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HOW IoT BASED SOLUTIONS CAN TRANSFORM THE AGRICULTURAL ECONOMY? AN ANALYSIS OF ITS SCOPE AND APPLICATIONS

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ABSTRACT

Digital technology has been rapidly changing the mechanism of the functioning of the entire economy including agriculture through its various applications and scope. The sector has been experiencing new developments in allied activities also including the non-farm sector. The first paradigm shift in technology-based development was the green revolution and now the new and innovative technology-based on software has been also changing its landscape. The High Yielding Varieties of seeds, irrigation, and mechanization during the green revolution in the country completely shifted the agriculture sector. But over time, new challenges are being emerged where the production & productivity along with the quality of food and organic way of cultivation are major areas of research and academic discourse. The recent advent of IT-based technological innovation has been providing new directions for the growth of the sector. The paper tries to capture these emerging issues and IoT-based technical developments and solutions for the growth of the sector. Keeping these facts in mind, this paper highlights the use of smart farming in agriculture, its benefits, and critical observations for minimizing the risks. Simultaneously, the use of IoT for smart farming and its working is also elaborated on in this paper. Various challenges in using IoT in smart farming services have also been discussed in this paper. The paper tries to associate elaborate on the relationship between technology and the economy for agriculture.

KEYWORDS: *IoT, Smart Farming, Sensors, Gateways, Cloud, Economy.*

Introduction

Globally, India is also ranked among the five largest producers of various agricultural commodities. In India, 42.38 percent of the population the country still depends on the sector for employment and as per the data, the overall Gross Value Addition (GVA) stands at only 14.39 percent (Central Statistical Organization, National Accounts Statistics, 2018). Therefore, the development of the sector itself becomes essential for the development of the country. Despite the low Gross Value Added, the agriculture sector remains significant in terms of its contribution and its role in other sectors of the economy. In India, various initiatives were taken for the development of the agricultural economy such as land reforms, green revolution, cooperatives reforms, marketing reforms, etc. The results of these initiatives are reported in various documents published by different agencies. A rise in food grains and productivity, accessibility of credit, subsidies, irrigations facilities, research, and development are a few examples. Agricultural extension activities have also been provided to farmers in the country through various channels to enhance the knowledge base. Various activities such as technology transfer, advisory services, and facilitation services are included under such a system. The committee on doubling the farmers' Income in India refined the agricultural extension as “Agricultural Extension is an empowering system of sharing information, knowledge, technology, skills, risk & farm management

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practices, across agricultural sub-sectors and along with all aspects of the agricultural supply chain, to enable the farmers to realize higher net income from their enterprise on a sustainable basis". The new technological developments under such services may provide an impetus for the larger welfare of farmers. This knowledge empowerment to farmers establishes a new paradigm in the growth of the agricultural sector in the country. The paper deals with such issues with a focus on IoT-based solutions for reforms in agriculture.

Internet of Things (IoT) and the Agriculture Sector

Recently, some new developments are taking place in the sector in which the role of information technology and related tools has increased significantly. Now with the advent of smart agriculture, new technological developments in the fields of information technology including the Internet of Things (IoT) are helping the agriculture sector to achieve the desired objectives. The paper tries to elaborate on these developments in detail covering various aspects. IoT already notifies its existence in home automation, industries, production and automation process, robotics, smart cities, and health monitoring. Now it is entering agriculture in a smart way as "smart agriculture or smart farming" (Chalimov, 2020). Nowadays, the quantity, variety, and types of agriculture, methods of farming, and goals of farming are more technology-focused and business-oriented globally. The different gadgets of farming, machinery, pest control, and weather predictions are more innovative to improve the sector (Chalimov, 2020). Irrespective of the entire technological enhancement in farming, there are certain issues and climatic disasters which cannot be controlled and farmers have to compromise with the existing conditions. The climatic problems increased more with the environmental changes, especially in India which is an agriculture-based country, in which the various issues of droughts and floods are being seen every year in different places. For example, in rainy seasons most of the areas near the canals, approach roads are seen flooded with the water. All the technological driven gadgets failed and farmers have to wait in such natural calamities to get things normal this way the overall production and productivity of agriculture declined. IoT sensors in agriculture help farmers to get data about the health of crops, soil quality environmental conditions, and humidity in storage, crops monitoring, detecting the optimal ratio of pesticides and fertilizers to be used. Apart from the natural calamities, the COVID-19 impacts open the door for IoT in agriculture. Due to the shortage of skilled workers and supplies for agriculture as well as the fear of epidemics inherently motivated to look for the alternates without going outside. (Chalimov, 2020).

