Climate Change and Indian Agriculture: Challenges and Adaptation Strategies

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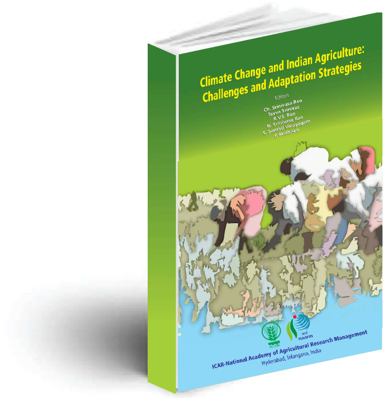

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CONTENTS

22. Recent Advancements in Artificial Intelligence (AI) and Internet of Things (IoT) for Efficient Water Management in Agriculture

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Abstract

Climate change is a big challenge in agriculture globally. Improvement of the water use efficacy can reduce the effect of the global climate change. The injudicious use of water is the biggest challenge of global climate change. Agriculture and allied sectors are embracing new technologies for achieving sustainable developmental goals. Among the new technologies Artificial Intelligence (AI) and the Internet of Things (IoT) have the potential to play a significant role. This chapter discusses the modus operandi of AI and IoT in achieving the proper utilization of the water resources for combating the climate change. The significance of AI and IoT based water management system models has also been discussed here.The worldwide patent status of water management in the fields of IoT and AI has also been presented. Finally, an optimized water management system based on IoT and AI has been proposed which have a greater potential in solving water management.

Keywords: Artificial Intelligence (AI),Internet of Things (IoT), Climate change, Water management

1. Introduction

Agriculture sector is continuously challenged by the drastic changes in climate and thus disrupting the food security. Climate change induced events like heavy rainfalls to droughts have been putting the life of people as well as the agriculture at risk. It has been observed that about 20% of global damage due to natural hazards is caused by droughts [1]. Almost 75% [2]of the total water available across the globe is used for irrigation.

Being the backbone of economy in most of the developing countries, a stable agriculture system plays a vital role in the overall development of the country. In recent times, climate fluctuations highly threatens and challenges the agriculture and is becoming a looming issue that needs immediate attention. In order to handle the huge risk due to the drastic change in climate, agriculture sector requires to adopt new strategies. This includes practices related to soil conservation, smart irrigation and efficient water management practices etc. Water management using Internet of Things (IoT) and Artificial Intelligence (AI) is a popular method for reducing the water wastage as well as increase the water use efficiency. IoT and AI are generally being employed to tackle complex business and industry problems. Till now, the strength of both the technologies to solve agriculture related problems have been less explored.

2. Climate Change and Water Crisis – Impact on Agriculture and Allied Sectors

The world is drastically moving towards urbanization and it is estimated that the global population will reach 9 billion by 2050. Thisrequires increase in food production that has to be achieved by overcoming the challenges like drastic changes in climate. The vast usage of water resources and their degradation is a potential risk to agriculture and allied sectors. Climate change over the past 30 years have already impacted significantly and caused reduction in the global agricultural production at the rate of 1 to 5% per decade [3]. For the future, the climate predictions shows that the agriculture sector might be challenged through multiple ways including heat stress caused by rise in temperature, extreme climatic events such as floods and droughts, major shifts in rainfall patterns. At the same time, the existing water resources are not utilized properly in an efficient way. As per studies by World

Bank, it is estimated that 25 to 35% of fresh water is not properly utilized which in turn costs our global economy an amount of $14 billion every year [4].

3. Recent Advancements in AI and IoT for enhancing efficacy of water management

Agriculture sector is currently undergoing a transformation; various practices and strategies are being implemented all over the world. There is no doubt that the current agriculture and allied sector is data-driven and data-centric. This makes the agriculture smarter than ever before. The revolutionary IoT and AI technologies are redefining all the industries including agriculture sector as well. IoT is essentially considered as an extension of the internet and other networks that connects various sensors and devices (often termed as 'things') to the internet. This enables the things to share data from their respective environments and the system provides high analytical capabilities and works as smart devices. These smarter devices generate massive volumes of data. Mining and deriving meaningful information from these data is very crucial for taking actionable results. This is where AI fits into the puzzle. Artificial intelligence enables the computer system to learn and think as the humans do. The AI algorithms learn themselves from the data and can perform high quality predictions and decision making. When the integration between IoT and AI systems come into action, the system becomes intelligent and highly controllable resulting in greater degree of automation.

