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Numerical Investigation of Future Potato Yields in Bangladesh Using Machine Learning and IoT

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Abstract

The changing environment has significantly affected Bangladesh for the past several decades, and a number of minerals and nutrients are in short supply in the human population. However, not only are we being affected by the effects of climate change, but also the crops cultivated on our farms are feeling its impact. The nutrient content and growth of food crops are affected by many components of climate change, such as rising temperatures, increased precipitation, rising CO2 levels, etc. It is commonly regarded that potatoes are one of the healthiest and most popular foods in Bangladesh, with an abundance of nutrients and electrolytes that are beneficial to the body. However, in the not-too-distant future, the production of potatoes will be affected by the high temperature, and decreased precipitation resulting from climate change. As potatoes are one of the most essential staple foods in Bangladesh, a viable solution must be found for continuous potato production in the country. A comprehensive examination of the evolution, production, and important nutrients of potatoes will be performed in this study. A range of sensors, networks, drones, cameras, and applications will be collected for the purpose of monitoring the potato field and ensuring that the crops are cultivated in an acceptable environment. This idea can aid our country economically and agriculturally by increasing potato production. Potatoes are affordable for consumers from all socioeconomic classes. Through this idea, Producers will achieve a successful harvest of nutrient-rich potatoes for public consumption.

Keywords: Potato, Micronutrients, IoT, Climate Change, Sensor, Forecast, ETS.

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1. Introduction

Micronutrients such as B, Cu, Fe, Mn, Mo, and Zn are crucial for the growth and development of field crops, and Ni and Co are believed to be essential for some plants in low concentrations. However, due to intensive cropping, soil erosion, leaching of micronutrients, soil acidification, and depletion, there has been an increase in the prevalence of micronutrient deficiency in crops. Micronutrients are vital for physiological functions and maintaining good health, but since the body cannot synthesize them, they must be obtained through diet. Efforts to improve food security and health recognize the importance of a balanced diet rich in micronutrients. Therefore, ensuring a sufficient intake of foods high in micronutrients is crucial for long-term strategies to prevent micronutrient deficits.

Micronutrient deficiencies can have serious consequences for health and development, particularly in children and pregnant women. Iron, vitamin A, and iodine deficiencies are the most common worldwide and are linked to increased mortality, decreased ability to fight off infections, impaired growth, and other negative outcomes. These deficiencies are responsible for a significant number of child and maternal deaths each year. Addressing the issue of micronutrient deficiencies through a balanced diet and other strategies is crucial to improving global health and reducing mortality rates, particularly among underprivileged populations in underdeveloped nations. According to the National Micronutrient Survey (NMS) 2019 Bangladesh, the usual diet is typically deficient in one or more micronutrients, notably vitamin A, iron, iodine, and zinc [1]. The World Health Organization added a multiple-micronutrient powder containing at least iron, zinc, and vitamin A to its List of Essential Medicines in 2019 [2].

Climate change caused by the increasing levels of CO2 in the atmosphere is putting the world's food supply at risk. 76% of the world's population depends on crops for daily nutrients, but droughts and flooding caused by climate change are threatening these staple foods. In addition, higher CO2 levels and temperatures are predicted to reduce the nutritional value of these crops, resulting in less protein and important micronutrients, and more carbs. This change would increase the risk of micronutrient deficiencies and lead to global malnutrition, particularly of iron and zinc. The impact of carbon dioxide is not limited to climate change but can also deeply affect our food and health.

Climate change poses a significant threat to food security and nutrition, with a predicted 30% reduction in agricultural production by the end of the century. In Bangladesh, where almost 50% of the population already suffers from iron and zinc deficiency, increased carbon dioxide emissions could further exacerbate micronutrient deficiencies. Additionally, rising salinity levels in coastal zones may affect the micronutrient concentration of staple foods like rice. The consequences of micronutrient deficiencies, particularly for young children and pregnant women, can have severe implications for nutrition and health. Thus, addressing the impact of climate change on food security and nutrition is crucial to ensure a healthy future for all.

Bangladesh has undergone rapid economic growth over the past two decades, but poverty, malnutrition rates, and poor nutritional status persist. As per the estimation of the Bangladesh Demographic and Health

Survey, stunted growth is experienced by 30.8% of children under 5 years of age and 21.9% of them are underweight [3]. Nearly one-third of children under the age of 5 suffer from stunted growth, and over 20% are underweight. Inadequate protein consumption, poor dietary diversity, and a lack of micronutrients contribute to undernutrition, with cereals accounting for 70% of the diet.

Bangladesh faces a significant burden of micronutrient deficiencies, including iron, folic acid, vitamin A, iodine, zinc, calcium, and B12. However, reliable data on the extent of these deficiencies was previously unavailable. The latest survey provides updated information on essential micronutrients such as vitamin A, iron, iodine, vitamin D, calcium, folate, B12, and anemia [4]. The study found that a significant proportion of preschool-aged children still suffer from deficiencies in vitamin A (20%), zinc (44%), and vitamin D (39%), as well as anemia (one-third) and iron deficiency (10%). Non-pregnant, non-lactating women commonly experience deficits in zinc (57%) and iodine (42%), while one-fourth of all adult women are affected by anemia, vitamin B12, and D deficiencies. Anemia is observed in about half of all pregnant or nursing women.

Climate change is exacerbating existing challenges related to food security and nutrition in Bangladesh. The reduction in agricultural production due to climate change is predicted to increase food insecurity in the country. Increased salinity in coastal zones is leading to changes in the macronutrient composition of foods, particularly rice, which could result in zinc and other micronutrient deficiencies [5]. This could lead to negative health impacts, such as pre-eclampsia in pregnant women, low birth weight, and infant malnutrition [6]. A limited number of agricultural technologies are suitable for the high-salinity coastal regions of Bangladesh. Due to the lack of agricultural technology and environmental hazards, food insecurity affects many areas of the country [7]. Additionally, the lack of agricultural technology suitable for high-salinity coastal regions is contributing to food insecurity in these areas.

Increased carbon dioxide emissions worldwide could cause a loss in the nutritional value of Bangladesh's main food crops, such as rice, wheat, peas, and soybeans. This could lead to lower zinc, iron, and protein content in staple crops, which would be a significant nutritional problem for a population where almost half of the people already suffer from iron and zinc deficiency [8]. This is especially concerning for young children and expectant women. As atmospheric carbon dioxide levels continue to rise, the issue of micronutrient deficiencies is expected to worsen, highlighting the need for measures to address this growing problem [9].

