INVESTIGATION ON WETTING PATTERN OF NORMAL AND SURGE IRRIGATION FOR VARIATION OF SOIL TYPES.

By

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Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(NUR ATIQRAH BINTI AZIZ)

ABSTRACT

Infiltration and irrigation plays an important role in connecting the relationship between soil and water. To come out with the best soil to use for the canal to supply water to the plant, that can gives adequate infiltration rate, optimum water retained and also can withstand surge and normal irrigation, this study was executed. Preliminary study was done to know the soil classification for six types of soil which are topsoil, sand, soil from corn farm, soil vegetable farm, soil from palm oil farm and peat soil. As for the soil classifications, it includes the moisture content, specific gravity, bulk density, porosity, permeability and particle size distribution. The soil classification result showed that the topsoil is the sandy clay, sand is purely sand, soil from corn farm, vegetable farm and palm oil farm is sandy loam and peat soil is sandy gravel. After the soil classification was done, final experiment where the six types of soil will be testing one by one using the SOLTEQ equipment to know the wetting pattern of the soils. Soil from corn farm and vegetable farm which are classified as sandy loam gave the best result in giving the most adequate infiltration rate which is 11520mm/day and 18000 mm/day respectively experimental and based on Department of Drainage and Irrigation (DID) Malaysia, the infiltration rate for sandy loam is 200 mm/day. This big difference is most probably due to the soil compaction as the table from DID (2009) take the infiltration rate from the field experiment. Both soil also retain the most water for the irrigation conveyance.

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First of foremost, I would like to express my gratitude to Allah SWT for the health and smooth progress that I encountered during this two semesters of final year. Not to forget my beloved supervisor, Dr. Husna bt. Takaijudin for her guidance and patience in helping me completing the course despite her tight schedule. Her support and motivation always drive me to always do my best in completing this project.

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ABBREVIATIONS AND NOMENCLATURES

α	=	Ratio between viscosity of water at test temperature and at 27°C
δL	=	Length of Irrigated area
δt	=	Time taken for the water to reach at certain depth of irrigated area
ρ	=	Bulk Density
ρ_d	=	Dry Density
ρ_s	=	Particle density of soil
ρ_w	=	Water density
a	=	Area of standpipe
A	=	Area of the soil column
C_u	=	coefficient of uniformity
C_c	=	coefficient of curvature
D_{10}	=	10% of material smaller
D_{50}	=	mean particle size
e	=	void ratio
f	=	Infiltration rate
G	=	Specific Gravity
h_1	=	Initial reading of standpipe
h_2	=	Final reading of sandpiper
i	=	Hydraulic gradient
K	=	Hydraulic conductivity
L	=	Length of soil column
m	=	Mass
n	=	Porosity
q	=	Rate of flow
R_d	=	Modified hydrometer reading
R_t	=	Correction factor
t	=	Time required to get head drop of Δh
V	=	Volume of mold
w	=	Moisture content

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

From the old days until now, agricultural field is one of the most popular sector in Malaysia. Based on Nations Encyclopedia website, the agriculture sector contributes up to 12% of the Malaysia Gross Domestic Products (GDP). GDP is primary indicators used to monitor the economy's growth in one's country. Therefore, agriculture sector is important in order to maintain the nation's economy. Furthermore, this sector also allocate around 16% of Malaysian populations with job.

There are many types of crops that available in Malaysia. The main crops that takes lots manpower are the rice, palm oil and also rubber. As a staple food in Malaysia, rice is indeed one of the most popular in agriculture sector. However, these days the production of rice in Malaysia is inadequate for the country's need. Therefore, Malaysia imported the rice from Thailand to tackle this problem. As for the palm oil and rubber, both of this crops remained as the crops that contributes a lot in supplying the palm oil and also the rubber to other countries.

Besides that, the fruits and vegetable also plays an important role in this sector. For the fruits and vegetables, it is also as one of the money sources for the farmer. But normally, the production of fruits and vegetable only for the small scale agriculture compared to rice, palm oil or rubber. There are a few factors that must be optimize the usage in order to increase the crop growth rate which are the irrigation optimization, land optimization, labor optimization, soil optimization, climate, fertilizers and pesticides optimization, transportation and also weed management (Saranya & Amudha, 2016).

