Plant Archives Vol. 25, Supplement 2, 2025 pp.2502-2512 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.318

ADVANCES IN AGRICULTURAL TECHNOLOGY IN INDIA: CURRENT PROGRESS, IoT INNOVATIONS, AND FUTURE PROSPECTS FOR SUSTAINABLE FARMING

M. Susmitha, N. Pranathi Dass, P. Navya Sri, J. L. Nandiswaraiah, N. Usman Ali, Ramgopal Mopuri and Chittimothu Suresh Babu*
College of Agricultural Science & Applied Research, Bharatiya Engineering Science & Technology Innovation University, Gownivaripalli (V), Gorantla (M), Sri Sathya Sai (Dst.), Andhra Pradesh – 515 231. India
*Corresponding author E-mail: chsuresh.asstprof@bestiu.edu.in
(Date of Receiving : 17-04-2025; Date of Acceptance : 25-06-2025)

ABSTRACT

Modernization is gradually affecting agricultural practices in India – essential because of emerging technologies in order to feed the ever-enhancing population. Pervasive fluctuations in climate and weather conditions, geographical situations, and traditional farming practices present the pressures that are beginning to have a resolution with the help of recent technological enhancements of digital agriculture, smart farming, and big data analytics. The above technologies offer important information on crop husbandry, yields, pests, and finances, to enhance the performance and profitability of farming. IoT has amplified the conception of smart farming instruments in agriculture through real-time data based on sensors and UAVs. These innovations apply to the best practices in all seasons from land preparation to harvesting, packaging and minimising losses and improving yields. Realizing the application of IoT in agriculture brings higher yield and better product quality, lower labor cost and higher farmer income, and promotes the process of modernization of agricultural services. Thus, while India continues to strive towards a smarter way to farm, there is even more to come on the IoT horizon and other advanced technologies. The future of agriculture, therefore, requires that current challenges, including the incorporation of these traditional systems with such systems, be well solved.
***Keywords*:** Agricultural Technology, Internet of Things (IoT), Smart Farming, Precision Agriculture, Sustainable Farming.

Introduction

The world's population is expected to expand to nearly 9 billion people by 2050, and the need for food production continues to surge rapidly. They say that global food production must grow to at least 70% to feed the world's population, and it has to be done within the climate change constraints and dwindling resources. Modern farming techniques are in a more and more unfavourable position to cope with the twin objectives of rising yield and food security. As such, there is high demand for the development and implementation of better technologies that can help to improve efficiency and productivity in agriculture as well as increase the sustainability of such practices.

Globally, there is increasing demand for urban habitats as global population density continues to increase with more than half of the world's population living in urban areas today, a projection expected to rise to about two thirds in 2050. This demographic change in the society not only changes the pattern of food consumption but also puts pressure on rural resources bearing in mind that urban centres convey more immense demand for food production due to the expanding population. As a result of these challenges, there is what is known as 'smart agriculture' where all the operations are preceded by technology. This shift is based on the Agricultural IoT that has found ways to solve the current challenges in the agriculture industry.

Defining Agricultural IoT

Agricultural IoT on the other hand is the utilization of interconnected devices, sensors and software application, amongst others to support timely information transfer and processing within different agricultural settings. Through integration of these physical components including plants, livestock, soil, equipment and environmental factors to the internet the various stakeholders in agriculture will be in a position to monitor, manage as well as control agricultural processes. This technological environment strengthens the outcome with relevant information that helps the farmers to improve resources, productions and practices.

The primary functions of Agricultural IoT are the intelligent identification, progressing and controlling of agricultural processes. With this technology the physical world becomes integrated with the digital and farmers are given the appropriate tools, with accurate data to make important decisions. For instance, in the case of IoT devices, farmers are able to monitor factors such as the soil humidity, status of crops and even the activity of their livestock so that the farmer is able to redo anything wrong by connecting the two worlds, technology and agriculture, IoT creates a platform for a new generation of smart farming.

The Development and Historical Beginning of Agriculture

Over a period of fifty centuries in particular, agricultural production has changed dynamically as humanity looked for ways of raising productivity and feeding the increasing population that is characterized by changes in eating habits. The change from peasant farming to extensive farming was a key one as and implemented mechanisms, synthetic fertilizers and monoculture. But the more these improvements were achieved, more impacts were observed in the negative regard, through effects such as soil erosion, loss of biodiversity and enhanced gas emissions.

In recent decades, however, the concern has arisen over how to develop agricultures that are efficient and sustainable and that are able to support increased production while at the same time protecting the environment. Precision agriculture developed as a function of the shortcomings of the traditional farming practices, with the use of information and communication technologies in an effort to increase farming yields. This development was the key to incorporating IoT into the agricultural process, and to providing farmers with higher levels of data specificity that would allow them to address changing environmental conditions as the need arose.

The management of crop monitoring, livestock tracking, and supply chain efficiency all require some of the important technologies and components of Agricultural IoT:

The success of Agricultural IoT hinges on several key technologies that work in synergy to facilitate data collection, analysis, and management:

Sensors: Installed wireless sensors installed in different agricultural fields regularly capture data regarding various relative environments including moisture content, temperature, humidity, and health of crops. These sensors give important information about the environment in farming and enable farmers to manage it appropriately.

Data Analytics: A large amount of data is produced by IoT devices, and other related data analysis tools analyze this data. Using big data and particularly machine learning and other AI patterns are useful in providing managers with insights to ponder on when contemplating on next actions, or advice farmers on issues they are likely to come across such as pests or nutrient deficiency.

