Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 3, July : 2023

AGRI TECH SENSE ADVANCED CROP MONITORING SYSTEM TO MAXIMIZE FARMING PRODUCTIVITY THROUGH AGRICULTURE 4.0-BASED INTELLIGENCE

Jivan L. Musale[1], Rahul B. Pawar[1], Ashutosh A. Garad[1], Amol B. Chounde[1], Suhas B. khadake[1] Assistant Professor, Department of Electronics and Telecommunication engineering, SVERI's College of engineering, Pandharpur, Maharastra, India

Abstract
This is leading to more sustainable and profitable farming practices, as well as reduced environmental impact. As the global residents hold up to rise, the requirement of daily bread will only boost. The latest farming revolution, known as "Agriculture 4.0," employs digital technologies to transform the industry into one that is smarter, more effective, and ecologically conscious. Technologies for agriculture have developed to improve sustainability and find more productive farming practices. All forms of digitization and automation, such as bulk data, the Agri Tech sense Advanced Crop monitoring system using industry 4.0, robotics and virtual and augmented reality, are included in this. These developments in technology are significantly altering our way of life. It introduces us to precision agriculture from a technical perspective. The majority data previous system was untapped, but at same time the aid of bulk data innovation techniques, such data utilize to enhance any crop's performance and output. Digitized harvesters can help manage large regions in many settings, particularly agriculture, depending on the crop variety and its growing requirements. This essay provides a succinct overview of Agriculture 4.0 and its state. Finally, suggestive applications of Agri Tech sense Advanced Crop monitoring system Agriculture 4.0 innovations are recognized and explored, along with smart farming, a number of essential technologies, particular domains for the Exploring Agriculture 4.0 Domain. Agri Tech sense Advanced Crop monitoring system use sensors to gather information on things like soil moisture, temperature, humidity, rainfall, and crop development. Following this data analysis, machine learning algorithms offer insights and suggestions to farmers to help them make better decisions.
In order to increase farming production in high-humidity areas, we deploy an industry4.0 based sharp Crop Monitoring system in our article on Smart Agriculture 4.0. Also, however Crop growth can be impacted by high humidity levels, which can raise the danger of illnesses and pests. Farmers may better monitor and manage their crops by utilizing IoT technologies. An IoT-based solution can assist in these areas in the following ways: and to increase farming output by utilizing Agri Tech Sensing Advanced Crop monitoring system Through Agriculture 4.0-based Intelligence.

Keywords:
Agri Tech sense, Industry 4.0, Internet of Things, sensors, Smart farming.

I. Introduction
Smart Agriculture 4.0 a type of agricultural technology known as Agri Tech sense Advanced Crop monitoring system uses industry 4.0 to gather data base from numerous sensing devices placed in a crop field. These technologies enable precision agricultural techniques and maximize crop yields by combining sensors, data analytics, and networking. Smart agriculture monitoring systems based on IoT can measure a variety of Physical parameters like Temperature, moisture, soil pH, nutrient levels, and even the presence of pests and diseases. Farmers may improvise the system to reduce waste and maximize crop quality and quantity by collecting and analysing this data in order to make knowledgeable decisions regarding irrigation, fertilization, and pest control. One of the key benefits of Smart Agriculture 4.0 IoT-based smart crop monitoring systems is their ability to provide real-time

data and alerts to farmers, allowing them to make necessary adjustments to crop management practices quickly. This real-time monitoring also allows for early detection of potential problems, such as plant diseases or insect infestations, which can be addressed before they cause significant damage.

Furthermore, Agri Tech sense Advanced Crop monitoring system can help farmers save resources, such as water and fertilizers, by allowing them to apply these inputs accurately based on real-time data, rather than a predetermined schedule. This precise, data-driven approach can lead to improved crop yields and a more sustainable farming operation Agri Tech sense Advanced Crop monitoring system intuition A form of agricultural technology known as advanced crop monitoring systems uses industry 4.0 to gather various sensing devices placed in farm. These newly innovated technologies enable precision agricultural techniques and maximize crop yields by combining sensors, data analytics, and networking. The future developments in Agri Tech sense Advanced Crop monitoring system include –

Integration with Block chain: Agri Tech Sense's block chain integration Block chain may be connected with advanced crop monitoring systems to provide safe and visible data exchange in between various participants to the present agricultural chain. To instance, in order to ensure that they are paid fairly for their goods, producers might exchange information with purchasers on crop yields and quality. To get intellect into tidy crop, crop growth rates, and final yield potential, the data gathered from these sensing devices is then examined using newly invented machine learning and other data analytics techniques. Farmers may utilize this information to make well-informed choices regarding crop management techniques including irrigation, fertilization, and pest control. Smart agricultural monitoring systems built on the IoT (Internet of Things) can significantly boost farming production in a number of ways:

