IoT-Based Decision Making of Irrigation and Fertilizer Management for Marginal Farmers in Bangladesh

Wahid Anwar, Tanvir Quader, Mudassir Zakaria, and Md. Motaharul Islam

Abstract With the current advancement of IoT and information technology, there are many solutions related to agriculture and soil condition monitoring. It is very important that these solutions need to be tailored as per the area and climate that the farmers are working in. The government of Bangladesh has also initiated many projects with specific goals and objectives to make agriculture more advanced in order to achieve the sustainable development of the country. But, there are limitations to getting efficient outcomes from these projects, as many services are not interconnected yet. This paper demonstrates a model for monitoring the soil condition of farming land, where a farmer can easily know the need for irrigation or fertilizer usage in his field. This model focuses on the affordability of the device for the farmers, and it also minimizes the utilization of devices.

Keywords IoT · Farming · Farmer · Soil · Moisture · Fertilizer

1 Introduction

IoT nowadays has become an integral part of doing everyday tasks. More and more home appliances, cars, and electronics have included IoT as an attractive feature. In this project, our goal is to provide marginal farmers with the means of technology solutions that are intelligent enough to monitor and compute optimal results for them.

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We say optimal results in terms of countrywide soil quality and crop wise need for irrigation and fertilizer management [3].

We plan to integrate data sources maintained by the government and from different releasing organizations. In different parts of the country, the practice of growing crops is different due to differences in climate, soil texture, and other influential factors. Based on these factors, the government of Bangladesh has divided the total arable area into 14 main regions. So we need to contextualize the national agricultural knowledge for a specific area [14].

In this paper, we expect that the Upazilla Agriculture Officer will contribute to contextualizing this knowledge for his Upazilla. Based on this Upazilla-based agriculture knowledge, we can analyze our reading and provide an intuitive answer to the farmers. This device will be handheld. Farmers will carry this to different sections of their cultivated land and take several readings. A similar technique of collecting data from several positions to recommend a suitable crop has been described in the paper [6] written by Larry Elikplim et al. When analysis is completed, the device will show the recommendations on an LCD monitor.

There are some key components which will increase the usage of this solution. Easy-to-use handheld sensor devices can help marginal farmers for monitoring crop and use of data sources from national services, like—soil and fertilizer recommendation from Soil Research Development Institute (SRDI), Fact-sheet of different crop variety from different releasing organization for example—Bangladesh Rice Research Institute (BRRI), Bangladesh Sugarcrop Research Institute (BSRI), Bangladesh Institute of Nuclear Agriculture (BINA), Agriculture Universities etc. Recommending the need of irrigation and fertilizer is widely worked on topic by the scholars as we can see in the work [13] of Alfian Ruslan et al.

We will construct our device to be a simple one, so that the farmers can easily carry it to the field. Our design does not include multiple sets of sensors, rather farmers will carry the device to different parts of their field and collect the readings. This will help reduce the cost of the overall solution. Firstly, less number of equipment will be needed. And Farmers School (10k), Farmers Club (30k), and Farmer Information and Advise Center (FIAC, 5k) can afford this easily. Secondly, farmers or entity responsible for maintaining the device will have to work on less number devices. We can see in most of the papers [9, 13, 17] the number of sensors is not considered a major issue. But, in our design we considered how to use less sensors as the amount of land our farmers own are of small sizes. This design will also increase the durability of the devices, as people will be able to easily check on its status. The major contributions to this paper are given below:

- We have proposed to integrate the data sources from Soil Research Development Institute (SRDI), fact-sheets of different crop varieties from different releasing organizations like Bangladesh Rice Research Institute (BRRI), Bangladesh Sugarcrop Research Institute (BSRI), Bangladesh Institute of Nuclear Agriculture (BINA), and agriculture universities.
- We proposed contextualizing national agricultural knowledge for a specific region.

