Monitoring and Control of Various Agricultural Parameters Using IoT Based Module

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Abstract - ***India is a land of agriculture, and it is called as the support system of the country which contributes a huge amount in the GDP. Still, the agriculture industry suffers from many challenges as climate change, lack of proper and advanced system of monitoring the fields with latest technology. Unlike other developed or developing countries India is still in need of advanced technology which helps the farmers to uplift the farming and boost productivity. In this paper, various sensors are assembled at one platform along with microcontroller ATMega328P that is used to create an advanced model which is based on IoT (Internet of Things). This model is further used in mobile app development which helps the farmers to monitor and control the various agricultural parameters. However, the app can be further converted to desktop system-based monitoring for bigger projects of agriculture.***

Keywords: IoT based, agricultural, sensors, salinity, crop production

1. INTRODUCTION

In India, agriculture doesn't only produce food but also offers a huge number of work opportunities to its rural residents. More than 58% of Indian population depends on agriculture for their livelihood. Who are still affected by a lot of problems in agriculture like lack of monitoring and control of the crops, which ultimately results in less productivity. Today, there are numerous gadgets and technologies are present which helps in monitoring the crops and improve their productivity. Generally, a smart system is created to monitor how much the crops need water, air, moisture, light etc.[1] In this area drones are also useful to help farmers monitor the crops, but it has certain limitations as it can't detect the inside features of the soil as the moisture or salinity or pH of the soil. So, an IoT based smart monitoring system is much useful for farmers to their monitoring and improvement of the crops.[2] Farmer today use several different devices to measure these agricultural parameters like soil moisture, humidity, water level, salinity etc separately which is time taking and cost effective.[3] Hence, with the help of the suggested model, an IoT based smart agriculture monitoring and control system is designed which aims at increasing agricultural productivity with the help of various sensors. This system uses various sensors to monitor the different surrounding conditions like moisture, humidity, and salinity and fertilizer's level in real time and through a microcontroller, the data is processes and transmitted finally to an android based app straight to the farmer's mobile phone, according to which he takes required action timely. The designed system is affordable and easy to operate by farmers. The whole system has other benefits also like the decrease in the need of labour. Due to the sensors involved, the accurate measurement can be taken, and the requirement of the manpower reduces. It will be cost effective to the farmers as well. The app has been digitalized but concentrated to be user friendly.[4]

The entire systems work in symphony so that the farmers' decisions will lead to increased crop yields, reduced costs, and improved profitability. Due to temperature sensor, this system could be useful for lands where temperature is keep changing. There are many IoT based smart agricultural devices are available in the market these days. But the farmers are still facing the issue of buying various set of systems that respond to different parameters which makes the monitoring difficult and takes more time, energy, and money. However, this research is a step ahead to make all the essential agricultural parameters available altogether at one platform which saves the time, energy, and money of the farmer. The resultant system will solve all these issues with higher accuracy in less time. This will lead to higher and improved production of crops. In this paper, an android based app is developed to monitor the crops with IoT based sensor system. The mobile application is quite easy to use for farmers. They can easily operate it and control the issues of irrigation, moisture, salinity, fertilizers need etc.

This application is constructive for farmers to early figuring out the issues related to the predefined agricultural parameters and monitor it. Farmers can also take primitive actions based on application recommendation to control the issues coming up with the land and soil in near future. This whole system can help the farmers to get the better quality of the crops. Table 1 shows the comparative study in a literature review.

Table 1: Comparative study in a literature review

Authors / Year	Work Detail	Platform	Findings
Rab Nawaz Bashir, Imran Sarwar, Muhammad Zahid Abbas, Amjad Rehman and Tanzila Saba[5] - 2022	Developed the system which provides IOT assisted salinity mapping at irrigation scheme level in the agriculture field. Used Bland Altman difference plot for comparison Portable and easy to carry	Web	Not Wi-Fi enable, no remote sensor, no app integration, no automation Manual operations
Archana P. Patil, Abhay B. Shelar, and Sagar M. Gawande[6] – 2020	Developed a system for analysing soil moisture in different soil.	Web	No app integration and Wi-Fi, manual control
Rab Nawaz Bashir, Imaran Sarwar Bajwa and Malik Muhammad[7]	IoT-assisted solution to determine soil salinity level and environment conditions to recommend irrigation water, with a purpose to leach down the salts from the root zone of crops in saline soils.	Web	The proposed model shows only 85% accuracy, and the data will be collected by the framer on the mobile phone via SMS, no app integration
Manoj A. Patil1, Amol C. Adamuthe and A. J. Umbarkar[8] - 2020	Proposed an arrangement which incessantly gathers real-time data from the adjacent situation over sensors. IoT technology is used to observe the plant situation over sensor information that works on parameters viz. soil humidity, leaf dampness period, pH level, temperature, and moisture. Incessantly monitoring of conservational circumstances shown to agriculturalists on mobile application	App based	Leaf wetness is not required by other cereal plants Other than that, only moisture temp and pH No testing of fertilizer
Sujatha Anand Catherine. J Shanmuga Priya. S and A. Sweatha[9] - 2019	Designed a system in which nutrients testing and monitoring of agricultural field systems.	Web	Only LED display , GSM SMS service, no app integration

2. RELATED WORK

One of the researchers' groups have designed and implemented a water quality monitoring system in aquaculture that will be implemented in SME.[10]
Similarly, a system for CO_2 along with other parameters has also been studied for onion farming in this system the author detects the different parameters of framing like PH, nutrient etc.[11] These data can be collected by farmers via IOT. In similar objectives, a system is focused in managing excess waterlog in the farmland and analyse the availability of micronutrients using IoT has been proposed[12]. Also, similar research found in systems with is developed mainly to monitor the behaviour of soil moisture, air humidity and air temperature to prevent crop damage where mostly it is not integrated with a mobile application. After the comprehensive literature review, it can be assessed that there are many smart agricultural systems have been planned but most of them have issues as- no app integration, lack of enough agricultural parameters, time consuming and costly etc. There are many approaches available in the market before IoT based ones. Those includes lab based chemical analysis, Electro Magnetic Induction methods (EMI)[13], and the Remote Sensing (RS) devices. But those are not suitable as Lab testing methods are accurate, but time consuming and costly

and EMI devices are costly and requires expert knowledge to operate and maintain while RS approach is only suitable for large geographical areas[14]

3. METHODOLOGY

To overcome all the issues with previous methods while retaining the cost effectiveness, accuracy and time saving capabilities, the prototype is being proposed. The study implements and evaluates it to identify the accuracy and cost effectiveness.