Bangladesh produced a record high of 1.09 crore tons of potatoes last year, making it the seventh largest producer in the world. The country now has an exportable surplus of over two million tons of potatoes, which is enough to meet its annual domestic requirements. Potatoes are rich in several micronutrients, including potassium, magnesium, vitamin C, vitamin B6, folate, and thiamin. However, the amount of these micronutrients in potatoes can be affected by factors such as variety, storage, and cooking methods. Boiling potatoes in water can lead to significant losses of water-soluble minerals and vitamins, especially if the potatoes are shredded or cut into small pieces. In P. C. Bethke and S. H. Jansky's study, they're told that potassium losses of over 50% were observed when potatoes were cut into 1 cm cubes and boiled for 10 min, with even greater losses (70–75%) observed when the potatoes were shredded; substantial losses were also reported for iron, magnesium, manganese, phosphorus, sulfur, and zinc [10] However, cooking methods that do not involve water, such as microwaving, baking, and sautéing, can help preserve the micronutrient content of potatoes. A medium-sized baked potato can contribute significantly to the daily reference nutrient intake for several micronutrients, including iron, magnesium, potassium, vitamin C, vitamin B6, and folate. Gibson and Kurilich reported that potato consumption contributed 15% of potassium, 15% of B6, 14% of vitamin C, 10% of folate, and 9% of magnesium in the UK diet [11].

The agricultural sector is undergoing a transformation through the use of Agri-Tech, also known as smart farming. This technology includes the use of artificial lighting, water-nutrient supply, automation, robots, machine learning, and artificial intelligence to increase efficiency and productivity. The Fourth Industrial Revolution, powered by the Internet of Things (IoT), has brought about this change. Smart farms use advanced technologies to become more efficient and productive in meetingthe growing food demands of the expanding population. The smart agriculture industry was valued at US$13.8 billion in 2020 and is projected to reach US$34 billion by 2026 [12].

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1.1 Materials and Methods

1.2 Data Collection

In this section, temperature, and rainfall data from the past 50 years are being gathered, with a focus on the months of December, January, February, and March, as potato production is prevalent in Bangladesh during thistime. Furthermore, IoT devices are being utilized to assist in the design of a new model for potato production in Bangladesh in the future.

1.3 *Temperature*

The purpose of this research is to control temperature and other agriculture-related catalysts through IoT technology to reduce micronutrient deficiency and improve potato production. To accomplish this aim, the following scope of work has been set: A significant impact on plant growth is made by temperature as it is a crucial factor for crop yield. A faster harvest will result from a higher average temperature during crop growth, but the plants produced may be weaker. Conversely, a higher-quality crop is often led by a cooler average temperature that may slow down crop growth. Soil and the micronutrients in food crops are also affected by temperature. Therefore, successful crop growth and the production of nutritious food require a proper temperature to be maintained.

This table and graph present the average temperature data from the past 61 years [13]. It can be observed that the temperature has been consistently rising over the years. A rise of 2.087°C over the past 61 years has been recorded, with the average temperature being 32.28°C in 1961 and 34.367°C in 2021. The impact of temperatureon potato production is crucial, as various physiological abnormalities in tubers, secondary tuberization, and decreased productivity can be promoted by high temperatures. Therefore, in our model, the aim is to mitigate the impact of temperature on potato production.

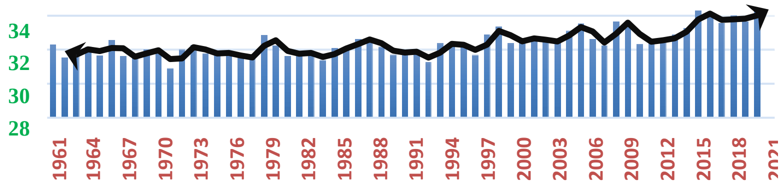


Figure 1: Bangladesh's average temperature in the last 61 years

The temperature changes in the month of January over the last 10 years are illustrated in the graph. It is observed that the temperatures have been fluctuating over the years, with an increase in 2014, a decrease in 2018, an increase in 2019, and another increase in 2021. It is generally noted that the temperatures have increased as compared to 2012, which has an impact on potato production.

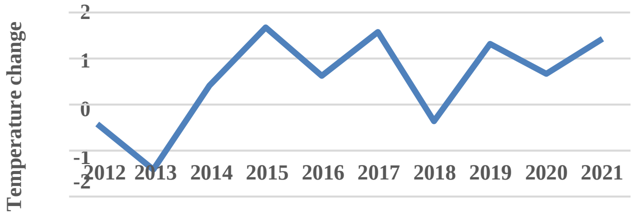


Figure 2: Last 10 years' temperature change in January

This graph illustrates the depiction of temperature change in Bangladesh. It can be observed that there is a fluctuation in temperature, with temperatures increasing or decreasing at times. Nevertheless, compared to 2012, an increase in temperature of approximately 1.5 degrees is noted. The fluctuation in temperature may have a significant impact on potato production in the country.

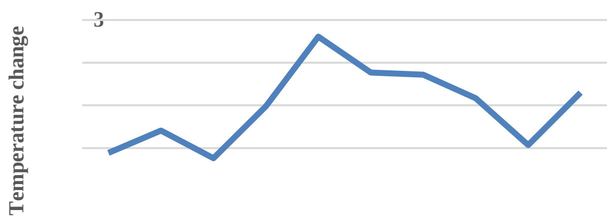


Figure 3: Last 10 years' temperature change in February

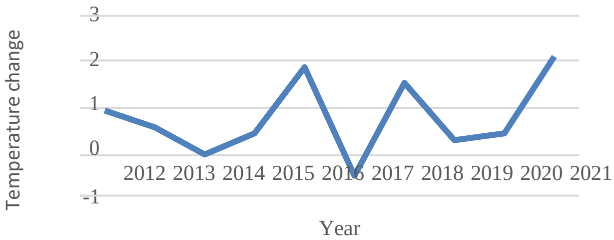


Figure 4: Last 10 years' temperature change in March

The temperature trend in Bangladesh during the month of March is depicted in this graph. It can be observed that there has been a significant increase in temperature over the years, with an increase of nearly 2 degrees in 2021. As a result of this increase, potato production is adversely affected.

