Design and Development of Arduino Based Physical Parameter Analyzer for Unprivileged Region Agricultural System

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Abstract. Introducing scientific methods to the cultivation system is sorely needed in overpopulated countries like Bangladesh. As the demand for food is rapidly increasing while the farming areas are squeezing day by day. The cultivation system of our country follows the traditional harvesting process which does not employ any scientific analysis of the agricultural sites. But proper measurement and analysis of these parameters can magnificently improve the harvesting result. This article presents the design and development method of Arduino based low-cost physical parameter analyzer which can be constructed easily and used by the farmers of rural areas. The system was controlled with an Arduino microcontroller which can receive analog signals from different sensors and show the measurement results in digital form through a liquid crystal display. DHT11 sensor is one kind of capacitor that has humidity holding substrate as dielectric which was interfaced with the microcontroller to measure both the relative humidity and temperature. While FC-28 soil moisture sensor measures the relative soil moisture by sensing electrical resistance of the soil. A JXCT-pH sensor was also incorporated to evaluate the pH level of the soil. The developed system is also capable of continuously monitoring an agricultural site and taking some emergency action if the standard value of the physical parameters deviates drastically

Keywords: Agricultural system, Microcontroller, Humidity sensor, Soil moisture sensor, pH sensor, Liquid crystal display.

1 Introduction

The proper cultivation system plays an important role in economic development of our country, as the majority of the population of this country makes their living from agriculture. But the cultivation systems are not enough scientific in the disadvantaged areas of our country [1]. So, establishing the connection between science-based analyses and agricultural systems became substantial for improving the harvesting results in these regions [2]. Imbalanced temperature and relative humidity can affect farming production drastically. When the temperature gets higher, plants close their stomata to reduce water losses. If this phenomenon sustains for a long-period then the plants stop transferring carbon dioxide and oxygen molecules which will make them suffocate. Again, if relative humidity levels increase critically then plants become unable to evaporate water and draw nutrients from the soil [3]. So, the temperature and relative humidity of the cultivation sites should be measured and monitored continuously for proper farming.

The pH factor of an agricultural site reflects the acidity and basicity level of the soil where plants grow. This parameter is also very important because different plants require different levels of pH for proper growth [4]. The soil's pH level affects the dispersal of important nutrients in the soil and an imbalance of pH in the soil can block plant’s ability to absorb the nutrients. Again, micro-organism activity also depends on the pH level of the soil, so measuring the pH levels before starting cultivation is mandatory [5]. The crop productivity can be affected due to deficiency of water in the habitat soil as plants lose water continuously through transpiration and evaporation [6]. Again, water deficiency during seed maturation affects the dormancy and germination of the plants [7]. So, the moisture level of the soil must be monitored continuously for saving the plants from sudden damage.

Though it is very important to analyze these physical parameters for successful farming the harvesters in unprivileged areas are not capable of purchasing readymade weather and soil analyzer. So, a low-cost, easily operable electronic device is needed for introducing scientific analysis in the agricultural systems. This research will give a brief idea about the importance of measuring different physical parameters and help the entrepreneur to construct a low-cost agricultural site surveying and monitoring tool.

2 Materials and Methods

The entire system can be powered with the help of a low voltage power supply source which provides regulated 5 volt dc and also can be powered with a 5 volt dc battery. The brain of the developed system is Arduino UNO R3 microcontroller which was interfaced with a DHT11 sensor, JXBS-3001-pH sensor and FC-28 soil moisture sensor. The microcontroller continuously receives analog input signals from the sensors and converts the analog value into an equivalent digital value and shows the measurement result through a 16x2 LCD monitor. For simplifying the entire system, a block diagram was structured. Block diagram helps design an electronic device as it represents different parts of the system along with their interconnections.[8]. The main circuit was carried out step by step according to the block diagram as shown in figure 1.

