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Smart Pre-Seeding Decision Support System for Agriculture

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Abstract

In recent years, the Internet of Things (IoT) brings a new dimension for establishing a precision network connectivity of sensors, especially in the agriculture and farming industry, medical, economic, and several sectors of modern society. Agriculture is an important area for the sustainability of mankind engulfing manufacturing, security, and resource management. Due to the exponential diminishing of the resources, innovative techniques to support the subsistence of agriculture and farming. IoT aims to extend the use of internet technology to a large number of distributed and connected devices by representing standard and interoperable communication protocols. This paper brings up a solution by IoT, presents the design and implementation of a smart pre-seeding decision support system for agricultural modernization. This project is accomplished by understanding the real-time circumstances in the agriculture field using wireless technology that highlighted the features including pH and temperature sensors, hardware, mobile application, system's frontend, and backend analysis, and stores the extracted information in the cloud using IoT. The system is made up of frontend data acquisition, data transmission, data processing, and reception, and is also experimentally validated to find out all possible crops that can be cultivated in a specific land with the required amount of fertilizers as well as the overall crops distribution lists.

Keywords: Agriculture; Internet of Things; Pre-seeding; Decision Support System.

1- Introduction

To fulfill the demand of the modern world, the development and modernization of agriculture are very much on the line with the development of society. In recent times, the concept of the Internet of Things (IoT) in agriculture has become an inevitable trend of agricultural information due to the advancement of internet technology and cloud computing. Technologies like identification and tracking, sensors, actuators, networks, enhanced communication protocols, and distributed intelligence for smart objects are just the most relevant for any serious contribution to the advancement of the IoT [1-4]. Generally, IoT is regarded as a network that interfaces everything with the internet by radio frequency identification (RFID), wired and wireless sensors, GPS, and other information sensing devices.

More than 75 billion devices will be estimated to be connected to the internet by 2025 which may lead to a huge economic impact on the global agriculture and farming markets. In these sectors, there are several issues such as the high capital cost, limitation of farming lands, farmer's poor knowledge on better farming methods, imbalanced utilization of fertilizers, shortage of quality seeds, poor production, dividing the country into zone based on different crops, etc. The rapid growth of IoT-based development technology may lead to inventive and precision agriculture and farming process and can be implemented for managing resources better, monitoring farming fields and crops, economic efficiency, etc. The sensors involved in IoT could be used to track and keep a record of the temperature, humidity, moisture, and pH level in the soil for quantitative productivity with good quality.

IoT-based precision agriculture and farming is convenient for continuous observation and controlling the agriculture industry, especially in remote locations efficiently. Such a smart sensing environment creates a connected network of devices that can share data within them and also be able to take decisions on behalf of a user, and act on the environment to improve its condition. For cultivation, soil testing and their result play an important role in crop selection. Traditional soil testing in the laboratory is time-consuming and inefficient. An

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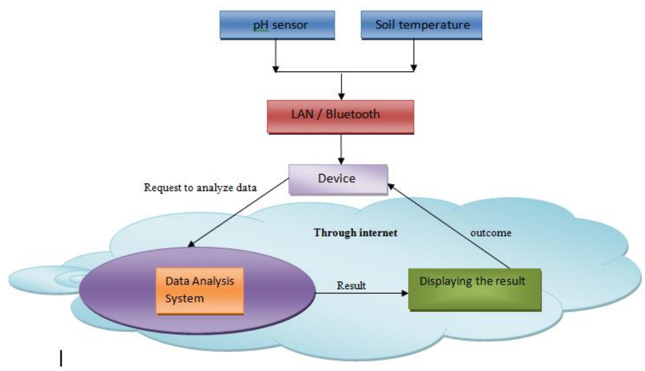
automated technique of measuring soil parameters may overcome this problem. IoT-based pre-seeding decision support using a smart sensing system, also known as a part of "Precision Agriculture", is an automated technique to identify the possible grains suitable for cultivating in any specific soil. The motivation of this work is to raise awareness among farmers on smart agriculture processes such as how to select an adequate crop list suitable for cultivation on featured land and the number of fertilizers needed for a particular crop that leads to effective productivity and irrigation management.