- **Accurate agricultural growth monitoring:** IoT sensors can keep track of a variety of environmental factors that influence crop development, including temperature, humidity, moisture, soil nutrient content, and sunshine. Farmers may make more informed judgments about crop management techniques and maximize crop development by carefully monitoring these characteristics. Industry 4.0 identify new indicators of agricultural illnesses and blight, enabling farmers to take preventive action before the issue gets uncomfortable This increases production and lowers crop losses.
- **Effective irrigation:** To optimize irrigation schedules, newly IoT based irrigation systems may monitor physical parameters weather predictions and crop water needs. This prevents water waste and promotes the health of crops by ensuring that they receive the proper amount of water.
- **More accurate agriculture yield forecasting:** IoT based sensing devices can gather information various crop , their physical conditions on basis of their growth percentage and soil quality that can be used to forecast crop yields with more accuracy. Agronomist can better use their resources and plan for the harvest thanks to this.
- **Remote monitoring and control:** Farmers may manage their crops from anywhere by using industry 4.0 based crop monitoring devices .that can be observed and managed remotely. Because of the time and money saved, farmers may concentrate to other areas also.
- **Higher crop yields:** By offering real-time information of crop strength and crop growth rates, agronomist may choose crop management strategies with greater certainty.
- **Reduced resource waste:** agronomists may maximize the use of crop newly water irrigation to improve crop strength by utilizing precision farming techniques, which reduces waste and increases efficiency.

Smart agricultural monitoring solutions based on the Internet of Things have a very bright future. Improving crop yields and assisting management decisions using high technology sensor and analysis tools precise sprinkling and soil observing has already demonstrated the potential of Industry 4.0 to

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 3, July : 2023

revolutionize agriculture. Agronomist can observe farming physical parameters like crop growth, conditions, pests and diseases in real-time with the use of the Industry 4.0, allowing them to make data-driven choices to maximize agricultural yields and efficiently use resources.

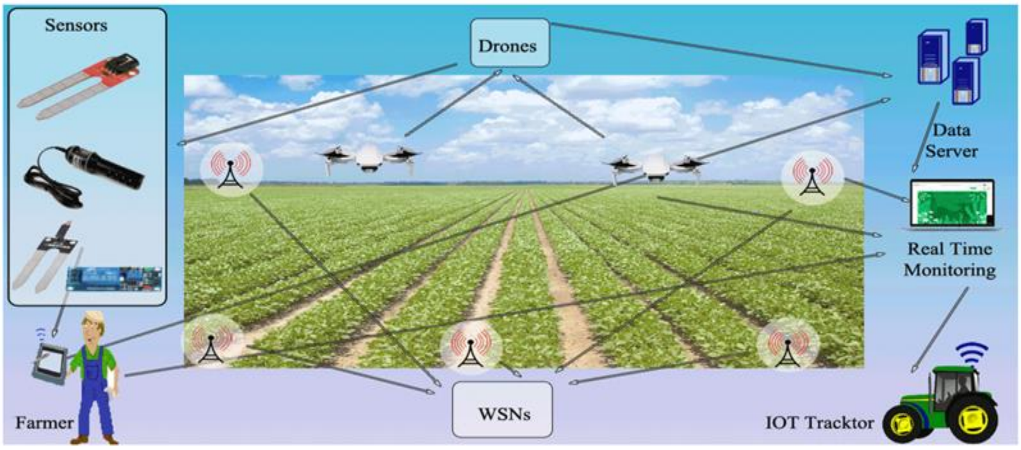

Figure 1: Advanced Crop monitoring system to maximize farming productivity Through IoT-based Intelligence.

1.1 Smart Agriculture

There are numerous uses of this technology. Intelligent agricultural practices are being used. To enhance the precision of fertilizer, pesticide, and herbicide applications. Robot Drones are used for various filed work and managing weeds, while robots are helping farmers with tasks like milking animals and weed removal. Smart Agriculture i.e. Agri sense 4.0 technologies enable farmers to adopt a more systematic manner to cultivation and make accurate predictions about the outcome. Some evolving technologies such as the Industry 4.0 is the Practicable to revolutionize farming, leading to a significant shift towards Smart Agriculture 4.

Technology has the attainable to improve practically every element of crop, from planting and planting through harvesting. This gives farmers a thorough awareness of their land, resulting in a more scientific and less arbitrary production method. [20-22]. Four most important parts form the foundation of Agri sense 4.0 i.e data-driven management, production using cutting-edge tools, sustainability, and professionalization. Agriculture will be moved toward a simplified and intelligent management strategy by the mobile Internet, IoT, computer vision, and intelligent quick decision-making. Specialized agro sense solutions that use 5G, cloud computing, and AI may boost productivity, optimize resource use, raise land yields, and more. With its high data rate, low abeyance, and broadband correlation capabilities, 5G facilitate data processing and also transmission, the stability and controllability of 5G drones and robots can allow new production scenarios including real-time remote diagnosis, video monitoring, and on-site analysis when paired with AI and cloud computing. [23-25].

1.2 The demand for Smart Agriculture 4.0

The need for Agriculture 4.0 arises from the potential benefits it offers in terms of improved efficiency, optimized resource management, enhanced monitoring and control, data-driven decision-making, and the professionalization of farming practices. By embracing these technologies, farmers can adapt to evolving challenges and opportunities in the agricultural sector, leading to a more productive and sustainable future.

The demand for Agriculture 4.0 arises due to several reasons. Firstly, evolving technologies such as the Industry4 .0 offers the probable to bring about a significant transformation in the agricultural sector. By harnessing these technologies, farmers can achieve improved efficiency, productivity, and sustainability in their operations.

Secondly, Agriculture 4.0 addresses the need for precise and optimized resource management. Through data-driven management and intelligent decision-making, farmers can make more informed choices regarding the use of fertilizers, pesticides, and water. This leads to reduced waste, lower costs, and minimized environmental impact.