The following are the reasons which inevitably demand a powerful tool to support farmers in precise decision-making and lead to the adoption of the technology.

- Advancements in Internet and web technologies and cheap & efficient communication devices (Reddy, 2020).
- Fewer times for monitoring of fields frequently.
- COVID-19 lockdowns, health issues, and migration of skilled labour.
- Education in villages and the role of media (news, social networking, webinars for educating the villagers about small-scale business as well as new agricultural methods & cropping) along with the government subsidies, and policies for farmers.
- Advantages of data accuracy and precision in real-time collection with IoT tools about the crop & cultivation (Reddy, 2020).
- Key applications of smart agriculture are as follows:
- Accurate data can be collected by the smart sensors installed on agricultural land.
- Better predictions with the correct & adequate data collected from the agricultural about the crop's health, quantity, and timing of harvesting.
- Use of the sensors to detect the various important factors and collect the data on crops, livestock, godowns, environment, and alarming for crop health issues as well suspicious activities in the fields to reduce agriculture & farming loss.
- Making the godowns automated increases the efficiency in production with a low spoilage ratio of storage, optimal resource utilization, and stowing of the crops for business purposes.
- Able to yield the crops to meet the Supply standards for the sale & exports and better yields used for research.
- Data collection by the sensors doesn't require Internet connectivity moreover, minimizing human interventions and other resources like agricultural equipment.

Advantages of IoT in Smart Agriculture

The following are the major advantages of smart farming with the use of IoT (Chalimov, 2019 & 2020); Zia H, et.al (2021).

- Data to be read by the experts and sophisticated software to produce accurate results.
- IoT tools help in identifying the different traits in a microclimate that can affect the harvesting, these traits are further categorized into controlled and uncontrolled parameters.
- Data is collected from the fields and sent to the clouds that are analyzed by sophisticated machine learning tools, and web applications and also observed by the professionals, and experts of the fields. This way better production and advice can be received to improve the crops' capacity, health, and, timings of the harvesting in a planned way (Chalimov, 2020)
- Greenhouse or godowns monitoring in terms of the light, humidity, temperature, precipitation (Chalimov, 2020), anomalies in the stored yields, etc., and notifications to adjust the various parameters for better management.
- Remote farm monitoring to detect certain irregularities to prevent diseases and swarms that can harm crops.
- Anywhere and anytime observations of the crops are now possible with the help of IoT.
- Data drove farming is called "Precision Farming" based on the matrix collected in a microclimate and biota (weather conditions in the fields and ecosystem) comprising CO2 level, pest arrivals, soil moistness, and other conditions to help the farmers to estimate the optimal amount of water, fertilizers, pesticides, reduce overheads and makes the healthier crops to meet targeted production and quality. IoT combined with geospatial data can create soil maps for each field showing different soil traits (Chalimov, 2020). This can be helpful to regenerate soil health, especially in those areas where productivity is an issue.
- The decision can be more informative in terms of reduced cost as a result of reduced expenditure probably by certain parameters control, timely information about crop health, pest controls, weather conditions, and optimized processes (Rashika,2020). The objective of doubling farming income can also be achieved through the reduction in costs and such tools can help to do so.
- Monitoring water levels and soil conditions help in deciding about the crops to be sowed and reaping schedules (Reddy, 2020). Water scarcity is now a common problem and this proper usage of this source can be ensured now.
- Predictive analysis for the smart farming with IoT to estimate the volume & quality of the crops and timing of harvesting in advance and even adjust parameters to get the desired output, vulnerability to flood & drought, select the yield traits to give the optimized nutrients to improve the crop quality, halt overwatering and over-fertilization, etc. (Chalimov, 2020).
- Well planned irrigation and harvesting make it possible to yield the target production and increase revenues (Rashika,2020). Apart from production, improvements in livestock farming and production, cost reduction, and water management are some other benefits (Krishnan et.al (2020)
- Excess, as well as the shortage of water, deteriorates the crop health so the proper scheduling for irrigation is necessary to strengthen the fertility area. The timing of the irrigation depends upon the soil quality, crop type, and weather conditions that can be easily scheduled based on the data provided by the IoT tools established in fields for real-time estimations of the water requirements Zia H, et.al (2021).
- In addition to the crops, the IoT system can also be incorporated into farm/dairy management by monitoring cows, buffaloes, other animals, their food requirements, health, irregularities in fields, or any suspicious activity on farms, automatic milking/vending machine management, etc.
- Taking one step ahead of farming, the IoT helps in the management of smart agri-business also. A smart information management system can be developed with the use of IoT. Information from fields, farms, transportations, markets, location of demand for a particular product, other processing tasks, scope of the business, availability of suppliers as well as consumers, etc., all at a single location help the user to take prompt decisions with the use of web technologies and connected smart devices (Reddy, 2020).