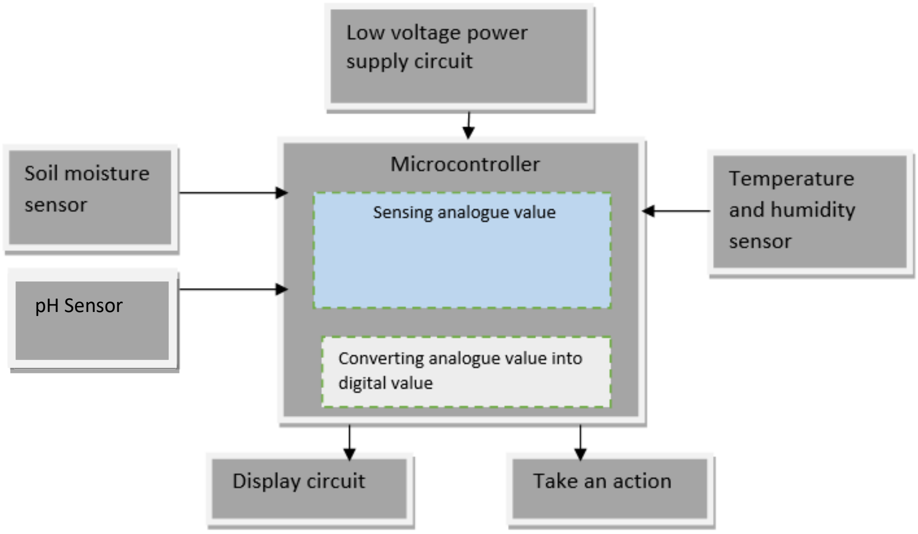

Fig. 1. Block diagram of the developed system for interfacing its different parts

2.1 Arduino Microcontroller

A microcontroller is very low power consuming integrated circuit used to govern a specific task in an embedded system [9]. In the developed system the third version of microcontroller board named Arduino UNO R3 was used which is relatively low cost and readily available. The Arduino microcontroller uses a simplified version of the programming language and the programming can be easily uploaded or erased from it [10].

2.2 Humidity and Temperature sensor

DHT11 sensor shown in figure 2, was incorporated with the Arduino microcontroller for offering reliable humidity and temperature measurements. The DHT11 sensor uses a capacitor that has two electrodes and a moisture-holding substrate as a dielectric between the electrodes. The value of capacitance changes with the chance of relative humidity. The microcontroller senses the changes and converts them into equivalent digital values [11]. The temperature sensing part of DHT 11 is consist of a negative temperature coefficient thermo-resistor whose resistance varies with the variation of temperature [12].

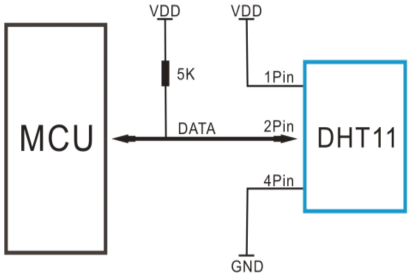

Fig. 2. DHT11 sensor for measuring humidity and temperature

2.3 Soil Moisture Sensor

FC-28 moisture sensor measures the volumetric water content in a given soil surface. The traditional measurement of relative soil moisture requires weighing the moist soil and drying it for further weighing. But in this system, the volumetric water content was measured by sensing the electrical resistance of the soil [13]. The relation between the electrical property and soil moisture was theoretically analyzed and practically calibrated to give an appropriate value [14].

2.4 pH Sensor

A JXCT pH sensor was used to analyze the value of acidity and basicity of the site. The probe of the pH sensor is directly placed into the soil to evaluate its pH level. The sensor uses an electrode, reference solution and a hydrated gel layer. When the electrode is stabbed into the soil an electrical current is produced which is sensed by the microcontroller and compared with the reference solution. From this comparison, the device provides a value of pH through the LCD display [15].

