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A growth of smart and sustainable agriculture: A review

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Abstract
The world's two main barriers to sustainable development are a scarcity of food and rising population. Artificial intelligence (AI), the Internet of Things, and mobile internet are contemporary breakthroughs that potentially offer practical solutions to the problems the world is currently facing. As a result, this study's emphasis is on creative approaches to smart farming (SF) from 2019 to 2021 and provides examples of effective methods for data collection, transfer, storing, analysis, and problem-solving. IoT is one of the essential pillars of smart systems since it links sensor devices to perform a number of fundamental operations. The foundation of smart irrigation is made up of intelligent controls, sensors, and a few mathematical relationships. This work also showed how robots and unmanned aerial vehicles (UAVs) can be used for a range of tasks, such as harvesting, seeding, weed identification, irrigation, spraying for agricultural pests, applications on animals, etc.

Keywords: Improved agricultural practices, smart farming, internet of things (IoT), crop management

Introduction
Sustainability in ecologically friendly food production is measured by the practice of sustainable agriculture (Srisruthi *et al*. 2016) [39]. Sustainable agriculture promotes farming techniques and strategies that help farmers and the environment. It is economically feasible, stops soil degradation, maintains soil quality, and conserves water. It also ensures a natural and healthy ecosystem, improves land biodiversity, and conserves resources (Brodt *et al.*, 2011) [8]. Protecting natural resources, preventing the reduction of greenhouse gas emissions, and preserving biodiversity all depend on sustainable farming (Obaisi *et al.*, 2022) [31]. Increased farming production can be achieved through sustainable agriculture without compromising environmental protection or meeting the needs of future generations. In terms of sustainable agriculture, crop rotation and soil preservation are the cornerstones of smart farming. Management of insect and disease outbreaks, water collection, recycling, and crop nutrient shortages all contribute to a safer environment overall. Based on the usage of fertilizers, waste emissions, biodiversity, decaying dead plants, herbicides, etc., living things are dependent. Plants are impacted by greenhouse gas emissions, it is necessary to create a better habitat for people, animals, and the environment existence of life (Latake *et al.*, 2015) [27] (Fig: 1). A whopping 18% of India's GDP comes from agriculture, which also employs about 57% of the country's rural population. India's total agricultural output has grown over time, while the percentage of growers has fallen, from 71.9% in 1951 to 45.1% in 2011 (Reddy and Dutta, 2018) [35]. By 2050, the labor force's proportion will be dropped to 25.7%, according to the Economic Survey 2018, as there will be an increase in agriculture. Due to rising farming costs, low per-capita productivity, inadequate soil maintenance, and emigration to non-farming areas or a more lucrative job, farming families in rural areas their following generation of farmers gradually disappears. At a time when the world is on the verge of a digital revolution, it is suitable to connect the agricultural landform with wireless technology to introduce and accommodate digital communication with farmers.

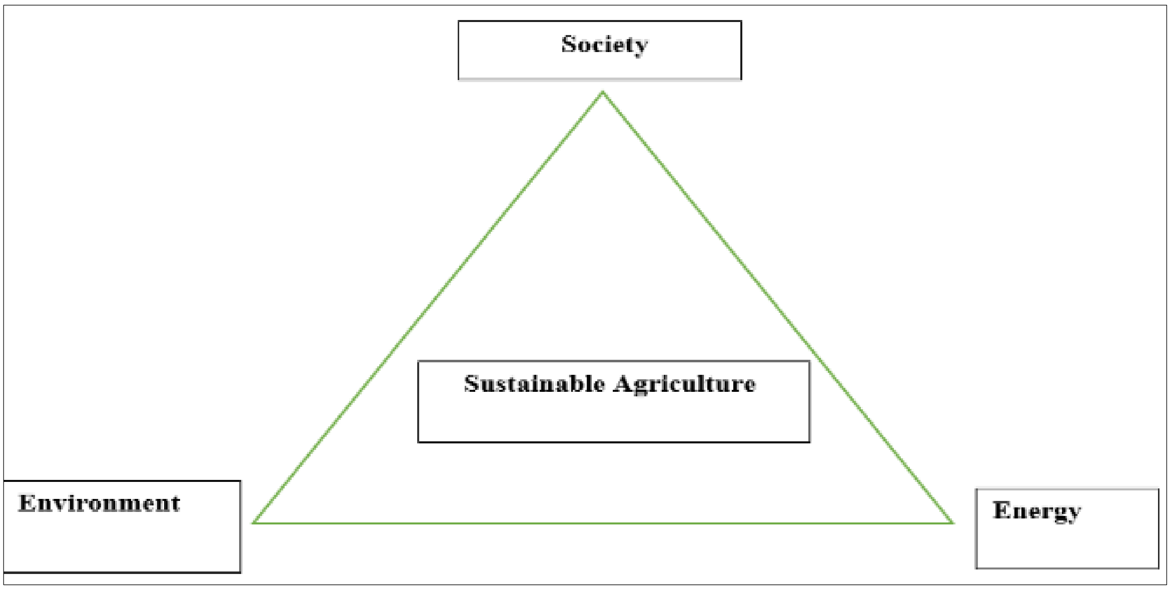

Fig 1: Factors of Sustainable Agriculture

Sadly, not all regions of the Earth's surface can be exploited for agriculture because of a number of restrictions, such as soil quality, topography, temperature, climate, and the fact that the bulk of the cultivable areas are not uniform (www.fao. org/3/a-y4252e.pdf). Furthermore, current agricultural land is political and fiscal characteristics, Moreover, urbanization is expanding, driving up the need for arable land (Figure 2). Recently, less agricultural area overall was used to generate food (Roser *et al.*, 2022) [36].