Due to the increasing of demand in agriculture sector, there are some transformation made by the Malaysian government in order to help the farmer and also Malaysia economy which is to transform this sector into a modern venture in the 9th Malaysian plan (Ismail & Yusoff, 2009). This transformation plan is the combination of ministries that includes Ministry of Agriculture (MoA), the Ministry of Plantation Industries and commodities (MPIC) and the Ministry of Rural and Regional Development (MRRD).

For this study, the focus is on the soil and also the irrigation. Based on Kavianand et. al (2016), irrigation can be defined as a man-made system of flowing the water to the dry soil which has less rainfall in order to grow crops. There are three types of irrigation which are surface irrigation, sprinkler irrigation and also drip irrigation. Among all of the types of irrigation, drip irrigation is the most efficient in controlling the wastage of the water being irrigated (Soulis et. al, 2014). This is because drip irrigation permits water to drip slowly to the roots through narrow pipeline that comes with emitters. Therefore, it reduces the evaporations of the water happened while irrigation. In order to improve this sector to become more significant to Malaysia's economy, this research was done in a way to get the most effective soil that can withstand the irrigations whether it is normal irrigation or surge irrigation.

1.2 PROBLEM STATEMENT

Malaysia is one of the countries that affected by the monsoon seasons or the rainy seasons. Because of this, there is time where the farmers lost their sources of income. According to Anees et. al (2015), many sector such as agriculture, environment, economy and so on are affected by the flood. When floods occur, plants such as corn, watermelons and pineapple are barely to survive. Besides flood, there are lots of challenges which causes in low crop production which are the inappropriate method of irrigation, problem with the climate changes, land allocation, manpower, crop selection and other resources (Saranya & Amudha, 2016).

The other problem that was stated by Kavianand et. al (2016) is the condition where the land becomes un-irrigated because of the continuous extraction of water from earth which lowering the water level at particular land. Moreover, the large amount of water being supplied goes to waste because of inappropriate planning of water usage. Besides that, for drip irrigation case which is the normal irrigation for this case, the root zone of particular plants will face constant water supply and this will cause root damage if the amount of water received is more than the amount of water required by the roots (Ramya & Ravi, 2016).

For this study, it involves the crop selection which mainly consist of the soil, season and irrigation water. Basically in this study, the relationship on the wetting pattern between the soils and irrigation will be tested. Normal irrigation is a condition when the minimum water is being flows out to the soil while for the surge irrigation is the when the maximum water is being flows to the soil.

1.3 OBJECTIVES AND SCOPE OF STUDY

The objectives for this study are;

1. To identify the adequate infiltration rate for variation types of soil.
2. To examine which soil are the best in giving the plant sufficient volume of water which has adequate volume of water retained above the ground level.
3. To compare the soil behavior between normal and surge irrigation when being tested

This study focusses on the how the soil behaves with water. Basically, this study is about soil-water relationship. Based on Easton and Bock (2016), there are four elements in the soil which are mineral solids, organic matter solids, water and also air. Besides that, the rate of water behavior moving through the soil and root penetration are affected by the soil structure. The soil structure is basically the way soil particles shaped and organized into units of aggregation. Soil bulk density and porosity also affect the water behavior. Deeper explanation regarding soil-water relationship from Easton and Bock (2016) is on the soil water content and soil water potential. The difference between these two are soil water content is the volume of water being stored in the soil for specific time while for the soil water potential, it is the energy needed for water to move water within the soil.

Both of these elements were being explained in Hydraulics and Geotechnical Engineering. In this study, several types of soil will be tested which are sand, topsoil, soil from corn farm, vegetable farm, palm oil farm and peat soil. Meanwhile for the water condition, normal irrigation and surge irrigation will be tested.