This paper introduces a cost-effective agriculture pre-seeding decision support system based on the implementation of smart wireless technology featuring pH and temperature sensors, mobile application, system's frontend, and backend analysis, data acquisition and processing, and information storage in a cloud environment using IoT. The experimental prototype of the proposed system is designed by considering the real-time circumstances of the featured agriculture field. This work aims to demonstrate the accuracy and potential intelligence of the designed system which helps farmers to take decision-making on crop distribution lists suitable for the various cultivating land using continuous monitoring and control of the pH level and soil temperature.

2- Literature Review

Different researchers gave their points of view on the IoT-based smart system for practical and accurate agriculture process applications. Authors in [5] developed a smart remote-controlled robot via ZigBee modules, camera, and actuators with Raspberry Pi for smart irrigation having intelligent decision-making capability utilizing the instantaneous field data. A scalable and feasible reference architecture for water management based on integrating IoT was proposed in [6]. Liang Zhao et al. demonstrated a wireless sensor network middleware for smart agriculture, demand management, crop growth augmentation, optimization, and controlling of agriculture process [7]. An automated intelligent wireless irrigation system was designed to provide an instantaneous feedback control system using LITE mote which effectively observes and controls all the activities of the irrigation system [8]. To enhance efficiency and lower the economic expenditure in the agriculture and farming industry, several smart decision-making and supporting systems based on cloud computing technology were developed [9-17]. Research by Wang and Liu in [16] was mainly focused on the implementation of IoT and cloud computing in agriculture and forestry for data sharing and remote data storage, interactions with farmers, expert consultation and discussion, and household management.

The literature survey mostly focuses on the different quality of service parameters and few of them address the mechanism to achieve an efficient and smart decision-making system for agriculture which may lead to customer dissatisfaction. In Bangladesh, farmers are still depending on the manual recommendation of crops and fertilizers by following a book which is referred from Soil Resource Development Institution (SRDI). This existing method has some limitations such as it recommends only those crops which are generally cultivating in that region and provides the amount of fertilizer that is taken from a previously tested solution. Therefore, it becomes very difficult for a farmer to cultivate crops like rice, wheat, jute, etc. in a small-sized land because all these crops are profitable only for large-sized land. The proposed smart system collects the specific soil parameters by the respective sensors and stores them in the cloud environment for further analysis which assists farmers to decide the suitable crops to be cultivated in a specific land with required fertilizers.



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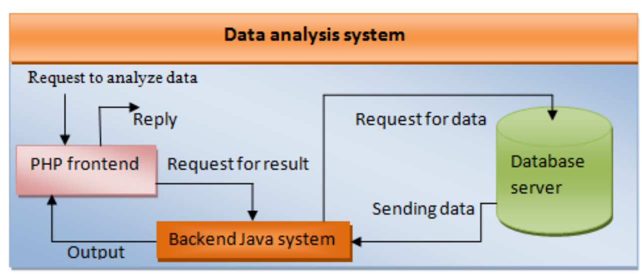

(b)

Fig. 1 (a) Schematic of system structure, (b) Data analysis system.

3- System Overviews

The pre-seeding monitoring system is designed to precisely select the list of suitable crops for cultivation through the remote monitoring and control of soil conditions. It is a typical IoT system that is built through Arduino Uno R3 and the coordination is adopted via

Arduino Bluetooth Module (JY-MCU). The system is designed for collecting soil information through frontend data acquisition, data transmission, data processing, and reception to guide farmers to find out all possible grains for any specific soil. The structure of the system is shown in Fig. 1.

