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RESEARCH

Sensor-Cloud based Precision Agriculture Approach for Intelligent Water Management

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Abstract
Water deficits reduce plant growth. Moisture stress affects the development of plant organs, which in turn can have very profound effects on plant growth. Initiation and differentiation of vegetative and reproductive organs, as well as cell division and cell enlargement, are very sensitive to water stress. The size of the vegetative organs in part determines the yield of grain crops, and therefore the yield is often determined before heading or flowering. Factors that determine the size of plant vegetative organs are many, and they are interrelated in a complex manner. Environmental factors rank high among those that determine vegetative growth, and among these environmental factors, nitrogen, soil temperature, and soil water play key roles. In this paper, we present a sensor-cloud based precision agriculture for intelligent water management for effective productivity in agriculture.

Keywords Smart water management · Naive Bayes · Sensor cloud · Precision agriculture

Introduction

Food manufacturing is a significant task, with the workforce, which will further exacerbate weather shift, decreased energy supply in many areas, and the economic impact of extensive crop and livestock manufacturing. Studies show that if each region in the globe is able (based upon local climate and financial circumstances) to maximize their agrarian property leadership methods effectiveness, appropriate nutrition resources should be available to help the population. In the latest centuries, ICT and industrial, technological developments have converged into smart agriculture, including precise agriculture, covering the site-specific plant leadership in response to inland plant fluctuations and interface changes. This approach will affect all agriculture regions, including plant and livestock leadership efficiency; enhanced output at less price; conservation of resource assets, such as water and energy; a reduction in fertilizer and pesticide quantities and economic effects while enhancing efficiency through timing, place and implementation optimization ("minimum economic footprint"). In this paper, we propose a new cloud-based application which aims in water conservation and productivity in agriculture.

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Related Works

In many fields, there are unique problems with irrigated crops with a small water intake frequency. Water should stay on the ground hours and sometimes even days before the soil moisture reaches its field capacity with surface irrigation. Ponding for extended periods often causes adverse crop growth conditions. Sprinklers are sometimes utilized where surface irrigation is impractical because the application rate and quantity of water applied can usually be more easily controlled (Adamchuk et al. 2004). An application rate that is greater than the intake rate will cause ponding, run-off, and on sloping lands, erosion as shown in Fig. 1. The application rate should be high enough to allow completion of the irrigation in a reasonable length of time, yet it must be low enough so that appreciable run-off does not occur. A slower rate of applying water to the soil may keep run-off from being excessive (Alchanatis and Cohen 2016). A low application rate may even eliminate run-off. Research workers who have studied sprinkler irrigation disagree on the application rate to use. Many feel that water should be left standing on the soil surface at the end of flooding. Others suggest that application rates well below the intake rate of the soil. In this sort of crop manufacturing, solutions are allowing the mapping between executed challenges in space/time to records approximately the problem itself, together with crop's yield or quantity of fertilizer applied (Apostol et al. 2003). The prevailing answers are tailored to mechanized manufacturing techniques, and they're no longer suitable to smaller scale farms or are not able to seize information in each step of the method (Åstrand and Baerveldt 2002). There are also farms with uniqueness crops (fruits, vegetables, and plants) in which there are not any vast machines worried at the sports being made and farmers need to use manual exertions within the production method (Bakhsh et al. 2000).

The problem of how soil water, nitrogen, and soil temperature affect crop size is complicated by the fact that these factors affect the rate of increase or growth of leaves and their overall dimensions differently (Bastiaanssen et al. 2000). This study was planned to determine how soil water suction and soil temperature affect the rate of (1) dry matter accumulation, (2) leaf area increase, (3) transpiration, and (4) nitrogen uptake.

Another hassle associated with specialty crops is the presence of perennial plants inclusive of trees or vines. Inside the agricultural subject communication and electricity as scarce assets, consequently, precision agricultural structures have to be power green or tailored to different resources of power along with solar cells, and need to not rely upon outside structures (Bauer and Cipra 1973). A device monitoring agricultural workforces must not impact the productivity of workers. It has to be seamlessly integrated with employee activities, not interfering in their overall performance or consolation and the farmer desires to have a granularity of statistics so we will detect issues in a person plant (Bausch and Duke 1996; Bhatti et al. 1991; Chen 1996).

Reeta et al. (2018) the IOT sensor and Cloud are used in this document to monitor the biodiversity, heat, and moisture of the soil for a better agricultural output. The mixture of IoT and the internet has encouraged farm growth and rendered it a viable route to fix the farm problem.

The information center is made up of a powerful platform, repository, and further subsystems include agro-eco-environmental power, environmental resources tracking, manufacturing process control, environmental and water security, ecological machinery and facilities, Fig. 2 contains the environmental power systems. The data center is a complicated collection of installations. It covers not only software systems as well as other systems (for example, communications and storage systems), but also unnecessary connections to the transmission of information, environmental inspection equipment, monitoring equipment, and multiple safety systems save fertilizer with precise fertilization. Soil fertility monitoring, moisture monitoring, and stream automatic monitoring and water conservation by water cultivation methods. The detector is interfaced effectively with Raspberry Pi, and cellular interaction between different requirements is accomplished. Every laboratory observational test in Fig. 3 proves that the initiative is a full picture of the issues associated with farm operations and water management. A scheme of this sort can certainly assist us in enhancing crop yield and overall output. Due to the compression of the earth, the efficient pressure increased based on the water material and humidity levels. It helped to incorporate correct fertilizer quantities. It measures the soil's moisture quality and then provides the required amount of moisture for the plant to reduce surplus water supplied to the plant to a minimum.