3.1. Architecture

The architecture is based on an Arduino based model system developed to monitor and control several agricultural parameters as temperature, humidity, salinity, pH etc which is shown in fig. 1 . This system uses an 8-bit microcontroller, and a Wi-Fi enables chip. ATmega328P is used as the microcontroller which is high in performance and yet low in power consumption which makes it perfect fit for such agriculture low-cost product.

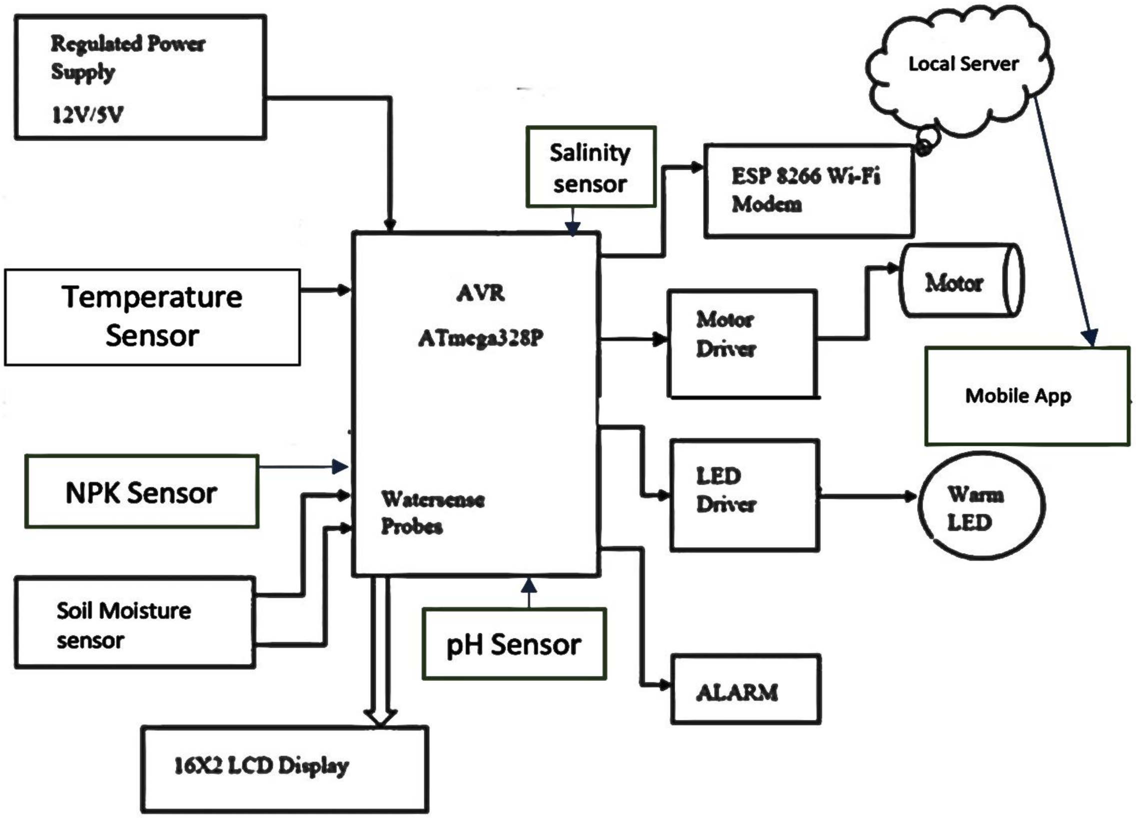


Fig : 1 Block Diagram (System architecture)

After careful selection, the server has been chosen as the local server instead of cloud server because the local server has increased performance since the data is stored and accessed on the same machine. It has faster loaded times and fewer errors. It is more secure since it keeps your data from being exposed to the public internet. It is cheaper than cloud hosting since you don't have to pay for the extra storage and bandwidth. It is more reliable since there is no risk of a service outage due to a third-party provider.

The working of the system starts with the soil parameters. The sensors capture data from the land and sent to the controller. Then the controller compares this information with the previously set parameters (as shown in table 2).

Sensors	Unit of Measurement	standard value-wheat	Standard value-rice
Temperature sensor	degree Celsius	20^{o}-25^{o} C[15]	21^{o}-37^{o} C[19]
NPK Sensor			

