PORE WATER PRESSURE VARIATION OF DECAYED VEGETATED SOIL

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ABSTRACT

As the use of Vetiver grass (Chrysopogon zizaniodes) in soil-bioengineering for an ecofriendly, green alternative slope protection method has been very popular in the last decade, following by certified advanced knowledge and developments in research and applications of this particular species. However, early related studies were found rarely focused on the properties of this particular species as they decayed. Therefore, this study will be conducted to observe the use of this particular species by the time they are decayed, aiming to acquire better knowledge about the decayed Vetiver grass roots in soil, both adverse and beneficial. In order to contribute to new developments of slope protection and improvement method using the information gained from the Vetiver grass in soil at the decayed stage.

From the final results of this study, the pore water pressure variation in section 1 and section 2 of the column obtained from the soil at the decayed stage of 2 months is 3 times greater than that obtained from the soil at its full grown and its decayed stage of 4 months, considering the recording time happened independently. It also refers to the decay stage that occurred separately at each section. As the decay stage grows longer, root biomass decreases resulting in a gradually decreased volumetric water content.

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Without the contribution of many people, this thesis would not have been completed and existed. It owes the existence to the supports and inspirations from a lot of people.

To our thesis advisor, Asst. Prof. Dr. Viroon Kamchoom of the Department of Civil engineering at King Mongkut's Institute of Technology Ladkrabang. We would like to express our deepest gratitude for the encouragement and supervision through all obstacles and challenges since the beginning until the end of our study.

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Nithiporn Sangsai

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TABLE OF CONTENTS

Chapter **Page**

LIST OF FIGURES

Chapter **Page**

CHAPTER 1

INTRODUCTION

1.1 Research Background

Existing soil problems related to decadence in natural soil resources are mostly surface erosion and slope failure from the rainfall. Not only causing damages to the soil resource itself, but to nearby environment and communities in either agricultural, vital, and property aspect also. In order to rectify the particular soil-related problems, the present engineering technologies of various types of retaining wall together with the mixed-use of various types of plants as in Soil-bioengineering method are used to solve the soil surface erosion and slope failure phenomenon. A good example for an efficient species of plant used is Vetiver grass (Chrysopogon zizanioides). The characteristics of this particular species are not only that they are very effective in filtrating sediments and slowing and spreading the runoff water due to their structure of densely hedge form, their massive finely structured root system are also fast to grow and reach 3 – 4 m underground, which makes them an effective and potent soil strength enhancer, using their root system to tightly hold the soil particles together and stabilize the slope area.

However, most of the previous related studies were conducted on the properties of the Vetiver grass in soil in their growing stage and not at their dying or decayed stage, so in this study, the observation and experiments will be mainly focused on the decayed stage of the Vetiver grass in soil. The ultimate goal is to have a better knowledge of their underlying properties and characteristics at the time they are dying through the obtained variation in pore water pressure and water content, in hope to contribute the newly gathered information to the new developments aiming to solve the existing and future soil-related problems, and to apply to the problems caused by the decay of roots in the Soil-Bioengineering method used in various works at the end of this study.

1.2 Objectives

- To study the change of pore water pressure in each 2-month period of the decayed 9-month old Vetiver grass roots in Lateritic soil.
- To study the change in soil matric suction and moisture content with respect to time.
- To investigate the change in matric suction along the depth of the column specimen.

1.3 Scope of study

1. Simulate the depth of 100 cm onto the columns for Vetiver grass planting in an open greenhouse with a diameter of 14 cm and a height of 125 cm for acrylic columns, and a diameter of 15.5 cm and a height of 125 cm for the PVC columns.
2. The tested Vetiver grass in this study is Chrysopogon zizanioids (species: Songkhla 3).
3. The Lateritic soil used in the column specimens was taken from Chachoengsao province, Thailand.

   3.1 The sourced soil is sifted through No.4 sieve and retained on the No.20 sieve.

   3.2 The soil is compacted into the columns with a degree of compaction at 80%.
4. Study the soil permeability through wet and dry process.
5. Solely study the 1-dimensional permeability in soil.
6. Kill Vetiver grass at the age of 9 months by adopting the mulching method to kill the plants off.
7. Study the Vetiver soil properties.

   7.1 Bare soil properties;
   - Atterberg limit ;ASTM D4318 and ASTM D427
   - Grain size analysis ;ASTM D422
   - Compaction test ;ASTM D698-91

   7.2 Vegetated soil properties;
   - Soil suction
   - Volumetric water content
   - Pore water pressure variation

1.4 Steps of the study

1. Identify the topic of the study
2. State the objectives and scope of the study
3. Make an observation on the related information and researches
4. Analyze the gathered information and adapt onto the topic of study
5. Prepare and calibrate the related instruments for the experiment
6. Collect data every 4 weeks and analyze each set of it to minimize the errors
7. Evaluate all the obtained data to begin the comparison
8. Conclude the study

1.5 Expected outcome

1. Have a better understanding about the relationship between the soil suction and moisture content in vegetated soil at its decayed stages during each 2-month period of the plants at decayed stage.
2. Acquire more information of how roots at decayed stage really affect and influent the permeability in soil.
3. Get to know more about the change in pore water pressure and variation in each period of the decayed stage.
4. Be able to determine for the relationship between the changes in soil suction, moisture content with respect to time and depth of the specimen column obtained at each 2-month period of the decayed stage.

CHAPTER 2

LITERATURE REVIEW AND RELATED THEORIES

2.1 Literature review

2.1.1 Effects evaluation of grass age on hydraulic properties of coarse-grained soil (2020). Binh T. Nguyen, Tatsuya Ishikawa, Takami Murakami

This study investigates the effects of grass age on hydraulic properties of coarsegrained volcanic soil, namely: Komaoka soil. The SWCC (Soil Water Characteristic Curve), unsaturated coefficient of permeability, outflow, inflow, runoff, and the variations in volumetric water content/matric suction under different rainfall intensities varying from 15, 30, 60, to 120 mm/h are measured by carrying out the column tests.

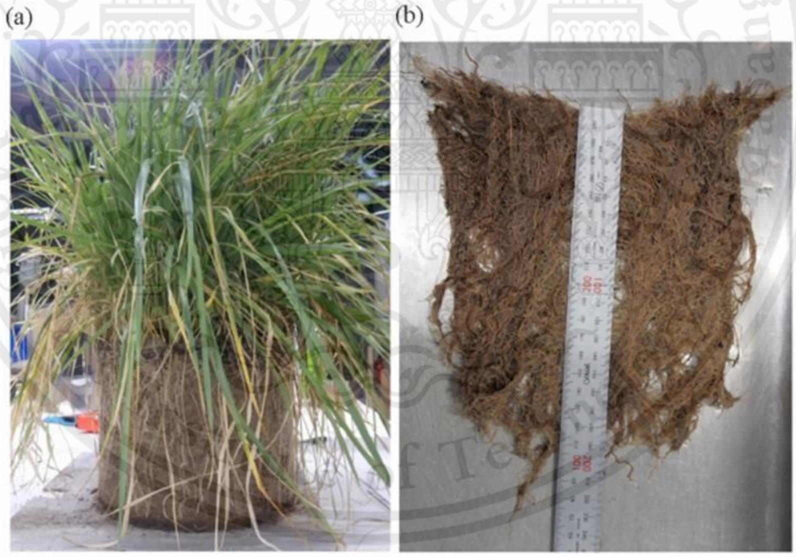

Figure 2.1: Example of (a) grassed soil specimen, and (b) grass roots of GK-4 in column test

In addition, permeability tests are performed to determine the saturated coefficients of permeability of bare soil and grassed soils. In these tests, grassed soils with grass ages varying from 1 to 6 months are used to study the influence of root volume ratio on the hydraulic properties.

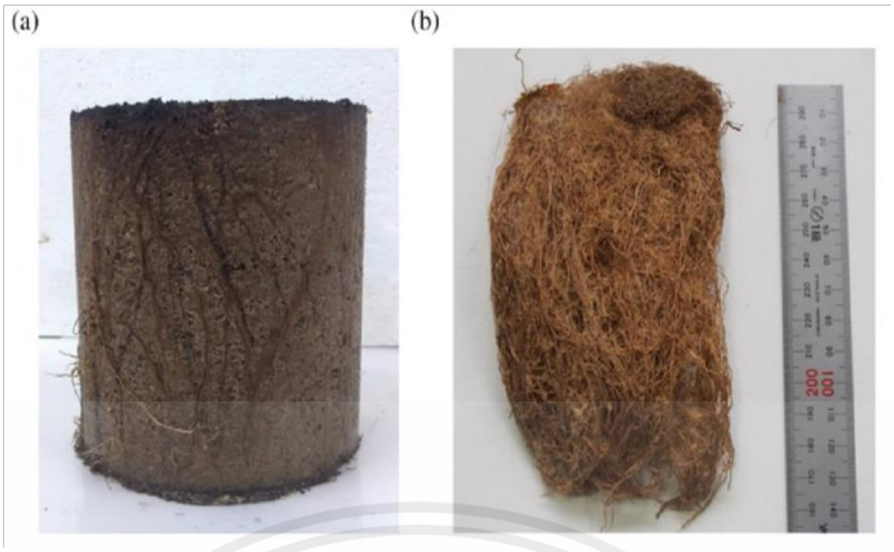

Figure 2.2: Example of (a) grassed soil specimen, and (b) grass roots of permeability test

The experimental results reveal that the grass age has an influence on the hydraulic properties of Komaoka soil. At the same volumetric water content, grassed soil with higher grass age has higher matric suction. Both saturated and unsaturated coefficient of permeability are significantly reduced with the increase in the grass age. Moreover, there is a decrease in the outflow and an increase in the runoff for grassed soil with higher grass age. Matric suction decreases later in grassed soil than that of bare soil under rainfall events. The higher the grass age, the longer time is taken to observe the change in matric suction. However, the matric suction of grassed soil is dramatically reduced while there is a gradual decrease in matric suction of bare soil. Furthermore, even though the matric suctions remain constant at somewhere in the vicinity of 2 kPa under long and intense rainfall events, higher volumetric water contents are recorded for grassed soil with higher age.

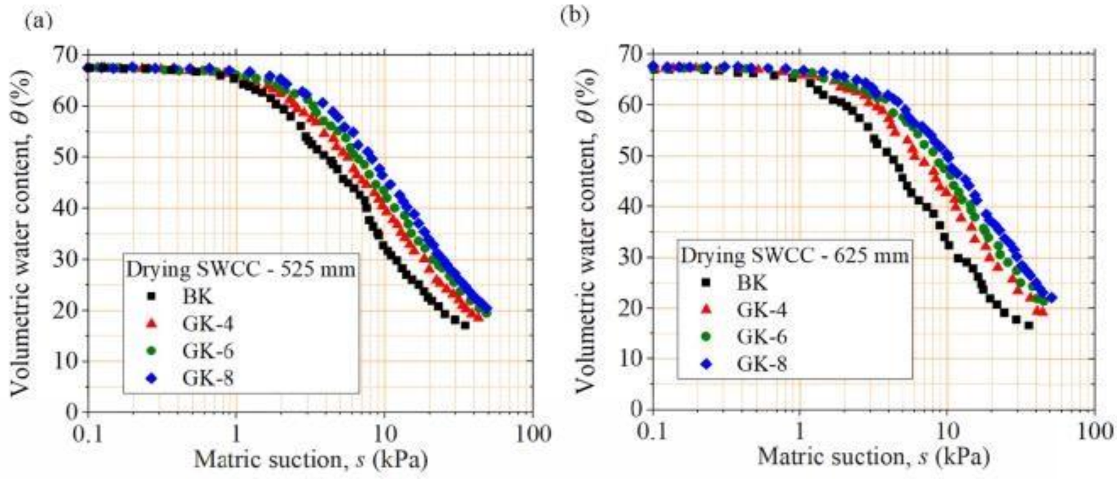

Figure 2.3: Relationship between the saturated coefficient of permeability of grassed soils (a) versus grass age, and (b) versus root volume ratio. (Number in brackets represents grass age).

