Internet of things based smart agriculture using K-nearest neighbor for enhancing the crop yield

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ABSTRACT

Agriculture is one of the major occupations in India and is one of the significant contributors to the economy of India. The agriculture plays a vital role in country gross domestic product (GDP) and is also part of civilization. The production of crop influences the economies of countries. However, still the agriculture filed stands technologically backward. In addition, the lack of favourable weather conditions might result loss of crops yields. The farmers need awareness about their soils, timely weather updates and techniques to improve their soil for growing healthy crops. Hence it is essential to develop a system which can technologically support the farmers for suggesting the crop and improving crop yields. With the development of electronics, researchers have been developed many applications and micro controller-based systems to do agricultural operations. The internet of things (IoT) has opened many opportunities to design and implements a smart agriculture system and machine learning (ML) algorithm can help to obtain accurate performance. Hence, in this analysis, IoT based smart agriculture using K-nearest neighbor (KNN) for enhancing the crop yields is presented. With the combination of IoT and ML algorithm this system is designed which integrates primary agriculture operations such as recommendation of crops, automated watering and fertilizers recommendation.

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1. INTRODUCTION

The agriculture industry is one of the primary contributors of the Indian economy is expected to develop even more as a result of technological advancements. Agriculture is a popular academic topic since it plays a significant part in world development and benefits humans in many ways. Farmers are constantly interested in learning new things, especially those that grow unconventional crops. They look to television, radio, newspapers, other farmers, government agricultural organizations, farm suppliers, and merchants for suggestions. For this reason, a system that gives farmers useful information is required [1]. The growing population and the effects of global climate change are closely related to the demand for smart farms. The world's population is expanding, which increases the up demand for food, but there is also an increasing shortage of people, which will only get worse as the population ages and shrinks [2]. In other words, as the population develops, crop cultivation time decreases due to urbanization, and farmers on the production site are aging. Due to this, the need of smart farming is increasing significantly. Though, they have lately expanded, smart farms are mostly focused in the area of smart horticulture, and research is being done in limited spaces [3].

Producing as many crops as possible on a small amount of land is the primary objective of agriculture. If the issue with crop production is found, it will be much simpler for an individual to produce a crop with the best yield. Selecting the appropriate crop for a particular area of land can help to farmers increase crop yield and profit. It is challenging to forecast agricultural yield because of a number of complex factors. Generally, the crop productivity is impacted by a number of factors, factors like climate, harvest planning, pest infestations, water accessibility, soil quality, and genotype [4].

Crop productivity is primarily impacted by local weather conditions all over the world. With the exception of a small number of crops developed in greenhouses or other controlled environments, the majority of agricultural production is highly dependent on atmospheric conditions [5]. "Weather" describes the unique state of the atmosphere at a specific place and time. Factors that are measured include wind direction and speed, air temperature, humidity, atmospheric pressure, cloudiness, and precipitation. There will be changes in the weather from season to season, day to day, even hour to hour. In the past, weather predictions were based on observations of weather patterns, particularly the type of wind and cloud pattern as their color. However, current weather forecasting is updated and utilizes technology [6]. In addition to being an essential source of food for the human population, seeds are also used as a starting point for the growth of crops. The quality of the seed has a major impact on crop yield, with environmental factors having slightly impact. Predicting the germination of seeds is an essential and important task. This is also necessary for evaluating the effectiveness of different seeds and enhancing the efficiency of the food chain [7].

