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APPLIED RESEARCH

Artificial Intelligence and Internet of Things for Sustainable Farming and Smart Agriculture

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ABSTRACT Technologies like AI and IoT have been employed in farming for some time now, along with other forms of cutting-edge computer science. There has been a shift in recent years toward thinking about how to put this new technology to use. Agriculture has provided a large portion of humanity's sustenance for thousands of years, with its most notable contribution being the widespread use of effective agricultural practices for several crop types. The advent of cutting-edge IoT know-how with the ability to monitor agricultural ecosystems and guarantee high-quality production is underway. Smart Sustainable Agriculture continues to face formidable hurdles due to the widespread dispersion of agricultural procedures, such as the deployment and administration of IoT and AI devices, the sharing of data and administration, interoperability, and the analysis and storage of enormous data quantities. This work initially analyses existing Internet-of-Things technologies used in Smart Sustainable Agriculture (SSA) to discover architectural components that might facilitate the development of SSA platforms. This paper examines the state of research and development in SSA, pays attention to the current form of information, and proposes an Internet of Things (IoT) and artificial intelligence (AI) framework as a starting point for SSA.

INDEX TERMS Smart agriculture, Internet of Things (IoT), artificial intelligence (AI), smart sustainable agriculture (SSA), smart farming.

I. INTRODUCTION

Agriculture that is considered sustainable is characterized by long-term viability and ecological compatibility in its grain production practice. Sustainable agriculture serves to support techniques and methods that are beneficial to the long-term survival of humans and natural resources. It is practical from a financial standpoint, and it protects the quality of the soil, slows down the rate at which the soil degrades, conserves water resources, increases the biodiversity of the land, and guarantees a healthy and natural atmosphere. The practice of sustainable farming plays a vital role in the protection of natural resources, the slowing of the loss of biodiversity, and the reduction of greenhouse gas emissions.

''Sustainable agriculture'' is a technique for maintaining nature without sacrificing the ability of future generations to meet their fundamental requirements. In addition, it is a technique for making farming more efficient. Sustainable agriculture is largely attributable to the central successes of intelligent farming, which include ''harvest alternation, the management of nutrient deficits in crops, the control of pests and diseases, recycling, and water harvesting''. These accomplishments lead to an overall safer world.

However, an ever-expanding worldwide population with increased hunger, rapidly changing climate conditions, overuse of resources, and wastage of food and water are obscuring the effect of sustainable agriculture. The need of time is to develop technologies and infrastructure capable of meeting the demands of the present as well as the future. Technological innovations have always been the fundamental means for the development of agriculture, from the pre-historic era to today, as illustrated in Figure 1. Breakthroughs like the development of simple tools and the utilization of animals; the use of fertilizers, pesticides, and small machinery; and the application of robots helped agriculture evolve to its present

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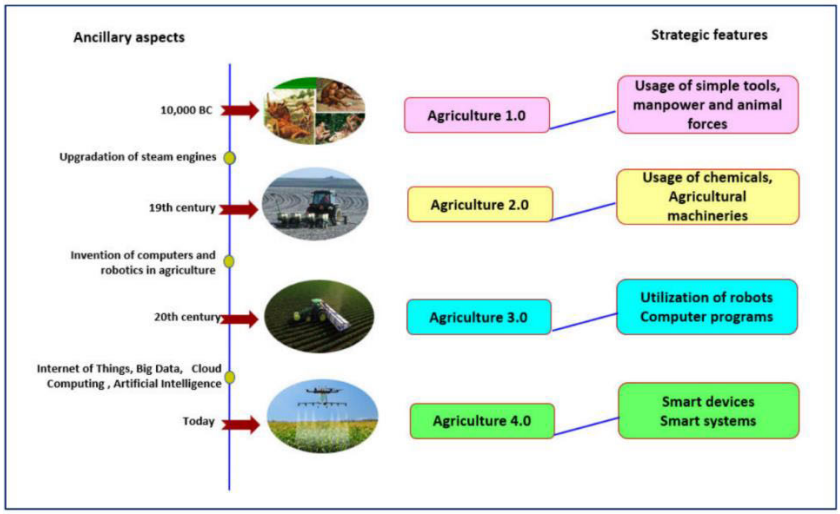

FIGURE 1. Upgradation of agriculture.

status, and now, with the use of smart technology, agriculture is impending to become smart.

