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A Study on Adoption of IoT based Smart Agricultural Practices in Kerala Using Analytic Hierarchy Process

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ABSTRACT

Background: In a rapidly digitizing world, technological advancements such as the Internet of Things IoT, automation technologies, blockchains, etc., hold the potential to revolutionize traditional agricultural practices to smart farming choices. In agriculture, IoT represents a system where physical elements like plants, animals, virtual objects, and environmental factors are interconnected with the internet via specific protocols and equipment. However, in the state of Kerala, India, IoT adoption in agriculture remains meager when compared to any other state.

Objectives: In Kerala, significant progress in this transition remains elusive, with limited practical implementation of Internet of Things (IoT) technologies. To bridge this gap and facilitate the modernization of Kerala's agricultural practices, this study seeks to comprehensively investigate the factors that influence the adoption of IoT in the smart agricultural practices.

Method: An Analytic Hierarchy Process (AHP) analysis was used to comprehensively investigate the multifaceted factors influencing the adoption of IoT technologies for smart agricultural practices in Kerala's agricultural sector. A total of five criteria with 33 items were used for the study. A total of 10 experts were contacted for the data collection.

Result: The findings suggest that all the 5 criteria viz Data management, operational factor, social factor, economic factor and government support system has significant impact in adoption of IoT based smart agricultural practices.

Conclusion: This study will offer valuable insights to inform policymakers, agricultural organizations, and technology providers, empowering them to make informed decisions and strategically plan for the seamless integration of IoT technologies into the agricultural domain.

Keywords: Internet of Things; Smart agriculture; Kerala agricultural sector; Analytic hierarchy process (AHP) analysis; Smart farming; Agricultural products; Sensors; Real-time systems; Agricultural monitoring; Agro-informatics; ICT for agriculture; Challenges; Security; Technology policies.

1. Introduction

Agriculture and its allied sectors forms the primary sector in India on which more than 50% workforce depending for its livelihood, thus forming the backbone playing pivotal role in contributing to about 20% of nations' GDP. The rapidly increasing population, has increased the demand for food which has increased the pressure on agriculture. The impact of change in climatic conditions, poor soil quality, non-availability of healthy seeds, lack of proper monitoring, and watering system has hugely affected the performance in agricultural sector to meet the growing need of the population. The revolutionary advancement of agriculture practices to new norms viz., smart agricultural practices which uses sophisticated technologies like robots, temperature and moisture sensors, aerial imaging and GPS systems which are expected to make farming more efficient, profitable, safe and environment friendly.

The application IoT powered smart agricultural practices have the capability to enhance monitoring, tracking intelligent identification and efficient management of agricultural objectives. The IoT acts as a potential tool for farmers to overcome the uncertainty of climatic change and food fluctuations. IoT in smart agricultural refers to a network in which the physical components such as plants, animals, various virtual objects, environmental elements, etc., in the agricultural system are closely inter-connected with the internet through an equipment, under certain protocols for exchange of information and to perform communication also. Its main intention is to enhance

production by analysing the positioning, tracking, monitoring, intelligent identification and management of agricultural objects and processes. The emergence of IoT in the field of smart agriculture has made humans to recognize, manage and control various agricultural processes and systems and capable of handling agricultural emergencies.

All over the world the agricultural sector is undergoing a transformative shift towards smart agricultural practices using automation and digitalization to meet the evolving demands of the modern world. However, in the Indian state of Kerala, significant progress in this transition remains elusive, with limited practical implementation of Internet of Things (IoT) technologies. To bridge this gap and facilitate the modernization of Kerala's agricultural practices, this study seeks to comprehensively investigate the key factors that influence the successful adoption of IoT in the agricultural sector.

1.1. Study Objectives

The main objectives of the study are: (1) Understanding the application of IoT in smart agricultural practices; (2) To identify criteria's affecting adoption of IoT in smart agricultural practices; (3) To understand and assess the sub criteria's affecting IoT adoption in smart agricultural practices; and (4) To assess and rank the criteria's and its sub criteria's in IoT based smart agricultural practices in in Kerala using Analytic hierarchy process.

