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# Development of an Electronic Precision Soil Auger with Depth Control

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***Abstract:*** *Proper soil sampling is a requisite for farmers in any forage or cropping system to determine the physicochemical properties of the soil. The emerging innovations in agriculture brought about the development of an electronic precision soil auger (EPSA) to provide timely and accurate soil cores per depth. This technology saves the excess use of human labour, time and also helps in the automation of agriculture. The EPSA was designed, constructed and tested on three different types of agricultural soil from sandy soil, clay soil, and loam soil. The drill depth was inputted using 4x4 keypad on a 16x2 liquid crystal display (LCD) screen, embedded with infra-red (IR) sensor that determine the required depth and carried out soil to the surface. The performance efficiency of EPSA when tested on 1meter sandy soil was 2.46seconds compared to 460.47seconds during manual drill, clay soil has 5.9seconds compared to 1666.67seconds, and loam soil 3.25seconds compared to 666.67seconds were obtained respectively. From the results shown, it is evidence that EPSA works satisfactorily without the physical effort required when using manual or hand drill. This study provide farmers the current trend on automation in agriculture through depth control sensor.*

**Keywords:** Depth control sensor, Agricultural soil, Flight drill, Arduino nano, Screw shaft

## 1. INTRODUCTION

Manually operated hand tools is still predominantly in use in Nigeria because tractors and engines required to mechanize land cultivation processes require resources that most Nigerian farmers do not have access to. Over the years, agricultural practices have been carried out by small-holders cultivating between 2 to 3 hectares, using human labour and traditional tools such as wooden plough, yoke, leveller, harrow, mallet, spade, big sickle etc. [1]. These tools are used in land preparation for sowing of seeds, weeding and harvesting [2]. Auger is an equipment used for agricultural purposes, mostly for soil collection. This equipment can be used for obtaining soil samples from various depths and also for drilling of holes for seed planting, borehole drilling and equipment installation [3]. The conventional augers depend on man power for effective operation resulting in low productivity and drudgery; they consist of extendable steel rods, rotated by a handle into the ground until they are filled, then lifted out of the borehole to be emptied. A number of different steel augers (drill bits) can be attached at the end of the drill for different soil formations [4]. However, handheld power earth drills are augers used for digging post holes. The rotating helical screw blade referred to flighting act as a screw conveyor to remove the drilled-out materials using the rotation of the blades. The mechanised soil augers developed from previous researchers function more effectively for digging holes than sample collection due to the torque generated and are mainly tractor operated thus making it financially out of reach for most farmers in Nigeria [5]. The need for agricultural automation and mechanisation in Nigeria must therefore be accessed with deeper understanding of the small holder farmer's activity.

Soil auger allows for a minimum of friction during penetration into the soil, and the extraction of the auger from the soil, which means less physical effort is exerted. The main drilling section of the soil auger is the conical shape which has two blades with a lower end and top end joined with the use of a bracket [6]. The two blades sit alongside each other in the auger point which can be likened to two spoons. During the drilling process the auger point twists into the ground and draws the soil from the bottom of the auger hole into the body of the auger. The auger blades perform the job of scooping up and holding together the soil sample in the auger body in a way that also allows it to be emptied with ease. The auger body for stony soils consists of a heavy steel strip, vaulted all along, which is bent double by forging. The pointed cutting bits of the strip are bent outward, thus creating a hole somewhat wider than the average body diameter [6] The augers body in the set that have the same diameter measured diagonally between the blades at the widest point of the main auger section [7]. This study presents an electronically powered precision soil auger with depth control as an alternative to the conventional man powered auger and/or tractor driven augers, to curb the gap in technology adoption and implements used by small and medium scale farmers. Thus, electronic precision soil auger (EPSA) provides an easy, fast and accurate way to profile soil layers and obtain a collection of core samples for analysis.

## 2. METHODOLOGY

### 2.1 System description and principle of operation

The electronic precision soil auger (EPSA) basically consists of a mild steel frame for structural support through the electric motor 220V AC that powered the mechanical torque for drilling soil to the surface. A detachable screw conveyors, guild bearings, hoist motor, 12V DC battery, hoist cable, Arduino Nano, 4x4 keypad, 16x2 LCD screen, IR and LDR sensors and 4-channel relay controlled by a digital microcontroller via a 2N3904 transistor that control the switching off the drill motor, lowering and lifting of the hoist. The 12V D.C battery supplies the electrical power required to run the system. To operate the auger required the use of 4x4 keypad with inputted figure at specified depth to control the drill is punched on the LCD interface which relate to the PLC and the hoist motor is turn "ON" and then lower the screw conveyor and drill motor to the ground.

