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Article

# Agricultural IOT, Cloud Computing and Mobile Based Application Integration for the Total Discharge Predication of Two Farms Smart Agricultural System to Avoid Flooding

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**Abstract:** The information technology has brought in a revolution in the area of digital agriculture and hydrological modeling . With the advent of IOT and AI such as machine learning is now capable of Predicating flood forecast, drought forecast and farms based water predication. In this article various machine learning algorithms, multiple sensors for environmental and agricultural has been proposed and used . The purpose is to acquire data of soil moisture, temperature, crop stages, irrigation and precipitation on a region constitute of two farms and then performed machine learning predication for total discharge predication at farms outlets so that in case of excessive rainfall or an irrigation event the water is adjusted in the second nearby farm or reroute to a reservoir for future use to avoid flooding. The focus is mostly to work on the concept and building of an andriod -ardiuno based mobile application for the endusers (agricultural system analyst, farmers) to provide an ease. The whole system of smart agricultural based on two farms and reservoir will provide an efficient,fully automatic, proactive and decision support system to save water waste and reuse. In future the work is also in progress for developing a desktop based application.

**Keywords:** agricultural engineering; machine learning; IOT; mobile application; hydrological modeling; NRCS simulator; Intelligent irrigation system; surface runoff ; flood prevention and cloud computing

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## I. Introduction

Global Climate change and increase in the world population has tremendous impact on the world's agricultural sector . The agriculture sector must meet the food security challenge of the growing population of the world which is almost estimated as 9.15 billion people on the year 2050 according to the UN population projections. There are two important variables for food security to achieve in the agricultural sector, the first is land resource and the second is water resource. Most of the world land resource is either under the forest or far away from human communities and not suitable for the cultivation purpose. A lot of land cultivation is done by rainfed as it covers 80% of the global agricultural cultivated land and output 60 % of crop production, less on irrigation which is about 20 % cultivated (arable) land but as due to the global warming the patterns of rainfall changes and those regions which have less rainfall or droughts now needs to be switched to modern forms of smart irrigation. Smart irrigation can increase land cultivation in the parts of the world such as in Africa and middle east where there is less rainfall and water scarcity. Water is the fundamental resource for the food production in agriculture [1].It is worth to note that 70% of Global fresh water goes into agriculture sector, 11 % to industrial and 8% to municipal. However due to water mismanagement methods such as flooding/surface irrigation . on the global scale irrigated area such as flooding covers 75 %, micro irrigation 7% and sprinklers 18% [2].

In China, India and Pakistan which have the largest irrigation land uses the method of flooding for the cultivation purpose [3]. Water mismanagement needs to be resolved and there is a great potential for these countries which are switching to micro irrigation systems (such as drip and sprinkler also known as precision irrigation) in order to save the water waste. Precision irrigation system is fully automatic, uses different wireless sensors such as soil moisture, crops, temperature, precipitation, humidity and solar monitoring and so many other related parameters of agriculture system. Precision irrigation reduces labor cost, and provide informed decision on the basis of data it has elicited from different sensors and an informed decision has to be carried out to the end users (that could be the stakeholders of the agriculture system such as agricultural system analyst, farmers etc) [4].

## II. Related work

In the related section, the papers are discussed from three aspect. 1) Applications of IOT in agriculture 2) Machine learning uses in agriculture 3) Mobile based applications in agriculture

### A. IOT in agriculture

In this research paper the focus is on the IoT-enabled sensor node for the agricultural monitoring purpose. The sensor node include ambient temperature and humidity conditions, soil moisture conditions along side with rainfall conditions. The data acquired is send to the ThinkSpeak through long-Range Wide area network (LoRaWAN) communication protocol. So that it acquire low cost for long time monitoring of agriculture fields and increase in obtaining large temporal and spatial resolution of the data. [5]

In this research paper the study is carried about IOT based sensors such soil moisture, precipitation, irrigation, temperature and crop sensors and its in depth analysis is given, how to be used with arduino uno for data elicitation and board state of the art machine learning algorithms such as multiple linear regression (MLR), support vector machine based on\_regression (SVM), decision tree based on\_regression (DT/RT) and artificial neural network (ANN) has been implemented for the optimal reservoir and back runoff channels based two farms irrigation total discharge predication so that the irrigation and rainfall water among two farms are controlled and saved. In case of surplus water in either farm is transfer to reservoir on the basis of back runoff channels by the opening and closing of gates or adjusted among neighboring farm. Thus machine learning and IOT sensors are integrated for this purpose. [6]