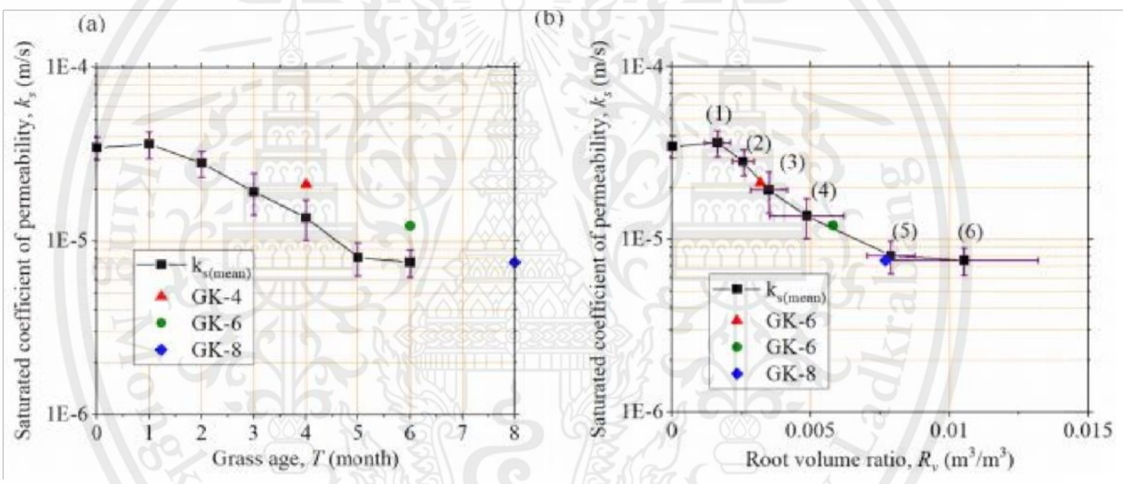

Figure 2.4: Soil-water characteristic curves of grassed soils and bare soil at elevations (a) 525 mm and (b) 625 mm

2.1.2 Modelling effects of root growth and decay on soil water retention and permeability (2019) J. J. NI, A. K. LEUNG, C. W. W. NG

This study proposes a new model that could capture the effect of root growth and root decay on both Soil Water Retention Curve (SWRC) and saturated permeability (ksat) of coarsed-grained soils. The testing plan was conducted in an existing laboratory and the field, performed at a site in Shenzen, China from 2016 to 2017. The tested soil specimen was a completely compacted decomposed granite (CDG) which composed of 18% gravel, 52.7% sand, 18.6% silt, and 10.7% clay. This type of soil is commonly used as construction materials for man-made slope, where vegetation would be planted. According to the Unified Soil Classification System (USCS: ASTM 2010a) the soil can also classified as a clayey sand (SC). The CDG was compacted to a dry density of 1670 kg/m^3 or 95% of maximum dry density. After the compaction, the six soil cores were sampled separately in random location in a plot to record for its dry density and ksat according to ASTM D5084 standard. The cylindrical core cutter used were in size of 76 mm in diameter and 100mm in height, these were all penetrated vertically into the ground to a depth of 100mm. Both dry density and ksat varied slightly from 1638 to 1670 kg/m^3.

The field plot in figure 5 was fully covered with grass turfs (*Cynodon dactylon*) in early February 2016. Then a shrub (*Schefflera arboricala*) was transplanted to the plot on 2 April 2016. Both selected shrub and grass species could survive in coarsegrained soil either in laboratory or in the field. The measurement material of three pair moisture probe and matric suction were installed at 100 mm depth for monitoring the response of soil volumetric water content (VWC). The measurement of soil moisture probes are based on the principle of time domain reflectrometry (Whalley 1993). Each probes generating an electromagnetic pulse to polarize the surrounding soil.

The field plot was left exposed to the natural environment for 16 months from April 2016 to July2017, during the process of soil metric suction and VWC were measured continuously.

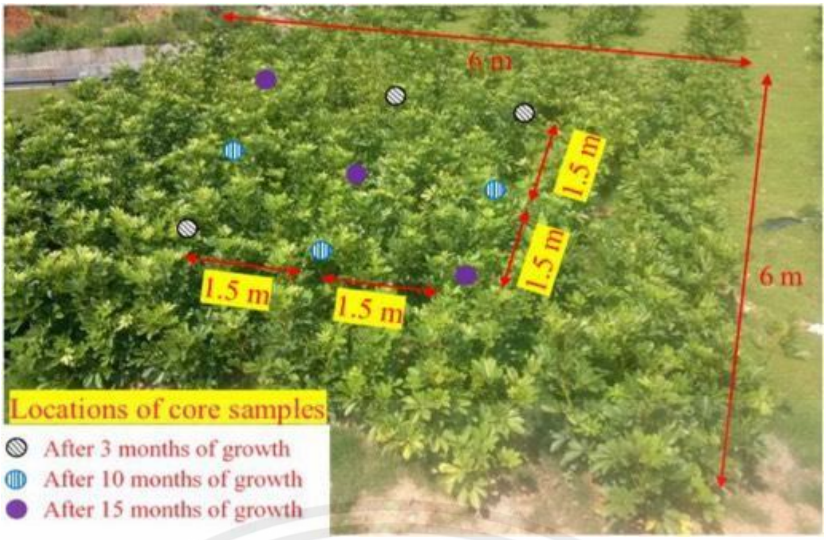

Figure 2.5: Overview of the test setup and locations of the core samples in the field test

In the laboratory test *Schefflera heptanylla* was used and transplanted into CDG in a steel drum with a spacing of 60mm and 180 mm. The soil surface was exposed to the same, constant atmospheric condition in plant room for evaporation and evapotranspiration. After 4 months of growth, all samples were all saturated then subjected to 4-day drying period.

Figure 2.6: Overview of test setup for the laboratory test conducted by Ng et al. (2016)

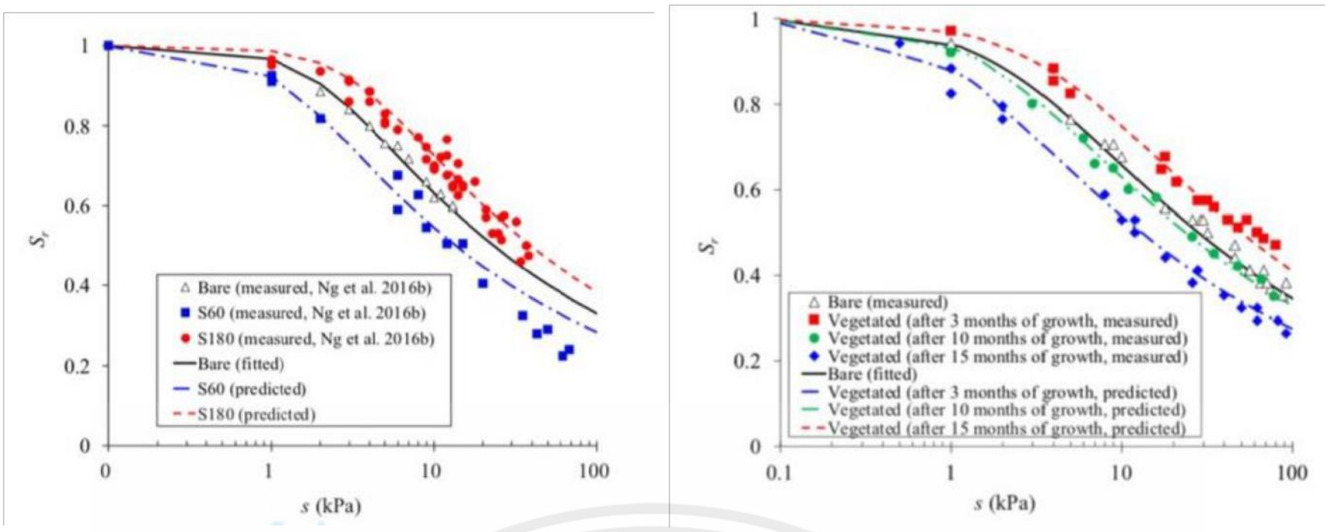

Figure 2.7: Comparison between measured and fitted/predicted SWRCs from (a) the laboratory test; and (b) the field test

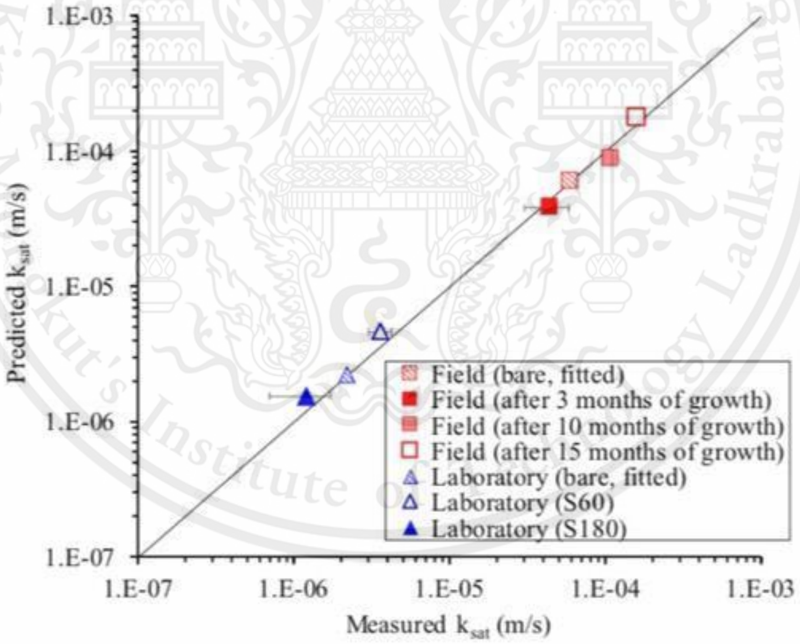

Figure 2.8: Comparison between measured and predicted k_{sat} of vegetated soils

2.1.3 Effects of grass roots on soil water retention curve and permeability function (2017). Apiniti Jotisankasa, Teerapat Sirirattanachat

In this study, two types of soil were investigated; one is clayey sand (SC); two is low plasticity silt (ML). The study focused on relating different values of root biomass of the Vetiver grass with the soil water retention curve and permeability of soil. The results are divided into three main parts categorized by the area of effects: the effects of roots on saturated permeability, effects of roots on Soil Water Retention Curves (SWRCs), and effects of roots on permeability functions.

For the part of effects of roots on saturated permeability, different set of results were obtained from two types of tested soil. In low plasticity silt (ML), when the biomass per volume, ρ_R, increased to about 6.5 kg/m^3, the permeability increased up to 2 to 5 times of that in bare soil. Once the root biomass exceeded 6.5 kg/m^3, the permeability started to decrease and became nearly one order of magnitude smaller when root biomass was about 8 kg/m^3, as shown in figure 8 (a).

In clayey sand, the lower bound of k_{sat} value tended to decrease by 20-90% once the root biomass increased to about 6 kg/m^3. Once the root biomass reached up to more than 8 kg/m^3, the k_{sat} value rose back to the same rang of bare soil as shown in figure 8 (b).