Heat waves, erratic precipitation patterns, increasing frequency of droughts and floods, and other effects of climate change have all had a negative impact on the agricultural sector globally. Furthermore, agricultural areas are under increased pressure to produce enough food due to the high pace of population growth and the current climate-related impacts on agricultural fields. The limited agricultural land needs to be used wisely in order to produce crops that are healthy and sustainable in order to meet the growing demand for food [8]. However, traditional intensive farming methods result in relatively lower yields and degrade the soil. In addition, farmers lack awareness of real-time market fluctuations and climatic change, which results in an insufficient availability of necessary crops. Given that resources are not being used efficiently, production costs are increasing per yield. For example, a lot of fertilizers and pesticides are utilized without being only required [9]. Smart irrigation systems that depend on the dynamic prediction of the field's soil moisture pattern and the precipitation prediction for the upcoming days are essential for the efficient and optimal use of fresh water during irrigation. India and other developing countries predict an increase in this industry in the upcoming years as a result of increased process efficiency. A large number of people in cities can farm using internet of things (IoT) based technologies. Making decisions about the tasks to be carried out on a farm might be improved by crop monitoring. More Smart agricultural systems are required to improve crop cultivation per hectare [10].

The majority of traditional farming techniques are manual and not very effective; there is potential for improvement. Using IoT technology, smart farming is a modern farming management concept that aims to increase agricultural output [11]. Farmers can utilize fertilizers other resources more wisely produce more crops of higher quality and quantity. It is not possible for farmers to be on the field all day. Furthermore, it's possible that the farmers lack the expertise to measure the appropriate environmental conditions for their crops using various tools. IoT gives them access to automated systems that may operate without human supervision and can alert them to appropriate decisions for handling various issues that may increase while farming. It can reach and alert farmers even when they are not in the field, enabling them to watch over a larger area of land and increasing productivity [12].

IoT is a new technology that appears to be an advantage for the 21st century. It connects all objects in a system together. The writers have described the connections between IoT and other technologies, such as big data, cloud computing, and machine learning (ML) [13]. Each of these technologies has a major impact on the the designing of IoT. Data and other helpful information produced by sensors, such as temperature, humidity, potential of hydrogen (pH), are stored in the cloud. IoT applications of big data and ML are to increase the efficiency of data storage. As the amount of data used and the number of connected devices increase, big data and ML are two more technologies that are being utilized when combined with IoT to address this issue [14]. They complement IoT by offering enhanced network performance, more effective data storage, wide-ranging data processing, and better system security. An automated system would be impossible to imagine without the IoT. IoT has enough applications in nearly every industry [15].

The agricultural industry is among the many sectors that are beginning to use IoT technology as it becomes more widely used. One application that uses IoT technology is smart irrigation, which irrigates the farm automatically based on its demands and attempts to use freshwater resources efficiently. Numerous studies have demonstrated that effective smart irrigation is at conserving water and it improves productivity in agriculture when compared to traditional irrigation [16]. There are several difficulties to overcome, including the temperature rise, changes in precipitation patterns, extreme weather, weather variability, and the complexity of elements affecting crop development. Therefore, accurate historical crop yield data is essential for managing agricultural risk. ML has been an extensively used technology to address these issues. Agriculture has allowed the investigation and development of numerous ML techniques [17].

The aim of agricultural planning is to create a maximum output using fewer resources, such as money, land, or fertilizers. This can be done with the use of several ML [18] and artificial intelligence (AI) approaches [19]. A ML algorithm will be used to create a system that can choose crops, irrigate them autonomously, and suggest fertilizers. A smart irrigation system based on open-source technology is presented. It uses Internet weather forecast data in combination with ground level sensing such as temperature and moisture levels, as well as environmental data to estimate field requirements for irrigation. The intelligence of the recommended system from an intelligent algorithm that considers elements from the near-term weather prediction, like ultra violet (UV), humidity, precipitation, and air temperature, in addition to sensing data. The prediction results are highly encouraging, and the system is fully operational [20].

State-of-the-art technologies are utilized to supply water to the agricultural field based on the soil moisture value, which is detected using an IoT sensor, to the intelligent farming system with weather forecast support and crop prediction was presented. The microcontroller receives the data that the sensors have collected. With the support of the ON/OFF buttons included in the application, the system is turned on through the mobile application. Additionally, when the system is set to automatic mode, when the soil moisture content decreases a certain threshold, the field is irrigated. Depending on the moisture content, the pump is turned ON. Additionally, the system uses an Android application to provide weather predictions and information about the agricultural productivity in a certain area from the previous year’s [21].

