IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

ANALYZING IOT POSSIBILITIES AND ITS IMPACT ON SMART AGRICULTURE INDUSTRY

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Abstract: The agriculture industry is facing numerous challenges such as climate change, population growth, and resource constraints. The sector is progressively using technological solutions like the Internet of Things (IoT) to enable smart agricultural practices in order to address these difficulties. IoT has the capacity to gather and analyze data from numerous sources, including sensors, weather stations, and other connected devices, in order to increase efficiency, raise crop yields, and decrease waste. This research paper investigates the potential of IoT for smart agriculture by analyzing existing literature and case studies of IoT implementation in agriculture. The paper identifies the potential applications of IoT in precision farming, livestock management, crop monitoring, weather monitoring, and supply chain management. The paper also discusses the challenges and opportunities associated with IoT implementation in agriculture and highlight the need for collaboration between stakeholders to enable successful adoption of IoT solutions. The results of this research provide insights for policymakers, farmers, and industry stakeholders to adopt IoT solutions and optimize agricultural practices for sustainable and efficient food production.

***Key Words*:** Agriculture, Smart Agriculture, Internet of Things (IoT), Precision Farming, Efficiency, Sensor Technology, Climate Change, Food Production, Sustainability

I. INTRODUCTION

This paper is based on technical advancements that, among other things, gave rise to the concept of smartness, including the Internet of Things, Big Data, and Cloud Computing. The Internet of Things (IoT) for farming is a network of screens, cameras, and computers that can all cooperate to improve a farmer's capacity to perform his job. They wouldn't need a human to help them communicate because this computer would be self-sufficient. In other words, the devices are preprogrammed with knowledge of what to do when and why they should interact with other components of the system. Some agricultural businesses have shifted to IoT engineering for smart farming to increase production, performance, global market share, and other qualities like minimal human involvement, time, and cost. Development of technology during the time makes sure that the sensors will become smaller than usual, much innovative and affordable also. Smart Agriculture is a very powerful and helpful concept for the betterment of society because IoT sensors are developing day by day and are able to provide data about fields and then act according to the given input.

II. IOT AND IT'S ROLE IN AGRICULTURE

A network of physical items, or "things," that have sensors, software, and other technologies built into them that can connect to and exchange data with other systems and devices through the internet is referred to as the "Internet of Things" (IoT). These devices range from basic household items to complex industrial equipment. IoT experts predict that, increasing from the present total of over 7 billion, there will be 10 billion linked devices by 2020 and 22 billion by 2025. Due to the exponential growth of the world's population, which will demand a 70% increase in food production by 2050, as well as, the shrinking amount of arable land and the depletion of finite natural resources, there is a pressing need to boost farm produce. The problem has gotten worse as a result of the diminishing yield trends of several major crops and the scarcity of natural resources like fresh water and arable land. Another barrier for the farming industry is the evolving demographics of the agricultural work force. Furthermore, the majority of the nations have seen a reduction in agricultural labor. In order to eliminate the demand for physical labor, internet connectivity technologies have been adopted in farming practices as a result of the shrinking agricultural workforce.

III. CHALLENGES AND BARRIERS OF IMPLEMENTING IOT IN AGRICULTURE

a) **Connectivity:** As high-speed internet is required for IoT devices to communicate with one another and with the cloud, many farms are situated in rural areas with little to no access to it.

b) **Data management**: Farmers must have the knowledge and resources to analyze and make sense of the massive amounts of data provided by IoT devices.

c) **Cost:** The cost of installing and purchasing IoT devices might be prohibitive for farmers who are not working on a very large scale and those in developing nations with not a wide variety of resources.

Table 1: Types of Sensors and IoT devices used on farms, their respective costs, and benefits:

Device/Sensor Type	Cost	Benefits
Soil moisture sensor	$50-$200 per sensor	Accurately measures soil moisture levels and reduce water usage.
Climate Sensor	$100-$500 per sensor	Monitors temperature, humidity and light levels to optimize growing conditions.
Drones	$1000-$5000 per unit	Conducts aerial surveys and identifies crop damage or disease early.
Automated irrigation systems	$3000-$10000 per system	Reduces water usage and labour costs.
Livestock monitoring sensors	$100-$500 per animal	Monitors animal health and tracks animal behaviour.

d) **Compatibility:** There are many different types of IoT devices and platforms, and they may not all be compatible with each other. This can make it difficult for farmers to choose the right devices and ensure they work together seamlessly.

e) **Security and privacy:** IoT devices can be vulnerable to cyber-attacks, and the sensitive data they collect, such as farm and crop data, must be protected from unauthorized access.