The LDR sensor was used to detect when the screw conveyor reaches the ground by sending an analog signal to the PLC. The Arduino nano on receiving this signal sends a digital write "HIGH" command of channel to the relay connected to the drill motor. This triggers the relay to "Open" thereby switching "ON" the drill motor. A corresponding signal is thus sent from the Arduino Nano to the two channels of the relay module connected to the hoist motor, switching it from lowering to lifting. Once the LDR detects the screw shaft as being completely above the ground a delay time is initiated to lift the screw shaft an extra 100mm from the ground and the hoist motor is turned "OFF" by the PLC. The Infra-Red (IR) sensor thus calculates the height of the screw conveyor above the ground as shown in Figure 1.

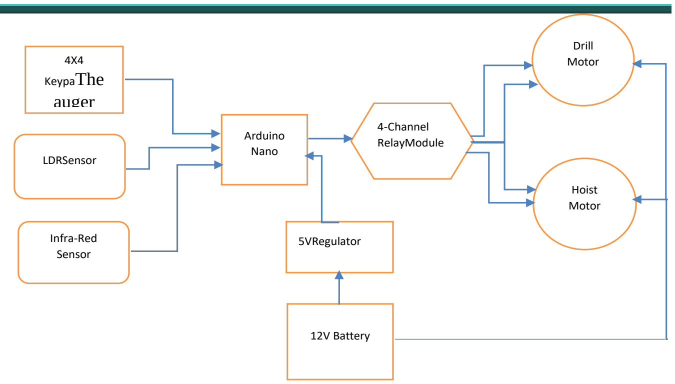


**Fig.1. Block Diagram Showing Circuit Component Interaction**

### 2.2 Design Considerations and Materials Selection

Materials with high resistance to corrosion and tensile strength and a low carbon steel (mild steel) was considered for the fabrication of the EPSA due to its known physical properties, availability and ability to be readily formed into intricate shapes.

#### 2.2.1 Inverter

An inverter is an electrical device which converts D.C voltage to A.C voltage. It could be a square wave or a pure sinusoidal wave that is achieved using power transistors of MOSFETs or IGBTs transformer with and gate drivers. The power rating of the A.C motor used was 220V, 1.9A, and 418Watts. A detailed electric motor with 3-phased 0.5hp, AC motor, and a 22:1 gearbox as specified in Table 1

**Table 1: Electric Motor Specification**

| ***Device*** | ***Specification*** |
|---|---|
| Voltage | 220v |
| Starting current | 1.9A |
| Mechanical Power | 0.372KW |
| Speed | 63rpm |
| Weight | 5.7kg |
| Colour | Green |
| Rotor diameter | 22mm |

#### 2.2.2 Arduino nano

The Arduino nano with an AVR based development board, built around the ATMega 328(P) microcontroller. The controller board capacity has an 8bit connected to a 16MHz crystal oscillator as shown in Table 2.

**Table 2: Arduino Nano Technical Specifications**

| *Device* | *Specification* |
|---|---|
| Microcontroller | AT Mega 328p |
| Recommended Input Voltage | 5-12V |
| Operating Voltage | 5V |
| Logic Type | TTL |
| Digital I/O Pins | 14 |
| Analog Pins | 8 |
| Supported Communication Protocols | $I^2C$, SPI, UART, USART |
| Output Voltage | 5V and 3.3V |
| Flash Memory | 32KB |
| Programmer | Arduino IDE |

### 2.2.3 4x4Keypad

The above mentioned device can be inputted with numeric values range (0 to 9) and some alphabet characters range (A to F) to set the required depth to be excavated which translate to the Arduino Nano. It has eight pins 9, 10, 11, 12, 13, A0, A1 and A2 connected to the Arduino Nano. These are lines of codes that enables the PLC to recognize the keypad in order for the controller to properly interpret commands and sent signals.