Channe et al. (2015) the multi-disciplinary model for smart agriculture centered on the most important technology: the Internet of Things (IoT) was proposed. The

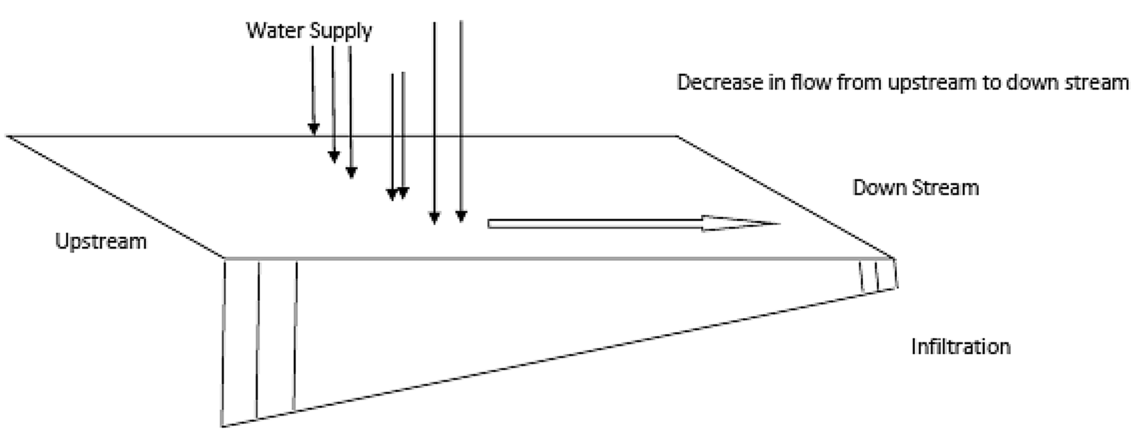

Fig. 1 Water irrigation

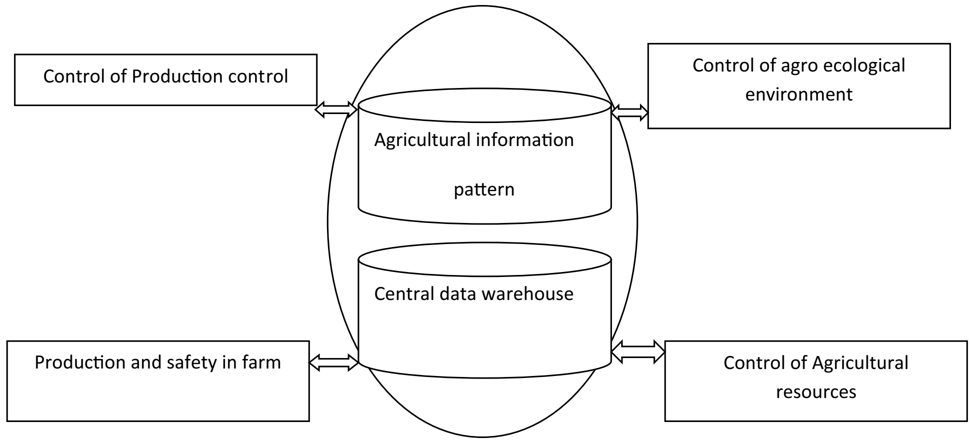

Fig. 2 Agriculture monitoring system

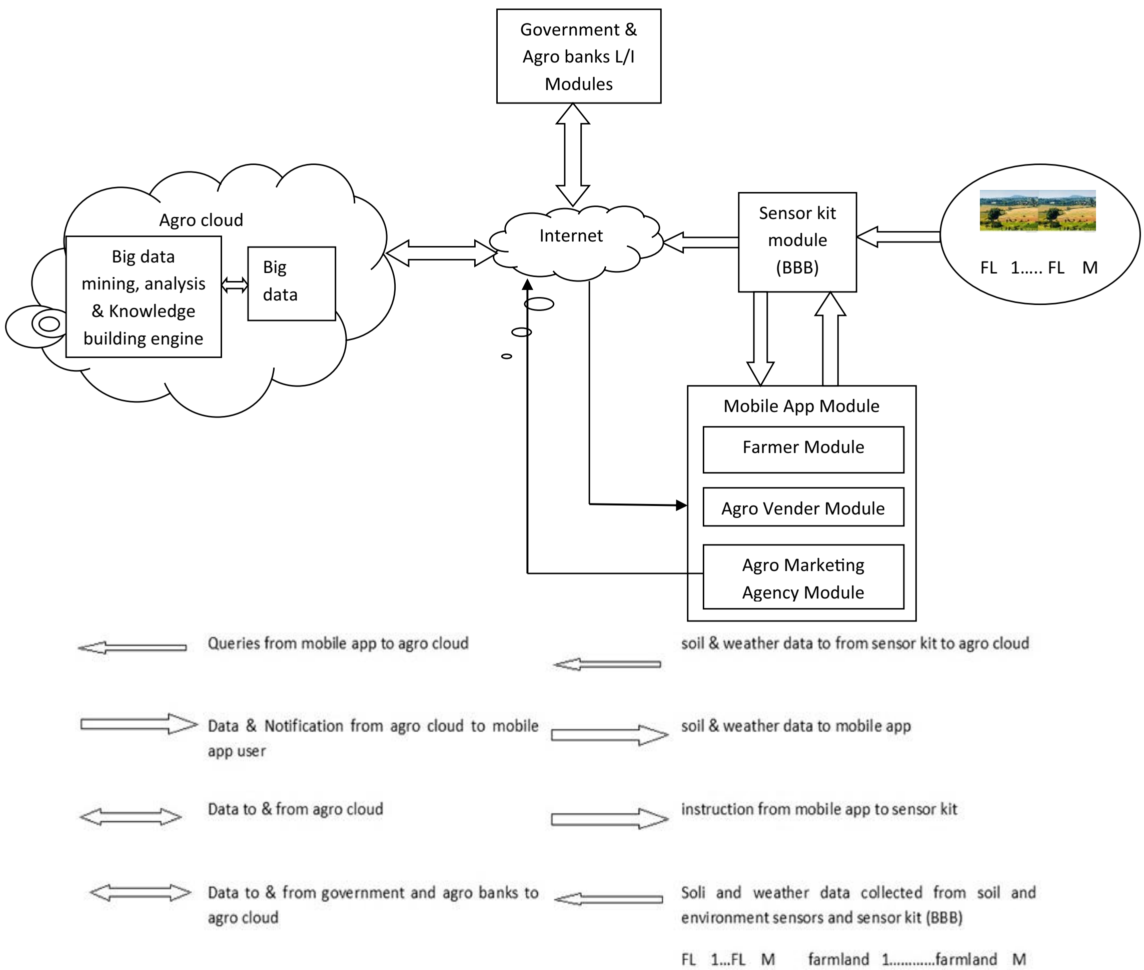

Fig. 3 Proposed architecture for multidisciplinary model for smart agriculture

module AgroCloud was module-based registration for farmers, agri-marketing organizations, and agro-vendors. AgroCloud retention serves to hold producers information, natural land assets, agricultural suppliers and agribusiness organizations, agro-e-governance systems, and modern environment. Environmental characteristics were felt and regularly sent by IoT (Beagle Black Bone) to AgroCloud. The model proposed was advantageous for a rise in farm manufacturing and the price management of agricultural products.

The multidisciplinary model architecture, as shown in Fig. 3, was made up of the five components: (1) SensorKitModule. (2) Module Mobile Apps. (3) The module of AgroCloud. (4) Module for Big Data Mining, Analysis, and Constructors. (5) Government &AgroBank UI Government.

The soil farmers achieved immediate fertilizer demands on their crops using real-time sampling. This approach was a fundamental demand for farmers in India to improve plant output with lower fertilizer price that maintained groundwater safety untouched. This model offered a piece of general information for the most beautiful plant sequences, next plant to be grown for stronger manufacturing, overall plant output in the region of concern, the general specifications of fertilizing material and other information of interest, as plant information was gathered for plant information and soil circumstances over the years. With the link between all farming-related organizations, delivery of cultivated plants facilitated to agro-marketing organizations, and producers prepared to receive the agricultural goods and facilities of agro-vendors. Besides, the system makes it easier to estimate the complete manufacturing demands per plant area in a timely and state-of-the-art manner. This method will help to regulate the costs of farm products. Farmers are also notified of present agricultural systems using notifications.