Additionally, each crop field has different essential components, such as the soil type, irrigation flow, fertilizer content, and insect resistance, which are each assessed separately in relation to a certain crop. Crop rotation and an annual cycle of crop growth and development, which both call for spatial and temporal adjustments are critical for maximizing crop production on a single plot of land (Hernández-Ochoa *et al.*, 2022) [20].

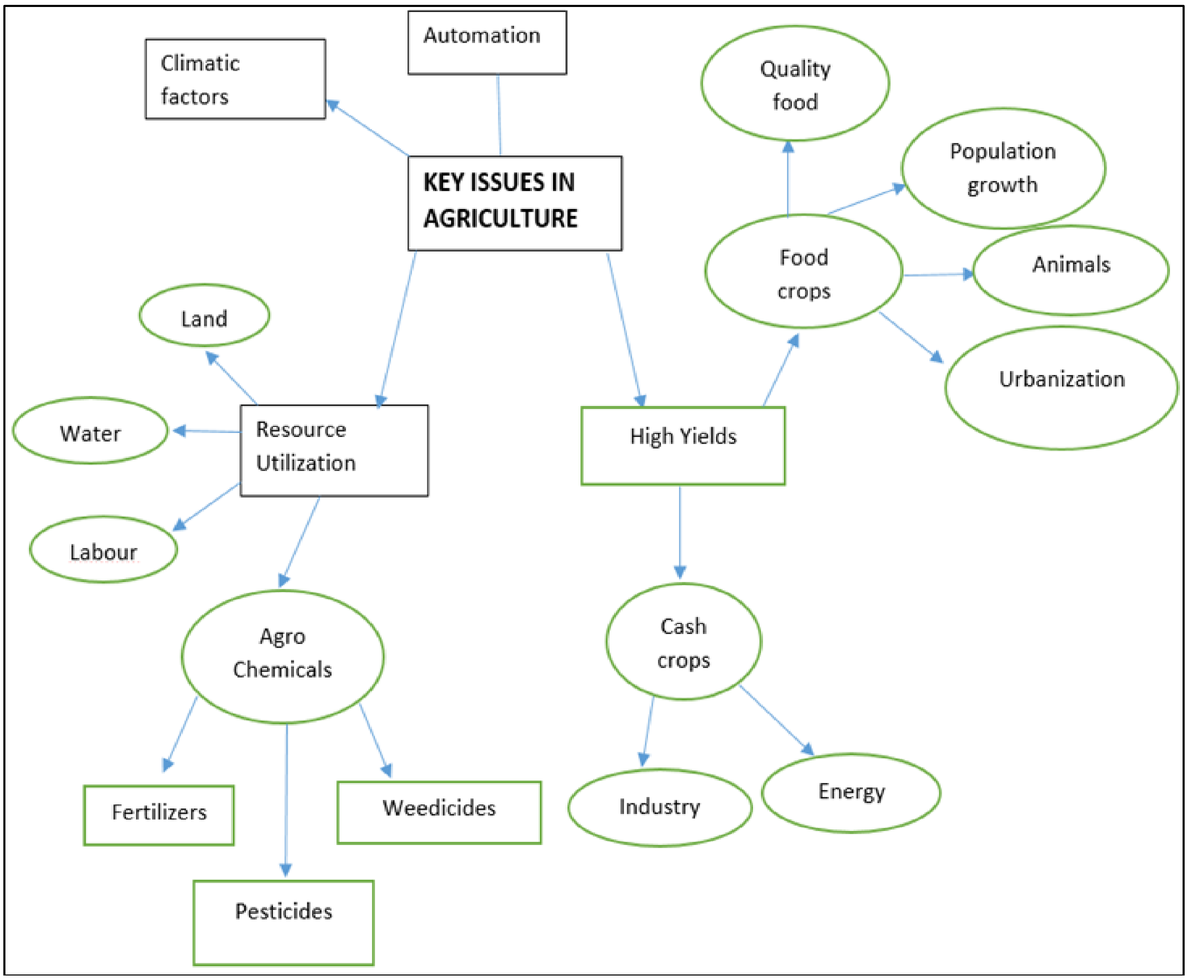

Fig 2: Important technological issues in the agricultural sector

Most often, a single crop undergoes changes in its characteristics, or the same crop is grown across the entire farm and requires site-specific analysis for best yield production. New technology-based approaches are necessary to handle these numerous challenges and produce more on a less amount of land. As part of traditional farming practices, farmers visit their fields frequently throughout the life of a crop to better comprehend the circumstances of the crop (Navulur *et al.,* 2017) [30]. Because modern sensor and communication technology gives farmers a precise perspective of the field, they may monitor ongoing field activities without physically becoming a professional. Digital sensors more precise agricultural tracking, and detection. Initial problem detection encourages frequent use of smart tools, from the beginning of planting until crop harvest (Ayaz *et al.,* 2018) [5].

The effective and clever use of sensors has revolutionized the entire farming process because of accurate monitoring. The numerous autonomous harvesters, robotic weeders, and drones all have sensors attached to them to collect data over short periods of time. However, because to the scale of agriculture, there are strong expectations for technical developments that are sustainable and have minimal environmental impact. Without having to physically be in the fields, farmers can take remote action by using sensor technology and wireless connection to learn about the various demands and requirements of crops (Lin *et al.,* 2017) [28].

Sustainable Agriculture

Sustainable agriculture, the Food and Agriculture Organization claims (FAO 2016), is "production that satisfies food security, environmental protection, and economic and social needs in rural areas." Because this activity involves both human actions, such farm management and agricultural regulations, as well as a number of independent variables, like climate conditions, geography, soil type, animal gas emissions, etc. (Cymerman 1994; Kiebasa *et al.,* 2016) [12, 23], this task is difficult.

