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Development of Automated Soil Infiltration Measuring Device with a Logger

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***Abstract*— Soil infiltration measuring device is an electronic system which can measure the amount of water depth falling into the soil at a particular time. The automated soil infiltration measuring device is employ by farmers and researchers in the determination of water intake on the Earth's surface. The system comprises of the percolation material, cylindrical tube, sensing unit, display unit, logger unit and microcontroller unit. Firstly, percolation material. The percolation material is made from the mixture of coarse sand, cement and water. It is molded to lube shape of thickness 150 mm and inserted at the lower end of the tube. Secondly, cylindrical tube. This is made of a cylindrical plastic material of height 300 mm and diameter 50 mm. The upper end of the tube contains four rectangular openings which are spaced at equal distance. Thirdly, the sensor unit. the sensor is made of VL 6180 module. The sensor is inserted into a circular disc plate and placed on the upper end of the tube. Its output signal of the sensor is connected to the digital input port of the microcontroller. Fourthly, the microcontroller unit. This is made of an Arduino UNO. The microcontroller contains the program codes and it is interfaced with the other hardware devices. Fifthly, logger unit. This unit contains the SD micro-card adaptor. It is connected to the digital output port of the microcontroller. Lastly, the display unit. This unit is made of 4 by 12 liquid crystal display (LCD) and it is interfaced with the communication port of the microcontroller. The measured data is display on the screen for visual. The soil infiltration device is use for irrigation farming practice and erosion control road construction.*

***Keywords*— Soil, Infiltration, Sensor, Water depth, Percolation material and Percolation tube.*

I. INTRODUCTION

The population growth of the Nation is increasing drastically yearly in an unprecedented manner. This increase in growth has lead to proportionate increase in the demand of agricultural produce and infrastructural activities of the underdeveloped and developed Nations. This drastic increase growth can cause shortage of food in the society and this can lead to starvation which have a negative impact in the labour force and account for increase in death rate of a Nation. In addition, farming activities are practiced in rural area and most of the rural dwellers do not practice mechanized farming. This makes farm produce insufficient for urban dwellers. Meanwhile, immigration of people from rural to urban settlement has reduce the population of farmers and this have led to shortage in farm produce and increase in the demand of agricultural produce in urban settlement. This accounts for the drastic increase in prizes of farm produce town and cities. Also, most of the farm produce is seasonal and during the dry season, most of the crops does not water for the transportation of soil nutrients for germination and proper growth. This contributes to scarcity of such farm produce and can lead to social-economic decay and decrease in the Nation gross domestic product. Hence, there is need to develop soil infiltration device which can be use by farmers for irrigation farming practice to measure the amount of water intake into the soil at a given time during the rainy and dry seasons. This will makes farm produce available all through the off-season. This device is simple to operate and can be repair when it develops fault.

Factors affecting soil infiltration

The interaction of a number of physical and chemical soil properties determines the rate of soil infiltration. These soil properties vary from one location to another and change over time due to cultural practices, water management and biological processes. The soil properties are;

Soil texture

The relative quantities of sand, silt, and clay in the soil have a significant impact on the hydraulic conductivity of the soil. Because of their small size and ability to fill spaces left by larger particles, clay particles are particularly significant because they play a key role in tying the soil matrix into more substantial structures. The hydraulic conductivity of a medium with a single particle size is roughly inversely related to the square of the particle diameter.

Soil moisture content

The matric potential, which is an inverse function of the moisture content, dominates the initial infiltration rate in an unsaturated soil. Because of this, the water content and distribution throughout the soil profile have a significant impact on the soil's hydraulic capabilities. Rainfall will also alter the moisture content both geographically and temporally. Surface irrigation, however, has the tendency to lower the spatial variability of soil moisture contents by 2 to 3% (for example, by reducing the CV, or coefficient of variation).

Soil organisms

The soil is made up of various living, liquid, gaseous, and mineral elements. The roots of crops and weeds are the last group of live soil organisms, followed by larger animals living in and on the soil surface and microscopic species that are undetectable to the unaided eye. The majority of these organisms alter aggregate stability, pore diameters, and pore connectivity, which in turn affects soil hydraulic conductivity. When roots die, they leave behind relatively big, interconnected

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macro pores that act as pathways for quick penetration. A significant portion of the variability in late season infiltration rates may be attributed to root canals.

Soil structure and compaction

The bulk of variables affecting infiltration rate have an immediate impact on soil structure, specifically soil porosity. The ratio of a soil sample's solid to liquid volume is referred to as porosity. The average pore size, pore size distribution, and pore connectivity are more significant factors for infiltration. It is possible for biological activity to build or modify soil pores, as well as shrinking brought on by changes in temperature or moisture, the creation of ice lenses, cultivation, and the collapse or clogging of larger holes.