- We have proposed to incorporate weather information for analyzing the recommendation.
- We have constructed a handheld device that will be used for soil condition sensing and showing recommendations.
- We have also proposed building an intelligent recommendation system for individual crops based on local agricultural knowledge. Once the data has been collected by the sensors, the system will analyze it to make an appropriate recommendation regarding irrigation and fertilizer usage.

The rest of the paper has been organized as follows: Sect. 2 describes the literature review and gap analysis. Section 3 demonstrates the methodology. And finally, Sect. 4 concludes the paper.

2 Literature Review

We have gone through several papers. Among them, some of them, we found, are to be very contemporary with our topic. First is the work of Larry Elikplim et al. They worked to take readings in five places and suggest suitable crops [6]. Also, they used a commercially available soil moisture sensor, FC-28. Again, in the work of Abdullah Na et al. determination of soil temperature is done using the DS18B20 sensor working on the Dallas one-wire protocol [10].

In the project "Smart agriculture to measure humidity, temperature, moisture, pH, and nutrient values of the soil using IoT" by Asadi Venkata Mutyalamma, Gopisetty Yoshitha, Althi Dakshyani, and Bachala Venkata Padmavathi, Arduino is used with various sensors to monitor the different stages of plant cropping like moisture, temperature, humidity, pH value, and nutrients of the soil [12]. They are using the Arduino Uno model with the GSM module to help with the processing, transmission, and reception of data between sensors and the microcontroller [1].

Objective of the study "Determination of soil moisture using various sensors for irrigation water management" by Praveen Barapatre and Jayantilal N. Pate is to examine and analyze prototyping an organized calibration and working of various soil moisture sensors. Outputs of this study indicate IoT-based soil moisture detection is an effective method that provides reliable front data that can be used to adapt and improve irrigation and precision farming methods [2, 4, 5].

In the journal "2017 International Conference on Energy, Communication, Data Analytics and Soft Computing, ICECDS 2017" by Manish Bhimrao Giri and Ravi Singh Pippal, they showed that wireless sensor networks provide a very optimal solution for water distribution using interpolation methods [7].

The study, "The IoT-Based Monitoring Systems for Humidity and Soil Acidity Using Wireless Communication", aims to create a pH and humidity monitoring system for agriculture's soil with wireless sensor network technology based on IoT. The monitoring system is able to display pH and soil moisture values in real time. Compared to commercial soil analyzers, the average error value of the soil pH sensor is equal to 1.66% and the YL69 sensor error average is 1% [8].

In another work, we evaluated "IoT-Based Soil Condition Monitoring Framework" by Selvakumar Manickam, discussed how IoT can help determine suitable crop for a land and also managing nutrient level by applying appropriate fertilizer [9]. Various sensors were used to measure temperature, moisture and light, humidity, and pH value for this project. The MCP3204 ADC was used to collect the data from sensors and then sent to cloud.

In the paper "Development and application of cell phone-based Internet of things (IoT) systems for soil moisture monitoring", Jose O. Payero, Michael W. Marshall, Bhupinder S. Farmaha, Rebecca Hitchcock Davis, and Ali Mirzakhani Nafchi developed and field tested affordable cell phone-based IoT systems for monitoring soil moisture. These IoT systems would be accurate, affordable for small farmers, robust under normal field conditions, reliable, and easy to use [11].

In the project "IoT soil monitoring based on lora module for oil palm plantation", Ahmad Alfian Ruslan, Shafina Mohamed Salleh, Sharifah Fatmadiana, Wan Muhamad Hatta, Aznida Abu, and Bakar Sajak worked to provide a solution to overcome the manual monitoring system used by the workers for a very long time. Their system will ensure the increased productivity and efficiency of the planter at the tip of their fingers [13].

Mrs. Shwetha designed and developed the system, which measures water quality using sensors such as pH sensors, temperature sensors, moisture sensors, and turbidity sensors in conjunction with the Raspberry Pi. The measured quality by sensors is transmitted to the Raspberry Pi, and then it is sent to the controlling center through the Internet. This IoT system allows the user to access the data from the database through the website and provides the advantages of improved accuracy, efficiency, and low cost [15].