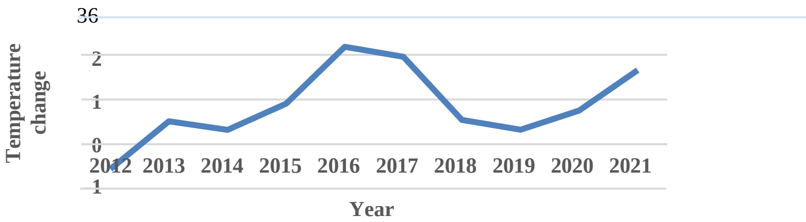
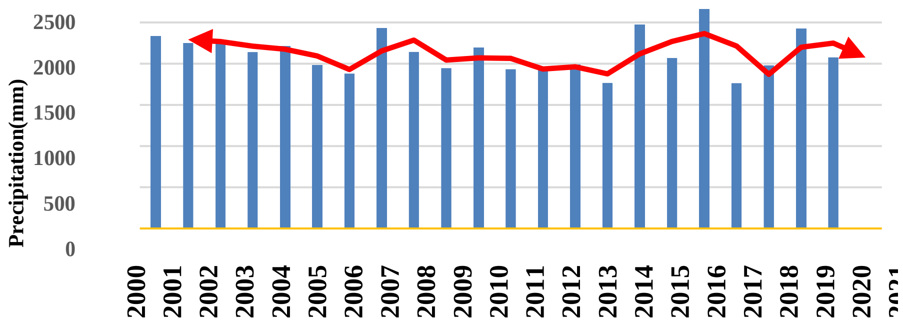


Figure 5: Last 10 years' temperature change in December

The temperature change over the past 10 years in the month of December is depicted in this graph, and it can be observed that potato seeds are planted during this month. However, several problems are being caused in potato production due to the rise in temperature.

1.3.1 Annual Precipitation

Potato production is significantly impacted by rainfall. In Bangladesh, potatoes are primarily cultivated during the winter season, but production in districts that grow potatoes throughout the year can be impacted by rainfall. The crop matures faster with precipitation, which is essential for potato growth. However, excessive rainfall can be detrimental to production. Significant variation in rainfall patterns is observed in Bangladesh.



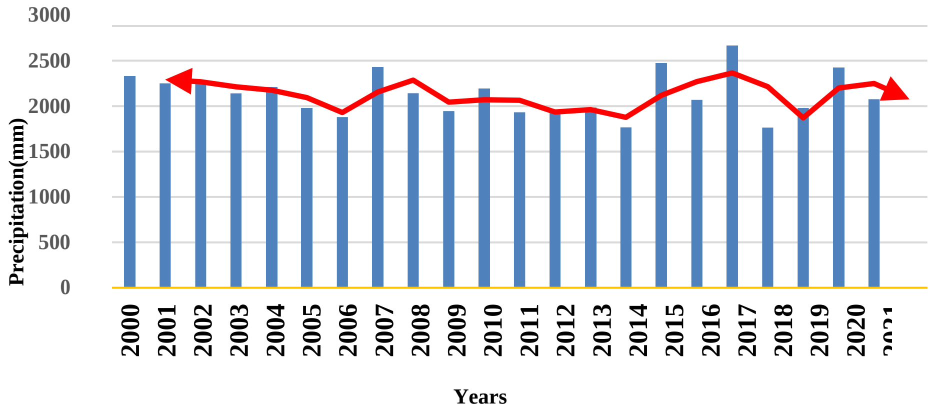


Figure 6: Annual precipitation of Bangladesh in the last 22 years

The precipitation data from the past 22 years in Bangladesh is presented in this graph and table [14]. From the data, it can be observed that there has been a significant variation in precipitation in Bangladesh. A decrease in precipitation has been recorded in comparison to the year 2000 and 2021, which has resulted in problems for potato production.

1.3.2 Potatoes Production

Data on potato production has been collected in the last 21 years, as agriculture is a source of livelihood for many people in Bangladesh, which is not a wealthy country [13]. Potatoes are low-priced vegetables and a good source of micronutrients, which can help people meet their micronutrient requirements. Our model is being developed based on the production rate of potatoes to improve potato production in Bangladesh.

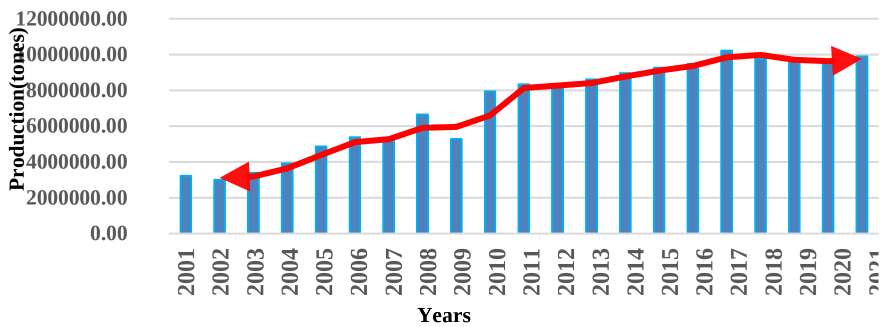


Figure 7: Potatoes production in Bangladesh in the last 21 years

It can be said that potato production in Bangladesh has increased from 3216000 tons in 2001 to 9887242 tons in 2021, as per the graph and table data. This increase in potato production is indicative of the growing demand for this crop, which is ranked third among the largest food crops in the country after rice and wheat.

N.B: To clearly Know More data (In Table format): https://drive.google.com/file/d/14W26L5ph_oVJqqubYAt--UXTh1RwdHt-/view

1.3.3 Apparatus Collection

However, despite this growth, challenges are being faced by the production of potatoes in Bangladesh, such as the effects of temperature and precipitation on the yield. The productivity of potatoes can be reduced by the lack of rainfall or excessive rainfall, which is a concern for the future of potato production in Bangladesh. To address this issue, a new advanced system has been proposed that incorporates various IoT devices such as sensors, networks, drones, and cameras to monitor and control the environment of potato fields. Various block diagrams, flow charts, and sketch diagrams were used in this system to explain the workings of each device and how they are used to improve potato production. The system has been designed to be easily monitored and controlled without the need for human intervention, ensuring a more efficient and effective method for potato production. Care has also been taken to include cost-effective devices that can be easily afforded by farmers, making this system accessible to the majority of farmers in Bangladesh.

Soil moisture sensor: Water resources are decreasing globally while demand is increasing due to population growth, urbanization, and industrial/agricultural expansion. Soil moisture sensors can detect water levels in the soil, allowing farmers to irrigate crops more efficiently. When farmers use this potato field, they can easily understand when they need to give water to the plants, and its cost is too low. Wireless sensor networks, utilizing IoT technology, have proven to be cost-effective tools for water savings in irrigation management [15]. Breadboard for Power Supply: The full system is primarily dependent on the power supply, which is of utmost importance. A power supply is required for the functioning of all Arduino boards, as it is what is used to provide electric power to them. The boards are powered through the use of the power supply.