2.5 LCD Monitor

A 16 x2 liquid-crystal display (LCD) was used to represent the measured analog values of the temperature, relative humidity, pH and relative moisture of the soil in a digital form. The LCD monitor is a flat-panel optoelectronic device that uses the optical activity property of liquid crystals [16]. It also uses a reflector to produce images in monochrome. The 16x2 LCD displays 16 characters per row and has two rows of such lines [17].

2.6 Low Voltage Power Supply Circuit

A low voltage regulated power supply of regulated 5volt dc was designed for powering up the Arduino microcontroller. The diagram of this circuit is shown in figure3.A step-down transformer having a primary winding of 400 turn and secondary winding of 40 turn collects 220volt ac from the main line and provides 22 volt ac as output [18]. A bridge rectifier circuit was constructed with four crystal diodes to rectify the ac into dc voltage [19]. This output was further fed to L7805 IC to achieve regulated5 volt dc supply**.**

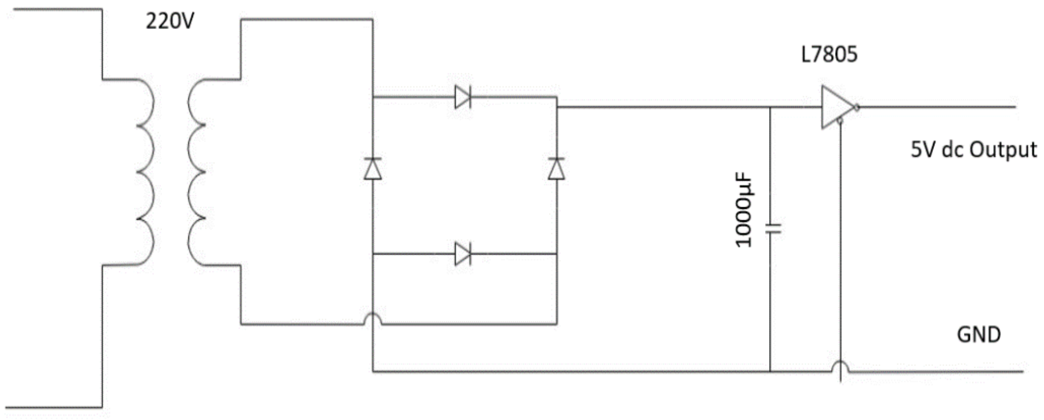

Fig. 3. Low voltage regulated power supply circuit for powering up the system

3 Circuit Design

The schematic circuit diagram of the developed system is shown in figure 4 and has been drawn with Proteus 7 software [20].