CHAPTER 2

LITERATURE REVIEW

2.1 SOIL - WATER RELATIONSHIP

Soil and water are the two elements that involved in this study. The relationship between these two elements can be seen by the wetting pattern of the soil which caused by the water. Moreover, the soil itself contained water as part of its composition (Easton & Bock, 2016). The most crucial field that can relate the soil and water relationship is the agricultural field. Based on Saranya and Amudha (2016), the key for optimum agricultural production is when the supply of land or soil and irrigation water is in the right time and also right quantity. To prove that soil and water are very significant in agriculture field, there are a lot of recent technology that invented an irrigation system which focused on detecting the soil moisture content, water level, checking the temperature and humidity of the in that particular area of agriculture. Ramya and Ravi (2016) suggested to use Zigbee transmitter to detect the water content in soil while Kavianand et. al (2016) proposed to use the smart drip irrigation system which consist of sensors that can coverts the physical parameter to the electrical signal. Thus, with several of technology being invented related to soil and water relationship, it really proves that this relationship is a very important factor in agricultural field.

The soil-water relationship is basically how the physical properties of soils effect the behavior of water. Based on Food and Agriculture Organization of United Nation (FAO) (2017), definition of soil can be presented as the natural element for plant growing. Soil also allows the root system of the plant to spread and get a strong hold to it. Soils are composed of mineral solids, organic matter, water and air. There are a few types of soil which are alluvial soil, black soil, red soil, laterite soil, mountain soil and desert soil. These types of soils are depending on the soil properties. Among all types of soil, there are two soils that is suitable to use for agriculture which are the alluvial and black (Saranya & Amudha, 2016). Alluvial soil is suitable for the production of rice, wheat and maize. The water holding capacity of these soils is fairly good and is good for irrigation. For the black soil, the capacity of holding the moisture and the fertility is very high. Thus, it is suitable for the production of cotton, millet and also tobacco. As for the soil structure, Easton and Bock (2016) stated that well-structured soils are more advisable to use in agricultural field as it can hold and conduct water and gases. It is also can withstand the load-bearing activities.

The most significant soil water relationships are the soil water content and soil water potential. Nyvall (2002) stated that the definition of soil water content is the total amount of water stored in the soil within the plant's root zone and it is determined by the soil texture and the crop rooting depth. Soil texture can be determine by referring to Figure 2.1 which is the United States Department of Agriculture (USDA) (1987) soil texture classification triangle. To refer to this triangle, the percentage of the soil composition must be known. As for the crop rooting depth, the longer the rooting depth, the higher the volume of water stored in the soil and this will lead to bigger amount of water for the agriculture production to be used for irrigation (Nyvall, 2002).

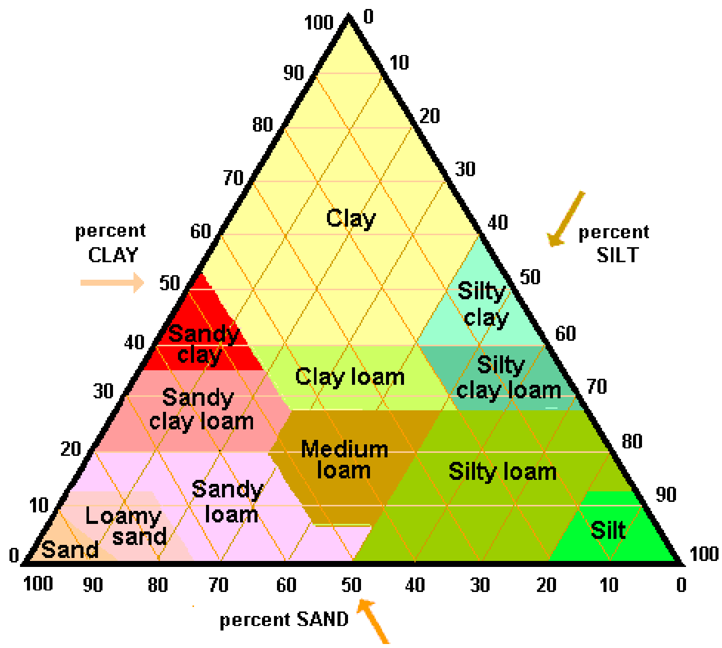

FIGURE 2. 1United States Department of Agriculture (USDA) Soil Texture Classification