Sustainable agriculture aims to preserve and safeguard natural resources. Some of these resources may be significantly damaged, contaminated, depleted, or all three (for example, soil nutrients or groundwater). Several natural resources, including phosphorous, are predicted to run out later this century. New sustainable agricultural practices are therefore emerging in order to protect and maintain resources (Cordell and White, 2011) [10].

Sustainable Nutrient management application for farms

At the agricultural level, the issues with global resources and environmental risks are less apparent. In this setting, nutrient management is essential to sustainable agriculture since it affects both agricultural productivity and soil and water quality (Pietrzak, 2013) [34]. Organic and mineral fertilizer management on farms must be sustainable and balanced because it affects both production results and the environment (Beegle *et al.,* 2000) [7].

Numerous instruments have been developed to help farm managers better manage nutrients and reduce nutrient losses. Nutrient flow studies conducted on farms are typically the basis for this. Analysis of the flow of nutrients on farms reveals whether it is required to concentrate on improving the effectiveness of some nutrients. When determining the balance for N, P, and K, the most frequent input channels, nutrient reserves (in cattle, manure, or other farm products), and the amount of output leaving farms are all taken into consideration (Fig. 3). The value of a FGB depends on how accurately the data is entered. Nutrient surpluses or deficits may be used as qualitative evaluations of a farm's environmental impact (Hendrix *et al.,* 2008; Ulen *et al.,* 2012) [21, 40]. A nutrient flow study may be used to build the farm-gate balance as a tool for sustainable agriculture. It is difficult to achieve sustainable nutrient management without a fertilisation strategy, which is another essential tool (Ulen *et al.,* 2013) [41]. The plan establishes the optimal amounts of mineral fertilizer and manure based on the nutritional requirements of each crop and the soil fertility, or the quantity of readily available macronutrients (Goulding *et al.,* 2008) [19].

The calculating model is an addition to a fertilization strategy. It was developed to assess how farming practices, such as crop rotation, ploughing intervals, yields from prior years, and fertilization activities, connect to the risk of nitrogen leaching from certain fields. The need for up-to-date knowledge on the nutrients in manure, which is something that is mostly absent in Poland (Oenema and Pietrzak, 2002) [32] - represents a specific problem with regard to fertilization. As evidenced by various research studies and practical outcomes, comprehensive knowledge of this aspect of farm management is required to handle the process of resolving nutrient flows from agricultural operations (Deumlich *et al.,* 1999) [14].

Smart Agriculture

According to Bacca *et al.,* 2019, the use of AI and IoT in cyber-physical farm management is at the centre of the field of smart agriculture. Smart agriculture addresses a wide range of issues pertaining to crop production since it makes it possible to keep an eye on climate changes, soil characteristics, soil moisture, etc. The Internet of Things (IoT) technology enables objects to be connected to the internet and operated autonomously, allowing for the connection of drones, robots, and ground sensors (Almetwally *et al.,* 2020) [2]. Enhancing spatial management methods to both boost crop output and decrease improper pesticide and fertilizer use is the core aim of precision agriculture (Amato *et al.,* 2015; Effat & El-zeiny 2017) [3, 15].