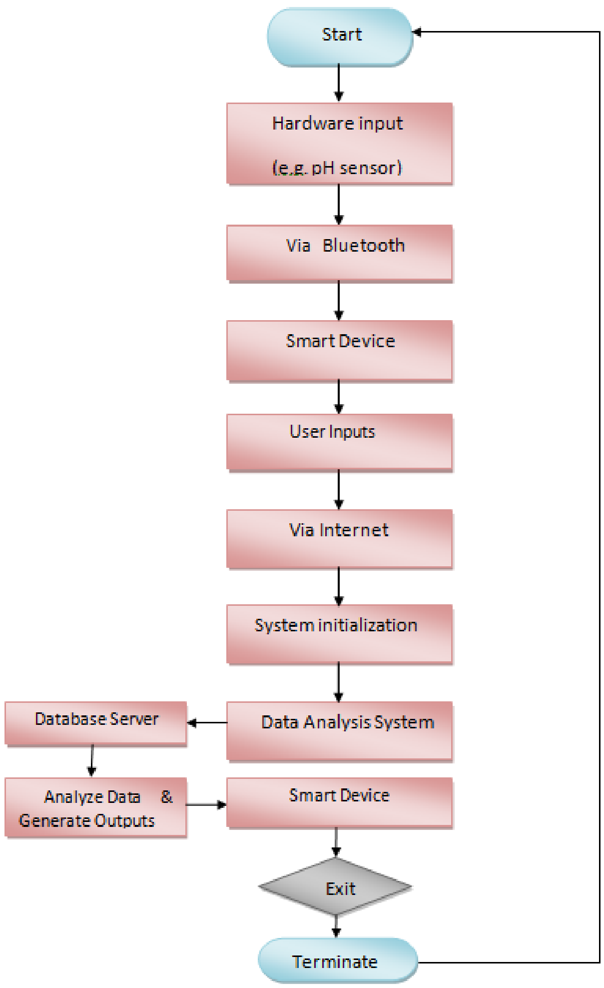

Fig. 2 Design flow of the IoT-based pre-seeding decision support system.

Fig. 2 describes the design flow of the system. In this system, the hardware section extracts inputs from the pH and temperature sensors and transmits them to a smart device (mobile, laptop, etc.) via Bluetooth connection. After receiving inputs, the user gives other necessary inputs manually through a smart device using the internet. The system will initialize all the parameters and transfer them to the data analysis system which is connected with a database server. The system will start processing after receiving all inputs and related data from the database server. During the process, the system will generate all possible desired outputs based on conditions, calculations, and comparison studies. Later, all the processed outputs will be sent back to the user's device using the internet.

4- Methodology and Experimental Setup

The initial design step of the experimental prototype of the pre-seeding system includes the fabrication of the hardware and combines it with the sensors and smart devices for data extraction. In the hardware structure of the system shown in Fig. 3, the Analog pH sensor is connected with Arduino Uno R3 at the Power pin 5V, GND, and Analog input pin A0. Pin RXD/TXD of the Bluetooth module (JY-MCU) is connected with the TXD/RXD pin of the Arduino module and vice-versa. After receiving the value from the pH sensor, the Arduino transmits that extracted value to the smart device using the Bluetooth module. The experimental setup and hardware setup are depicted in Fig. 4.

At the beginning of the processing, the system is initialized by the inputs taken from the hardware, sensors, and users (e.g., location information, soil information, and conditions) through a smart device. Later for final processing, all that information is transferred to the section of the data analysis system via the internet. The data analysis system is developed using java and PHP platforms, and connected with the database server. Fig. 5 illustrates the flow of the processing algorithm used in the system. It goes as in the following process:

