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EFFICIENT IOT-ENABLED HIGH SPEED AND ENERGY EFFICIENT EARLY LANDSLIDE DETECTION AND MONITORING SYSTEM BASED ON GEOTECHNICAL PARAMETERS

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A B S T R A C T

Landslides are a growing threat in steep regions of the world, taking lives and damaging property. The recent damages caused by landslides demand that authorities pay attention to catastrophe risk mitigation strategies. One crucial risk reduction strategy is the creation of an efficient landslide early warning system (LEWS), which will allow authorities and the public at large to be informed in advance of any landslide incidents. In order to construct a system of early warning for landslides, a wireless sensing network may collect data on the geological features and a few physical surroundings characteristics. The recommended system's primary objective is to predict when a landslide could happen and alert authorities to prevent or at least minimize casualties. In this study, we show how Internet of Things-based sensors (temperature, soil moisture ,humidity) may be used to observe and alert authorities to impending landslide danger. An advanced landslide tracking system built on Internet of Things infrastructure is shown here. The system is comprised of a group of self-sufficient wearable sensors, each of which wears a sensor costume designed for tracking landslides, and a microprocessor that aggregates data from a wide variety of sensors.

1. INTRODUCTION

Landslides are a type of natural catastrophe that can occur in a short amount of time owing to differences in environmental activity. They are responsible for causing harm to human life, agricultural properties, and other areas of the environment (Eknath et al., 2018). The movement of a mass of rock, debris, or earth down a slope is known as a landslide Landslides can be caused by a number of external stimuli, including strong rains, shaking from earthquakes, changes in water levels, storm waves, or rapid stream erosion that causes the shear strength or shear stress of slope-forming materials to rapidly increase or decrease. The amount of deaths from natural catastrophes like landslides may be reduced by continual observation, particularly in poor nations (Pitambar et al., 2019). During monsoon season, the soil and rocks are subjected to hydrodynamic pressures generated by rainwater percolating through

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the ground. As a result, tension builds up, causing the soils and boulders to lose their cohesive powers and cause landslides (Abraham et al., 2020). Many lives are lost every year because of landslides that wipe out farm and forest, wash away roads, and devastate Earth's natural ecosystem (Ahmed & Saad, 2016; Crawford & Bryson, 2018; Elmoulat & Ait Brahim, 2018). It can also have long-lasting negative effects on things like water supply, fishing, sewage treatment systems, bridges, and roads.

Whenever the slope is unsteady, the slight disturbance may cause landslide to take place. Slope instability may be triggered by natural factors like shocks, which add stresses to an already precarious slope, or evacuation, which occurs when groundwater levels empowering to destabilise a slope (Kshirsagar et al., 2018, 2020; Debauche et al., 2018, 2019). Land clearing, farming, and building further weaken the already precarious slopes, as do vibration from vehicles and other equipment. Landslides come in many forms, including rock landslides, mudslides, topsoil, and mud flows. Natural disasters like landslides may happen everywhere (Debauche et al., 2018). Landslides are a common hazard on mountains with a slight hillside. Experts from all across the globe have examined various case studies in an effort to better understand how to detect, forecast, and analyze landslides. Governmental organizations must improve their knowledge of landslide hazard and make defensible financial decisions for landslide risk management in order to solve the landslide issue.

Utilizing wearable technologies to keep monitor on water levels has gone from science fiction to hard fact during the last twenty years. Underground water monitoring requires "the establishment of a platform for gathering, transmitting, and analysing actual information," which might be accomplished using a Wi-Fi connection (Manoharan et al., 2020). Fifteen years later, many businesses using a variety of wireless technologies have begun offering subsurface network architecture. When it pertains to individual communications and Internet connectivity, moreover, Wi-Fi, 3G, & 4G networks well beyond the geological society (Tao et al., 2018). Notwithstanding, the geological society currently lacks an uniform and country's official framework for mobile communications.

Any use of the Internet of Things (IoT) in the field of ground improvement would benefit from explanations of the underlying principles of the IoT (Pahlevan & Obermaisser, 2018). With the goal of bringing attention to the importance of the Internet of Things (IoT) as a potential domain for future standardisation, the International Telecommunication Union (ITU) has produced a suggestion that aims to give such a roadmap. In the field of geotechnical, this advice may serve as a starting point and guide for any future Applications (Dilip et al., 2022). The IoT is a far-reaching concept having technical and social ramifications, according to the International Telecommunications Union. These are accompanied by a general technical description and criteria that are vague and lack information about the underlying technology or any measurable attributes (Nanao & Laishram, 2019). However, the IoT standard model published by the ITU consists of four levels with their own set of features. Moreover, the IoT ecosystems model developed by ITU expands the IoT reference architecture by include the legitimate user.