Rao and Sridhar (2018) a scheme of low-complex drainage for PA cultivation is created. Two captors are used to obtain calibrated data on the plan effectively: size and soil humidity in the loop. The different nodes have been effectively interfaced with two detectors and Raspberry Pi microcontroller of all three nodes. The suggested full approach to farm operations, irrigation issues and the application of such a scheme on site is demonstrated by all findings and laboratory studies and can certainly assist in enhancing the crop area and overall production. This strategy also offers fully operational drainage systems with real-time data on the soil and plants that will help peasants to decide appropriately. In these two detectors, the irrigation system can be controlled so that troubleshooting is readily carried out when needed over a cloud platform. Temperature and soil humidity measurements for the limit voltages are selected for sensor adjustment in recent months. Depending on the harvest and planting, threshold readings could vary. The machine learning algorithm will be introduced into the future to process the information and decrease device nature. The use of vitalization technology to achieve a vibrant delivery and load stability in an agronomic data network is incorporated into the energy base.

Suresh and Koteeswaran (2019) an efficient novel IoT structure is developed and assessed for the water irrigation system was proposed, and Fig. 4 shows the suggested architecture. In this study, the suggested scheme for using the IoT detector for data collection from areas is outlined in the methodology. The field-plant sensors offer different farming characteristics such as humidity, sort of soil, temperature, minerals, etc. This information is gathered in the real moment and transmitted and sent to the tank regularly. The transmitted data is a result of a pipeline that includes several analytical activities. The study encourages the use of IoT devices in the collection and conversion of the outcomes using the cloud-based machine learning algorithm. In the local processing unit in which flow computing is carried out, the actual entry information is initially handled, and duties such as information conversion, design, and inclusion are carried out. The transformation of information enables to transform data into an informative structure for information analysis. The suggested method is focused on a scheme that leads in a more explicit land depiction and offers landowners with an intuitive computer-based system that will help peasants to decide such things as reducing pollution, improving efficiency and the sort of fertilizer to use. This will enhance