1) The initial step of processing is to identify the location. After initializing, the system requests to the database server for all possible mapping units that are presented on that Mouza which is known as the lowest single-area revenue collection.
2) The next step is to identify the soil. At the beginning of this process, the system fetches all soils according to selected mapping units. Then the system will filter soils according to land type information given by the user. Later on, the system selects those soils which are fulfilling two conditions such as water removal condition from the surface and soil consistency at the same time. If the system cannot find any related soil with the above conditions, it will look for a single condition to fulfill which is either water removal condition from the surface or soil consistency. If one of these conditions is accepted, the system collects soil types from the database server. And if none of these have been selected then the system continues with the soils which have been selected according to land type.
3) After selecting the soil series, the system gathers all possible crops information according to irrigation type such as crop name, suitable land type for cultivating, and calculate fertilizers according to crop and recommend it. The system is also capable of

showing the crop distribution lists. And at the same time, it measures whether the pH value is suitable for the crop or not, and can provide suggestions based on pH value.

4) Lastly, the system stores all the processed data and displays it in the smart device through the internet as per user requirements which assists the user to select the suitable crop for cultivation on a particular land.

The exact fertilizer nutrient required for a recommended soil and crop can be stated as

$$F_r = \left(\frac{U_f - C_i}{C_S}\right) \times (S_t - L_S) \quad (1)$$

where,

F_r = Fertilizer nutrient required for given soil test value,

U_f = Upper limit of the recommended fertilizer nutrient for the respective soil test value interpretation (STVI) class,

C_i = Units of class intervals used for fertilizer nutrient recommendation,

C_S = Units of class intervals used for STVI class,

S_t = Soil test value, and

L_S = Lower limit of the soil test value within STVI class

To obtain the adequate result, the user needs to provide the following information as input to the system:

a) The land type is based on what becomes the scene of the land during the rainy season, whether it goes underwater or not, and if it goes underwater then how much it goes.

b) The soil consists of the land measured by pressing two fingers on the soil.

The water removal condition of the land measuring by when it is possible to cultivate.

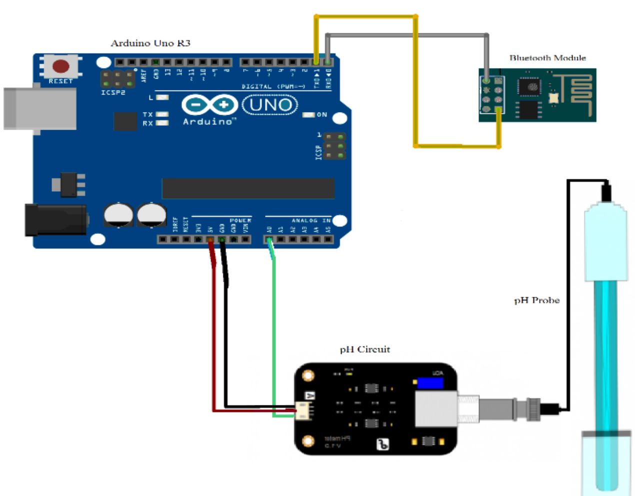

Fig. 3 Circuit diagram of the hardware units.

(a)

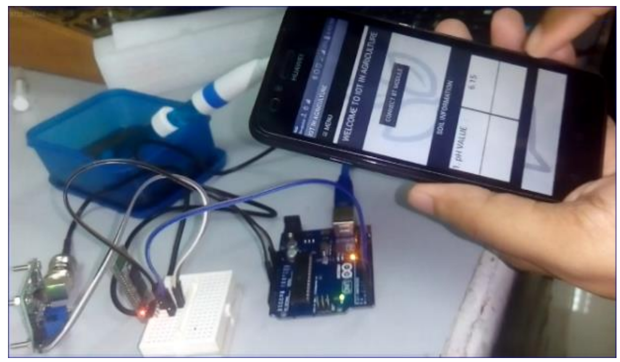

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Fig. 4 (a) Hardware setup, (b) Experimental setup of the system.