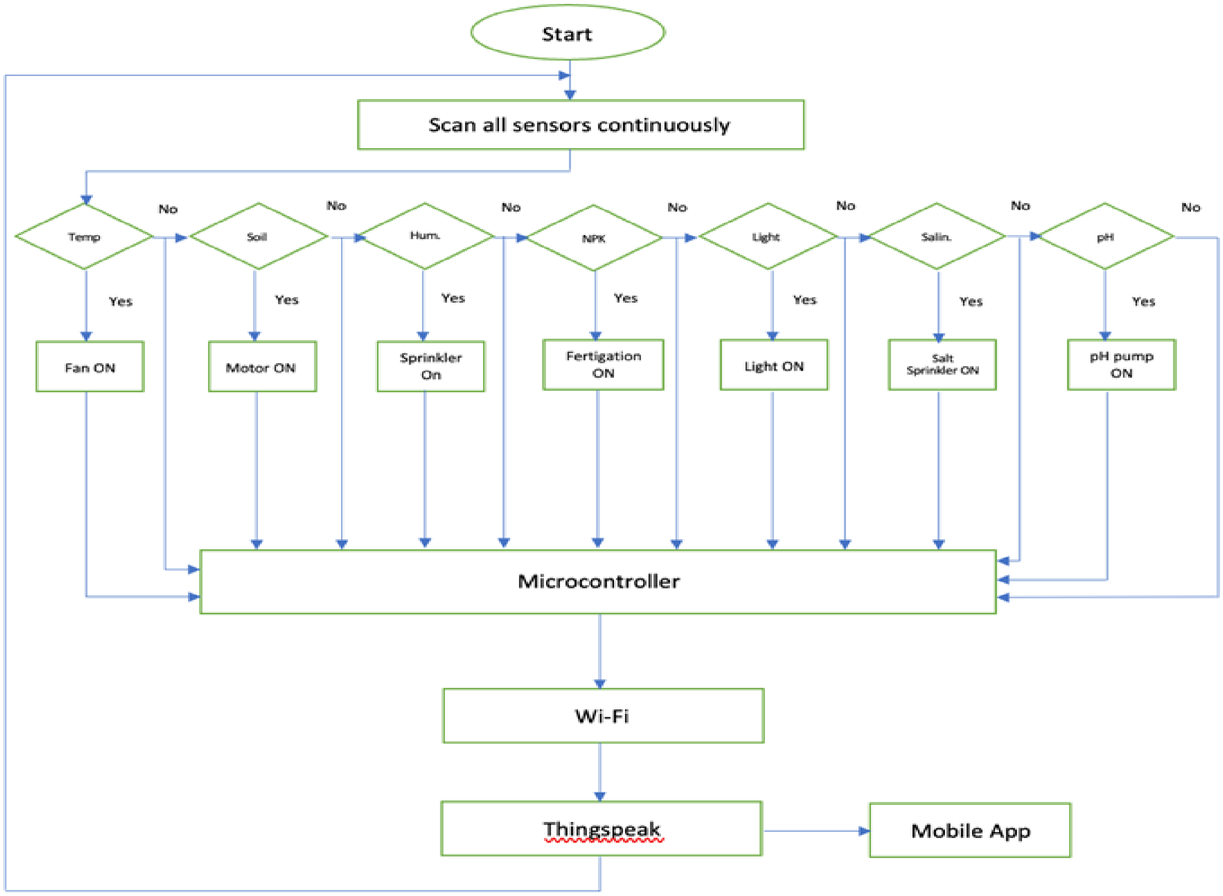
Nitrogen	Kg	120 kg/hectare[15]	50 kg/acre[20]
Potassium	Kg	30 kg/hectare [15]	12 kg/acre [20]
Phosphorus	Kg	60 kg/hectare[15]	12 kg/acre [20]
pH Sensor	scale of 1 to 14	6-7.5 [16]	5.5-6.5 [21]
salinity sensor	Deci-Siemens per metre (dS/m)	>7 dS m^{-1} [17]	1.9-3 dS/m [22]
moisture sensor	water frame by volume (wfv or m3m-3)(Ø)	50-60% [18]	50-75% [23]

Table : 2 Sensors and Their Standard Values

The crops have been chosen based on major crops selection by Indian farmers – Wheat and Rice.

The functioning of the prototype starts with the soil parameters (sensors). These sensors capture data from the land and sent to the controller. Then the controller compares this information with the previously set parameters as shown in table 2.

Now if the values of the parameters are beyond the threshold point then the consequent device is in ON state. For example, if the temperature of the field is compared to the standard value in the micro controller and if it is beyond the threshold point then the fan gets ON or if the soil moisture of the field is compared to the standard value in the micro controller and if it is beyond the threshold point the water motor gets ON. Similarly, if the humidity of the field is compared to the standard value in the micro controller and if it is beyond the threshold point the sprinklers gets ON and so on for the other sensors. Then the values acquired from the sensors are sent to the thing speak IOT web page through Wi-Fi module and is represented in a graphical format which is further connected to the GSM mobile based app to the end user. Once the values reach to the standard level, the devices will automatically turn off. On a standard level, it takes around 15 seconds to upload information of each sensor and this process repeats as cycle as shown in the flowchart below.



Flow Chart : 1

3.2. Features of the Prototype

1. It is value for money as compared to the EMI and RS-based other systems are available, in terms of initial cost and operating cost.
2. The proposed solution is applicable to map soil salinity, temperature, moisture, pH, and fertilizers(NPK) level in agriculture.
3. The prototype of the system is portable so that it can be hurriedly redeployed through the grassland, without any cost.
4. The data about the soil salinity, temperature, moisture, pH, and fertilizers (NPK) level is stored at a local server which is accessible by farmers.
5. The prototype system can be used regularly in a cost- effective method.
6. The prototype system can be effectively used for monitoring and control of salinity, temperature, moisture, pH, and fertilizers (NPK) level

3.3. System Details

The equipment used to implement the proposed solution is the soil salinity sensor, pH sensor, temperature sensor, moisture sensor and NPK sensor shown in Fig.2 .

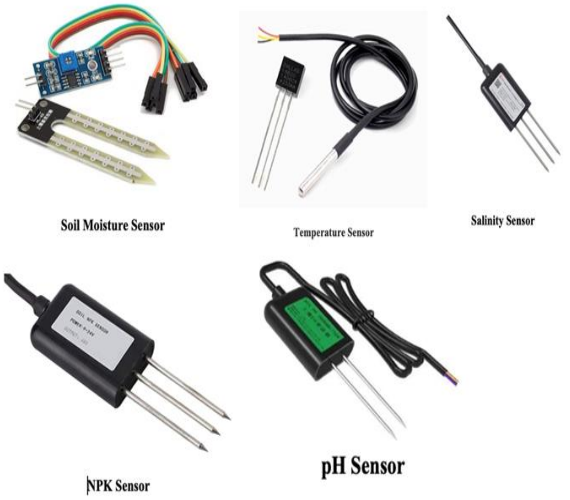


Fig 2 : sensors

These are inexpensive, commercially presented sensors. These sensors are configured with an Atmega328P is a single-chip microcontroller based on an 8-bit RISC processor core. Fig: 3 shows a small microcontroller is low-powered and affordable.