Cloud Computing: The management of data through use and storage are integral to cloud computing to support IoT devices. Cloud platforms also allow farmers to obtain relevant information from far for collaborative purposes in sharing information among the key stakeholders to improve decision making.

Unmanned Aerial Vehicles (UAVs): The farmers can use drones fitted with a camera and a sensor to quickly cover big areas of land under cultivation. Paradropping UAVs provide images which help in surveillance, locating diseases affected areas and deciding on the most appropriate action to take.

Automation and Robotics: Agricultural IoT helps to automate processes in the field of agriculture and construction, for example, vehicles and equipment can plant, water or harvest crops without people's interference. Such automation actually aids in the enhancement of efficiency, and at the same time, labor scarcity in the agricultural business.

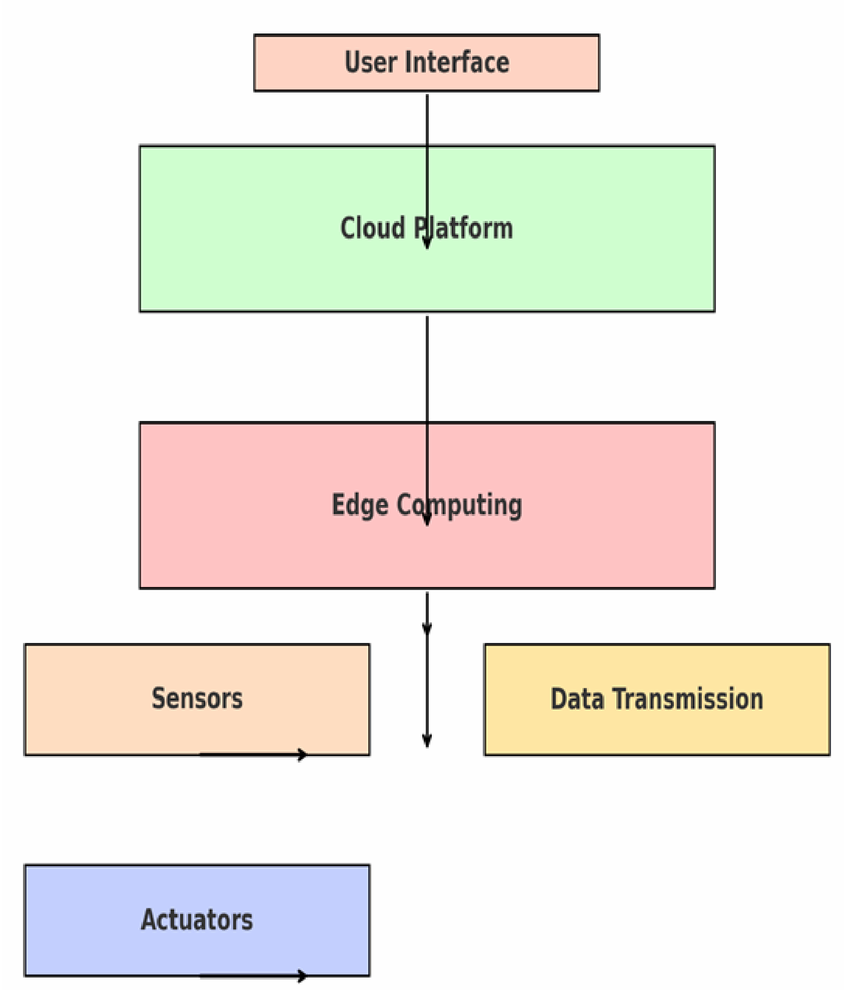

Fig. 1 : Architecture of Agricultural IoT

State of Research and Future Development in Agricultural Internet of Things:

The present knowledge about AI in the agricultural sector is a subject of multiple investigations of its opportunities, advantages, drawbacks, and prospects. Although there are best practices which have been deployed experimentally, the broad adoption of IoT technologies is still an ongoing process. In the previous section, various pieces of research have been reviewed in detail in order to determine the benefits of IoT integration including increased yield, reduced input factor and optimal usage of resources.

For instance, based on Agricultural IoT, several uses have been pointed out in the agricultural field such as precision agriculture, animal farming, intelligent greenhouse, and logistics and distribution. All these areas present the probable opportunities of IoT technologies to optimize performance while encouraging responsible usage.

However, there are various challenges that give traction to the implementation of Agricultural IoT. Even with the increased focus on Agricultural IoT, it faces the following challenges. Challenges like fragmented markets, lack of network in the rural areas, and high fixed costs are the main challenges faced. Moreover, data protection and privacy issues are present when devices are interconnected as used at the present moment. These challenges call for collective endeavours involving all the stakeholders to ensure they develop an appropriate environment that will support the implementation of IoT in agriculture.

Agricultural IoT Insights

Indeed, Agricultural IoT has a bright future as a major player for proposing enhanced farming approaches to guarantee food security in the future world. These assistance solutions are likely to advance over time as new innovations come into the market in producing food more efficiently with less and promoting sustainable use of resources. Internet of Things as an enabler for precision agriculture and environmental monitoring as well as supply chain management will play a significant role in addressing the problems of the world where the population continues to grow as the resources become scarce.

Stakeholders, such governments, research institutions as well as private enterprises are likely already funding efforts towards enhancing IoT in agriculture. There will be a necessity to involve cooperation strategies designed on the creation of strong infrastructures, improvements in the connectivity, and also offering training programs to farmers to ensure that IoT technologies will be implemented successfully in Kenya. Additionally, it will also be equally crucial to create policies to disseminate the data collected by Agricultural IoT and to examine the legal recourse of farmers to get involved.