2. REVIEW OF LITERATURE

Jadhav Kanchan Eknath et al. (2018) have determined that most disasters in tropical regions, like Thailand, fall into the category of shallow catastrophes. Intense monsoon rains are the primary cause of these modest landslides. Soil loses its deleterious pressure within the pores when it absorbs rainwater. Using a rainwater surveillance system, one may create a landslides monitoring program. However, precise levels of ground water monitoring is both time-consuming and costly.

Pawar Pitambar et al. (2019) employed LIDAR that uses geographical photos to analyze the landscape and identify recent landslides action. Adjusting the Level of Detail in an Image. For landslide monitoring, neural network training use aerial imagery. Using smart algorithms and a KNN classifier, autonomous landslide monitoring from remotely sensed data is achieved by a scene clustering algorithm predicated both BoVW & pLSA.

M. T. Abraham et al. (2020) applied MEMS-based sensor that measure increasing volume contention and tilt are used to keep tabs on the dynamic slopes in a given region. A modern communications module is implemented to facilitate interaction between several sensors. Adjustable monitors were embedded inside this soil to detect tilt orientations and soil water content for a real-time field study to determine the sensors' usefulness. The biosensor data was analysed by contrasting it with manually observed and manually gathered precipitation data. The research investigated the connection amongst precipitation, tilt degree, and indeed the rate at which in volumetric moisture contents.

Ahmed and Saad (2016) findings would help raise awareness of landslide danger. In the event of a landslide reversal, the platform's angle led to technological observations of the inclination edges, the hydraulic pressure sensor measures the amount of water present at the mountainside cliff, and the temperature controller detects surface temperatures. Since the sensors' code is defined in an Arduino, all of the instruments' hubs may talk to one another and to the Raspberry Pi to collect information. When all data collection is complete, the results are sent on to Zig bee for communication.

3. OBJECTIVES

This study details the design and implementation of a landslides early detection system that makes use of wearable networks tied to the IoT. Households in landslide-prone areas may get advance warning from the developed framework. In addition, national authorities may use analysis of seismic ground information to create relevant policy, approach, and implementation. This study presents an IoT-based landslides forecasting system's. The Arduino Types as follows 2560 microcontroller in this setup is responsible for gathering information from the various sensors. Every access point also has a Gsm / gprs modem connected for incoming calls. The knowledge is sent to a server over the GSM communication systems.

4. SYSTEM OF ARCHITECTURE

The Internet of Things (IoT) infrastructure forms the basis of the suggested landslides advance warning service's. Through the use of M2M technology, the systems may operate autonomously, without the need for any human intervention. As can be seen in Figure 1, the recommended system takes into account not one but three distinct areas: the sensor networks domain, the communications website, and indeed the access control website (Baah & Naghavi, 2018). Numerous nodes spread over several locations make up the initial domain. The data assets of each node are the monitoring devices that comprise up each node (Sundaramurthy et al., 2020). Temperatures, humidity, ground failure, and soil moisture are only few of the physical characteristics that may be gauged by this apparatus. A solitary controller coordinates the collection and processing of data from several sensors. A number of sensors in an Iot, each of which contributes a unique kind of data (Culman et al., 2017). The information gathered by the node is sent via the gateways of the telecommunications field to the central database in the access permissions domains. Data are stored on the computer and analyzed to produce a landslides emergency alert using an intelligent system. One coordinators and four detectors (one each for temperature, moisture, slope, and moisture content) make up each node. The detectors' data is gathered by a microprocessor on a microchip. Figure 1 shows system architecture.