Smart farming has become an important component of sustainable agriculture [1]. Traditionally, a huge amount of time, money, and effort is invested in growing any crop. It is worth mentioning the time and effort required in the processing, transportation, and marketing of harvested crops and all other logistics associated with them. Technologies of smart farming present a way to deal with and alleviate these problems, offering an improved way of doing agro-businesses.

In addition, farming is vulnerable to pesticides, poor environmental conditions, and the deteriorating quality of soil, air, and water due to pollution. The nature of biodiversity is essential to the survival of living species, and these organisms are vulnerable to contamination by waste emissions, the application of fertilisers and pesticides, decomposed dead plants, and other factors. Because the release of greenhouse gases has an effect on all living things, including plants, animals, and people, as well as the environment, it is necessary to create a more favourable atmosphere for living things.

Agriculture is the sector that contributes the most to India's GDP, accounting for 18% of the country's total and employing around 57% of the population in rural regions. Although India's overall agronomic production has grown over the years, the number of growers has decreased from 71.9% in 1951 to 45.1% in 2011. This decline occurred during the course of the country's history. The Economic Survey for 2018 found that the percentage of the entire employment that is comprised of agricultural employees would fall to 25.7% in the year 2050. In rural places, agricultural families progressively lose the next generation of farmers as they are overwhelmed by the increased expenses of agriculture, poor per capita production, insufficient soil upkeep, and migrations to occupations that are either non-farming or better paying than farming [2]. The globe is on the edge of a technological age; therefore, now is the time to connect the agricultural landscape with wireless technology to facilitate digital interaction among farmers. Agricultural landforms are characterised by large areas of open space.

Unfortunately, not all of the land on the surface of the earth can be farmed owing to a variety of factors, including the quality of the soil, the terrain, the temperature, and the climate; in addition, the majority of the regions that are appropriate for farming are not all the same. In addition, existing agricultural land is fragmented due to political and budgetary factors as well as rising urbanisation, all of which contribute to a persistent rise in the amount of pressure placed on the availability of arable land. In recent years, a smaller percentage of overall agricultural land has been put into use for food production [3]. In addition, the quality and quantity of each crop field's soil, the presence of nutrients, the flow of irrigation, and resistance to pests are all measured separately. These critical characteristics include the type of soil, the flow of irrigation, the presence of nutrients, and the resistance of the crop to pests. Differences in space and time are required for maximising crop production in the same field via crop rotation and a yearly crop growth development process. These differences are important for optimising crop output.

IoT and AI will assist companies in becoming more productive, reducing the amount of waste they create, and satisfying the need for food that customers have. Based on the findings of a number of studies, it has been determined that AI and IoT have a wide range of potential applications within the agricultural sector, as illustrated in figure 2.

A. SMART GREENHOUSES IN AGRICULTURE

The Internet of Things may help enhance yield in smart greenhouses by allowing for the development of proportional control systems. They employ sensors to give a regulated environment for the crops that they grow. The system is