3.1. Internet of Things (IoT)

Protection of the existing water supply networksare as important as conserving the water resources. Underground pipeline infrastructure plays a crucial role for planning an efficient water management strategy in developing countries. The recent advancements in technology helps in achieving this to a great extent. One such system has been developed and implemented inSanya city of Hainan, China [5]. This system uses the advanced technologies such as Internet of things and advanced GIS technology to setup urban sewerage pipe network system. The system comprises of a real-time web-based monitoring and usesIoT technology to collect the data from the installed sensors. Further the massive data is analysed for deriving conclusions such as leakage and water wastage prevention. Another significant study has been made by Edmondson *et al.,* [6] for analysing the real-time sewer data and building a Smart Sewer Asset Information Model (SSAIM) prototype. This model integrates sensor data collection and the predictive data analysis inorder to foresee a flood condition in sewage network with the help of IoT technology.

IoT based smart cities are being widely adopted to meet the urbanization challenges. While developing a smart city framework, smart water management plays a crucial role in meeting the sustainable water management. Sensor driven IoT network followed by big data analytics can give intelligent and real time solutions [7],[8],[9].

Significant work has been done on precision irrigation in agriculture with IoT-based smart water management platform in Brazil and Europe [10] to deal with increasing crop yield, lowering input cost and achieving environment sustainability. Their study leads towards the development of precision agriculture having smart management of fresh water. Another variant of smart water management system has also been developed that is suitable for long-distance communication with the help of low-energy sensor nodes [11].N. Cherukutota *et al.,* [12] developed a smart IoT based on water metering for efficient water use based on ultrasonic flow measurement technology.As the technologies are being adopted widely, security has become a major concern. To address the security issues related to the smart water management a new Authorization and Access Control Servers (AAC) architecture for dealing with them has been introduced [13]. One more approach that has been introduced for efficient water management is with the help of OPC UA (an industry standard information model implements in microcontroller)architecture which are interoperable, manageable in context of water management process [14]. As smart cities got introduced, smart water monitoring architecture backed by machine learning also got more significance in countries like India [15],[16]. Adaption of cloud and IoT along with AI can further refine the system. Especially when installed in a tank, the water level can be analysed and visualized on real-time basis using the application installed on the mobile phone [17].

Numerous workhave been done for water monitoring in real time and feedback interface in low cost environment [18],[19],[20]. The system has used several sensorsto monitor the water management parameters like temperature, pH and Flow of water. The system also blend the sensor data with the cloud for further analysis. Water management and irrigation system using the IoT with automated control using smart phone has been reported [21],[22].The smart water purification also has great importance for judicious use of the water. The waste water generated from the household can be purified and can be used for further use like agriculture [23].

3.2. Artificial Intelligence (AI)

Water quality parameters play a major role in crop modelling.For better management of water for agriculture, there is a crying need for a good water quality prediction model. Due to the presence of noise in the data, it is difficult to make predictions accurately. An artificial intelligence technique named as 'Neuro-Fuzzy Inference model'has been developed to predict the water quality parameters and 'augmented wavelet', a de-noising technique has been used as the basis for this model. Using this model, the parameters viz., ammonical nitrogen, suspended solid and pH are predicted [24].

There is high reduction of the fresh water availability due to continuous uncontrolled irrigation inthe agricultural fields. In this case, advances in artificial intelligence can be used to model the irrigation water demand. An Artificial Neuro-Genetic Networks (ANGN) has been developedto forecast the daily irrigation water demand [25].This work has been further enhanced by developing new tools which will help in making decision about the use of water and energy.In this approach, Bayesian framework and Genetic Algorithms (GA) have been coupled withthe ANN architecture .In this enhanced work, the short-term daily irrigation water demand prediction can be done when there is limited data availability [26],[27].

The uniform emitter discharge is the key success factor for the desirable functioning of drip irrigation systems. The emitter outflow discharge is heavily dependent on the temperature and pressure. The emitter discharge of the drip irrigation system has been modeled by the AI technique under a wide range of temperatures (13−53 °C) and operating pressure (0–240 kPa) conditions. . The artificial neural network (ANN), neuro-fuzzy sub-clustering (NF-SC), neuro-fuzzy c-Means clustering (NF-FCM) and least square support vector machine (LS-SVM) have been applied to model the discharge system. The following factors were considered as the input parameters such as operating pressure, water temperature, discharge coefficient, pressure exponent and nominal discharge. The model gives the ratio of measured discharge to nominal discharge (modified coefficient) as its output. Among the several modelsdeveloped, the LS-SVM model had the lowest error, followed by the NF-SC model which had a slight difference [27].