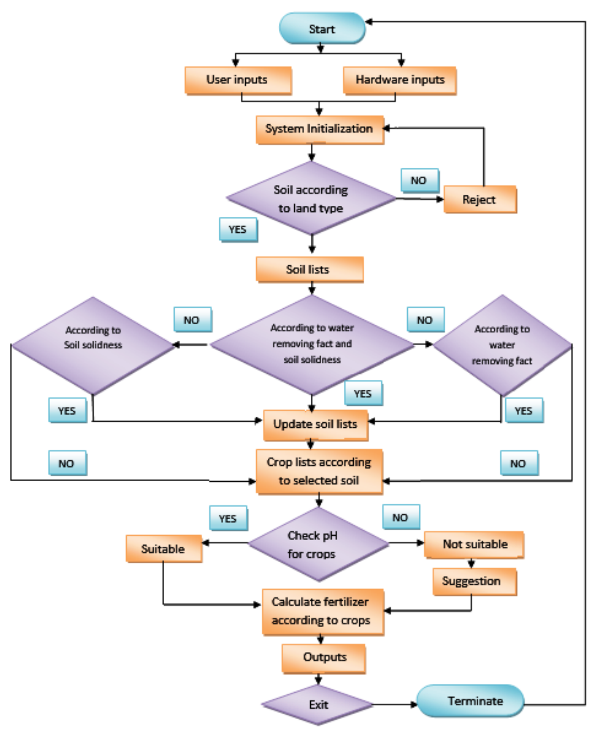
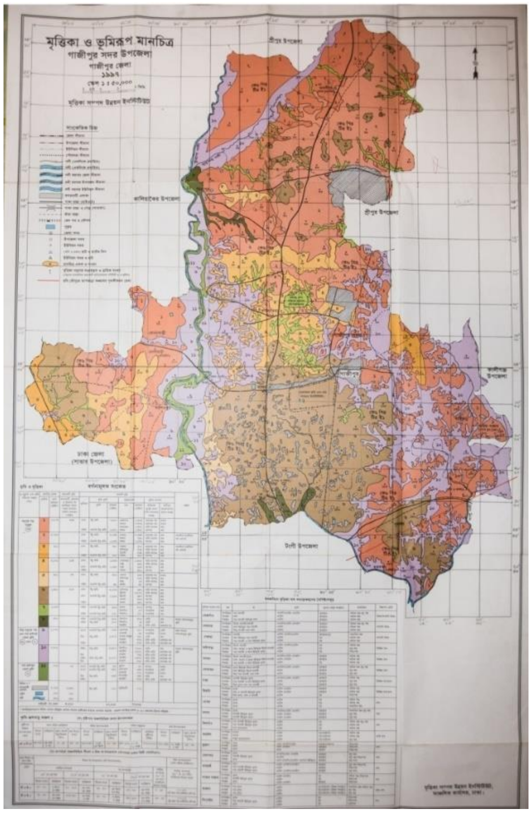


Fig. 5 Flow of the processing algorithm of IoT-based pre-seeding system.



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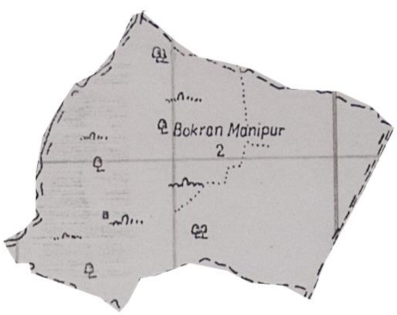

(b)

(c)

Fig. 6 Mapping units of (a) Gazipur Sadar Upazila, (b) Bokran Manipur with Mouza boundary, and (c) Bokran Manipur with mapping units.