- In the local areas, where electricity is also a big challenge in the implementation of plans that hinders the growth of rural areas, IoT benefits a lot with minimal use of electricity. As all the processing are well planned and managed, the resources are used optimally moreover most of the IoT devices are solar-based, decreasing the demand for the electricity poles, reducing the wiring in the fields, and life hazards as well.
- IoT with web map service via connectivity with the satellite for imaging, sensors to examine the soil, water, weather, reporting on farm equipment or the instruments, storage conditions, number of seeds planted, etc. helps in making informed decisions (Reddy, 2020).

Therefore, productive cropping and smart farming by the use of precise & timely data, overall increase the efficiency of farming with reduced cost, enhanced quality, and more security is conceivable (Reddy, 2020). IoT can bring a remarkable change in the agriculture style, the financial status of the farmers, and their living style. As IoT tools minimize human interventions, therefore, the same farming time can now be devoted to other small-scale businesses, farming & agricultural-based industries.

Applications of Sensors in Smart Farming

Along with the connectivity and wireless communication between devices with unique identification, sensors play an important role in detecting the events and collecting data about specified parameters. The following are the sensors used in smart farming.

- **Soil Sensors:** Soil sensors are used to observe the soil properties regarding pH value, salinity, and the ratio of nitrogen, potassium, and phosphorus. The pH value defines the activity of hydrogen in soil; it is used to measure the water quality by categorizing it into three parts i.e. acidic, neutral, and basic. These pH values lie between 0 to 14, where a value less than 7 is acidic, 7 is neutral and a value greater than 7 is basic. The elements to determine soil quality is categorized by Reddy, 2020 and Markus et.al, 2020.
  - Penetration of water (called infiltration) into the soil during rainfall or irrigation.
  - Soil density to know how well the seeding will take place and air penetrate through the soil.
  - Salinity indicates how much a soil becomes slurry during rainfall or irrigation times.
  - Earthworms indicate soil fertility and cultivation power.
  - Penetration resistance to know the capability of soil in gripping the roots of the plants.
  - Precipitation of the soil helps in deciding the irrigation method, type & quantity of fertilizers to be used, and the best timing for the sowing and harvesting as well as rate of growth of the plants, types of crops suitable, and the plant health as well.

Sensors as a Tool

Reddy (2020), mentioned some important usages of the sensors as tools as below:

- **Water Sensors:** Water sensors are used for the management of water levels and timing in the fields and also the precipitation of soil and leaves helps in deciding the right method of watering as well as the timing and quantity of water in irrigation.
- **Pest Management:** Sensors are used to identify different pests on the plants, their categories, and locate the harmful pests, their rate of growth helps in selecting the pesticides.
- **Hydroponics & Aeroponics:** a fully automated system for smart farming made by different sensors to collect data at regular intervals.

Challenges in Implementing Smart Farming and Operation Performed

Before installing any system in the fields, the farmer has to take the advice of the experts in selecting the right hardware and choose the right sensor depending on the crop type, geography, and data required. Selecting a service provider for smart farming is another issue, cost and profits in employing such smart systems in the fields are the challenges which make it difficult for uninformed farmers to utilize the technology. The better option is a government initiative to motivate the farmers in hiring such IoT tools in farming at a console rate. Further, the experts of different areas (scientists from agriculture and technology experts in machine learning & data analytics) can be involved in data observations to provide accurate information and predictions regarding the crop conditions and harvesting time. Further data is collected in a remote location probably in a cloud with wireless connectivity in an autonomous environment where the anomalies can be automatically notified to the farmer. The infrastructure for this remote monitoring, installing IoT tools for smart sensing, data storage, maintenance & reliability of the system even in bad weather and

abnormalities is very challenging. Storing the data in a protected system with secure connectivity, prohibiting intruders, and proper backups in case of system failures, electricity has gone, or solar stopped working due to calamities further augmented the current challenges. If all such issues are tolerable, then the management of the system is another challenge. The frequency of data collection (whether periodic or random or condition-based), in form of snapshots, videos or excel data, size of the data to be transferred over remote location, timely delivery, data analytical software, appropriate reporting & notification methods are also a challenger that depends on the crop type, budget and farmer's intellectual (Chalimov, 2020). Another challenge may involve the applicability of AI Tools to note the suspicious activities in the fields to avoid theft or other hazards.