### 2.2.4 LCD display unit with a 4-channel relay

The display unit comprises of a 16x2 LCD screen and a 10K potentiometer for contrast control of the LCD. The LCD is powered by the 5V DC used in powering the PLC, Six pins of the LCD are connected to the PLC, namely pins; E, RS, 11, 12, 13, 14. The LCD display the inputted values from the keypad as shown in Table 3. A four channel 5V relay control switching of the drill motor and the lowering and lifting of the hoist. The relay is controlled by a digital pin on the microcontroller via a 2N3904 transistor.

**Table 3: LCD to Arduino Nano Connection**

| LCD Pin | Arduino Nano Pin |
|---|---|
| VSS | GND |
| VDD | 5V (VCC) |
| VO | 10k potentiometer |
| RS | D7 |
| RW | GND |
| E | D6 |
| D0 | Not connected |
| D1 | Not connected |
| D2 | Not connected |
| D3 | Not connected |
| D4 | D5 |
| D5 | D4 |
| D6 | D3 |
| D7 | D2 |
| A | 5V (VCC) |
| K | GND |

### 2.2.5 Infra-red sensor (IR)

An IR sensor consists of an IR transmitter and IR receiver pair. The IR transmitter is basically an LED which emits waves in the near infrared region constructed with an IR LED, a power supply voltage (5-9V) and current consumption between 3mA to 5mA. The IR receiver is used in detecting infrared radiations which exists in the form of a photodiode or phototransistors.

## 2.3 Design Theory and Calculations

***2.3.1 Total power consumption and maximum operating time***

$$P_T = P_M \quad (1)$$

$$P_M = \frac{VQ}{T} = VI \quad (2)$$

Where;

$P_T$= Total Electrical Power [Watts]
$P_M$= Power consumed by Electric Motor [Watts]
V= Supply voltage [V].
I= Current [A]
Q= Quantity of charge [C]
T= time [s]

$P_M$ Hoist Motor $= \text{VI} = 12 \times 10\text{A} = 120\text{Watts}$
$P_M$ Drill Motor $= \text{VI} = 220 \times 1.9\text{A} = 418\text{Watts}$
$P_{M\,T} = 120 + 418 = 538\text{Watts}$

$$\text{Discharge time} = \frac{I_B}{I_T \times P} \quad (3)$$

$$\text{Charging time} = \frac{I_B}{I_C} \quad (4)$$

Where,
$I_B$= Battery rated current [A].
P = Peukert exponent. For lead acid battery, P=1.3.
$I_T$= I=Total Current [A].
$I_C$= Current supplied by Battery Charger [A].

$$\text{Discharge time} = \frac{7.2}{11.9 \times 1.3} = 0.46hr = 28.2mins = 1692s$$

$$\text{Charging time} = \frac{I_B}{I_C} = \frac{7.2}{2} = 3hrs36mins$$

***2.3.2 Diameter of screw shaft***

$$T = \frac{60P}{2\pi n} \quad (5)$$

$$T = \frac{60 \times 0.37}{2\pi 63} = 0056Nm$$

$$M = \frac{Wl}{2} = \frac{2.6 \times l}{2} = 1.3 \quad (6)$$

$$\sigma_{max} = \frac{860}{3} = 286.7MPa$$

$$\boldsymbol{\tau_{max}} = \frac{\sigma_{yp}}{2F.S} = 143.33MPa \quad (7)$$

$$d=\sqrt[3]{(\frac{16T}{\pi\tau_{max}}[\sqrt{(M^2+T^2)})} \quad (8)$$

$$d=\sqrt[3]{(\frac{16\times 0.056}{\pi 143.33}[\sqrt{(1.3^2+0.056^2)}}$$

$$d=\sqrt[3]{(0.002\times 1.32)} = 0.138\text{m}$$

where:
P = Power transmitted in the shaft.
n = speed of the electric motor [rpm].
W= Weight of the shaft screw [N].
T = Twisting moment$on\ the\ shafts$.
M = Maximum bending moment in the shafts.
$\Sigma_{yp}$= Yield point stress of shaft material.
$\Sigma_{max}$ = Maximum allowable bending stress.
$\boldsymbol{\tau_{max}}$ = Maximum allowable shear stress.
$\sigma_{yp}$ = Yield point stress of shaft material [860]
F.S = Factor of Safety [3]