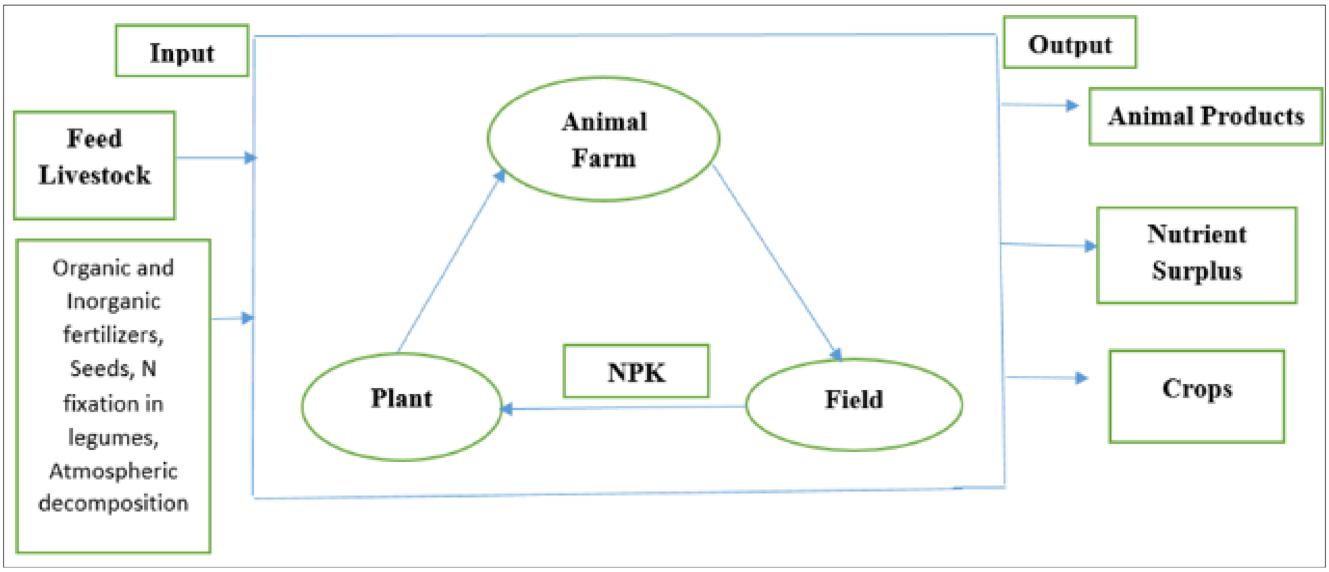

Fig 3: A farm's nutrient flow model

Numerous research have examined the use of ANN models in smart irrigation water management (SIWM). One of the essential criteria for agricultural irrigation is the determination of reference evapotranspiration (ETo), as it affects irrigation schedule (Cruz-Blanco *et al.*, 2014) [11]. The model of Penman-Monteith (PM) is the one that is most generally used to estimate evapotranspiration, despite the fact that good ET estimations require a lot of data. (Shitu *et al.*, 2018) [38]. The links that GIS has with other technologies, such remote sensing, AI, GPS, and others, may allow it to conserve a significant quantity of water that would Otherwise, irrigation would be required. For simple access to several viewpoints for the rice IWM Scheme, (Mohd *et al.*, 2014) [29] developed SWAMP (Soil-Water-Management for Paddies), a web-based Geospatial Decision Support System (DSS), and a (Graphical user interface), GUI based on Technology for widgets. The system offers data on irrigation water demand and supply, as well as irrigation efficiency and a water productivity index. One of the most crucial aspects of this system is its capability to visualize the results and deliver real-time information. The three main issues that, Climate-Smart Agriculture (CSA) was created to address are food security, adaptation, and mitigation (Palombi and Sessa, 2013) [33]. CSA has generated a great deal of interest, particularly in developing countries, due to its potential to improve food security and the resilience of farm systems while reducing greenhouse gas emissions (Palombi and Sessa, 2013) [33]. In order to distant implementation of multifunctional farm management supported by alternative relevant solutions of farm management in real-time, smart agriculture, which is an evolution of precision agriculture, requires the creation of novel approaches. According to Fig. 4 (Wolfert *et al.*, 2014) [42], In order to partially automate the electronic cyber-physical cycle, robots could carry out essential agrarian controls and prepare for automatic analysis and planning.

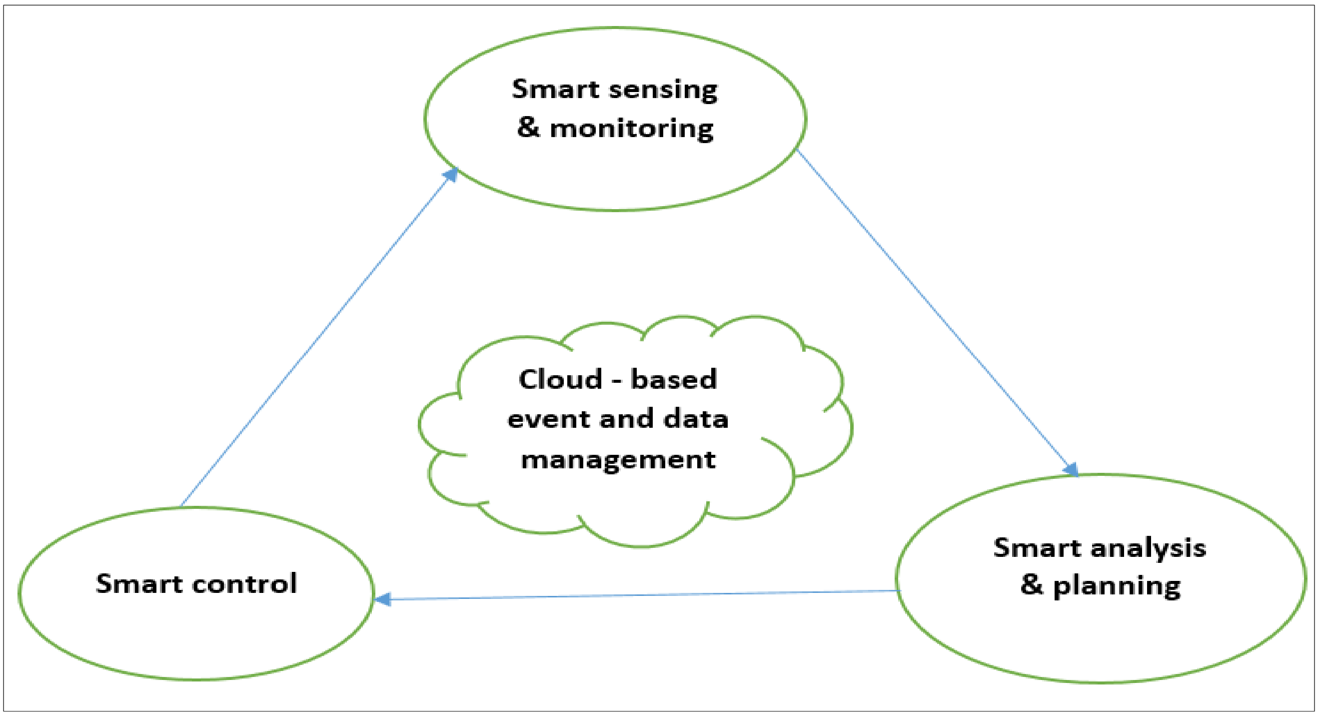

Fig 4: Cycle of smart farming

Smart agriculture technology built on the Internet of Things (IoT) has several advantages for all agricultural practices and processes in real-time, including plant watering and protection, product quality improvement, fertilization process control, disease prediction, etc. (Adamides *et al.*, 2020) [1].

The advantages of smart agriculture

- The expansion of crop real-time data volume.
- Monitoring and managing farmers remotely.
- Controlling how natural resources, like as water, are used.
- Improving the management of livestock.
- Accurate evaluation of the crops and the land.
- Increasing agriculture's output.

loT in smart agriculture

As seen in Fig. 5, The Internet of Things (IoT) is a sophisticated and cutting-edge technology that provides unique and helpful solutions in a range of industries, including smart cities, smart homes, traffic management, healthcare, smart agriculture, etc. Farm management in the field of agriculture has been greatly improved by IoT technology. By connecting all agricultural machinery and equipment, this technology enables informed decisions to be made about irrigation and fertilizer supply (Kumar and Periasamy, 2021) [25]. Smart solutions increase the precision and efficiency of machinery that monitors plant growth and even livestock care. Wireless sensor networks (WSNs) are used to collect data from various sensing devices. In order to analyse and process the distant data that enables decision-making and the implementation of the best decisions, cloud services must be connected with IoT (Farooq *et al.*, 2020) [6]. Smart farm management requires the use of ICT, ground sensors, and control systems placed on robots, autonomous vehicles, and other automated devices. The success of smart systems depends on having access to fast internet, cutting-edge mobile devices, and satellites that provide (positioning of images).

