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A Mathematical Model to Estimate Soil Parameters using Wireless Sensor: An Efficient Way of Data Collection in Precision Agriculture

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***Abstract:** Environmental and field parameters have high impact on agricultural productivity. The environmental parameters include temperature, humidity, rainfall and wind direction etc. whereas field parameters include salinity, nutrient content, oxygen levels, soil type, soil PH and soil moisture etc. Among them, Soil pH and moisture are highly correlated which can affect soil salinity, nutrient level and soil conductivity. So, these two parameters need to be measure precisely to take management decisions. Till now the process which is applied to measure soil parameters are entirely depends on laboratory testing of soil sample. This process has some overhead like availability of laboratory, manpower and cost. To overcome these challenges, we developed a virgin sensor based automated data collection technique which maintains the agricultural productivity with sustainable development. But practically sensor-based data retain some error which defers from laboratory result. In this paper, we have developed a new efficient technique to reduce the error in calculating pH value using sensors. In this research work, ten different types of soils are tested in laboratory to get the actual (pH level in soil. These values are considered as the ground truth for the experiment. The pH values of all the ten types of soil are collected from the field using wireless sensor. Our proposed mathematical model reduces the error to 0.01 between collected values and ground truth values with back propagation method based on soil moisture, environmental temperature and humidity. Here, the proposed model is empirically tested by taking some real field data values.*

***Keywords:** Precision agriculture; Mathematical model; Soil pH; Wireless sensor.*

I. INTRODUCTION

Agricultural productivity depends on field and environmental variability. These two parameters play a significant role to maintain quality product in agriculture. Precise estimation of these two groups of parameters is required to sustain ecological balance and manage farm according to soil and crop type. If soil parameter is very low or excessively high, then it may be harmful for the crops [1].

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A farmer cannot monitor the moisture and pH level of the soil as well as other parameters like: Environment parameter, temperature, nutrient content etc.as per the dynamic requirement. As result, most of the times it causes over or under usage of resources. It also affects the quality of the soil. Currently, the soil parameters of a land are examined in following steps: collect the soil sample from the field, dry the sample and go to the nearest agricultural office to test the soil ingredients. After so many days office informs the farmer about the result of the test. At that time the soil characteristics may change with the weather condition. Not only that, it is time consuming and requires a significant amount of man power [2]. To overcome this difficulty in agricultural practice in rural area, an automated system is developed in this paper to measure pH level considering environmental parameter and soil moisture level. It is a very easy system, which uses microcontroller (AVR board) to display the soil parameters of crops in a fully automated manner. As the soil moisture and pH are depended with each other, so it is very important to control the soil pH level and soil moisture. In case, the soil is dry then it effects on the soil parameter as example: soil moisture and ph. If the soil parameter is low the requirements of soil parameter, then the farmer can take some steps to fulfill the requirement of soil parameter. The system contains an LCD display to notice all parameter values that are arranged and a real time clock and a GSM module which sends SMS to the farmer if the parameter value will be crossed the threshold valued. This system contains an AVR board to control the full system. To notice the moisture level, the system usages a water level sensor and a moisture sensor. Various types of sensors are used to detect the soil parameters like: moisture, temperature, humidity, and pH. Depending on the value of the sensors, the AVR Microcontroller takes decision to fulfill the requirements of crop's parameter.[3] If the moisture level of soil is very low and the temperature is very high then there is essential of irrigation for plants, but irrigation's time will be selected is different for different temperature range and the requirements of crops. Because if the temperature is exact high than requirement then the evaporation rate is also very high and so we have to provide water for more time in order to achieve the appropriate moisture level in the soil. Through pH detection sensor, Soil pH is also sensed and restrained. pH of the soil is also essential issue which will affect the growth-ness of plant. Acidic or basic nature of the soil will influence the nutrient availability of the soil.

Soil nutrients. Hence there is need to measure soil pH. Depending upon the measured pH of the soil, proposals can be given to the farmer to increase various chemicals in proper way to goal the preferred pH level of the soil for decent plant growth. [4]

Automated parameter monitoring system not only reduces the manpower, but also helps in collecting accurate values of the soil parameter. It evaluates the condition of field parameter in real time. It also helps to maintain the water level of the crop as per their requirements. This sensor-based system facilitates the farmer to calculate pH level of the soil according to the environmental condition without taking the soil sample to the laboratory physically.

II. LITERATURE REVIEW

Gainwar et al. proposed the main two process through which the water is constantly losing from soil are the evaporation and plantation by transpiration both are combined together and form the name Eva-transpiration. Soil is rich with both micro and macro minerals this results in soil PH reflecting acidic and alkaline in nature. The amount of alkaline or acidic both will damage the crops. In this paper the measurement of evapo-transpiration equation as well as soil nature calculated depending upon some equations. This paper also constructs a simulation model through which the water level and the PH balance can be measured [5].

Poyen et al. build the real time water quality monitoring station in Lake manzala were mathematically investigated to calculate the regional and seasonal variation from some amount of selected water quality parameters in relation with the temperature and humidity of the air. In this paper the researcher used the Data Fit software to predict the selected water quality parameters of the lake including the PH, Dissolve Oxygen, Electrical conductivity, Total Dissolved solids, Turbidity, and the air temperature measured by the chlorophyll [6].

SaschaReth, Markus Reichstein & Eva Falge are worked with the inorganic nitrogen in the soil is the source of N for non-legume plants. They are studied the effect of soil acidity or alkaline and discovery origin mass of the field. The impact of soil temperature on Co_2 emissions was extremely important with all land-use types, except for one field campaign with constant rain [7].