### B. Machine learning uses in agriculture

In this research paper of Machine learning [7], The author has used a data set consisting of 500 images of crops for experimental study. Three machine learning classification techniques such as SVM-support vector machine, ID3 and C4.5 has been used to classify different crop images which helped in crop diseases predication. The result will be the reduction in crop waste.

This above paper also explains about the machine learning that it is the new area of data mining. Machine learning has two broad types 1) supervised learning and 2) unsupervised learning. The supervised learning is a technique in which the training dataset is known in prior, training dataset consists of known inputs and output. then testing is carried out on the unseen dataset to find out the difference between predicated and original output values. if the difference is minimum the model is said to be accurate. The supervised learning have further two types 1) classification and 2) Regression. The unsupervised learning type is clustering.

In this research paper a compressive review has been done about the machine learning applications in agriculture, the focused areas are soil moisture predication, crop yield predication, crops weeds and disease detection, intelligent irrigation and intelligent harvesting techniques which helped in reduce labor cost to maximum extent.

In this research paper [8] the author work is focused on various machine learning algorithms such as ANN, SVR, DT and MLR and the input parameters to the system are irrigation depth, curve

number and time of concentration and the output parameter is runoff time . The supervised machine learning technique has been used .A dataset is collected of 4095 samples from NRCS simulator, the results are acquired on the basis of training and testing ratio 70:30, 30:70 and k- fold cross validation where k=2,5 and 10. The result showed that DT and ANN perform well than other two algorithms for accurate predication in terms of root mean square error (RMSE),  $R^2$ , mean square error (MSE) and certain other benchmark parameters. The work is based on hydrological modeling in farms.

In this research paper [9] the focus of the work is the predication of runoff volume at a single farm outlet. Machine learning algorithms and NRCS based simulator is used for data elicitation and predication of runoff volume .

In this conference [10] which is held in university of Southampton united kingdom the idea of runoff volume predication through various state of the art machine learning models has been presented.

### *C. Mobile based applications in agriculture*

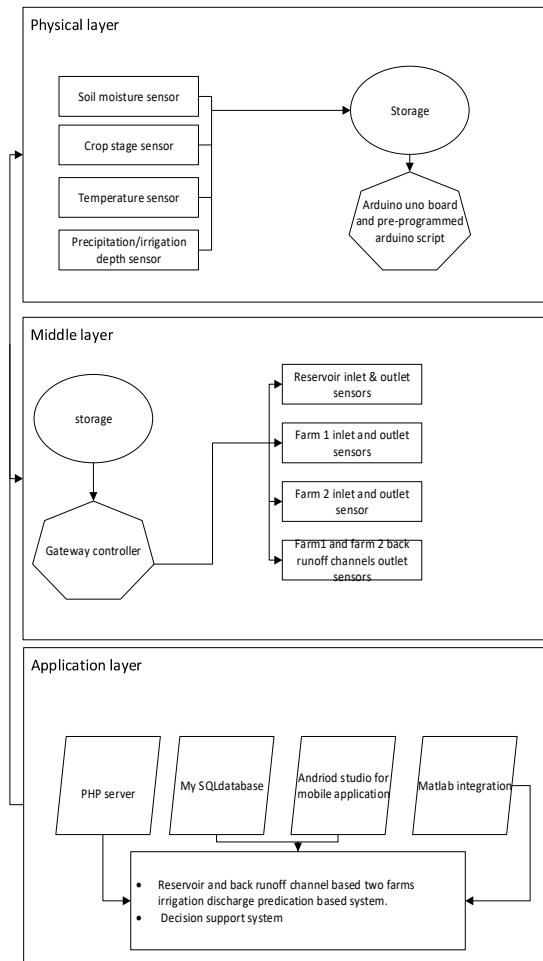
In this paper the authors proposed the deployment of WSN to water the crops for the optimization of agriculture and build a web based application and Smartphone based application for data management of sensors nodes deployed in the agriculture crops on a farm. There are three components, the first is the hardware part which is responsible for collection of agriculture data, the second part is the web based which is used for the crop data collection and field information and the third part is based on Smartphone which is used to control the watering of farm. The data mining technique is used to predict the parameters such as temperature, humidity and soil moisture to be used in the future plans. [11]