Technology in Agriculture

Digital agriculture

Digital agriculture is a modern way of transforming and using various technologies at the same time while conforming to one common framework. This integration enables farmers and other players in the value chain to improve food production in a big way. Compared to traditional farming systems and sensor approaches used in farming, digital agriculture provides a more complex model to help farmers understand agricultural practices in real time. This enables them to decide correctly the many conditions touching on their crops and resources, immediately. Additionally, digital agriculture significantly changes the process of yield improvement in crops. As it grants farmers access to important scientific information and solution-oriented data in the sphere of agriculture, it gives farmers the tools to spread innovation best practices. It also enhances work productivity together with the production of sustainable agriculture thus improving food security and the management of the natural resource base. In essence, farmers can improve their functions and effectiveness through the use of digital agriculture to come up with improved crop outputs capable of withstanding the odds of climate change, market instability among others.

Digital agriculture's user interface system supports the sharing of knowledge and experience by farmers. Not only does this source enable the sharing of knowledge about diverse methods of cultivation in various areas of the world but it also prepares those farmers, who are interested in that, with technology and business skills needed for transforming their farming into a lucrative business.

Fig. 2 : The concept of digital agriculture

Digital agriculture helps farmers in maintaining their cultural practices in agriculture. On the other side offers the set information that can help farmers to improve their practices. Also, it provides availability of past data to the farmers so that they are able to see what challenges and situations they have faced in the past in order to make a good decision. For better agricultural practices and substantially higher yields in crops, effective implementations of solid automated systems are needed; the focal point of lifting up developmental tempo and control of cost. These systems are particularly important for controlling potential contaminants motivated by the current focus on agricultural safety. Automating agriculture is a broad concept that covers the following; field machinery; irrigation; greenhouse automation; animal husbandry; and fruiting machinery; all of these improve the output of the farm and in general farming.

Smart farming

Smart farming is a novel concept that aims at incorporating information and communication technologies into the cyber-physical farm management continuum of agriculture. This development can be seen as a part of the Third Green Revolution because it involves the use of Information–communication technologies to improve agricultural practice. Thus, in India smart farming approaches need to be implemented in order to transform the agricultural activity from the traditional farming system. Smart farming is sometimes called the Internet of Agriculture Technology (IoAT), the use of ICT in the analysis of farming factors that allow farmers to maintain optimal conditions as they make little effort towards it while freely maximizing on the benefits in terms of costs. This leads to optimized, efficient and hence more profitable crop rearing enterprises carried out on farms.

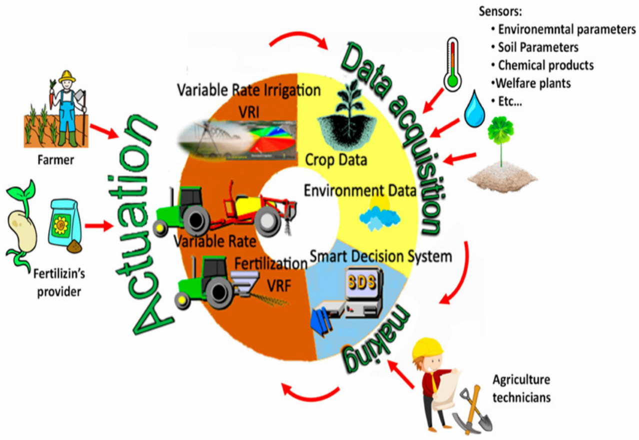

Fig. 3 : Integrating Cyber-Physical Systems in Smart Farming Practices

Smart farming models are simplified and developed to be more comprehensible and as such easily implementable by farmers. By 2050 there will be 9.5 billion people in the world; feeding everyone will be a problem because there will not be enough arable land and because of the large-scale industrial methods of food production. The only feasible solution to this mammoth challenge is smart agriculture and the use of IoT in the farming practices to mitigate crop challenges such as biotic and abiotic stresses, crop failures, crop damage and productivity loss, and thereafter crop wastage. IoAT entails attending real-time conditions such as the intensity of light, humidity, temperature, and moisture in the soil, in addition to advanced irrigation, and watering management techniques to reduce the use of water. As for the benefits of IoAT, they are enormous perceptive based field monitoring, efficient resource mapping, distant crop surveillance, present climate observation/ negotiation, directed application of fertilizers /pesticides, and hasty crop output estimates.

Navigating Supply Chains

Hunger is always topical, and there are many concerns regarding food shortage in the near future. To feed the increasing population on vacant soil, consistent food loss can be minimized through improvement of Food Security Measuring mechanisms that employ Automate supply chain methods. Automation is also a critical process in every phase of crop production, from seed selection that involves the use of private seed varieties to planting the young plants, protection from pests that cause incredibly dangerous crop losses, and providing the appropriate nutrients and water to improve yields without crop failure. Besides, growers are able to implement a controlled and an efficient pattern of harvesting hence minimizing wastes, this reduces the time and costs on collection, processing and marketing of the produce. For the food products to be acceptable in the market, the buyers have confidence in the foods especially after having paradigm shift measures put in place to enhance food safety. This can be done by explaining the safety measures adopted at the course of crop handling right from the growing, reaping and processing phases as well. Through the implementation of these automated food chains, the industry stands to have its image boosted while at the same time ensuring farmers are boosted in confidence, and many people get motivated to practice agriculture**.**