Table 2: Percentage of Farmers Who Have Concerns About Data Privacy and Security When Using IoT Technology

Concern	Percentage of Farmers
Data Privacy	30%
Data Security	25%
Both data privacy and security	15%

f) **Insufficient knowledge and instruction:** Many farmers are not aware of the amazing and potential benefits of IoT in field of agriculture or do not have the knowledge and skills to implement and use these technologies effectively.

g) **Regulatory barriers:** There may be regulatory barriers that prevent or restrict the use of IoT devices in agriculture, such as privacy or data protection laws.

IV. BENEFITS OF IOT IN AGRICULTURE

With the passing years, IoT has improved a lot and did wonders for the betterment of human living. IoT has also helped so many farmers in the field of agriculture and had provides so much better methods and strategies to improve the old ways of traditional farming.

a) **Increased efficiency and productivity:** IoT devices can help farmers optimize their operations by automating tasks, monitoring crops and livestock, and providing real-time data on environmental conditions. This may improve decision-making for farmers, decrease waste, and boost output all around.

b) **Improved resource management:** IoT devices can help farmers better manage their resources, such as water, fertilizer, and energy, by providing real-time data on usage and efficiency. This can help reduce waste and costs, and improve the sustainability of agricultural practices.

c) **Enhanced crop and livestock health:** IoT devices can monitor the health of crops and livestock, detect disease or pest outbreaks, and provide early warning of potential problems. This can help farmers take proactive measures to prevent and treat health issues, leading to healthier and more productive crops and livestock.

d) **Increased yield and profitability:** By optimizing operations, managing resources, and improving crops and livestock health, Farmers' yields and profitability can grow with the use of IoT technology.

e) **Better decision-making:** Farmers will be able to make better decisions about planting, harvesting, and other activities by using real-time data from IoT devices on a range of aspects, including weather, soil moisture, and crop development.

f) **Remote monitoring and control:** IoT devices can be monitored and controlled remotely, allowing farmers to access real-time data and make adjustments from anywhere, at any time.

g) **Improved traceability and food safety:** IoT devices can help track the movement of crops and livestock from farm to consumer, providing greater transparency and improving food safety.

V. SUCCESSFUL SMART AGRICULTURE IOT APPLICATIONS

a) IoT Based Agricultural Robots:

These are the kinds of robots that are employed in various agricultural processes. Robotics advancements for various agricultural tasks have been greatly aided by the Internet of Things (IoT), where robots can now carry out a variety of tasks in addition to humans. In addition, the robots can get rid of up to 80% of the pesticides used on farms. Robots for agriculture will be helpful in addressing manpower shortages in smart agriculture, also during the disastrous diseases such as Covid 19, where human touch is prohibited. There is a wide variety of agricultural robots, such as equipment for animal applications, insect infestation, weed identification, irrigation, and harvesting. In future we will get to see more technology like these.

Figure 1: IoT based agricultural robot

b) IoT Based Drones:

Since the beginning of the 1980s, drones have been employed in agriculture for a small number of commercial purposes. However, as communication technology advanced and the Internet of Things (IoT) became more widely used, the employment of unmanned aircraft has gained significant importance.

Figure 2: Drones Based on IoT

Numerous tasks it may carry out will enhance farming methods. Drone activities include things like soil analysis, irrigation, agricultural spraying, crop inspection, and planting. The drone's detector array can also be used to cover crop health pointers, vegetable viscosity, fungicide prospecting, fertilizer, cover mapping, field vaticination, factory count, factory height dimension,

field water mapping, exploratory reports, and nitrogen dimension. Islam and associates (2012). It's also possible to cover the health of shops using several vegetative indicators that may be directly reckoned from multi-spectral photos, including one of the most well-known ones, the NDVI (Normalized Difference Vegetation Index). Kim et al. presented in 2019 examples of the numerous applications of UAVs. (UAV for Harvesting, Spraying, Mapping, and Sensing).

VI. CASE STUDIES OF SUCCESSFUL IOT IMPLMENTATIONS IN AGRICULTURE

a) **Precision irrigation:** An IoT-based precision irrigation system that employs sensors and data analytics to optimise water consumption in agriculture has been created by Israeli start-up Netafim. Farmers may modify their irrigation practises as necessary thanks to the system's real-time measurements of soil moisture levels and meteorological information. The method has helped farmers save money and boost their profitability by decreasing water wastage and raising crop yields.

b) **Livestock-monitoring:** The health and behaviour of dairy cows are tracked by Connecterra, a Dutch start-up, using an IoT-based system based on sensors and machine learning algorithms. The technology monitors the cows' activity levels and movements and notifies farmers of any symptoms of disease or discomfort. The method can assist farmers in enhancing the production and health of their cows while lowering the usage of antibiotics by identifying health concerns early.

c) **Crop monitoring:** The Climate Corporation, a subsidiary of Bayer, has developed an IoT-based platform called Field View that helps farmers monitor and manage their crops. To deliver real-time insights into soil moisture levels, weather information, and other elements that impact crop development, the platform makes use of sensors and data analytics. The platform can assist farmers in making better educated decisions regarding irrigation, fertilisation, and other areas of their operations by giving them precise information on their crops.

d) **Pest control:** Semios, a Canadian company, has developed an IoT-based pest control system that uses sensors and data analytics to monitor insect populations in orchards and vineyards. The system uses pheromone traps and temperature sensors to detect and track insect activity, and alerts farmers to any signs of infestation. By providing early warnings of pest outbreaks, the system can help farmers in reducing the usage of pesticides and hence will improve the health of their overall crops.