In the work of P. Divya Vani and K. Raghavendra Rao, they showed how a low-cost soil moisture sensor with a CC3200 LaunchPad can be used to measure the soil condition [16]. They collected two types of soil, namely red and black, from the field and carried out experiments at room temperature. For moisture level measurement, the FC-28 soil moisture sensor was used. Finally, the data was uploaded to AT & Ts' M2X Cloud. This data is made available through web and mobile applications.

In the project "IoT-based soil moisture measuring system for Indian agriculture", V. Vanitha, Rajat Kumar Dwibedi, Ben Painadthu, Kiran Venugopal, and Aby Varghese Thomas provided a soil moisture sensor system to test and monitor soil humidity with the Node MCU system. The two major parts are the moisture measuring system and the mobile application for better user experience. The data is accessed by the mobile application whenever required. The mobile application would be made generic for the other sensors, and the required security would be provided at the user level. They also created a cloud-based platform that allows users to query soil moisture of any land resource from their smartphones [17].

Most of the papers we have gone through have mainly focused on the IoT solutions for irrigation or gathering nutrients needed in a field. But, it is very important to base the irrigation suggestion on the soil texture of our country. Also, the need for nutrients must be based on the variety of crops our farmers produce. In Fig. 1, we have shown how we plan to fill the gap by using IoT with national data sources.

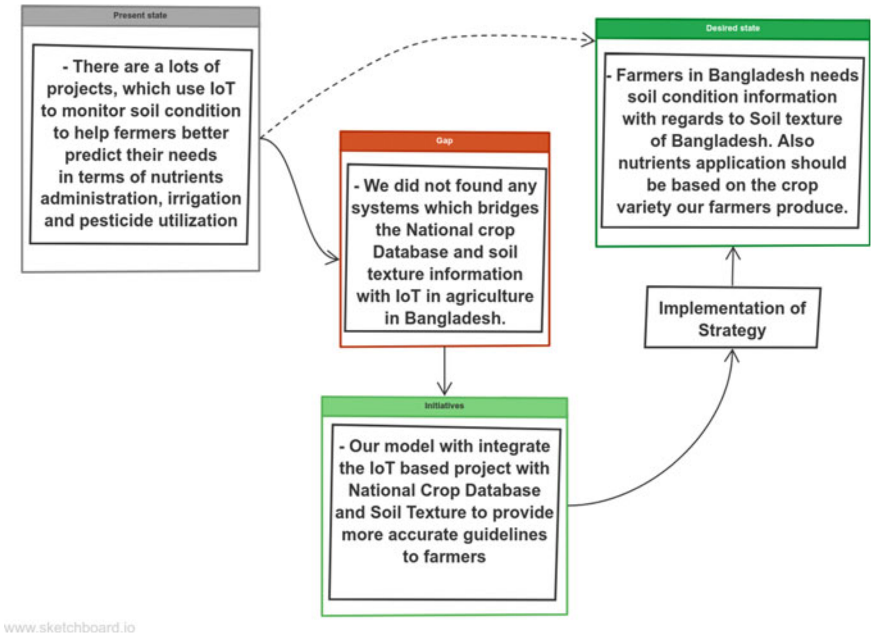

Fig. 1 This figure describes gap analysis

3 Methodology

In this project, we will build a simple handheld IoT device that can read soil conditions and send these readings to a server for analysis. When readings are received by the server, it will initiate a process for recommending farmers. This process will incorporate data from the Soil Research Development Institute (SRDI) and fact-sheets of different crop varieties from different releasing organizations, for example, Bangladesh Rice Research Institute (BRRI), Bangladesh Sugarcrop Research Institute (BSRI), Bangladesh Institute of Nuclear Agriculture (BINA), and agriculture universities. Based on these national data sets formulated for specific crops, soil texture, or areas, we will be able to provide a precise recommendation for the farmer.