2. Importance of IoT in Smart Agricultural practices

IoT has a wide range of applications in the domain of not only societal challenges but also environmental challenges that has been faced by the agricultural sector. Internet of Things can transform the sector from farm to fork, thereby providing food safety and reduction of food waste (Brewster et al. [1]). One of the major challenges faced today by the agricultural sector is to prepare and use land for crops in the farm and to supply it to the end customer, by offering the best quality and best price. IoT basically runs on real-time data and alert the user to take necessary measures or actions wherever needed, thereby reducing the human involvement (Shenoy & Pingle [2]). IoT in agriculture comprises of network topologies, network layers and network architecture along with the technologies such as big data, cloud computing and analytics. IoT being an agglomerate of the sensors, it is easy to communicate for the future generation technologies (Muangprathub et al. [3]). Agricultural crops shall be watered using the wireless sensor system. The three major constituents include in IoT are hardware, mobile application and web application. Hardware was used to collect data regarding the crops. IoT shall be defined as an M2M or machine-to-machine devices that is used for controlling, monitoring as well as for unmanned machinery. Agricultural IoT shall reduce the labour, increasethe quality of crop as well as production and promote automation in each industry (Kim et al. [4]). Internet of Things (IoT) enables the technologies to face the future challenges. The application of IoT in the agricultural sector creates a hybrid of traditional businesses alongwith the implementation of digital connectivity. The optimum use of IoT shall be reached when the agricultural industry shall be alerted (Adesta et al. [5]). In order to improve the cost-effectiveness and yield of the crops, it is very vital to raise the agricultural productivity and processes of farming. Hence IoT makes agricultural sectors more efficient by automation, thereby reducing the human intervention (Madhushanki et al. [6]). In order to balance the demand and supply of the agricultural outcome, both the environmentalsensors as well as the growth production system and the

amount of crop production shall be increased by collecting the information (Lee et al. [7]). IoT promotes smart agriculture techniques by gathering real-time data, processing, analyzing and by providing improvement in the overall management of the farm. A standard IoT-based system can be categorized mainly into four, namely gateway, communication technologies, things and cloud infrastructure (Farooq et al. [8]). IoT represents the future of technology thereby rising the communication using cloud computing. Cloud computing acts as a scalable and visualized resource for wide application in agriculture sectors (Patil et al. [9]).

Agriculture being the corner stone of the Indian economy plays a vital role in our day-to-day life. Man power is the major problem that is faced by the farmers which might arise due to the migration of farmers. The connected devices on automation and IoT find several ways to improve the traditional techniques that are being used by the farmers (Kumar [10]). Rise in population has brought a major rise in the pressure in agricultural field. IoT has converted both the quality as well as the quantity of agricultural sector. In order to tackle the growth of population which is predicted to raise to 8 billion people around 2025, so almost 70% of food production must be increased in order to achieve stability (Arora et al. [11]). It is very essential to target on sustainable agriculture in order to meet the demand of Indian irrigation. In order to completely automate the agricultural system, it senses both humidity as well as temperature and thereby reducing the human interference (Boobalan et al. [12]). In order to increase the production of food, modern agricultural techniques have been adopted inIndia. These emerging modern agricultural practices cause certain risks to the human health condition. These hazards include vector-borne diseases, occupational hazards, inequity in the development and changing nutritional status (Sarkar et al. [13]).