***2.3.3 Minimum lift torque***

$$T = R\times m\times g$$

$$T = 0.006\times 6.3\times 9.8 = 0.37044\text{Nm}$$

### 2.4 Software Design and Principle of Operation

The intelligence governing the entire system was written in C++ language using the Arduino IDE (Integrated Development Environment) which serves as the compiler, converting the C++ code (.ino) to machine code (.hex) which the microcontroller understands. The software designed for the operation of the EPSA relate the inputted number command from the 4x4keypad as read by the arduino nano PLC with integers of two digits to a desired depth. The PLC thus sends a signal to the hoist motor which is then turned “ON”, to lower the screw conveyor and the drill motor to the ground. The LDR sensor detects when the screw conveyor reaches the ground by sending an analog signal to the arduino nano PLC. When this signal is received by the Arduino Nano PLC, a “HIGH” signal is sent to the digital pins on the PLC board which are connected to the relay trigger.

This triggers the relay to a “Normally Open” configuration, thereby turning “ON” the drill motor. The Infra-Red (IR) sensor senses the screw conveyor above the ground and relayed to the PLC to ascertain the depth entered by the operator. When the desired depth is reached, the Arduino Nano sends a “LOW” signal to the relay, returning it to “Normal Closed”. Thus turning off the drill motor, and halting the generated torque to grip the soil samples and the polarity of the hoist motor is reversed by two channels of the relay, lifting the screw shaft.

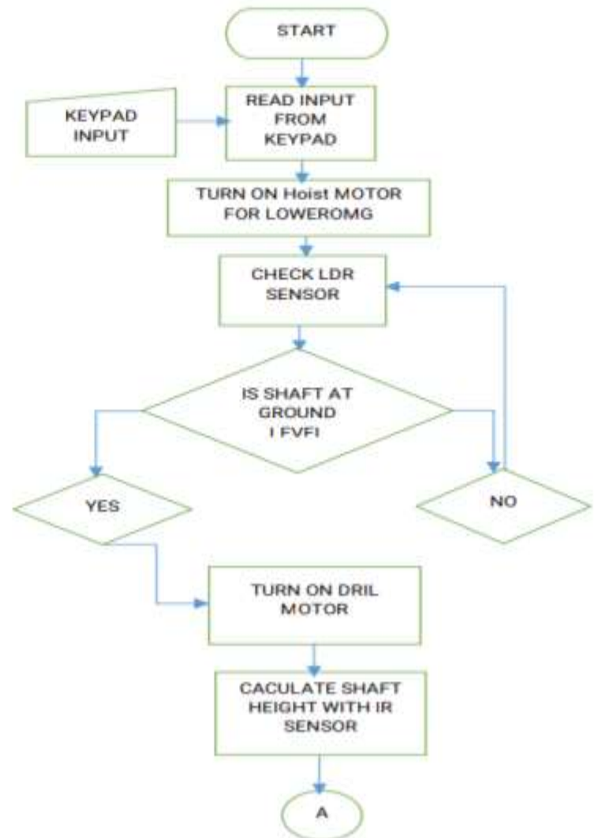


**Fig.2: Flowchart Algorithm**

### 2.5 Fabrication Process

The fabrication of the EPSA was carried out in parts. The screw shafts was fabricated using 8mm stainless-steel washers placed in-between two pipe of 8mm in diameter which is then cut into a half spiral. The pipes are aligned to the half spiral of the top pipe closed to the bottom pipe. The flights was then welded to the drill shaft permanently using an arc welding machine with model number Cruxweld 10-400A. The frame of the EPSA was fabricated from pipes 38.1x38.1mm$^2$. Two pieces measuring 1524mm and a 355.60mm long was cut using a hacksaw with one end chamfered.

The tacked frame of 700mm was checked for straightness using a square and correction made using a hammer and angle grinder. The corrected frame was welded firmly with open spaces using a 2mm filler wire in line with [8]. The guide rail of the electric motor was welded to the middle of the frame using 38.1mm x 25.4mm flat bars and four 6mm rollers used for the electric motor rotor grip. An angle grinder, bending press and welding machine is used in fabricating this part. The

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hoist pulley was fixed to the hoist motor welded using a 6204 bearing is used in coupling the hoist shaft to the frame. Excess welds are grinded off the frame using an angle grinder and filing stones. The frame is then sandpapered to remove rust and painted. The hoist cable was attached to the drill motor assembled to the frame. The electronic control unit (ECU) was mounted with all necessary connections made as described in Figure 3.