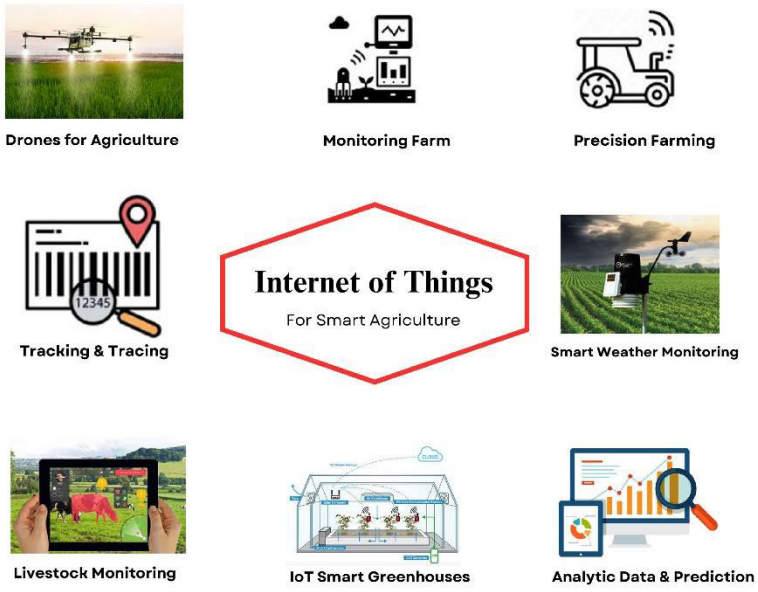

FIGURE 2. IoT for Smart agriculture.

monitored remotely, and the data processing is done via the use of cloud servers [4]. While reducing the need for human interaction, the smart greenhouse keeps track of the quantity of temperature, light, and humidity in the environment.

B. DRONES FOR AGRICULTURE

The drones that can operate both on the ground and in the air can help in the evaluation of crop health, the monitoring of infestations, and the examination of soil more efficiently. In addition, they may be used for the collection of real-time field data, the sowing of seeds, the management of irrigation systems, and the spraying of crops [5]. The information that was acquired may be used to make production forecasts, evaluate nutrient levels, and map external impacts.

C. SYSTEMS FOR PRECISION FARMING

One of the most common applications of agricultural technology is precision farming. It provides services such as variable rate irrigation (VRI) optimization, soil moisture testing, and cloud-based centralized water management. Through the use of sensors, autonomous equipment, and an internet connection, the system makes efficient use of the resource water.

D. SOLUTIONS FOR TRACKING AND MONITORING LIVESTOCK

Wireless Internet of Things networks and linked devices may reduce the amount of labour required at the ranch by keeping an eye on the cattle. Internet of Things devices are able to determine the location of an animal and even monitor its overall health [6]. On big farms, the farmers are able to quickly detect the animal and even halt the spread of illness by unscrambling sick animals from the rest of the herd. This helps safeguard the product and keeps the cost of cattle down.

E. SENSORS FOR CROP AND SOIL MONITORING

Robots and unmanned aerial vehicles armed with thermal or multispectral sensors are used to conduct continuous assessments of the state of crops and soil. This makes the application of fertilizer spray and controlled watering easier. The sensors analyze the levels of the various biomes in the soil in order to ensure that the crops have a high nutritional value. Additionally, in order to select the most profitable crops, AI analyses the features of the soil.

F. CURRENT WEATHER MONITORS

Smart sensors connected to the Internet of Things can assist gather real-time weather and climate data. Farmers are able to better analyze their crop requirements with the help of a thorough projection [7]. Farmers may also get alerts from some systems, allowing them to safeguard their crops in the event that severe weather strikes.

G. ROBOTS FOR AGRICULTURE

Agricultural robots lessen the need for manual work and save time by performing a number of tasks simultaneously on farms. They assist in agricultural monitoring and harvesting in a way that is more effective than using humans. They have received instruction in AI in order to maintain the crop's quality while also preventing the spread of weeds. These devices are able to sift the produce according to quality and pack it in a far more expedient manner than traditional procedures [8]. The use of AI in agriculture provides assistance to farmers

with the goals of enhancing their output and minimising negative impacts on the environment.

H. DEVICES FOR ESTIMATING FUTURE HARVESTS AND PRICES

When estimating the yield of their crops, farmers are using a variety of new technologies, including AI, ML, and big data. When harvest time comes around, it is important to make price predictions by looking at historical data to analyze price fluctuations. Farm mapping makes it feasible to calculate yields per hectare with a high degree of accuracy. Farmers take into account a wide range of criteria in order to arrive at a conclusion [9], such as the amount of precipitation, the kind and number of pesticides used, the temperature, and other meteorological conditions.