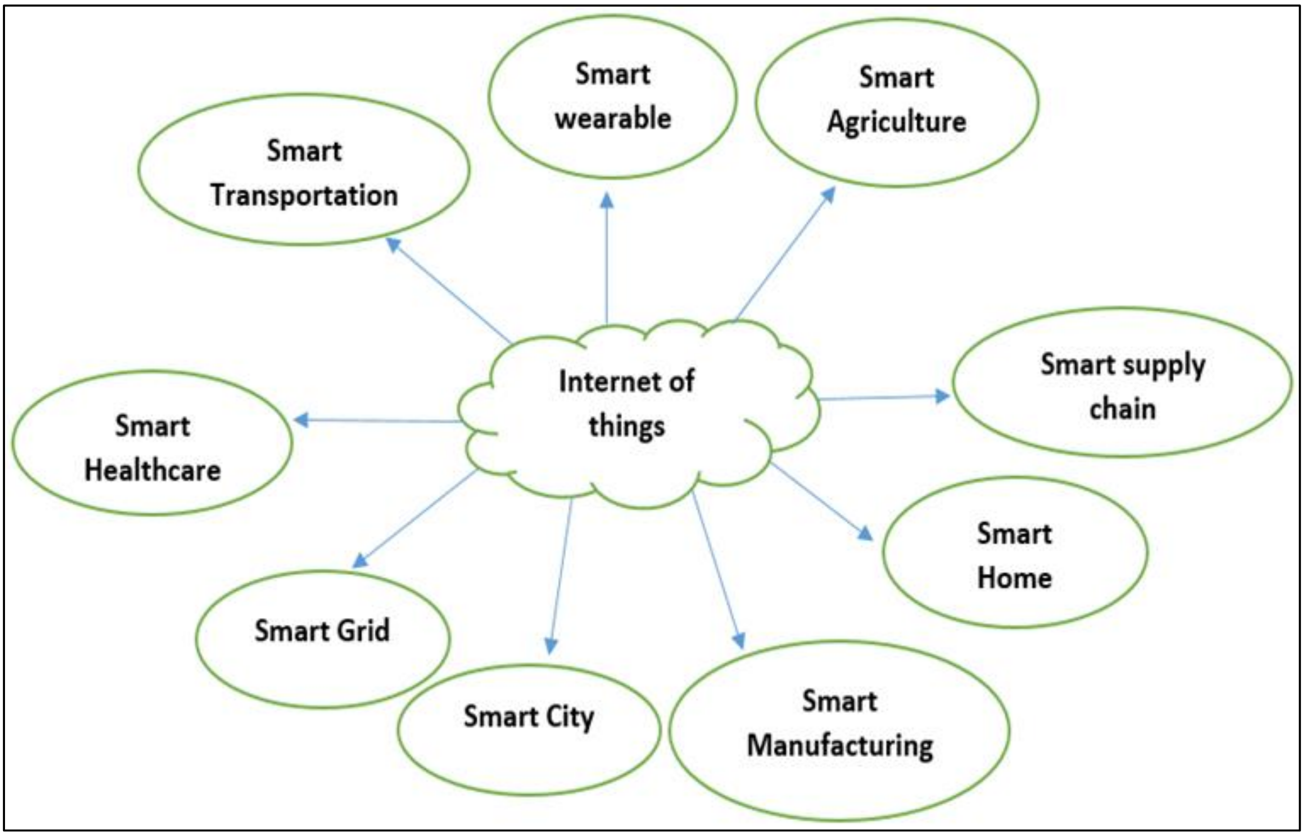

Fig 5: Application of IoT in different areas (Samaila *et al.*, 2018)

The Food and Agriculture Organization (FAO 2017) [17] claimed that inadequate 20-40% of crops are lost each year due to pests, diseases, and other problems because of crop monitoring. Due to the use of sensors and intelligent systems, it is now possible to monitor weather conditions, fertility levels, and calculate the correct amount of fertilizer needed for crop growth. The fertility of the soil is negatively impacted by the overuse of fertilizers. (Farooq *et al.*, 2020) [6] examined 67 research publications published between 2006 and 2019 that discussed the usage of IoT in diverse agricultural applications. They discovered that about 16% of the papers discussed precision agriculture, along with 16% that discussed irrigation monitoring, 13% that discussed soil monitoring, 12% that discussed temperature, 11% that discussed animal monitoring, 11% that discussed humidity, 5% that discussed air and disease monitoring, and 7% that discussed water monitoring. Finally, only 4% of the research studies examined fertilization monitoring (Fig. 6).