II. MATERIALS/METHODOLOGY

Materials

i. Arduino MEGA 2560
ii. VL6180 sensor
iii. Plastic cylindrical pipe
iv. Copper strip board
v. Percolation material

Methodology

The complete circuit diagram of the soil infiltration measuring device is shown in figure 1.

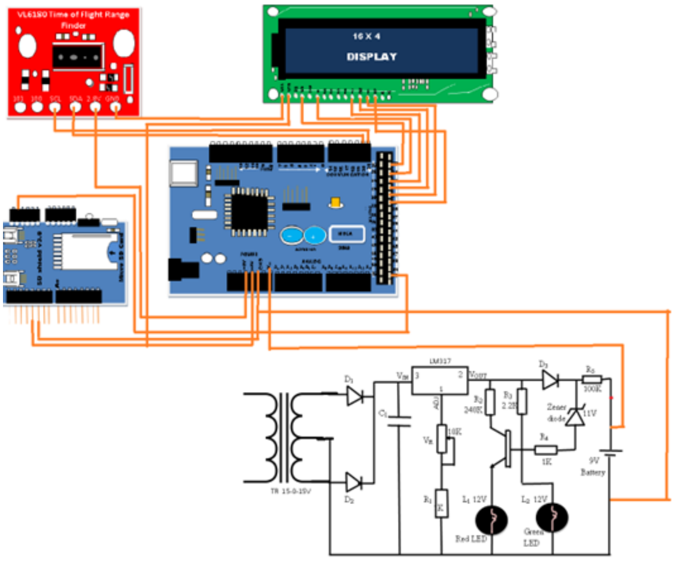

Figure 1: Soil infiltration measuring device

Percolation material

The percolation material allows the water to move gradually on the soil surface and prevent soil disturbance. It was molded from coarse sand that was collected from a drainage site or peat. The coarse sand was washed to remove moisture and dry under the Sun. It was then mixed with cement and re-dry again. The mixture was molded of coarse sand, cement and water in the ratio of 5:2:1. The cement serves as a binding material for the sand particles. The mixture was molded to form a lump of diameter of 50.00 mm as shown in figure 2. The lump sample was then dried in an Oven at a temperature of 200^{o}C for four hours. This removes any dust particle present on the surface of the percolation material.

Percolation tube

Then the percolation material was rubbed with abrasive gum and inserted into a plastic cylindrical pipe of length 250.00 mm and diameter of 50.00 mm. The gum prevents water from sipping through the edge of the two surfaces. The upper end of the tube has a vent which allows light to penetrate into the tube. The percolation and the tube made up of the percolation tube as shown in figure 3.

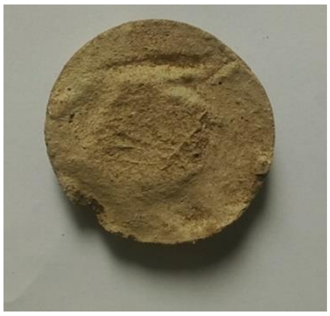

Figure 2: Percolation lump

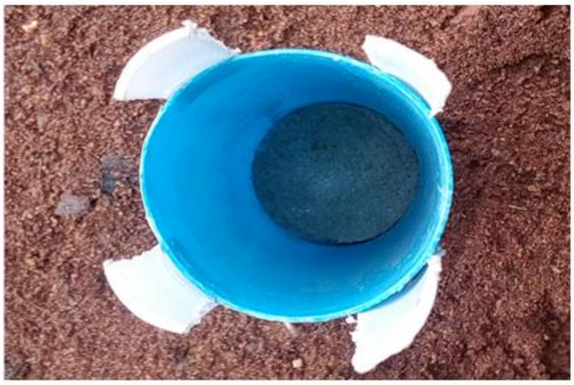

Figure 3: Percolation tube

Sensor

The sensor is a device that detects and responds to some input from the physical environment. The input could be light, heat, motion, moisture, pressure or any other of environmental phenomena. The output signal can be converted to human-readable display at the sensor location or transmitted electrically for further processing. The VL6180 sensor was used to measure the depth falling level of the water inside the tube. This device allows the absolute distance of the target to be measured independently based on reflectance. Figure 4 shows the VL6180 sensor breakout board.