VII. COMPARISON OF IOT WITH TRADITIONAL FARMING METHOD

By supplying farmers with real-time data, automation, and optimization tools to increase efficiency, production, and sustainability, IoT technology has the potential to revolutionize conventional agricultural practices. This section will examine the effects of IoT and conventional farming practices on the environment and productivity.

a) **Resource management:** Traditional agricultural methods often rely on guesswork and experience to manage resources such as water, fertilizers, and energy. This can result in inefficient usage and waste. In contrast, IoT technology provides real-time data on resource usage and efficiency, allowing farmers to optimize their resource management, reduce waste, and improve the sustainability of their operations.

b) **Crop and livestock health**: Traditional agricultural methods may involve periodic manual inspections and visual observations to monitor crop and livestock health. However, these methods are often prone to human error and can be time-consuming. IoT technology provides farmers with real-time data on crop and livestock health, allowing for early detection of diseases, pests, and other issues. This can help farmers take proactive measures to prevent and treat health issues, leading to healthier and more productive crops and livestock.

c) **Decision-making:** Traditional agricultural methods often rely on experience and intuition to make decisions about planting, harvesting, and other operations. Whereas in comparison to traditional method of farming, IoT technology domain generates data on a real time basis related to the conditions of weather in a region or area, it also provides data of the temperature, soil moisture, and other factors, which allow farmers and individual to take more detailed and informative decisions for their operations.

d) **Environmental impact:** Traditional agricultural methods mostly include usage of huge amounts of water, fertilizers, also the pesticides, which possibly can have so many negative environmental impacts such as pollution and soil degradation. Whereas, IoT technology will help farmers in optimising resource usage as well asin reducing waste, leading to more sustainable agricultural practices with reduced environmental impact.

e) **Productivity:** IoT technology has the potential to significantly increase productivity in agriculture by optimizing operations, managing resources, and improving crop and livestock health. In contrast, traditional agricultural methods may be less efficient and more prone to human error, leading to lower productivity.

f) **Economic Benefits:**

Table 3: Comparison of the Economic Benefits of IoT Technology in Agriculture, including a Cost-Benefit Analysis and Return on Investment Calculations is depicted below.

Benefit	Cost	Return on investment
Increased crop yield	$10000	$20000(2:1 ROI)
Decreased resource usage	$5000	$12000(2.4:1 ROI)
Labour cost savings	$8000	$15000(1.9:1 ROI)

VIII. FUTURE TRENDS IN IOT FOR AGRICULTURE

By giving farmers access to real-time data and insights that can assist them in making better decisions about crop management, irrigation, and other elements of their operations, the Internet of Things (IoT) has the potential to upgrade agriculture. The following are some anticipated developments and trends in IoT for agriculture:

a) **Machine learning**: Algorithms of Machine Learning can help in analysing the massive amounts of data generated by IoT devices in agriculture. For example, machine learning can be used to predict crop yields based on weather data and soil moisture levels.

b) **Big data analytics:** The ability to collect and analyse large amounts of data is critical for the success of IoT in agriculture. Farmers may use big data analytics to find patterns and trends in their data that will help them make better decisions and increase crop yields.

c) **Blockchain:** Blockchain technology can help improve transparency and traceability in agriculture by enabling farmers to track the movement of their crops from field to market. This can help prevent food fraud and improve food safety.

d) **Precision agriculture:** Precision agriculture is the use of technology to optimize crop production and minimize waste. IoT devices such as sensors and drones can help farmers monitor crop growth and health in real-time, allowing them to make adjustments to their irrigation and fertilization practices as needed.

e) **Smart irrigation:** Farmers can monitor soil moisture levels and improve irrigation techniques with IoT sensors to save money and water. Weather data may also be linked into smart irrigation systems to automatically change watering schedules based on rainfall predictions.

f) **Robotics:** Robotics technology can help automate tasks such as planting, harvesting, and weed control. IoT sensors can be used to guide robots and ensure they are operating efficiently.