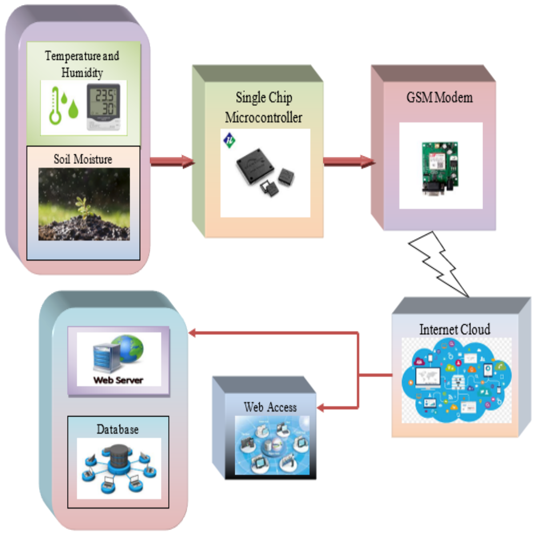

Figure 1. System Architecture

5. LANDSLIDE DETECTION SYSTEM

Figure 2 depicts the components of the system, which include the number of nodes, microcontroller, and raspberry pi located at the weather station. Sensor network are often deployed in clusters to cover larger areas. Measurements for monitoring landslides, also including deformation, soil humidity, and steering angle, are collected via a network of sensors. With the suggested setup, a moisture sensor for soil powered by 3.3 V to 5 V is used. It uses two plates to determine how much moisture is present in the ground. Electrical current passing between the plates is directly linked to the amount of water present (Culman et al., 2017; Romdhane et al., 2017). As ambient humidity rises, the satellite's current draw increases, resulting in lower operational amplifier and a lower output voltage. Also, when ambient humidity is low, the sensors draws reduced current, leading to higher operational amplifier and a higher voltage (Kshirsgar et a., 219). While both analogue and digital outputs from moisture sensors may be utilized with a multiplexer's analogue input signal, the former is recommended. ADXL335 (Tao et al., 2018), an accelerator with a polycrystalline earth's crust fabricated detector and signal processing circuitry, is utilized for vibrations detection (slope movement measuring).

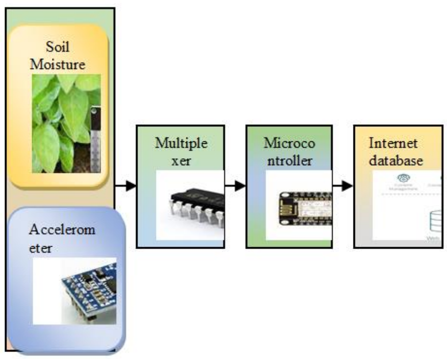

Figure 2. Landslide Detection System

An accelerator consists of a stationary reference plates and a rotating measuring plate. As the traveling plate is deflected by the displacement, the differentially inductance is disrupted, and an outputs voltage is released that is proportionate to the acceleration and braking (Romdhane et al., 2017). The X, Y, and Z output pins of the ADXL335 spectrometer each have an analogue voltage that is proportionate to the momentum in that axis. And through multiplexing CD4051B (Pahlevan & Obermaisser 2018), the sensor information is sent to the microcontroller. Since the NodeMCU (esp8266) (Dilip et al., 2022) control system that was used has just a single analogue input wire and an integrated Wi-Fi component, both of which are essential for sending data to a central surveillance hub, this is implemented. If a different microcontroller is used, one with more analogue input pins and better suited for communicating with a Wi-Fi modules, the multiplexing block may be disregarded. Sensor networks information is accepted by the controller (Raptis et al., 2018). It sounds an alarm if the values of the detected data exceed a prescribed limit. All of the information is separated into the "safe zone," the "intermediate zone," and the "target zone." Data collection and analysis is the responsibility of the control point. NodeMCU uses the MQTT protocol to send the detected data to a weather station. Python program is used for data receiving and transfer by raspberry pi to server (Lee et al., 2017). The rescue helicopter is also notified when the user enters the DANGER zone. The Internet of Things is supported by the "Things Speaking" platform (cloud storage). On the Thing Speaking webpage, the gathered information is visually depicted to facilitate analysis.

6. IOT BASED ENERGY EFFICIENT EARLY LANDSLIDE MONITORING AND DETECTION

The suggested architecture, dubbed the Internet of Things based Energy - saving Early Slope stability Classification models, is able to identify the landslide far in advance of its manifestation, hence saving lives. artefacts from all around the place, including, This accelerometer is designed to detect and measure the underlying forces generated by the displacement of foundations following earthquakes (Kshirsagar et al., 2022). Instrumentation for detecting precipitation: When a flood strikes, this sensors will go off instantly. The amount of moisture on the surfaces is read by the precipitation sensor, which responds with an alteration in the resistance. Connecting to the networks, the rain-sensing nodes share their findings with their peers (Pandey & Litoriya, 2019). Connectivity between the many locations and indeed the centralized IoT hub allows for data collection and message dissemination. It also notifies the node in charge of sounding alerts and waking up the traffic lights in the instance of an emergency.