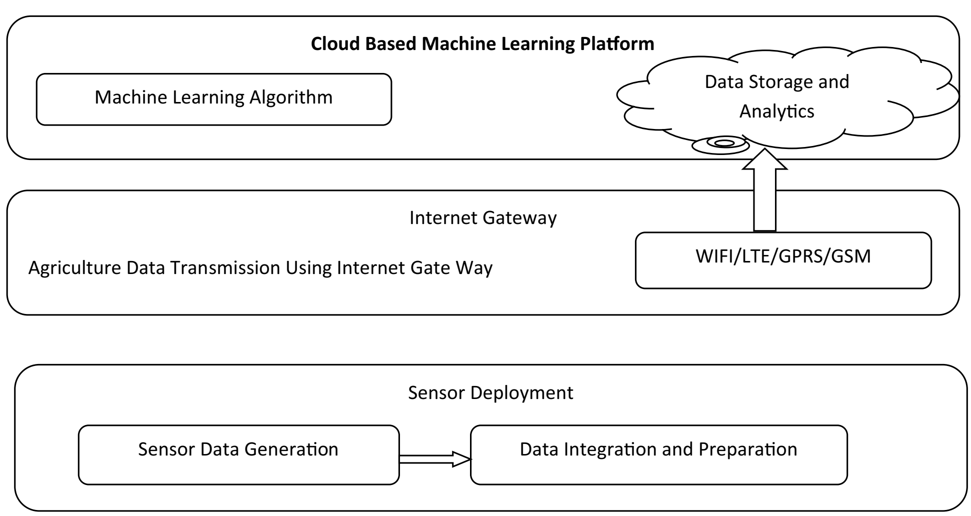

Fig. 4 Proposed framework for smart precision agriculture

cultivation and help farmers in significant figures through predictive decision-making. The choices made under the suggested method can create the IoT actuators appropriate for the plants to develop excellent and productive land.

About the end-to-end interval, efficiency and package distribution, this document generates the suggested scheme excellent outcomes as the packet transfer ratio, throughput, and reliability increased to 98%, 99%, and 96% respectively.

Ferrández-Pastor et al. (2018) in this regard, the author suggested a technique of using edge computation on the significant systems of portal node and fog computing can develop prevalent capacities, for each of the three installations listed above, Sensors 2018, 18, 1731 12 out of 21. The parallelization of subsystems and AI assistance was accomplished with this setup. In integrated systems, control signals for the already deployed devices become outputs to border servers and a cloud server that interfaces all plant devices. Irrigation and inner regulate of the atmosphere are necessary procedures in all greenhouses. Users from agriculture understand how passive checks are programmed and automatic systems configured. Two prospective facilities that agronomists can provide through their experiences are to optimize these assets (soil, power). One of the suggested improvements is also the connectivity of subsystems. An implementation is intended and applied for an integrated assembly. This situation demonstrated how to enforce if automatic facilities are already available. This situation was also a reference to other kinds of crop facilities. In a greenhouse, an experimentation job was done. Communication servers were mounted, and the professional customer built a new system centered on a choice tree paradigm. The installations that created the use of the suggested template interoperable weather command and groundwater subsystems, enabling farmers to develop new embedded power regulations. With the fresh, integrated communication model, the peasant can analyze modifications and improvements. This study initiated a new working methodology for farmers that can more readily use these new techniques.

Karim and Karim (2017) in this initiative the authors are concerned in the establishment and screening in the framework of precision agriculture of a scheme centered on a wireless device channel and the Web of IOT and items and cloud devices. In this document, the author suggested a prototype scheme centered on the detector system and an IoT cloud which alerts the grower to irrigation of plants. A three-third implementation described the overall design Fig. 5 of our monitoring scheme.

In the first part, they have described the steps in the implementation of the support system for decision making aimed at an agricultural community to calculate the quantity of water needed in addition to being able to evaluate the amount of water required. The landowner uses a graphical desk tool to track the differences in groundwater circumstances, an exact moment, to manage the crops and to transmission a method of reporting by SMS via the website when a critical amount is achieved to prevent air pressure. This implementation can be enhanced so that it is highly advanced that the evapotranspiration method is