Viacheslav et al. proposed mechanism for soil categorization not that much cost effective that's why new techniques invented which is named like on the go sensing techniques. These newly developed techniques combine both the soil electrical and soil pH. This was implemented in the eight-production field of six US state where the data are collected and compare with the grid sampling. After the examination it was measured that the calibration on the go technique have less than 0.3 PH in the case of non-conventional on the go technique have error more than 0.4 PH[8].

In 2011, Michael et al. has made a study to calculate the variation of pH manager under several condition of farming in field. Sensor evaluations were paralleled with data achieved by standard protocols of soil pH calculation. Experiments appropriated place under different scenarios: (a) controlled tests in the lab, (b) semi-controlled experiment on transects in a stop-and-go mode, and (c) assessments under practical conditions in the field with the sensor working in its typical on-the-go mode. [9].

III. DATA COLLECTION MODULE

To maintain the soil parameter, we use some sensors as AVR board, LED display and GSM module. All the components are showed in the block diagram which is given below as well as describe about all the components.

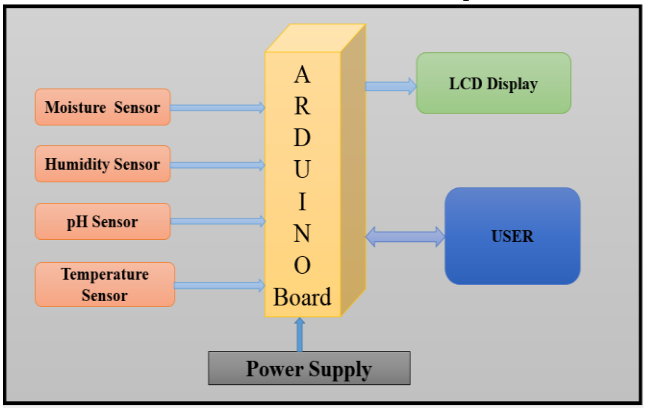

Fig. 1 : Block Diagram of Architecture

A. AVR Board

AVR board is an open-source microcontroller-based electronics platform which is used to implement hardware and software in an easy way. AVR boards are intelligent to read analogue as well as digital inputs – any environmental and soil effect on a sensor, is accepted as input and provide output on serial monitor on PC and LCD display. With respect to the output, parameters are controlled.

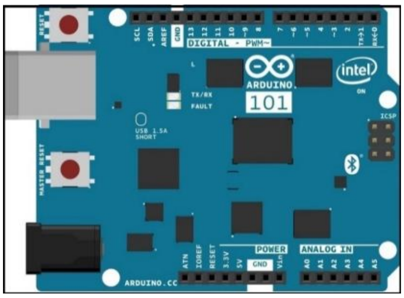

Fig. 2: AVR Board

Specification of the AVR board is given below:

Table 1: Specification of AVR Board

Microcontroller	ATmega1280
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA

Flash Memory	128 KB of which 4 KB used by boot loader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16MHz

B. Moisture Sensor

The features of the soil moisture sensor are given below:

Table 2 : Pin Configuration of Soil Moisture Sensor

Input Voltage	3.3 – 5V
Output Voltage	0 – 4.2V
Input Current	35mA
Output Signal	Both Analog and Digital

The soil moisture sensor has four pins which are given below:

Table 3: Features of soil moisture sensor

VCC	Power
A0	Analog Output
D0	Digital Output
GND	Ground

The Module holds a potentiometer which will use to set the threshold value. Depend upon threshold value, output will be controlled.

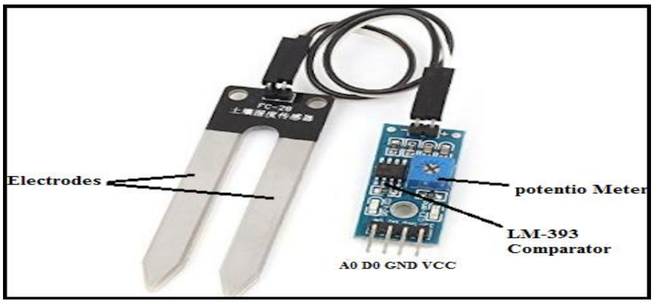

Fig. 3 : Soil moisture Sensor

C. Humidity Sensor

The DHT11 Sensors are precisely adjusted in the laboratory and the results are stored in the memory. A one wire communication can be established between any microcontroller like Arduino Mega2650 and the DHT11 Sensor. The ranges, accuracy and specification of the DHT11:

Table 4: Specification of the DHT11 Sensor

Humidity Range	20-90% RH
Humidity Accuracy	±5% RH
Temperature Range	0-50 °C
Temperature Accuracy	±2% °C
Operating Voltage	3V to 5.5V

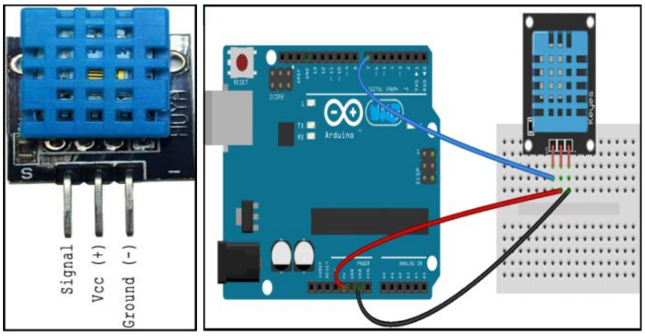

Fig. 4: Humidity sensor with Ardunio Board

D. pH Sensor

pH is a label of acidity or alkalinity of a soil solution; the pH scale ranges from 0 to 14. The pH specifies the concentration of hydrogen [H] + ions present in assured solutions. pH can precisely be measured by a pH sensor that determines the potential difference between two electrodes. We also have to implement an electronic circuit to condition the signal appropriately and we can use this sensor with a micro-controller, such as Arduino.