A hybrid heuristic methodology has been developed to predict the schedules of irrigation eventsat farm level to improve the irrigation management. The method combines the two famous data mining algorithms viz., Decision Tree and Genetic Algorithm. This heuristic method models the farmers' behaviour and predicting the schedules of the irrigation events. The developed method has been tested and validated in a real time irrigation system [28].

Water stress management has become a challenging area in the current scenario. A cloud-based artificial intelligence technique such as IBM Watson's visual recognition service has been used for optimisation of real time water stress management. In this work, near infrared images has been collected by unmanned aircraft system for the crops with no, low and high water stress conditions which are used to train the Watson generated model. The model was able to identify the stress indicators after 48hours of water deprivation inspite of the small dataset with low resolution images [29].

A novel approach has been done to model the evapotranspiration rate of the crops which ultimately help in agricultural water management. In this experiment, multivariate adaptive regression splines (MARS) and gene expression programming (GEP) have been applied to estimate the daily evapotranspiration rate. The developed model used two types of input data namely, daily weather- based and evapotranspiration based data [30].

High nitrogen concentration is required for Durum wheat production. In order to avoid low protein concentration and to maximize grain yieldnitrogen, fertilization and irrigation must be managed. The research gap is that there seems to be no evidence in literature which tells us about how farmers manage these operations and the association among these operations. For this purpose, the researchers developed a model for decision making, that includes:1. The temporal associations among the special actions of a crop management flow.2. Rules that decide when to perform a particular operation based on the state of environment and crop status. 3. Optional actions implemented based on forecast of the crop model. Under this work, one survey has been conducted by28 farmers in five crops in France studying a variety of growing situations for recognizing the potential limitations and decision rules for the producers[31].

Precision farming gives the methods to operate in-field variability and connect variability into irrigation choices. The major disadvantage of this technique is the settlement of various information origins and the creation of irrigation schedule charts. In this study, the researchers examine the use of the cosmic-ray neutron probe, which is used to estimate the soil water content in the 25-30 cm of the top soil. The benefits of CRNP are that these are passive sensors, mobile, soil temperature-invariant and non-invasive which makes information gathering more fit with the farm works and increasing the mapping time. The goals of this research include the following: (1) enhance the representation of irrigation area within a range and (2) determine spatial soil hydraulic characteristics to produce accurate watering decisions. Ten such studies were done in a 53 hectare area in Nebraska. These surveys were examined to separate the underlying spatial composition using Empirical Orthogonal Functions. The researchers introduced a soil sampling approach for more reliable quantifying soil hydraulic characteristics utilizing CRNP+EOF techniques. While the recommended approach may enhance overall effort, increasing analysis for farm water-use could lead to a cost-effective approach [32].

With the growing awareness of variable-rate irrigation control, it is essential to review the number and position of soil water observing areas in this perspective. Volumetric soil water content (**v**) was observed at 72 places in a centre pivot irrigated farm in Eastern Nebraska, using a neutron probe (NP). The spatial correlation scale was observed to be less than the nearest spacing of monitoring positions in this research work. The observations were documented after performing temporal stability and variance reduction analysis on **v**.This concluded that, number of sensor is more relevant than sensor position in quantifying the areal mean **v** for irrigation control [33].

Today, remote sensing technologies (involving pictures and vegetation records collected using satellites and drones) are being utilized for controlling watering and other farming methods. But, generalized use of these devices needs an in-depth understanding of crop water requirements and associations among them along with the records collected by remote sensing. This work presents various methods to cope with observed water levels in tanks, precisely discovering crop water requirements and new criteria for observing crop water state and property [34].

4. Patent Status

The worldwide patent status of water management according to https://www.uspto.gov/ website in the fields of IoT and AI are described in the following two tables.