In Figure 3, the precipitation detector will be engaged if rain is detected, and the accelerometer will be triggered if an earthquakes is detected. Node 1 will collect this data from the sensors and regularly update the IoT Hub (Brown & Lisa, 2018). Depending on the size of the monitored region, a large number of sensors and networks will be deployed, with the data collected from each being sent to its corresponding node through an Internet of Things hub. Whenever node 3 transmits data about the landslides monitoring reports, a doorbell will sound in a transportation command center. Consequently, the signalized intersections sensor system is activated and adjusted to divert traffic away from the affected area, and every one of these data are now transmitted to an Iot platform, which continues to monitor all of the research findings and, when necessary, alerts the governing party via SMS with the assistance of a privileged access smartphone. To warn other locations and keep information in the cloud, it is also necessary to save and distribute the data through a web service. The suggested methodology would allow us to identify collapses in their earliest stages, at which point we may send alarm signals to our president's disaster preparedness sector, allowing them to take the preventative measures needed to save our lives.

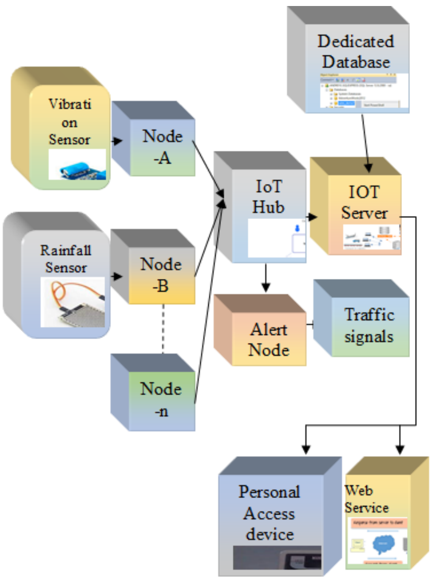

Figure 3. IoT based Energy Efficient Early Landslide Monitoring and Detection

The suggested system makes use of a number of different devices and components, including an Arduino Microcontroller 2560, an Arduino Uno R3, an ESP8266 Wi-Fi modules, as well as a Sensor ZigBee module. Moisture in the soil sensor (MPU6050), gyro-accelerometer (DHT22), and humidity sensor (both DHT22). The DHT22 is a very cheap digital sensors for measuring both humidity and temperatures (Sruthy et al., 2020). It measures the surrounding air's temperature and moisture levels using a humidity sensor sensors and digitally outputs the results. Data from the sensors may well be up to two seconds old when employing the

DHT22 libraries in the Arduino programme. Six axes of motion data are collected by the MPU 6050 IMU (Inertia Management Unit). There are three magnetometer readings and three barometer values. In reality, a single chip houses both the magnetometer and the magnetometer. Inter-Integrated Circuit (I2C) protocol is used to communicate with the chip (Romdhane et al., 2017; Kshirsgar et al., 2020). Another sensor employed is a relative humidity sensor, which measures the quantitative measure of moisture content. The MPU 6050 sensor will also be used to detect the three-dimensional earth's surface movements (x, y, and z axes). ZigBee delivers data gathered from the broadcaster side microprocessor while Arduino monitors soil surface conditions (such as temperatures, moisture, vibrations, and wetness). Zig will get data broadcast from transmitters at the site of reception, and ESP8266 functions as a browser to upload this information to the computer (Xiong, 2021). When it comes to storing and retrieving information from devices, Blynk is really the accessible applications and programmatic interfaces to use whether communicating via the World wide web or a local area networks (LAN). This software also enables the user to create area monitoring apps with automatic updates and sensors recording applications. Blynk was implemented in this experiment to gather data from Arduino devices and keep track of it. Following figure is a block diagram showing how the suggested system would work. Figure 4 shows IOT based energy efficient early landslide detecting system.