II. REVIEW OF LITERATURE

Wolfert [10] explained in his study that agri-food systems face sustainability issues. Digital technologies like IoT may help achieve economic, environmental, and social sustainability objectives. However, it is difficult to assess how much such technologies contribute to sustainable development casting doubt on their influence. This study presents a stepwise method for assessing and monitoring IoT sustainability in real life. The approach's typology and presentation of sustainability as a business opportunity are based on the UN SDGs. The EU-funded IoF2020 project created and tested 33 use cases. The study shows how the measuring and monitoring tool is used in five agricultural subsectors to verify the strategy. The findings show that IoT improves sustainability, but they are also influenced by external variables that are hard to see. This method provides tools for practitioners to assess the sustainability effects of fast-changing technology like IoT in real life. Other stakeholders in major IoT initiatives that meet strategic sustainability goals may use these tools. The stepwise strategy helps farmers, policymakers, and investors make decisions.

In this study, Eissa [11] says that IoT, AI, and other sophisticated computer technologies have long been used in agriculture. Smart technologies are getting more attention. Agriculture has fed humans for thousands of years, including the creation of crop-specific agricultural practices. New IoT technology can monitor agricultural environments to assure high-quality goods. However, Smart Sustainable Agriculture (SSA) research and development is lacking, and the fragmentation of agricultural processes creates complex obstacles, such as data sharing and management, ''the control and operation of IoT and AI machines, interoperability, and large amounts of data storage and analysis''. This research first examines SSA IoT and AI technologies and then finds a technological architecture that can support SSA platform development. ''This study examines SSA research and development and proposes an IoT/AI architecture for a Smart, Sustainable Agriculture platform''. It also provides an exhaustive review of existing work in the field, highlighting various tools that are being implemented for the development of smart agriculture, such as Farmapp (to monitor pests and illnesses), Growlink (providing wireless automation, data collection, optimisation, and monitoring), GreenIQ (connects to home automation systems, controls irrigation, saves water), Farm Logs, Cropio, etc. (Table 1).

In his study report, Jagadale [12] states that IoT and AI are among the most preferred digital transformation technologies. Sensors gather ambient data, and AI algorithms analyze it to make gadgets act intelligently. This article discusses how IoT and AI have changed agriculture. It explores the agricultural revolution caused by AI and IoT technologies like drones and UAVs. Such technology simplifies forecasting meteorological conditions, including precipitation, temperature, humidity, fertilizer needs, water consumption, etc. IoT and AI technology boost agricultural productivity and reduce waste in agriculture. Smart farming using IoT and AI might transform traditional farming.

Punjabi et al. came up with a simple temperature sensing application with the goal of obtaining on-field information, which could be acquired by just sending a pre-programmed format of message to an already installed GSM+ARDUINO system that transmits the field data on the mobile phone [13].

Uddin et al., in order to overcome the difficulties in acquiring information from Wireless Sensor Networks (WSNs), developed a method of collecting data from specific areas through selected nodes by using Unmanned Aerial Vehicles (UAVs). Through simulation and proof-of-concept devices, they were able to show that this system succeeded in collecting real-time field data, helping in the detection of any nourishment deficiency, insect infestations, or diseases well in time, allowing timely remedies to save crops [14].

In the research of Alam and Khan [15], they argued that feeding the world's population growth is the biggest challenge. Food shortages have several causes, and agricultural advances are needed to solve them. ICT and other cutting-edge technology will accelerate the Sustainable Development Goals (SDGs). Mobile-broadband access devices, IoT, specialized drones, robots, big data analytics, and AI have given farmers tools to boost productivity and marketing. Smart Agriculture is transforming agriculture in Budaun, a tiny Uttar Pradesh city. Smart agriculture and blockchain technologies are helping agriculture develop sustainably. New technology has raised production/yield by 20% and earnings by 30%.