An intelligent model called AgroConsultant is presented for assisting the Indian farmer to make an appropriate decision regarding crop growth based on sowing season, characteristics of soil, geographical location and other factor includes rain fall as well as temperature. In addition, rainfall predictor system is also implemented which can predict the rainfall throughout the year [22]. An automatic and remote monitoring system is described as alternative to conventional systems. Phonological data is extracted from the satellite images combined with crop calendar and supports AEZ (agro-ecological zoning) for accurate classification and monitoring of crop. These extracted satellite images are compared with the calendar data of crop are compiled for area of interest. This method obtained 91% accuracy [23].

A crop yield prediction model is presented. This model uses pesticide records, crop yield information, meteorological data and ML models. Rigorous techniques are used for gathering, cleaning and enhancing the data. The trained data is evaluated on different ML techniques. GridSearchCV method is employed for hyper-parameter tweaking for the identification of suitable hyper parameter throughout the K-fold cross validation aims to enhance the performance [24].

A non-orthogonal multiple access (NOMA) relay-supported uplink transmission system was designed for agricultural wireless sensor networks (WSNs). More sensor nodes can be accommodated with the same number of resource elements (RE’s) using the NOMA approach for a typical periodic and bursty short-range uplink transmission. For WSNs in agriculture, a mixed transmission scheme featuring both uplink and downlink transmission has been proposed. Relay-aided NOMA scheme is used for uplink transmission from the sensor nodes to the sink node, while traditional orthogonal multiple access (OMA) is applied for downlink transmission. The NOMA technique can be a competitive choice for both uplink and downlink transmission for WSNs in agriculture, as demonstrated by numerical simulation results that indicate WSNs with relay-aided NOMA achieve a lower outage probability and higher sum data rate [25].

Considering WSNs with solar energy harvester nodes, a new distributed connected dominating set (CDS) technique is suggested for applications involving precision agriculture. Traditional flooding techniques and an energy-efficient CDS algorithm are compared with the unique distributed connected dominating set construction with solar energy harvesting in smart agriculture applications algorithm. According to the results, as compared to traditional flooding techniques and CDS-based methods, the suggested methodology increased the lifetime of WSNs by up to six times and 1.4 times, respectively. Moreover, only 15% of the entire lifetime is devoted to the CDS developing process [26].

This study presented a high-resolution spatiotemporal image fusion approach (HISTIF) that consists of multiplicative modulation of temporal change (MMTC) and filtering for cross-scale spatial matching

(FCSM). Both the point spread function effect and the geo-registration errors between fine and coarse resolution images were taken into consideration in FCSM. HISTIF effectively decreased the fusion error from cross-scale spatial mismatch and successfully transformed spatial details within fields, regardless of whether the data were simulated or real, according to the analysis. According to the results, HISTIF might be useful for regularly and thoroughly monitoring crop growth at the subfield level [27].

In order to predict crop yield, the suggested study builds a deep recurrent Q-network model, which is a recurrent neural network deep learning algorithm over the Q-learning reinforcement learning algorithm. The data parameters enter the layers of the recurrent neural network, which are stacked consecutively. Based on the input parameters, the Q-learning network creates an environment for predicting crop yield. The Q-values are mapped from the output values of the recurrent neural network to a linear layer. By maintaining the original data distribution, the proposed model accurately predicts the crop production with 93.7% accuracy, more than previous models [28]. To solve the above-mentioned issues, this paper presents IoT-based smart agriculture using KNN to increase crop yield. The organization of the work is described as follows: The section 2 presents IoT Based smart agriculture using KNN for enhancing the crop yield. The section 3 evaluates the result analysis. Finally, the conclusion is provided in section 4.

2. IOT BASED SMART AGRICULTURE USING KNN

In this section, IoT based smart agriculture using KNN for enhancing the crop yield is presented. Figure 1 displays the presented system's block diagram. Crop development and productivity can be impacted by weather, and an IoT-based agricultural weather monitoring system can offer valuable information about these weather patterns. This technology helps farmers make informed decisions regarding planting, irrigation, other agricultural tasks by collecting the data from multiple sensors and equipment.