From Data to Decisions: Exploring Mining and Analytics Techniques

Data mining tools play a crucial role in the improvement of decision support systems (DSS) in agriculture. Ideally, data mining aims at finding rich information from large databases and assembling it in a manner presented in a form convenient for higher level applications. In soil fertility studies specifically data mining is very helpful in helping farmers decide on which crops to grow in order to get the best yields. The classification of the soil enables the determination of engineering property of the soil and its compatibility with certain fertilizers hence giving farmers the necessary information they require. The conventional quantitative methods of soil analysis or simple statistical techniques which need laboratory analysis take a lot of time, cost and energy. However, more efficient data mining techniques are being emerged to process a sheer amount of complicated soil type data with higher accuracy and less time. Methods, including GPS-based mapping, k-means clustering, Support Vector Machines (SVMs), and K-nearest fertilizer methods, are very useful for analysis of the soil characteristics, estimation of pollution of the atmosphere, and definition of factors which influence the yield of crops. Having known that other tests common in soil analysis are on fertility, impurities, and possible deficiencies, farmers use the results to apply corrective action. There are government and private laboratories that offer methods for determining the characteristics of soil, and everything is described in the resulting report. As a result of these diagnoses, the types of fertilizers that should be used based on the type of soil should be used are suggested. It assists in use of appropriate fertilizer varieties for the particular crops at the right times of planting season, and therefore proficiency is realized.

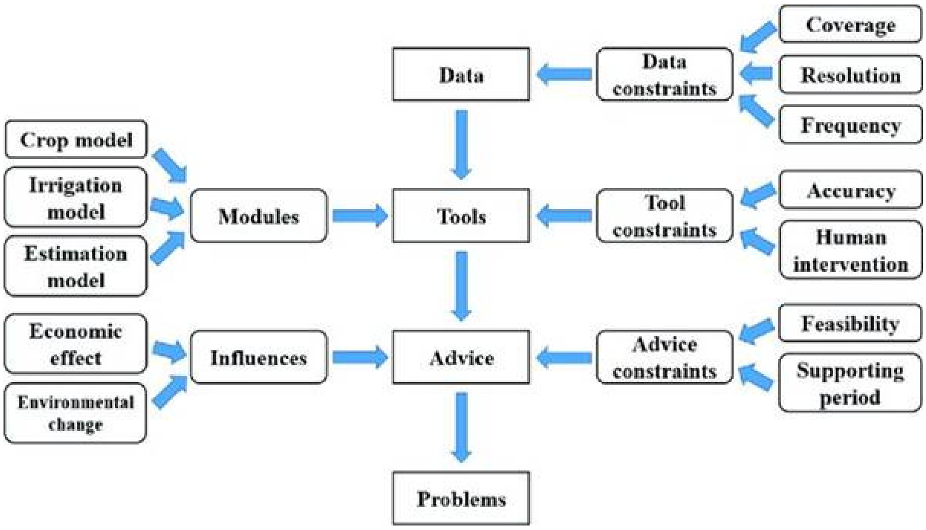

Fig. 4 : A general framework of agricultural decision support systems.

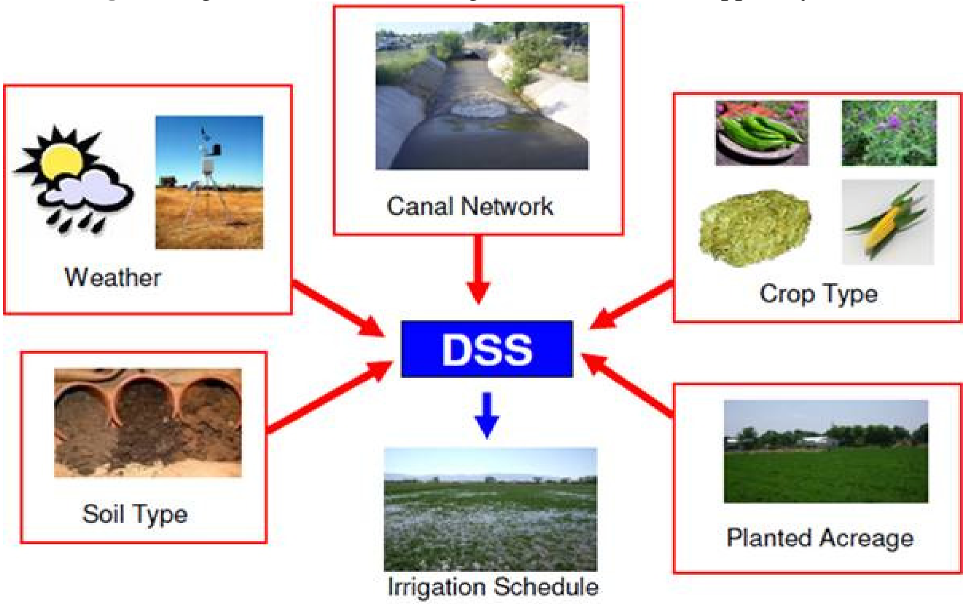

Fig. 5 : Simplified View of the DSS.