Humidity Sensor: The DHT11 is an affordable sensor that can measure relative humidity and temperature in various environments [16]. It provides calibrated digital output using a 1-wire protocol and is easy to use with an STM32 board. It consists of a humidity-sensing sensor and a thermistor for accurate measurements.

Breadboard: A solderless breadboard called BreadBoard-400, with 400 connection tie points is utilized, wherein there are 300 tie-point IC-circuit areas along with four 25-tie-point power rails, and it is made of White ABS plastic with printed numbers and letters of rows and columns [17].

Buzzer Alarm: The BB400 breadboard has technical specifications of 36V, 2A, 400 tie points, and 50,000 insertions. It's a non-permanent connection system used in electronics, ideal for beginners. An electronic alarm buzzer is a crucial component, producing continuous sound when an electric current is passed through it [18]. With a sound pressure of 85db, it's affordable and helpful for farmers in agriculture.

Arduino UNO: The Arduino Uno R3, an open-source hardware computing platform, uses the ATmega328 microcontroller with built-in USB-to-serial conversion for standalone or connected applications in smart agriculture [19]. It allows an input voltage range of 6-20V and is powered by an AC-to-DC adapter or battery. Each input or output pin uses 40mA, and it is programmed with Arduino Software.

LCD Display: The Arduino display is crucial for smart agriculture as it shows data like temperature, humidity, and soil moisture, enabling necessary actions based on the displayed data [20].

Board Module: Relay modules are electromagnetic switches that use a small current to turn high electric circuits or appliances on or off. There are two commonly used types: ac and dc. They are effective at high temperatures and can be purchased easily and inexpensively, making them accessible to farmers. Relay modules can control the AC Motor pump.

Motor Pump: Motor pumps are used in agriculture to supply water by converting motor energy to mechanicalenergy [21]. The price varies based on quality and can be purchased according to farmers' needs.

GSM GPRS Module: The SIM900A GSM Module is a low-cost solution for GPRS/GSM communication in embedded applications. It operates on 900 and 1800MHz frequency bands, facilitating mobile calls and SMS with a mobile SIM. It offers a keypad and display interface for customized applications and has two modes: command and data. This module enables the communication between mobile devices and systems, making it useful for smart agriculture [22].

Mobile/Desktop Application: Apps/Desktop can fetch soil data, analyze pH, carbon, color, climate, and elevation based on location, and control IoT systems [23]. The apps can also evaluate water quality, temperature, algae coverage, level, clarity, and obstructions before reaching crops.

NPK Sensor: The NPK sensor is a low-cost, portable device made with durable steel probes that can measure Nitrogen, Phosphorus, and Potassium levels in soil accurately. It has a measuring range of 0-1999mg/kg and a high precision of ±2%, with readings displayed on smartphones. Farmers can use the sensor's data to optimize fertilizer usage, resulting in higher potato yields [24].

PH Sensor: Soil pH plays a critical role in determining nutrient and chemical availability to plants, with near- neutral pH being ideal. Acidic soils increase the availability of some nutrients but can lead to toxicity, while alkaline soils may cause nutrient deficiencies. Regular monitoring of soil pH is essential for optimal plant growth, and soil pH sensors have various applications in agriculture, industry, environment, animal husbandry, and sewage treatment [25].

Temperature Sensor: The DS18B20 temperature sensor by Maxim Integrated is widely used to monitor the humidity levels of the soil in agricultural fields [26]. It measures changes in capacitance, resulting from changes in humidity, and helps farmers manage the temperature of their fields for optimal crop growth. Shade nets are often used to control temperature and the combination of the sensor and shade nets leads to healthier crops.

Plastic Shade: Shading can protect crops from rain, hail, and wind damage, reduce airflow, and prevent sun scorch and weed growth. It also reduces soil evaporation and leaching of fertilizers when combined with drip irrigation and plastic mulch. Digital plastic shading can effectively control temperature and rain, reducing soil compaction and increasing crop yields. The cost is affordable for farmers [27].

Solenoid Water Valve: Solenoid valves regulate the flow of gas, liquid, or water by using an electromagnetic coil to open or close the valve [28]. They are commonly used in agriculture with an Arduino board and a soil moisture sensor to supply water to plants automatically when needed, making it cost-effective and affordable forfarmers.

Agriculture Spraying Drone: The JMR 1080x1020 JMMRC Carbon Fiber 5Litre Agriculture Spraying Drone is an efficient and cost-effective solution for farmers. It has a 5kg capacity, measures 2050x1805x543mm, and ismade of carbon fiber. Equipped with a digital and hyperspectral camera, it can monitor crops and identify plant diseases. The drone holds 5 liters of water and other materials, takes snapshots and videos, and is an affordable option compared to other advanced drones.

Solar Cell: Solar cells can provide an alternative source of electricity for farming fields located outside the electrical supply network. A proposed model for potato production uses machine learning techniques and IoT devices to monitor and control the agriculture system, eliminating the need for manual intervention. The model aims to increase potato production and improve the micronutrient content of potatoes to address vitamin deficiencies in the population [29].

Based on the data collected on temperature, rainfall, and potato production, it is believed that future potato production will be challenging. A new model for potato production in the future is proposed using machine learning techniques to make predictions and a new model of a potato field using IoT devices. With this model, everything can be controlled using a mobile app and all relevant information can be received through it, eliminating the need for farmers to worry about temperature, precipitation, and manpower. It is believed that thismodel will increase potato production and improve the micronutrient content of the potato, helping to address vitamin deficiencies in the population.

1.4 Methods

Forecasting data for Bangladesh's yearly temperature, precipitation, and the individual months of January, February, March, and December temperature change have been generated using the AAA version of the Exponential Smoothing (ETS) method, which employs historical data as input. The forecasting model was created using Excel and machine learning.

The forecast is generated by adding together a level component, a trend component, and a seasonal component. The level component represents the underlying baseline value of the time series, the trend component represents the linear trend in the data, and the seasonal component represents recurring patterns in the data. Smoothing parameters determine the responsiveness of the model to changes in the data, managing the weight assigned to recent observations in the weighted average used for forecasting.

The AAA version of ETS is a practical and effective method for various time series forecasting issues, including weather forecasting, sales forecasting, and demand forecasting. However, it assumes linear trends and additive seasonality in the data, which may not always be accurate. Alternative techniques, such as ARIMA or state space models, may be more appropriate in such cases.

1.4.1 Forecast Data

It is crucial for agricultural improvement to have temperature forecasting, as farmers who depend on weather conditions must plan their irrigation, planting, and harvesting schedules carefully. Accurate temperature forecasts can help farmers increase their yields and lower the chance of crop damage.