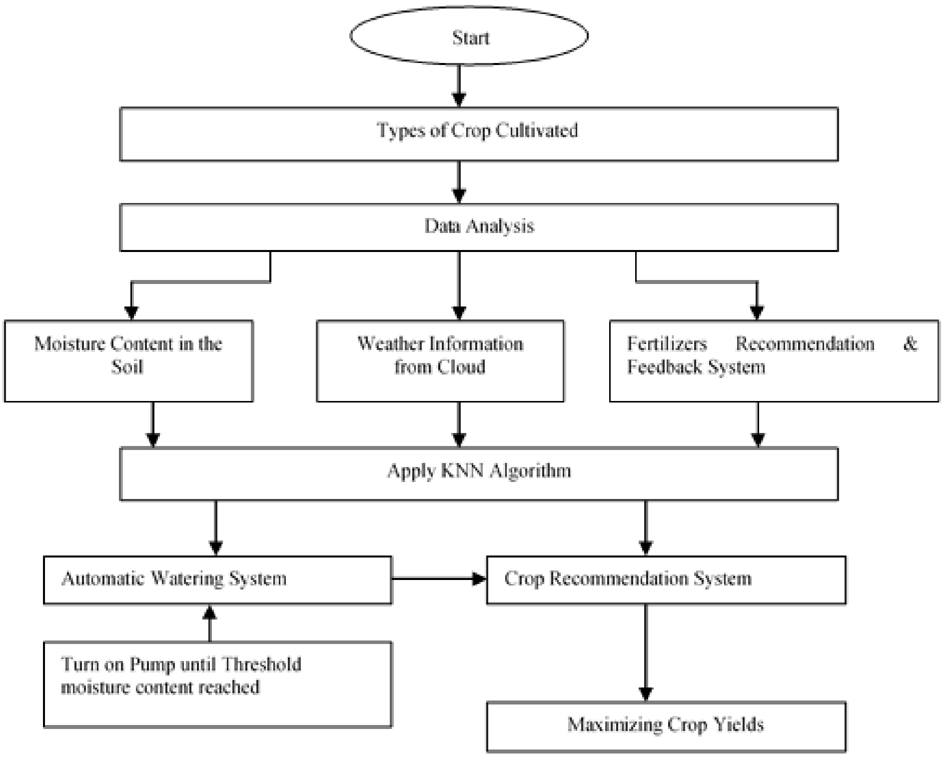


Figure 1. Block diagram of IoT based smart agriculture system using KNN

Here, in this analysis, various sensors are used namely nitrogen, phosphorus, and potassium (NPK) sensor, pH sensor, temperature and humidity sensor, rainfall sensor, air quality sensor and barometric sensors and all these sensors' data is collected on timely basis for effective crop management. Firstly, the soil temperature, rainfall and humidity are checked and then soil pH and NPK values are checked. An NPK sensor is used to collect the NPK values and pH sensor is used to collect the pH data. The percentage of each nutrient by weight is shown in the product's N-P-K values.

Soil reaction or soil pH indicates the soil alkalinity or acidity of soil and its units are pH units. The soil pH can be defined as the negative algorithm of hydrogen ion concentration. The range of pH is 0 to 1 where 7 is neutral point. Data from all these sensors are collected and used for crop monitoring.

The microcontroller is used to upload the collected data to the cloud database, where the server instructs the data to be saved in a database. Then weather API is opened using cloud platform to gather the rainfall, temperature and humidity values. The gathered values are inserted into a ML algorithm to recommend the best crops. Weather forecasting: the weather forecasting helps the user to protect the crop during sudden climate changes. Temperature and humidity sensor, rainfall sensor, air quality sensor and barometric sensors are used to forecast the weather. Soil moisture sensor: this sensor can determine the amount of water is retained in the soil horizon by measuring the moisture content of the soil. The soil moisture content is being measured by the soil moisture sensors, and the measured amount is compared with the predefined threshold. The agricultural database decides the threshold value based on type of crop and soil moisture content.