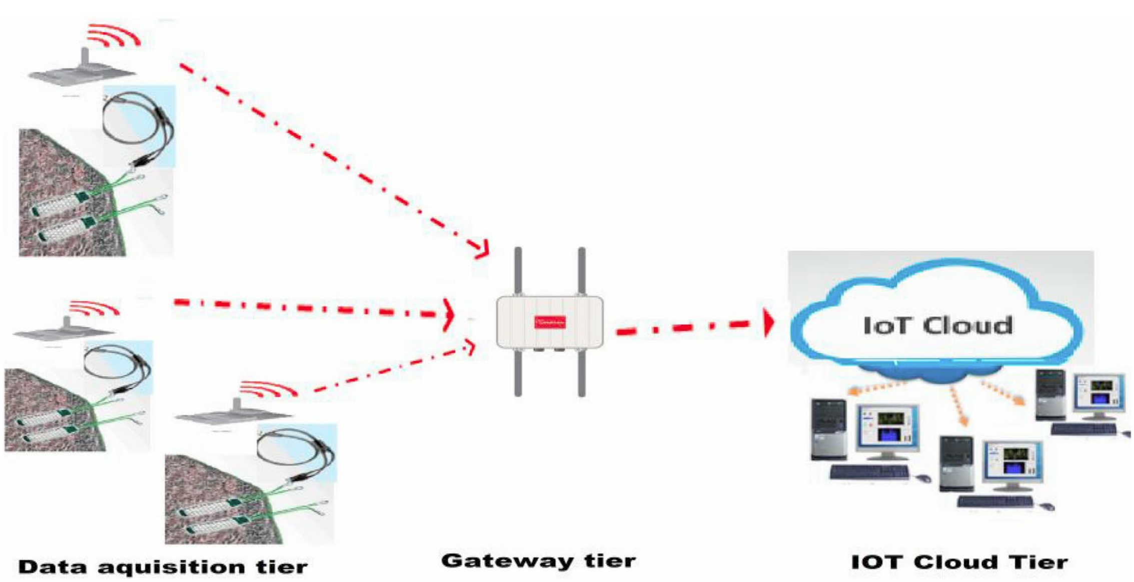

Fig. 5 Architecture system design

integrated into our decision support system to calculate the water demand of an individual plant daily.

Solution Description and Approach

The soil water quality shifts both to the resistors and to the pathway water vacuum values (Corwin and Lesch 2003; Crookston 2006). With elevated ground suction and elevated transpiration between evaporation and air absorption, plant moisture is lowered, particularly inward neurons, causing dissolution. This improves water vapor strength, which decreases the sweat frequency. About the motion of Stomatology, a system is available for controlling the rate of transpiration (Lindgren et al. 1994) for water permeability of the cell membranes that can be influenced by elevated soil water suction. Some reports show the transpiration rate to be independent of soil water (Link et al. 2002, 2006).

Due to different situations, plants always need water. These situations can be determined by changes in temperature, leave wetness, soil moisture, or risk of disease. This fluctuation will trigger the irrigation control system to start an event of the irrigation process using the sensor nodes data collected (Long et al. 2008; Mamo et al. 2003). The control can be done manually by user's commands from anywhere, or through a scheduled process set through a clock of the time interval in different periods which is more independent of being in real-time interaction with the radio communication system.

Data are collected in the scheduled irrigation process via WSN as shown in Fig. 6 and irrigation begins more responsibly than the irrigation process in real time, as in some cases, if there are no radio connections, these data are not reliable on a real-time event. Figure 7 describes the overview of the system employing the Internet of things and Sensor cloud.

However, we applied the idea to lower the cost of automatic irrigation scheduling operating off-the-shelf components, while still improving irrigation performance. To achieve the preferred goal, we made use of RFID tags for data transmission to the central node (laptop with antennas). Other solutions require the use of licenses for radio frequency while using RFID tags communication, at 2.4 GHz, there is no need for licensing, leading to a cost reduction.

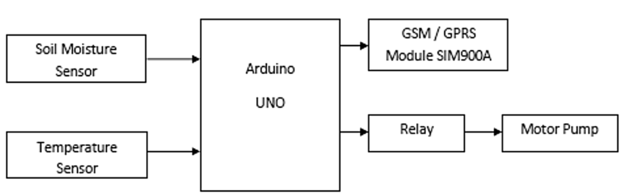

Fig. 6 Components of the proposed architecture

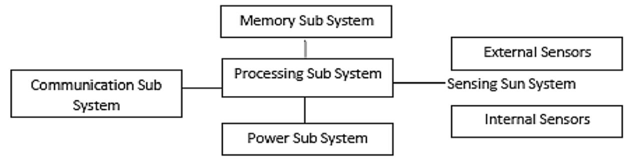

Fig. 7 An overview of a system employing the internet of things and Sensor cloud

The surrounding plants make a significant impact on the wireless transmitters, and they needed to be positioned above the top of the plants to avoid signal attenuation. The smart sensor boards were powered with a 9 V battery that was able to provide power during the entire crop's growing season, performing sensor measurements and data transmission every hour in that period.

Dimension Reduction Techniques

This decrease is only the way the number of independent factors of the variable declines without harm. The higher number of entry factors and large samples of information lead to the increasing complexity of the information set. To decrease the memory and statistical time, the dimensionality of the dataset is reduced. This reduction also helps to abolish unnecessary input variables like replication of variables or variables with a truncated significance level. These Reduction techniques are of two types, namely Feature Selection and Feature Extraction.

Economic Analysis to Increase Profit

Training the data is placed through a particular process of subset production, which is shown in Fig. 8, for instance, sequential backward selection. The subsequent set is now placed through the procedure to test its performance. If this performance ensures the anticipated conditions, then it will

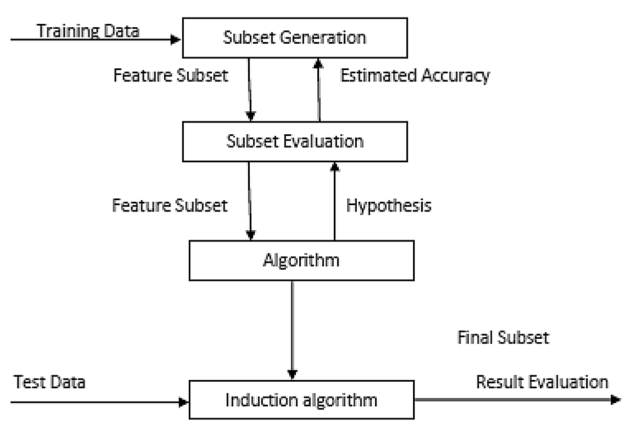

Fig. 8 Feature selection

be designated as the final subset. Or else, the deriving subset will once more be placed through the procedure of subset generation for more fine-tuning.