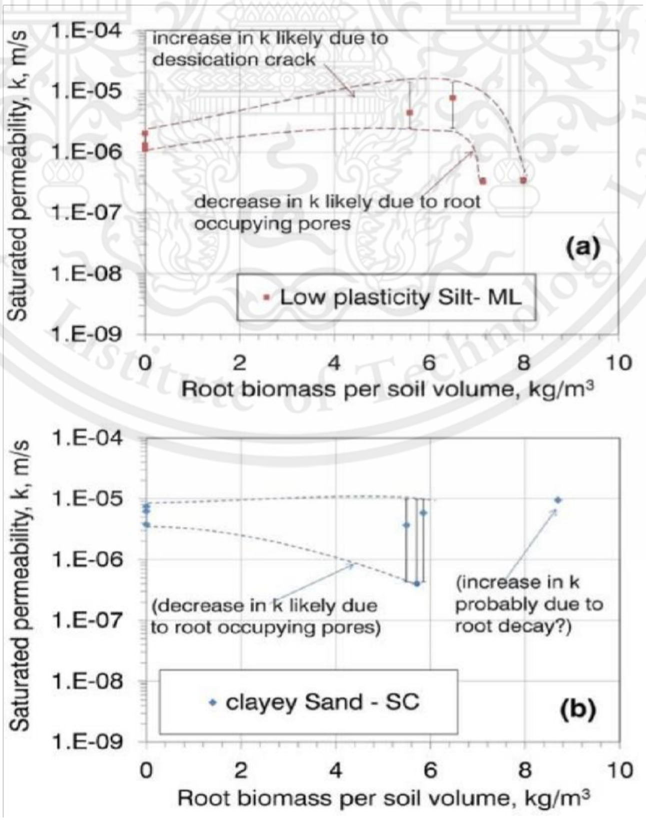

Figure 2.9: Variation of saturated permeability with root content of (a) Low plasticity silt (ML), and (b) clayey sand (SC)

For the effects of roots on Soil Water Retention Curves (SWRCs) obtained from two types of soil, both are measured from the suction reading from the tensiometer which represented the average suction in the sample. In ML soil, air-entry suction slightly decreased from 2.3 to 0.7 kPa as root biomass increased to 6.5 kg/m^3, and the air-entry suction went slightly up from 0.7 to 1.8 kPa as root biomass exceeded 6.5 kg/ m^3. As root biomass increased and occupied more void space, the porosity decreased accordingly and the soaked volumetric content, θ_s, also decreased.

In clayey sand (SC), the porosity decreased as the root biomass and soaked volumetric water content decreased. Once the root biomass exceeded 8 kg/m^3, the soaked volumetric water content somehow decreased.

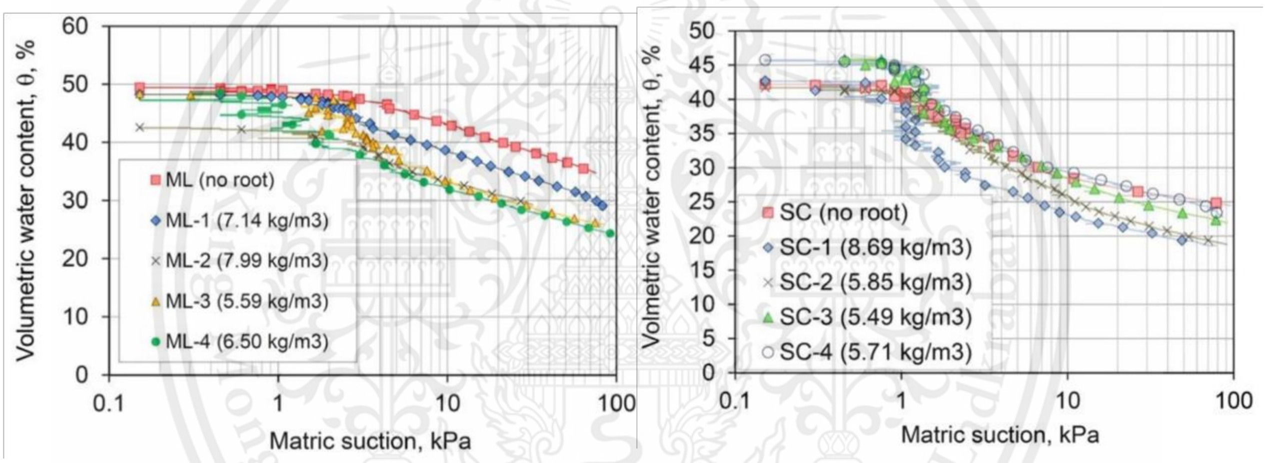

Figure 2.10: Comparison between; (a) SWRCs of silt samples (ML) with and without roots; (b) SWRCs of clayey sand (SC) with and without root

2.2 Root properties

2.2.1 Effects of roots on soil properties

The study of the effects of plant roots to the hydraulic properties and permeability of runoff into soil is based on the unsaturated soil mechanism, mathematical model, and the properties of vegetated soil (Vetiver grass are planted). It can be evaluated in many aspects including both the beneficial and adverse side to the soil stabilization. Some examples of the effects would be; one, the vegetated soil with Vetiver grass roots penetrated into it has shear strength due to the interception of rainfall and absorption from plants (transpiration) reduces the pore water pressure in the voids which is good for the soil stabilization itself, but the increased surface roughness and root content might slightly increase the coefficient of permeability and could lead to more undesirable penetration of runoff into soil also. However, the decay of organic matters together with the biological activities occurred around the roots area also cause the soil surface to be more porous making an effective run-off slower method, plus the porous soil surface helps absorb amounts of run-off, buying more time before flash flood occur. Also, the porous soil prevents the penetration of runoff into deep layers of soil mass by spreading the runoff to the sides, based on the unsaturated permeability function of the soil surface.

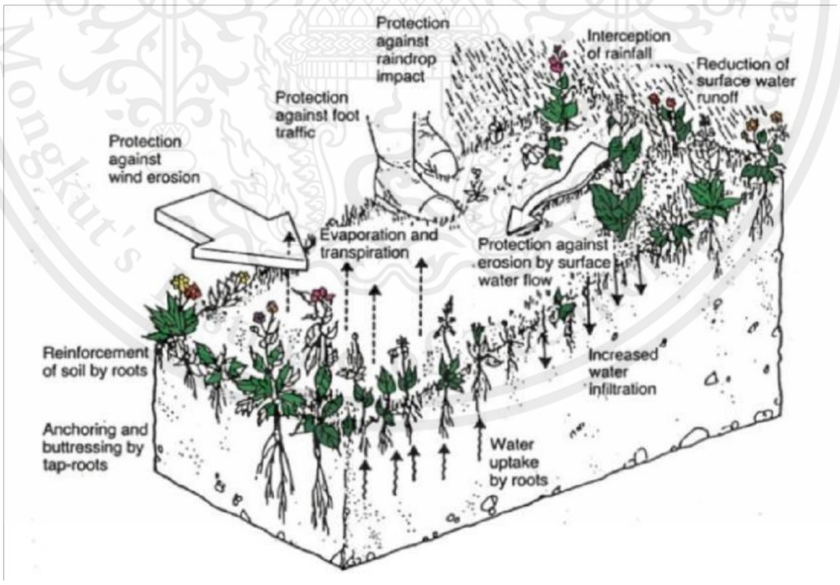

Figure 2.11: Illustration of the influences of vegetation to the surface flow

2.2.2 Vetiver grass

Vetiver grass (Chrysopogon zizanioids) is a perennial bunchgrass of the family Poaceae, commonly found in every parts of Thailand. The grass is well-grown in almost every type of soil, forms clumps of stiff and erect stems as wide as it grows, and does not interfere with the existing planted vegetation nearby. Its massive root system can also reach a great depth of 3-4 meter in the first year, dispersed to the whole underground area, making it a living retaining wall. The Vetiver grass is used as a potential soil and water conservative method due to its strength of the stems that can effectively spread and slow the runoff, and its massive finely structure root system.

In Thailand, two types of Vetiver grass are commonly found: Vetiver nemoralis, and Vetiveria zizanioides.

The first type, Vetiver nemoralis is mostly found in dry and drought-prone areas. It grows in both the places with broad sunlight, and the shady areas. This type grows in a smaller height than another one, rough surface on the leaves with a few wax on. When reaches full length, it bends over just like lemongrass, with the need of lower maintenance, and a root system at up to 80-100 meter depth. Some examples of the species are: Ratchaburi, Prachuap Khiri Khan, Roi Et, Kamphaeng Phet 1, Nakhon Sawan, and Loei.

Another type is Vetiveria zizanioides. This particular type grows fast into longer roots and leaves, its roots can reach up to 100-130 meter depth. The leaves have smooth surface and a lot of wax covering, making it well-grown in high humidity places or in the swamp areas, but does not favor the shady areas. However, the leaves of this particular type of Vetiver grass need to be cut and trimmed to extend its lifespan (higher maintenance). Some examples of the species are: Surat Thani, Kamphaeng Phet 2, Sri Lanka, and Songkhla 3.

According to the previous information of the Vetiver grass, the Vetiveria zizanioides is chosen to be tested in the experiments due to its ability of deeper penetration of roots and growth in swamp areas. As the Land Development

Department of Thailand chose for the species of Vetiver that is suitable for both sandy areas and lateritic-clayey areas out of the 122 examples of Vetiver grass throughout the country, the species Songkhla 3 is chosen to be suitable for both sandy and lateritic-clayey areas. The particular species, Songkhla 3, is then chosen to be used in our study.

2.3 Basic properties of soil

2.3.1 Lateritic soil

Lateritic soil is made from the weathering process of rocks in arid or semiarid climate with high temperature and humidity. The intensity of red color of this particular type of soil is varied by its moisture content which is a main component of Iron oxide, Aluminum, TitaniuJm, and Magnesium.

Vallerga and Rananand [1969] has concluded the study of Lateritic soil in Thailand as followed, the commonly found Lateritic soil is in the form of gravel sediment and clay soil that contains high amount of Iron oxide. Unlike the clumps of red earth gravel that are rarely found. The Lateritic soil used in the construction of highways is regularly from digging out and stockpile, both of which processes give out high-Iron oxide clay soil with non-uniform hardness.

2.3.2 Unsaturated soil

In general, one unit volume of soil contains 2 components: soil particles, and void ratio. In the case that voids are fully replaced with water, the soil is then called saturated soil. On the other hand, if the voids are only filled with some moisture content with some vacancy unfulfilled, the then is considered as unsaturated soil.

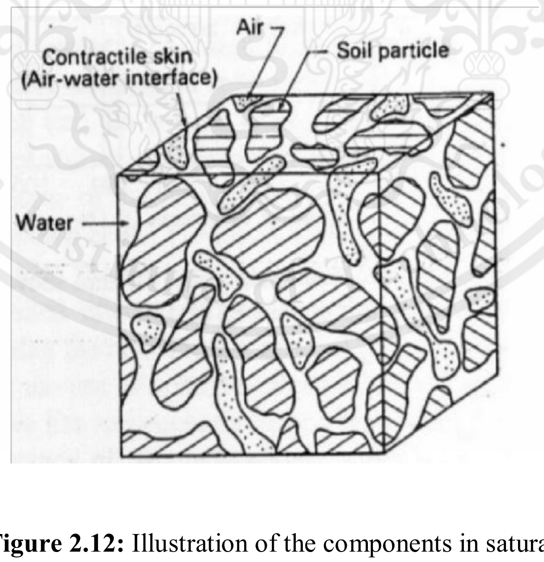

Figure 2.12: Illustration of the components in saturated soil

The pattern of vertical matric suction in saturated soil is influenced by several factors: soil ability to absorb, SWCC (Soil Water Characteristic Curve), Hydraulic conductivity function, and an environmental change in infiltration and evaporation at top soil surface such as; head of underground water table that cause the matric suction values to be varied by depth as shown in a figure below.