Thirdly, the integration of advanced technologies in agriculture allows for better monitoring and control of farming processes. Drones equipped with sensors and computer vision can aid in early detection of crop diseases, pest infestations, and weed growth. Robots can automate labor-intensive tasks, freeing up human resources for more strategic and value-added activities.

Depending on the needs of the farm and the goal of settling IoT, the linked farming framework requires real-time data and can cover a large area. All management tasks, including as planting, cultivation, irrigation, fertilizing, and harvesting, are handled by the robot. [26, 27]. Small wardrobes, conservatory, and indoor agricultural conditions may all be used by open source precision agriculture CNC farming project. The problem of erratic or nonexistent network coverage necessitates the creation of ad-hoc solutions that offer service access via cloud-based platforms. Additionally, to overcome the reluctance of agricultural professionals to accept new technology, personalized understanding that are catered to their unique demands and working circumstances are needed. [28-30].

More data for improving traceability, gratify local and global buyer presumption, and boosts the competitiveness and profitability of the whole agricultural value chain. IoT data may now be easily integrated into many other applications appreciate to mobile software, making it more commonplace in agricultural equipment than not. As a result, there are less time and money costs related to human mistakes. Important elements including soil nutrition, temperature, humidity, and others are monitored via sensors. [31, 32]. The IoT makes it possible for seamless connection between various agricultural instruments, doing away with the necessity for manmade data entry into several disconnected applications. The broad use of smart farming still faces difficulties with data sharing across different agricultural units. It is now being worked on to create same communication protocols for IoT devices and the introduction of 5G and other technologies like space-based Internet are expected to help. [33, 34].

Beyond effective data understanding and analysis from linked gear, digital farming goes farther. Among other things, it uses IoT to automate irrigation systems and monitor fields with sensors. Drones are essential for analyzing the quality of the soil, keeping track of crop health, applying fertilizer, forecasting agricultural output, and monitoring weather patterns. Insights from digital farming go beyond what humans can observe. In-depth information on terrain characteristics like contours and slopes, which might impact farming, is available thanks to advanced imaging technology. It provides thorough investigation to soil characteristics such things, quantity of organic matter, and moisture content as well as reliable measurement of soil conductivity.

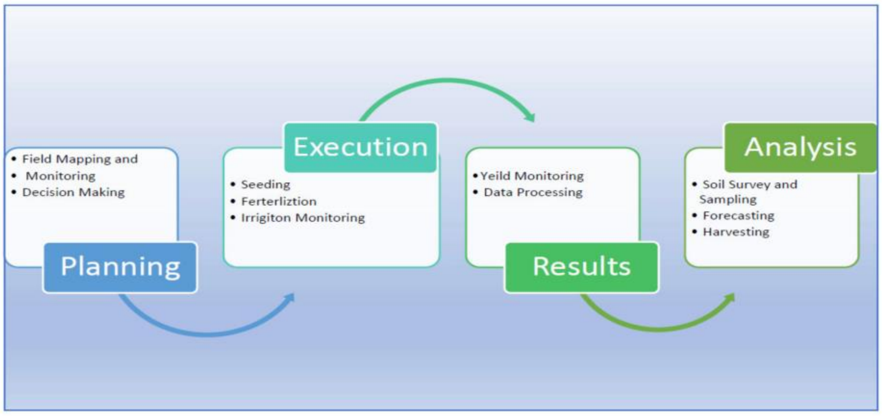

Figure 2: Process for Agri sense 4.0.

II. Different key technologies to explore the field of Agri sense 4.0

Agri Tech sense Advanced Crop monitoring system integrates various smart agronomics technologies and practices to enhance agricultural processes, increase efficiency, and address challenges faced by the agriculture industry. These technologies include AI, machine learning, IoT, remote sensing, and data analytics, enabling farmers to make data-driven decisions, optimize resource allocation, and improve sustainability. Responsible innovation and conservation agriculture are also vital components of Agriculture 4.0, promoting sustainable and inclusive agricultural practices.

The concept of Agriculture 4.0 encompasses various smart and superior technological practices aimed at revolutionizing the agricultural domain. These practices include:

Smart Agri sense Characteristics: Agriculture robots, digital agriculture, and new smart agronomic technology are key components of Agriculture 4.0. In the field of Agriculture various tasks robots can perform such as planting, harvesting, and monitoring crops, increasing efficiency and reducing labor requirements. Digital agriculture involves the use of newly available digital technologies to collect the data and analyze the data for optimized decision-making in farming operations. Smart farming integrates technologies like IoT, remote sensing, and AI to enable real-time monitoring and management of agricultural processes.

Agriculture Management: Agriculture 4.0 emphasizes efficient pantry systems, fast decision-making processes, and total sustainability. Technologies like AI, machine learning, and big data analytics can generate actionable insights to improve rate of crop yield, control pests, and aid in soil management. These newly adaptable technologies enable agronomist to collect, visualize, and analyze crop and soil health parameters at different stages of yield, facilitating timely interventions and also solutions.

Agriculture Science: Precision agriculture, cultivation techniques, and addressing agriculture production issues are key aspects of Agriculture 4.0. Precision farming involves using various ongoing technologies like GPS, remote sensing, and data analytics to optimize resource allocation, monitor crop health, and apply inputs precisely. Cultivation techniques focus on sustainable and resource-efficient farming practices. Addressing production issues involves leveraging technology to mitigate challenges like climate change, population growth, and urbanization.