Pin Configuration:

Table 5: Pin Configuration of pH sensor

To	Temperature
Do	Limit pH Signal
Po	Analog pH value
G	Analog GND
G	Supply GND
V+	Supply (5V)

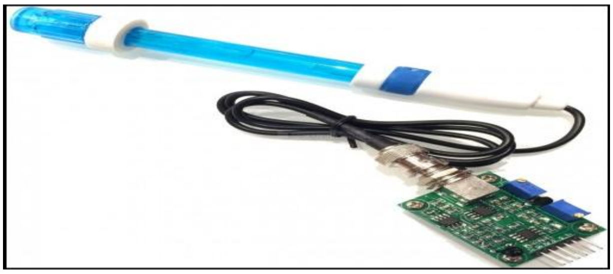

Fig. 5: pH Sensor

Specification of pH sensor:

Table 6: Specification of pH sensor

Module Power	5.00 V
Module Size	43*32 mm
Measuring Range	0-14 pH
Measuring Temperature	0-60° C
Accuracy	±0.1 pH (25 °C)
Response	≤1Min

E. Temperature Sensor

LM35 is a temperature sensor which shows the output to the temperature (in ^{o}C). Temperature can be measured more precisely than with a thermostat by using the sensor. It also retains low self-heating.

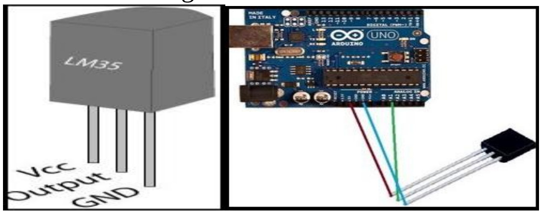

Fig. 6: Temperature Sensor with Arduino Board

F. LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module which is used with the micro-controller. These modules are ideal rather than the other multi segment LEDs. It is used in heavily for these reasons: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters, animations and so on. A 16x2 LCD means it can display 16 characters per row and there are 2 such rows.

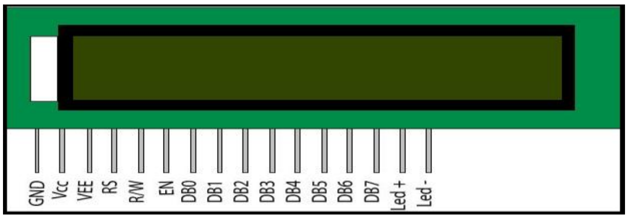

Fig. 7: 16*2 LCD Display

Table 7: Pin configuration Of Led Display

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

G. Power Supply

The power pins are as follows:

VIN: The input voltage to the Arduino board is 5 volt when it's running with an external power source. Otherwise, when it connected with the PC it takes 5 volt from the USB connection. If it can access with external power source then power jack is connected.

5V: The regulated power supply used to power the microcontroller (Atmega328p) and other components on the board. AVR board be supplied by USB or another regulated 5V supply.

3V: A 3.3-volt supply generated by the on-board FTDI chip. Maximum current draw is 50 mA.

GND. Ground pins. There are two GND pins.

H. Arduino Software (IDE)

For testing soil moisture and pH, firstly AVR code install into Arduino Mega 2650.To install the code into microcontroller, we use Arduino IDE 1.8.5. This is also helpful to monitor the serial data which is come in from sensors as analogue data.

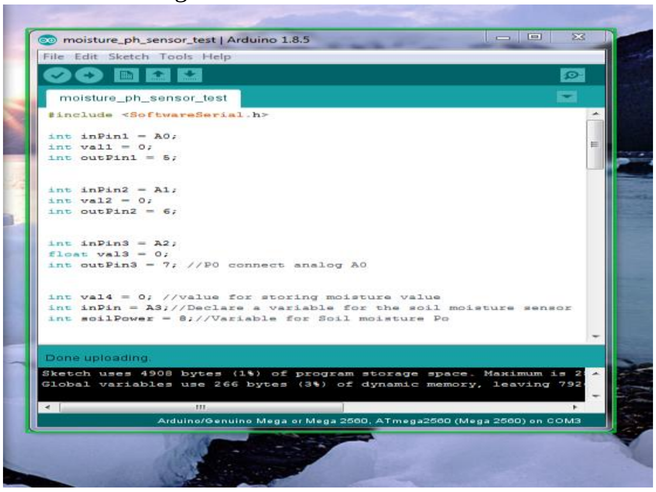

Fig. 8: Arduino IDE 1.8.5

IV. MATERIALS AND METHOD

To develop the model, we use some hardware and software which are given below one by one.

a) Arduino mega2650
b) pH sensor
c) moisture sensor (DHT11)
d) Humidity and temperature sensor
e) Arduino 1.8.5 IDE
f) Laptop

To get the accurate value of soil parameters (pH, soil moisture), there is need to maintain steps in proper order in one after another. The procedures are described below one after another:

a. Initialization the system with proper connection of the sensor with the AVR board.

b. Connect the AVR board to the PC which is preloaded by the AVR software.

c. Configure the com port and board in perfectly.

d. Switch on the power supply to turn on the system.

e. Loaded the AVR program for particular that sensors into the microcontroller of the AVR board.

f. Test all sensors work properly or not.

g. Firstly, to get actual pH value, some dry soil sample is taken and then mixed with water in proper way.