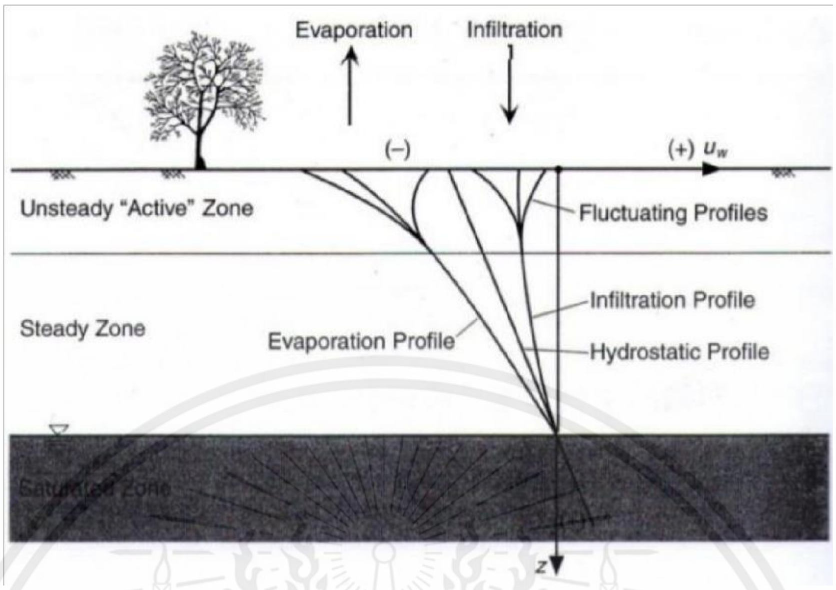

Figure 2.13: The concept of suction simulation in unsaturated soil

2.3.3 Water content

Soil mass consists of soil particles which contain minerals and organic matters. The particles are in 3-dimensional form which cause voids to be in between each particle, when voids are totally replaced with liquid (water), the soil is considered as in a saturated stage, and the soil is considered as dry when voids are filled with air. To determine for the water content in soil, ratio of weight of water to the weight of soil mass is used in the calculation.

Naturally, soil composes of 3 main components: a solid part or soil mass, liquid, and air. Nevertheless, the soil does not need to contain all 3 parts to be considered as soil, depends on the presence of soil particles as in the figure below.

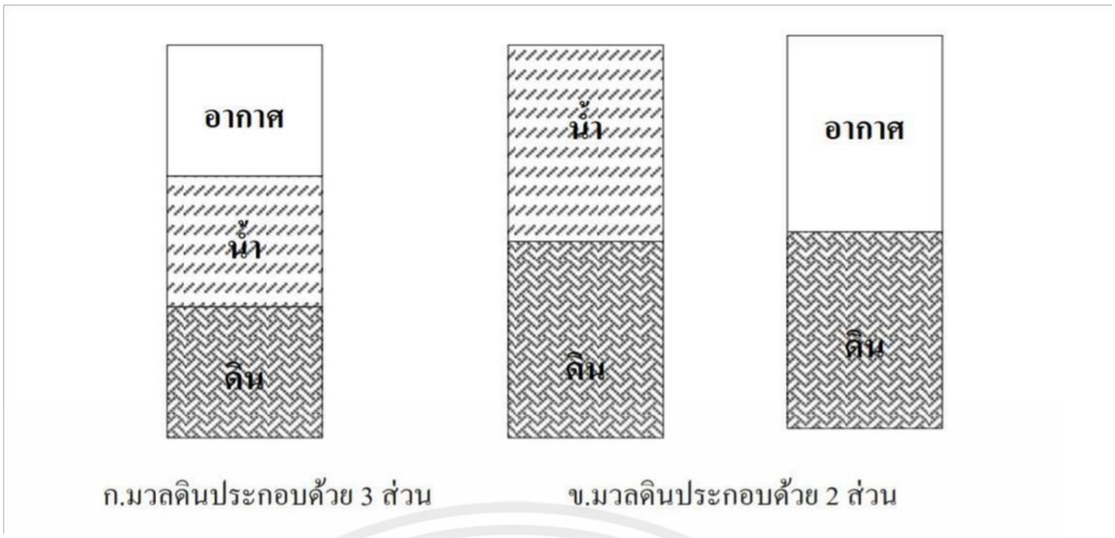

Figure 2.14: Components of soil mass

The 3 commonly used determinations of water content are

1. Gravimetric water content

It is the simplest method derived from a comparison between the weight of moisture in soil and that weight of oven-dried soil. The unit is either expressed in gram/gram or percentage by weight (% by weight).

$$\theta_m = \frac{m_w}{m_s}$$

2. Volumetric water content

It is a comparison between the volume of moisture content in soil and the volume of soil. The unit is either expressed in millimeter/millimeter or percentage by volume (% by volume)

$$\theta_v = \frac{V_w}{V_b}$$

3. Depth water content

It is calculated from the ratio or percentage of the moisture in soil by volume or weight. In this calculation, depth of soil in the same unit as the unit height of soil must be identified. This particular determination is mostly used in irrigation works.

$$V_W = \theta_v A z$$

2.3.4 Soil moisture sensor

The soil moisture sensor as shown in the figure below is an instrument used to measure for the moisture content in soil. It works by placing its two stems into the soil. The sensor is 12 centimeters in total length, 2.5 centimeters in base width, and 2 centimeters in the width of the stem. The sensor reads the resistance values in soil which can be converted into the values of moisture content later. With high moisture content in soil, the read resistance value will be lesser due to its good conductivity, and with low moisture content, the read value of resistance will be greater since soil is struggling to conduct.

Figure 2.15: Soil moisture sensor

Moreover, a relationship between the reading values and the actual moisture amount in soil needs to be calibrated due to fluctuation from several variables such as: type of soil, temperature, and the conductivity property. In general, the sensor is able to read from 0-100% with the accuracy of 1-2%.

2.3.5 Suction sensor

The suction sensor as shown in a figure below coms with a diameter of 1.5 centimeters and a total length of 5 centimeters. It composes of a porous ceramic plate component, mounted to a sensor which is linked to a data logger. The suction sensor works by touching the ceramic with desired soil, the sensor then calculate the amount of water left on the ceramic plate using the porous ceramic's absorption property to calculate for the suction in soil that ranged between 0-100 kPa with an accuracy of 0.25 kPa. It is used to measure the amount of matric suction in soil, which is the pressure that dry soil exerts on its surrounded soils to equilibrate the moisture content in the overall block of soil. The matric suction is expressed in the unit of kPa.

Figure 2.16: Suction sensor

2.3.6 Pore water pressure

It is a pressure exerted by the fluid in a porous medium (in this case; soil) consists of solid matter and pores filled or partially filled with fluid. It is expressed in a unit of N/m^2 or P (Pascal).

CHAPTER 3

METHODOLOGY

3.1 Experimental Apparatuses Preparation

3.1.1 Sensor calibration

- Volumetric Water Content Sensor

Compacted soil at 80% standard proctor, then added water content once at a time to 5 different amount and collecting voltage date with data logger to formulate and calibrate equation for voltage then converted to percentage of water content.

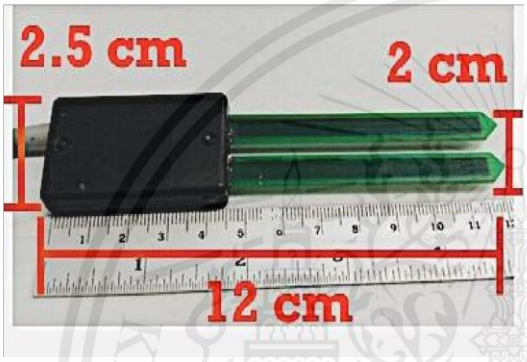

Figure 3.1: Moisture Sensor Calibration

Figure 3.2: Moisture Sensor Calibration Method

- Matric Suction Sensors

Immersing the ceramic tubes and sensor to get them fully saturated, then mouthed the senser with the vacuum pump and pumping them 0-600 mmhg each, 100mmhg forward and backward to collecting the voltage data for the calibration equation.

(Voltage, kPa)

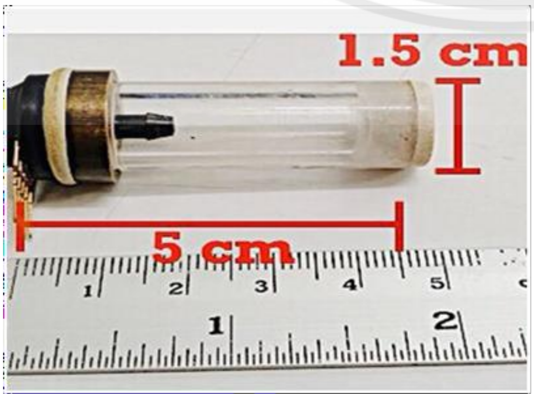

Figure 3.3: Size of Suction Sensor

Figure 3.4: Suction Sensor Calibration Method

- Data Loggers

A data logger is a box that receiving a voltage data from a sensor wires electronically every 10 seconds.

Figure 3.5: Data Loggers

3.1.2 Column Preparation

- Eradicating the moss and lichen buildup, cleaning up the soil surface to the best condition. Checking up and clean in case there is any kind covering up things that could interrupt the process of data collecting.

Figure 3.6: The moss and lichen buildup on the moist soil surface

- Watering daily to keep soil fully saturated and ready for the data collecting process.

Figure 3.7: Saturate the soil by watering

3.2 Data Collection Using Instantaneous Profile Method

• Wet Process

In the process of collecting data in wet process the water level need to be set to constant higher than soil surface at 6 cm and all water gates need to be all exposed.

1. Install Suction sensor and Moisture Sensor to the Data logger to check for the availability for working.
2. Collecting the data 15 minutes for each column to have most accurate value from the sensor, then recording Qin value from Mariotte Bottle.
3. Checking Sensor availability after used, clean the sensor, put Suction Sensor to water to keep them fully saturate then keep Moisture Sensor properly in appropriate place to keep them dry.
4. Collecting data every 2 days until the process stopped when Suction value decreased from 80 kPa to 0 kPa.

• Dry Process

1. Install Suction sensor and Moisture Sensor to the Data logger to check for the availability for working.

2. Collecting the data 15 minutes for each column to have most accurate value from the sensor.

3. Checking Sensor availability after used, clean the sensor, put Suction Sensor to water to keep them fully saturate then keep Moisture Sensor properly in appropriate place to keep them dry.

4. Collecting Data every 2 days until the process stopped when Suction value increasing from 0 kPa to 80 kPa.

Figure 3.8: Installing Sensors for Data Collection

3.3 Method of Killing

• Black impermeable sheet as coverage (mulching)

Kill the plants off by not letting the plants receive any sunlight using black impermeable sheet to cover the entire plants and soil. After 2-3 months, the vetiver grass will gradually die.

Figure 3.9: Black Impermeable Sheet as Coverage (Mulching Method Procedure)

3.4 Data Analysis

3.4.1 The Change of Pore-Water Pressure and Volumetric Water Content with Respect to Time

3.4.2 The Change of Matric Suction along the Depth

3.4.3 The Change in Root Content over Time

1. Adjust the pictures taken from each section along the column specimen at 3 stages of soil.

2. Digitize each image pixel by pixel by using Python program to determine for the side root area ratio (number of root pixels divided by total number of pixels).

3. Determine the relationship between the digitized image with the bar chart illustrating the change in pore water pressure variation of soil at 3 stages.

3.4.4 The Changes in Normalized Slope Ratio and Root Content Ratio

1. Calculate the changes in pore water pressure (slope) of section1 and section 2 for all stages of soil and divide it with one another.

2. Take the slope of section1 over that obtained from section2 to be represented by a bar chart, compare each one to another.