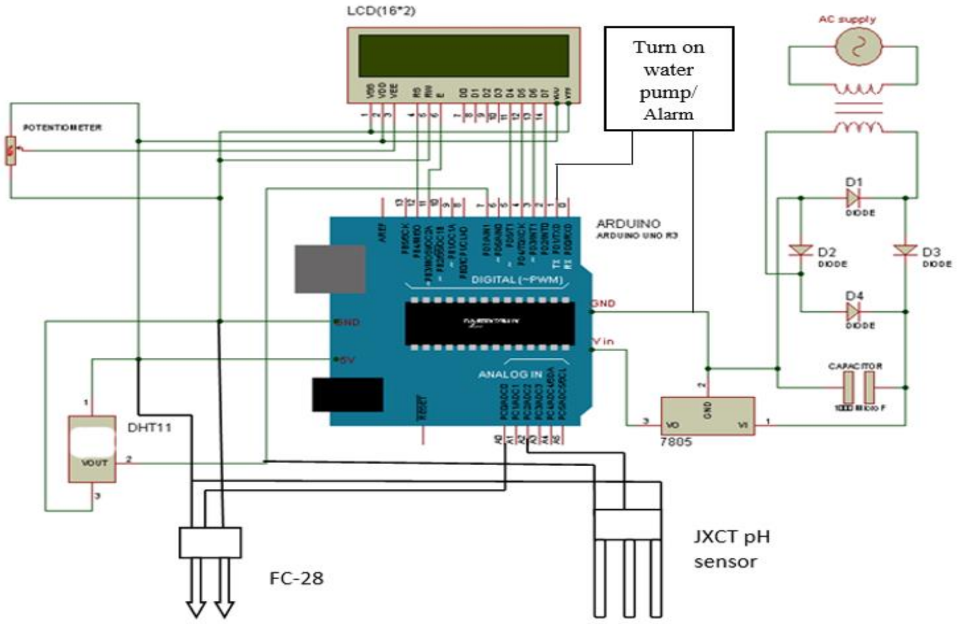

Fig. 4. Complete circuit diagram of the developed system with microcontroller, sensors and power source

4 Programming

In the developed system Arduino UNO R3 microcontroller has been used to sense the analog input, convert it into a digital value and present the result through a liquid crystal display. The used microcontroller should be programmed appropriately for performing this particular task.

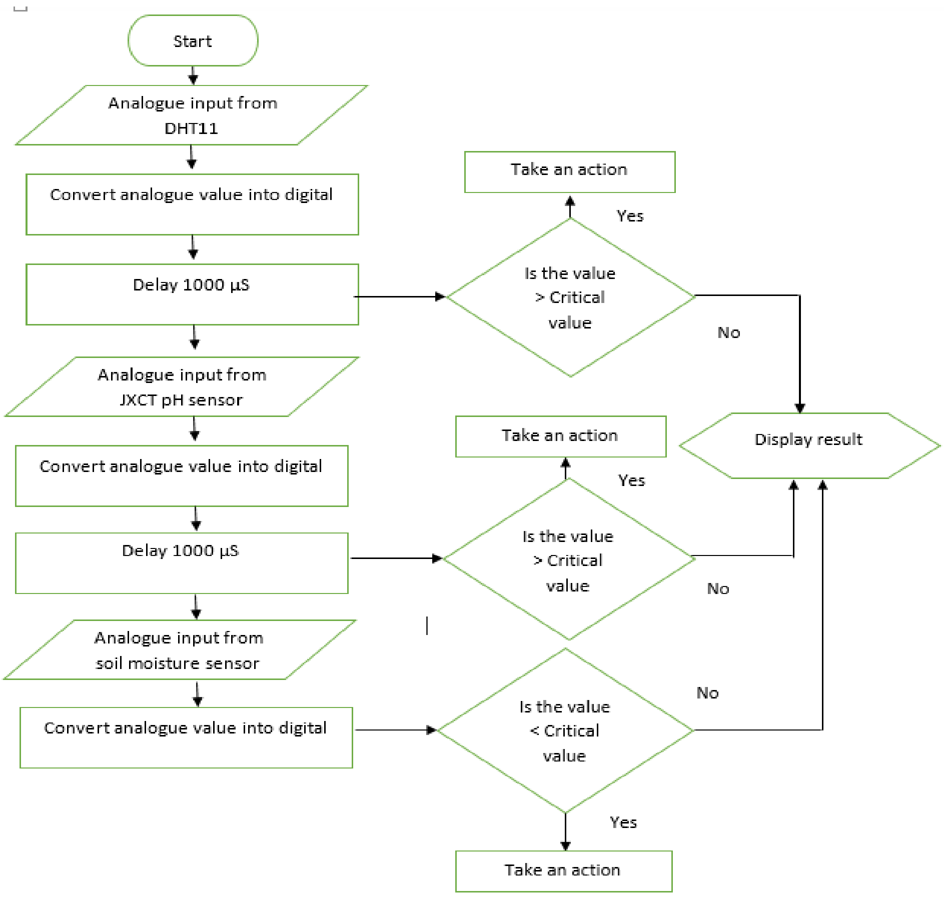

Fig. 5. Flowchart for building the program of the microcontroller

C programming language has been used to build up the program and instruct the microcontroller [21]. Arduino (Genuino) software was used to build up the program. The programming was uploaded to the microcontroller from a PC through a data cable. A flowchart shown in figure 5 that has been designed to understand and build the program easily [22].