## **III. Research methodology**

In this research methodology the problem of how to save the water that has been wasted through surface runoff from one farm to another farm from irrigation or rainfall . the solution provided is the use of wireless sensor network (WSN), internet of things (IOT), Machine learning algorithms for proactively predict the runoff estimation that could be reuse in the other farm or reroute back to the reservoir for future use . For giving an easy interface for endusers (system analyst, farms),Mobile based application has been developed which rendered the farms environmental status as well as predicated values of total discharge at the farms outlets on the basis of sophisticated machine learning algorithms. Then the algorithms performance has been analyzed and compare against the NRCS simulator based predicated value for total discharge at farms outlets.

### *A. WSN and machine learning deployment in real world (AIOT)*

AIOT (Artificial intelligence and Internet of Things) and Andriod mobile based application is developed and integrated which will help the user to retrieve the status of two farms on mobile device. Data is retrieved from arduino soil moisture sensor and temperature sensor (LM35 arduino sensor).while for crop stages proxy values are assigned to the model which is constituted on NRCS and TR 55 document on small watershed for urban hydrology to reflect on real world values for crop stages such as fallow land, small grain less than 50 percent cover and small grain with 75 percent surface cover [12]. The precipitation values are feeded into the system from the local meteorological site available on the mobile samsung that is connected with Accuweather [13].The data is further analyzed and the current condition of farms are being displayed on mobile. On the physical layer WSN nodes are deployed on two farms for data elicitation from the real world, While Machine learning is used on application layer for the decision making that how much total amount of water is discharged. The predication for total discharge (cfs) is developed at farms outlets. While in the middle layer such as gateway is responsible for inlet and outlets sensors of reservoir, farms and farms back runoff channels to open and close the flow paths after the decision making on the application layer. The below figure provide a diagrammatic representation of physical, middle and application layer.



**Figure 1.** Physical, middle and application layers overview.

The real challenge is that how precision irrigation system and WSN deployed on the two farms save water waste, energy and also is cost effective.

There are various climatic, soil moisture and crop growth development parameters to be measured on these sensor deployed on the farms for onward processing and decision making to be taken on machine learning at the application layer.

#### *B. Experimental setup*

The connected nodes to the arduino Uno device, a Large number of nodes are scattered through a geographic agricultural location to monitor environmental and soil parameters that can affect the irrigation process. Some important nodes of our developed system are discussed as follow: soil moisture, irrigation(water flow sensor) /precipitation sensor, temperature sensor and crop stage sensor. [14]

- The fundamental node to monitor and estimate the soil moisture of a farm is mandatory because it will help to know that how much water is required by the plants to be provided by the irrigation system. When the soil moisture of the farm is known in prior a specific amount of water should be provided to save water waste. The soil moisture sensor that has been used with the arduino Uno board is the arduino soil moisture sensor . [15]
- The weather node is responsible for monitoring the environment, there are various types of sensors to monitor the environments that are humidity, temperature, windspeed, solar radiation etc.

However, Air temperature to monitor has a crucial impact on the crops growth, low air temperature there is less water absorption and movement of water in plants.

"The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature.." (LM35 Precision Centigrade) LM35 is three terminal linear temperature sensor from National semiconductors. [16]

- Pole mounted Multispectral/hyperspectral camera connected with arduino The pole mounted camera can be placed horizontally to arduino uno or pole mounted vertically to take crop images . [17]
- For precipitation measurement the local meteorological site available on the cell phone has taken into consideration which uses international integration of radars based system and other relevant parameters for quantitative estimation of precipitation over a region. [18]
- Irrigation(water flow sensor) is also taken into account and used its values interchangeably in the mobile based application against precipitation values for ease . [19]

#### *C. Base Station*

Base station is referred as a centralized component that is specifically used for the data elicitation from the different sensor nodes attached to arduino uno, In the experimental setup the base station is composed of two further components that is a laptop and a gateway mote. The laptop runs on windows operating system. whenever the data is received by the base station /laptop from the gateway mote which in turns receive data from different nodes of arduino uno boards, the laptop has various WSN based software (arduino IDE ) and machine learning algorithms Script for the real world data processing and execution to provide intelligent decision support system by predicated total discharge at the farms outlets level.