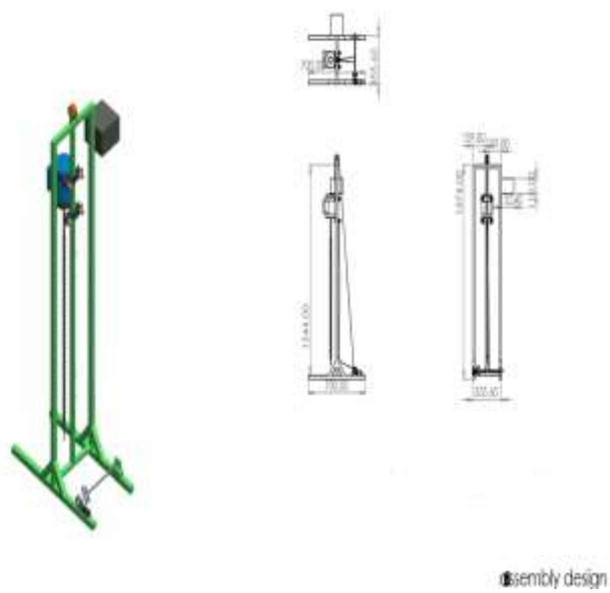

**Fig.3: Orthographic drawing of EPSA**

### 3.1 RESULTS AND DISCUSSION

#### 3.1.1 Determination of soil type

The electronic precision soil auger (EPSA) fabricated in this work functioned when the machine is turned on and requesting for ‘‘SET DRILLING DEPTH’’ which triggers sensors to displayed on the LCD screen with the desired drilling depth inputted. When this was done, the hoist motor lowered the drill motor and the shaft to the ground and was observed that upon getting to the ground, the LDR sensor triggered the switching of the relays connected to the drill motor turning it on thus, commencing drilling. When a depth of 1meter was achieved, “DRILLING COMPLETE” was displayed on the LCD screen and the hoist motor was observed to lift the motor and the screw shaft up from the drilled hole [8] PSA was done, after which performance evaluation was carried out, comparing drilling electronically with manual drilling; it was found that for sandy loam soil, the EPSA was 2.46 times more productive than manual drilling with the screw shaft to a depth of 1 meter as shown in Figure 5, and 6 respectively.

For a clay loam soil, the ESPA was found to be 5.9 times more productive than manual drilling when a depth of 1 meter was to be drilled. In silty loam soil, the ESPA was found to be 3.25 times more efficient than when drilling a 1-meter hole manually. Soil type was carried out in order to determine the nature and texture of the soils the auger was to be tested on. The electronic precision soil auger (EPSA) was tested in three different locations A, B, C to observe the penetration of the auger on sand, silt and clay soil within the study area as shown in Table 4 and Figure 4.

The fabricated electronic precision soil auger was tested on three soil types and the time taken to drill a depth of 1m as shown in Fig. 5 and 6. The time taken to drill on sandy loam soil and the fabricated screw shaft was also tested manually by using man power to operate it, upon carrying out the process of drilling in different soil types, the results also which is presented in Figure 6.

**Table 4: Determination of Soil Particle**

| Sample | Soil Type | Soil Texture | | |
|---|---|---|---|---|
| Location A | Sandy Loam | Sand 80% | Silt 5% | Clay 15% |
| Location B | Silty Loam | Sand 50% | Silt 30% | Clay 20% |
| Location C | Clay Loam | Sand 15% | Silt 30% | Clay 55% |