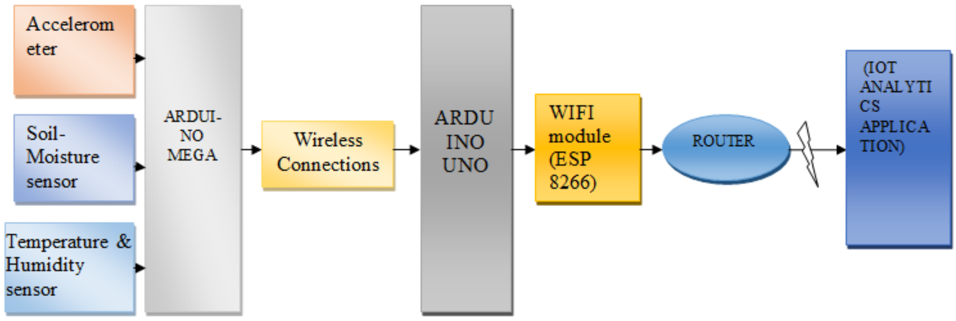

Figure 4. IoT based Energy Efficient Early Landslide Detecting System

7. METHODOLOGY

Figure 5 displays the components' operational sequence. All of these sensors and the micro - controller will determine the soil's overall condition. In particular, an accelerator will assess the three-dimensional motion of the soil's surface (x,y,z axis). Humidity ,temperature and soil moisture meters are also being deployed to monitor state of the environment.

The material is gathered once per hour to decrease power usage and increase the lifespan of the platform's batteries. In contrast, the technology will collect samples and log information for each observed pile foundations if an accelerator is present (Xiong, 2021). The information will subsequently be sent electronically to a receiving device. The data will be uploaded to the cloud through the Wi-Fi-enabled transmitter (Xue et al., 2018). The collected information gathered by the sensors is shown via a mobile app. If the programmer detects any significant groundwater flow, an alarm will be sent.

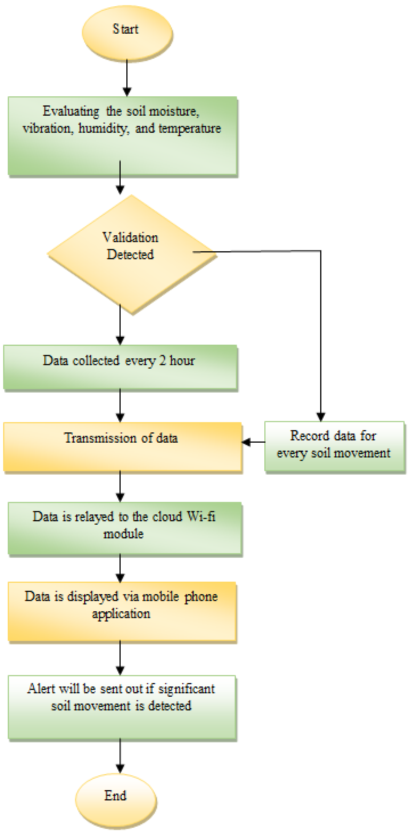

Figure 5. Operation Flow Chart of IoT Based Landslide Monitoring System

8. RESULT AND DISCUSSION

The research work shows the accurate findings of measurements of devices inside the sensor network space. The measured data from sensor and actual data were compared to ensure the network sensors performed correctly or not. Multiple sensors, including ones that take measurements of temperature, Humidity, and moisture content, were used to thoroughly evaluate the warning system.

8.1 Temperature sensor

Table 1 and Figure 6 makes available the data collected by Sensor DHT22, which includes the temperature that was observed (blue line without dot markers). True temperatures is shown as a red line with white dots. The diagram displays the value dissimilarity between both the two lines. Averaging the differences leads to a result of 0.175^{0}C. As a result, we conclude that the temperature controller has been functioning normally.

Table 1. Measurement of Temperature Sensor

S.No	Time	Measured Temperature(^{0}C)	Actual Temperature (^{0}C)
1	21:15	34	34
2	21:35	34	33
3	22:15	33	31
4	22:35	33	32
5	23:15	34	33
6	23:35	32	31
7	0:00	32	30
8	1:15	30	28
9	1:35	32	29
10	2:15	32	31
11	2:35	27	32
12	3:00	26	29
13	4:00	26	28
14	5:00	25	27
15	6:00	25	26

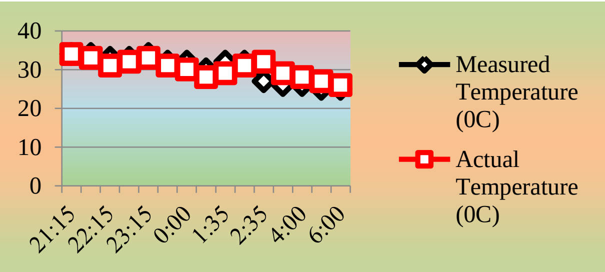

Figure 6. Measurement of Temperature Sensor

8.2. Humidity Sensor

Humidity readings may be taken using the DHT22 sensor. The Figure 7 and Table 2 represents the sensor's actual humidity readings. Humidity readings taken with a humidity sensor are also shown here for comparison. As we can see, the two sets of information are not identical. We calculate a difference of 4.522 percent between the two values. It's possible that inaccurate measurements may lead to an increase in this occurrence.