5- Results and Discussion

The main objective of the project is to implement the IoT concept in the agriculture field for making the pre-seeding decision process simple. As a Mouza, the Bokran Manipur area under the Mirzapur union of Gazipur Sadar Upazilla in Bangladesh with mapping units: map-1, map-2, map-7, and map-10 were selected, as shown in Fig. 6. The initial value of Nitrogen (N), Phosphorus (P), and Potassium (K) were selected as 0.25, 15, and 0.34, respectively. The pH level of 6.8 to 7.2 is considered neutral and suitable for the land. After updating the values, we got all possible mapping units that are map-1, map-2, map-7, and map-10 according to the union and Mouza, given in Table 1. High land and crumbly soil with immediate water-removing facts were chosen. The designed system can filter the soil series concerning the selected land type listed in Table 2. Table 3 shows the filtered soil based on the “advanced” water removal condition and “crumbly” soil consistency provided by the user. Now, based on the selected soil type (without irrigation), the designed system provides a suggestion about the suitable crop lists (Rabi, Kharif 1, Kharif 2, one-year and Multi-year crops) with recommended fertilizers which are presented in Tables 4 to 8, respectively. Now, based on the selected soil type (without irrigation) the designed system provides the suggestion about the suitable crop lists (Rabi, Kharif 1, Kharif 2, One-year and Multi-year crops) with recommended fertilizers which are presented in Tables 4 to 8, respectively. From the soil pH analyses results, it is observed that Rabi, Kharif 1, Kharif 2 and one-year crops are suitable to grow at a pH value of 7.2 and multi-year crops are suitable to cultivate in the high land of having pH value equal to 6.8. Compared to Rabi and Kharif 1, Kharif 2 class crops require a large amount of Urea, TSP, and KCI per hectare to promote NPK for crop cultivation. Similarly, high quantities of fertilizers are also required for cultivating One-year crops compared to Multi-year crops.

Table 1: All possible soils according to the mapping units

Map units	***Soil series***				
	High land	Medium high land	Medium low land	Low land	Very low land
Map no – 1	Tejgaon, Belab, Noadda	Kolma	–	–	–
Map no – 2	Gerua, Salna	Kolma	–	–	–
Map no – 7	–	Kolma, Khilgaon	Khilgaon	–	–
Map no – 10	–	–	–	Khilgaon, Korail, Kajla	Korail, Kajla

Table 2: Filtered soil with respect to land type

Map units	***Land types***	***Soil series***
Map no – 1	High land	Tejgaon, Belab, Noadda
Map no – 2	High land	Gerua, Salna

Table 3: Filtered soil with water removal condition from the surface and soil consistency

Soil series	***Water removal condition from the surface***	***Drainage system***	***Soil type***	***Soil solidness***
Tejgaon	Immediate	Medium good	Loam	Crumbly
Belab	Immediate	Medium good	Loam	Crumbly
Gerua	Immediate	Medium good	Loam	Crumbly

Table 4: List of Rabi crops based on the selected soil type (without irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Mustard	7.2 (Neutral)	High land	104.56	8.867	8.867
Masculi-ne	7.2 (Neutral)	High land	13.406	40.03	2.333
Mung bean	7.2 (Neutral)	High land	16.087	100.067	5.6

Table 5: List of Kharif 1 crops based on the selected soil type (without irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Red spinach	7.2 (Neutral)	High land	72.391	60.040	4.667
Chili	7.2 (Neutral)	High land	210.140	15.400	2.391
Kakrol	7.2 (Neutral)	High land	53.623	100.067	4.667
Brinjal	7.2 (Neutral)	High land	174.275	140.093	25.200
Lady's finger	7.2 (Neutral)	High land	85.797	110.073	9.800
Ground -nut	7.2 (Neutral)	High land	26.812	90.060	7.933
Bona aus Rice	7.2 (Neutral)	High land	40.217	30.033	9.600

Table 6: List of Kharif 2 crops based on the selected soil type (without irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Red spinach	7.2 (Neutral)	High land	72.391	60.040	4.667
Mascu- line	7.2 (Neutral)	High land	13.406	40.027	2.333
Mung bean	7.2 (Neutral)	High land	16.087	100.067	5.6