Technologies: Agriculture 4.0 that farming revolution 4.0 with industry 4.04 technology such as IoT, remote sensing, AI, digital technology, ML and also deep learning. IoT enables the interconnection of devices and systems for efficient data collection and communication. Remote sensing including the use of soil sensors and unmanned aerial surveys provides valuable insights into crop and soil health parameters. AI, machine learning, and deep learning algorithms can analyze data and generate real-time insights, reducing farmers' workload and enabling informed decision-making.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 3, July : 2023

Responsible Innovation: Responsible Innovation in agriculture involves adhering to principles like responsibility, inclusion, due care, and transparency to society. It focuses on bringing about positive changes that benefit society and the environment. It is essential to involve farmers and rural communities as co-learners in the innovation process and consider their valuable knowledge and experiences.

Data and Connectivity: Data collection, management, and exchange play a crucial agro tech sense advanced crop monitoring. it enables seamless connectivity and data transfer between devices and systems, optimizing data collection while minimizing human interaction. Cloud-based data base and end-to-end IoT platforms are crucial for managing and analyzing the most of data which generated by IoT devices. Secure and timely transport and exchange of data is a significant challenge in smart farming.

Conservation Agriculture: Conservation agriculture aims to improve yields over time while minimizing environmental impact. It involves techniques like crop rotation and soil cover to conserve organic matter and maintain soil health. Innovations, adaptive research, and new technologies assist farmers in implementing conservation agriculture and overcoming challenges related to adoption and implementation.

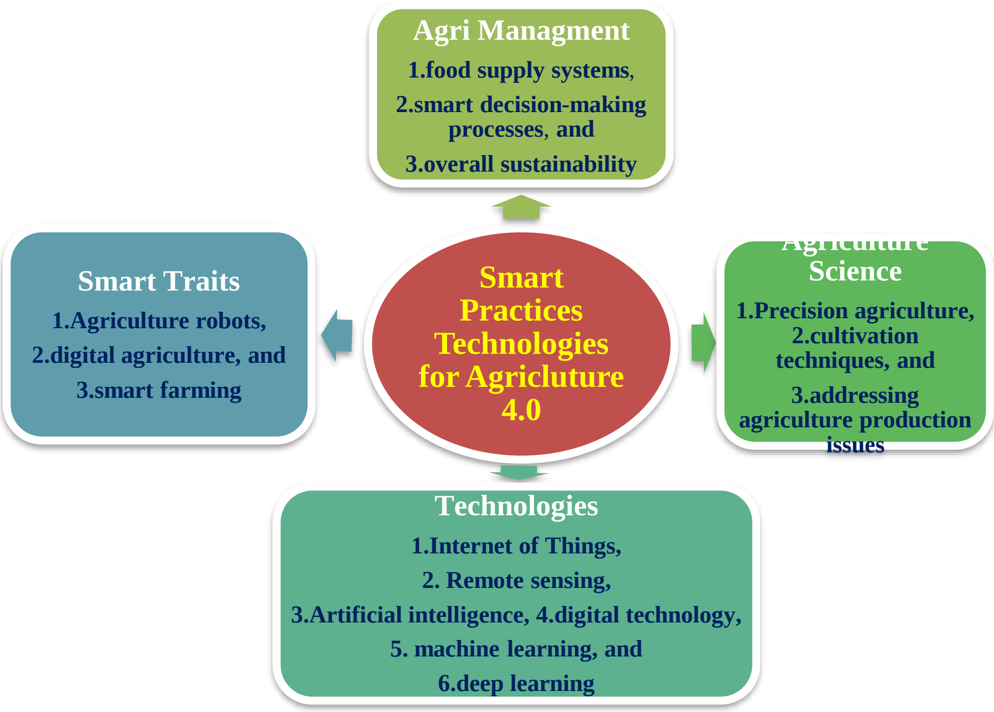

Figure 3: Technologies for Smart Agriculture 4.0.

In this paper Smart agriculture 4.0. These sensors can be embedded in the soil, crops, machinery, and other agricultural equipment to collect real-time data base on various parameters such as temperature, humidity, soil moisture, nutrient levels, and crop growth. In This paper Smart Agriculture 4.0 we use an IoT-based Intelligent Crop observing system in areas with high humidity can be beneficial for maximizing farming productivity. High humidity levels can impact crop growth and increase the risk of diseases and pests. By implementing IoT technology, farmers can monitor and manage their crops more effectively. Here are some ways an IoT-based system can help in such areas [38–42].

The Internet of Things (IoT) plays a crucial role in connecting these sensors and devices to a centralized system where the data is collected, analyzed, and processed. IoT enables seamless communication and data exchange between different components of the agricultural ecosystem, including farmers, agricultural experts, and automated systems.

Artificial intelligence (AI) and machine learning (ML) algorithms are employed to analyze the vast amount of data collected from sensors and other sources. These technologies can identify patterns, make predictions, and provide valuable insights to farmers for decision-making. For example, AI algorithms can analyze weather patterns and historical data to predict optimal planting times, irrigation schedules, or identify potential pest or disease outbreaks. ML algorithms can also help in automating tasks such as weed or pest detection and crop yield estimation [43,44].
Remote sensing technologies, such as satellite imagery and unmanned aerial vehicles (UAVs), are used to capture high-resolution images of agricultural fields. These images provide valuable information about crop health, growth, and nutrient deficiencies. Farmers can use this data to monitor their crops' progress, identify areas of concern, and take necessary actions to optimize yields.
Big data analytics is another critical component of agriculture 4.0. The large volume of data collected from various sources, including sensors, satellite imagery and market trends, can be processed and analyzed to gain valuable insights. Farmers can leverage these insights to optimize their farming practices, improve resource management, and make informed decisions about crop rotation, fertilization, and pest control.