Then, soil pH sensors are inserted and get actual pH value for these types of soil.

h. Insert sensor into the soil into the field to get various value of soil moisture and pH at different place of the field as like different samples of soil.

i. The process is showed that what is the requirement of soil parameters and what is exist in the field

j. Make a mathematical model with respect to the value of the environmental humidity, temperature soil moisture and soil pH. The mathematical model is showed the relation among the actual soil pH and soil parameters: soil pH, soil moisture, environmental temperature and humidity.

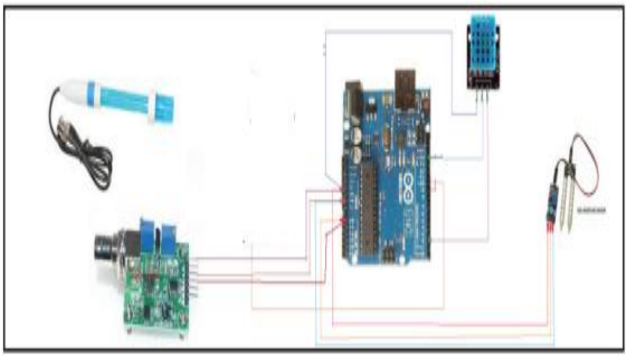

Fig. 9: Wire connection with Arduino Board and sensor

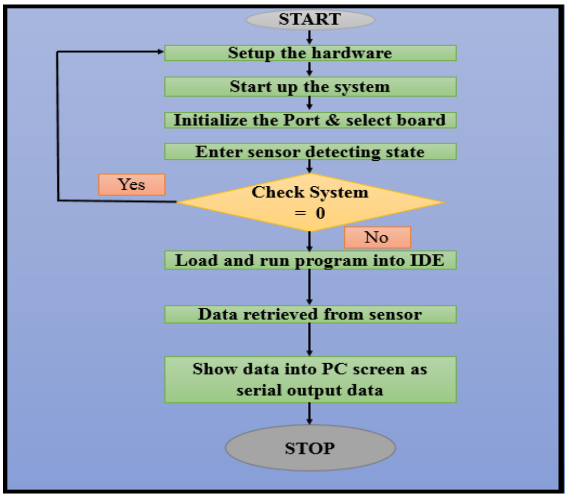

Fig. 10: Flow chart for processing

V. PROPOSED ALGORITHM FOR CALCULATION SOIL PARAMETERS: DEVELOPED BY JANA & ROY

Input:
Deployment soil moisture & soil pH sensor into the deep 1΄ to 3΄ of the soil and Humidity & Temperature sensors exist in air.

Output:
The output value of soil moisture, soil pH, humidity and temperature as Serial output are shown on the PC Screen and as well as the formulated pH.

Procedure:

Step1: if (initialization = = 1)
then,
AVR board is prepared configured with the sensors.
Else,
Serial.output = = 0 || ERROR

Step2: if (PC is connected with AVR board = = TRUE) || (power supply = = TRUE)
then, AVR board power = = ON && component LED = = 1;
else,
power cable && Component = = ERROR and go to the Step1 & recheck;

Step3: if (Arduino IDE = = open)
Then,
select AVR board version as well select COM port;
else,
Check software && reload it;

Step4: if (sensor_test = = 1)
then go to next step;
else,
go to **step 1** and check all steps again;

Step5: Deploy the sensor into the field and take the value of soil moisture and pH & environmental humidity and temperature which are shown in the pc screen as serial output data.

Step6:
Calculation: Formulated the soil pH level depend on another parameter, according to Equ (6).

Step7: Deploy the sensor for another types of soil and continued the process.

VI. MATHEMATICAL MODEL

The Mathematical model is defined by using the relation among the environmental parameter and soil parameter: Soil moisture, pH, Humidity and temperature. These four parameters are defined as follows:

A. Soil pH

Soil Parameter, pH value, is the negative logarithm of the molar concentration of hydronium ions aH+ in the solution and is described by equation as follows:

pH = - log(aH+)

The soil pH is calculated by the given way when we use the pH sensor:

$$\mathbf{pH(X) = pH(S) +} \frac{E(S)-E(X)}{R \times \frac{T}{F\log 10}} \quad \text{.............} \quad \text{Equ.(1)}$$

Where,
R: The Gas Constant
T: The thermodynamic temperature
F: The faraday Constant
pH(X): Unknown pH value of the solution
pH(S): Known pH value of the Standard solution.
E(S) and E(x) explain the electrode potential of a pH cell containing a standard solution with known pH value.

B. Soil Moisture

The soil moisture is determined by using a probe that is installed into the field in the deep of 1’ to 3’. If the water content of the soil is changed then it gave an effective effect on the Capacitance(C) of the soil.

