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Water Resource Management in Agriculture Using Smart Irrigation Scheduling

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Abstract—Agriculture is dependent on fresh water, but India has 17 % of the world population and only 4 % of the world's fresh water resources are available.

Effective use of water resources leads to high yield. water is transferred from the soil to the environment as evaporation and water is transferred through the plants to the environment in the form of transpiration. water enters into deep soil and this process is termed percolation. (p*ercolation* is the process of a liquid slowly passing through a filter. It's how coffee is usually made. *Percolation* comes from the Latin word percolare, which means "to strain through." *Percolation* happens when liquid is strained through a filter, like when someone makes coffee.)

These two processes, evaporation and transpiration combined is known as evaporation-transpiration. Penman-Monteith(Montecito) FAO 56 or lysi meters helps to calculate the total water loss in evaporation-transpiration, percolation and runoff. Evaporation-transpiration mainly depends on temperature, solar radiation, relative humidity, wind speed and rainfall. IoT sensor helps to monitor the weather parameter. Reinforcement learning take input from IoT sensor and decision are made on when you irrigate and how much to irrigate so that it helps to reduce the water loss by the environment. Irrigation has a directly impact on crop yield. More amount of irrigation leads to soil nutrition loss, changes in soil property, high chance of diseases, major changes in crop growth and yield.

Keywords— Smart irrigation scheduling, Penman-Monteith FAO 56,agriculture sensor network, IoT, lysimeters, evaporation-transpiration, percolation, etc

I. INTRODUCTION

Agricultural and allied section account 13.7 % of the GDP. India stands second place in agriculture production. India has different types of water source like river, ground water, well, canal, tank and rain water. In India agriculture is mostly depending on ground water. There are around 160 million ha of cultivated land in India, among which 39 million ha of cultivated land has been irrigated by ground water, 22 million ha of cultivated land has been irrigated by canals and about 100 million ha cultivated land depends on monsoon. Because of the climatic changes in India there is not sufficient monsoon rain for agriculture. Total water availability in the country is help to indicate water stress and scarcity. As per international norms, per capita water availability is less than 1700 m^3 it indicates water stress and if per capita water availability is less than 1000 m^3 it indicates water scarcity. India has only 1544 m^3 per capita water availability so India is already in water stress and it is moving towards water scarce.

In agricultural field when water has irrigated. Some water loss through runoff. Balance water observed by soil. Some water evaporated from the soil. Some water transpiration from plant. Some water percolation in deep soil. Poor water management lead to low crop yield, poor water use efficiency and increase water demand for agriculture. Limited water resources and the climate change will lead to poor crop yield. To increase the crop yield to be understood the crop biological property and monitor the various environmental, soil, fertilizer and irrigation condition.

In the earlier irrigation system, there was an approximate irrigation system without having knowledge of soil moist, crop requirement and weather forecasting, it leads to a wastage of fresh water, energy and loss of crop growth. When rainfall immediately after irrigated if will effort crop and wastages of resource. This kind of problems is handled by the IoT based sensor network with better solutions and optimized water resource management with sensor data and weather forecasting information.

Similar soil, climate, fertilization and irrigation, but Crop yield will be varying from variety to variety. Internet of Things (IoT) and Artificial Intelligent has a big challenge in crop monitoring, environment, soil, fertilization and irrigation. Internet of Things (IoT) sensor based solutions help to solve very complex problem in an intelligent way. Monitoring environment, it gives the best solution to improve the crop yield. A sensor is used for analysis the various parameters in agricultural domain based on the IoT based sensor technology. Irrigation scheduling will be optimum utilization of water.

Sustainable irrigation management reliable and easy to use method and tools to support real time scheduling with respect to the availability of water requirement and a crop’s response to stress. Irrigation scheduling is based on crop evapotranspiration or a water balance methodology using real time weather data.

The soil water requirement is limited to the knowledge of the volumetric soil water content at field capacity the wilting point and saturation the electric conductivity the organic matter and the effective soil depth. Soil moisture, precipitation and evaporation are the major parameter for design irrigation scheduling. Evaporation can be calculated using other metrological essentials. For evaporation, we use an empirical model given by Penman The entire evaporation (ET) depends on the thermodynamic evaporation (Eh) and the dynamic (Em), where Em depends upon the velocity of the land storm, air temperature, relative humidity of the air and UV radiation. Proposed an automatic irrigation scheduling based on direct soil measurement that utilizes water proficiently over manual irrigation system [3].