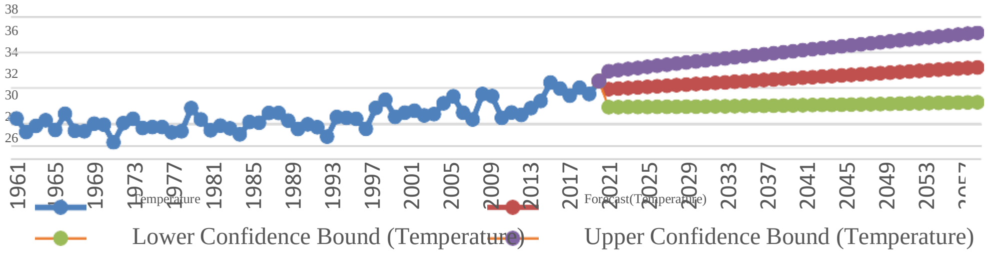


Figure 8: Forecast temperature graph for the years 2022-2060

The forecast graph and table show that there will be a temperature increase of 1.21℃ from 2022 to 2060. Based on the assumption graph, it can be seen that the temperature in Bangladesh has also increased and it seems likely that it will continue to rise. If the temperature continues to rise in Bangladesh, then potato production and productivity will be at risk. Potato yields in Bangladesh are considered important in January, as it is within the winter season when the climate is suitable for potato cultivation. Therefore, the forecasting of temperature changes in the month of January is deemed more important.

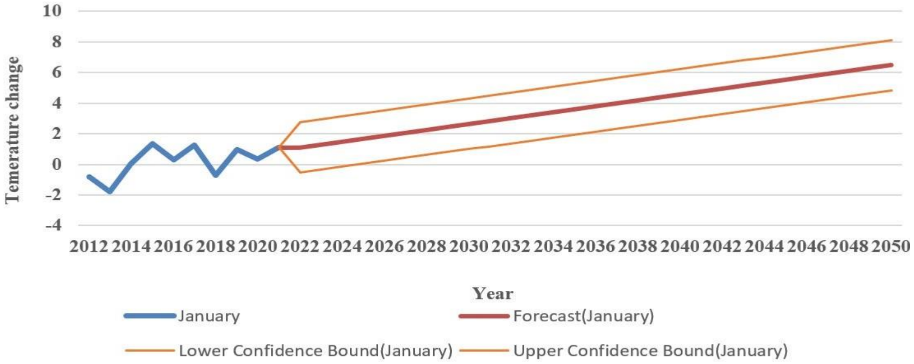


Figure 9: Forecast temperature change graph in January 2021-2050

It appears from the temperature change table and graph that a persistent change in temperature has been observed over the course of 30 years. In 2021, a temperature change of 1.104℃ was recorded, but in 2050, the temperature change in January is estimated to be approximately 6.473℃. A significant increase in temperature has been observed when compared to the temperatures between 2012 and 2050. High temperatures pose a risk topotato production.

During the winter season in Bangladesh, which spans from November to February, potatoes are typically grown. Therefore, the month of February is also considered important for potato yield, and future years' temperatures for this month need to be predicted.

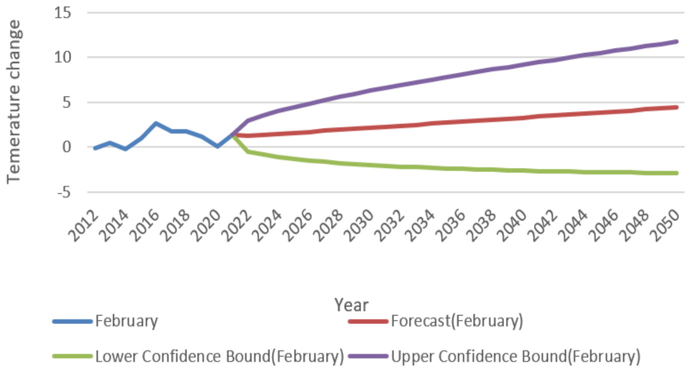


Figure 10: Forecast temperature change graph in February 2021-2050

Based on the temperature change table and graph for the month of February, it can be observed that a continual change in temperature has been occurring over the course of 30 years. A temperature change of 1.297℃ was observed in February 2021, but it is projected to reach 4.397℃ by 2050. Although the change in temperature is relatively less significant when compared to that of January, it still has an impact on potato production.

In Bangladesh, potatoes are also grown in the month of March, although potato production is greatly affected by temperature. Therefore, it is essential for the assumption of temperature change for the coming year to be made.

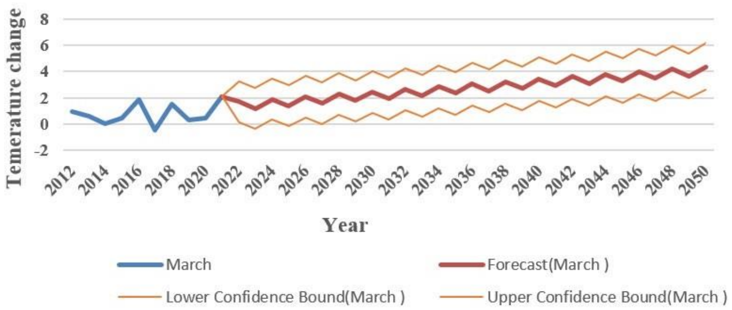


Figure 11: Forecast temperature change graph in March 2021-2050

Based on the temperature change table and graph for the month of March, it can be observed that acontinuous change in temperature has been occurring over the past 30 years. In 2021, a temperature change of 2.085°C was observed, while by 2050, an increase of around 4.360°C is expected in March.

It is during the winter season when Bangladesh's prime potato-growing season occurs, making December a significant month for the country's potato output. The growth and development of potato plants continue throughout this month, and the tubers begin to fill out with starch, which can considerably impact the crop's final production by providing adequate care and management, including appropriate irrigation, fertilizer application, and pest and disease control. Proper temperature maintenance in December is crucial for yield, and future years require the forecasting of temperature changes.