The capacitance(C) is calculated by the given way:

$$C = \varepsilon_r \varepsilon_o \frac{A}{d} \quad \text{.................................} \quad \text{Equ(2)}$$

Where,
C: Capacitance
A: Overlapping area of the plates
d: Distance between the plates
εr: Dielectric Constant of the materials inside the plate
εo: Dielectric constant

Soil moisture has always stay between 0 and 100%. By using capacitance, we determined moisture level as follows:

$$M_o = (C+1123) / 10 \quad \text{............................} \quad \text{Equ(3)}$$

C. Environmental Temperature

Voltage at pin of the sensor = (Reading from ADC) * (5000/1024)

When, sensor is connected to the 5000 mv= 5 v

Voltage at pin of the sensor = (Reading from ADC) * (3300/1024)

When sensor is used in 3300 mv= 3.3 v

Where,
ADC: Analogue data from sensor

So, the temperature measurement in centigrade is calculated as follows:

Centigrade temperature (t_c)
= [(Analogue voltage in mv) - 500]/10 .... Equ.(4)

D. Environmental Humidity

When we use the humidity sensor DHT11,the relative Humidity is determined as follows

$$R_H = \left(\frac{\rho w}{\rho s}\right) \times 100\% \quad \text{..............................} \text{Equ(5)}$$

Where,
RH: Relative Humidity
ρw : Density of water vapor
ρs : Density of water vapor saturation

If the soil is dry, then sensor cannot retrieve any data on pH value. After giving some water in the soil i.e. crossing the threshold value of moisture level of the soil, the pH value is retrieved from the sensor. When we increased the soil moisture level then the pH value of the soil is decreased. So, it is showed that the pH and soil moisture are inversely proportional with each other (pH ∝ 1/Mo). The formulated pH of the soil is calculated as follows:

1st Part: The 1st part is defined by adding the sensor pH with the '1' which is divisible by value of soil moisture (As pH ∝ 1/Mo). One constant (Z) is multiplied with the soil moisture value for minimizing the error which is the difference between Actual pH (ApH) and Sensor pH (pH).

2nd Part: Since tc∝ 1/Mo and pH ∝ 1/Mo
So, pH∝tc
Since, pH ∝ 1/Mo
So, pH*Mo = Constant

Again, Environmental humidity (RH) and temperature (tc) are related inverse proportional way with each other. So,
RH ∝ 1/tc
i.e; RH*tc = Constant

But, soil parameters (pH, Mo) and environmental parameters (RH, tc) are not directly related. So, to minimize the error between Actual pH (ApH) and Sensor pH (pH), multiplication of environmental parameters (RH*tc) is divided by multiplication of the soil parameters (pH*Mo). The equation is defined by

$$(RH*tc)\ \left\{\frac{1}{L\times Mo\times pH} - \frac{1}{K}\right\}$$

With respect to these the parameters which are described in above, a mathematical model is defined as

$$A_{pH} = \left\{pH + \left(\frac{1}{Z\times Mo}\right)\right\} + (RH*t_c)\ \left\{\frac{1}{L\times Mo\times pH} - \frac{1}{K}\right\} + E_r \quad \text{..............} \quad \text{Equ. (6)}$$

Where,
ApH: Actual pH of the soil solution
pH: Standard pH of the soil solution
Mo: Value of soil moisture
RH: Environmental Humidity
Mo: soil moisture
tc: Centigrade temperature
Z: constant (value: =10)
K: Constant (Value: =1000)
L: Constant(Value:=480000)
Er: Error = ± 0.01

VII. RESULT AND ANALYSIS

A soil sample that is self-possessed of ten sub-samples (10 replicates) to represent the selected soil properties at each sampling is carried out by using sensors with Arduino daily for the duration of ten days. The soil samples were taken randomly with consideration on field condition such as landscape, land morphology, area coverage management technique, vegetation cover and others.

For analyzing the data, we take 10 subsamples from ten different fields in daily basis. From Every subsamples, we retrieved the data using sensor. In this way we have taken 100 subsample in 10 days from ten different fields. The ten type's soils are: Very strongly alkaline soil, strongly alkaline soil, Moderate Alkaline, Slightly alkaline, sand soil and five types of clay soil.

In this section, the actual pH level of the soil is compared with the pH value measured using sensor for each soil type. The relation is shown in the graph of Fig.11. We have shown that "how the standard pH level of soil is related with the pH level measured with sensor and how pH is affected by soil moisture, environmental humidity & temperature".

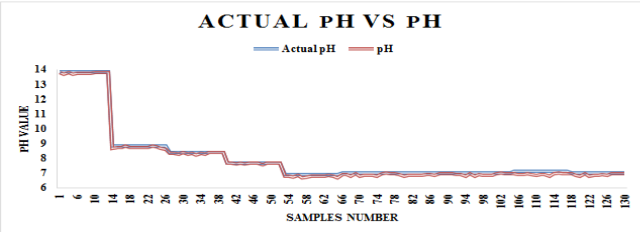

Fig. 11: Graphical Representation Actual pH Vs pH with sensor

In this section, the actual value pH value of soil is compared with the calculated pH value which is determined from in our mathematical module. The relation is shown in the graph of Fig.12.

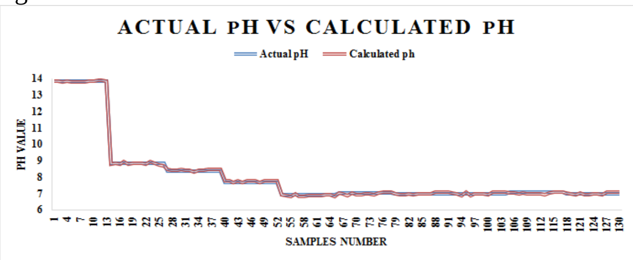

Fig. 12: Graphical Representation Actual pH Vs calculated pH with sensor

The two above figure shows that difference between Standard pH value and normal pH value.But the Actual pH Vs calculated pH shows the very low difference between standard pH value and pH value which is calculated using the mathematical model. According to this model, the error is ±0.01 which is very low and can be considered as system error. Fig. 13 clearly shows that the difference between actual pH level of the soil and pH sensor value is about 0.1106. Whether the difference between actual pH level and calculated pH value with the mathematical model is about 0.0073 which is less than the previous one.