Suggested evapotranspiration (ET) based approach, which is an important parameter to decide crop irrigation needs influenced by climate parameter, e.g. solar radiation, relative humidity, temperature, wind velocity, and crop features such as phase of the growth, assortment and plant density, properties of soil, nuisance and disease water irrigation scheduling.

Evapotranspiration can be calculated with lysimeters or water balance approach or estimated from weather data.

II. METHODOLOGY

Smart irrigation scheduling is the best way to make optimum utilization of water resources. It is based upon crop water requirement, soil moister contend, soil water balance, field capacity, evaporation, transpiration, deep percolation, runoff, irrigation and rain fall. IoT based sensor network are the input parameter for calculation all kind of water loss in the field. Weather parameter like temperature, solar radiation, relative humidity, wind speed and rain fall helps to calculate Evapotranspiration. In agricultural field 30% of the fertilizer is taken by crop Smart irrigation scheduling and balance 70 % of the fertilizer are lost in runoff and deep percolation. So smart irrigation reduces fertilizer loss in soil.

Smart irrigation scheduling is also depending upon weather forecasting of the next 5 days given by India Meteorological Department (IMD). Weather forecasting will predict next 5 days' water requirement by calculating evapotranspiration. The reference evapotranspiration (ET0) was estimated by the FAO Penman-Monteith equation

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

(Where Rn is the net radiation available at the crop surface(MJ/m2/d),
G is the soil heat flux density (MJ/m2/d),
T is the mean air temperature at 2 m height (C),
U2 is the wind speed at 2 m height (m/s),
(ea- es) is the vapour pressure deficit at 2 m height (kPa), is the slope of the vapour pressure curve
(kPa/C), and is the psychometric constant (kPa/C).)

The computations of the considered parameters were performed following the formulas reported in Crop evapotranspiration (ET_c) was calculated as a product of the reference evapotranspiration and crop coefficient Kc:

$$ET_c = K_c \times ET_0$$

Soil water balance will calculate daily basis water requirement for the crop. It also estimated water depletion in the effective root zone Dr,i (mm).

$$D_{r,i} = D_{r,i-1} - P_i - IR_i + ET_{c,i} + DP_i.$$

Where $D_{r,i-1}$ represent the root zone depletion of previous day i-1 (mm), P_i is precipitation, IR_i is net irrigation, $ET_{c,i}$ is evapotranspiration and DP_i is deep percolation, when the precipitation and irrigation are more than the soil infiltration then have to consider runoff also.

Total available water (TAW) is calculated by subtracting field capacity from crop wilting point and divide by root depth.

$$TAW = (FC - WP)/ 100\ Rd$$

Wher Rd is given in mm. Readily available water(RAW). Represents the amount of water that can be depleted from the root zone without compromising crop growth. RAW is calculated from fraction(p) of TAW

$$RAW = p \times TAW$$

Irrigation is depending up on depletion, which can be lower than or equal to RAW then it is optimal irrigation and

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maximum yield else it will affect crop yield by water stress. Water stress level Ks is calculated

$$Ks = TAW - D_r / TAW - RAW$$

Runoff coeff (C), you can calculate the Q by using:

$$Q = C \times P$$

Then use the Q to this equation from Soil conservations SCS method: . Q and P is known. if you do not know the value of I, you have to assume I as a percentage of P (lets say I=0.2*P).

Calculate S from this equation.

$$Q = (P - I) \hat{}2 / \{(P - I) + S\}$$

then use the S in this equation to calculate the curve number (CN):

$$S = (1000 / CN) - 10$$

Current soil moisture estimation = rainfall + irrigation + previous day soil moisture – runoff – evaporation – transpiration – deep percolation.

Actual evaporation and transpiration is depending up on soil moisture and root depth. The crop root depth is depending up on crop age. So we can calculate root depth by using date of planting and current date. The available soil moisture in the top 10 cm layer will be the major contribute for evaporation and transpiration then remaining soil moisture till root depth is available for crop usage (transpiration). The crop vegetation growth is inversely proportional to evaporation.

soil moister is divided into multiple layer (flow chart). Estimated soil moister = previous estimated soil moister + irrigation or rainfall – runoff. It estimates soil moister till field capacity for every layer in the soil depth. if soil moister is less than the crop wilting point then calculate crop water requirement. layer –wise soil moister estimation help to calculate exact water requirement.