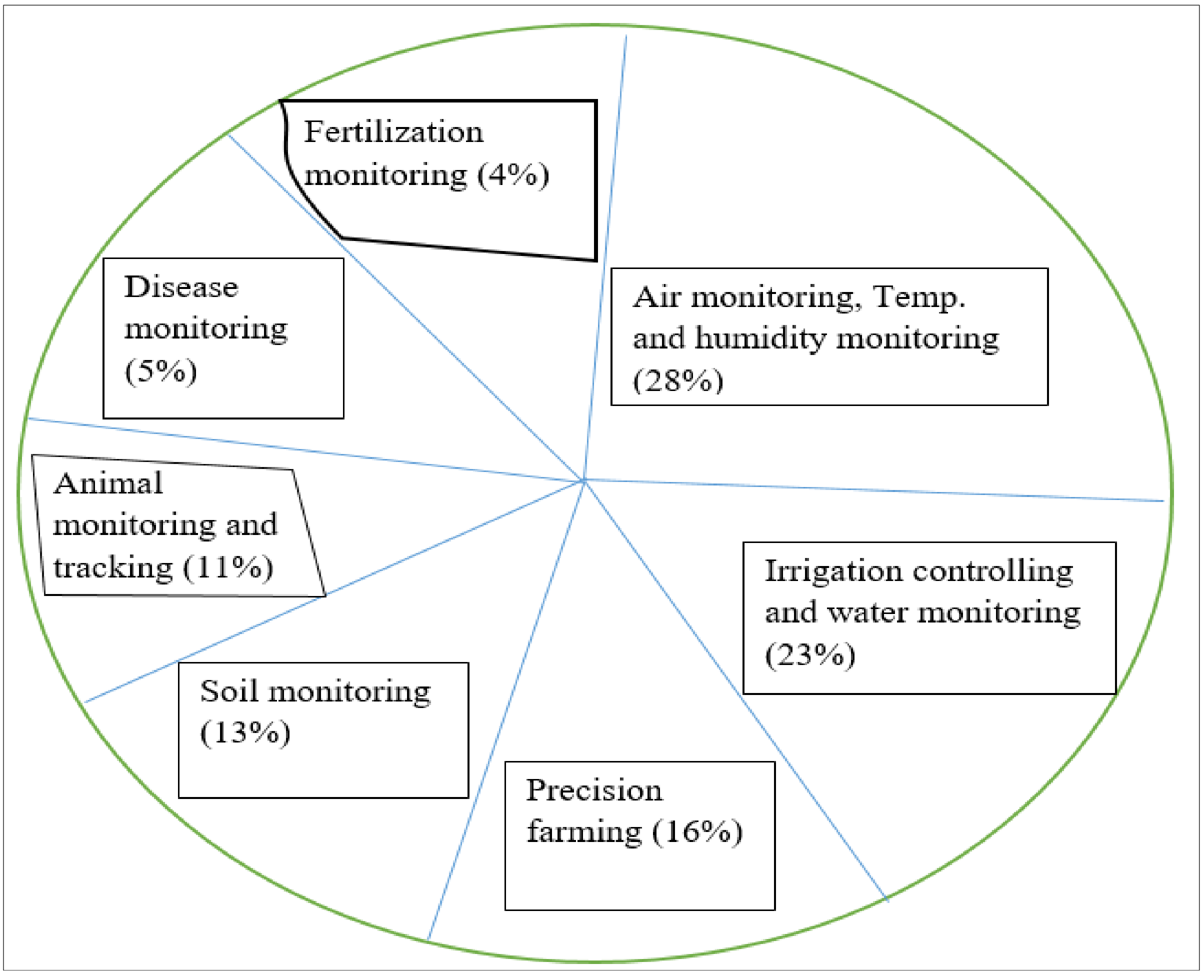

Fig 6: IoT implementation in smart agriculture

Smart sensing for Agriculture

Sensors are used to measure and monitor every component of the smart system; for instance, specialized sensors are used in soil health monitoring to measure nutrients, phosphates, soil moisture, compaction, and other factors. The smart irrigation system included numerous sensors for tracking water levels, irrigation efficiency, climate sensors, etc. At farm sites, the sensors can track and measure changes in the soil, yield, and local weather. In order to analyse the farm statutes and come to a proper choice, the sensors can collect various data. These advanced sensors improve the quantity and quality of agricultural output while monitoring changes in the health of the soil, crops, and livestock. The typical sensors used in smart agricultural networks include soil moisture sensors that monitor changes in soil moisture, soil temperature sensors that track soil temperature, air temperature sensors, soil pH sensors that measure soil pH, humidity sensors, N, P, and K sensors, among others (Kumar *et al.*, 2021) [9].

Application of IoT in smart farming

Since the Internet of Things (IoT) serves as the foundation for all intelligent applications, smart systems are primarily associated with.

IoT based for drones

Since the early 1980s, despite their limited use, drones have been employed economically in agriculture. However, with the advancement of communication technological aspects and the growing uptake of IoT, the usage of automatic aircraft has become more crucial. It can do a range of functions that improve farming practices. Monitoring crop health, soil testing, planting, crop spraying, and irrigation are all drone operations. If the drone is equipped with a variety of sensors, 3D cameras, thermal, multi-spectral, and optical imaging cameras, it can also be used to monitor crop conditions and diseases, plant health indicators, vegetable density, pesticide prospecting, fertilizer, canopy cover mapping, field prediction, plant count, plant height measurement, field water mapping, exploratory reports, and nitrogen measurement (Islam *et al.*, 2021) [9].

Limitations use of drones in agriculture

Although using unmanned aircraft has many benefits, there are still significant challenges to be overcome, especially in underdeveloped countries (Ayamga *et al*. 2021) [4]. These obstacles include the following.

- The drone can only fly for an hour or less at a time, therefore while deciding on the flight line direction, it's vital to consider how the flight lines will overlap.
- Drones are pricey, especially those with top-notch hardware, software, cameras, and thermal imaging gear.
- The need for authorization, which can be difficult in many countries, and the need that the pilot's height not exceed 400 feet are among the drone operating rules.
- Climate impact: Drone operation is impacted by climatic factors. Before beginning any task, the weather must be taken into account because rain and wind have an impact on drone operation.