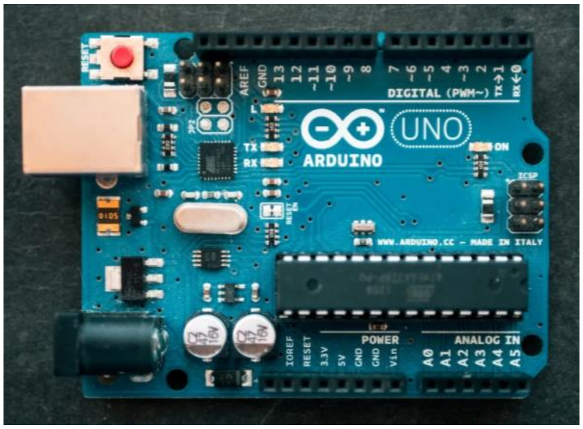


Fig : 3 Atmega328P is a single-chip microcontroller

The captured data are displayed on the display unit and then transported to the local server for broaden administering, storing, and investigation purpose. Figure 4 shows the assembled prototype.

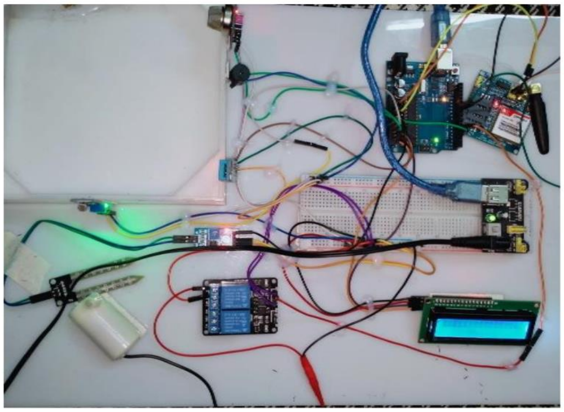


Fig : 4 Prototype system

4. EVALUATIONS

The prototype system purposes to plot the soil salinity, temperature, moisture, pH, and fertilizers (NPK) level correctly and profitably. The accurateness of the prototype system in soil salinity, temperature, moisture, pH, and fertilizers (NPK) level plotting is matched with the laboratory-based chemical analysis method, which is the prevailing technique for agricultural parameters evaluation. For experimentation, a region of one acre with 207 feet in length and width is selected, which is relentlessly affected by soil salinity, temperature, moisture, pH, and fertilizers (NPK) level shown in Fig.5 In this land, 64 sample are taken to observe by both methods- standard method and with the prototype system, so that the difference of the accuracy can be observed.

Fig : 5 Experimental land

For experiment, the land is equally divided in 64 parts and one part is of 8 x 8 feet in length and width. One by one all the sensors (in the prototype) would be inserted and taken the values from each sample. The next step is to identify the comparison of the prototype system with the standard method and determine the accuracy for the selected agricultural parameters of soil salinity, temperature, moisture, pH, and fertilizers(NPK) level.

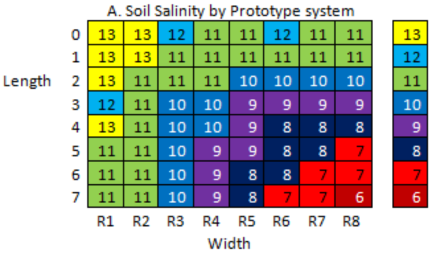
5. ANALYSIS AND DISCUSSION

In this part, a descriptive analysis is presented to understand the comparison of the prototype system and the standard system which could explain why this prototype is accurate, cost effective and reliable than the chemical analysis laboratory method.

5.1. Accuracy comparison

5.1.1. Accuracy of Soil salinity

The prototype system's salinity mapping displays the annotations in the trial area at 64 sampling points in part "A," and by the standard method in part "B" of Fig.6 . It is detected that salinity values in the trial region are higher on one side of the designated area as matched to the other directions by both types of annotations. The salinity annotations by the prototype system's salinity mapping and standard method display analogous values at most of the sixty-four sample points in the trial area, shown in Fig.6.



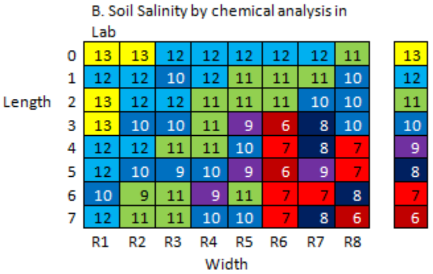
A. Soil Salinity by Prototype system

Length	R1	R2	R3	R4	R5	R6	R7	R8
0	13	13	12	11	11	12	11	11
1	13	13	11	11	11	11	11	11
2	13	11	11	11	10	10	10	10
3	12	11	10	10	9	9	9	9
4	13	11	10	10	9	8	8	8
5	11	11	10	9	9	8	8	7
6	11	11	10	9	8	8	7	7
7	11	11	10	9	8	7	7	6

Width

Fig 6 : A

Fig 6 : B



B. Soil Salinity by chemical analysis in Lab

Length	R1	R2	R3	R4	R5	R6	R7	R8
0	13	13	12	12	12	12	12	11
1	12	12	10	12	11	11	11	10
2	13	12	12	11	11	11	10	10
3	13	10	10	11	9	6	8	10
4	12	12	11	11	10	7	8	7
5	12	10	9	10	9	6	9	7
6	10	9	11	9	11	7	7	8
7	12	11	11	10	10	7	8	6