CHAPTER 4
RESULT

4.1 Changes in Pore Water Pressure with Respect to Time

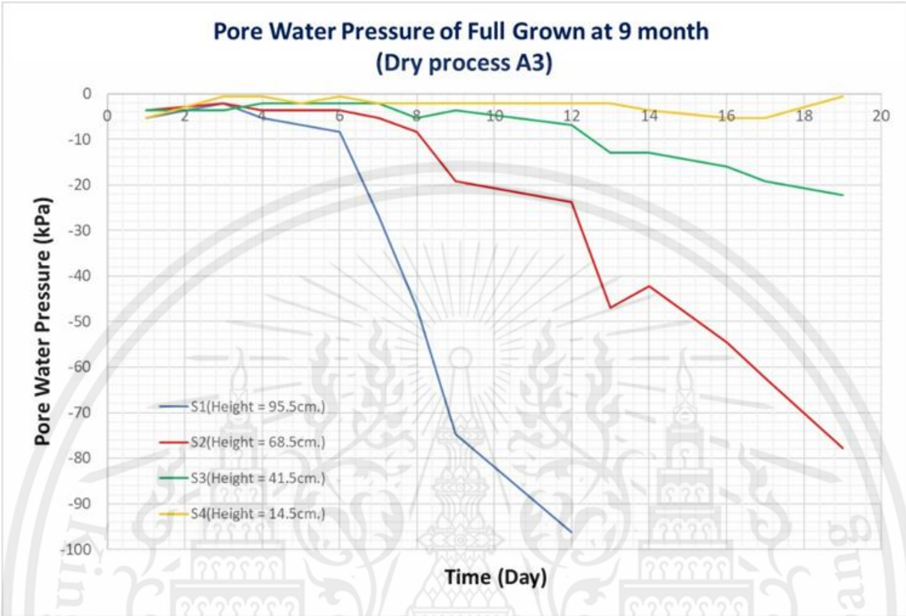

Figure 4.1: The graph shown above illustrates the changes in pore water pressure with respect to time in the vegetated soil specimen at its full grown stage of nine-month old when subjected to a drying process.

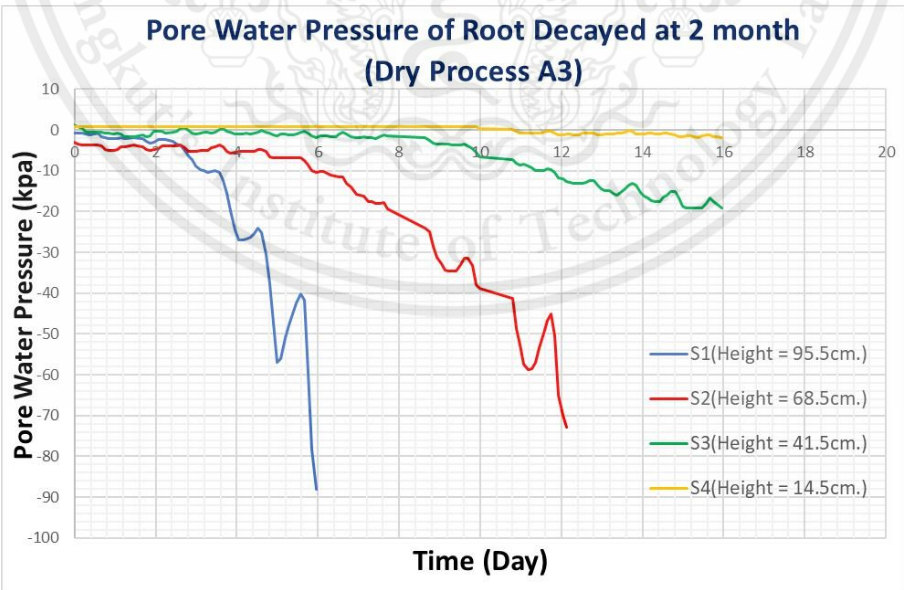

Figure 4.2: The graph illustrates the changes in pore water pressure with respect to time in the decayed vegetated soil specimen subjected to a dry process at a decayed stage of two months after mulching method was done.

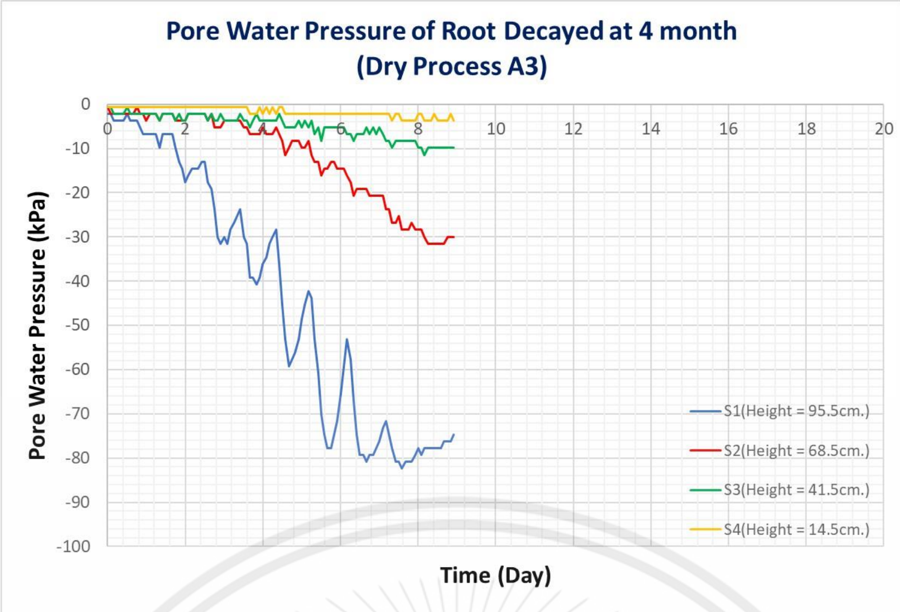

Figure 4.3: The graph illustrates the changes in pore water pressure with respect to time in the decayed vegetated soil specimen subjected to a dry process at a decayed stage of four months after mulching method was done.

Figure 4.1, 4.2, 4.3 shown above signifies the changes in pore water pressure with respect to time in each stage of the vegetated soil specimen column; full grown stage, decayed stage of 2 months and 4 months. The figures mentioned above are represented with S1, S2, S3, and S4, where S1 (M1) denotes from the sensor at the height of 95.5 centimeters. S2 (M2) denotes the sensor plugged in at the height of 68.5 centimeters. S3 (M3) represents the sensor at the height of 41.5 centimeters, and S4 (M4) represents the sensor plugged in onto the column at the height of 14.5 centimeters respectively with the bottom of the column as datum point. According to Figure 4.1, the change (ratio) of the pore water pressure of section1 and section2 are 14.67 kPa/day from 88 kPa divided by 6 days as a time period and 3.33 kPa/day from 20 kPa divided by 6 days respectively. Where Figure 4.2 indicates that the change (ratio) of the pore water pressure of section1 and section2 obtained when the vegetated soil is at a decayed stage of 2 months are 14.5 kPa/day (from 87 kPa over 6 days) and 1.17 kPa/day (from 7 kPa over 6 days). Lastly, Figure 4.3 shows the values of section1 and section2 obtained when the vegetated is at a decayed of 4 months, which are, 10.67 kPa/day (from 64 kPa over 6 days) and 2.33 kPa/day (from 14 kPa over 6 days).

4.2 Changes in Matric Suction along the Depth

- **Vegetated soil at a full grown stage of nine-month old**

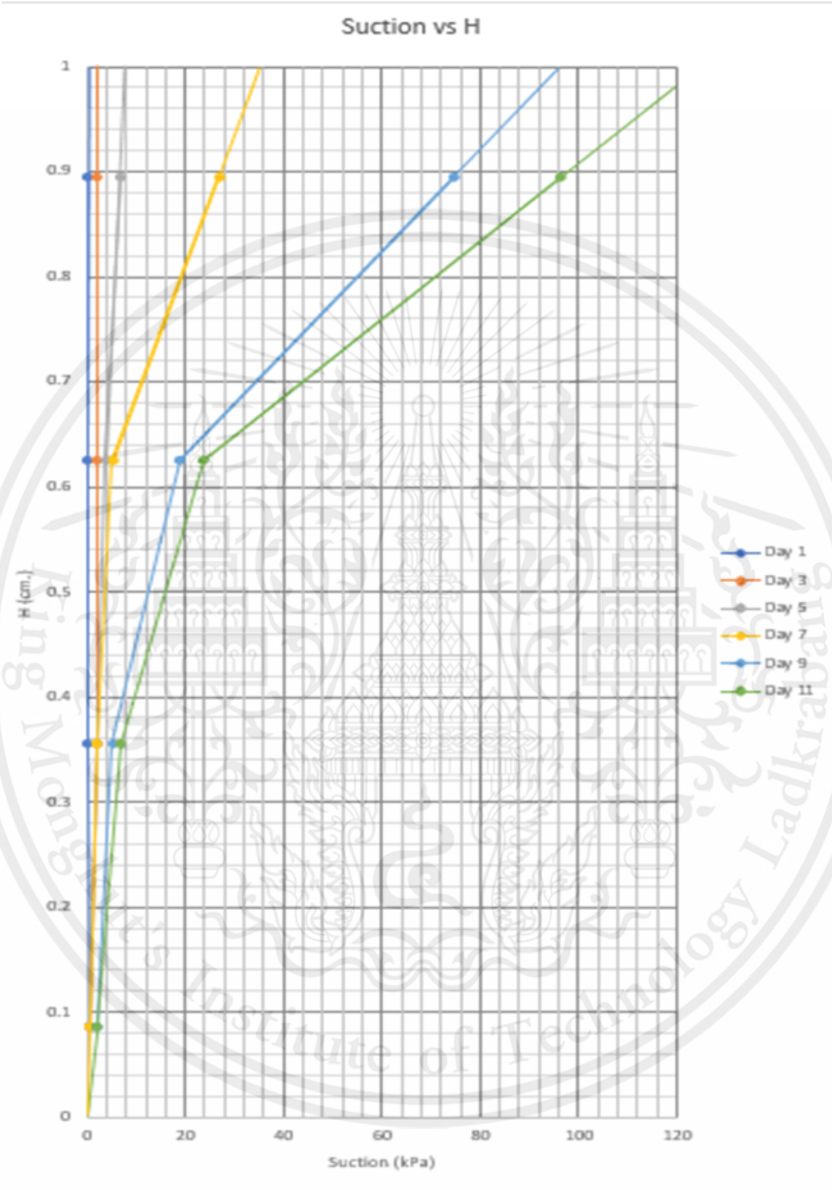

Figure 4.4: The graph illustrates a relationship between the matric suction obtained from the vegetated soil specimen at its full grown stage (nine-month old) and depth along the column specimen.

- **Decayed vegetated soil at a decayed stage of two months**

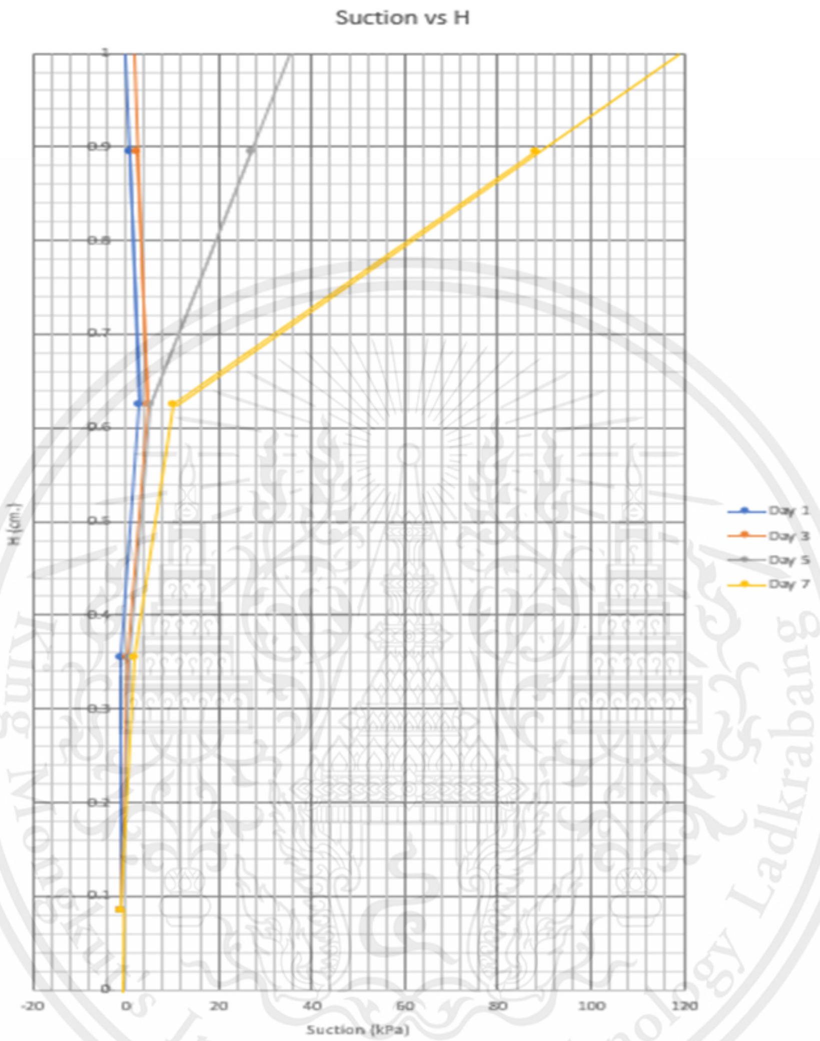

Figure 4.5: The graph illustrates a relationship between the matric suction obtained from the decayed vegetated soil specimen at its decayed stage of two months and depth along the column specimen.