IoT agricultural robot

The agricultural robot is a machine used in many agricultural operations. IoT has facilitated the creation of agricultural robots that can do a range of jobs that would otherwise require humans. They grew to include the US, Europe, and many Asian countries' adoption of such modern technology in agriculture. Robots have improved agricultural productivity by reducing operating expenses and labor hours (Kootstra *et al.,* 2021) [24]. The robots can also get rid of up to 80% of the pesticides used on farms without doing any damage to the environment. Agriculture robots will be helpful tools to provide innovative solutions for smart agriculture in order to manage labor shortages and the development of diseases like Covid 19. Robots are used for the harvesting, seedlings, unwanted plant detection, required irrigation, infestation of pest, applications for animal, and other duties are only a few of the many agricultural robots that can do one or more jobs (Darwin *et al.,* 2021) [13]. The successful development of a multi-purpose smart farm robot (MpSFR) using IoT and computer vision (CV) for technologies was reported by Chand *et al*. in 2021 [9]. The gadg*et al*so makes use of battery-powered photovoltaic (PV) electricity. The robot has a tank for insecticides and water, and the experts have confirmed that it runs on autopilot. Sensors that use infrared light to check crop health operate the robot. The robot can cover a 5 m^2 space. Robots have also been successfully used in many different industries, including quality control, handling of material, transportation purpose, processing purpose, and inspection purpose.

Conclusion

The purpose of the current study was to highlight the importance of smart agriculture in boosting and increasing agricultural productivity in order to assist close the gap between the supply and demand for food. Since it connects every component of intelligent systems used in both agricultural and other fields, IoT is recognized as the base of smart agriculture technology. IoT has several applications in agriculture, including monitoring farms, irrigation, pest control, harvesting, etc. IoT integrates several sensors with processing devices, processes data, and then chooses how to move right away. This study looked at the use of IoT integration with AI-controlled UAV and robotic systems as well as the problems with their use in underdeveloped countries. Finally, because these smart technologies are intended to increase productivity and improve the efficient use of water and land resources, governments in developing countries should support them at the level of small farms.

Reference

1. Adamides G, Kalatzis N, Stylianou A, Marianos N, Chatzipapadopoulos F, Giannakopoulou M, *et al*. Smart Farming Techniques for Climate Change Adaptation in Cyprus. Atmosphere. 2020;11(6):557. Available from: https://doi.org/10.3390/atmos11060557.
2. Almetwally SAH, Hassan MK, Mourad MH. Real Time Internet of Things (IoT) Based Water Quality Management System. Procedia CIRP. 2020;91:478-485.
3. Amato F, Havel J, Gad A, El-Zeiny A. Remotely Sensed Soil Data Analysis Using Artificial Neural Networks: A Case Study of El-Fayoum Depression, Egypt. ISPRS International Journal of Geo-Information. 2015;4(2):677-696. Available from: https://doi.org/10.3390/ijgi4020677.
4. Ayamga M, Tekinerdogan B, Kassahun A. Exploring the Challenges Posed by Regulations for the Use of Drones in Agriculture in the African Context. Land. 2021;10(2):164.
5. Ayaz M, Ammad-uddin M, Baig I, Aggoune E.M. Wireless Sensor‘s Civil Applications, Prototypes, and Future Integration Possibilities: A Review. IEEE Sens. J. 2018;18:4-30.
6. Bacco M, Barsocchi P, Ferro E, Gotta A, Ruggeri M. The digitisation of agriculture: A survey of research activities on smart farming. Array. 2019;3-4:100009. Available from: https://doi.org/10.1016/j.array.2019.100009.
7. Beegle DB, Carton OT, Baily JB. Nutrient management planning: justification, theory, practice. Journal of Environmental Quality. 2000;29:72-79.
8. Brodt S, Six J, Feenstra G, Ingels C, Campbell D. Sustainable Agriculture. Nat. Educ. Knowl. 2011;3:1.
9. Chand AA, Prasad KA, Mar E, Dakai S, Mamun KA, Islam FR, Kumar NM. Design and Analysis of Photovoltaic Powered Battery-Operated Computer Vision-Based Multi-Purpose Smart Farming Robot. Agronomy. 2021;11:530.
10. Cordell D, White S. Peak phosphorus: Clarifying the key issues of a vigorous debate about long-term phosphorus security. Sustainability. 2011;3(10):2027-2049.
11. Cruz-Blanco M, Lorite IJ, Santos C. An innovative remote sensing based reference evapotranspiration method to support irrigation water management under semi-arid conditions. Agricultural Water Management. 2014;131:135-145.
12. Cymerman R. Gospodarka zrównoważona (eko rozwój) na obszarach wiejskich. W: Doradztwo w eko rozwoju obszarów wiejskich. Szczecin; c1994. p. 11-36.
13. Darwin B, Dharmaraj P, Prince S, Popescu DE, Hemanth DJ. Recognition of Bloom/Yield in Crop Images Using Deep Learning Models for Smart Agriculture: A Review. Agronomy. 2021;11(4):646.
14. Deumlich D, Mioduszewski W, Kocmit A. Analysis of nutrients entering rivers with surface flow in the Odra catchment. Journal of Water and Land Development. 1999;3:33-45.
15. El-Zeiny A, El-Hefni A, Sowilem M. Geospatial techniques for environmental modeling of mosquito breeding habitats at Suez Canal Zone, Egypt. The Egyptian Journal of Remote Sensing and Space Science. 2017;20(2):283-293.
16. Farooq MS, Riaz S, Abid A, Umer T, Zikria YB. Role of IoT technology in agriculture: A systematic literature review. Electronics. 2020;9(2):319.
17. FAO. The future of food and agriculture-Trends and challenges. Annual Report. 2017.
18. FAO. Sustainability assessment of food and agriculture systems (SAFA) [Internet]. Rome: Food and Agriculture Organization of the United Nations; c2016 [Accessed 07.11.2016]. Available from: http://www.fao.org/nr/sustainability/sustainability-assessments-safa/en/
19. Goulding K, Jarvis S, Whitmore A. Optimizing nutrient management for farm systems. Philosophical Transactions of the Royal Society - Biological Sciences. 2008;363(1491):667-680.