Dhanaraju et al. [16] write that smart farming emphasizes ''ICT in machinery, equipment, and sensors in network-based high-tech farm monitoring cycles''. Advanced know-how, the Internet of Things, and cloud computing are expected to spur expansion and introduce agricultural robots and AI. Groundbreaking agricultural practices are disturbing and challenging. This study examined the methods and equipment utilised in wireless sensor applications in IoT agriculture and the predicted problems of integrating technology with traditional farming. This technological information helps producers from planting to harvest and is researched for packaging and shipping.

TABLE 1. Describes different categories in which AI is used in the field of agriculture, what tools are used and how it is being implemented in farming.

Category	Tool/Company	Description
Greenhouse automation	Far mapp	It is quicker and more effective to monitor pests and illnesses while also producing information for mobile applications. The synced data from the server and the data that was previously saved enables real-time viewing of metrics like a satellite map, sanitary status, comparison heatmaps, and graphs and reports on pests and illnesses.
	Grow link	a system that combines hardware and software to provide wireless automation, data collecting, optimization, and monitoring, among other smarter working features.
	Green IQ	a solution that connects IoT devices to automation platforms and allows users to control irrigation and lighting from any place.
Climate conditions Monitoring	allMETEO	a gateway for managing Internet of Things (IoT) micro weather sensors, gathering data in real-time, making a weather map, and offering an API for simple data transmission.
	Smart Elements	a group of technologies that increase productivity by employing sensors to provide reports to an internet dashboard, enabling quick choices based on current circumstances.
Agriculture machines /drones	Sky Squirrel	a drone system intended to increase crop productivity and lower expenses. A drone's path is preprogrammed by users, and computer vision is used to capture photographs. Users may download the data from the drone when its trip is complete and upload it to a cloud drive. The collected data and photographs are then combined and analyzed by algorithms to produce a comprehensive report on the health and condition of crops.
	See & Spray	a machine built to manage forests and safeguard crops. To monitor and accurately spray weeds and diseased plants, it makes use of computer vision.
	CROO	a machine that helps in crop picking and packing. According to the manufacturer, this robot can complete the task of thirty human employees and harvest eight acres in a single day.
Crop management	Arable	a gadget that combines measurements of the weather and plants and sends the information to the cloud for immediate retrieval from any place. It provides constant signs of illness, pests, and stress.
	Semios	a system that enables farmers to use real-time data to monitor and react to pests, diseases, and crops, forming on-the-ground sensing, big data, and predictive analytics solutions for long-term agricultural goods.
Crop and Soil Health Monitoring	Plantix	a technology based on machine learning for managing and controlling the farming process, preventing illness, and growing superior crops
	Trace Genomics	By analysing a soil sample's DNA and comparing it to a sizable soil DNA database, a soil monitoring system employs a machine learning technique to create a health report for the sample.
Predictive Analytics	Farm shots	a system that maps possible disease, pest, and malnutrition indications in agriculture fields using satellite and drone imagery. To create prescriptions, generated data may be sent to agricultural software.
Livestock monitoring and management	Cowlar	a smart neck collar for tracking the temperature, activity, and other behavioural traits of dairy cows. It employs a solar-powered base unit and a minimally intrusive, waterproof monitoring device that are both comfortable for the animal. To accurately diagnose oestrus, it may track body movement patterns and gait.
End-to- end farm Management systems	Farm Logs	This technology keeps track of field conditions, making it easier to plan and control crop output. Additionally, it sells agricultural goods.
	Cropio	a tool for making decisions that integrates meteorological data with satellite data to track crops and make field forecasts while optimising fertilisation and watering.