Width

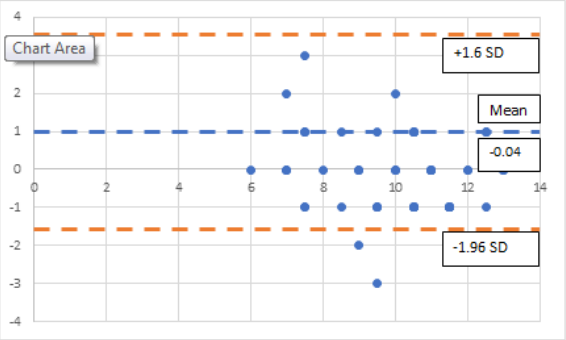


Fig. 7 : Bland Altman difference plot for Soil Salinity observations

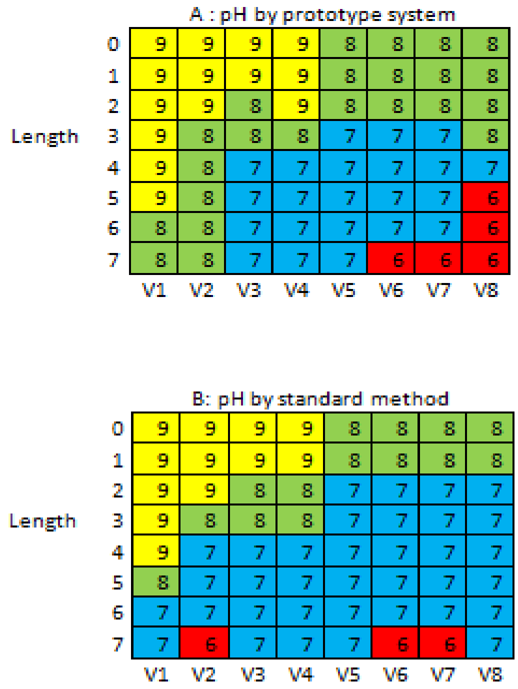
The Bland–Altman difference plot is used to uncover the alteration in salinity mapping by two methods. To examine the difference in observation by two methods, the Bland–Altman difference plot is drawn in Fig.7. The difference in observation of two methods is plotted against the mean of two observations in Fig.7.

It is observed that the mean difference between the salinity observation by the prototype system's salinity mapping and the standard method is − 0.04 for each sampling point. Thus, the bias between the two methods for salinity observations is − 0.04 for each sample point. This means that the proposed IoT-assisted salinity mapping, on average, measures 0.04 less salinity than the standard method of soil salinity for each sample point observation. Thus, the bias between the prototype system's salinity mapping and the standard method is very low. The bias can be used to standardise the prototype system's salinity mapping(S) by Eq.1, where Sm is observed S, and Sc is the standardised S.

$$Sc = Sm + 0.04 \qquad (1)$$

5.1.2. Accuracy of pH observations

The pH annotations by the prototype system are shown in part “A” and by the standard method of chemical analysis in part “B” of Fig.8. Both techniques show similar pH annotations at utmost points. Both techniques perceived the pH in the series of 6–9 at each of 64 sample points in the designated trial zone.



A : pH by prototype system

Length	V1	V2	V3	V4	V5	V6	V7	V8
0	9	9	9	9	8	8	8	8
1	9	9	9	9	8	8	8	8
2	9	9	8	9	8	8	8	8
3	9	8	8	8	7	7	7	8
4	9	8	7	7	7	7	7	7
5	9	8	7	7	7	7	7	6
6	8	8	7	7	7	7	7	6
7	8	8	7	7	7	6	6	6

B: pH by standard method

Length	V1	V2	V3	V4	V5	V6	V7	V8
0	9	9	9	9	8	8	8	8
1	9	9	9	9	8	8	8	8
2	9	9	8	8	7	7	7	7
3	9	8	8	8	7	7	7	7
4	9	7	7	7	7	7	7	7
5	8	7	7	7	7	7	7	7
6	7	7	7	7	7	7	7	7
7	7	6	7	7	7	6	6	7

Fig. 8

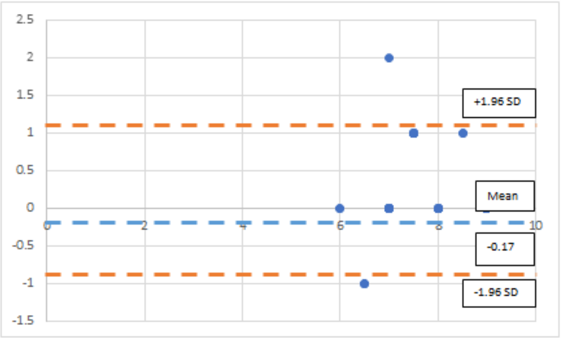


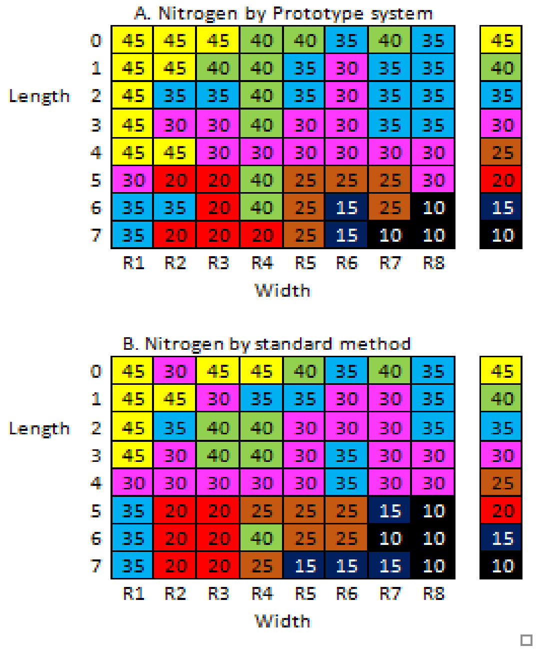
Fig .9 : Bland Altman difference plot for pH observations

The Bland–Altman plot in Fig.9, displays the mean variance in pH annotations for 64 sample point annotations by both the prototype and standard methods. The mean variance for the pH annotations by the prototype system and standard method is − 0.17. Thus, the bias amid the two methods for pH annotations of soil pH is − 0.17. The bias − 0.17 in pH annotations, means that the prototype system, on average, measures 0.17 less pH than the chemical method of pH for each sample point annotations. Thus, the bias between the prototype system and the standard method is low for pH observations. The bias can be used to standardise the prototype system by Eq.2, where pHm is the observed pH, and pHc is the standardised pH.

$$pHc = pHm + 0.17 \qquad (2)$$

5.1.3. Accuracy of NPK observations

The NPK (separately for Nitrogen, Phosphorus and Potassium) annotations by the prototype system are displayed in part “A” and by the standard technique of chemical examination in part “B” of Fig.10, 11 and 12 respectively. Both techniques display similar NPK annotations at most of the sample points.