3. Adopting IoT in Smart Agriculture Practices

Smart agriculture acts as a good solution for the efficient resource management, labour utilization and also for the growth of food production. Highlights the complications and challenges faced while transforming traditional agricultural practices to modern technology (Suma [14]). The demand for agricultural products increases day-by-day, but the land size provided for farming as well as the labour workforce is declining today. The cost of adoption of IoT plays a major role because the farmers should increase their production to the maximum and decrease the damage of crops (Setiaji et al. [15]). The current barriers that affect the implementation of modern technologies in agriculture sector in order to promote a sustainable agricultural environment are focused. A sum total of 53 barriers were identified. Of which 28 were external to the farmers and 23 internal to the farmers (Campuzano et al. [16]). The major challenges faced by the Indian agriculture is that of soil deterioration, soil quality, quantity of farm produce, poor harvest practices, unforeseen weather condition and unattractive wages for producers. To make organic agriculture smart, latest high yielding technologies along with value based technological innovations and interventions are considered (Kumar [17]). IoT aims at creation of a large network by the integration of multiple devices that are linked. The use of sensors is to track the various parameters such as humidity, temperature, water level and moisture content (Vanitha et al. [18]). Sustainable agriculture acts as a critical part of the Indian agriculture. The degradation of the natural resources as well as the environment causes an unsustainable agriculture. The demand for eco- friendly agricultural products have risen to a great extent in the international market (Sundar [19]). The application of ICT in agriculture includes monitoring of soil moisture, system of irrigation monitoring, fertilizer administration, identifying and controlling crop diseases and pest control,

yield monitoring forecasting and harvesting, climatic condition monitoring. The challenges and issues in smart agriculture are involving infrastructure, mobility, hardware maintenance, data privacy and data security (Rehman et al. [20]). The rapid alteration in the climatic condition and unexpected urbanisation causes serious threat towards the African agricultural system. The risk of shortage of food shall arise in the upcoming future. In order to promote sustainable farming, digitalization and adoption of smart farming plays a crucial role (Balogun et al. [21]).

4. Benefits of IoT in Smart Agricultural Practices

IoT provides with two types of data namely timely-based data and real-time data. Large amount of data is being generated by the use of big data technology. The IoT technology in the Industry 4.0 acts as an emerging technology with effective information sharing, processing and tracking of the supply chain (Yadhav et al. [24]). Smart farming mainly focuses on information technology as well as communication technology. Innovative technologies such as cloud computing and Internet of Things has been utilized for initiating the application of robots a well as artificial intelligence in farming activities (Dhanaraj et al. [23]). An empirical study was conducted among 670 Italian farmers to understand the awareness, adoption rate benefits and obstacles in adopting smart farming or agriculture 4.0. The result showed a heterogeneously distributed level of knowledge on agriculture 4.0 and there is a significant increase in level of adoption of smart farming techniques. The major application of smart farming are in water monitoring, soil and moister monitoring, temperature sensors, fertilizer administration crop disease and pest controlling, yield monitoring, forecasting and controlling, etc. The major obstacles identified were limited or no interoperability, lack of connectivity, lack of return on investment, insufficient assistance, difficulty of use lack of skills and limited flexibility (Maffezzoli [22]). Intensive agriculture is mainly focused on the factors of production acting per unit area such as chemical fertilizers and pesticides in order to stimulate production purposes. Food security is hence ensured but the chemical residues that are overleft in the food causes health hazards to humans (Stoian et al. [25]). IoT connects all the physical objects to the internet and thereby helps in collecting, processing and communicating data without the interference of human. The certain areas that benefit from IoT includes smart farming, pest monitoring, livestock movement monitoring, irrigation management, controlled usage of fertilizer, scientific diseases and intelligent greenhouses (Shi et al. [26]). IoT not only help the farmers to improve the technology but also to increase their productivity thereby finding a better optimal solution for problems that have been involved from sowing the seed to harvesting the crop. IoT application that takes place in small and medium enterprises helps in both decision making as well as in transforming into digital companies. The tracking system of IoT is widely used in real time products such as Radio Frequency Identification (RFID) and Wireless Sensor Networks (WSN) for controlling and monitoring the environmental conditions such as temperature and humidity (Moghayedi et al. [27]). The implementation of IoT application reduces the usage of fertilizers and pesticides thereby controlling the usage of water consumption. It also reduces the dependence on human labour foragriculture related activities (Pillai & Shivathanu [28]). Today with a rise in the global population, the demand for energy is also rising. Adequate measures need to be taken in order to reduce Greenhouse Gas emissions and to raise the renewable sources of energy. In order to achieve higher growth rate, both self-sustainability as well as agricultural growth is critical for India (Mahto et al. [29]). The fourth agricultural revolution (Agri 4.0) acts as a remedy to improve the agricultural growth. It ensures that the future needs of the global population are met. Expansion of the

production of agriculture in an environmentally sustainable manner depends on both technology as well as innovation (Aggarwal & Singh [30]).