Meteorological Forecasting Strategies

Climate change is undoubtedly one of the biggest problems for agriculture today and more broadly for human life. Unlike e-commerce, advertising, big data has not leveraged its potential in contributing to comprehension of the environment. In this field complexity has been a major issue in handling climatic data. However, now Big Data is being used to work with tremendous amounts of climate data, discussing disparities between the common Big Data approaches and approaches useful for operation on climate ones. Climate change impacts in India have been most apparent in the plant growth and agricultural output. Climate change impacts have reduced crop durations as well as increased crop respiratory rates and thus pest attack behavior. Quite a number of crops have evolved to respond to the day lengths characteristic of middle and lower latitudes but have difficulty in dealing with the extended summer days. Further, warmer temperatures enhance the rate of CO_2 release during the warmer period unknowingly reducing crop productivity. With data on rainfall and temperature for the past five years collected in the course of Big Data analysis, it is possible to identify shifts in the climate of Indian agriculture. Sensors also ensure early forecasting of invasions by pests and diseases and determine efficacy of certain seeds and fertilizers on various segments of the farm. As explained earlier in Figure 5, software tools can also recommend to farmers where to plant hybrid varieties of seeds in one area while sowing different varieties in other areas.

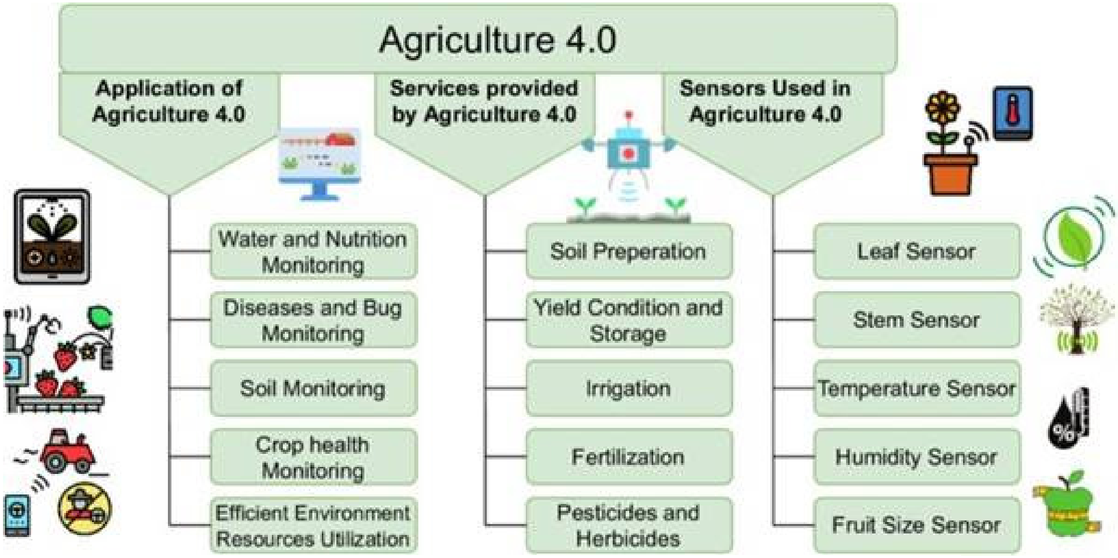

Fig. 6 : Various applications, services and sensors used in Agriculture

Farm Systems Management

That is why I have insufficient information to assess certain actions related to crop protection and weed control. In general, public policies and goals of organization concerning agriculture and food have a multi-objective character that involves production yield, economic return, and cost efficiency, on one hand, and resource conservation and environmental quality on the other hand. Thus, an amalgamated strategy that incorporates or incorporates the use of technology together with social and ecological sensibilities appears most reasonable. Nonetheless, any possible action has specific considerations linked to its costs and benefits that change according to local circumstances and desires. It is essential to have an open discussion involving all relevant stakeholders based on evidence.

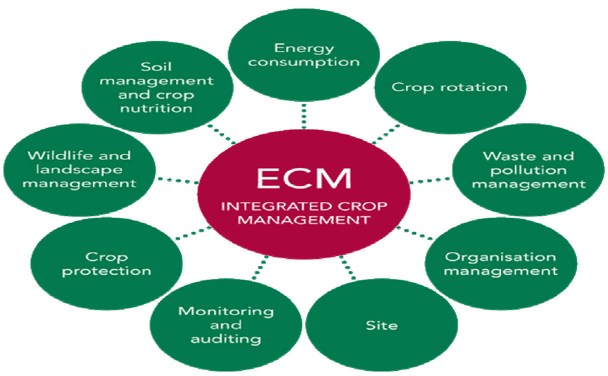

Fig. 7 : Application of integrated crop management (ICMs) in agriculture

Core Applications and Services in Agriculture

Traditional agricultural practices have been transformed by advanced technologies like IoT and UAVs. Modern innovations, such as wireless sensors, have opened new doors for crop improvement by addressing challenges like disease control, efficient irrigation, and drought management. The hierarchy of these advanced agricultural technologies, sensors, and their applications to enhance crop production.

One important application is Soil Monitoring. Soil is essential for plant growth, and regular monitoring helps farmers make better decisions throughout the growing season. Soil analysis measures nutrient levels and other factors like moisture and pH, which are crucial for optimizing fertilizer and irrigation needs. For example, soil health tests are usually recommended in spring but can vary depending on local conditions. Tools like Agro Cares' Scanner and Lab-in-box provide daily soil analysis without needing a traditional lab.

Monitoring soil moisture is critical for estimating water needs. Tools like remote sensors, in situ moisture sensors, and satellites (e.g., SMOS, SMAP) provide global and farm-scale moisture data. Robotic tools like Farm Bot and Agri bots are also being developed for smart farming, improving efficiency in seeding, weeding, fertilizing, and irrigating.

Irrigation is another crucial aspect, as agriculture consumes 75% of global freshwater. Efficient water use is key to reducing shortages, and smart irrigation technologies like IoT sensors help optimize water use by considering factors like soil type and moisture levels. The Crop Water Stress Index (CWSI) is one tool used to monitor plant water needs and improve irrigation efficiency.