5 Result and Discussions

After developing the system several data for humidity, temperature, pH and relative soil moisture were taken from different agricultural sites in Tangail, Bangladesh. The performance of the developed system was studied by comparing the collected results with the theoretically calculated values or other reliable devices.

5.1 Result for Humidity

Relative humidity is defined as the ratio of the amount of water vapor present in the air to the amount of water vapor required to saturate the air at that temperature [23].

Theoretically, Relative Humidity = (actual vapor density / saturation vapor density) × 100%

Table 1. Data for relative humidity obtained from the theory and developed system

No. of observations	Temperature in °C	Value of Humidity in %		Percentage of error in %
		Obtained theoretical value (approximate)	Obtained from developed project	
01	23	75	79	5.33
02	24	73	75	2.73
03	24	73	74	1.36
04	29	70	67	4.10
05	26	74	71	4.05
06	26	74	75	1.35
07	27	73	70	4.10
08	27	73	75	2.73

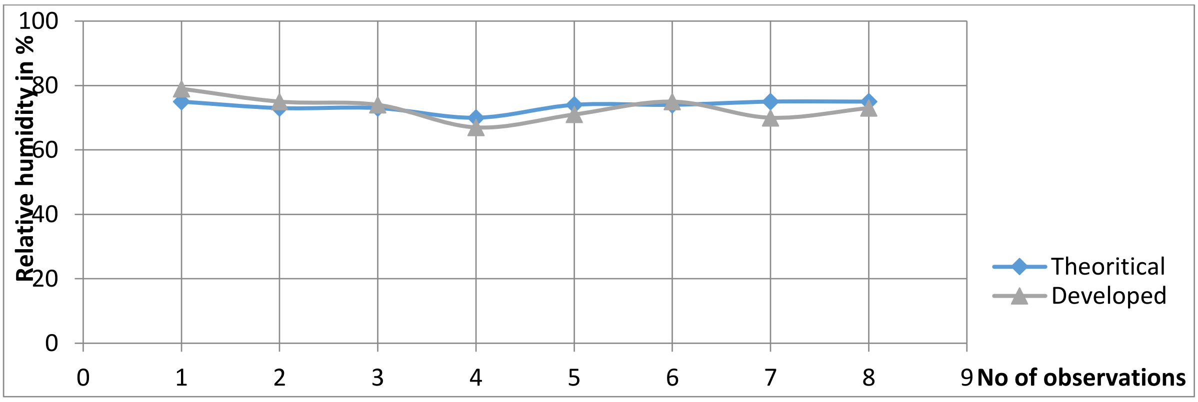

Fig. 6. The comparison graph between theoretical value and measured value for relative humidity

5.2 Result for Temperature

Temperature is a measure of the thermal state of an object with respect to a reference value. In physics, heat is the ability of a body to impart thermal energy to a cold body [24]. Thermometers are calibrated in various temperature scales but the most used scales are the degree Celsius scale (°C), the Fahrenheit scale (°F), and the Kelvin scale (K). The developed system was calibrated with a degree Celsius scale [25].

The temperature of different cultivation areas have been measured with the developed system and the obtained values were compared with Rossmax TG100 digital thermometer [26].

Table 2. Data for temperature collected with a digital thermometer and the developed system.