IoT can efficiently make the farming as well as agriculture industry processes more effectively by decreasing the human labour through automation. During the process of automation, IoT collects data using sensors, processes it using controllers and thereby completes the process of automation using actuators. Artificial Intelligence as well as Internet of Things has been widely used in agriculture for a long period along with the other technologies.

5. Factors Affecting Adoption of IoT Based Smart Agricultural Practices in Kerala Agriculture Sector

Table 1. Factors affecting adoption of IoT based smart agricultural practices in Kerala agriculture sector

S. No.	Criteria	Operational Definition	Items
1.	Data Management	Guidance providedby IoT for collection, processing, storing,and effective management of data	Data privacy
			Data security
			Big data management
			Data governance
			Data analytics
			Real time monitoring
			Alerting
2.	Operational factors	Tools and techniquesused for improving the internal operations	Interoperability
			Complexity
			Network range
			Connectivity
			Scalability
			Internet availability
			Reliability
			Redundancy
			Response time
			Maintenance
3.	Social factors	Relationship with society and understanding of the society	User acceptance
			Technical skillknowledge
			Trust
			Environmentalsustainability
			Ease of use
			Risk assessment
4.	Economic factors	Monetary benefits and effective use ofresources	Huge capitalinvestment
			Energy efficiency
			Cost-benefitanalysis
			Return on investment
5.	Government support system	Better decision making panel toprovide general support	Legislation
			Regulatory framework
			Standardisation
			Heterogenity
			Infrastructure
			Decentralization

SOURCE: By Author

5.1. Research Design

This study is exploratory and descriptive in nature. The major criteria which shall affect the adoption of IoT based smart agricultural factors in Kerala agricultural scenario were sourced from literature review. Five major criteria were identified viz., Data management, Operational factors, Social factors, Economic factor and Government support system. Under this five criteria a total of 33 items were categorized. A Delphi technique was followed for data collection. A total of 10 experts were identified to perform the data collection. To learn more about the importance of these criteria that contribute to the adoption of IoT in agriculture sector's success, direct interview, telephonic interviews as well as Google meet sessions are undertaken with experts in this field. Ten experts were identified from various sectors like agricultural Institutes, Agri-tech experts, Agri-Start-up entrepreneurs etc. Common understanding among experts is attained for the variables by doing a Likert scale type survey among the experts. Further, using statistics the consistent primary elements was identified. A paired-wise comparison survey is conducted between the targeted sample in order to rank the critical factors. After reviewing these interviews, a multi-criteria analysis method, analytical hierarchy process (AHP) is used to weigh the criteria and give ranking for different criteria and items which can significantly affect the adoption of IoT based smart agricultural practices in Kerala agricultural sector.

6. Results and Discussions

To identify the criteria, AHP was performed. AHP, the rankings of priorities were found out by determining the product of priorities of each factor and the weights of corresponding categories. This study has found out the weight of all categories and critical factors under each category. Table 2 shows the relative rank (RR) which prioritizes the criteria for adoption of IoT based smart farming technique. It also gives the relative ranking of items, under each criteria, thus providing significant importance of items which can significantly affect the adoption of IoT based smart farming. The global ranking (GR) gives the overall ranking of all the items taken together.