The basic day-to-day operations a farmer has to perform in smart farming are described as follows.

- Regular maintenance of equipment.
- Irrigation schedules estimations correct water level estimations from the different parameters like the soil temperature, humidity levels (Chalimov, 2020)., and estimating over watering and under watering of the plants. Zia H, et.al (2021).
- Correct plantation timings by identifying the biological needs of the plants. (Chalimov, 2020) and Zia H, et.al (2021).
- Measuring soil moistness, identification, and categorization of pesticides as some pests are necessary for crop development. Locating the pests on the crops or the plants, study & analyze their behaviour for an optimal ratio of pesticides for individual plants or confined areas.
- Soil conditioning for selecting the optimal ratio of fertilizers or manures. The study is even more vital for eco-friendly farming with minimum use of chemical fertilizers and pesticides as well. (Chalimov, 2020) and Zia H, et.al (2021).
- Examining the different soil traits for insemination of an optimal mixture of crop seeds (mixed cropping) in an area with different sensors ingrained in smart soil monitoring devices.
- Cloud infrastructure for data processing and timely information transfer. Data gathering on weather like sun radiation, precipitation, humidity, wind speed, and estimated crop damage in any probable calamities or diseases.
- Fields monitoring with the smart devices mounted in fields to detect unnoticed irregularities due to occasional visits to fields.
- Installation of the system with advanced analytical software as well as data transmitting technology based on distance and size of the data, data can be exchanged using Bluetooth or another low-cost wireless medium. If an area is small LAN structure is sufficient otherwise for a remote transferring WAN is obligatory. (Chalimov, 2020).

Issues and Hesitations Impeding IoT for Smart Farming

- No uniformity of technologies that are being used.
- Internet connectivity issues discourage farmers to use this technology.
- Small land ownership and the cost of technology discourage people to go for the technology.
- With the increased connectivity to the rural areas, the impact of global factors also increased on the local people. The economic downstream or fall, supply chain issues, demand factors, fear of jobless of people involved in farming and agricultural activities due to automaticity, security attacks, hacking of important data and misuse or manipulation by intruders, cybercrime, logic bombs, cultural effects are un- estimated challenges in the life of the farmers.
- Fewer government provisions, policies, and subsidies for smart farming.
- Fewer guidelines and training facilities for the farmers in opting right smart technology, budget factors, and utilizing the advanced tools in agriculture.

Though the challenges are hard to face during the initial stage of mounting and establishing IoT infrastructure, however, as the current COVID-19 scenario demanded healthier food production, low-cost farming, and unavailability of skilled labourers because labor movements in COVID-19 automatically dragged toward smart farming that is only possible through the use of IoT in farming. The pandemic has now provided opportunities amid challenges and this push factor may enhance the usage of this technology in the sector.

Conclusions

India is a country where agriculture has immense significance and for its growth, we have to work on three aspects of agriculture - a new variety of crops, the number of crops, and the quality of crops. IoT proves to be effective in all these three tasks. Apart from the greenhouse of the fields, another form of the crop has emerged, that is growing the crop on the terrace of the houses or in the flats in which vegetables, grains, and fruits come and this area is very less. In COVID-19, new issues have emerged such as migration of labourers, changing patterns of crops, increased cost of raw material, and ruining of crops due to lack of good & timely market for the ripped crops. This concern increases, even more, when the new generation prefers less to work in the fields, and women have also started paying attention to other jobs. The paucity of time, paucity of resources, and paucity of land give credence to adopting smart farming. But, without the initiative and support of the government, the scope of smart farming cannot be enlarged. The support of the government is very important for providing the proper policy, and resources at a subsidized rate, protecting farmers from online fraud, proper information and training so that farmers understand the importance of new technology and do farming by making a proper balance of profit and loss due to it. Performing farming-related business and enhancing living standards as well, overall strengthening the agricultural economy. Technology-based smart agriculture has enormous scope for the agriculture sector in the country and with the successful implementations, the cost can be minimized with a high level of income further, this technology is also helpful for sustainable agricultural development in the country. The journey from inputs-intensive to knowledge-intensive agriculture in India essentially requires major policy changes that can ultimately enhance the welfare of the farmers in the country.

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