Crop Disease Management is a major challenge that can result in significant crop losses. While pesticides are widely used, advanced technologies like IoT and remote sensing offer safer alternatives. These tools help monitor disease outbreaks, predict pest activity, and assess plant health, making crop management more sustainable.

Fertilization plays a critical role in plant growth. Advanced tools help monitor nutrient levels in soil, ensuring the right amount of fertilizers are used to avoid environmental harm. Technologies like IoT, GIS, and GPS are used to apply nutrients precisely, improving crop yields while reducing waste.

Crop Harvesting Monitoring and Forecasting are essential for determining the best time to harvest and evaluating crop quality. Technologies like yield monitors and smartphone apps like Farm RTX help farmers track grain moisture, yield, and other important factors, allowing them to make informed harvesting decisions. These tools help farmers plan better and improve crop quality by monitoring the development stages.

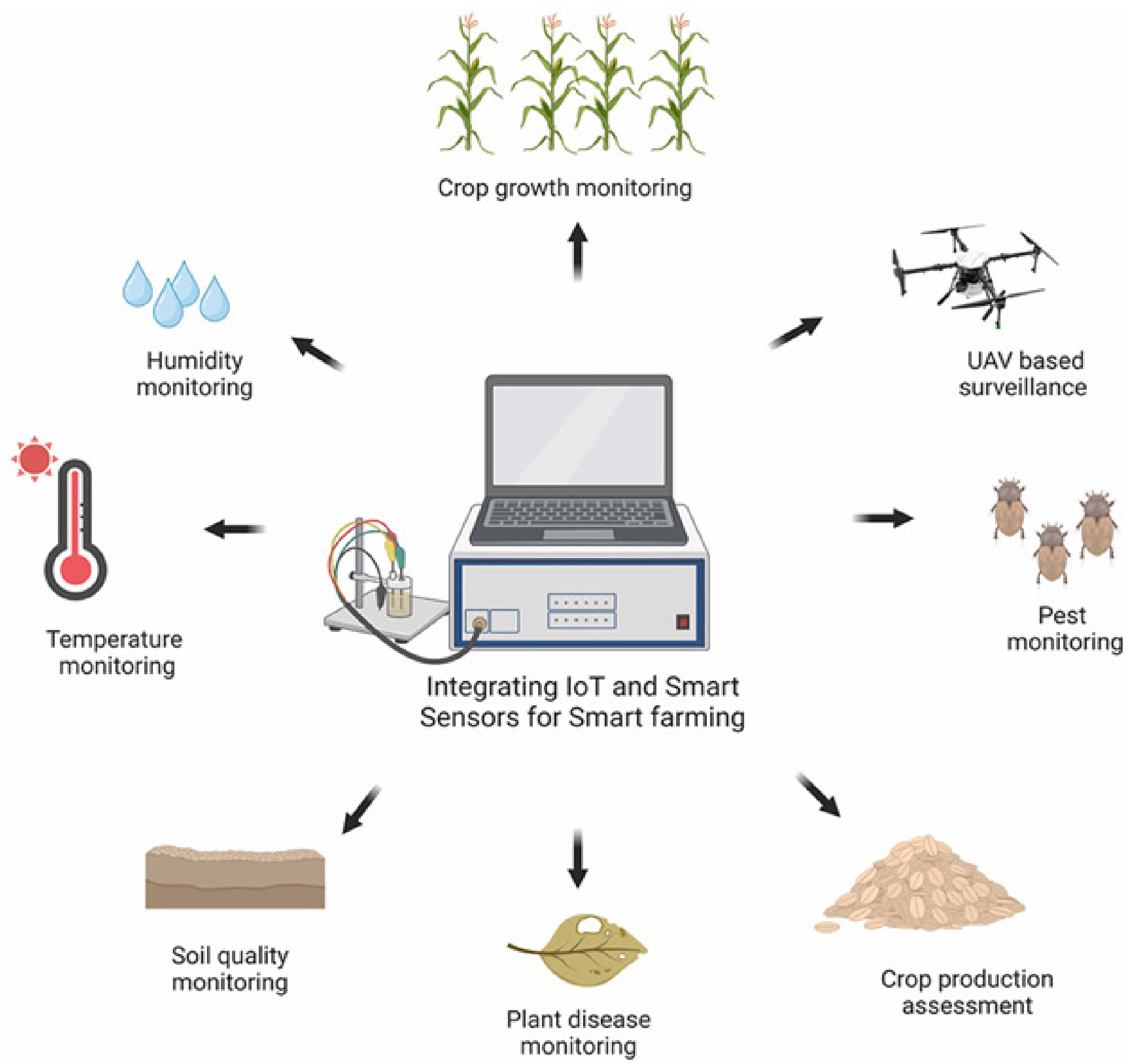

Fig. 8 : Internet of Things (IoT)

Smart Agriculture Techniques

I have a few comments which I think are worth considering. It will therefore be important to look for ways of meeting the growing food demands given that as we look for ways of feeding the growing world population it will be important to consider the emerging technologies in agriculture on one hand, but also the likelihood of associated benefits and drawbacks on the other hand. A clear and balanced approach which challenges such strategies and devices how the integrated application of traditional and modern approaches might lead to the achievement of sustainable and more equal conditions is possible. Nevertheless, most fundamentally, such decisions should be made inspired by concern for all those involved. Certainly, every strategic plan includes the concern about what we are ready to sacrifice; yet, as long as we support the aesthetic and moral underpinnings of our strategies, I stay confident.