In this process, the Upazilla Agriculture Officer will play a vital role. These officials serve as the primary points of contact between farmers and the scientific community. They know the area's specific crop cultivation practices better than anyone else. If the nation's wide agricultural knowledge is not used with the adjustment needed for local context, we will fail to reap the full potential. Agricultural universities across the country are the first to disseminate the results of their scientific research to farmers. They conduct workshops or demonstrations in the field to make the farmers aware of this information. Unless the agricultural officers communicate the knowledge of the scholarly community to the farmers, it will have little value. So, for accurate soil and crop information, these national databases are intriguingly dependent on the refinement of agriculture offices.

In the current scenario, farmers have to go through 8–10 steps to know the need for fertilizer on their land. They collect samples and send them to the agricultural office to analyze. After getting soil condition results, agriculture extension officers check the crop fact-sheets and fertilizer recommendation database to evaluate the results.

In Fig. 2, we can see the steps farmers have to follow to get the recommendations. Finally, the farmers are provided with a recommendation based on the result (Fig. 3).

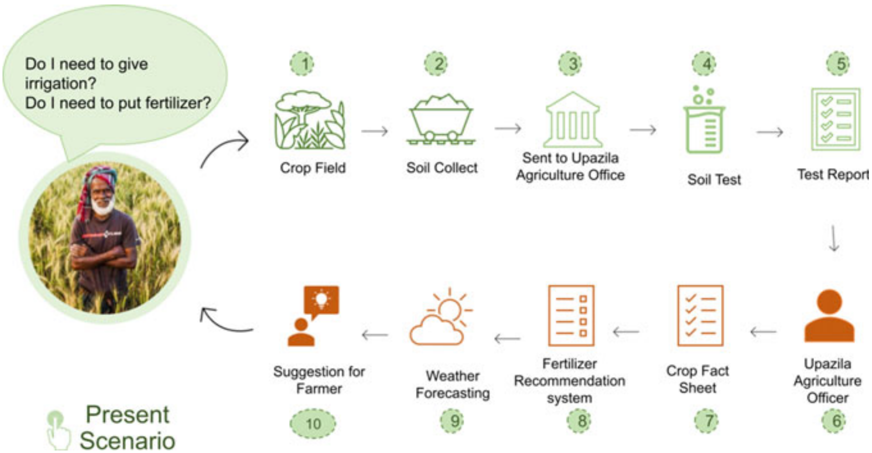

Fig. 2 Current scenario how farmers now avail this service

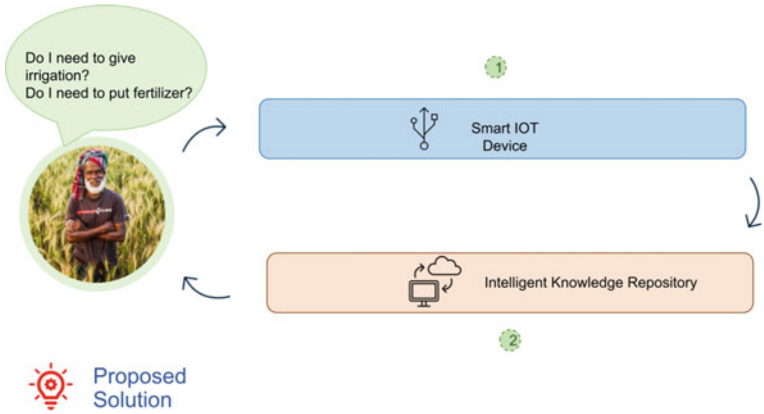

Fig. 3 Proposed solution to replace current process

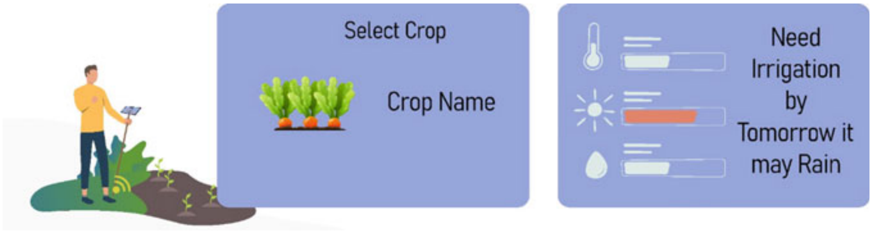

Fig. 4 Sample process for moisture detection output

In Fig. 4, we show a sample process of the outcome of the service we are proposing to replace the current one. Here, we have shown how the need for irrigation for the field may be communicated with the farmers. Similarly, the need for specific fertilizer applications may also be shown in the display.

