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RESEARCH PAPER

Challenges and opportunities for IoT applications in smart agriculture

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Abstract: This paper presents an overview about Digital Agriculture and specifically about Internet of Things (IoT) for agriculture. The potential for IoT solutions is manifold, and there are very high hopes pinned on this. It is expected that IoT could help in addressing the global challenges of poverty, malnutrition and environment degradation. This paper also outlines the opportunities for IoT application in digital/ smart agriculture and the current challenges in its wider adoption. The IoT in agriculture can help in enhancing productivity, profitability of farmers. The technology can also help in saving the environment. The potential is manifold and could easily transform and recast the lives of smallholder farmers. However, the technology solutions need to be cheaper, reliable, and simple to use for smallholder farmers. Startup companies should adopt newer and innovative business models to deploy the solutions. The general awareness on the usefulness and evidence on the return of investment on IoTs should be demonstrated to farmers for wider adoption.

Key Words: Adoption, Management, Network, Smart agriculture

Introduction

According to the 2018 FAO reports there were about 821 million people who were facing chronic food deprivation in 2017, which is about 5 percent higher than that of 2015. Additionally, the global undernourishment is increasing for three consecutive years from 2015 (FAO, 2018). The United Nations recognizes poverty, food and nutrition security and climate change as key global challenges amongst others. Approximately 83 percent of the 570 million farms in the world are smallholders (less than 2 ha) operating about 12 percent of the total farmland (Lowder *et al*., 2016). The majority of these 473 million smallholder farmers are under tremendous stress due to various reasons including their dependence on rain, degraded natural resources, limited capacity to invest, and lower adoption rates for new technologies and awareness (Maponya *et al*., 2013).

Evolution of Digital Agriculture

ICT and Agriculture: Technology advancements and innovations in Information and Communication Technologies (ICT) and plant breeding (improved varieties and hybrids) have the greatest potential for meeting the global challenges of sustainability by increasing productivity in a balanced manner (Basso & Antle, 2020). ICTs can help to accelerate the productivity and market linkages across the agriculture value chain. Some of the examples of the services include weather forecasting, crop yield prediction, crop selection, irrigation management, crop diseases and pest management, agricultural marketing and agricultural pest management (Nazirul Islam Sarker *et al*., 2019).

Ag 3.0 and m-Agri: The application of ICT for development including agriculture is continuing to evolve and transform since the 1980s but more in the 1990s and 2000s. Eventually, in the late 90s and 2000s, the affordability and accessibility of the internet, computers and mobile phones created a boom in developing countries as well. During this time the developed countries with large farms ventured into precision farming with GPS and computing technologies which can be dubbed as Agriculture 3.0. Contrasting to Agriculture 3.0 established in the developed world, the developing nations at the same period with evolving mobile penetration and mobile internet focused on information services delivered through SMS, IVRS, mobile telephony or accessed through portals from common computing facilities.

Digital Agriculture or Ag 4.0: As defined by (Shepherd *et al*., 2020), DAG is the use of digital data and technologies guiding informed decisions and solutions across the agriculture value chain. Digital Agriculture is a wider theme that includes several technologies including IoTs, big data analysis, satellite imagery, drones, robotics, decision making and artificial intelligence for agriculture. Of these technologies, IoT is one important technology which along with big data analysis and visualization is transforming farm monitoring and management. IoT technology uses sensors to collect data on different agriculture variables on soil, weather and hydration and automate the irrigation practices. IoT uses a set of sensors and its network and big data analysis to make data-driven farm decisions leading to more timely and cost-effective production and management of farms, and at the same time reducing their environmental impact.

Internet of Things (IoT)

Madakam *et al*., 2015 defined IoT as comprehensive network of objects that auto-organizes, shares information, data and resources, reacting and acting to the environment without manual intervention. IoT in agriculture consists of sensors, processing, connectivity, gateway and cloud solutions optimized in their working according to specific use cases.

A complete IoT enabled agriculture system include the (i) sensors (accelerometers, temperature, humidity, pressure) to collect signals on physical events; (ii) processors (micro-controllers *etc*.) to process the signal from the sensors; (iii) connectivity protocol and devices (Bluetooth, NFS, LAN, WPAN) to transfer the signals to the terminal; and (iv) power source (battery, convertors, solar panels) to power the sensors and processors.