- **Decayed vegetated soil at a decayed stage of four months**

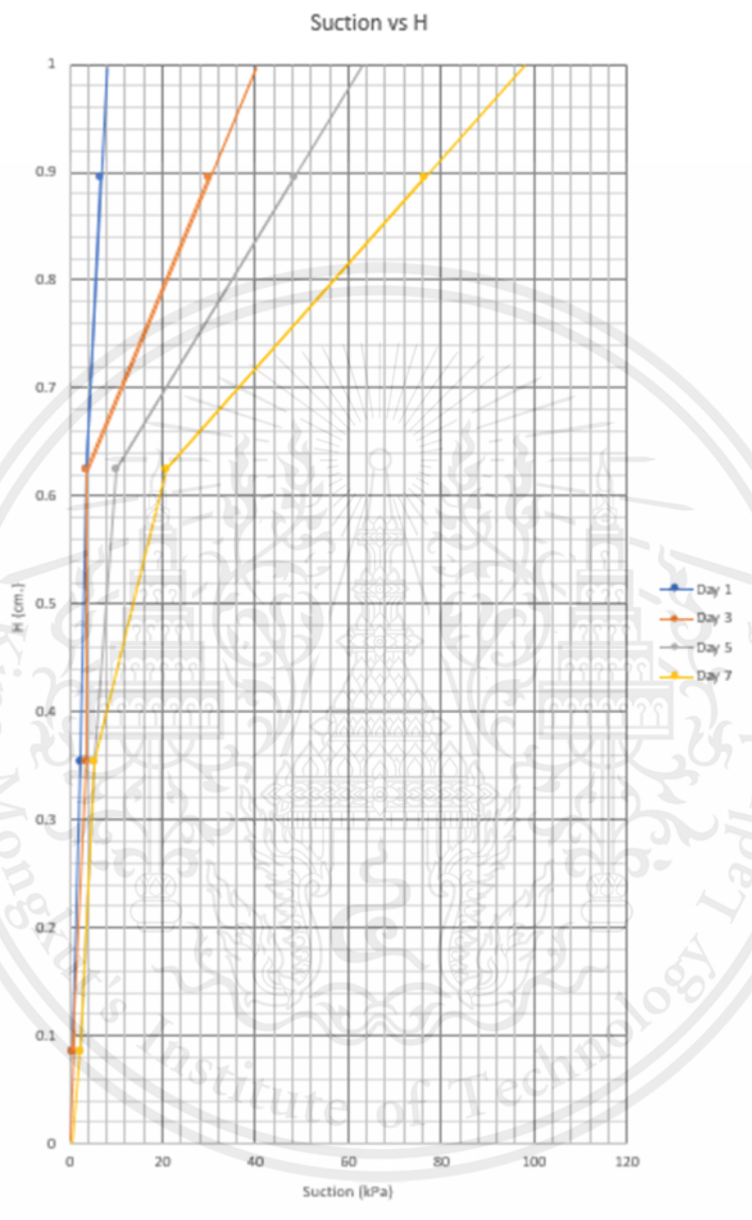

Figure 4.6: The graph illustrates a relationship between the matric suction obtained from the decayed vegetated soil specimen at its decayed stage of four months and depth along the column specimen.

In accordance with Figure 4.4, 4.5, and 4.6 illustrating graphs of soil matric suction-depth obtained from three different stages of soil above, which indicate the soil ability to maintain equilibrium within its overall soil blocks. It is obvious that the greater the decay of roots occurs, the greater range in values of matric suction acquired. It is possible considering the fact that the more the roots decay, the greater the void ratio in soil mass, which causes preferential flow that leads to more vanities for water content to penetrate into for lower sections (section 3,4), and more space for moisture to leaves the soil upwardly (evaporation). However, the graph obtained at each stage of soil cannot be used to compare with another one obtained from a different stage of soil. Since, every graph was obtained from the data recorded at different time, different stage, and under different climate, it is to be concluded that only the comparisons among the graph lines within the same stage of soil are valid.

4.3 Changes in Volumetric Water Content with Respect to Time

- **Vegetated soil at a full grown stage of nine-month old**

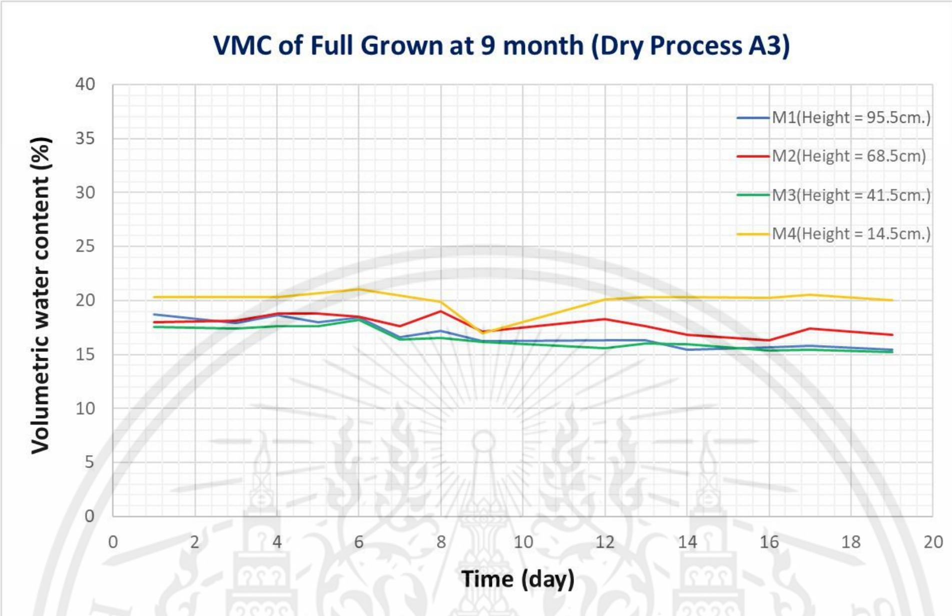

Figure 4.7: The graph illustrates a relationship between the volumetric water content with respect to time in vegetated soil specimen at its full grown stage at the age of nine-month old when subjected to a drying process.

- **Decayed vegetated soil at a decayed stage of two months**

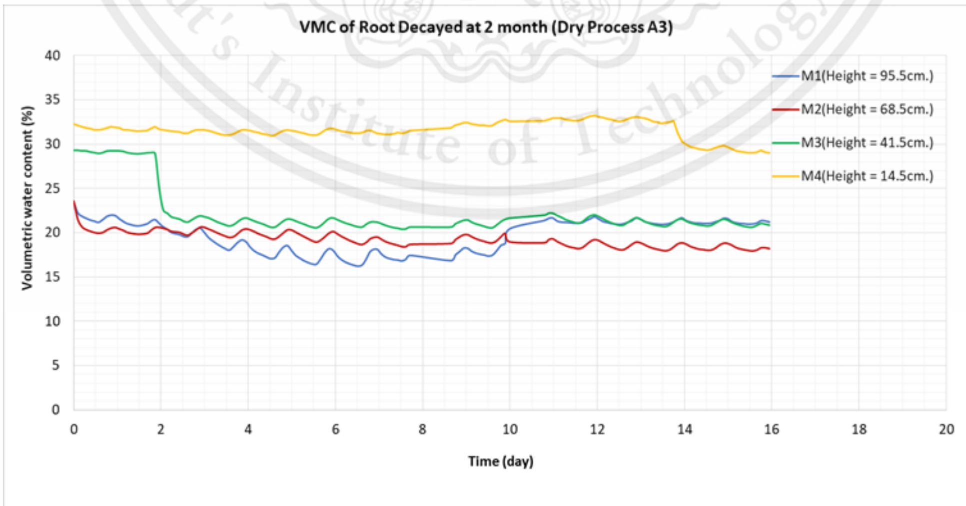

Figure 4.8: The graph illustrates a relationship between the volumetric water content with respect to time in decayed vegetated soil specimen subjected to a drying process after two months of mulching method began.

- **Decayed vegetated soil at a decayed stage of four months**

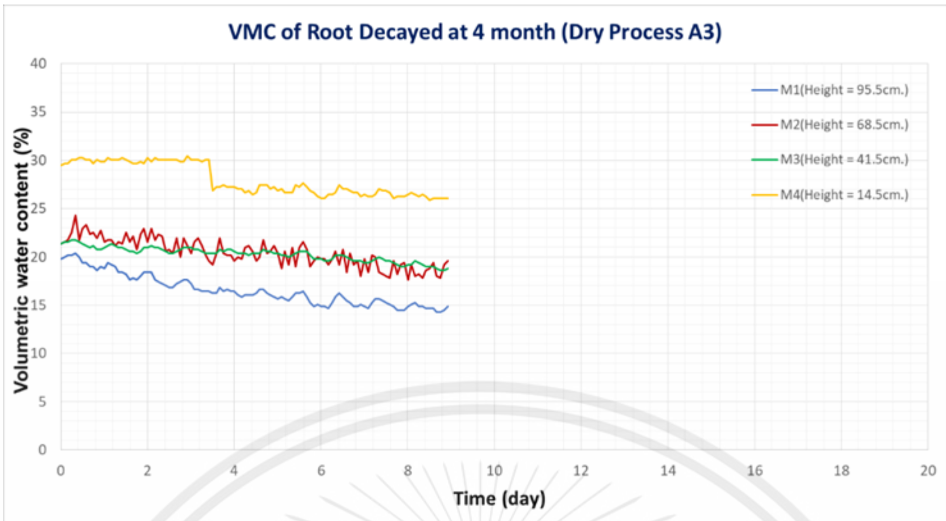

Figure 4.9: The graph illustrates a relationship between the volumetric water content with respect to time in decayed vegetated soil specimen subjected to a dry process after four months of mulching method began.

Figure 4.7, 4.8, and 4.9 shown above illustrating the changes in volumetric water content with respect to time in each section of the vegetated soil specimen column at its full grown stage, decayed stage of 2 months, and 4 months respectively. M1 (S1) denotes from the moisture sensor at the height of 95.5 centimeters. M2 (S2) denotes the moisture sensor plugged in at the height of 68.5 centimeters. M3 (S3) represents the moisture sensor at the height of 41.5 centimeters, and M4 (S4) represents the moisture sensor plugged in onto the column at the height of 14.5 centimeters respectively with the bottom of the column as datum point. As seen on the graphs, the volumetric water content gradually decreases as time increases with the same pattern for all graphs obtained at different stages of soil. M4 has the greatest volumetric water content values, followed by that of section3, section2, and section1 respectively. The occurrence possibly due to the location along the height of the specimen column, since section 4 is located at the bottom of the column where water permeate down to and the furthest place for evaporation to take place, followed by the location of section3, section2, and section1 where the highest volumetric water content values are obtained.