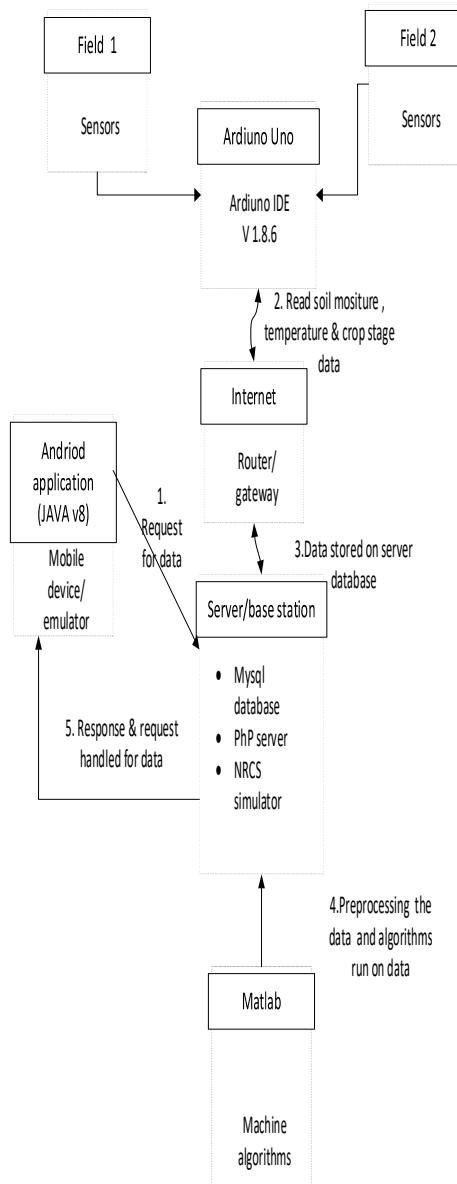
#### *D. IOT based model practical setup on two neighbouring farms*

A practical setup on the farms has been carried out by the implementation of different sensor nodes for soil moisture based on arduino (Decagon EC 5), temperature sensor (LM35) and crop camera CCTV that must be attached to a pole and connected to arduino uno board for the two nearby adjacent farms.

- The point-to-point topology of the two neighbouring farms A and B which has been considered in this experimental setup.
- For fallow land (crop stage 1 ) mean 0 % surface cover, when soil moisture condition is dry . the data from the soil moisture, crop stage and temperature is rendered from sensors installed in the fields and precipitation depth value is given from the local meteorology data available on mobile app by the end user.
- For small grain (crop stage 2) means that the land is covered with < 50 surface cover and here soil moisture condition is dry as well.
- For small grains with => 75 % surface cover (crop stage 3) with dry soil moisture condition . The sensors for temperature, soil moisture and crop camera ardiuno is installed in the fields and are able to have Ethernet connection as well as wifi connection between ardiuno uno boards installed on two fields 1 and 2.

#### *E. AIOT design diagram*

The AIOT Figure 2 below shows that how two farms are connected with each other through different agricultural and environmental sensors through arduino microcontroller. A list of these sensor is given in the results and discussion section . It also shows that how machine learning is used in the hydrological modeling . How the mobile based application came into existence for this hydrological modeling of the two farms is also discussed . A compressive overview is given in the results and discussion section .



**Figure 2.** AIOT design diagram.

#### IV. RESULT AND DISCUSSIONS

The following tools are used in this research work to obtain the data, storing, processing and displaying to the end users are as follows.