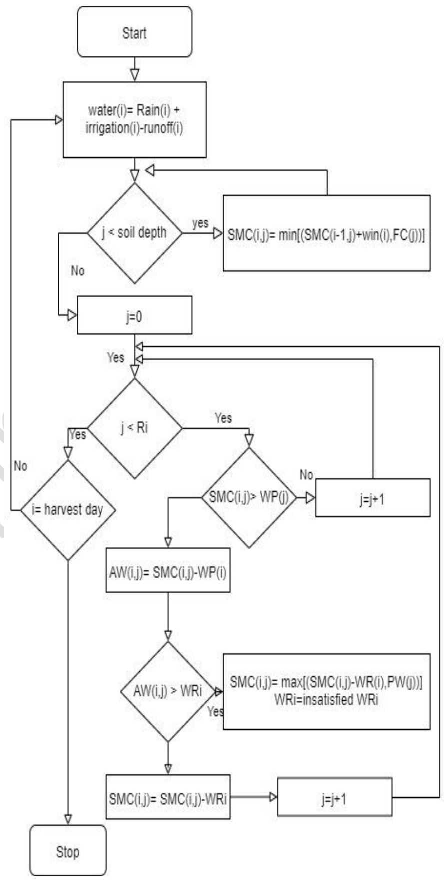

Figure 1. Flow chart of layer-wise soil moister estimation. I, time (day); j, depth; SMC, soil moister content; FC, Field capacity; R, root depth; WP, wilting point; AW, available water, WR, water required).

Crop water requirement (CWR) and Evaporation demand (ED) are going to estimate daily water requirement for the crop

$$CWR = K_c \times ET_0$$

$$ED = (1 - K_c) \times ET_0$$

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If:$\sum_{j=1}^{root\ depth} AWC > CWR\ then\ T = CWR$

Otherwise T= $\sum_{j=1}^{root\ depth}$ AWC

If:$\sum_{j=1}^{10cm} AWC > ED\ then\ E = ED$

Otherwise E= $\sum_{j=1}^{10cm}$ AWC

Available water content = field capacity – permanent wilting point. Water content is estimated in every soil layer (1cm = 1 soil layer).

Water volume at day$_i$ = water volume at day$_{i-1}$+ inflow received (runoff) + rainfall over the water body – evaporation from the water body – spillover amount – infiltration from reservoir bottom (artificial groundwater recharge)- water withdraw or utilized.

The proposed system :

A. **System architecture***:*

The IoT sensor based irrigation scheduling have major components, such as data logger read all sensor data and stored in microsd card memory; GSM module read the data from microsd card memory and send data to web server using http protocol.; web server retrieves the crop profile from the database; web server will estimate the crop water requirement using sensor data and crop profile; web server response to the farmer mobile application, amount of water requirement for the irrigation.

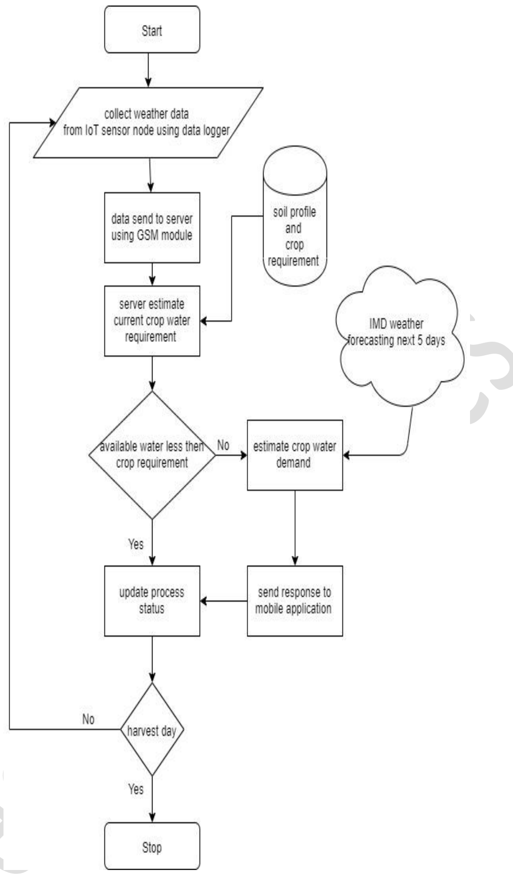

Figure 2. Flow chart of smart irrigation scheduling.

B. Data logger read sensor data:

Data logger is an electronic device that read sensor device over time and store in memory we used Campbell data logger CR100 with 16gb microSD flash memory. In this data logger consists of five sensors. There are temperature & humidity, wind speed, wind direction, solar radiation and rain gauge. Data logger read the sensor data and stored in the memory. If any issues in transferring data from data logger to server. Data logger can store up to 2 years of data in memory. Whenever network is connected it transfer all the data to the server.