Table 2. Measurement of Humidity Sensor

S.No	Time	Measured Humidity (%)	Actual Humidity (%)
1	21:15	61	65
2	21:35	61	65
3	22:15	61	65
4	22:35	61	65
5	23:15	60	65
6	23:35	60	65
7	0:00	61	64
8	1:15	61	63
9	1:35	61	62
10	2:15	61	64
11	2:35	60	64
12	3:00	59	63
13	4:00	59	63
14	5:00	59	63
15	6:00	59	63

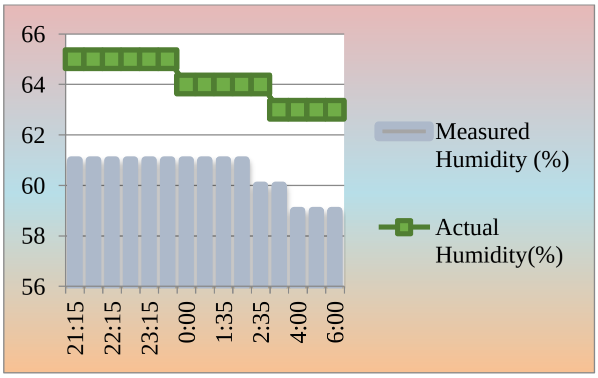

Figure 7. Measurement of Humidity Sensor

8.3. Soil Moisture Sensor

Optimized soil moisture sensing readings are shown in Figure 8 and Table 3. This data demonstrates how well the relative humidity fluctuates over time. After it rains on the experimental soil, the values go up.

Table 3. Measurement of Soil Moisture Sensor

S.No	Time	Soil Moisture (%)
1	21:15	92
2	21:35	92
3	22:15	93
4	22:35	93
5	23:15	94
6	23:35	94
7	0:00	92
8	1:15	92
9	1:35	93
10	2:15	93
11	2:35	96
12	3:00	96
13	4:00	96
14	5:00	96
15	6:00	96

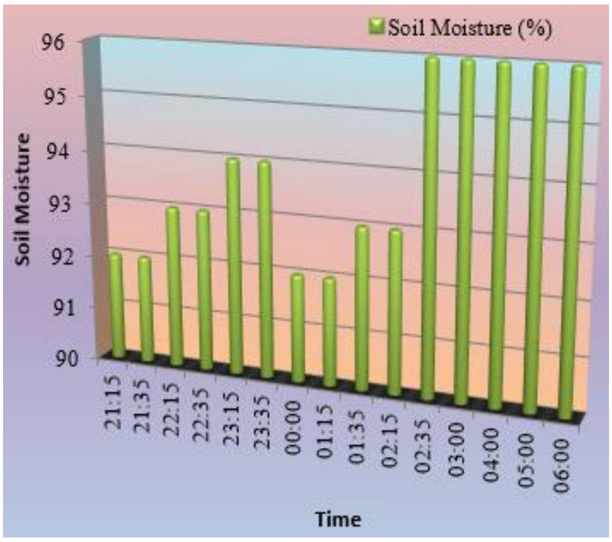

Figure 8. Measurement of Soil Moisture Sensor

9. CONCLUSION

The goal of the proposed research work is to recognize landslides at an early stage utilizing readily accessible, low-cost equipment. In order to achieve this goal, the recommended work makes use of cutting-edge Internet of Things technologies and standard electrical devices and equipment. In the suggested model, the reliability of landslide susceptibility mapping and the effectiveness of the network in disseminating case of emergencies information signal are both enhanced. The prediction accuracy and resource effectiveness of the suggested system have been shown in both real-world deployment and virtualized settings. Many of the physical attributes that might cause a landslide tragedy have been effectively measured using proposed network system. There are three sensors in the node itself: one each for humidity, temperatures, and moisture levels. The sensing results were converted to the experimental measurements that related to them. Using a telecommunication modem, the collected information is uploaded to the Cloud infrastructure.

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