A. Nitrogen by Prototype system

Length	R1	R2	R3	R4	R5	R6	R7	R8	
0	45	45	45	40	40	35	40	35	45
1	45	45	40	40	35	30	35	35	40
2	45	35	35	40	35	30	35	35	35
3	45	30	30	40	30	30	35	35	30
4	45	45	30	30	30	30	30	30	25
5	30	20	20	40	25	25	25	30	20
6	35	35	20	40	25	15	25	10	15
7	35	20	20	20	25	15	10	10	10

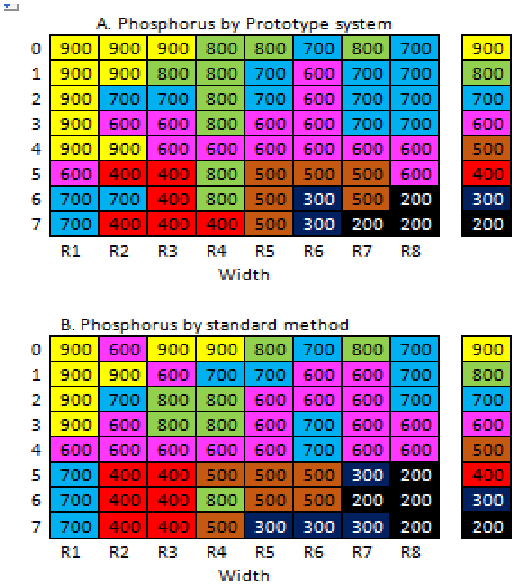
Width

B. Nitrogen by standard method

Length	R1	R2	R3	R4	R5	R6	R7	R8	
0	45	30	45	45	40	35	40	35	45
1	45	45	30	35	35	30	30	35	40
2	45	35	40	40	30	30	30	35	35
3	45	30	40	40	30	35	30	30	30
4	30	30	30	30	30	35	30	30	25
5	35	20	20	25	25	25	15	10	20
6	35	20	20	40	25	25	10	10	15
7	35	20	20	25	15	15	15	10	10

Width

Fig. 10



A. Phosphorus by Prototype system

	R1	R2	R3	R4	R5	R6	R7	R8	
0	900	900	900	800	800	700	800	700	900
1	900	900	800	800	700	600	700	700	800
2	900	700	700	800	700	600	700	700	700
3	900	600	600	800	600	600	700	700	600
4	900	900	600	600	600	600	600	600	500
5	600	400	400	800	500	500	500	600	400
6	700	700	400	800	500	300	500	200	300
7	700	400	400	400	500	300	200	200	200

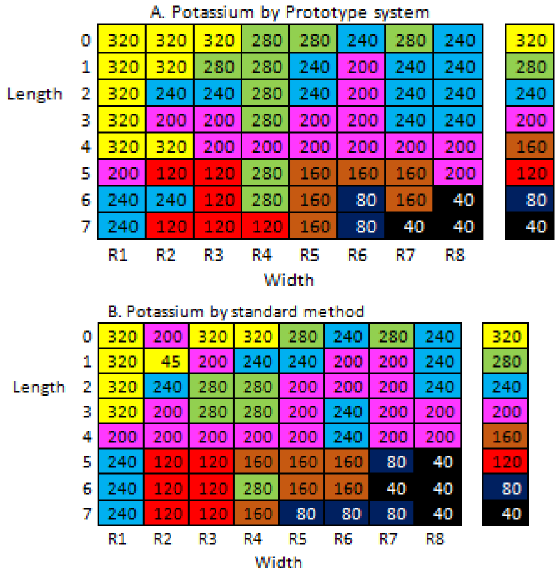
Width

B. Phosphorus by standard method

	R1	R2	R3	R4	R5	R6	R7	R8	
0	900	600	900	900	800	700	800	700	900
1	900	900	600	700	700	600	600	700	800
2	900	700	800	800	600	600	600	700	700
3	900	600	800	800	600	700	600	600	600
4	600	600	600	600	600	700	600	600	500
5	700	400	400	500	500	500	300	200	400
6	700	400	400	800	500	500	200	200	300
7	700	400	400	500	300	300	300	200	200

Width

Fig.11



A. Potassium by Prototype system

		R1	R2	R3	R4	R5	R6	R7	R8	
	0	320	320	320	280	280	240	280	240	320
	1	320	320	280	280	240	200	240	240	280
Length	2	320	240	240	280	240	200	240	240	240
	3	320	200	200	280	200	200	240	240	200
	4	320	320	200	200	200	200	200	200	160
	5	200	120	120	280	160	160	160	200	120
	6	240	240	120	280	160	80	160	40	80
	7	240	120	120	120	160	80	40	40	40

Width

B. Potassium by standard method

		R1	R2	R3	R4	R5	R6	R7	R8	
	0	320	200	320	320	280	240	280	240	320
	1	320	45	200	240	240	200	200	240	280
Length	2	320	240	280	280	200	200	200	240	240
	3	320	200	280	280	200	240	200	200	200
	4	200	200	200	200	200	240	200	200	160
	5	240	120	120	160	160	160	80	40	120
	6	240	120	120	280	160	160	40	40	80
	7	240	120	120	160	80	80	80	40	40