The expected value-variance (E-V) model is derived for decision making, which benefits for framers in-term of profits as well as limit environmental impacts. The expected value-variance (E-V) model makes use of mean and variance of net returns, choosing a higher mean and lower deviation. The field time is determined by multiplying the average number of working field days a week by 13 working hours a day. The purpose of this analysis is to predict the average profits with its function value. General Algebraic Modeling System was employed as

$$\text{Max } \bar{y} - \phi\sigma_y^2 \tag{1}$$

$$\sum_E \sum_V \sum_P \sum_S X_{E,V,P,S} \tag{2}$$

$$\sum_E \sum_V \sum_P \sum_S EXPYLDLB * EXPYLD_{C,E,V,P,S,YR} X_{E,V,P,S} - SALES_{C,YR} = 0 \tag{3}$$

$$\sum_E \sum_V \sum_P \sum_S REQLB * REQ_{I,P*} X_{E,V,P,S} - PURCh1 = 0 \ \forall I \tag{4}$$

where, $\overline{Y}$ expected net returns above variable cost (mean across years)

Y_{YR} net returns above variable cost by year (net returns)

$X_{E,V,P,S}$ production of enterprise E of variety V with a plant population P under sowing date S in acres

$SALES_{C,YR}$ bushels of crop C, sold by year

$PURCH_I$ purchases of input I

Coefficients include;

ϕ Pratt risk-aversion coefficient

P_c Price of crop C in dollars per bushel

IP_j Price of input I

EXPYLDLB Multiplier representing area planted without lightbar = 1 and with lightbar = 1.02 as discussed below

$EXPYLD_{C,E,V,P,S,YR}$ Expected yield of crop C for enterprise E of variety V planted in population P planted on sowing date S in bushels per acre for

C = Crop

E = Enterprise

V = Variety of crops

P = Plant population

S = Sowing date

I = Input

WK = Week

YR = Year

R = Rotation category

Result and Discussion

The experiment was conceived to determine the impact of the pond on soil moisture and if the ponding is optimal, peak soil humidity is uniform. The experiment was also conceived to determine the impact on soil humidity and the pitch of the parts. The question was also whether irrigation induced a distinction in soil moisture uniformity. Plants always need water because of distinct circumstances. The modifications in the temperature, leave wet, soil moisture or the danger of disease can determine these circumstances. The irrigation control system is triggered by this variation to begin an irrigation incident, which uses the gathered sensor nodes.

The monitoring can be carried out directly via user orders from everywhere or by means of a programmed method laid by a moment interval clock during distinct phases, which is more autonomous of being interacting in real time with the radio scheme. The scheduled irrigation process using WSN to collect data, then start irrigation its more liable than the real-time irrigation process, because if there is no radio connection in case of some problems this data at the real-time event is not reliable. Figure 9 shows the requirement of rainfall, water demand for the crops and the irrigation requirement and Fig. 10 shows the sensor data of air and soil temperature in IOT mode. The Table 1 gives the details of soil, moisture and depth of the test area.

The agriculture dataset was obtained from USDA-ARS-AFRS (United States Department of Agriculture—Agricultural Research Service—Appalachian Fruit Research Station). The open agricultural land of 1000 acres was considered. The only constraint for production is that the total amount of labor needed should be less than the number of available field days. Likewise, the amount of output should be equal to the amount of sold crop. By adding the requirement of the input with total acreage, we obtained purchase input. Mean Net returns by year are determined by the purchase input and sales.

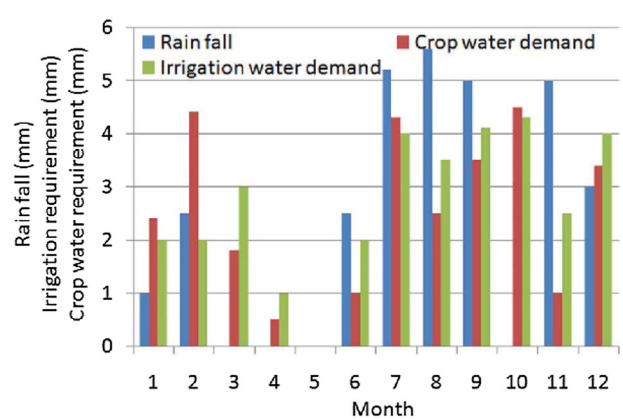

Fig. 9 Rainfall, water demand, and irrigation requirement

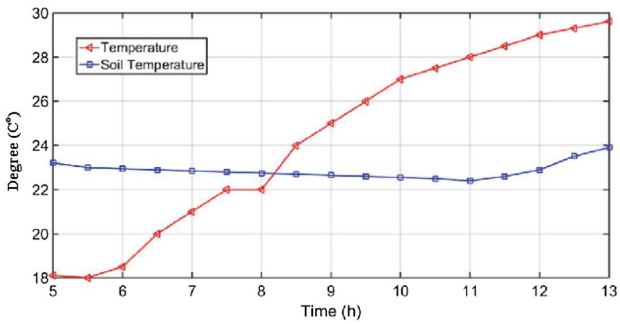

Fig. 10 Temperature of air and soil in IOT mode

Table 1 Soil, moisture and the depth of groundwater in the test area

Parameters	Branches		
	B1	B2	B3
Annual surface water supply (104 m^3)	1032	567	1154
Annual ground water supply (104 m^3)	142	615	35
Upper bound of ground water depth(m)	6	15	7
Lower bound of ground water depth (m)	3	3	3
Upper bound of soil moisture (mm)	237	238	237
Lower bound of soil moisture (mm)	185	185	185
Area of the Test field (ha)	5245	5163	4363

The economic and production costs, time requirement, input cost as well as yield benefits determine the risk neutral. By employing sensitivity analysis, possible prices, as well as production performance, were analyzed as shown in the above Table 2 in terms of yield, field days, time requirement as well as requirements of labor.