The handheld device will consist of two sensors and a monitor. There will be a soil NPK sensor in the device which will provide the soil nutrition requirement. Another soil humidity and soil moisture detection sensor will be used to detect if the field needs irrigation or not. There will be a simple monitor to display the recommendations provided by the server. In Fig. 5, we have demonstrated the process flow of how the device will perform.

In Fig. 6, it is shown how the analysis of suggestions will take place with respect to the sensors' readings. The sensor reading data will be sent to the server after being collected from the field using the microcontroller's WiFi module. Then the server will initiate the processing of formulating the suggestions. When ready, this data will be sent back to the device from the server. Finally, the device will display the suggestions to the farmers. The suggestions made from server side analysis will consider the soil texture of the particular area, crop variety specific information, and weather information. It is vital to consider this information for the solution, which will provide an edge to the farmers while making decisions regarding irrigation and fertilizer administration.

The NPK sensor will provide the nitrogen, phosphorous, and potassium readings of the soil. It also helps to measure the fertility of the soil and facilitate the systematic assessment of its condition. It can be buried in the soil for a long time. The NPK sensor has a high-quality probe, electrolytic resistance, rust resistance, salt, and alkali corrosion resistance, to ensure the long-term operation of the probe part. So, this sensor is suitable for the detection of all kinds of soil, like alkaline soil, substrate soil, acid soil, seedling bed soil, and coconut bran soil.

It does not require any chemical reagent and can be used with any microcontroller as it has a fast response speed, high measurement accuracy, and good interchangeability. Since it has a Modbus communication port, we cannot use the sensor directly with the microcontroller. Hence, we need a Modbus Module like "RS485/MAX485" to connect the sensor to the microcontroller. The NPK sensor operates from 9 to 24 V and has very low power consumption. It is accurate to within 2%. The nitrogen, phosphorous, and potassium measuring resolution is up to 1 mg/kg (mg/l). We can