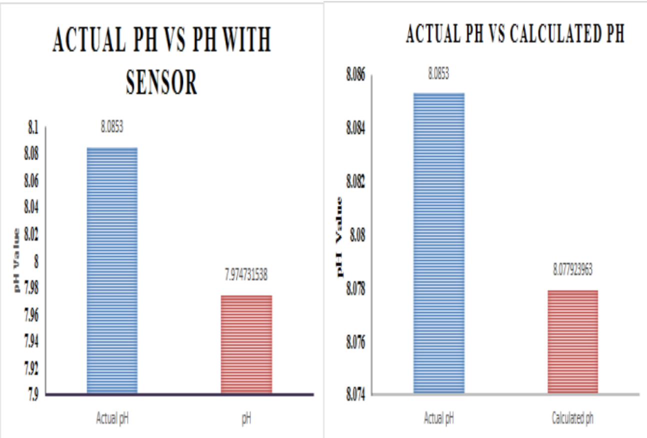

Fig. 13: Bar Chart Representation Actual pH Vs pH with sensor and calculated pH

In this section, we have shown the graphical representation of soil moisture and pH value for very strongly alkaline soil. The graph in Fig. 14 shows the change of pH level with respect to the soil moisture level. For very strongly alkaline soil, the range of pH value is 13.7 to 13.82. This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

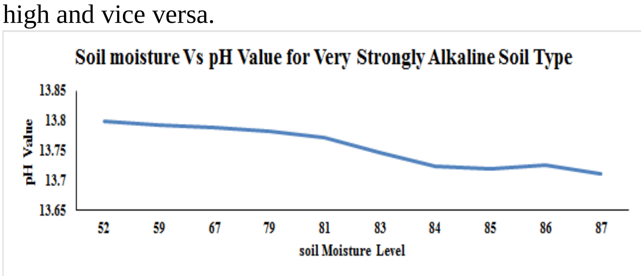

Fig. 14: Graphical Representation Soil moisture Vs pH for very strongly alkaline

In this section, we have shown the graphical representation of soil moisture and pH value for strongly alkaline soil. The graph in Fig. 15 shows the change of pH level with respect to the soil moisture level. For strongly alkaline soil, the range of pH value is 8.615 to 8.754. This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

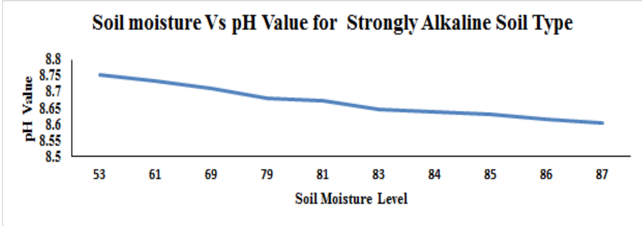

Fig. 15: Graphical Representation Soil moisture Vs pH for strongly alkaline

In this section, we have shown the graphical representation of soil moisture and pH value for moderate alkaline soil. The graph in Fig. 16 shows the change of pH level with respect to the soil moisture level. For moderate alkaline soil, the range of pH value is 8.301 to 8.38. This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

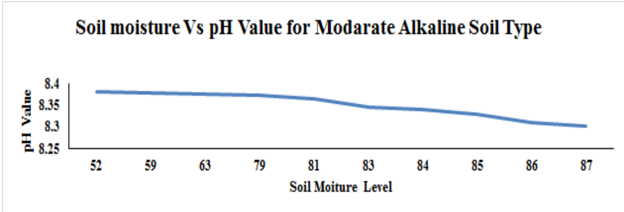

Fig. 16: Graphical Representation Soil moisture Vs pH for modarated alkaline

In this section, we have shown the graphical representation of soil moisture and pH value for slightly alkaline soil. The graph in Fig. 17 shows the change of pH level with respect to the soil moisture level. For slightly alkaline soil, the range of pH value is 7.613 to 7.683. This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

In this section, we have shown the graphical representation of soil moisture and pH value for sand soil. The graph in Fig. 18 shows the change of pH level with respect to the soil moisture level. For sand soil, the range of pH value is 6.713 to 6.83. This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

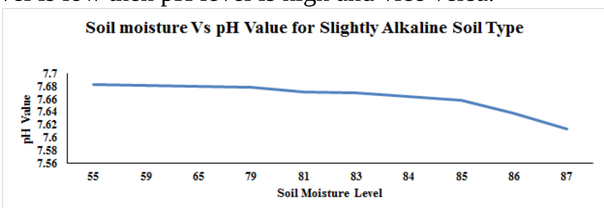

Fig. 17 : Graphical Representation Soil moisture Vs pH for slightly alkaline

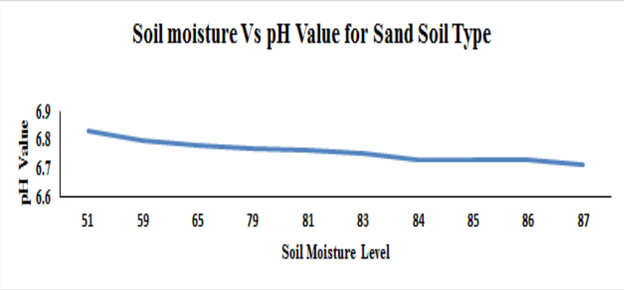

Fig. 18: Graphical Representation Soil moisture Vs pH for sand soil

In this section, we have shown the graphical representation of soil moisture and pH value for clay_type (1) soil. The graph in Fig. 19 shows the change of pH level with respect to the soil moisture level. For clay_type (1) soil, the range of pH value is 6.813 to 6.99 This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