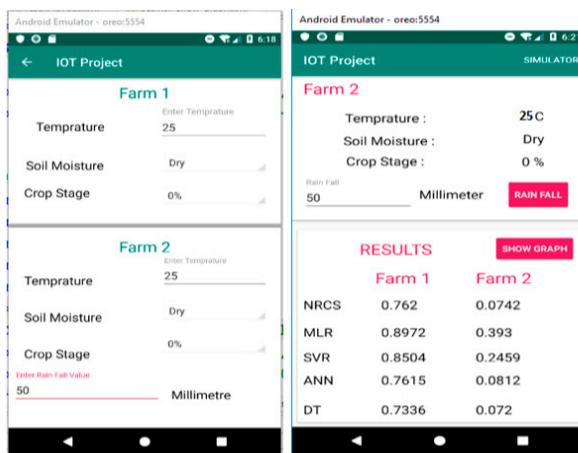
- Wireless sensors (IOT), It contains various field sensors and arduino uno board, the sensors are connected to the arduino board. It provides the feature for wireless communication with other arduino board.
- Internet is used as gateway for the communication purpose.
- The Xampp server is installed which can act as local server and live server, developed by apache friends, consists of apache http server, mariadb data base (derived from mysql) and read scripts written in php and perl. The data request is then forwarded to the arduino uno which has been configured by arduino IDE V1.8.6 and relevant arduino sensors for temperature, crop stage, water flow sensor and soil moisture through a router/gateway
- JAVA v8 is used for the mobile application development.
- Matlab tool is used for machine learning algorithms predictions and NRCS simulator results.

##### *A. Mobile emulator results for dry condition*

In this emulator results the data is retrieved from soil moisture sensor, crop stage sensor, temperature sensor and precipitation sensor/ irrigation water flow sensor, both the fields 1 and 2 have dry conditions and crop stage one. Here crop stage means fallow land (0 % surface cover).

The values for precipitation/irrigation can be given in the range of 0 to 100 millimeter numeric values in the mobile emulator for both farm 1 and farm 2 . The temperature is in the range of 0 to 50 centigrade. The other soil moisture conditions are dry, average wet, wet and extreme wet while the crop stages are crop stage 1 (0% surface cover), crop stage 2 ( 50 % surface cover) and crop stage 3 ( $\geq 75$  % surface cover).

Figure 3 below shows farm 1 and farm2 initial variables such as temperature, soil moisture, crop stage and precipitation or irrigation value variable in millimeter for both field 1 and field 2 and also shows the results for total discharge predication in the numeric values for farm 1 outlet on the basis of NRCS, MLR, SVR, ANN and DT and similarly for farm 2.



**Figure 3.** Total discharge from farm1 and farm2 against event numbers.

Here Figure 4 below shows the total discharge values against event numbers for farm 1 and farm 2 in bar graphs form.

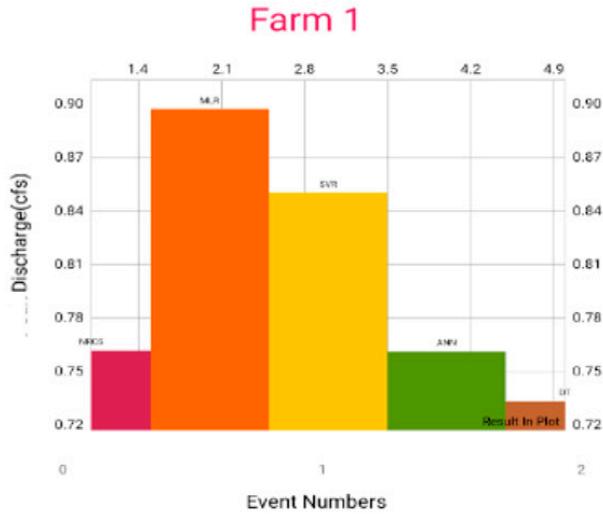


**Figure 4.** Total discharge values against event numbers for both farms in bargraphs form.

The X-axis represented in the below Figure 5 shows bar graph for farm1 Event numbers (sample numbers/ tuple numbers which is in the range of 0 and 2 that is equal to 1) while the Y-axis shows the discharge in cubic feet per second (cfs). Figure 5.9 shows that the NRCS value for total discharge predication is closely predicated by ANN, then followed by DT however SVR and MLR predication is not that closer to the NRCS predication value for total discharge.