Sensors are hardware devices that convert physical events or variables into electrical signals, which later is transferred to computer systems or other device over internet. Actuators are hardware that convert the electrical signals into the physical events or characteristics. It takes the input from the system and gives output to the environment. Actuators usually send outputs and receive inputs to trigger actions within the system.

IoT Applications in agriculture

IoT in the Agriculture Industry helps the farmers to maintain the quality of crops and fertility of the land, thus enhancing the product volume and quality. Popular applications of IoT in agriculture are listed below:

1. Precision agriculture: Precision farming usually a large farm solution uses sensors placed in the farm or the farm implements to collect data, analyze and control the systems. In some cases, the systems are trained to take decisions based on the data. Examples of precision agriculture include farm mechanization/vehicle tracking or irrigation management. Precision agriculture commonly used in large scale farms increases efficiency and effectiveness of the operations.
2. Livestock monitoring and management: Similar to crop-farm monitoring, IoT sensors implanted to farm animals could track the location, movement, health and other parameters of the animals, on a farm to monitor their health and log performance.
3. Aquaculture: Similar to crop and livestock monitoring IoT sensors placed within the aquaculture ponds help in maintaining the temperature, oxygen level, circulation of the water, apart from harnessing data on multiple parameters that are vital for managing the aqua systems.
4. Weather and soil monitoring: Sensors placed within the farms and outside the farms collect real-time weather information and soil conditions (pH, moisture). These data are analyzed to provide actions to farmers to take decision on nutrition, irrigation, and other related management.
5. Agricultural Drones: Drones with sensors and specialized cameras (RGB, multi-spectral, hyper-spectral cameras) collect data crop and soil health which are then analyzed for actions leading to enhanced crop health assessment, irrigation, crop monitoring, crop spraying, planting, and soil and field analysis.
6. Smart greenhouses use IoT based weather stations to read and adjust the climatic condition of the greenhouse based on the pre-defined conditions and instructions. This eliminates the human intervention and enables efficiency.
7. Predictive analysis: The data collected through the IoT devices and sensors help in monitoring the real-time status of the fields. Analyzing this data can help in predicting and guiding the decision on the production of the crop, its storage, marketing techniques and risk management.

Challenges and Constraints in IoT adoption

While the importance and potential of IoT in agriculture is well known, there are challenges and constraints that are restricting its adoption in developing countries like India. These challenges are:

(i) Poor and unreliable connectivity: in the recent years, mobile and internet connectivity has penetrated rural households. However, the network performance and its reliability in the farm locations need to be improved. Hence deploying sensors and IoT systems is not feasible everywhere.

(ii) Cost of hardware: the cost of the sensors and its components are still expensive, making it economically non-viable to deploy for farmers who cultivate low-income crops.

(iii) Small land holdings: the average land holdings of farmers in India are small. Deploying a complete IoT solution for each of the farm doesn't make good economic sense. Maybe the cooperative model of where farmers pool and share the IoT infrastructure can be introduced to address this.

(iv) Data privacy: the question of who owns the data - whether the farmers or the technology providers is still a question in discussion. Policies and guidelines needs to be streamlined for effective adoption.

(v) Ag-tech start-up: the IoT agriculture industry is powered by Agri tech start-ups. Not all start ups are successful. This has led to some of the deployments and solutions failing quickly.

(vi) Reliability and maintenance: many of the IoT solutions are still in pilot mode. The farmers are yet to be convinced with evidence on the practical use of IoT solutions.

(vii) Awareness: Above all, the general awareness on IoT based farming solutions need to be created in developing countries like India.

Conclusions

The IoT in agriculture can help in enhancing productivity, profitability of farmers. The technology can also help in saving the environment. The potential is manifold and could easily transform and recast the lives of smallholder farmers. However, the technology solutions need to be cheaper, reliable, and simple to use for smallholder farmers. Startup companies should adopt newer and innovative business models to deploy the solutions. The general awareness on the usefulness and evidence on the return of investment on IoTs should be demonstrated to farmers for wider adoption.

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