Farooq et al. presented a comprehensive list of various components of IoT devices, along with the underlying network architecture and protocols, highlighting security concerns. In addition, applications for smartphones and sensors meant for various stages of farming were presented, such as the 3D Crop Sensor Array with PAR Addon to regulate the temperature, humidity, and carbon dioxide; Arable Mark, which connects the global weather data with the field observations, and Bluetooth-based Grofit, which stores data for 30 days and provides information about air humidity, temperature and radiation [17].

There are many other benefits that smart farming offers resulting in increased productivity by investing less labour and allowing better time management. All the data collected through various IoT devices are employed to gain knowledge regarding significant parameters such as soil conditions, water requirements, infestations, plant diseases, herbicidal growth, etc. Though these devices are now being employed by farmers, they are burdened by the increase in capital investment and maintenance costs especially the small farmers [18]. Hence, providing these facilities to farmers through cooperative organizations may be a more economical alternative.

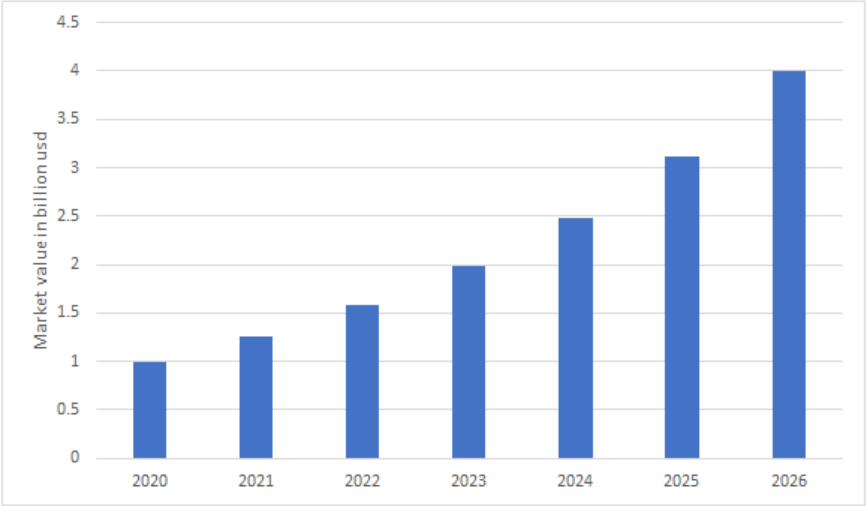

FIGURE 3. Projected artificial intelligence in agriculture market from 2020 to 2026.

Chukkapali et al. proposed a smart farming cooperative ecosystem connecting IoT devices on a community level with continuous incorporation of computational and physical components. This newly developed ecosystem adds small farmers to complicity with regulations and policies. They then discussed the benefits of the system classifying it into four broad categories of marketing and distribution, resources and equipment, labor, and service and supply. This system can prove beneficial in drawing small farmers towards the implementation of IoT for better crop production [18].

III. RESEARCH METHODOLOGY

This study analyzed papers from various periodicals and conference proceedings from respected scholarly sources. Most of the discoveries and methods have been used to build predictive analytics.

The research project consisted of a literature evaluation that began with a search for information on agriculture and practices related to it, and was performed using the three most prominent academic databases: Scopus, IEEE, and Science Direct. Some of the terms and phrases that were discussed were ''smart farming,'' ''irrigation facilities,'' ''AI and IoT in farming,'' ''Implementation of technology in agriculture,'' and ''the situation of farming in India.'' The first round of filtering was performed based on two primary criteria: the quality of the journal and the year the article was published. The titles and abstracts of the studies were then modified to reflect the changes. In order to get perspective, a minimum of 20 articles were documented. The titles of ten different papers each made up one of the criteria used to remove those ten papers. In conclusion, a summary of ten different research articles has been created based on the recent advances that have been made in the field of technological agricultural operations. The operation of a certain implementation approach was the most important aspect that needed to be emphasized. Following an in-depth analysis of all of the papers, each of the proposed strategies that were found in the selected ones was taken into consideration and worked on.