Greenhouse Agriculture

Greenhouse farming, a relatively modern agricultural technique, involves growing plants in controlled environments. Its rise in popularity can be traced back to the 19th century when countries like Italy, the Netherlands, and France began constructing greenhouses to cultivate off-season fruits and vegetables. By the 20th century, this method was rapidly adopted by countries facing climate challenges. In a greenhouse, crops require minimal inputs, as the controlled environment provides optimal conditions for growth. This control allows for the cultivation of both seasonal and off-season crops year-round, anywhere in the world. With the integration of modern technologies, such as wireless communication and mobile devices, greenhouse farming has become more efficient. Benke and Tomkins conducted a comprehensive analysis and highlighted how advanced tools like wireless sensor networks can enhance the adoption of greenhouse technologies. These sensors monitor critical factors such as temperature, humidity, and pressure, ensuring that the crops thrive in ideal conditions.

Hydroponics

Hydroponics, an advanced method of growing crops without soil, involves cultivating plants in water under controlled conditions. Nutrients and fertilizers are directly supplied through irrigation, enabling precise management of plant nutrition. When combined with vertical farming (VF), hydroponics offers a highly efficient agricultural solution, using 95% less water and nutrients than traditional methods while eliminating the need for chemical inputs. Due to the complexity of nutrient management in hydroponics, accurate control systems are essential. A wireless control system for hydroponic tomato cultivation has been proposed to ensure precise monitoring of water content and nutrient levels. A turnkey solution, based on wireless sensors, offers real-time data on plant growth in hydroponics systems, providing insights without the need for soil media. New tools, such as compact sensors utilizing oscillator circuits, have also been developed to monitor fertilizer concentration and irrigation levels, further advancing this sustainable method of agriculture.

Vertical Farming (VF)

As arable land diminishes due to population growth, urbanization, pollution, and soil erosion, vertical farming (VF) presents a progressive solution in modern agriculture. VF enables crops to be grown in vertically stacked layers within controlled environments, minimizing land use while maximizing resource efficiency. Unlike conventional farming, which demands extensive land and resources, VF significantly reduces the consumption of water, energy, and nutrients, making it an ideal method for densely populated urban areas. Traditional farming practices often deplete soil health, with soil erosion rates reported to be 10 to 40 times higher than soil formation. This degradation, coupled with the extensive freshwater usage in conventional agriculture about 70% of global freshwater consumption poses a threat to sustainable food production. VF addresses these challenges by utilizing less land and water, offering a viable alternative to industrialized farming practices that erode soil and strain water supplies.

Phenotyping

The emergence of smart agricultural techniques such as VF and hydroponics has shown promising advancements, but further optimization is needed to maximize crop yields. Phenotyping is one such advanced method, bridging genetic engineering and biotechnology to better understand and enhance the agronomic traits of crops. This approach correlates genetic sequences with physiological and agronomical attributes like drought tolerance, disease resistance, and growth rate. Over the past few decades, significant advancements in genetic engineering have been made, but challenges remain in key areas, such as improving grain weight and overall crop resilience.

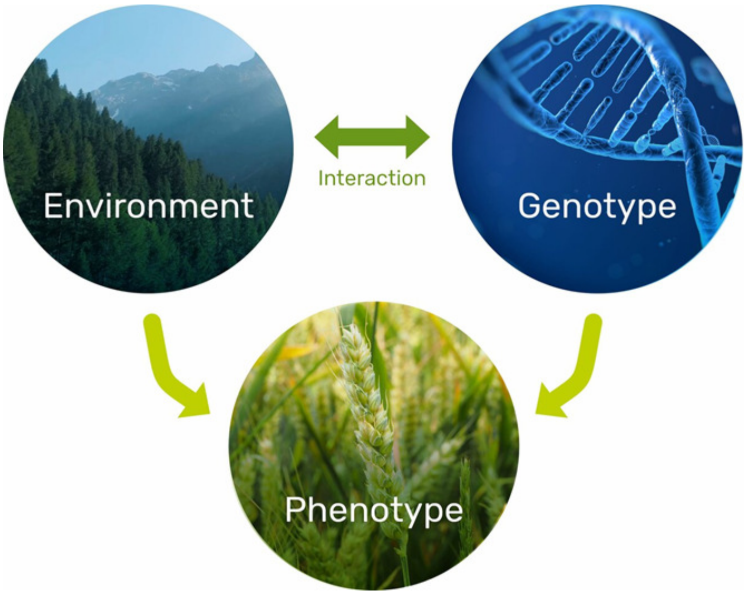

Fig. 9 : The process of phenotyping.

Conclusion

The increasing global population has intensified the demand for food, driving the need for more efficient agricultural practices. As arable land continues to shrink due to urbanization, adopting advanced technologies is no longer optional but essential. In India, where agriculture remains a critical livelihood for a large portion of the population, the challenge lies in the disconnect between farmers and the available technological advancements. Digital and precision agriculture, while promising, have not yet fully bridged the gap, as many farmers lack access to or understanding of these tools. Government efforts to introduce innovative methods have made progress, but the potential for user-friendly agro-advisory systems remains largely untapped. These systems can guide farmers in making crucial decisions about crop selection, growth stages, and yield optimization, reducing costs and increasing productivity.