Table 1: The phrases and the no. of patents available in IoT

Sl. No.	Phrases used	No. of patents
A	Water Management and IoT	22
B	Smart Irrigation	54
C	Smart Irrigation and IoT	3
D	Irrigation and IoT	133
E	Smart Water Management	3
F	Irrigation Monitoring	35
G	Water Scarcity and IoT	2
H	Irrigation Control and IoT	26

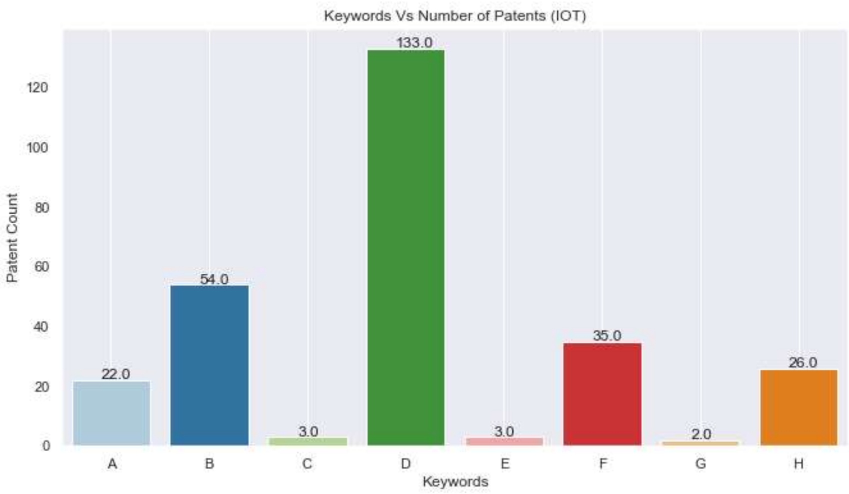

Figure 1: The bar diagram depicting the no. of patents available in the field of IOT for water management where A, B, C, D, E, F, G and H are the phrases used for the patent search in Table 1

Table 2: The phrases and the no. of patents available in Artificial Intelligence

Sl. No.	Phrases used	No. of patents
A	Water Management and Artificial Intelligence	52
B	Irrigation Scheduling and Artificial Intelligence	8
C	Smart Irrigation and Artificial Intelligence	1
D	Irrigation and Artificial Intelligence	375

E	**Climate change and Artificial Intelligence**	**98**
F	**Water Quality testing and Artificial Intelligence**	**3**
G	**Water Stress and Artificial Intelligence**	**18**
H	**Water Scarcity and Artificial Intelligence**	**3**

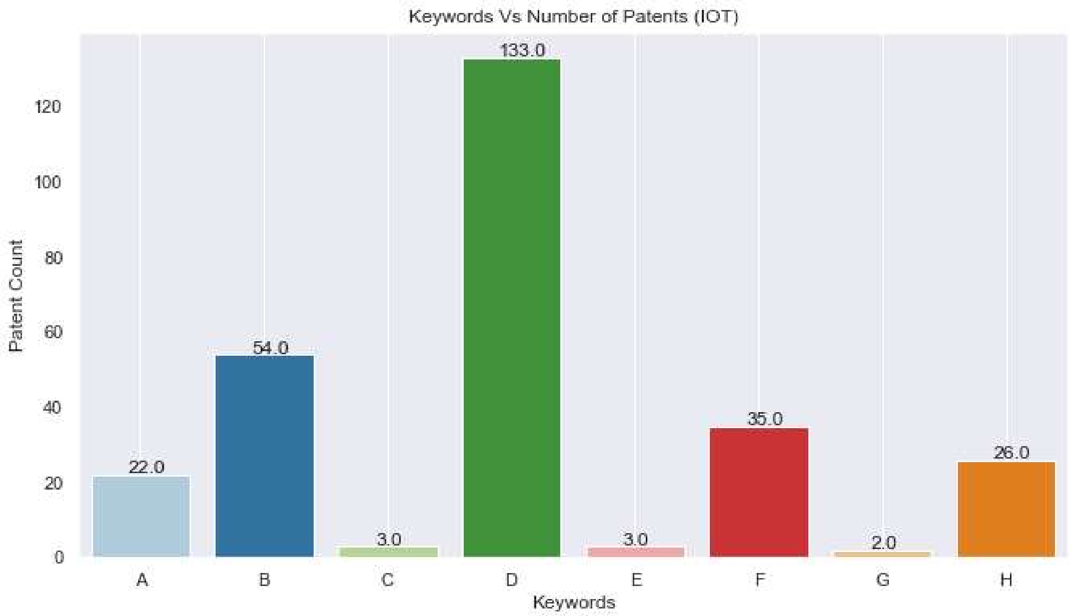

Figure 2: The bar diagram depicting the no. of patents available in the field of Artificial Intelligence for water management where A, B, C, D, E, F, G and H are the phrases used for the patent search in Table 2.