IV. RESULTS AND DISCUSSION

In an attempt to affect a different outcome, the agriculture industry embraced AI with great fervor. As a by-product of advancements in artificial intelligence, the methods by which our food is produced are undergoing transformation, and as a consequence, the emissions produced by the agricultural sector have decreased by 20%. AI lends a hand in the management and regulation of any unanticipated natural situations. The majority of new businesses entering the agricultural sector have chosen to implement an AI-enabled approach in order to boost the efficiency of agricultural output. AI provides assistance to the agricultural industry in the processing of data in order to minimise the occurrence of undesirable results.

Recent studies have uncovered a number of efforts aimed at fostering smart farming techniques, such as the digitalization of farm cooperatives as agricultural producers, the nascent development of a start-up ecology, and ''government-led digital farming projects''. Other actions include the modernization of farm collectives as farmer-producer organisations. Unmanned aerial vehicles, often known as UAVs, find the greatest amount of use in the field of agriculture. According to the research findings, as the country's agricultural sector continues to develop, more businesses are anticipated to invest in reasonably priced drones. These drones may provide assistance to farmers and help them enhance their information, while also creating employment opportunities for young individuals living in rural areas. It is clear that the administration is helping to foster an environment that is conducive to the growth of farm technology businesses by funding and operating incubators. Under the banner of ''AI for all,''

the government of India has developed comprehensive rules to be followed in order to cultivate India's AI ecosystem via the NITI Aayog. The good news is that it is projected that agriculture will have a substantially better structure in the not-too-distant future than it has right now.

Figure 3 states the data on projected AI in the agriculture market from 2020 to 2026, which was 1 billion USD in 2020 and is projected to be 4 billion USD by the year 2026 [19].

V. CONCLUSION

This study has shown that the use of contemporary and modern computer technologies, notably AI and IoT, is crucial to the success of the agricultural industry. Agriculture is often regarded as an essential component to the sustained existence of humans. Improving the efficiency, quality, and quantity of produce in conventional farming by incorporating more contemporary IoT and AI technology into existing farming processes is possible. In this study, an analysis of the current IoT and AI technologies was carried out using primary research journals in the field of agriculture. In addition to this, it provided a categorization of the most important aspects of intelligent and sustainable agriculture. These aspects include crops, human resources, soil, weather, fertilizer, agricultural products, pests, irrigation/water, animals, machinery, and fields. The AI or IoT technology framework for SSA is the key contribution that this paper brings to the table. As a direct result of this, there has been an increased emphasis placed on the investigation and advancement of an integrated AI and "IoT platform for SSA". This is being done with the intention of successfully fixing problems that have surfaced as a direct result of the fragmentary nature of farming production.

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CONFLICT OF INTEREST

There is no conflict of interests.

REFERENCES

[1] J. Wu, L. Ping, X. Ge, Y. Wang, and J. Fu, "Cloud storage as the infrastructure of cloud computing," in *Proc. Int. Conf. Intell. Comput. Cogn. Inform. (ICICCI)*, Kuala Lumpur, Malaysia, Jun. 2010, pp. 380–383.

[2] J. Roux, C. Escriba, J. Fourniols, and G. Soto-Romero, "A new bi-frequency soil smart sensing moisture and salinity for connected sustainable agriculture," *J. Sensor Technol.*, vol. 9, pp. 4–35, Sep. 2019.

[3] L. Nóbrega, P. Gonçalves, P. Pedreiras, and J. Pereira, "An IoT-based solution for intelligent farming," *Sensors*, vol. 19, no. 3, p. 603, Jan. 2019.

[4] K. Gai, M. Qiu, H. Zhao, L. Tao, and Z. Zong, "Dynamic energy-aware cloudlet-based mobile cloud computing model for green computing," *J. Netw. Comput. Appl.*, vol. 59, pp. 46–54, Jan. 2016.

[5] K. Lakhwani, H. Gianey, N. Agarwal, and S. Gupta, "Development of IoT for smart agriculture a review," in *Proc. ICETEAS*, Nov. 2018, pp. 425–432.