Globally, the push for sustainable agriculture has spotlighted the role of cutting-edge technologies like the Internet of Things (IoT), unmanned aerial vehicles (UAVs), remote sensors, and cloud computing. These innovations are instrumental in addressing the growing food demands by improving crop management, resource allocation, and real-time monitoring. However, to truly benefit farmers and close the communication gap between stakeholders farmers, suppliers, retailers, and buyers these technologies must be made more accessible. Collaborative efforts between technology developers, governments, and agricultural communities are necessary to implement solutions that are both practical and scalable. Moving forward, research must focus on simplifying these tools to ensure they meet the needs of farmers on the ground, paving the way for sustainable agriculture that can keep pace with the world's rising food needs.

References

Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., Aggoune, E.-H.M. Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk. IEEE Access 2019, 7, 129551–129583.

B.M. Sagar and Cauvery N.K. (2018). Agriculture Data Analytics in Crop Yield Estimation: A Critical Review, *Indonesian Journal of Electrical Engineering and Computer Science*, 12(3), 1087-1093.

Babu, T.G. and Babu, G.A. (2016). Data Analytics to Produce Big Results in the Agricultural Sector, *International Journal of Advanced Research in Biology Engineering Science and Technology*, **2**(3), 67-75, 2016.

Baseca, C.C. *et al.* A Smart Decision System for Digital Farming, *Agronomy*, **9**(5), 216-234.

Edan, Y. *et al.* (2009). Automation in Agriculture," Springer Handbook of Automation, 1095-1128.

Elder, M., Hayashi, S. (2018). A regional perspective on biofuels in Asia. In Biofuels and Sustainability; Springer: Berlin/Heidelberg, *Germany*, 223–246.

He, Y., Nie, P.C., Liu, F. (2013). Advancement and trend of internet of things in agriculture and sensing instruments. *J. Agric. Mach.* **44** (10), 216–226. https://doi.org/ 10.6041/j. Issn.1000-1298.2013.10.035.

http://breakthrough.unglobalcompact.org/disruptive-technologies/digital-agriculture/.

Jayaraman, P.P. *et al.* (2016). Internet of Things Platform for Smart Farming: Experiences and Lessons Learnt, *Sensors*, **16**, 1-17.

Kinzli, K.D. *et al.* (2011). Linking a developed decision support system with advanced methodologies for optimized agricultural water delivery, Efficient Decision Support Systems-Practice and Challenges in Multidisciplinary Domains, *IntechOpen*, 187-212.

Lin, G. and Zhongwei, H. (2011). Analysis of agricultural products e-commerce models based on supply chain management, *International Conference on E-Business and E-Government* (ICEE), 1-3.

Mirjankar, N. and Hiremath, S. (2016). Application of Data Mining in Agriculture Field, *International Journal of Computer Engineering and Applications* (iCCSTAR-2016), 363-368.

O'Grady, M.J. and O'Hare, G.M.P. (2017). Modelling the smart farm, *Information Processing in Agriculture*, **4**(3), 179-187.

Pongnumkul, S. *et al*. (2015). Applications of Smartphone-Based Sensors in Agriculture: A Systematic Review of Research, *Journal of Sensors*, 1-18.

Rani, A.S. (2017). The Impact of Data Analytics in Crop Management based on Weather Conditions, *International Journal of Engineering Technology Science and Research*, **4**(5), 299-308.

Sekhar, C.C. *et al*. (2018). Effective use of Big Data Analytics in Crop planning to increase Agriculture Production in India, *International Journal of Advanced Science and Technology*, **113**, 31-40.

Shamshiri, et al. R.R. (2018). *Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture*, *International Journal of Agricultural & Biological Engineering*, **11**(1), 1-22.

Tripathi, A. and Mishra, A.K. (2017). Knowledge and passive adaptation to climate change: An example from Indian farmers, *Climate Risk Management,* **16,** 195-207.

Tripathi, A.D., Mishra, R., Maurya, K.K., Singh, R.B., Wilson, D.W. (2019). Estimates for world population and global food availability for global health. In The Role of Functional Food Security in Global Health; Elsevier: Amsterdam, The Netherlands, 2019; 3–24.

Tsiolias, D. *et al*. (2015). Big Data and Agricultural Supply Chains: Opportunities for Increased Food Security, *Proceedings of the Homburg International conference of Logistics* (HICL), **22**, 331-354.

United Nations Department of Economic and Social Affairs. 68% of the World Population Projected to Live in Urban Areas by 2050, Says UN; United Nations Department of Economic and Social Affairs: New York, NY, USA, 2018.

Walewski, J.W. (2011). Internet-of-things architecture, report on project deliverable D1.2 initial architectural reference model for IoT. Project Co-funded by the European Com mission within the Seventh Framework Program Grant agreement, 2011 (257521).

Walewski, J.W. (2011). Internet-of-things architecture, report on project deliverable D1.2 initial architectural reference model for IoT. Project Co-funded by the European Com mission within the Seventh Framework Program Grant agreement, 2011 (257521).

Wolfert, S. et al. (2014). A Future Internet Collaboration Platform for Safe and Healthy Food from Farm to Fork, Annual SRII. Global Conference, San Jose, CA, USA, pp. 266-273, 2014.

Xu, Z.Y., Lou, B.D., Shao, G.C. (2012). In: Wang, Y.H., Zhang, X.M. (Eds.), An Intelligent Irrigation System for Greenhouse Jonquil Based on ZigBee Wireless Sensor Networks. Internet of Things. Springer, Berlin Heidelberg.

Zhang, X. and Davidson, E.A. (2018). Improving nitrogen and water management in crop production on a national scale. In Proceedings of the AGUFall Meeting, Washington, DC, USA, 10–14 December 2018; p. B22B-01.