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AUTONOMOUS ROBOT FOR SOIL HEALTH MONITORING IN TEA PLANTATION

Lisha Bharali, Department of Power Electronics and Instrumentation Engineering, Student, Jorhat Institute of Science and Technology, lishabharali1@gmail.com
Krishna Kamol Duarah, Department of Power Electronics and Instrumentation Engineering, Student, Jorhat Institute of Science and Technology, krishnakamalduarah12@gmail.com
Aparna Sarmah, Department of Power Electronics and Instrumentation Engineering, Student, Jorhat Institute of Science and Technology, aparnasarmah99@gmail.com

Abstract: The Tea industry is an industry which is one of the significant agricultural sector and plays an important role in a nation's economy. Robotics plays an important role in tea plantations which enhances an effective and precision soil health monitoring and also reduce human errors and labour costs. A necessary step in tea plantation is the effective management of Soil. However, due to the lack of knowledge on effective soil management, it adversely affects the quality and yielding of tea plantation. One of the reasons also includes the shortage of labours which might lead to delayed interventions and hence deficient soil conditions. This research paper presents the implementation and development of an autonomous robot to address such issues. This robot is equipped with an ultrasonic sensor and a soil moisture senor which drills on the soil and collects the data of the moisture content. This robot provides a real time monitoring of the soil moisture content and thus reduce the need manual sampling and can be assessment with minimum labours. This helps to take timely actions and maintain a good soil health which helps to increase the yield and quality of the tea. Thus, this approach not only helps in enhancing tea plantation but also plays an important role in better resource management and thus overall plantation

***Keywords*— Autonomous robot, tea plantation, Smart robot, Ultrasonic Sensor, Soil Health Monitoring, Soil moisture sensor**

1. Introduction

Sustainable Agriculture plays a very important role in tea plantation. However, due to different climatic factors such as soil degradation and other climate changes the quality and yield of tea production is adversely affected. A shortage of labour can be another factor which made it difficult to maintain a good quality tea production. The collection of data over a large spatial of land accurately is highly essential, but through manual process it is a time consuming process also prone to errors even when used advanced equipment. The traditional methods of soil monitoring and tea planation is labour intensive and is often not reliable. In modern times, a precise and timely data on the conditions of the soil is crucial. Yet, due to the shortage of labour the productivity and the quality of the tea are affected to a large extend and to tackle these challenges, an autonomous robot equipped with soil moisture sensor and ultrasonic sensors are introduced in the tea plantation of Assam to ensure effective and accurate data collection. Assam's tea industry acts on the backbone of the entire state's economy serving as the livelihood of many people. The success of a good quality tea production depends on various factors such as weather patterns, soil conditions, pest

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control, etc. All these factors are essential for a healthy tea plantation for production high yield and quality tea.

One of the factor that plays a very important role is the moisture content of the soil. The fluctuations in the moisture of the soil greatly impacts the productivity and quality of the tea production. A low level of moisture content in the soil hinders the growth of plants and also makes them susceptible to various pest and diseases, as a result the entire growth of the plant may be stunned. An optimal moisture content of the soil enhances the ability to absorb the nutrients content in the soil effectively thus ensures a good yield and quality of tea. Soil moisture management is one of the key factors for sustainability the tea industry to increase productivity and to have a high quality tea. Soil moisture plays an important role in maintaining the microclimate for tea production. By maintaining an adequate moisture of the soil it maintains the temperatures of soil by keeping it cool so that the plant does not get heat stress. This is important in areas such as tropical and subtropical regions where the tea production is predominantly found, as these areas experiences a higher temperatures which might affect the tea plants due to heat stress.

The use of soil moisture sensor in the autonomous bot is used to enhance the accuracy, efficiency and also sustainability. The Traditional practices which Includes manual practices are time consuming and also led to inconsistent irrigation practices. These sensors provides an accurate and real-time data of the moisture content of the soil by measuring the volumetric content of the soil, through which the planters can make informed decisions on irrigation. The sensors promotes the conservation of water and also helps in growth of plants. Thus improving the overall production of tea plantation

The autonomous robot has been developed to operate independently and minimized the need of human labor. This robot consist of soil moisture sensor module, ultrasonic sensor and drilling mechanism. The ultrasonic sensor is used to detect any obstacles and navigate through the path accurately. The robot can move through the tea plantation comprehensively without the need of manual interventions. The drilling mechanism helps the soil sensor to penetrate through various depth of the soil to collect an accurate real-time data of the moisture content of the soil. These data are essential for the making crucial analysis of soil conditions and also for irrigation.

The autonomous robot ensures sustainable agriculture practices through maintaining a healthy soil monitoring system. It collects real-time data of the soil moisture content which ensures improvement in the soil nutrients utilization, enhancing tea production and also quality of the tea. The use of autonomous robot in tea plantation paves the way for a cost-effective and sustainable tea plantation practices thus increase the yields and quality of the tea.