Figure 2.2 shows the percentage of water content in several soil texture and also the position of field capacity and wilting point (Easton & Bock, 2016). There are two conditions that can explain the soil water content which are the field capacity and the wilting point. The field capacity can be defined as the amount of water remaining in the soil profile after 48 to 72 hours of free drainage following saturated condition (Easton & Bock, 2016). Moreover, it is also can be explained as one-third of atmospheric tension which the water is held in the soil weakly and it is an easy water for plant uptake. Field capacity also might affecting the irrigation scheduling (Easton & Bock, 2016). As for gravitational water, it is the water that drains freely under gravity and depending on environmental conditions, this water might be used by plants. For the wilting point, it is a condition which has the minimum volume of water and it cannot use to support the plants any longer.

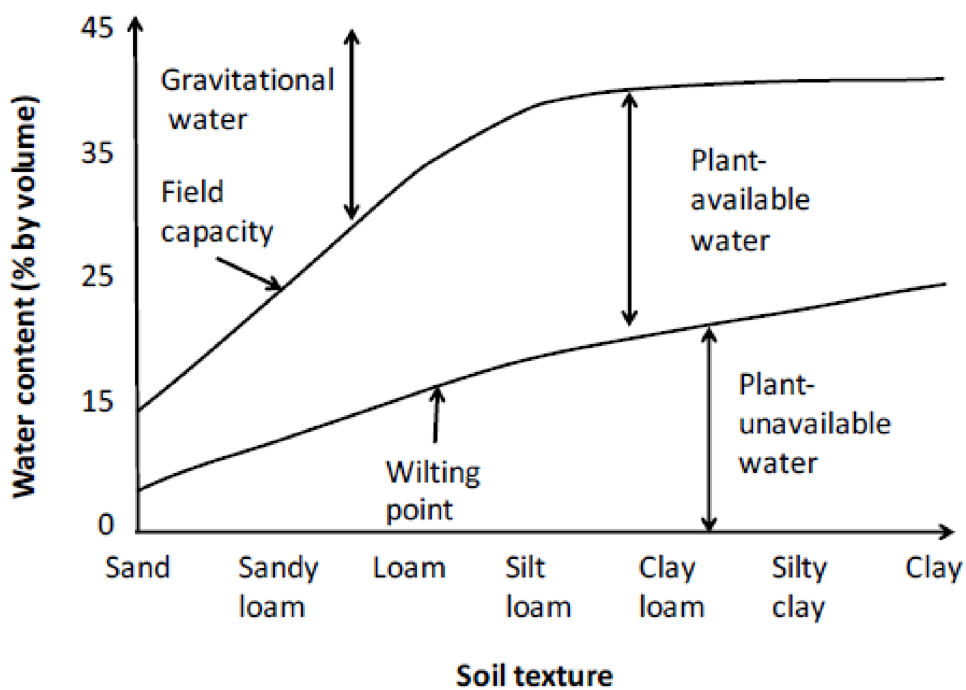

FIGURE 2. 2 Relationship between soil texture and water content (%)

Soil water potential is defined as the amount of energy present in the soil water which used in the movement of water (Easton & Bock, 2016). In soil, water movement are normally from higher to lower potential and it is not essential from higher to lower water content. The water content percentage does not affect the movement of water in soil. The potential energy that involved in the movement of water is the matric potential, gravitational potential and pressure potential. The matric potential is basically a result of force exerted on the water by the soil. The value is never to be positive as it is always zero for saturated soil and negative for the soil has the water contents below saturation. For the gravitational potential, it happen because of the gravitational force pulling the water. Meanwhile for the pressure potential, it is related to the hydrostatic force exerted by water in a soil (Easton & Bock, 2016).