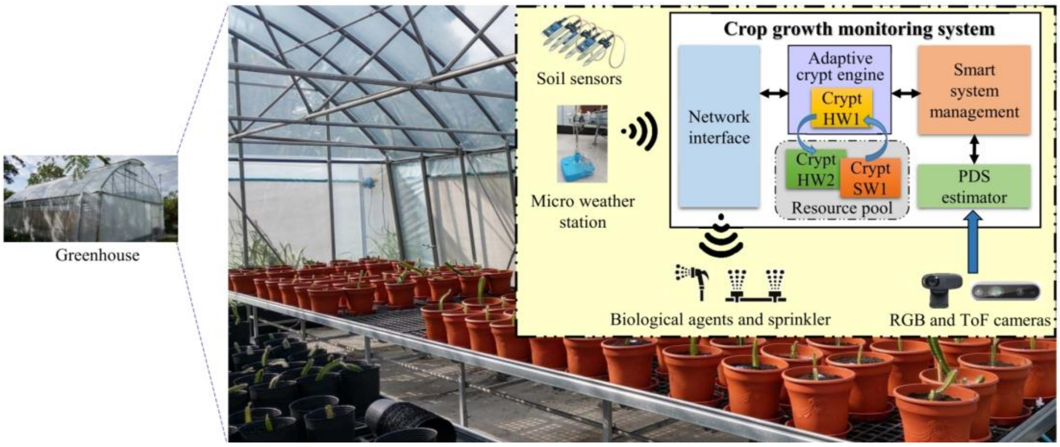

Figure 4: Proposed crop growth monitoring system.

Overall, the integration of smart traits, digital technologies, and data-driven approaches in agriculture 4.0 offers several benefits, including increased productivity, resource efficiency, and sustainability. It enables farmers to make more informed decisions, optimize their operations, and respond effectively to challenges such as climate change and population growth and to maximize farming productivity as shown in figure 4.

2.1 Domains of Agriculture 4.0: Enhancing Agricultural Practices with Technology

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 3, July : 2023

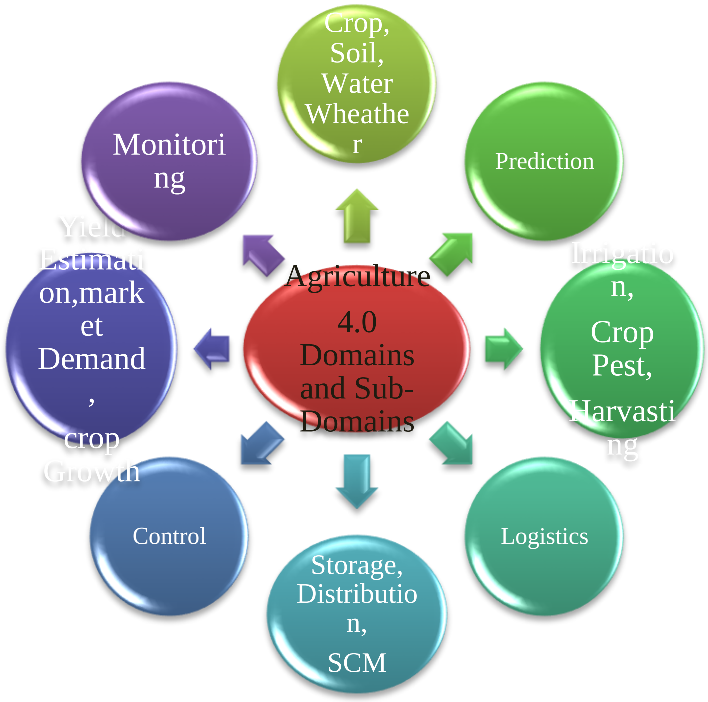

Figure 5: Agriculture 4.0 Domains and Sub-Domains.

The concept of Agriculture 4.0 encompasses several domains and sub-domains that contribute to its overall thematic concept. These domains include monitoring, prediction, logistics, and control, each associated with specific sub-domains. The following sub-domains are part of this framework:

Crop & Soil Data Collections: This sub-domain focuses on collecting data related to crops and soil conditions. It involves monitoring parameters such as soil quality, weather patterns, and irrigation patterns to provide insights for making informed decisions.

Yield Estimation: Estimating crop yields accurately is crucial for effective planning and resource allocation. This sub-domain involves employing advanced technologies to predict and estimate crop yields based on various factors like historical data, weather conditions, and growth patterns.

Market Demand: Understanding market demand is essential for efficient production and supply chain management. This sub-domain involves gathering data on market trends, consumer preferences, and demand forecasts to align production accordingly.

Irrigation: Efficient water management is vital for sustainable agriculture. This sub-domain focuses on using precision irrigation techniques and technologies to optimize water usage, reducing wastage and ensuring adequate supply to crops.

Harvesting: Harvesting plays a critical role in agriculture. This sub-domain explores technologies and methods for efficient and timely harvesting, improving productivity and reducing post-harvest losses.