No. of observations	Reading in (°C) from digital thermometer	Reading in (°C) from developed system.	Percentage of error in %
01	22°C	23.46°C	6.63
02	23°C	24.44°C	6.26
03	24°C	25.90°C	7.91
04	25°C	26.88°C	7.52
05	25°C	27.37°C	5.26
06	27°C	28.10°C	4.07
07	28°C	28.59°C	2.10
08	29°C	29.81°C	2.79
09	30°C	30.30°C	1
10	31°C	30.55°C	1.45

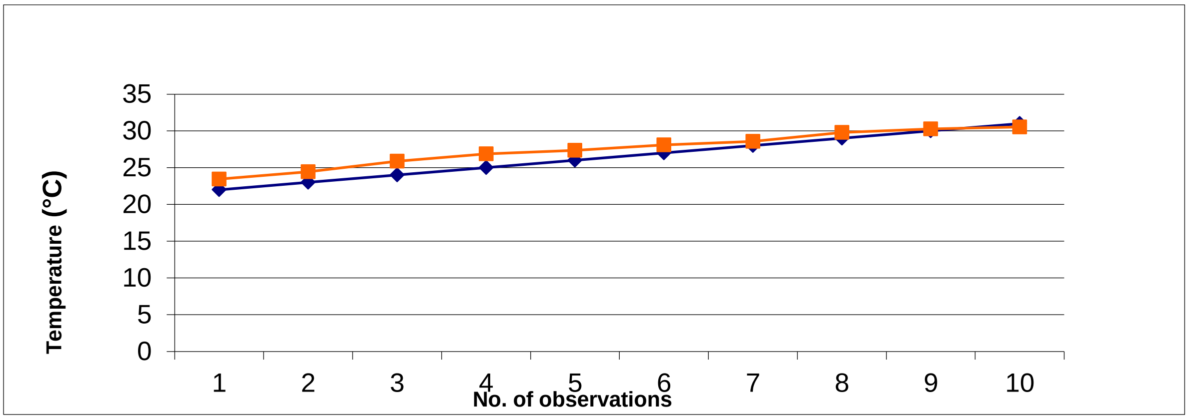

Fig. 7. The comparison graph between Rossmax TG300 thermometer and developed system

5.3 Result for pH

Soil pH is the measurement of the acidity level or alkalinity level of a soil sample. It is defined as the negative logarithm of the activity of hydronium ions in a sample [27]. The pH value of soil from different agricultural sites was measured with the developed system. The collected soil was also tested in the chemistry lab with 1 M KCl solution to obtain the lab-tested pH value and the obtained results were compared [28].

Table 3. Data for pH of the soil measured with 1M KCl solution and developed system.

No. of observations	Measured pH in chemistry Lab	Measured pH from developed system	Error in %
01	6.5	6.5	0.00
02	6.0	6.5	8.33
03	6.5	6.0	7.69
04	7.0	6.0	14.28
05	7.5	7.5	0.00
06	7.0	6.5	7.14

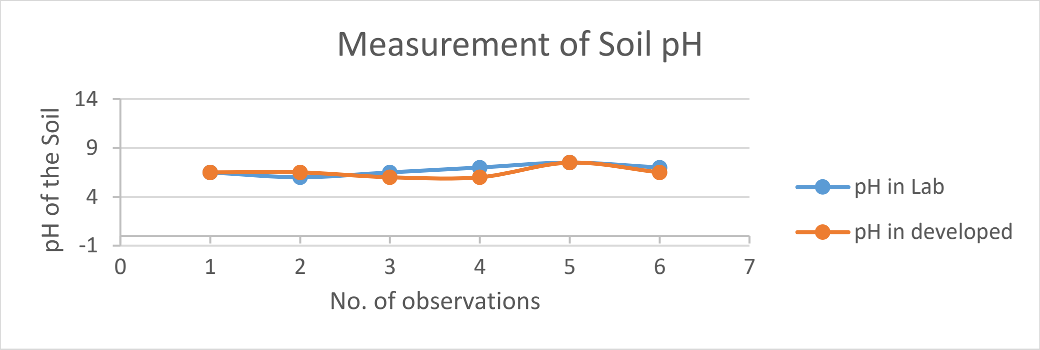

Fig. 8. The comparison graph for pH measurement in the lab and with the developed system

5.4 Result for Relative Soil Moisture

Theoretically, the relative soil moisture was measured by weighing the sample before and after drying. The ratio of this difference in weight to the weight of dry soil provides the theoretical value of relative moisture [29, 30]. Relative soil moisture was measured with the developed system and compared with the theoretical value.