20. Hernández-Ochoa IM, Gaiser T, Kersebaum KC, Webber H, Seidel SJ, Grahmann K, Ewert F. Model-based design of crop diversification through new field arrangements in spatially heterogeneous landscapes. A review. Agron. Sustain. Dev. 2022;42:74.
21. Hendrix PF, Coleman DC, Crosseley DA Jr. Using knowledge of soil nutrient cycling processes to design sustainable agriculture. In: Agroecology and sustainable food systems. Taylor & Francis Group; c2008. p. 63-82.
22. Islam N, Rashid MM, Pasandideh F, Ray B, Moore S, Kadel R. A Review of Applications and Communication Technologies for Internet of Things (IoT) and Unmanned Aerial Vehicle (UAV) Based Sustainable Smart Farming. Sustainability. 2021;13(4):1821.
23. Kiebasa B, Drangert JO, Ulen B, Tonderski K. Drivers and constraints for Polish farmer's implementation of measures to remediate nutrient leaching to waters. International Scientific Journal Mechanization in Agriculture and Conserving of the Resources. 2016;62(4):22-26.
24. Kootstra G, Wang X, Blok PM, Hemming J, Van Henten E. Selective harvesting robotics: current research, trends, and future directions. Current Robotics Reports. 2021;1-10.
25. Kumar TU, Periasamy A. IoT Based Smart Farming (E-FARM)'S. International Journal of Recent Advances in Multidisciplinary Topics. 2021;2(4):85-87.
26. Kumar R, Mishra R, Gupta HP, Dutta T. Smart Sensing for Agriculture: Applications, Advancements, and Challenges. IEEE Consumer Electronics Magazine; c2021.
27. Latake PT, Pawar P, Ranveer AC. The Greenhouse Effect and Its Impacts on Environment. Int. J. Innov. Res. Creat. Technol. 2015;1:333-337.
28. Lin J, Yu W, Zhang N, Yang X, Zhang H, Zhao WA. Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications. IEEE Internet Things J. 2017;4:1125-1142.
29. Mohd MM, Soom M, Amin M, Kamal R, Wayayok A. Application of Web Geospatial Decision Support System for Tanjung Karang Rice Precision Irrigation Water Management. In: International Conference on Agriculture, Food and Environmental Engineering (ICAFEE'2014). Jan. 15-16, c2014. p. 24-28.
30. Navulur S, Sastry ASCS, Giri Prasad MN. Agricultural Management through Wireless Sensors and Internet of Things. Int. J. Electr. Comput. Eng. 2017;7:3492-3499.
31. Obaisi AI, Adegbeye MJ, Elghandour MMMY, Barbabosa-Pliego A, Salem AZM. Natural Resource Management and Sustainable Agriculture. In: Handbook of Climate Change Mitigation and Adaptation. Springer; c2022.
32. Oenema O, Pietrzak S. Nutrient management in food production: Achieving agronomic and environmental targets. AMBIO: A Journal of the Human Environment. 2002;31(2):159-168.
33. Palombi L, Sessa R. Climate-smart agriculture: sourcebook. Climate-smart agriculture: sourcebook; c2013.
34. Pietrzak S. Sporządzanie bilansów składników nawozowych metodą „u bramy gospodarstwa". In: Samoocena gospodarstw w zakresie zarządzania składnikami nawozowymi i oceny warunków środowiskowych. Eds. B Ulén, S Pietrzak, K Tonderski. Falenty; Wydaw. IMUZ; c2013. p. 7-33.
35. Reddy T, Dutta M. Impact of Agricultural Inputs on Agricultural GDP in Indian Economy. Theor. Econ. Lett. 2018;8:1840-1853.
36. Roser M, Ritchie H, Ortiz-Ospina E. World Population Growth. Available online: https://ourworldindata.org/world population-growth (accessed on 1 August 2022).
37. Samaila MG, Neto M, Fernandes DA, Freire MM, Inácio PR. Challenges of securing Internet of Things devices: A survey. Security and Privacy. 2018;1(2):e20.
38. Shitu A, Tadda MA, Danhassan AU. Irrigation water management using smart control systems: a review. Bayero Journal of Engineering and Technology. 2018;13:2449-2539.
39. Srisruthi S, Swarna N, Ros GMS, Elizabeth E. Sustainable agriculture using eco-friendly and energy efficient sensor technology. In: Proceedings of the 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT). IEEE; c2016. p. 1442-1446.
40. Ulen B, Djodjic F, Buciene A, Masauskiene A. Phoshporus load from agricultural land to the Baltic Sea. In: Ecosystem Health and Sustainable Agriculture 1: Sustainable Agriculture. Ed. Ch. Jakobsson. The Baltic University Programme. Uppsala Univ.; c2012. p. 82-102.
41. Ulen B, Pietrzak S, Tonderski K. Self-evaluation of farms for improved nutrient management and minimised environmental impact. Baltic Sea 2020. Falenty; Wydaw. ITP; c2013. ISBN 978-83-62416-67-7. p. 92.
42. Wolfert S, Goense D, Sorensen CAG. A future internet collaboration platform for safe and healthy food from farm to fork. In: 2014 annual SRII global conference. IEEE; c2014. p. 266-273.
43. World Agriculture: Towards 2015/2030: An FAO Perspective and Summary Report. FAO; c2002. Available online: www.fao.org/3/a-y4252e.pdf.