Similary Figure 6 shows that the NRCS predicated value for discharge at farm2 outlet is closely predicated by ANN, followed by DT, however SVR and MLR predication is not that closer to the NRCS value. Both SVR and MLR shows a high rise away from the NRCS predicated value in the bar graph.

The other conditions are Average wet, Wet condition and extreme wet for soil mosityure, crop stages (1= fallow 0%, 2= small grain < 50%, 3= small grains=>75%) and the range of values for the precipitation temperature from 0 to 50 .



**Figure 5.** Total discharge (cfs) against event numbers at farm 1.



**Figure 6.** Total discharge (cfs) against event numbers at farm2.

#### B. Tabulated results of machine learning algorithms and NRCS simulator.

In the below table a tabulated summary is given that Artificial neural network (levenberg-Marquardtt), Decision tree (regression tree), Support vector machine (SVR) and Multiple linear regression has been used for total discharge predication at farms outlets . In which ANN performed outstandingly well than the rest of algorithms in this hydrological predication of total discharge as compared with the natural resource conservation service (NRCS) based simulator . The algorithms are ranked on the basis of performance accuracy . In the table there is also mentioned the key advantages that is associated with the deployment of this system on full scale.

**Table 1.** Representation of ML algorithms, NRCS simulator, comparison, ranking and its advantages.

ML learning algorithms used	Hydro simulator	RAN K of algorithm for Total discharge prediction at both farms	Inputs parameters	Advantages
ANN	NRC S	1st	Soil moisture	Save water waste and avoid flooding
DT	NRC S	2nd	Crop stage	Low labor cost
SVM	NRC S	3rd	Temperature	Full automatic
MLR	NRC S	4th	Rainfall/ irrigation	Efficient and ease of use for enduser.

## V. Conclusion

This paper presents a brief overview that how IOT based sensors for agriculture such as soil moisture, crop stages, temperature, perception and machine learning techniques such as ANN, DT, SVM, MLR are to be integrated on two farms scale for the predication of total discharge at the farm 1 and farm 2 outlets respectively. The broader purpose is to save precious water, reduce labor cost, make the system fully automatic, efficient and also to reroute the saved water on the basis of back runoff channels to the reservoir from these flow channels, which will have its own IOT based sensor for opening and closing the paths. Thus the reroute water to the reservoir can be utilized for further irrigation of these farms incase of droughts the water from one farm can be reutilized in other farm irrigation according to the local farm environment and the flooding will be prevented in the case of excessive rainfall. The state of the art machine learning techniques such as ANN (levenberg-marquardt), DT (regression tree), SVM (regression) and MLR has been used for this rainfall / irrigation based hydrological modeling over a two large farms scale region. In this hydrological modelling the machine learning techniques that is ranked first is ANN, ranked 2nd is DT, ranked 3rd is SVM and ranked 4th is MLR. Further there is a need felt to have an Andriod -Ardinuo based mobile application for the endusers such as agriculture system analyst and farmers to be informed about the status of their farms well on time and ease of understanding of multiple scenarios that could be erupted. The mobile application shows the rendered data of farms agriculture parameters such as soil moisture, crop stages, temperature, precipitation/irrigation and the total discharge predication for farm1, farm 2 and the total discharge predicated by machine learning models as well as NRCS predication value for total discharge and thus outclass the rest of algorithms. The results are also shown in the bargraphs form by the mobile application for ease to the endusers.

**Acknowledgment:** The first author worked on the detail conceptualization for smart farms hydrology, data engineering, machine learning model predication and mobile development, The second author worked in conceptualization, NRCS simulation and Validation of data and research paper lay out and paper presentation. The first author worked in Matlab simulation environment as well while The second author worked in the local base station/live base station setup Xampp server. Finally the work is integrated in presented in this research article.

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## Author biography



Mr: Marwan khan has done his master in information technology from university of Malakand, Pakistan in 2007 . He is working as lecturer in department of computer science awkum from 2013. He pursue his higher studies from university of Southampton united kingdom and got the degree of Mphil in computer science in 2002 . He has published number of research articles and have conference presentation in Southampton university Uk. His research interest are machine learning, WSN, IOT, mobile application and digital agriculture.

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