Microcontroller

Arduino microcontroller is an open-source platform consisting of both a physical programmable circuit board (referred to as a microcontroller) and a piece of software or IDE (Integrated Development Environment) that runs on a computer system. The Arduino MEGA 2560 was interfaced with the sensor and liquid crystal display (LCD).

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Figure 4: Developed soil infiltration device

III. Results and Discussion

Results

A test of the developed soil infiltration measuring instrument was carried-out on three different soil samples and the results obtained are shown in table 1.

TABLE 1: Data for soil infiltration on sandy, sandy-loamy and clay soil

Time (Min)	Depth (mm)	Depth (mm)	Depth (mm)
1	52	57	118
2	56	58	118
3	61	71	119
4	63	73	120
5	71	82	122
6	74	88	123
7	78	93	124
8	82	100	126
9	83	101	127
10	84	107	128
11	90	110	130
12	94	111	132
13	95	112	133
14	99	113	135
15	104	115	136
16	103	116	137
17	105	117	138
18	107	118	139
19	109	120	139
20	111	121	140
21	113	122	141
22	116	123	142
23	118	125	143
24	122	126	144
25	124	126	144

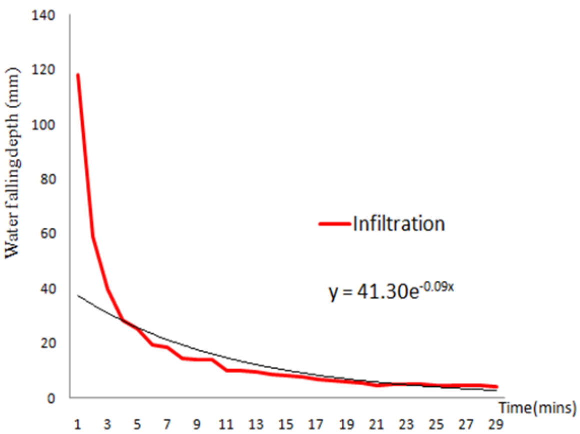

Figure 5. Infiltration rate of sandy soil

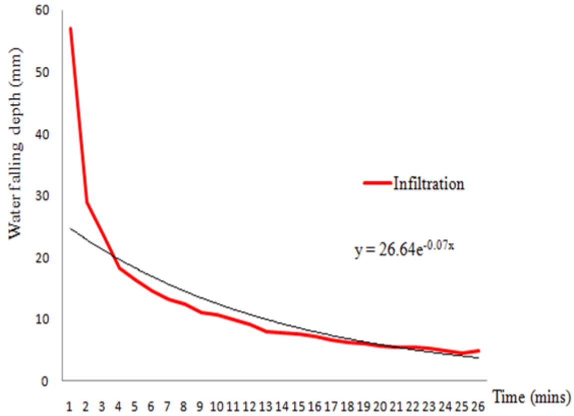

Figure 6. Infiltration rate of sandy-loamy soil

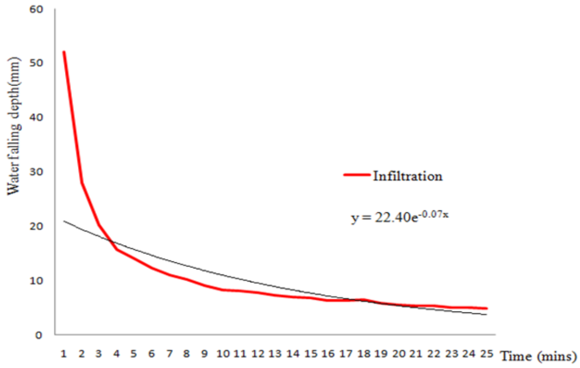

Figure 7. Infiltration rate of clay soil

Discussion

The percolation tube was designed to allow water to flow gradually onto the soil and the water falling depth was measured with the sensor for sandy, sandy-loamy and clay soil as shown in table 1. From table 1, it shows that soil infiltration was high at the initial time of percolation with values of 52 mm, 57 mm and 118 mm. The depth of falling water at any given time was used to determine the amount of water the soil can absorb at a particular period of time (infiltration rate). The graphs in figure 5, 6 and 7 showed that infiltration rate decreases exponentially with time for all the soil. This shows that soil infiltration rate decreases with time until a steady–state is reached when the soil can no longer absorb water (saturation state). At saturation state, any addition of water supply to the soil will cause soil erosion at the earth surface.

IV. Conclusion

The mixture of sand, cement and water in their appropriate proportion showed a good performance for water percolation onto the soil. The performance evaluation shows that the soil infiltration instrument can be used by farmers and researchers on different type of soil during the dry season. The graphs from the various soil types was in agreement with Horton's equation.

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