Storage Issues: Proper storage of agricultural produce is essential to maintain its quality and prevent spoilage. This sub-domain addresses challenges related to storage techniques, preservation methods, and monitoring systems to ensure optimal storage conditions.

Supply Chain Management: The agricultural supply chain involves various stages, from production to distribution. This sub-domain focuses on optimizing supply chain operations, including transportation, logistics, and inventory management, to minimize wastage and ensure timely delivery.

Advancements in technologies like the industry 4.0 have revolutionized agriculture by enabling real-time data collection and analysis. Industry 4.0 sensing devices play a vital role in remotely monitoring agricultural conditions, optimizing resource utilization, and enhancing crop protection measures.

Figure 5. Illustrates the interplay between these domains and sub-domains, highlighting the diverse aspects of Agriculture 4.0 and its potential for sustainable farming, economic growth, and bridging the rural-urban economic divide.

2.2 Discussion about Agriculture 4.0 technology and explore its impact on society

The lack of security measures on farm equipment and IoT devices, such as drones, poses a significant risk to data security in agriculture. These devices often connect to the internet without proper authentication or encryption, making them vulnerable to hacking and data theft. This is a concern because precision Farming and industry 4.0 technologies rely on handling large amounts of data, including sensitive information about crops, weather conditions, and farming practices. a key challenge in Agriculture 4.0 is the need for information sharing and communication standards that link number of systems into a single system that covers all areas of farming use. The ability of farmers to devote in and enlarge agricultural processes is another bottom line concern in the ratification of Agri sense 4.0. For industry 4.0 to be used in farm, rural communities must expand their connectivity infrastructure. Industrial systems that were formerly kept apart and under strict security are suddenly analogous to the Internet, leaving them vulnerable to a variety of dangers. Hopefully, the introduction of 5G and other technologies like space-based internet will address this problem. The ideal data collection rate might be tricky to determine since there are so many different sorts of data in agriculture. Data from various devices, software applications and environmental sensors, as well as handheld analytical data, can be limited and regulated. The secure and timely interchange of this data is one of the key concerns in smart agriculture. Due to the massive volumes of data that IoT and precision agricultural technology must analyse, there are potentially more security flaws that may be exploited by hackers and data thieves. Unfortunately, the idea of information security in agriculture is still very new. Many farmers employ drones to transmit data to their agricultural equipment. Although it has an Internet connection, this gadget has minimal to no security features like remote access authentication or user passwords.

III. Conclusion and future scope

In conclusion, Agri Tech sense Advanced Crop monitoring system to maximize farming productivity Through Agriculture 4.0- driven by technologies such as IoT, AI, and data analytics, is a transformative trend in the farming industry that is here to stay. It offers numerous benefits and opportunities for farmers to improve productivity, reduce costs, and mitigate environmental impact. The integration of communication and information technologies, particularly through smartphones, enables farmers to stay connected and access crucial data anytime, anywhere.

The challenges faced by agriculture, such as population growth, resource scarcity, and climate change, can be addressed by Agriculture 4.0. Through precision farming techniques and IoT, farmers can gather real-time data about their farms, allowing them to make informed decisions and tailor their practices to their specific land and current conditions. This leads to increased efficiency and effectiveness in various aspects of agriculture, including irrigation, livestock management, and vehicle monitoring.

Agriculture 4.0 also facilitates climate-smart agriculture, which focuses on adapting to and mitigating the effects of environmental change. By utilizing IoT and precision farming, farmers can monitor soil conditions, optimize water and nutrient levels, andlevels, and thinks on weather conditions and crop harvests. This proactive approach ensures the resilience of farming systems, helps sequester carbon in the soil, reduces greenhouse gas emissions, and enhances overall yeild and profitability while ensuring food security.

The use of industry 4.0 devices and smart sensors enables real-time observation of crops, soil, and environmental conditions. This data, combined with advanced analytics, allows farmers to make predictions and better manage their operations. Data analytics tools, driven by the wealth of real-time data from IoT devices, improve decision-making, particularly in areas such as crop harvesting timing, disease and pest management, and yield forecasting. Furthermore, weather stations and crop management devices play a crucial role in collecting specific data for crop cultivation, enabling autonomous adjustments to meet optimal conditions.

Figure 6: Data collection in the greenhouse

In the future, the development of Agriculture 4.0 will continue to advance, driven by previous planting methodologies, automated farming equipment, and improved production systems. The adoption of smart technologies and precision farming will further propel the agricultural industry into the era of Agriculture 4.0. Farmers will have access to real-time data and predictive insights, empowering them to make informed decisions, optimize resource usage, and maximize crop yields.

Overall, Agriculture 4.0 holds great promise for the agricultural industry, offering sustainable solutions to the challenges it faces. By leveraging technology and data-driven approaches, farmers can embrace innovation, increase efficiency, and contribute to the long-term viability of agriculture while meeting the growing demands for food production in a changing world.

References

[1] D.C. Rose, J. Chilvers, Agriculture 4.0: broadening responsible innovation in an era of smart farming, Front. Sustain. Food Syst. 2 (2018) 87.

[2] Z. Zhai, J.F. Martínez, V. Beltran, N.L. Martínez, Decision support systems for agriculture 4.0: survey and challenges, Comput. Electron. Agric. 170 (2020), 105256.

[3] F. da Silveira, F.H. Lermen, F.G. Amaral, An overview of agriculture 4.0 development: systematic review of descriptions, technologies, barriers, advantages, and disadvantages, Comput. Electron. Agric. 189 (2021), 106405.