4.4 Changes in Root Contents

- **Physical changes of roots in acrylic column (A3)**

  - Section 1 (starting from the height of 81-108 cm.)

Figure 4.10: The figure shows the roots of section 1 at full grown stage of nine-month old.

Figure 4.11: The figure shows the roots of section 1 at a decayed stage of two month after mulching process was conducted.

Figure 4.12: The figure shows the roots of section 1 at a decayed stage of four month after mulching process was conducted.

- Section 2 (starting from the height of 54-81 cm.)

Figure 4.13: The figure shows the roots of section 2 at full grown stage of nine-month old.

Figure 4.14: The figure shows the roots of section 2 at a decayed stage of two months after mulching process was conducted.

Figure 4.15: The figure shows the roots of section 2 at a decayed stage of four months after mulching process was conducted.

- Section 3 (starting from the height of 27-54 cm.)

Figure 4.16: The figure shows the roots of section 3 at full grown stage of nine-month old.

Figure 4.17: The figure shows the roots of section 3 at a decayed stage of two months after mulching process was conducted.

Figure 4.18: The figure shows the roots of section 3 at a decayed stage of four months after mulching process was conducted.

- Section 4 (starting from the height of bottom of 0-27 cm.)

Figure 4.19: The figure shows the roots of section 4 at full grown stage of nine-month old.

Figure 4.20: The figure shows the roots of section 4 at a decayed stage of two months after mulching process was conducted.

Figure 4.21: The figure shows the roots of section 4 at a decayed stage of four months after mulching process was conducted.

- **Digitized image of changes in root content**

  - Section 1 (starting from the height of 81-108 cm.)

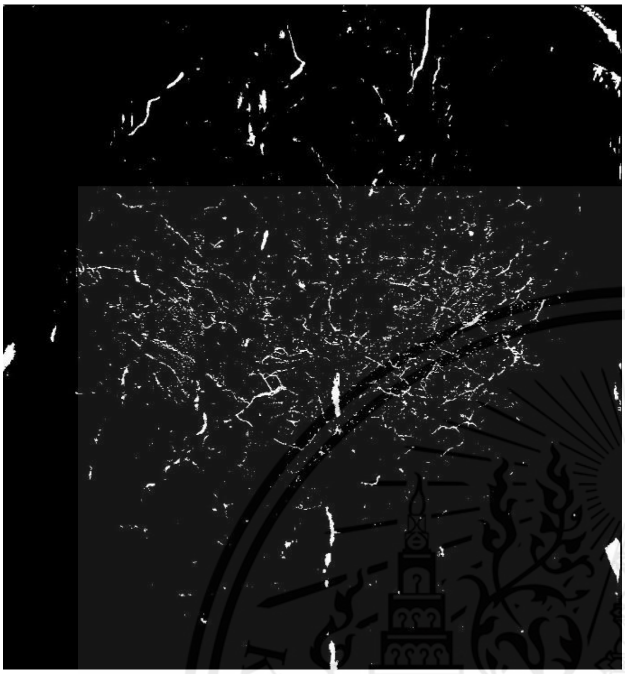

Figure 4.22: The figure shows the roots of section 1 at full grown stage of nine-month old expressed in term of digitized pixels.

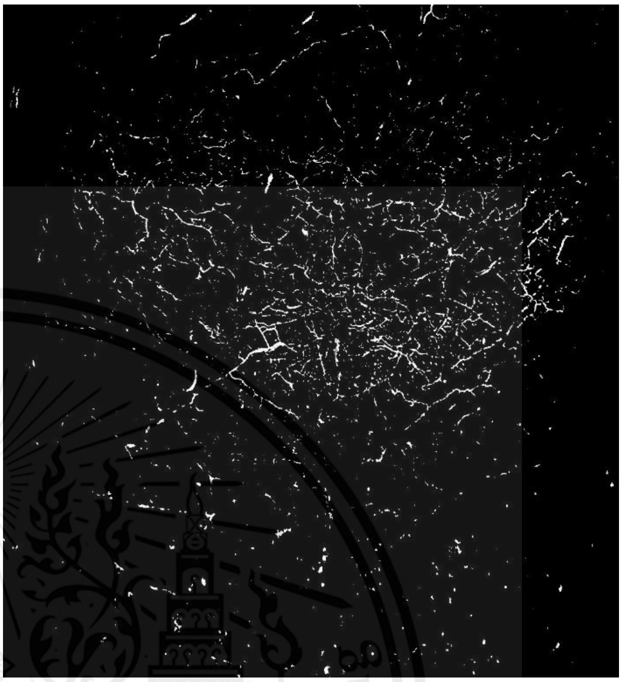

Figure 4.23: The figure shows the roots of section 1 at a decayed stage of 2 months old expressed in term of digitized pixels.

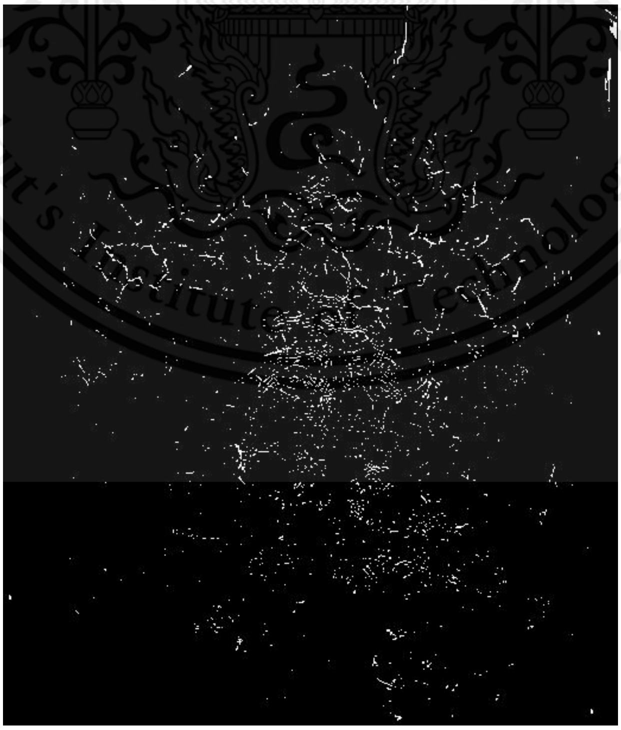

Figure 4.24: The figure shows the roots of section 1 at a decayed stage of 4 months old expressed in term of digitized pixels.

- Section 2 (starting from the height of 54-81 cm.)

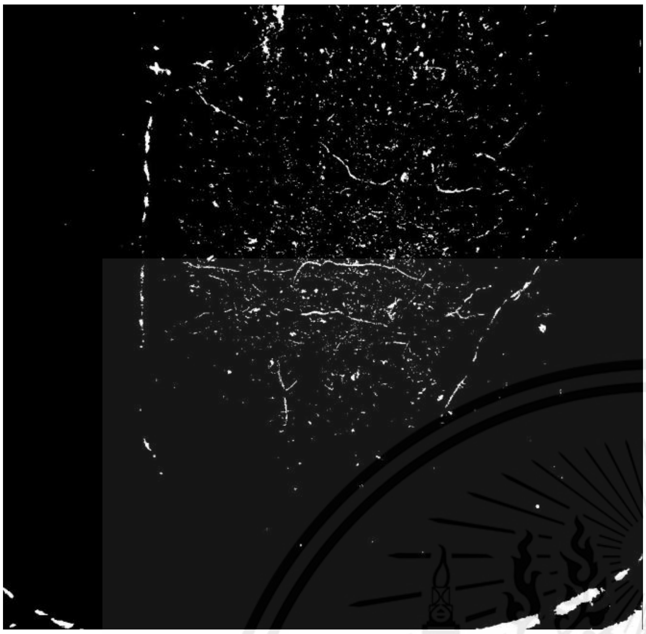

Figure 4.25: The figure shows the roots of section 2 at full grown stage of nine-month old expressed in term of digitized pixels.

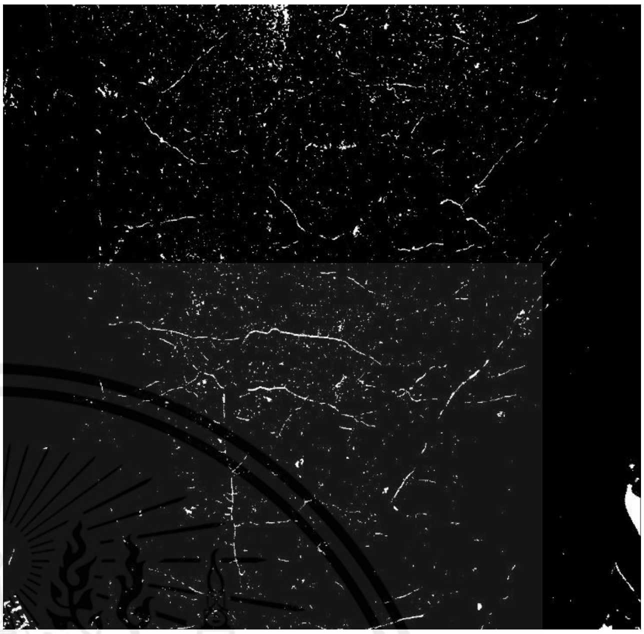

Figure 4.26: The figure shows the roots of section 2 at a decayed stage of 2 months old expressed in term of digitized pixels.

Figure 4.27: The figure shows the roots of section 2 at a decayed stage of 4 months old expressed in term of digitized pixels.

In accordance with Figure 4.22 to Figure 4.27 illustrated above, it is shown that the quantity of root pixels (white pixels) decreases as the decay stage grows longer. However, the picture of digitized images also show that the ratio of the decay of root is different in each section. The point made from the digitized images are coherently related to the graph of pore water pressure-time, and the bar chart showing the difference in the ratio of changes in matric suction occurred at section and section 2 of soil at three stages., as stated below in the conclusion.

4.5 Changes in Matric Suction Variation Ratio

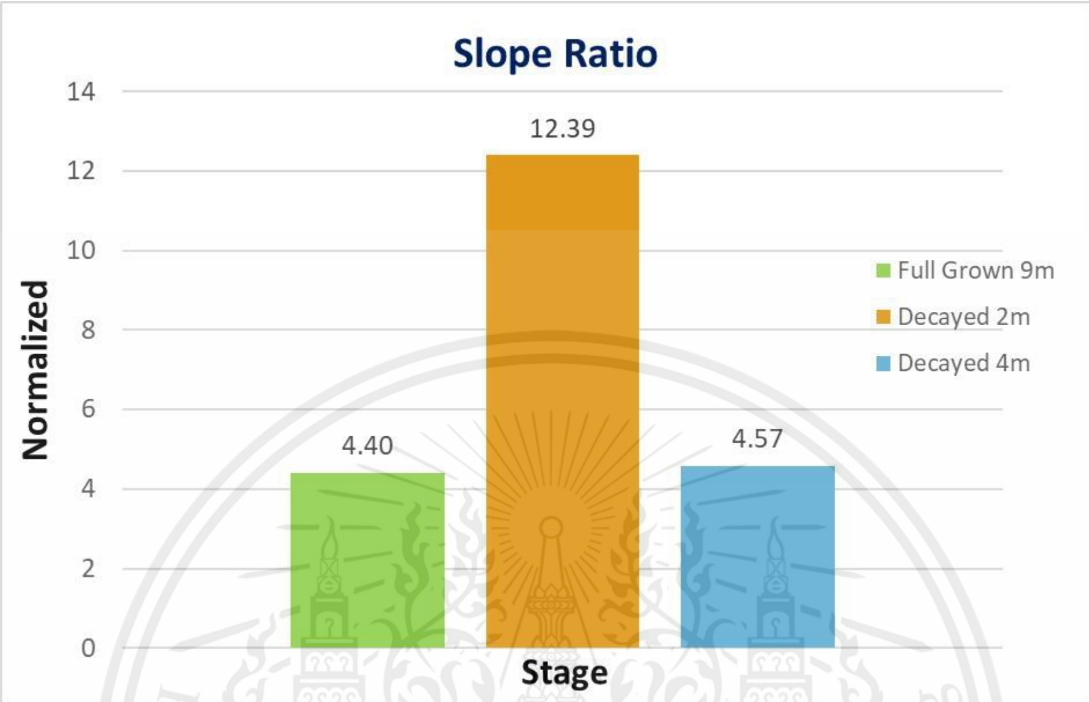

Figure 4.28: The bar chart shows the difference in pore water pressure ratio obtained from section1 and section2 at three stages of soil.