Table 7: List of One-year crops based on the selected soil type (without irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Sugarca-ne	7.2 (Neutral)	High land	158.188	200.133	25.200
Banana	7.2 (Neutral)	High land	120.652	100.067	20.067
Ginger	7.2 (Neutral)	High land	120.652	170.113	17.733
Pineapp-le	7.2 (Neutral)	High land	201.187	280.187	35
Turmeric	7.2 (Neutral)	High land	88.478	110.073	12.6

Table 8: List of Multi-year crops based on the selected soil type (without irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Lemon	6.8 (Neutral)	High land	69.710	50.033	8.867

Table 9: List of Rabi crops based on the selected soil type (with irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Wheat	7.2 (Neutral)	High land	107.246	110.073	12.6
Corn	7.2 (Neutral)	High land	107.246	110.073	13.067
Potato	7.2 (Neutral)	High land	120.652	100.067	18.667
Mustard	7.2 (Neutral)	High land	104.565	100.067	8.867
Sunflow-er	7.2 (Neutral)	High land	88.478	100.067	8.4
Cabbage	7.2 (Neutral)	High land	174.275	140.093	25.2
Red spinach	7.2 (Neutral)	High land	72.391	60.04	4.667
Chili	7.2 (Neutral)	High land	210.14	15.4	2.391
Lady's finger	7.2 (Neutral)	High land	85.797	110.073	9.8
Brinjal	7.2 (Neutral)	High land	174.275	140.093	25.2
Cotton	7.2 (Neutral)	High land	99.203	110.073	15.4
Carrot	7.2 (Neutral)	High land	120.652	130.087	14
Cauli-flower	7.2 (Neutral)	High land	131.377	170.113	18.667
Ground-nut	7.2 (Neutral)	High land	26.812	90.06	7.993

Table 10: List of Kharif 1 crops based on the selected soil type (with irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Red spinach	7.2 (Neutral)	High land	26.812	90.06	7.933
Corn	7.2 (Neutral)	High land	107.246	110.073	13.067
Chili	7.2 (Neutral)	High land	210.14	15.4	2.391
Kakrol	7.2 (Neutral)	High land	53.623	100.067	4.667
Brinjal	7.2 (Neutral)	High land	174.275	140.093	25.2
Lady's finger	7.2 (Neutral)	High land	85.797	110.073	9.8

Table 11: List of One-year crops based on the selected soil type (with irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Sugarca-ne	7.2 (Neutral)	High land	158.188	200.133	25.2
Banana	7.2 (Neutral)	High land	120.652	100.067	20.067
Pineapp-le	7.2 (Neutral)	High land	201.087	280.187	35

Table 12: List of Multi-year crops based on the selected soil type (with irrigation)

Crop name	***pH status***	***Suitable land***	***Fertilizer (Kg/hectare)***		
			N (Urea)	***P (TSP)***	***K (KCl)***
Lemon	6.8 (Neutral)	High land	69.71	50.033	8.867
Betel	6.8 (Neutral)	High land	53.623	150.1	7

Table 13: Crop distribution lists provided by the IoT based pre-seeding system (without irrigation)

Serial no.	***Distribution of crops***
1	Mustard-kharif vegetables/kharif groundnut
2	Fallow-aus-masculine
3	Sugarcane
4	Banana/Ginger/Turmeric
5	Fallow-T.aus

Table 14: Crop distribution lists provided by the IoT based pre-seeding system (with irrigation)

Serial no.	***Distribution of crops***
1	Sugarcane
2	Rabi vegetables/groundnut Kharif vegetables
3	Rabi crops/bona aus
4	Banana/Pineapple
5	Betel/Lemon

Table 15: Comparison of detected key soil parameters for Wheat, Rice, and Sugarcane