[6] C. V. Raja, K. Chitra, and M. Jonafark, "A survey on mobile cloud computing," *Int. J. Sci. Res. Comput. Sci., Eng. Inf. Technol.*, vol. 3, no. 3, pp. 2096–2100, Mar./Apr. 2018.

[7] S. S. Kale and P. S. Patil, "Data mining technology with fuzzy logic, neural networks and machine learning for agriculture," in *Data Management, Analytics and Innovation* (Advances in Intelligent Systems and Computing), vol. 839, V. Balas, N. Sharma, and A. Chakrabarti, Eds. Singapore: Springer, Sep. 2019.

[8] S. Rajeswari, K. Suthendran, and K. Rajakumar, "A smart agricultural model by integrating IoT, mobile and cloud-based big data analytics," in *Proc. Int. Conf. Intell. Comput. Control (I2C2)*, Jun. 2017, pp. 1–5.

[9] S. J. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*. Malaysia: Pearson, 2016.

[10] S. Wolfert and G. Isakhanyan, "Sustainable agriculture by the Internet of Things—A practitioner's approach to monitor sustainability progress," *Comput. Electron. Agricult.*, vol. 200, Sep. 2022, Art. no. 107226, doi: 10.1016/j.compag.2022.107226.

[11] E. Alreshidi, "Smart sustainable agriculture (SSA) solution underpinned by Internet of Things (IoT) and artificial intelligence (AI)," *Int. J. Adv. Comput. Sci. Appl.*, vol. 10, no. 5, pp. 93–102, 2019.

[12] A. A. Jagadale, "Role of IoT and AI in agriculture technology," *Int. J. Adv. Res. Sci. Commun. Technol.*, vol. 2, no. 2, pp. 257–268, Jun. 2022.

[13] H. C. Punjabi, S. Agarwal, V. Khithani, V. Muddaliar, and M. Vasmatkar, "Smart farming using IoT," *Int. J. Electron. Commun. Eng. Technol.*, vol. 8, no. 1, pp. 58–66, 2017.

[14] M. A. Uddin, A. Mansour, D. L. Jeune, M. Ayaz, and E.-H.-M. Aggoune, "UAV-assisted dynamic clustering of wireless sensor networks for crop health monitoring," *Sensors*, vol. 18, no. 2, p. 555, Feb. 2018.

[15] M. Alam and I. Khan, "IoT and AI for smart and sustainable agriculture," presented at the Int. Conf. Comput. Techn. Intell. Mach. (ICCTIM), Bathinda, India, Nov. 2020.

[16] M. Dhanaraju, P. Chenniappan, K. Ramalingam, S. Pazhanivelan, and R. Kaliaperumal, "Smart farming: Internet of Things (IoT)-based sustainable agriculture," *Agriculture*, vol. 12, no. 10, p. 1745, Oct. 2022, doi: 10.3390/agriculture12101745.

[17] M. S. Farooq, S. Riaz, A. Abid, K. Abid, and M. A. Naeem, "A survey on the role of IoT in agriculture for the implementation of smart farming," *IEEE Access*, vol. 7, pp. 156237–156271, 2019.

[18] S. S. L. Chukkapalli, S. Mittal, M. Gupta, M. Abdelsalam, A. Joshi, R. Sandhu, and K. Joshi, "Ontologies and artificial intelligence systems for the cooperative smart farming ecosystem," *IEEE Access*, vol. 8, pp. 164045–164064, 2020.

[19] M. Shahbandeh. (Sep. 2, 2022). *AI in Agriculture Market Value Worldwide 2020–2026*. [Online]. Available: https://www.statista.com/statistics/1326924/ai-in-agriculture-marketvalue-worldwide/

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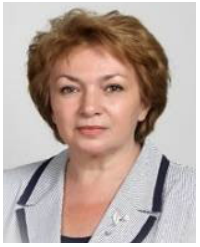

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