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Fig 1: Picture of the autonomous robot

2. HISTORICAL BACKGROUND

The integration of IoT systems in agriculture has revolutionised the way farmers manage resources and monitor crop health. Farmers now have the resources necessary for precise mapping and soil condition monitoring thanks to sensors and ultrasonic technologies. R. Nivetha et al. created solar-powered robots to maximize monitoring, watering, and sowing in order to increase agricultural productivity [20]. Edulji et al. developed a GPS-enabled robotic device that uses auger-based mechanics and Arduino-integrated sensors to automate soil sampling with greater accuracy and efficiency [3]. Monalisha, et al. developed an IoT-enabled irrigation system with soil moisture sensors and automatic gates increased water efficiency to 86.6% utilizing real-time data. Sensor placement optimization showed significant promise for enhancing long-term irrigation methods [5]. Hari Mohan, et al. studied and developed an AgriBot combines IoT and Arduino UNO to automate farming tasks, increasing efficiency and reducing labour expenses. It monitors parameters like as soil moisture and temperature, and stores real-time data in the cloud for remote management [11]. Omia, Emmanuel, et al. Remote sensing technologies, including MSI, HSI, and LiDAR, enable precise crop monitoring and resource optimization. Integrated with IoT, robotics, and GPS, they enhance agronomic efficiency, address climate challenges, and advance sustainable, precision farming practices [23]. Huang, et al. studied on an advanced polynomial and BES-optimized LSTM algorithm is used in a predicted tea tree growth model that uses data on soil temperature, moisture, and conductivity. This improves tea plantation management and helps farmers make well-informed decisions, which advances precision agriculture [7].

However, while these technological advancements have shown promise, the application of such systems specifically in tea plantations, particularly in regions facing severe climatic challenges,

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remains limited. This study aims to address this gap by developing an autonomous robot that leverages IoT to monitor and manage soil health in tea plantation.

3. MATERIAL AND METHODOLOGY

To ensure proper motion and functioning of the bot, this project uses a variety of sensors, microcontrollers, and other components. Here Arduino Nano, Servo Motor, DC Motors, Soil Moisture Sensor, Ultrasonic Sensor, two regular wheels and one castor wheel are the primary components utilized in this project.

Table 1: The components that are used in the autonomous robot

Arduino Nano	L298N Motor Driver	DC motors	Servom otors	Soil Moisture Sensor	Ultrasonic sensor
					

The frame of the robot was created using wood and plywood for a simple and sturdy body for proper movement.

Here we integrate these components with the frame to proper operation of the bot. For proper functioning of the bot, we are using proper collection and processes of survey and data collection using sensor:

1. As a preliminary step before data collection a comprehensive study of soil and different types of soil based on its specific requirements are studied to learn with the overall topographical details.

2. The soil moisture sensor continuously records and collects the data from various selected areas and provides real-time data of the moisture level.
3. The overall frame is designed based on the problem and its requirement so that it can move through the difficult areas easily.

4. Each of the components has its own specialty to select it for this project. We have used Soil Moisture sensor for continuous monitoring of soil moisture data for different areas , Regular wheels and plywood frame based on the problems requirement, a motor driver specifically L298N to run the motors and microcontroller Arduino NANO to run the motors specifically without hampering the design due to its compact size .

5. To obtain accurate and correct data, the data was collected from the Tocklai Tea Research Institute with assistance from their soil department. We have chosen a few samples for the

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soil moisture measurement and calibrated it using the more recent, precise sensor that is in the labs. One of the commonly used method 'GRAVIMETRIC METHOD' is used here in this project. Here soil samples are collected from different locations and depths using a soil auger. The collected soil is then sealed in an airtight container or plastic bag so moisture is not lost before weighing now after determining wet weight, the soil is placed in an oven for 24 hours at 220ºF, and the dry soil sample is reweighed to determine the amount of water lost [14] After calculating the % change in weight we can get the total amount of Moisture content .After getting these moisture level, we verified the amount of moisture measured by our sensor and changed it accordingly to get the accurate readings.

4. RESULT & DISCUSSION

After the collection and calibration of data the autonomous robot succeeded to measure the moisture of various areas across the field with an accuracy of over 95% with obstacle avoidance and autonomous movement and collection of data. The collection of data and movement operated successfully without the need for human interaction. This helps in reducing the workload of human interaction in the field and saves the labour expenses and time drastically. The results are summarized in Table 2 and 3.

Table 2: Soil Moisture level and Analog reading by the autonomous robot

For analog read	Percentage of moisture level
401	The sensor is showing 0% moisture content
1024	The sensor is showing 100%moisture content

Table 3: Soil Moisture readings by the autonomous robot.

Sl. No.	Soil Moisture content (in percentage)
1.	**11%**
2.	**12%**
3.	**11%**
4.	**16 %**

This autonomous robot's accomplishment opened up a wider area of agricultural technology and showed the tremendous progress made in precision agriculture. Comparing our research with other related studies, we can observe that the use of inexpensive hardware develops helps in the continuous collection of high-quality data, which undoubtedly opens the way for future advancement and use in the field of autonomous robot application, particularly in agricultural applications.

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5. Conclusion:

In order to increase the tea plantation with a high quality of tea, this paper presents an autonomous robot equipped with advance sensors such as soil moisture sensor, ultrasonic sensor and drilling mechanism. The ultrasonic sensor helps to navigate accurately by avoiding any obstacle in its path. The drilling mechanism through which the soil moisture sensor collects the moisture content of the soil, this automation ensures an accurate and real-time data collection. The future improvements might involve using of advanced sensors such as pH sensor, also by using internet of things together with geoinformatics so that the data collected are geotagged. Thus, this will ensure resource management, capability and accuracy. This research demonstrate the potentials of robotics in the field of tea plantation by revolutionize the soil health management system of tea industry, thus paving the way for future advancement in precision tea plantation.

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