2.2 HISTORY OF IRRIGATION SYSTEM IN MALAYSIA

Irrigation is a system which illustrate a good representation of how soil and water relate with each other while in another picture, irrigation is equivalent to agriculture. From the past thousand years, irrigation has always evolving and modernizing to suit the current ways of people working in the agricultural industry. Archeological investigation has been verified that irrigation begins from ancient Egyptians until now and it keeps growing concurrent with the upgrading of the water technology and also agriculture system.

Before irrigation system was used, people merely depends on the rainfall which is not consistent and the problem will arise when drought comes. Irrigation system has two objectives. The first one is to supply essential moisture for plant growth, which includes transport of essential nutrients and the second one to leach or dilute salts in soil (Shirsath, 2009). Irrigation gives full focus on the food production and improving food security by not only concentrating on achieving whole crop production but also pay attention on pests control, nutrients addition, land physical improvement and elimination of excess salinity of the soil (Mancosu, et. al, 2015).

The history of irrigation system begins in Malaysia with the Kerian Irrigation Scheme and Wan Mat Saman Scheme. Both of this scheme using a very large scale of irrigation system. For Kerian Irrigation Scheme, the water supply is from the Bukit Merah Reservoir that was built in 1906 (Valera & Desa, 1992). In 1978, there were some reconstruction of the Kerian irrigation Scheme which aimed to boost the rice production and to raise farms revenue. The prime design features of the finished project is the formation of two main canals which are the “Main canals” and the “Selinsing canals”. The main canals and the secondary canals are the earth canal while for tertiary canals are concrete-lined. This scheme also come out with a network of secondary and tertiary drainage which designed to control flooding and to give protection from the influx of the sea water (Valera & Desa, 1992).

As for Wan Mat Saman Scheme, it is the longest aqueduct in Malaysia to raise the rice production and this canal is the reason why Kedah's nickname is Malaysia's rice bowl. Back in 1932, the realization of ensuring the crops to grow healthily and avoiding any crops failures in Malaysia leads to the formation of the Drainage and Irrigation Department (DID) and Department of Agricultural (DOA). These departments was also formed to manage and organized the irrigation system in Malaysia. As for DID, this department is the one who manage and operate the Kerian Irrigation Scheme (Valera & Desa, 1992).