[4] M. Erdo˘gan, Assessing farmers' perception to Agriculture 4.0 technologies: a new interval-valued spherical fuzzy sets based approach, Int. J. Intell. Syst. 37 (2) (2022) 1751–1801.

[5] L. Bollini, A. Caccamo, C. Martino, Interfaces of the Agriculture 4.0, WEBIST, 2019, September, pp. 273–280.

[6] M.E. Latino, A. Corallo, M. Menegoli, B. Nuzzo, Agriculture 4.0 as Enabler of Sustainable Agri-Food: A Proposed Taxonomy, IEEE Transactions on Engineering Management, 2021.

[7] M.E. Latino, M. Menegoli, M. Lazoi, A. Corallo, Voluntary traceability in food supply chain: a framework leading its implementation in Agriculture 4.0, Technol. Forecast. Soc. Change 178 (2022), 121564.

[8] A. Łukowska, P. Tomaszuk, K. Dzier˙zek, Ł. Magnuszewski, Soil sampling mobile platform for Agriculture 4.0, in: 2019 20th International Carpathian Control Conference (ICCC), IEEE, 2019, May, pp. 1–4.
[9] I. Zambon, M. Cecchini, G. Egidi, M.G. Saporito, A. Colantoni, Revolution 4.0: Industry vs. agriculture in a future development for SMEs, Processes 7 (1) (2019) 36.
[10] M. Swain, R. Singh, A.K. Thakur, A. Gehlot, A machine learning approach of data mining in agriculture 4.0, Int. J. Emerg. Technol. 11 (2020) 257–262.
[11] D.D. Mühl, L. de Oliveira, A Bibliometric and Thematic Approach to Agriculture 4.0, Heliyon, 2022, e09369.
[12] M. De Clercq, A. Vats, A. Biel, Agriculture 4.0: the Future of Farming Technology, Proceedings of the World Government Summit, Dubai, UAE, 2018, pp. 11–13.
[13] Y. Liu, X. Ma, L. Shu, G.P. Hancke, A.M. Abu-Mahfouz, From Industry 4.0 to Agriculture 4.0: current status, enabling technologies, and research challenges, IEEE Trans. Ind. Inf. 17 (6) (2020) 4322–4334.
[14] M. Raj, S. Gupta, V. Chamola, A. Elhence, T. Garg, M. Atiquzzaman, D. Niyato, A survey on the role of Internet of Things for adopting and promoting Agriculture 4.0, J. Netw. Comput. Appl. 187 (2021), 103107.
[15] A. Corallo, M.E. Latino, M. Menegoli, From industry 4.0 to agriculture 4.0: a framework to manage product data in agri-food supply chain for voluntary traceability, Int. J. Nutr. Food Eng. 12 (5) (2018) 146–150.
[16] V. Kupriyanovsky, Y. Lipuntsov, O. Grinko, D. Namiot, Agriculture 4.0: synergy of the system of systems, ontology, the internet of things, and space technologies, Int. J. Open Inf. Technol. 6 (10) (2018) 46–67.
[17] S. Monteleone, E.A. De Moraes, R.F. Maia, Analysis of the variables that affect the intention to adopt Precision Agriculture for smart water management in Agriculture 4.0 context, in: 2019 Global IoT Summit (GIoTS), IEEE, 2019, June, pp. 1–6.
[18] S. Katamreddy, J. Walsh, S. Ward, D. Riordan, Closed loop process control for precision farming: an Agriculture 4.0 perspective, in: 2019 30th Irish Signals and Systems Conference (ISSC), IEEE, 2019, June, pp. 1–6.
[19] S.O. Oruma, S. Misra, L. Fernandez-Sanz, Agriculture 4.0: an implementation framework for food security attainment in Nigeria's post-Covid-19 Era, IEEE Access 9 (2021) 83592–83627.
[20] M.A. Ferrag, L. Shu, H. Djallel, K.K.R. Choo, Deep learning-based intrusion detection for distributed denial of service attack in Agriculture 4.0, Electronics 10 (11) (2021) 1257.
[21] C. Price, Agriculture 4.0: bioinformationalism and postdigital hybrid assemblages, in: Bioinformational Philosophy and Postdigital Knowledge Ecologies, Springer, Cham, 2022, pp. 113–131.
[22] A.M. T˘ab˘arașu, Benefits regarding the implementation of Agriculture 4.0 in the current context, Ann. Univ. Craiova-Agricult. Montanol. Cadastre Ser. 50 (2) (2021) 544–551.
[23] K.G. Arvanitis, E.G. Symeonaki, Agriculture 4.0: the role of innovative smart technologies towards sustainable farm management, Open Agric. J. 14 (1) (2020).
[24] C. Weltzien, Digital agriculture or why agriculture 4.0 still offers only modest returns, Landtechnik 71 (2) (2016) 66–68.
[25] S.O. Araújo, R.S. Peres, J. Barata, F. Lidon, J.C. Ramalho, Characterising the agriculture 4.0 landscape—emerging trends, challenges and opportunities, Agronomy 11 (4) (2021) 667.
[26] N.P. Jellason, E.J. Robinson, C.C. Ogbaga, Agriculture 4.0: is sub-Saharan Africa ready? Appl. Sci. 11 (12) (2021) 5750.