Crops	***Soil parameters***	***Designed systems***		
		Spandana et al. [16]	***Badhe et al. [17]***	***Proposed model***
Wheat	***Land type***	Red	-	High land
	pH value	4	5.5-6.5	7.2
	Moisture	50	21-24	-
	Urea (N)	-	-	107.246 Kg/hectare
	TSP (P)	-	-	110.073 Kg/hectare
	KCI (K)	-	-	12. 6 Kg/hectare
Rice	***Land type***	Red	-	High land
	pH value	7	5.5-7	7.2
	Moisture	60	21-37	-
	Urea (N)	-	-	40.217 Kg/hectare
	TSP (P)	-	-	30.033 Kg/hectare
	KCI (K)	-	-	9. 6 Kg/hectare
Sugar-cane	***Land type***	-	-	High land
	pH value	-	5-8.5	7.2
	Moisture	-	28-32	-
	Urea (N)	-	-	158.188 Kg/hectare
	TSP (P)	-	-	200.133 Kg/hectare
	KCI (K)	-	-	25.2 Kg/hectare

The system also provides a suitable list of crops according to the irrigation technique listed in Tables 9 to 12. Similar to the crop lists under the selected soil type (without irrigation), the optimum suitable pH value is between 6.8 – 7.2 for the crops according to irrigation technique. In this case, the selected land type requires a large number of fertilizers per hectare to cultivate Rabi and One-year crops, respectively.

As observed, the proposed pre-seeding system is capable of providing suggestions regards the possible crops to cultivate (with or without irrigation) along with recommended fertilizers as per the selected land type and suitable season. The system can also be capable of providing the crop distribution lists in a sequence for cultivating based on irrigation techniques, which are shown in Table 13 and Table 14, respectively. In contrast with previous research in [16] and [17] on crop recommendation using IoT, the proposed model is capable of effectively recommending land type, specific pH label, and the exact amount of fertilizers required for the three most important crops: Wheat, Rice, and Sugarcane in Bangladesh which is highlighted in Table 15. Compared to those works, the extracted soil pH status using the designed prototype is neutral and all three crops are suitable to cultivate at this value. On requirement, the user also gets to know the number of optimum fertilizers required to boost NPK in the soil which is not analyzed in previous studies.

6- Conclusions

As agriculture is now one of the most important sectors for the growth of the economy in developing countries, technological advances must be utilized to stay aware of the increasing demand of the human populace. In this paper, an IoT-based smart pre-seeding decision support system is developed which realizes intelligent recommendations of suitable crops for the specific farming area. The hardware resources in the agriculture information network are integrated with the IoT sensors and smart devices. To validate the model through experiment, high land and crumbly soil of Bokran Manipur area under the Mirzapur union of Gazipur Sadar Upazilla in Bangladesh were chosen. The experimental test and all observations show its effectiveness in suggesting farmable crops based on the irrigation technique with recommended fertilizers and pH status along with the crop distribution list. It is found that a suitable pH range of 6.8-7.2 is required to grow Rabi, Kharif 1, Kharif 2, One-year, and Multi-year crops depending on the soil irrigation method. The selected soil types based on both without irrigation and with irrigation require a large quantity of Urea, TSP, and KCI fertilizer to grow Kharif 2 and Rabi crops, respectively via elevating the NPK value in the land.
Although this study has made significant progress in some areas, there are still a few shortcomings. The designed prototype requires continuous internet connectivity which is the biggest challenge to implementing the smart agriculture farming concept, especially in rural areas of Bangladesh. Also, farmers in rural areas are less interested to acquire technological knowledge for smart farming and prefer traditional farming. Finally, the designed pre-seeding decision-making system would help farmers to make intelligent decisions on planting, fertilizing, and harvesting crops. In the future, the system could be enhanced to cover large acres of agricultural lands, analyze their moisture level, and be integrated with the website and mobile applications to ensure direct information exchange between farmers and the system. Also, the system can be integrated to check the soil quality and the growth rate of crops.

Acknowledgments

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