour, M. M., Barbabosa-Pliego, A., & Salem, A. Z. M. (2022). *Natural Resource Management and Sustainable Agriculture*. In Handbook of Climate Change Mitigation and Adaptation Cham: Springer International Publishing. 2577-2613.
- Obaideen, Khaled, Bashria AA Yousef, Maryam Nooman AlMallahi, Yong Chai Tan, Montaser Mahmoud, Hadi Jaber, and Mohamad Ramadan. (2022) "An overview of smart irrigation systems using IoT." *Energy Nexus* 100-124.

- Roy, T., & George, J. (2020). Precision Farming: *A step towards sustainable, climate-smart agriculture*. 199 – 220.
- Subeesh, A., & Mehta, C. R. (2021) "Automation and Digitization of Agriculture using Artificial Intelligence and Internet of Things." *Journal of Artificial Intelligence in Agriculture* 5: 278- 291.
- Srisruthi, S., Swarna, N., Ros, G. M. S., & Elizabeth, E. (2016). Sustainable Agriculture using eco- friendly and energy efficient sensor technology. *IEEE Internal Conference on Recent Trends in Electronic, Information and Communication Technology (RTEICT)* pp. (1442- 1446) Bangalore, India: IEEE. 10.1109/RTEICT.2016.7808070
- Steup, R, Lynn D., and Norman, M. S. (2019) "Feeding the world with data: visions of data-driven farming." In *Proceedings on Designing Interactive Systems Conference*, pp. 1503-1515.
- Panchasara, H., Samrat, N.H., & Islam, N. (2021). Greenhouse Gas Emissions Trends and Mitigation Measures in Australian Agriculture Sector - *A review Agriculture*. 11(2), 85, <https://doi.org/10.3390/agriculture11020085>.
- Patil, K. A., & Kale, N. R. (2016) A model for smart Agriculture using IoT. In *International Conference on global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC)* pp. 543- 545. Jalgaon, India: IEEE. 10.1109/ICGTSPICC.2016.7955360
- Pivoto D., Waquil P. D., Talamini E., Finocchio, C. P. S., Dalla Corte V. F., & deVargas M, G. (2018). Scientific development of smart farming technologies and their application in Brazil. *Information Process Agriculture* 5C21–32.
- Vallejo-Gómez, D., Marisol, O., & Carlos, A. H., (2023) "Smart Irrigation Systems in Agriculture: A Systematic Review." *Journal of Agronomy* 13, (2), 342.
- Vincent, D. R., Deepa, N., Elavarasan, D., Srinivasan, K., Chauhdary, S. H., & Iwendi, C. (2019). "Sensors driven AI-based agriculture recommendation model for assessing land suitability," *Sensors*, 19(17), 3667:1–3667:16,
- Wu, J., Yang, G., Wang, X., & Li, W. (2020). "PZT-Based soil compactness measuring sheet using electromechanical impedance," *IEEE Sensors J*, 20(17), 10240 – 10250.