[27] M.K. Sott, L.B. Furstenau, L.M. Kipper, F.D. Giraldo, J.R. Lopez-Robles, M. J. Cobo, M.A. Imran, Precision techniques and agriculture 4.0 technologies to promote sustainability in the coffee sector: state of the art, challenges and future trends, IEEE Access 8 (2020) 149854–149867.
[28] L. Klerkx, D. Rose, Dealing with the game-changing technologies of Agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? Global Food Secur. 24 (2020), 100347.
[29] C.R. Eastwood, J.P. Edwards, J.A. Turner, Anticipating alternative trajectories for responsible Agriculture 4.0 innovation in livestock systems, Animal 15 (2021), 100296.
[30] K.E. Khujamatov, T.K. Toshtemirov, Wireless sensor networks based Agriculture 4.0: challenges and apportions, in: 2020 International Conference on Information Science And Communications Technologies (ICISCT), IEEE, 2020, pp. 1–5. November.
[31] B. Ozdogan, A. Gacar, H. Aktas, Digital agriculture practices in the context of agriculture 4.0, J. Econ. Financ. Account. 4 (2) (2017) 186–193. [32] D.C. Rose, R. Wheeler, M. Winter, M. Lobley, C.A. Chivers, Agriculture 4.0: making it work for people, production, and the planet, Land Use Pol. 100 (2021), 104933.
[33] L. Klerkx, E. Jakku, P. Labarthe, A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda, NJAS – Wageningen J. Life Sci. 90 (2019), 100315.
[34] A. Corallo, M.E. Latino, M. Menegoli, Agriculture 4.0: how use traceability data to tell food product to the consumers, in: 2020 9th International Conference on Industrial Technology And Management (ICITM), IEEE, 2020, pp. 197–201. February.
[35] D. Albiero, R.L.D. Paulo, J.C. F´elix Junior, J.D.S.G. Santos, R.P. Melo, Agriculture 4.0: a terminological introduction, Rev. Cienc. Agron. 51 (2021).
[36] I. Pogorelskaia, L. V´arallyai, Agriculture 4.0 and the role of education, J. Agric. Inform 11 (2020) 45–51.
[37] R. Abbasi, P. Martinez, R. Ahmad, The digitization of agricultural industry–a systematic literature review on agriculture 4.0, Smart Agricult. Technol. (2022), 100042.
[38] M. Paustian, L. Theuvsen, Adoption of precision agriculture technologies by German crop farmers, Precis. Agric. 18 (5) (2017) 701–716.
[39] A. Belhadi, S.S. Kamble, V. Mani, I. Benkhati, F.E. Touriki, An ensemble machine learning approach for forecasting credit risk of agricultural SMEs' investments in agriculture 4.0 through supply chain finance, Ann. Oper. Res. (2021) 1–29.
[40] U. Adam, C.S. General, Agriculture 4.0–the Challenges Ahead & what to Do about Them, in: CEMA Secretary General, 12, Club of Bologna, Hannover, 2017.
[41] G.V. Fedotova, I.S. Larionova, M.S. Maramygin, Y.I. Sigidov, B.K. Bolaev, N. N. Kulikova, Agriculture 4.0. as a new vector towards increasing the food security in Russia, in: IOP Conference Series: Earth and Environmental Science, 677, IOP Publishing, 2021, p. 32016. March, 3.
[42] M. Lezoche, J.E. Hernandez, M.D.M.E.A. Díaz, H. Panetto, J. Kacprzyk, Agri-food 4.0: a survey of the supply chains and technologies for the future agriculture, Comput. Ind. 117 (2020), 103187.
[43] G. Singh, R. Sahu, A Bibliometric Analysis on Agriculture 4.0, NOLEGEIN-Journal of Operations Research & Management, 2019, pp. 6–13.
[44] H. Khujamatov, IoT based agriculture 4.0: challenges and opportunities, Bulletin of TUIT: Management and Communication Technologies 4 (2) (2021) 5.
[45] T. Pisanu, S. Garau, P. Ortu, L. Schirru, C. Maccio, Prototype of a low-cost electronic platform for real time greenhouse environment monitoring: an agriculture 4.0 perspective, Electronics 9 (5) (2020) 726.

[46] S. Linsner, F. Kuntke, G.M. Schmidbauer-Wolf, C. Reuter, Blockchain in agriculture 4.0-an empirical study on farmers expectations towards distributed services based on distributed ledger technology, in: Proceedings of Mensch Und Computer 2019, 2019, pp. 103–113.
[47] N. Creedon, C. Robinson, E. Kennedy, A.O. Riordan, Agriculture 4.0: development of seriological on-farm immunosensor for animal health applications, in: 2019 IEEE SENSORS, IEEE, 2019, pp. 1–4. October.
[48] V. Polyakov, Agriculture 4.0: the theoretical concept and its practical implementation, in: E3S Web of Conferences, 273, EDP Sciences, 2021, 08073.
[49] J.H. Huh, K.Y. Kim, Time-based trend of carbon emissions in the composting process of swine manure in the context of agriculture 4.0, Processes 6 (9) (2018) 168.
[50] R. Simionato, J.R. Torres Neto, C.J.D. Santos, B.S. Ribeiro, F.C.B.D. Araújo, A.R. D. Paula, J.H. Yi, Survey on Connectivity and Cloud Computing Technologies: State-Of-The-Art Applied to Agriculture 4.0, 51, Revista Ciˆencia Agronˆomica, 2021.