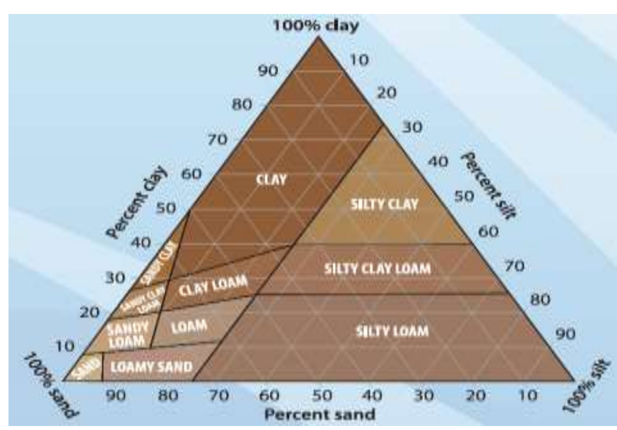


**Fig 4. Soil Textural Triangle [9]**

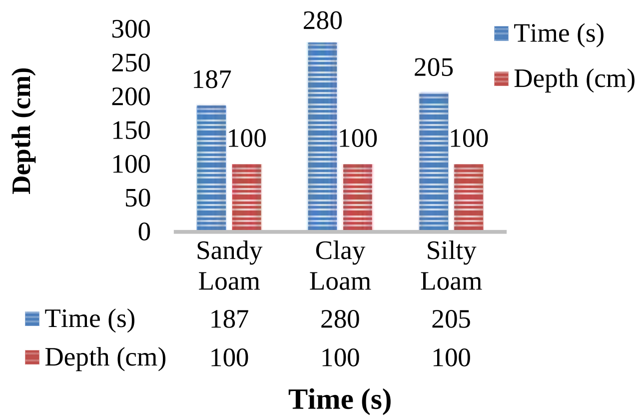


**Fig.5. Drill Depth and Time using EPSA**

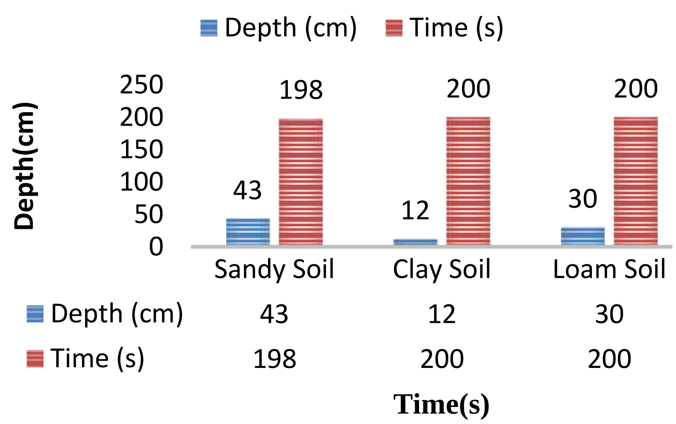


**Fig 6. Drill Depth and Time using Manual Drill**

### 3.2 Performance of EPSA on Various Soil Types

The performance of EPSA and manual drill on different soil types was calculated with respect to time (t) in a 1m depth. The time taken to drill 1m manually was then divided by the time taken to drill 1m using the EPSA. However, the sandy loam soil took 198secs to drill a depth of 0.43m manually, and 187secs to drill 1m depth using the EPSA. Hence, the time taken to drill 1m depth manually was calculated thus:

198sec - 0.43m
t - 1m

$$\frac{198s}{t} = \frac{0.43m}{1m}$$

$$t = \frac{198m/s}{0.43m} = 460.47secs$$

Time Taken in Sandy Loam Soil at 1m Depth = $\frac{Drilling\ 1\ Meter\ Manually = 460.47sec}{\frac{460.47}{187}}$

$= 2.46$ (9)

It will take two and half times the time it will take to drill manually as compared to using the electronic auger for sandy loam soil.

Time Taken in Silty Loam at 1m Depth= $\frac{Drilling\ 1\ Meter\ Manually = 666.67sec}{\frac{666.67}{205}}$

$= 3.25$ (10)

Time Taken in Clay Loam at 1m Depth= $\frac{Drilling\ 1\ Meter\ Manually = 1666.67sec}{\frac{1666.67}{280}}$

$= 5.9$ (11)

The results in Fig 5 and 6, shows that the drilling time for sandy loam was less than that for the other soil types for reasons of the particle size distribution and indeed the soil type. Equations 9, 10 and 11 show that the drilling time increases with the increasing clay content of each of the soils. All things being equal, the electronic auger is better than the manually operated auger.

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## CONCLUSION

This study evaluate the challenges associated with manually operated soil auger and to safe time fabricated a depth control soil auger. The auger was developed on the Arduino IDE with an Arduino Nano serving as the programmable logic controller of the device. An LDR sensor and IR sensor was used in determining the drilling depth. The desired depth to drill was inputted using 4x4 keypad, and 16x2 LCD screen to display the operation mode of the machine. The LDR sensors and the 4-channel relay module controls the hoist motor to lift the drill motor and the screw shaft up from the drilled hole. However, between the flights of the screw shaft, soil samples was transported to the surface were within 5 to 7 g, thus satisfying the objective of this study. The operation of EPSA was found to be efficient as soil samples were carried to the surface with depth control drilled.

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