4. Path of AI and IoT for water management

4.1 AI and IoT enabled water system

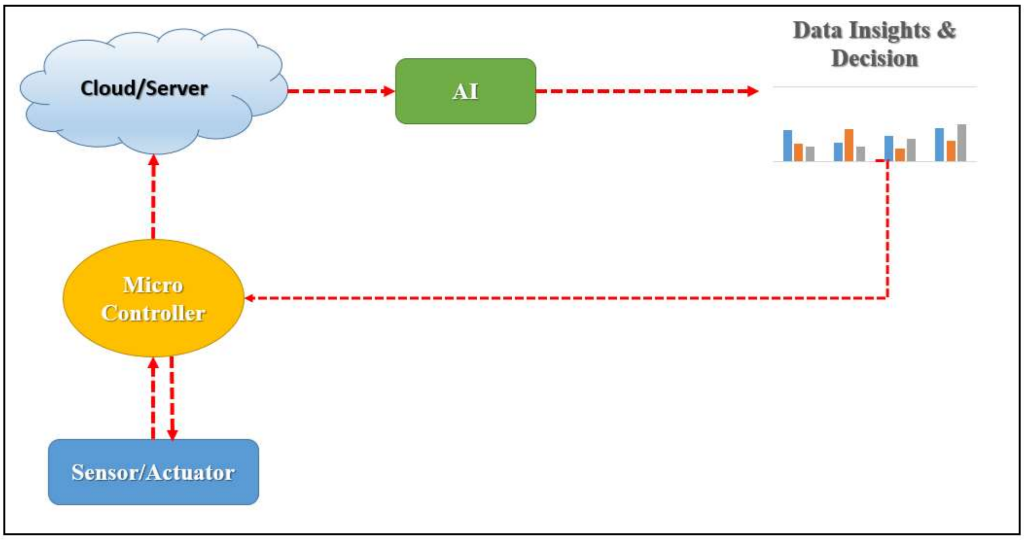

Figure 3: IoT and AI enabled system architecture

A generalized system for water management using IoT and AI is depicted in Figure 3. Various sensors like water-level, flow sensors are installed on the sites and these constitute the source for data generation. The data generated from these sensors are accessed using the processing unit which could be any affordable micro-controllers like Arduino,Raspberry Pi etc.The data from the processing unit is segregated at the server or cloud where the AI algorithm can be executed to get an actionable result. Based on the output of the algorithm the actuator can be controlled and appropriate action can be performed according to the various situations.

4.2 Optimized water management system

Optimization in theIoT and AI enabled system can be performed on variousparameters like performance, cost and scalability. It is essential to communicate the actionable insights on a real-time basis since any delay in communication can make the result irrelevant. For enhancing the performance, technologies like cloud computing can be relied upon. This not only serves the purpose of performance but also it gives an extra edge of security and scalability. Scalability is essential in water management solutions since the system requires to be extended to a larger area. Low cost hardware selection and solar powered systems can optimize the cost of the system.

5. Challenges and Opportunities

With the advancement of AI and IoT systems, the farming practices have improved to a great extent. At the same time, the major challenge is to educate the farmers for adopting and accepting the technology over the traditional methods. Requirement of initial investment also makes the large scale implementation quite difficult.Embracing the new technology like IoT and AI can assure the betterment of overall agricultural scenario. Theimprovement in the telecommunication networks has made significant impact on the society in terms of internet usage and this helps to set a right platform for the AI and IoT solutions to be implemented. Slowly AI and IoT solutions are revolutionizing the agriculture and allied sectors.

The overall improvement of the adoption of the IoT and AI has some downside also. The adoption of these modern cloud based technology also increase the cybersecurity risk. High adoption cost as well as the increasein electronicwaste are the other downsides.

6. Conclusion

IoT and AI systems are mainly adopted in industries providing superior solution to the consumers like smart cities, smart homes but they are not often thought of as a solution for the environment problems. The recent studies shows that IoT and AI enabled systems have a greater potential in solving climate change triggered environmental issues including water management. In this digital era, adapting these technologies can greatly improve our agriculture practices and this can enhance the livelihood of the farming community.

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