As shown in Fig. 11, proper water management leads to higher conductivity and enhances soil moisture. The experiment was also designed to determine the effect crop cover, and slope of the plots would have on the resulting soil moisture uniformity. Another factor considered was whether irrigation caused a difference in the consistency of soil moisture.

This gave a decreased application rate as the distance from the sprinklers increased. For practical analysis of the data, it was necessary to divide each plot into a north and south section concerning the east–west center-line of the plot. From the above results in terms of water management in agriculture environment, according to soil, water and temperature is calculated. From the results it is noticed that the SDN based wireless sensor nodes can sense and perform well in any environment.

The effect of soil temperature and soil water suction on the rate of growth and rate was observed. Proper management of water contributes to increased conductivity and improves humidity in the land. Another consideration was

Table 2 Sensitivity Analysis of Economic Costs

	Benefits	Risk neutral			
		Time req	Labor cost req	Input cost req	Yield benefits
Double crop soybeans					
S27.MG3	29.43	67.28	56.77	29.43	29.43
S27.MG4	216.41	149.43	168.03	216.41	216.41
S27.MG5	341.45	325.41	329.87	341.45	341.45
004.MG4	87.71	132.88	120.33	87.71	87.71
004. MG5					
N22.MG5					
Wheat	474.35	437.86	448	474.35	474.35
Com					
A26.late	200.65	237.14	227	200.65	200.65
A05.late					
AlSJate					
M24.late					
Soybean yield					
Bu/ac	28.71	28.76	28.74	28.71	28.71
Wheat yield					
Bu/ac	58.67	58.4	58.47	58.67	57.52
Com yield					
Bu/ac	125.52	125.48	125.49	125.52	123.06

Where *A26* sowing date of April 26th, *S7* sowing date of September 27th, *A05* sowing date of April 5th, *A19* owing date of April 19th, *mg4* plant variety 4 for soya beans, *mg3* plant variety 3 for soya beans, *mg5* plant variety 5 for soya beans, *late* lant variety late for corn

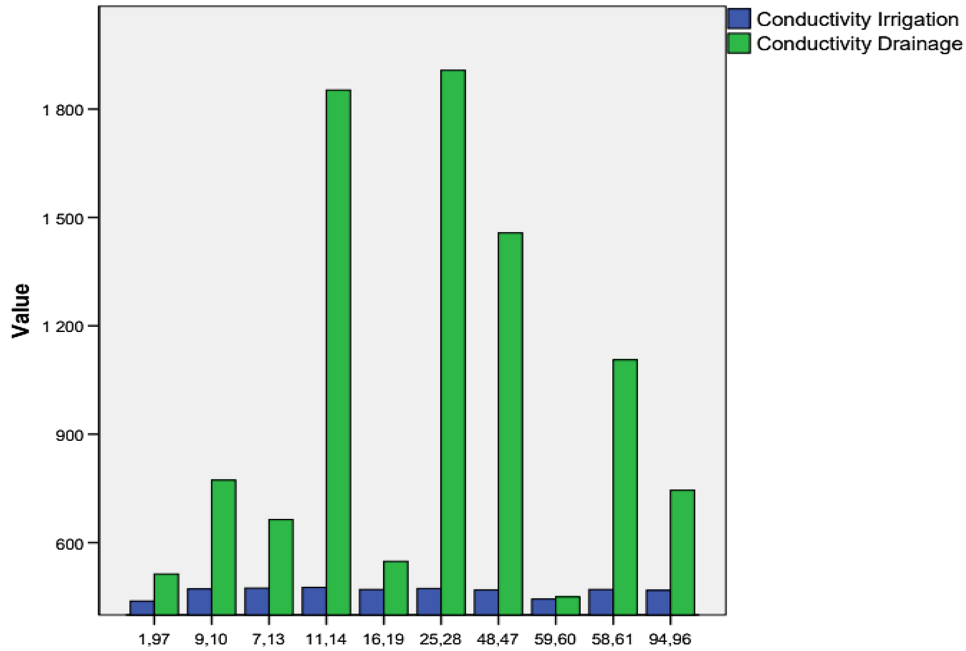

Fig. 11 Effectiveness of smart water management

whether irrigation created a distinction in groundwater moisture uniformity. As the range from the sprinklers expanded, this resulted in reduced implementation speed. By applying appropriate agricultural technologies such as WSN, this will not only increase resources mobilization but also facilitate and promote public/private partnerships access to delivery real development to the agriculture as a main of source of income in the agriculture-dependent countries.