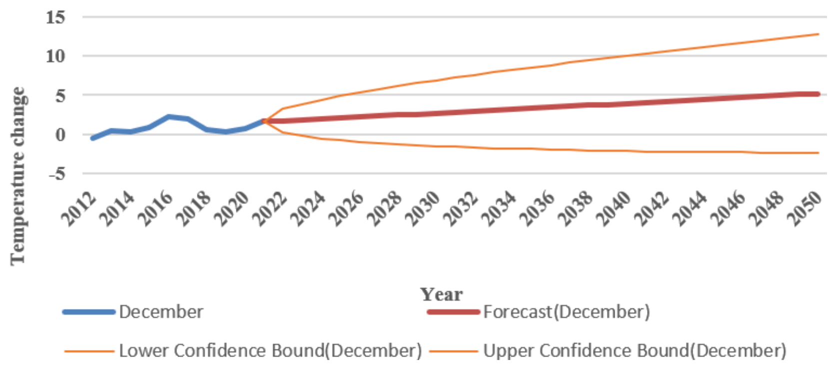


Figure 12: Forecast temperature change graph in December 2021-2050

According to the temperature change table and graph for the month of December, it can be observed that there has been a continuous change in temperature over the past 30 years. In 2021, the temperature change was 1.658℃, but by 2050, it is expected to increase to approximately 5.173℃ in December. It should be noted that during this time, potato seeds are usually planted, and excessively high temperatures can be very harmful to potato production.

Potato yields are influenced by precipitation. Adequate water is required throughout the growth cycle of potatoes, and precipitation is one of the main sources of water for potato crops. When there is insufficient rainfall, potatoes may not receive enough water, which can lead to reduced growth, lower yields, and smaller tubers. Similarly, if there is excessive rainfall, the soil can become waterlogged, which can also reduce yields. Therefore, it is important for precipitation levels to be monitored by potato growers and for the right amount of water to be provided. In regions with limited precipitation, irrigation can be used to supplement the water needs of potato crops.

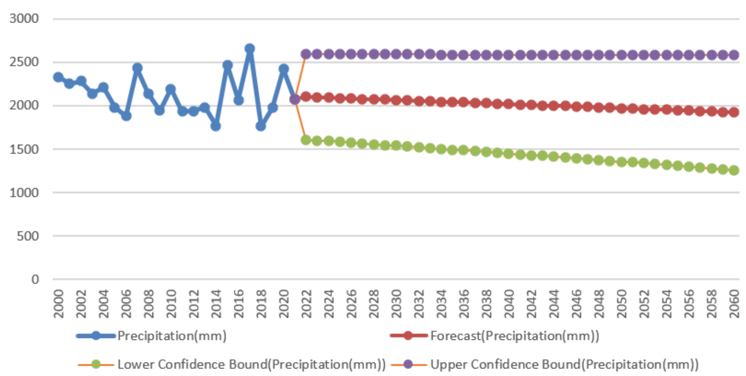


*Figure 13**:** Forecast graph of precipitation data for the year 2022-2060*

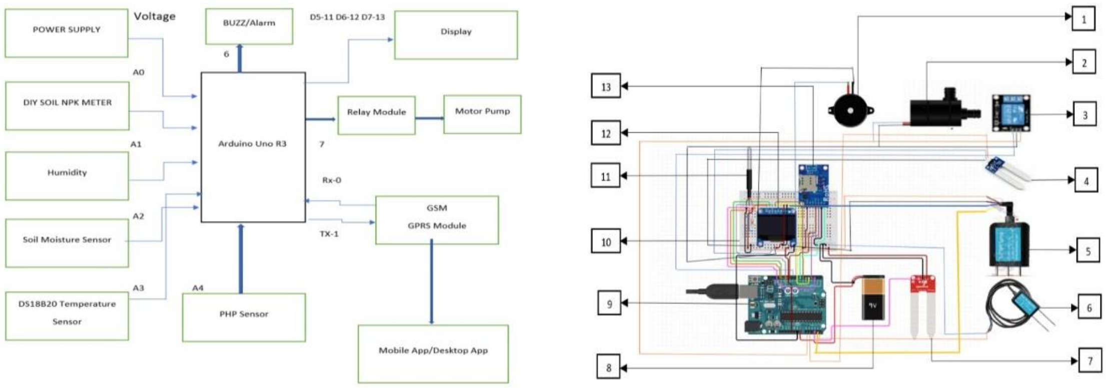
Variations in precipitation data and graphs suggest that precipitation may decrease in the future, which could lead to difficulties in potato production. Our proposed model aims to overcome this issue.

1.4.2 Block Diagram and Circuit Diagram

Based on past and future data, it has been determined that there will be significant changes in temperature and rainfall, resulting in a decrease in potato yield and nutritional quality. To address this problem and increase potato yields in the future, a potato field model using IoT devices has been proposed in our paper. With this model, the environment of the potato field can be easily controlled by farmers using a mobile or desktop application, without the need for manual intervention.

In the data collection section, all the IoT devices used in our future model have been discussed. A block diagram, circuit diagram, and flowchart of all devices have been provided, making it easy for anyone to understand and implement our system.

In the below, we connect all of the sensors with the use of Arduino Uno R3 and Bread Board:



(a) Block Diagram. (b) Circuit Diagram.

Figure 14: Block and circuit diagram of potato field using IoT

Figure (a) is illustrated a Block diagram of a potato field that is used by IoT. An Arduino Uno R3 is set up in apotato field to monitor micronutrients, temperature, and pH levels. A power supply is connected to the Vin PIN, and solar cells are used when there is no power source nearby. A buzzer/alarm connected to pin 6 alerts if any ofthe monitored parameters are not in the desired range. A display connected to pins RS-8, EN-9, D4-10, D5-11, D6-12, and D7-13 shows all the data. The relay module connected to pin 7 controls the motor, and the GSM GPRS module connected to the Rx-0 and Tx-1 lines and powered by a mobile SIM provides network connectivity to connect to a mobile or desktop app. The DIY Soil NPK Meter, Humidity Sensor, Soil Moisture Sensor, DS18B20 Temperature Sensor, and PH Sensor are connected to pins A0, A1, A2, A3, and A4, respectively, using a breadboard to ensure proper wire connections. Overall, this setup allows for comprehensive monitoring of soil conditions and efficient management of crops in the field.

Again, Figure (b) represents the circuit diagram for the potato field that is used by IoT. The circuit diagram is intended to illustrate the visual connections of all sensors. TO achieve this, all sensors are connected to the Arduino Uno via a breadboard. The breadboard and Arduino Uno are positioned in the center of the potato field, and the soil is where all the sensors are connected. Jumper wires are employed to link all of the sensors to the Arduino

Uno board. A plastic tape shade, which is a three-layer tape-x-tape model, is used at the top of the potato field to control the temperature and rainfall.

There, 1) Buzzer Alarm 2) Motor pump 3) Relay module 4) Soil moisture sensor 5) NPK sensor 6) Temperature sensor 7) Humidity sensor 8) Power source 9) Arduino UNO 10) Breadboard 11) PH sensor 12) LCD display 13) GSM GPRS module.

1.4.3 Flowchart

The functioning of the sensors in a potato field will be discussed. To provide a better understanding, a flowchart has been created that clearly depicts the working of all the components involved.