Width

Fig. 12

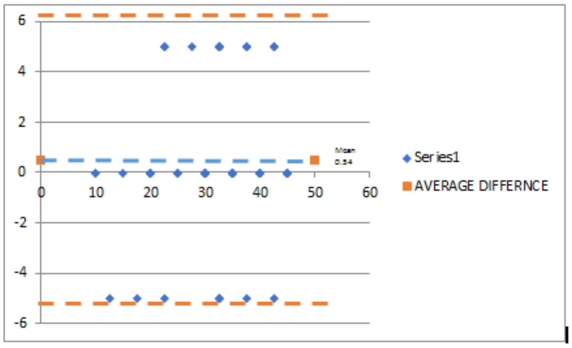


Fig.13 : Bland Altman difference plot for Nitrogen (N) observations

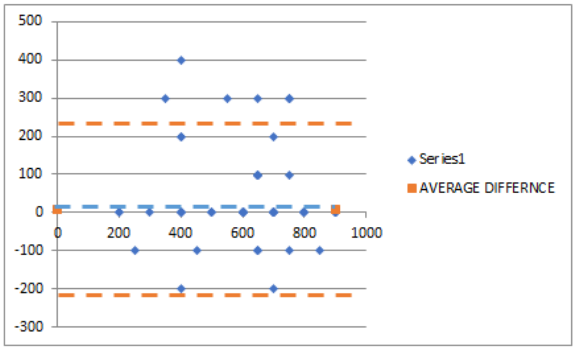


Fig.14 : Bland Altman difference plot for Phosphorus (P) observations

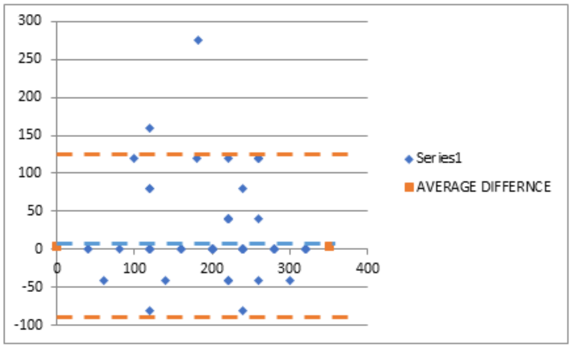


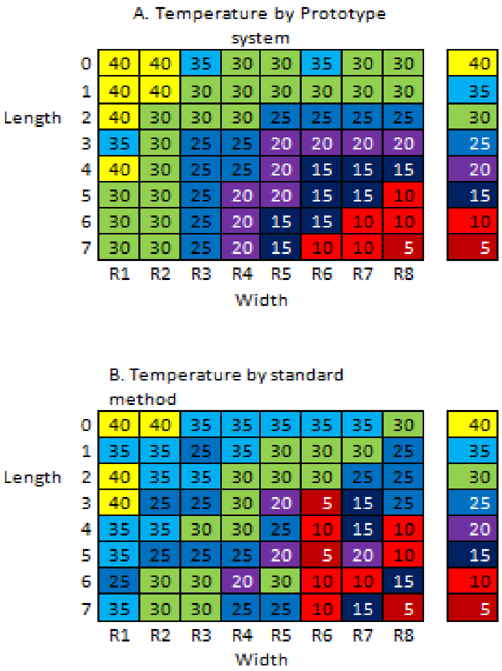
Fig.15 : Bland Altman difference plot for Potassium (K) observations

The Bland–Altman plot in Fig.13,14 and 15 respectively displays the mean difference in NPK annotations by both the prototype and standard techniques. From Fig.13, 14 and 15, it is detected that the mean difference for NPK annotations by the prototype system and standard method of NPK is −0.54, -35.93 and -18.67 respectively. The bias of is −0.54, -35.93 and -18.67 in NPK annotations means that the prototype system, on average, measures 0.54, 35.93 and 18.67 less than the laboratory method for each of the 64 observations. Thus, the bias between the prototype system and the standard method is low. The bias is used to standardise the prototype system by Eq.3, where NPKm is observed NPK, and NPKc is the standardised NPK.

$$NPKc = NPKm + (0.54, 35.93, 18.67) \qquad (3)$$

5.1.4. Accuracy of Temperature observations

It is observed that the mean difference between the temperature observation by the prototype system and the standard method is − 0.93 for each sampling point.



A. Temperature by Prototype system

Length	R1	R2	R3	R4	R5	R6	R7	R8
0	40	40	35	30	30	35	30	30
1	40	40	30	30	30	30	30	30
2	40	30	30	30	25	25	25	25
3	35	30	25	25	20	20	20	20
4	40	30	25	25	20	15	15	15
5	30	30	25	20	20	15	15	10
6	30	30	25	20	15	15	10	10
7	30	30	25	20	15	10	10	5

Width

40
35
30
25
20
15
10
5

B. Temperature by standard method

Length	R1	R2	R3	R4	R5	R6	R7	R8
0	40	40	35	35	35	35	35	30
1	35	35	25	35	30	30	30	25
2	40	35	35	30	30	30	25	25
3	40	25	25	30	20	5	15	25
4	35	35	30	30	25	10	15	10
5	35	25	25	25	20	5	20	10
6	25	30	30	20	30	10	10	15
7	35	30	30	25	25	10	15	5

Width

40
35
30
25
20
15
10
5

Fig.16

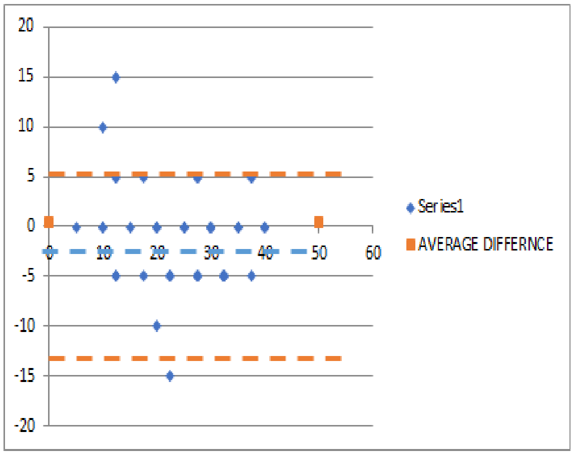


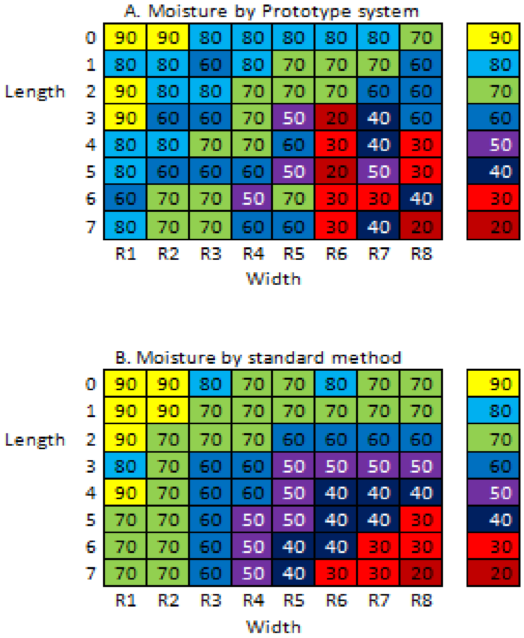
Fig.17 : Bland Altman difference plot for Temperature observations

Thus, the bias between the two methods for temperature observations is − 0.93 for each sample point. This means that the prototype system, on average, measures 0.93 less temperature than the standard method of temperature for each sample point observation. Thus, the bias between the prototype system and the standard method is very low. The bias can be used to standardise the prototype system by Eq.4, where Tm is observed T, and Tc is the standardised T.

$$Tc = Tm + 0.93 \qquad (4)$$

5.1.5. Accuracy of Moisture observations

The moisture annotations by the prototype system are displayed in part "A" and by the standard technique of chemical examination in part "B" of Fig.18. Both techniques display similar moisture annotations at most of the sample points.