Moisture sensors are used to measure the moisture content of the soil, and cloud platform open weather API's are used to check the weather. Flow sensors are used to calculate the amount of water is being put into the soil. This system checks the temperature values every P hours. When there is less soil moisture and no chance of rain, the mechanism checks the temperature. In the case that the temperature is normal, the system activates the pump to water the plants for X minutes, or until the crop's moisture threshold is satisfied. In case of high temperatures, the mechanism initiates the pump to irrigate the plants for X+Y minutes, or until the crop reaches its maximum moisture requirement. Furthermore, the mechanism will wait until it starts if rain is predicted. The size of the field, the flow sensor readings, and the amount of water required by the plants are used to calculate to water. This capability is implemented using microcontrollers. This method ensures that the plants grow healthily and receive the proper amount of moisture.

The fertility of the soil affects crop development. Soil fertility is mostly determined by the N, P, and K content of the soil. These readings can be examined with an NPK sensor. Every crop would have a set of consistent NPK values. The land where crops are grown is analyzed using all of the values taken into consideration. The crop being grown and the information that has been obtained both examined. Finally, the algorithm would decide if fertility is at its highest level. Normal fertilizers are would maintain the soil's fertility is recommended if conditions are excellent. If not, it is recommended to apply extra fertilizers on top of the regular fertilizers as needed by the crop. Recommendations for fertilizer dosage are also provided by the system. This would be a support of maintaining the fertility of the soil around the crop until it was harvested. The fertilizer ratio can be computed by taking the lowest number in the grade and dividing each of the three numbers on the container representing the fertilizer grade, represents the fertilizer product's percentage of phosphate, potash, and nitrogen. The collected NPK values are applied to KNN for fertilizer recommendation.

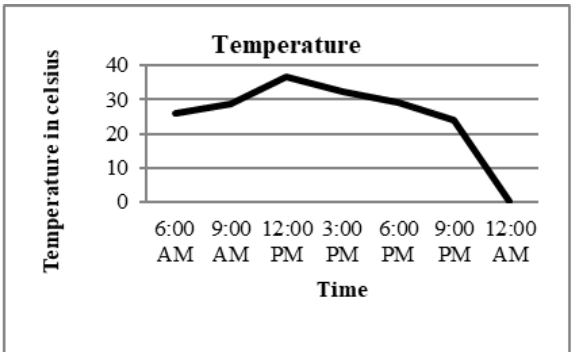
Before recommending a crop, ML is used by the crop recommendation system to evaluate several factors, such as weather, pH, phosphorous (P), potassium (K), and nitrogen (N). The KNN classifier recommends a crop that will grow in the given soil by analyzing various soil parameters and meteorological conditions. The automatic watering system allows the KNN classifier to analyze the soil's moisture content and weather. Considering the current soil moisture content and the future weather, the automatic irrigation system irrigates the crops automatically. The KNN then decides whether the plant needs to be watered or not based on its moisture requirements. In order to support healthy growth, the third system, referred to as the fertilizer recommendation system, provides the recommendations for the amount and timing of fertilizer applications to the crop. These three subsystems work together to enhance crop development when combined into one main system.

3. RESULTS AND DISCUSSION

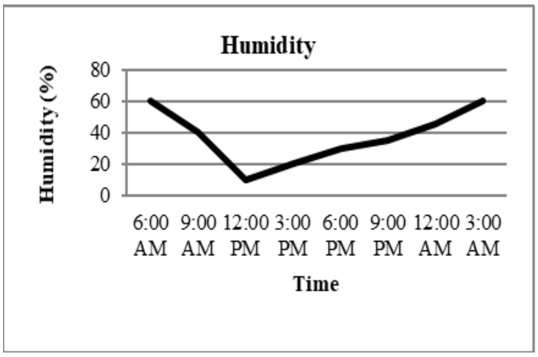
In this section, IoT based smart agriculture using KNN for enhancing the crop yield is implemented. The result analysis of presented approach is demonstrated here. The Figure 2 shows the farm parameters monitoring. The Figures 2(a) and 2(b) displays the crop monitoring in terms of temperature and humidity respectively. In Figure 2(a), the y-axis indicates temperature in degrees Celsius, while the x-axis shows the time. The Figure 2(b) shows humidity performance where x-axis shows the time and y-axis indicates the humidity. To calculate the soil's moisture content, temperature and humidity measurements are taken on a regular basis. Table 1 displays the comparison of performance. Compared to decision tree (DT) classifier, presented approach IoT with KNN has better accuracy for crop recommendation and fertilizer recommendation. In addition, this system has achieved better performance for improving crop yields.