Figure 15 depicts the flow chart of the Soil sensor and Water Pump and outlines the operation of this system. It begins with system initialization, followed by checking soil moisture levels. If the levels are insufficient, an alarm sounds, and a message is sent if the user doesn't respond. If the conditions are met, the motor begins supplying water, and it automatically turns off when the conditions are no longer met. If the water supply is insufficient, an alarm is sent, and the motor shuts off.

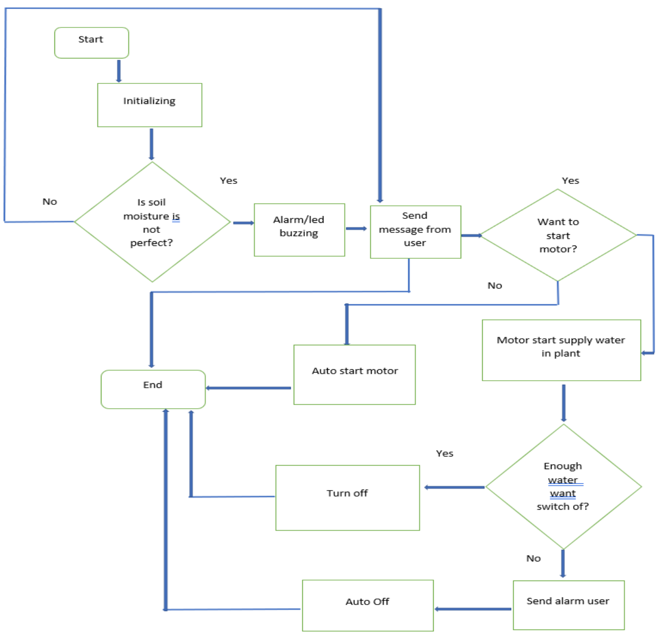


Figure 15: Flow chart of soil sensor and water pump

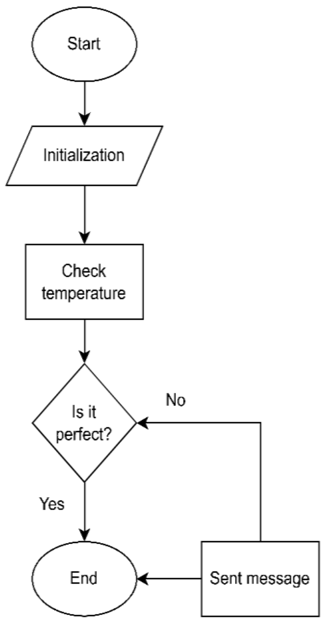


Figure 16: Humidity sensor flowchart

Figure 16 illustrated the operation of the Humidity sensor in the flow chart. The humidity sensor begins operating when connected to power with a set maximum humidity limit. If the temperature limit is exceeded, a message is shown, otherwise, it functions normally. The PH sensor in Figure 17 operates similarly to the Humidity sensor. It is activated when connected to a breadboard or Arduino and sets the highest PH value for the soil. If the limit is exceeded, a message isdisplayed; otherwise, it continuously measures the soil's PH. Figure 18 depicts the flow chart of the DIY and NPK sensor, which constantly measures soil nutrient levels and alerts when they exceed the default value. This ensures uninterrupted and efficient monitoring and maintenance of healthy plants.

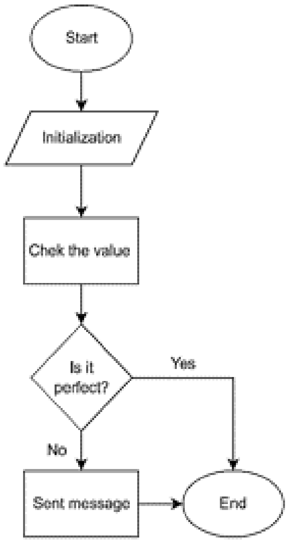


Figure 17: PH sensor flowchart

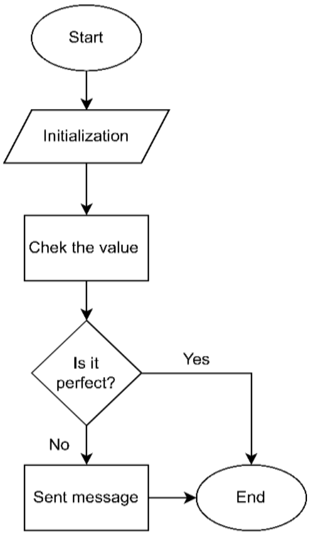
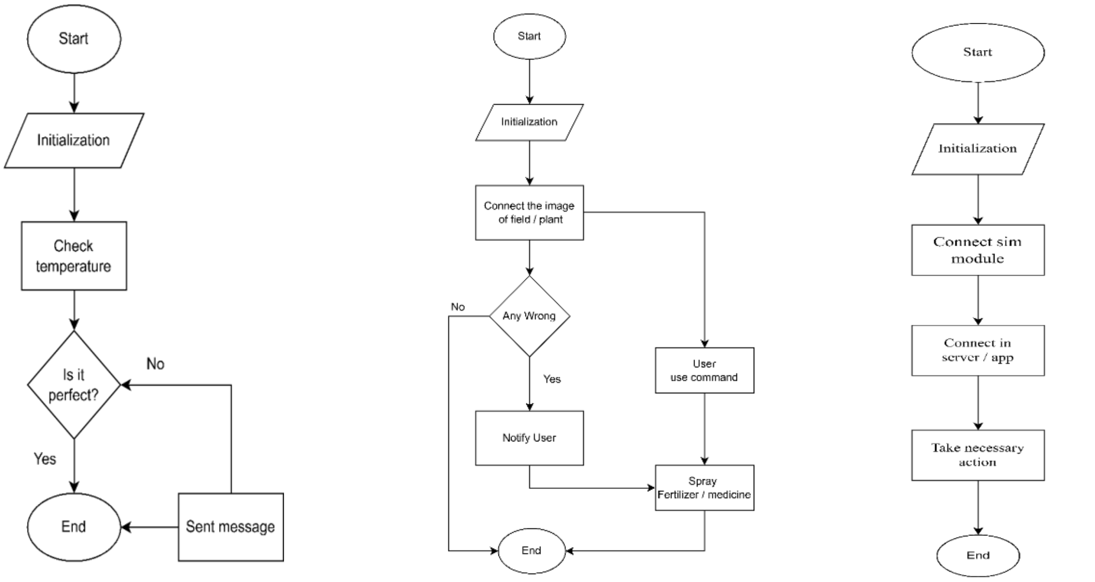


Figure 18: DIY and soil NPK sensor flowchart

Figure 19 illustrates the flowchart of the Temperature sensor, GSM GPRS module, and drone.