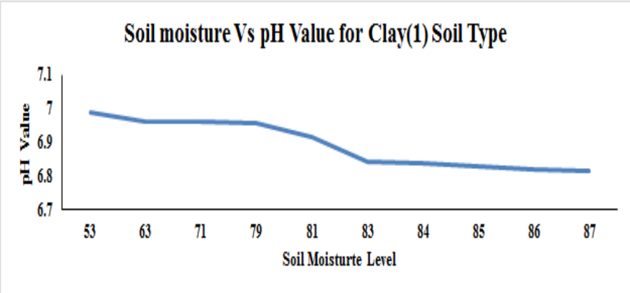

Fig. 19: Graphical Representation Soil moisture Vs pH for very Clay_type1

In this section, we have shown the graphical representation of soil moisture and pH value for clay_type (2) soil. The graph in Fig. 20 shows the change of pH level with respect to the soil moisture level. For clay_type (2) soil, the range of pH value is 6.831 to 6.988 This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

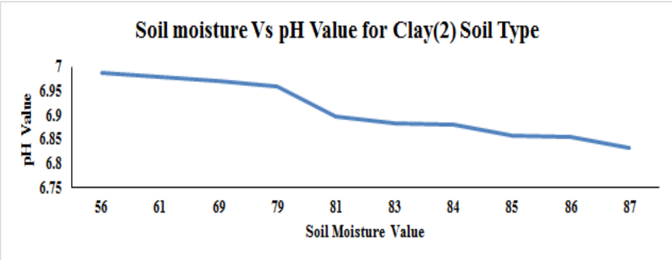

Fig. 20: Graphical Representation Soil moisture Vs pH for clay_type2

In this section, we have shown the graphical representation of soil moisture and pH value for clay_type (3) soil. The graph in Fig. 21 shows the change of pH level with respect to the soil moisture level. For clay_type(3) soil, the range of pH value is 6.831 to 6.988 This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

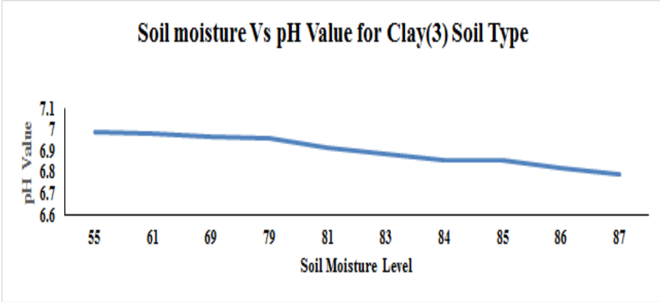

Fig. 21: Graphical Representation Soil moisture Vs pH for clay_type3

In this section, we have shown the graphical representation of soil moisture and pH value for clay_type(4) soil. The graph in Fig. 22 shows the change of pH level with respect to the soil moisture level. For clay_type(4) soil, the range of pH value is 6.802 to 6.99 This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

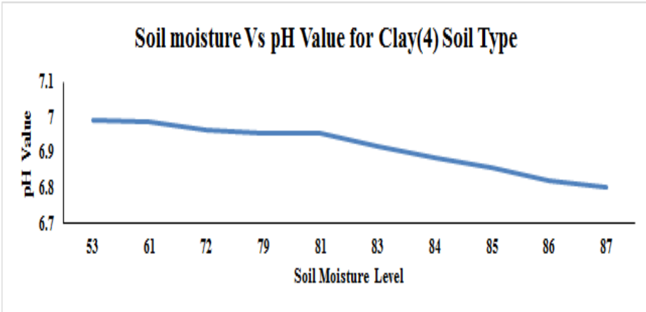

Fig. 22: Graphical Representation Soil moisture Vs pH for clay_type4

In this section, we have shown the graphical representation of soil moisture and pH value for clay_type(5) soil. The graph in Fig. 23 shows the change of pH level with respect to the soil moisture level. For clay_type(5) soil, the range of pH value is 6.807 to 6.979 This graph depicts that the soil pH and moisture level are inversely proportional to each other. When soil moisture level is low then pH level is high and vice versa.

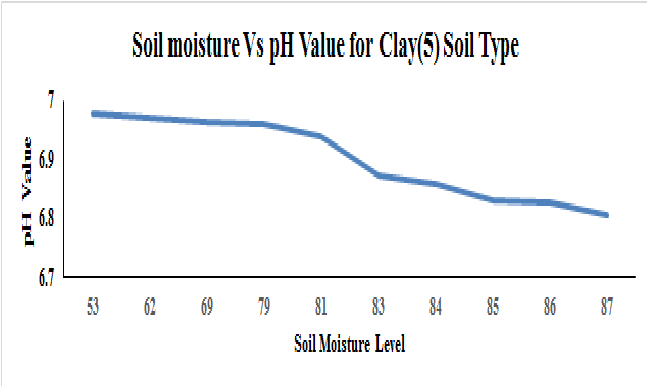

Fig. 23: Graphical Representation Soil moisture Vs pH for clay_type5

Table 8: Mean, Median and standard deviation for sensor_pH,Formulated_ph, Actual_pH for all types of soil