Table 2. Priority ranking for criteria and items affecting adoption of IoT based smart agricultural practices in Kerala Agricultural sector

Criteria (1)	RPW (2)	RR (3)	SF (4)	LW (5)	RER (6)	GW (7)=(2)*(5)	GR (8)
Operational factors	0.38	1	Internet availability	0.16	1	0.0610	4
			Redundancy	0.15	2	0.0564	5
			Reliability	0.15	3	0.0554	6
			Maintenance	0.14	4	0.0518	7
			Response time	0.12	5	0.0455	9
			Scalability	0.08	6	0.0290	12

			Connectivity	0.07	7	0.0276	13
			Network range	0.06	8	0.0236	16
			Interoperability	0.04	9	0.0163	22
			Complexity	0.02	10	0.0091	28
Data Management	0.35	2	Data security	0.34	1	0.1179	1
			Big data management	0.22	2	0.0752	2
			Data Privacy	0.18	3	0.0639	3
			Data governance	0.11	4	0.0388	11
			Data analytics	0.06	5	0.0192	19
			Real time monitoring	0.05	6	0.0162	23
			Alerting	0.04	7	0.0146	24
Social factors	0.12	3	Technical skill knowledge	0.43	1	0.0509	8
			Trust	0.18	2	0.0219	17
			Environmental sustainability	0.18	3	0.0216	18
			Risk assessment	0.09	4	0.0105	25
			User acceptance	0.08	5	0.0091	27
			Ease of use	0.04	6	0.0051	31
Government support system	0.10	4	Legislation	0.40	1	0.0392	10
			Regulatoryframework	0.20	2	0.0190	20
			Standardisation	0.17	3	0.0167	21
			Heterogenity	0.11	4	0.0104	26
			Infrastructure	0.07	5	0.0072	30
			Decentralization	0.05	6	0.0049	32
Economic factors	0.06	5	Huge capital investment	0.42	1	0.0261	14
			Energy efficiency	0.42	2	0.0261	15
			Cost-benefit analysis	0.12	3	0.0073	29
			Return on Investment	0.04	4	0.0024	33

Note*: RPW-Relative Preference Weights, RR-Relative Rank, SF-Specific Factor, LW-Local Weight, RER-Relative Rank, GW-Global Weight, GR-Global Rank.

It is found that among the criteria which can affect the adoption of IoT based smart agricultural practices in Kerala, operational factors is ranked first followed by data management (ranked 2), social factors (ranked 3), government support system (ranked 4) and economic factors (ranked 5). The study found out that priority towards operational factors and data management are the most critical factors that affect the IoT implementation in Kerala agriculture. From the global ranking of items, it is found that data security, big data management and data privacy under the criteria Data management, Internet availability, redundancy, reliability and maintenance under the Operational factors, and technical skill knowledge under the Social factor are vital for adoption of the IoT based smart agricultural practices in Kerala agricultural scenario.

7. Conclusions

The advancement of technology in agricultural sector has been a boon all over the world. India is also in the verge of adoption of smart agricultural practices. There are many success stories across the world which had implied the significance of using these smart technology like IoT, big data analysis, block chain technologies, sensors, Drones, etc., in mitigating the agricultural challenges. As for the developing country, there are many factors which can affect the adoption of smart agricultural practices.

This study focused on the factors that contribute to the adoption of IoT based smart agricultural practices in Kerala agricultural scenario. The most critical items are namely data security, big data management, data privacy, internet availability, redundancy, reliability, maintenance and technical skill knowledge which was ranked and weighed most by experts. Thus a far more advanced technological infrastructure, good data management system, and availability of skilled personals to handle these technology based smart agricultural practices is crucial for effective adoption of IoT based smart agricultural practices in Kerala.

Since this is a novel empirical study, more studies must be considered for understanding the adoption of much more technologies like 1) Adoption of artificial intelligence and machine learning (AI & ML) in smart agricultural practices, 2) Focusing on IoT adoption focusing on region specific for Kerala‘s diverse agricultural landscape, 3) A study on socio-economic impact on IoT in Agriculture, Environmental sustainability of IoT based agricultural practices, Policies and government initiatives to promote IoT adoptions in rural Kerala, and 4) Factors affecting adoption and usage of block chain technology, drones in smart farming can be focused as future studies which can significantly contribute to the agricultural sectors.

Declarations

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

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