The Figure 3 shows precision comparison. In Figure 3, the crop recommendation models are shown on the x-axis while y-axis indicates precision performance. The KNN model has obtained better precision than DT model. The Figure 4 shows the performance metrics comparison. The Figure 4(a) shows accuracy comparative graph and Figure 4(b) shows F1-score comparison graph.

From the Figures 4(a) and 4(b), it is observed that the KNN has better accuracy and F1-score for fertilizer and crop recommendations. The Figure 5 shows the crop yields performance. Compared to DT, presented IoT with KNN has provides better crop yields. Hence this system has effectively performed various applications like farm monitoring, crops recommendation, fertilizer recommendation, automated water irrigation and improved crop yields.



(a)



(b)

Figure 2. Farm monitoring (a) temperature and (b) humidity

Table 1. Performance comparison

Metrics/model	Decision tree (DT)	IoT with KNN
Accuracy (%)	92	96
Precision (%)	89	95
F1-score	90	95.2

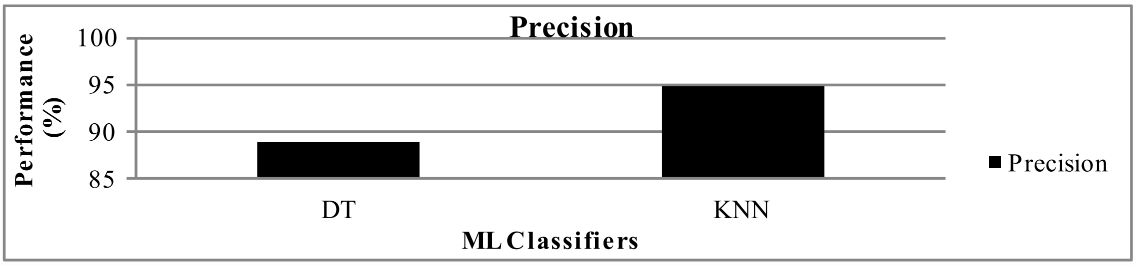
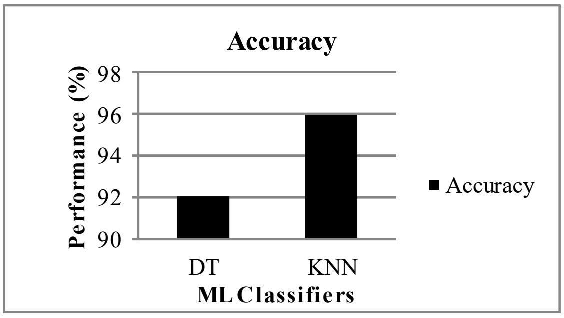
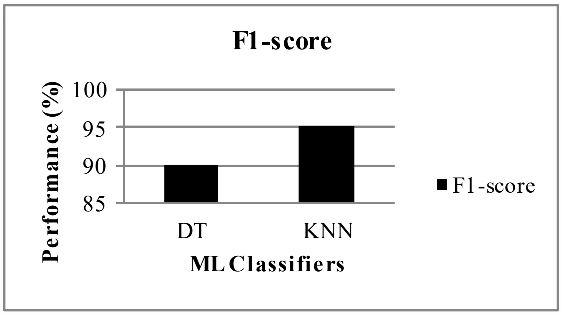


Figure 3. Precision comparative graph



(a)



(b)