Soil Type	Mean			Median			Standard Deviation		
	Actual pH	Sensor pH	Formulated pH	Actual pH	Sensor pH	Formulated pH	Actual pH	Sensor pH	Formulated pH
Very Strongly Alkaline	13.87	13.7543	13.85094	13.8	13.746	13.84183	$3.69778*E^{-15}$	0.033720381	0.035018
Strongly Alkaline	8.854	8.7273	8.828548	8.854	8.73	8.829901	$2.54789*E^{-15}$	0.061503596	0.061056
Modarate Alkaline	8.389	8.3391	8.387974	8.389	8.346	8.446764	$1.84889*E^{-15}$	0.042003663	0.043688
Slightly Alkaline	7.689	7.6561	7.693653	7.689	7.69	7.772238	$77334*E^{-15}$	0.035074291	0.0364484
Sand Soil	6.932	6.7715	6.884512	6.932	6.773	6.876482	$9.2445*E^{-16}$	0.047188656	0.048336
Clay_type 1	7.01	6.8926	6.996051	7.01	6.884	6.987431	$9.2445*E^{-16}$	0.066968132	0.069022
Clay_type 2	7.003	6.8915	6.997731	7.003	6.879	6.982247	$8.0945*E^{-16}$	0.06269053	0.06482
Clay_type 3	7.001	6.8981	7.005822	7.001	6.885	6.988929	$6.2745*E^{-16}$	0.069651329	0.071688
Clay_type 4	7.102	6.9215	7.024943	7.102	6.919	7.022354	$2.77334*E^{-15}$	0.051359093	0.053392
Clay_type 5	7.003	6.8949	6.996062	7.003	6.88	6.9833249	$2.2445*E^{-16}$	0.067347929	0.06939

Table 8 represents the summary statistics of the pH values according to the soil type. The difference among actual pH level, sensor value and calculated pH value is shown with respect to mean, median and standard deviation. The differences among these summary statistics reveal that the proposed mathematical model results in more accurate pH value calculation than original sensor value.

We make the Mathematical data model depend upon some retrieving data. To prove the mathematical model is true for very large number of significance data, we make the t-test by using MATLAB.T-test(also known as**Student's t-test)**, in statistics, a method of testing hypotheses about the mean of a small sample-drawn from a normally distributed population when the population standard deviation is unknown. After t-test, if the result is lies between 0.5 and 1.0, then the model is significant for any number of significant data. The result of t-test of our model is 0.867. So, the model is also true for any number of significant data.

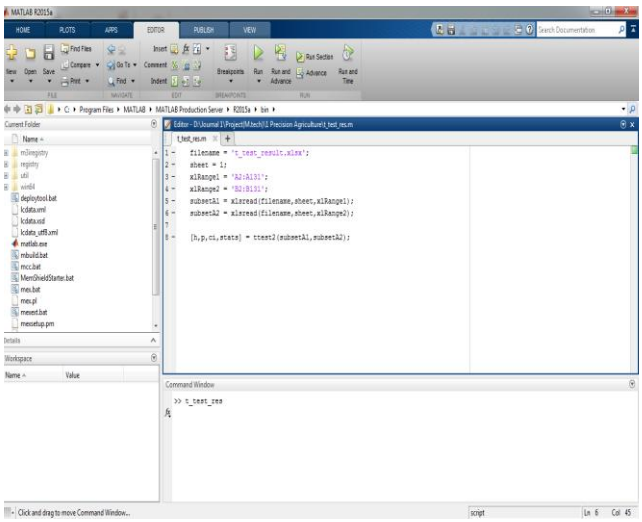

Fig. 24: t-test in MATLAB

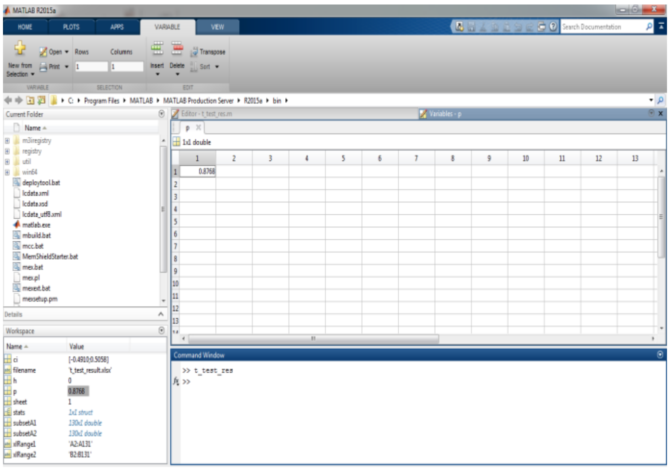

Fig. 25: t-test result in MATLAB

VIII. CONCLUSION

In this study we proposed a prototype model to estimate actual pH level based on field (soil type, moisture and current pH level) and environmental parameters (relative humidity and temperature). For this study ten types soil are considered. These are – Very strongly alkaline, strongly alkaline, moderated alkaline, sand and five different types of clay. The standard pH value for these ten types of soils is collected from laboratory testing to prepare the ground truth. Then soil pH values are collected with the soil pH sensor under practical field conditions for all these soil types. A mathematical model is proposed that reduces the error between standard pH and calculated pH value with respect to field and environmental parameter with back propagation. At each level of back propagation error between these two values are minimized. Some of this error is due to the wrong measurements caused by machine-driven problems. For enhancing post-processing, the driver should be accomplished to set a flag at the calculation point where the problem had happened. In spite of these enhancements, it can be predictable that individual calculation of an automated machine-driven system in the field will be errorless than pH values derived from soil analysis in the lab as well as less effort of man power.

Former tests under precise conditions demonstrated an extraordinary grade of linear relationship between actual soil pH values and pH values which retrieved from pH sensor. Though, these experiments also exposed that additional calibration is necessary soil parameters to reduce errors when expecting pH ($CaCl_2$).

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