Relative soil moisture = [{weight of moist soil (A)-weight of dry soil (B)}/Weight of dry soil (B)] × 100% (1)

Table 4. Data for relative soil moisture measured theoretically and with developed system.

No of observations	Theoretical value in (%)	Obtained value in (%)	Error in (%)
1	22.74	21.99	3.29
2	34.53	36.56	5.87
3	34.73	34.12	1.75
4	35.72	35.68	0.11
5	36.76	36.07	1.87
6	37.31	43.60	16.86
7	38.02	37.73	0.76
8	48.73	49.07	0.71
9	55.06	57.12	3.74
10	65.04	64.81	0.35

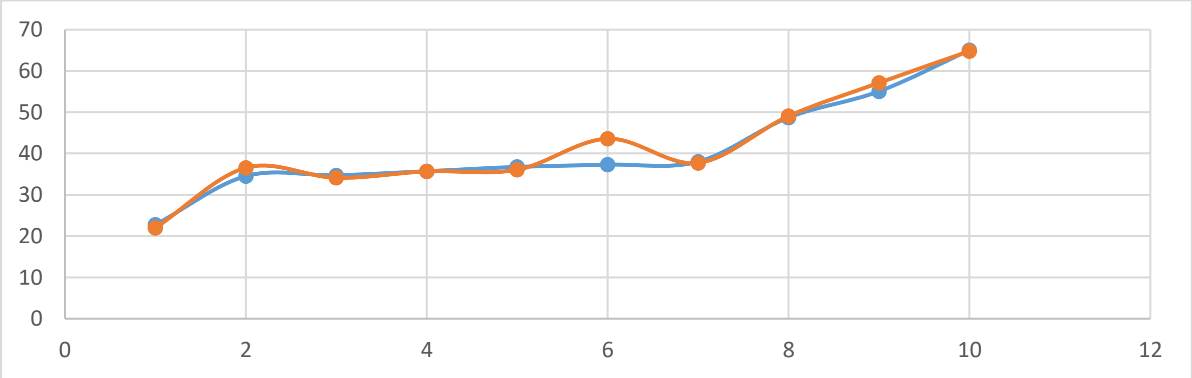

Fig. 9. Comparison graph between the theoretical and obtained value of soil moisture.

5.5 Cost Analysis of the Developed System

Different equipment and parts of the developed project were collected from the local market in Tangail, Bangladesh. The total cost of constructing the system is given below:

Table 5. Price of different parts of the developed system

Equipment	Price in USD	Price in BDT
Arduino Microcontroller	4.00	360
DHT11 sensor	1.00	90
FC-28 Soil Moisture Sensor	1.00	90
JXCT pH sensor	8.00	720
LCD Monitor	4.00	360
Low Voltage Power Supply Circuit	4.00	360
Connecting Wires	1.00	90
Total	23.00	2070

6 Conclusion

In this work, the negative effect of imbalanced physical parameters on agriculture was studied and a low-cost physical parameter analyzer was designed and constructed for the unprivileged regions agricultural systems. The performance of the developed system was analyzed and compared with the standard values. The comparison graph between the developed system and theoretical value illustrates the system as a reliable one and also good efficient.

The device has been designed with components that are readily available in our country. Again the cost of manufacturing the system is only about 23 US dollars which seems bearable by the harvesters. So the developed system can be proven as a useful tool for introducing scientific methods in the cultivation systems, especially in the area of underdeveloped countries. By using this device farmers can easily measure the temperature, humidity of the cultivation sites as well as pH and relative moisture of the soil and take necessary steps according to their measurements.

Again, the microcontroller was also programmed to take some autonomous emergency actions like turning on the switch of a water pump if the soil moisture drops critically or giving a signal (LED or alarm) if other parameters transcend a critical value. This unique property of the developed system can save the crops from sudden damage.

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