Conclusion and Future Work

The effect of soil temperature and soil water suction on the rate of growth and speed was observed. Wheat seeds were planted and grown in non-adsorbing material made by exploding sand grains at high temperatures. During this time, the plants should be watered and supplied with nutrients daily. Proper management of water contributes to increased conductivity and improves humidity in the land. Another consideration was whether irrigation created a distinction in groundwater moisture uniformity. As the range from the sprinklers expanded, this resulted in reduced implementation speed. By applying appropriate agricultural technologies such as WSN, this will not only increase resources mobilization but also facilitate and promote public/private partnerships access to real delivery development to the agriculture as a main of the source of income in the agriculture-dependent countries.

References

Adamchuk, V. I., Hummel, J. W., Morgan, M. T., & Upadhyaya, S. K. (2004). On-the-go soil sensors for precision agriculture. *Computers and Electronics in Agriculture, 44*(1), 71–91.

Alchanatis, V., & Cohen, Y. (2016). Spectral and spatial methods of hyperspectral image analysis for estimation of biophysical and biochemical properties of agricultural crops. *Hyperspectral remote sensing of vegetation* (pp. 324–343). Boca Raton: CRC Press.

Apostol, S., Viau, A. A., Tremblay, N., Briantais, J. M., Prasher, S., Parent, L. E., et al. (2003). Laser-induced fluorescence signatures as a tool for remote monitoring of water and nitrogen stresses in plants. *Canadian Journal of Remote Sensing, 29*(1), 57–65.

Åstrand, B., & Baerveldt, A. J. (2002). An agricultural mobile robot with vision-based perception for mechanical weed control. *Autonomous Robots, 13*(1), 21–35.

Bakhsh, A., Jaynes, D. B., Colvin, T. S., & Kanwar, R. S. (2000). Spatio-temporal analysis of yield variability for a corn-soybean field in Iowa. *Transactions of the ASAE, 43,* 31.

Bastiaanssen, W. G., Molden, D. J., & Makin, I. W. (2000). Remote sensing for irrigated agriculture: examples from research and possible applications. *Agricultural Water Management, 46*(2), 137–155.

Bauer, M. E., & Cipra, J. E. (1973). Identification of agricultural crops by computer processing of ERTS MSS data. LARS Technical Reports. Paper 20. http://docs.lib.purdue.edu/larstech/20. W. Lafayette: Purdue Univ.

Bausch, W. C., & Duke, H. R. (1996). Remote sensing of plant nitrogen status in corn. *Transactions of the ASAE, 39*(5), 1869–1875.

Bhatti, A. U., Mulla, D. J., & Frazier, B. E. (1991). Estimation of soil properties and wheat yields on complex eroded hills using geostatistics and thematic mapper images. *Remote Sensing of Environment, 37*(3), 181–191.

Channe, H., Kothari, S., & Kadam, D. (2015). Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis. *International Journal of Computer Technology & Applications, 6*(3), 374–382.

Chen, J. M. (1996). Evaluation of vegetation indices and a modified simple ratio for boreal applications. *Canadian Journal of Remote Sensing, 22*(3), 229–242.

Corwin, D. L., & Lesch, S. M. (2003). Application of soil electrical conductivity to precision agriculture. *Agronomy Journal, 95*(3), 455–471.

Crookston, R. K. (2006). A top 10 list of developments and issues impacting crop management and ecology during the past 50 years. *Crop Science, 46*(5), 2253–2262.

Ferrández-Pastor, F., García-Chamizo, J., Nieto-Hidalgo, M., & Mora-Martínez, J. (2018). Precision agriculture design method using a distributed computing architecture on internet of things context. *Sensors, 18*(6), 1731.

Karim, F., & Karim, F. (2017). Monitoring system using web of things in precision agriculture. *Procedia Computer Science, 110,* 402–409.

Lindgren, F., Geladi, P., & Wold, S. (1994). Kernel-based PLS regression; Cross-validation and applications to spectral data. *Journal of Chemometrics, 8*(6), 377–389.

Link, A., Panitzki, M., Reusch, S., & Robert, P. C. (2002, July). Hydro N-Sensor: Tractor-mounted remote sensing for variable nitrogen fertilization. In *Proceedings of the 6th International Conference on Precision Agriculture* (pp. 14–17). Madison, USA: ASA/CSSA/SSSA (published on CD).

Link, A., & Reusch, S. (2006). Implementation of site-specific nitrogen application-Status and development of the YARA N-Sensor. In *NJF seminar* (Vol. 390, pp. 37–41).

Long, D. S., Engel, R. E., & Siemens, M. C. (2008). Measuring grain protein concentration with in-line near infrared reflectance spectroscopy. *Agronomy Journal, 100*(2), 247–252.

Mamo, M., Malzer, G. L., Mulla, D. J., Huggins, D. R., & Strock, J. (2003). Spatial and temporal variation in economically optimum nitrogen rate for corn. *Agronomy Journal, 95*(4), 958–964.

Rao, R. N., & Sridhar, B. (2018). IoT based smart crop-field monitoring and automation irrigation system. In *2018 2nd International Conference on Inventive Systems and Control (ICISC)* (pp. 478-483). IEEE.

Reeta, R., Pushpavathi, V., Sanchana, R., & Shanmugapriya, V. (2018). A Deterministic Approach For Smart Agriculture Using Iot And Cloud. *International Journal of Pure And Applied Mathematics, 118*(18), 2413–2424.

Suresh, P., & Koteeswaran, S. (2019). An Effective Novel IOT Framework for Water Irrigation System in Smart Precision Agriculture. *International Journal of Innovative Technology and Exploring Engineering, 8*(6), 558–564. **(ISSN: 2278-3075)**.