(a) Temperature sensor flowchart *(b) GSM GPRS flowchart.* *(c) Drone flow chart*

Figure 19: Flowchart of temperature Sensor, GSM GPRS, Drone

Temperature Sensor flow chart shows its use in soil management to monitor soil temperature continuously. It alerts the user if the temperature exceeds the default value, aiding optimal plant growth conditions. The GSM GPRS module flow chart shows how it collects data from sensors and transmits it to mobile apps for remote monitoring. Notifications are sent to farmers if action is required. This system enables efficient management of agricultural sensors. The Drone flow chart depicts its applications in capturing images, spraying fertilizers, and more. The user controls the drone manually through commands, and it alerts them in case of errors. The drone captures field and plant images and can spray medicine as required. The program ends if there are no errors. These flow charts offer an efficient means for agricultural operations, aiding remote monitoring and management of sensors and drones for optimal plant growth conditions.

1.5 Working Procedure

Firstly, the Soil Sensor, NPK Sensor, PH Sensor, Temperature Sensor, Power Supply, and Humidity Sensor are connected to the Arduino Uno through a breadboard. The Alarm, GSM Module, Relay Module, Water Pump, and Display are also connected to the Arduino Board. The soil sensor constantly checks the amount of water in the soil, and if there is not enough water, the alarm will sound, and the automatic water pump will start to supply water to the potato field. Once the necessary amount of water has been supplied, the pump will automatically stop working. The NPK sensor checks the levels of nitrogen, phosphorus, and potassium in the soil. If the levels are not optimal, the alarm will sound, and farmers will need to use fertilizer. Similarly, the temperature sensor checks the temperature in the field and if it is too high, the alarm will sound, and farmers will need to use a tape shade net to regulate the temperature. The PH sensor and humidity sensor work similarly. All of the data is displayed for farmers to check at any time. A GSM GPRS module with a SIM card is used to provide an internet connection to the Arduino board. A mobile application is used to monitor and control everything. There are many software options available in the market that can be used to easily control the system. In addition to the tape shade net, which helps regulate temperature and excess rainfall, the most important component of the system is the drone. The drone can quickly supply fertilizer and medicine to the field. It is an advanced technology model that features a hyperspectral camera used to capture images of potato plants and identify any diseases. The proposed model works as described above, and if implemented correctly, itwill help farmers in Bangladesh produce a good quantity of potatoes that can meet the demand of the country and be exported abroad. This will help meet the nutritional needs of the Bangladeshi people.

2. Results

The implementation of IoT technology in potato production in Bangladesh is expected to result in significant improvements in the sector. Farmers will be able to optimize their operations and improve the overall efficiency of the potato production process by using various sensors and connected devices. For example, Soil sensors can measure temperature, moisture levels, and nutrient content, allowing farmers to make informed irrigation and fertilization decisions. Drone technology can also be used to collect data on potato crops such as plant height, leaf growth, and fruiting patterns, which can then be analyzed to determine when to harvest and how to maximize yield. Furthermore, IoT technology can help improve the Bangladesh supply chain by providing real- time information on crop yields, inventory levels, and delivery times. This can help to reduce the need for manual labor while also increasing the overall efficiency of the potato production process. In the future, drone technology could be used for aerial spraying of pesticides and fertilizers, reducing the need for manual labor andimproving application accuracy. This can lead to fewer harmful chemicals being used and a more sustainable potato production process. Overall, the use of IoT technology in potato production in Bangladesh is expected result in significant improvements in farmer efficiency, productivity, and profitability, as well as a moresustainable and reliable food supply for Consumers.

2.1 Future Work

In the subject of IoT-based potato production in Bangladesh, there are various areas that could be explored for future research. Artificial intelligence and machine learning could be used to analyze large amounts of data from sensors and drones, allowing farmers to make more accurate predictions about crop growth and production, as well as detect patterns and trends in the data. Weather forecasting and soil analysis could be utilized to collect data on weather patterns and soil conditions, which can assist farmers in making more informed planting and harvesting decisions, as well as forecast potential weather-related issues and take preemptive actions to mitigate tempest and disease detection could be improved by employing drones outfitted with cameras and sensors to detect pests and diseases sooner, resulting in more efficient and effective treatment. Automated harvesting utilizing robots and autonomous vehicles could make the harvesting process more efficient and less labor-intensive. Water resource management could be optimized by collecting data on water usage and water quality, allowing farmers to reduce waste and improve water usage efficiency, resulting in moresustainable potato production. These are just a few examples of potential future work in the field of IoT-based potato cultivation in Bangladesh. As technology continues to advance, there will certainly be many more opportunities to leverage IoT and other advanced technologies to enhance the efficiency and sustainability of potato production in the country.

3. Discussion

It is observed that proper nutrition from potatoes, which are the primary food in Bangladesh and a significant source of micronutrients, is not being obtained due to micronutrient deficiency in the food, which is influenced by various catalysts such as temperature and precipitation. The optimum temperature and rainfall for potato production are not being maintained due to the high instability of temperature and rainfall over the years. Although potato production has increased, it is still insufficient to meet the needs of the large population of Bangladesh. Therefore, a new advanced system has been proposed that incorporates various IoT devices such as sensors, networks, drones, and cameras to monitor and control the environment of potato fields, which will be used to increase potato production and ensure the right number of micronutrients. It is believed that the proposed IoT system will enable farmers to produce a large number of potatoes, and the apparatus of this advanced system will not be too expensive, making it easily affordable for farmers. Additionally, machine learning will assist the system in obtaining real-time data on potato fields. It is further believed that this system and its operation will not only solve the micronutrient problem but also contribute to Bangladesh's economic advancement.

4. Conclusion

It can be concluded that the savior of future potato production will be the Internet of Things (IoT) and machine learning-based potato yields, as these two technologies complement each other. This is because the evaluation of the temperature, pH, NPK (nitrogen, phosphate, and potassium), and moisture of the soil, which is essential for determining crop yield, is a part of the IoT. The field is monitored by an agricultural spraying drone equipped with a camera, and a plastic shade is used to protect the crops from the sun, wind, and precipitation. Water and other necessities are sprayed onto the field using a drone. The technology offers high efficiency and precision in its operations, allowing for precise data collection, such as soil temperature and moisture content. An intelligent farming system based on the IoT is suggested by this study, which will assist farmers in increasing agricultural yield and managing food production efficiently. Accurate real-time measurements of the temperature of the surrounding environment and the moisture content of the soil will be consistently collected by the system, which will also assist farmers in environmentally responsible food production.

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