Figure 4. Performance metrics comparative graphs (a) accuracy and (b) F1-score

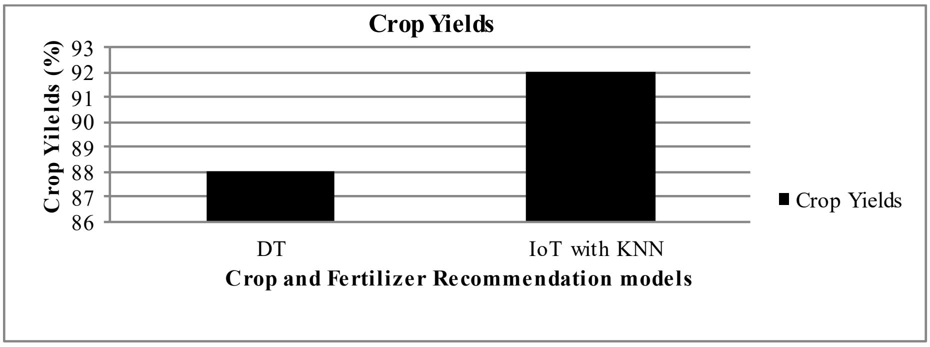


Figure 5. Crop yields performance comparison

4. CONCLUSION

In this work, IoT based smart agriculture using KNN for enhancing the crop yield is presented. The sensors that made up this system are able to measure soil pH, temperature, humidity, NPK value, wind direction, and speed. The sensors are connected to a microcontroller that processes the data and transmits it over a cellular network or Wi-Fi to a web server. The data is stored and analyzed by the cloud server, which also generates reports, diagrams, and notices. Through an interface, the server provides past information, forecasts, and current updates. The described system is created with IoT and machine learning algorithm i.e., KNN, and is capable of crop selection, autonomous irrigation, and fertilizer recommendation. The performance of this system is measured in terms of accuracy, precision, and F1-score. The KNN has achieved better accuracy for crop recommendation as well as fertilizers recommendation. In addition, this model has resulted better and improved crop yields compared to previous models because best crop is chosen based on soil condition, water is supplied adequately and appropriate fertilizers are recommended based on soil NPK parameters. This model has produced better yields and accuracy when compared to previous models. As a future work, crop disease detection and classification using hybrid machine learning will prevent the diseases and improve the crop yield.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Kalyankumar Dasari		✓	✓		✓	✓		✓	✓	✓			✓	
Mukund Ramdas Kharde	✓	✓		✓		✓	✓	✓		✓	✓	✓		
Kuruva Maddileti			✓		✓		✓		✓		✓		✓	
Venkat Rao Pasupuleti		✓		✓		✓		✓		✓		✓		
Mylavarapu Kalyan Ram	✓		✓	✓		✓	✓		✓		✓	✓		
Challapalli Sujana	✓		✓			✓	✓	✓		✓			✓	
Govindu Komali		✓		✓	✓				✓		✓		✓	
Shaik Baba Fariddin	✓	✓		✓		✓		✓		✓		✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

- The data that support the findings of this study are openly available in [Vidhya K *et al.*,] at http://10.3390/engproc2023059020.org/[10.3390/engproc2023059020], [9].
- The data that support the findings of this study are openly available in [Kamila Koteish *et al.*,] at http://10.1016/j.jksuci.2022.06.017.org/[10.1016/j.jksuci.2022.06.017], [7].
- The data that support the findings of this study are openly available in [Manjunathan Alagarsamy *et al.*,] at http://10.11591/ijres.v12.i1.pp70-77.org/[10.11591/ijres.v12.i1.pp70-77], [12].
- The data that support the findings of this study will be available in [IEEE] [DOI:10.1109/ACCESS.2024.3486653] following a [6 month] embargo from the date of publication to allow for the commercialization of research findings.
- The data that support the findings of this study will be available in [IEEE] [DOI: 10.1109/ACCESS.2024.3376735] following a [6 month] embargo from the date of publication to allow for the commercialization of research findings.

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