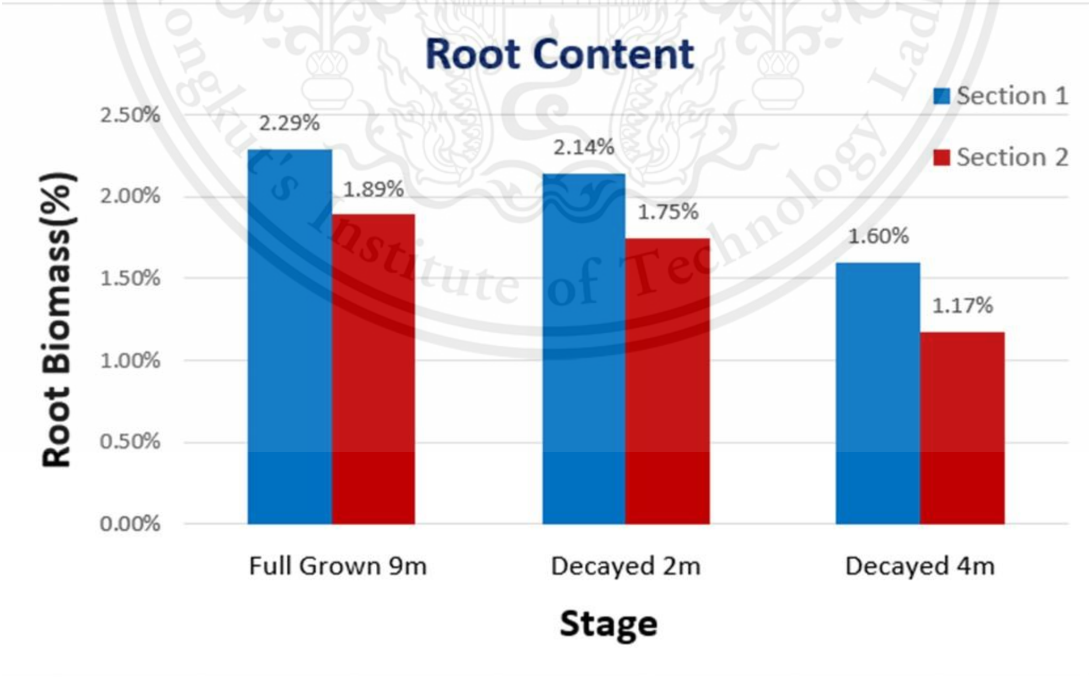

Figure 4.29: The bar chart shows the difference in root content (%) of section1 and section2 of soil in 3 stages as time increases.

It can be seen from Figure 4.28 that the difference in pore water pressure obtained from the vegetated soil at a decayed stage of 2 months is 3 times greater than that of the soil at full grown, and decayed stage of 4 months. This occurrence signifies that the decay of roots happened at section 1 noticeably drops greater from the decayed stage of 2 months onwards, while not so much decay of roots in section2 is observed at this stage of soil. Which is coherent with figure 4.29 showing a slight difference in root biomass of section 2 at a decayed stage of 2 months. On the other hand, the slope ratio obtained at a decayed stage of 4 months drops to similar a number as the one obtained at full grown stage is due to the progressive decay of root happened at section2 which allows water to penetrates downwardly more easily that makes its slope steeper, results in a low number of slope ratio.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Prologue

The conclusion of this thesis is concluded from the study of pore water pressure and water content variations in decayed vegetated soil at its decayed stage of two and four months compared with that from vegetated soil at full grown stage of nine months. The observation of vegetated soil at the decayed stage is formulated with compacted Lateritic soil at 80% standard proctor, Songkhla 3 vetiver grass specie (Chrysopogon zizanioides). The experiment is conducted by simulating drying and wetting processes onto the 125 centimeters specimen columns, located in an enclosed, fully-controlled greenhouse.

5.2 Conclusion

1. The decrease in pore water pressure of soil at a decayed stage of 2 months is 3 times greater than that of vegetated soil at full grown stage and decayed stage of 4 months which suggests that the decay of root happen at a different time for each section, starting from the top to bottom location of the column.

2. The changes in void ratio due to the decay of roots significantly affect the soil porosity that leads to the changes in its ability to captivate the moisture content within the soil mass.

3. Root biomass decreases as decay stage continues longer.

REFERENCES

1. Binh T. Nguyen, Tatsuya Ishikawa, Takami Murakami (2020). Effects evaluation of grass age on hydraulic properties of coarse-grained soil.
2. Apiniti Jotisankasa, Teerapat Sirirattanachat (2017). Effects of grass roots on soil water retention curve and permeability function.
3. J. J. NI, A. K. LEUNG, C. W. W. NG (2019). Modelling effects of root growth and decay on soil water retention and permeability.

APPENDIX

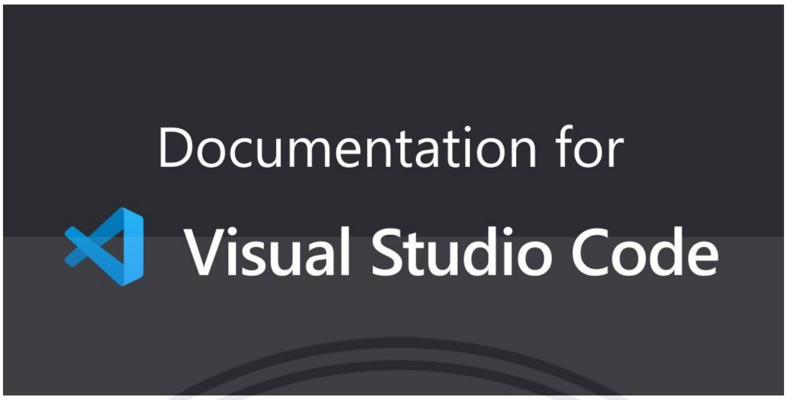

Fig 6.1: The image shows the program used in root pixels determination

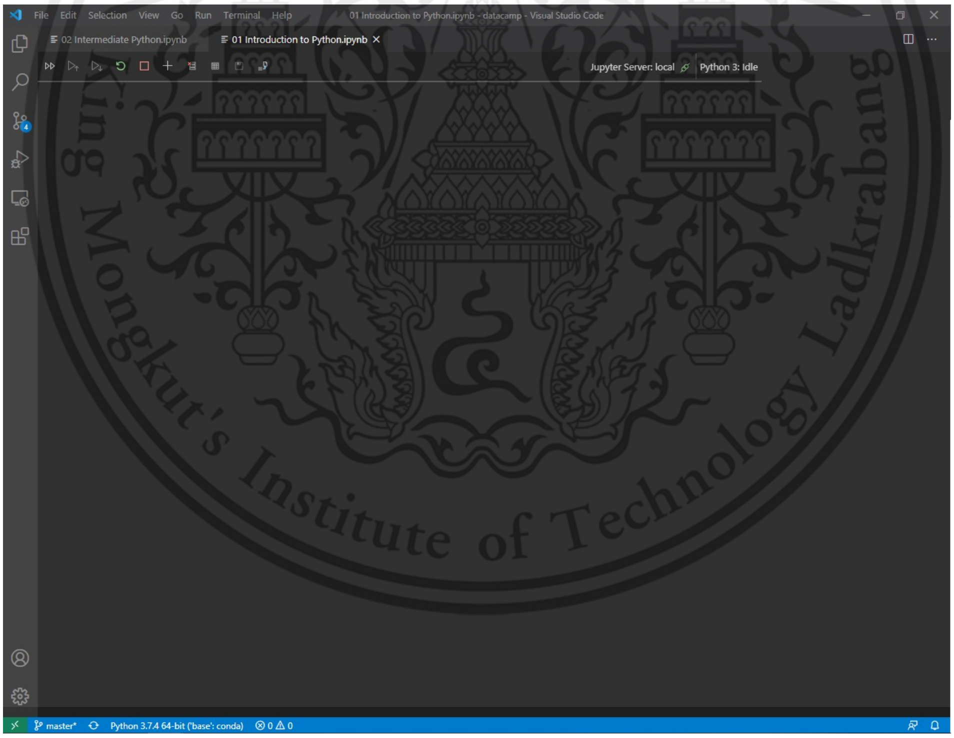

Fig 6.2: The figure shows the program desktop before the coded command is inserted.

x

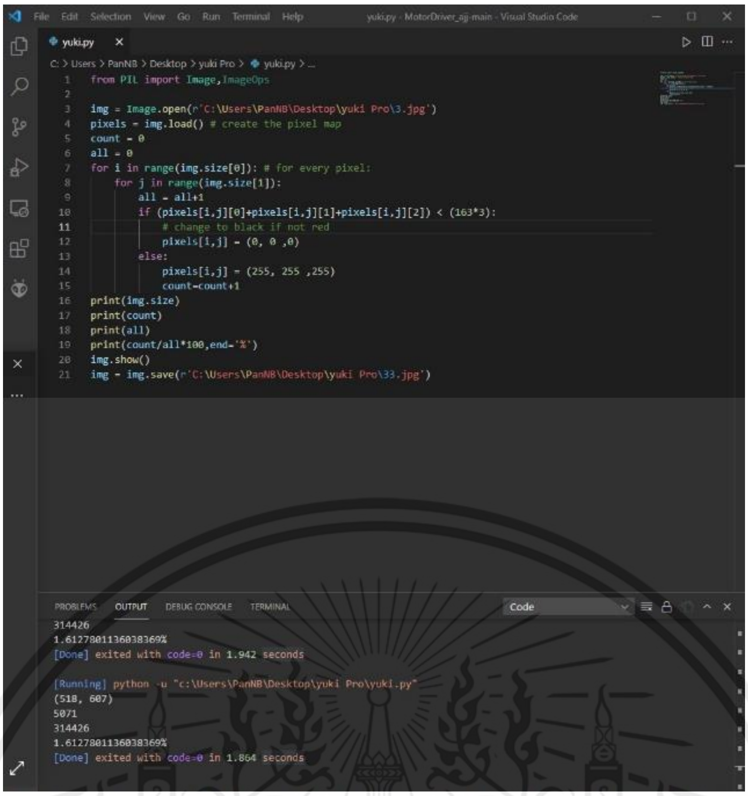

Fig 6.3: The image shows the run coded program with its results below.

```
from PIL import Image,ImageOps

img = Image.open(r'C:\Users\PanNB\Desktop\yuki Pro\13.jpg')
pixels = img.load() # create the pixel map
count = 0
all = 0
for i in range(img.size[0]): # for every pixel:
    for j in range(img.size[1]):
        all = all+1
        if (pixels[i,j][0]+pixels[i,j][1]+pixels[i,j][2]) < (200*3):
            # change to black if not red
            pixels[i,j] = (0, 0 ,0)
        else:
            pixels[i,j] = (255, 255 ,255)
            count=count+1
print(img.size)
print(count)
print(all)
print(count/all*100,end='%')
img.show()
img = img.save(r'C:\Users\PanNB\Desktop\yuki Pro\013.jpg')
```

Fig 6.4: The figure shown above illustrates the coded command used. The command is set to run each loop pixel by pixel by fix a value to part the difference in color of roots and soil. If the obtained output is more than the set value, it is taken as root pixel. If it is less than the set value, it is taken as soil pixel. Take all the root pixels over total pixels of the image to be the percentage of root in that particular image/area.