IX. ETHICAL CONSIDERATIONS FOR IOT IN SMART AGRICULTURE

Some of the key ethical consideration which should be taken are:

a) **Data privacy and security**: IoT devices gather and send a lot of data, some of it can be sensitive and private. Farmers and other stakeholders must ensure that the data collected is protected from unauthorized access, theft, and misuse.

b) **Equity and access:** The use of IoT in agriculture may exacerbate existing inequalities if not implemented in an equitable manner. Farmers with limited resources may not have access to the necessary technology and may be left behind. It is required to make sure that IoT is implemented in such a way which benefits all the farmers, regardless of their location or economic status.

c) **Transparency:** The usage of IoT in domain of agriculture can result in large amounts of data being collected and analyzed. It is important those farmers and other stakeholders are transparent about the data collection and analysis process and that their data is used in an ethical manner.

d) **Automation and job displacement:** IoT technology has the potential to automate many tasks in agriculture, which could lead to job displacement for some workers. Farmers and other stakeholders must consider the potential social and economic impacts of automation and ensure that the benefits are distributed fairly.

e) **Environmental impact:** The usage of IoT in agriculture will improve the efficiency and reduces wastage, leading to more sustainable agricultural practices. However, farmers and other stakeholders must also consider the potential environmental impacts of IoT and ensure that its use does not harm the environment.

X. POTENTIAL POLICY AND REGULATIONS FOR IOT IN SMART AGRICULTURE

In order to assist farmers in making better decisions regarding crop management, irrigation, and other elements of their operations, the Internet of Things (IoT) should provide them with real-time data and insights which have the potential to alter agriculture. However, Internet of Things (IoT) could have the following policy and regulatory effects on agriculture:

a) **Data privacy and security:** The data generated by IoT devices in agriculture, such as soil moisture levels and weather data, can be sensitive and must be protected from unauthorized access. Policies and regulations around data privacy and security will be crucial to ensure that farmers and other stakeholders can trust and use this data effectively.

b) **Standards and interoperability:** To ensure that different IoT devices can communicate with each other effectively, standards and interoperability protocols will be needed. Policymakers and regulators can play a role in developing and enforcing these standards.

c) **Access to technology:** The cost of IoT devices can be a barrier to adoption, particularly for smaller farmers or those in developing countries with limited resources. Policies and regulations that promote access to technology, such as subsidies or tax incentives, may be needed to encourage widespread adoption of IoT in agriculture.

d) **Intellectual property**: IoT devices and platforms may be subject to intellectual property laws, which could restrict their use or development. Policymakers and regulators may need to consider how to balance the need to protect intellectual property with the need to promote innovation and access to technology.

e) **Liability:** The use of IoT devices in agriculture could raise questions about liability in the event of equipment failure or data breaches. Policymakers and regulators may need to clarify the legal responsibilities of farmers, technology providers, and other stakeholders in the application of IoT in farming.

f) **Environmental impact:** The usage of technologies such as IoT in field of agriculture can have environmental implications, such as increased energy consumption or electronic waste. Policymakers and regulators are needed to take into consideration about how to promote the sustainable and best usage of technologies like IoT in agriculture and mitigate any negative environmental impacts. Overall, policies and regulations will be critical to ensure that IoT can be effectively and responsibly used in agriculture to promote sustainable and efficient food production.

XI. CONCLUSIONS

In conclusion, Internet of Things (IoT) has significant potential to transform agriculture into a smarter and more efficient industry. By using IoT devices, farmers can collect real-time data on crop growth, soil moisture levels, weather conditions, and livestock health, among other factors. This data can then be analysed using machine learning and big data analytics to generate insights and inform decision-making. The possibilities of IoT in agriculture are vast, from precision irrigation and crop monitoring to pest control and livestock management. By optimizing resource use and reducing waste, IoT can help farmers increase their yields and profitability while promoting sustainable farming practices. Moreover, the use of IoT in agriculture can lead to a more transparent and traceable food supply chain, improving food safety and quality for consumers. However, the implementation of IoT in agriculture also presents challenges, such as data privacy and security, access to technology, and environmental impact. Addressing these challenges will require policy and regulatory frameworks that promote responsible and sustainable use of IoT in agriculture. Overall, the impact of IoT on smart agriculture in terms of present and future potential is significant, and this technology continues to evolve rapidly. With the right policies and investments in place, IoT can help farmers produce more food with fewer resources, while reducing the industry's environmental footprint and contributing to food security and safety. Smart agricultural technology has applications which are benefitting developing countries; one of such country is Egypt. Projects of Egypt that signal the emergence of the expansion of such technology can help in the growth of the agriculture area and also in achieving farm feasibility and greenery in such nations. Finally, governments in third-world nations should also support these smart technologies at the level of small farms because they aim to increase productivity and improve the efficient use of land and water resources.

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