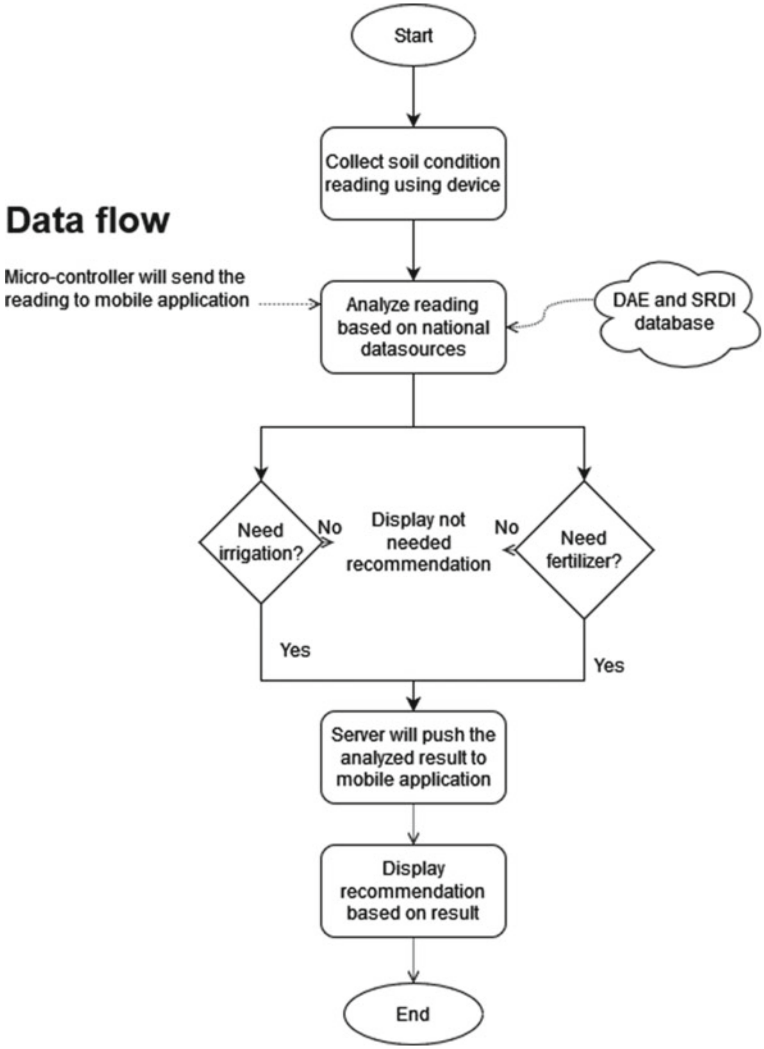

Fig. 5 This figure describes the flow of the process

create our own Arduino soil NPK meter or any cloud IoT-based soil nutrient content monitoring system using the soil NPK sensor. In Fig. 7, we have shown a sample NPK sensor we will use. If the initial project is a success, we will add more soil nutrient sensors.

As we mentioned earlier, we will provide irrigation recommendations to farmers. For that, we will use the soil humidity sensor along with the previous one. A humidity sensor is shown in Fig. 7. Our device will include a simple monitor to display the recommendation to the farmers. A sample monitor is shown in Fig. 7.

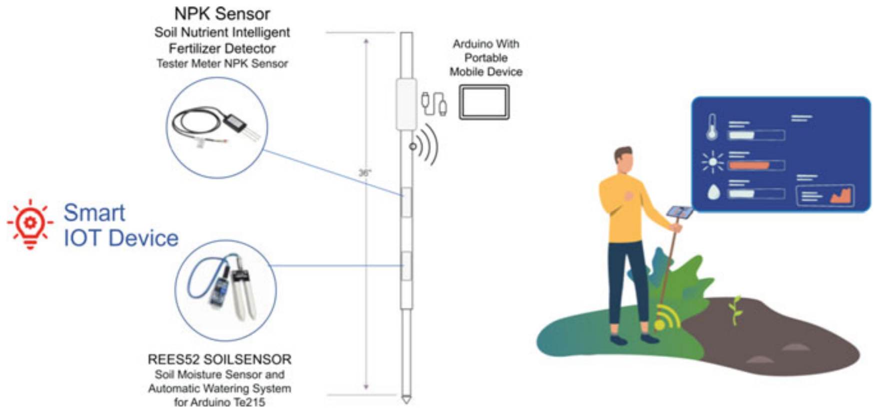

Fig. 6 Different components of the device

Fig. 7 yl-69 soil humidity moisture sensor, soil NPK sensor, and LCD display of the device

We will integrate our readings from the IoT device with the Bangladesh Rice Knowledge Bank for specific needs for the varieties our farmers produce. Another integration with the national fertilizer administration info database will be done. Based on the readings from our device, accurate fertilizer administration guidelines will be formulated from this data source.

We shall revisit the proposition of using a mobile application along with the proposed one in the future.

4 Conclusion

IoT-based agricultural solutions are making farmers more able to meet the requirements of this modern era. The resources used in agriculture will not change much, but the techniques used will evolve over time. More mechanical usage may help get a better yield, but information technology is playing a vital role in making the process more efficient.

Our proposed model is an initial step where we try to bring the power of IoT and intelligence from data sources like the National Crop Database and Fertilizer Administration Database. This model can be further enhanced by adopting more sensors and intelligence sources if necessary.

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