A. Moisture by Prototype system

Length	R1	R2	R3	R4	R5	R6	R7	R8
0	90	90	80	80	80	80	80	70
1	80	80	60	80	70	70	70	60
2	90	80	80	70	70	70	60	60
3	90	60	60	70	50	20	40	60
4	80	80	70	70	60	30	40	30
5	80	60	60	60	50	20	50	30
6	60	70	70	50	70	30	30	40
7	80	70	70	60	60	30	40	20

Width

90
80
70
60
50
40
30
20

B. Moisture by standard method

Length	R1	R2	R3	R4	R5	R6	R7	R8
0	90	90	80	70	70	80	70	70
1	90	90	70	70	70	70	70	70
2	90	70	70	70	60	60	60	60
3	80	70	60	60	50	50	50	50
4	90	70	60	60	50	40	40	40
5	70	70	60	50	50	40	40	30
6	70	70	60	50	40	40	30	30
7	70	70	60	50	40	30	30	20

Width

90
80
70
60
50
40
30
20

Fig.18

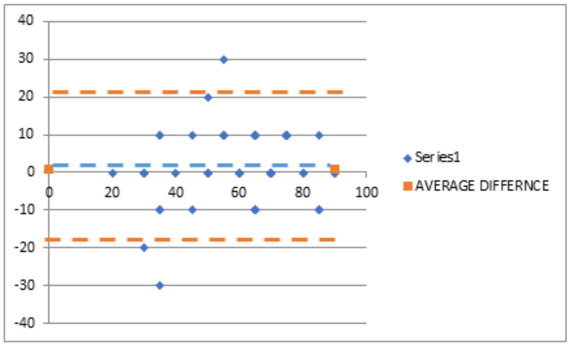


Fig.19 : Bland Altman difference plot for Moisture observations

The Bland–Altman plot in Fig.19 displays the mean difference in moisture annotations by both the prototype and standard techniques. From Fig.19, it is detected that the mean difference for moisture annotations by the prototype system and standard method of moisture is – 1.90. The bias of – 1.90 in moisture annotations means that the prototype system, on average, measures 1.90 less than the laboratory method for each of the 64 observations. Thus, the bias between the prototype system and the standard method is low. The bias is used to standardise the prototype system by Eq 5, where Mm is observed M, and Mc is the standardised M.

$$Mc = Mm + 1.90 \qquad (5)$$

6. COST ANALYSIS

6.1. Cost Comparison

The cost of the proposed solution is compared against the existing methods of soil monitoring systems in terms of installation cost and operational cost. The installation cost is a one-time cost that covers the cost of equipment and related software and accessories.

The installation cost of the proposed solution is 300 US$, which is much lower as compared to the chemical analysis, EMI devices, and RS- based solutions that cost very high. The operational cost of the proposed solution is around 0.2 US$ that is very low as compared to other solutions. The cost of the different soil monitoring systems is summarized in the Table 2. It is observed that the installation and operational cost of the chemical analysis, EMI devices, and RS is much higher than the proposed solution. Hence the proposed solution is cost-effective against the existing solutions.

Method	Installation cost (US $/device)	Operational cost (US $/sample)
Chemical Analysis	1500	2.31
EMI Devices	10970	9.32
Remote Sensing	20000	1000
Proposed IoT based system	300	0.2

Table 3: Cost Comparison of different solutions

The approximate cost of the proposed system is $300. Amongst previous works, Bashir et al3 proposed a system which costs $1000 but without Wi-fi enabled, no remote sensor, no app integration, no automation, and manual operations. While Novita et al4 designed and implemented a water quality monitoring system in aquaculture that will be implemented in SME which costs $83.79 but it has only water quality management.

Whereas Raju et al19 developed the system mainly to monitor the behaviour of soil moisture, air humidity and air temperature which costs around $383 but it only measure moisture air humidity and temperature, no app integration.

Also, Bhanarkar & Korake20 proposed a system which displays the analog data on the coordinate window read by the system, and this received data could be shared with mobile and the internet which costs around $543 but it is only for grapes, only moisture, no app integration.

6.2. Cost analysis of the device prototype

No.	Components	Quantity	Unit	Price ($)	Total Price	Life span (Years)
1	Temperature sensor	1	Piece	2.98	2.98	2
2	pH sensor	1	Piece	20.44	20.44	2
3	Soil salinity sensor	1	Piece	48.84	48.84	2
4	Moisture sensor	1	Piece	1.11	1.11	2
5	NPK sensor	1	Piece	46.88	46.88	2
6	LCD (16x2)	1	Piece	6.9	6.9	2
7	Atmega 328p	1	Piece	3.01	3.01	3
8	Modem Wi-Fi	1	Piece	20.69	20.69	3
9	Micro SD Card	1	Piece	5.17	5.17	3
10	SD card shield Arduino	1	Piece	3.45	3.45	3
11	Power supply	1	Piece	3.45	3.45	3
12	Box panel	1	Piece	4.14	4.14	3
13	Buzzer Circuit	1	Piece	2.39	2.39	3
14	transistor driver			1.38	1.38	3
15	app development			64.94	64.94	
16	Android based mobile phone			63.89	63.89	
					299.66	

Table 4 : Cost analysis of the device prototype

7. CONCLUSION

IoT based smart agricultural system in the agricultural land is proposed to monitor and control various agricultural parameters for the development of better and improved crop production. The developed prototype access the agricultural parameters via various sensors as for soil salinity, pH, temperature, NPK and moisture. This prototype, with the help of android app can map all the agricultural parameters on single platform in a portable, cost effective and accurate way. The data about soil salinity, pH, temperature, NPK and moisture are transferred, stored, and processed at a local server which is easily accessible for the farmers on mobile phone via android app . The prototype is accurate in terms of all the agricultural parameters when compared with the standard chemical analysis laboratory method.

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