C. GSM module send sensor data to web server:

GSM module read the data from memory and transfer to web server over time. It has inbuilt sim card slot. Using phone sim card with mobile data GSM module can communicate with any server. Web server IP address has been configured in GSM module. So GSM module send sensor data to web server through http protocol in every time interval.

D. *Web server retrieves the crop profile*:

Crop information has been stored in the database such crop name, planting date, crop coefficient and other crop life cycle information. It also includes land information such has soil type, soil depth, soil water holding capacity and soil test report. All this data was sorted in mysql database whenever it required server retrieve data from the mysql database. PHP program framework is used to connect server and mysql database.

E. Web server estimate crop water requirement

An algorithm is developed to estimate crop water requirement with the help of this estimation we can create irrigation scheduling. Input of this algorithm are weather data get from the sensor, Crop and land profile. Using Penman-Monteith method algorithm has been processed and give out has crop water requirement.

F. Web server response to mobile application:

Farmer mobile application is developed in android platform. Android application is developed in java and xml. Whenever famer need information about irrigation. Mobile application send request to server then server will response to mobile application request and send the irrigation scheduling based on crop water requirement.

It's based sensor network monitor the weather parameters and send the data to server through internet on daily basics. Every day server receives weather data and estimate evapotranspiration, water loss in the environment. Irrigation scheduling is based upon current soil moister, crop water requirement and field water holding capacity. It's based sensor network estimate water demand and irrigation time. Estimated irrigation scheduled instruction sends to the IoT device.

III. RESULT AND DISSUSSION

Smart irrigation scheduling is depending on the weather parameter and crop requirement. Every growth stage crop requirement is increasing and also control water loss in an environment. Using FAO Penman-Monteith equation estimating reference evapotranspiration and product of crop coefficient it will give actual evapotranspiration. Table 1 was estimating evapotranspiration from IMD weather forecasting.

The crop water requirement for the crop finger millet (1 acres) depend upon weather parameter and soil profile. The water requirement will change when weather data changes. Smart irrigation scheduling estimates, actual water demand for the particular location. It will reduce the water loss and leads to optimum water resource utilization. Irrigation varies in various crop growth stage it will increase based on crop vegetation stages. Controlling the water flow and decreasing water loss, it will indirectly reduce fertilizer loss in soil.

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Table 1. Automatic weather station sensor data, estimate evapotranspiration and crop coefficient.

Date	Air Temperature Max	Air Temperature Min	Rain fall (mm)	Win speed Avg	Wind Direction	ET0	kcb
14-06-19	32.47	38.78	26.78	24.89292	2.601	33.07	6.50135
15-06-19	33.34	37.99	28.1	23.58877	2.401	27.58	5.782087
16-06-19	32.18	39.51	27.02	23.33465	2.297	21.73	6.59337
17-06-19	32.52	38.69	26.9	24.31466	3.09	21.17	6.659024
18-06-19	32.37	38.27	26.91	23.24951	2.574	21.68	6.282041
19-06-19	32.84	38.9	26.99	24.88343	2.674	25.88	6.552347
20-06-19	31.96	37.27	27.1	23.16309	2.88	25.63	5.946978
21-06-19	30.72	34.61	27.17	18.45441	2.562	37.08	4.746552
22-06-19	29.5	37.4	25.13	17.50093	1.992	73.9	6.127368
23-06-19	26.62	35.06	23.13	NAN	1.539	59.31	5.560976

Table 2. The finger millet crop water requirement depending on weather condition.

Date	Rainfall	Demand (mm)	Demand (L)
01-11-18	0	31.08	124,311
03-11-18	0	31	123,900
06-11-18	0	30.98	123,900
09-11-18	0	31	123,982
12-11-18	0	31.24	124,943
15-11-18	0	30.81	123,230
18-11-18	0	30.41	121,628
21-11-18	0	30.68	122,724
24-11-18	0	30.43	121,716
27-11-18	0	30.49	121,947
02-12-18	0	49.64	198,555
23-12-18	0	184.31	737,257
14-01-19	0	227.46	909,844
03-02-19	0	229.88	919,521

IV CONCLUSION

This paper has established IoT technology in agriculture. Water resource management is the major problem in agriculture if more water contained in the soil also lead to decrease the crop yield and water stress also affect the crop growth. Its technology has been transformed the agricultural sector in different form. Climatic changes and resource management are the hot topic in current research. IoT technology and Artificial intelligent help to take forward research in agricultural sector. It also controls the resource exploitation. IoT technology will increase the farmer income and reduce the expenses by optimum utilization of the resources. This study is mainly focus on irrigation scheduling on time and quantity of water. Results describe when to irrigate and amount of water apply to the field.

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