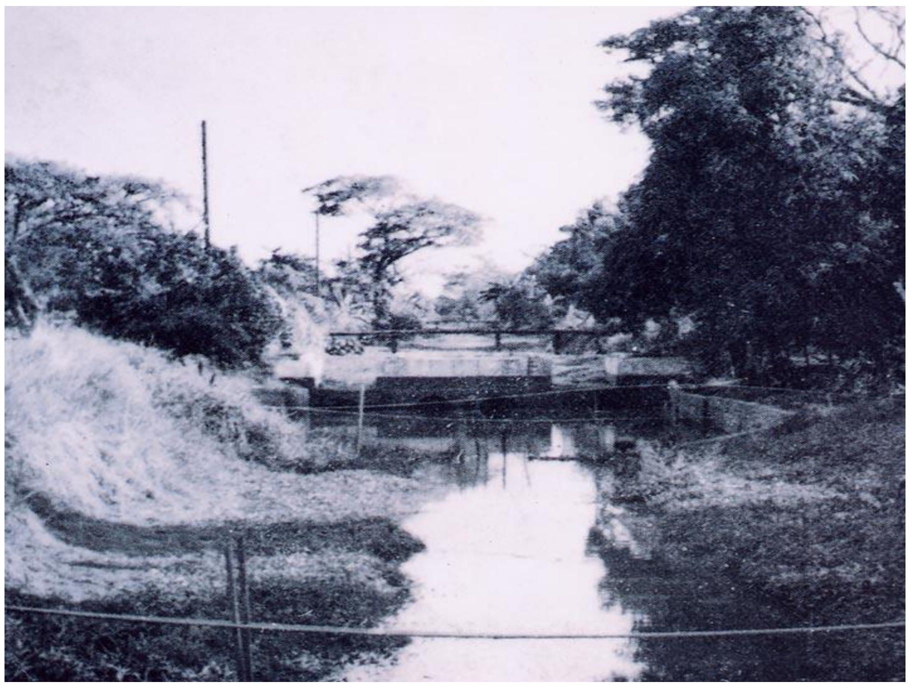

FIGURE 2. 3 Wan Mat Saman Canal

2.3 TYPE OF IRRIGATION SYSTEM

The irrigation system has gradually changed throughout the years and went through few stages of evolution. The original idea of irrigation system is by controlling the water supply through the drainage system in the existing area of horticulture. By definition, irrigation is a method to let the water flow artificially to the soil for the plant growth. It is one of the important factor that determine the quality of the agriculture production because it gives adequate moisture to the plant to grow, provides sufficient nutrient and decrease the soil salinity. Irrigation is affected by many factors such as physical texture of soil, climate change and the need of the crop growth (Saranya & Amudha, 2016). There are several type of irrigation which are the surface irrigation, drip irrigation and sprinkler irrigation based on Figure 2.4, 2.5 and 2.6 respectively.

FIGURE 2. 4 Surface Irrigation

FIGURE 2. 5 Drip Irrigation

FIGURE 2. 6 Sprinkler Irrigation

To further explaining in details regarding the types of irrigation, there are a few more methods used in surface irrigation which are basin irrigation, furrow irrigation and uncontrolled flooding. Basin irrigation usually used in a small field and it is the most general form of surface irrigation. The shape of the basin is usually square and it is surrounded by the earth banks. This method of irrigation allow certain amount of water to flow into the basin and left the water to infiltrate (Walker, 1989). Based on Miao et. al (2015), soil infiltration is an important factor impacting surface irrigation design and operation, namely the advance and recession and the distribution uniformity. They also quoted Bai et. al. (2011) which stated that precise land levelling gives relevant reduction of the irrigation advance time and encourage uniformity of infiltration. This will lead to water saving and crop growth.

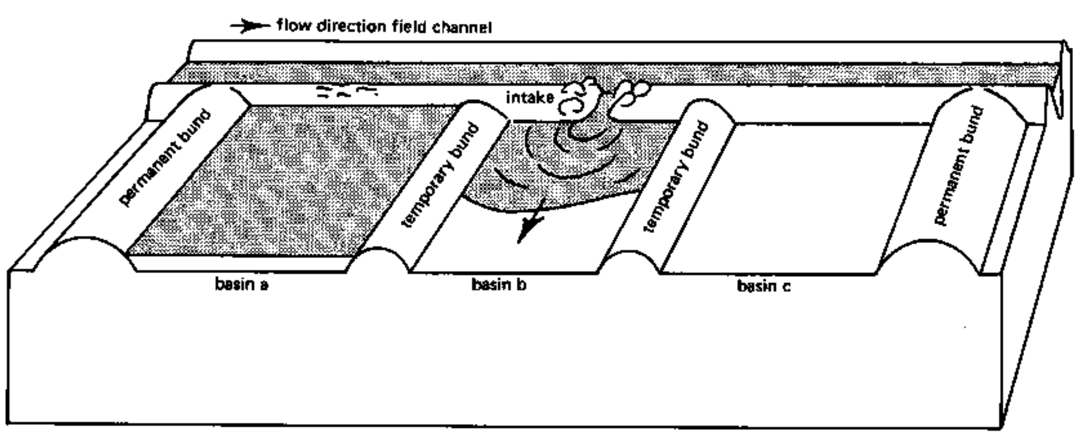

FIGURE 2. 7 Basin Irrigation

Next method of irrigation is furrow irrigation which helps in channeling the water flow throughout the primary direction and most importantly it can avoids flooding in the field. Furrows irrigation also has basins and borders which can lower the topographical variation and crusting impact (Walker, 2003). Based on Kara et. al. (2008), furrow irrigation is recommended to have less than 2-3% slope and by intermediate to slow intake soils. They also said that length of the furrow depends on water inflow rate and field slope and the user more likely to use long furrow because short furrows take lots of time and labor but long furrows only need high inflow rate.

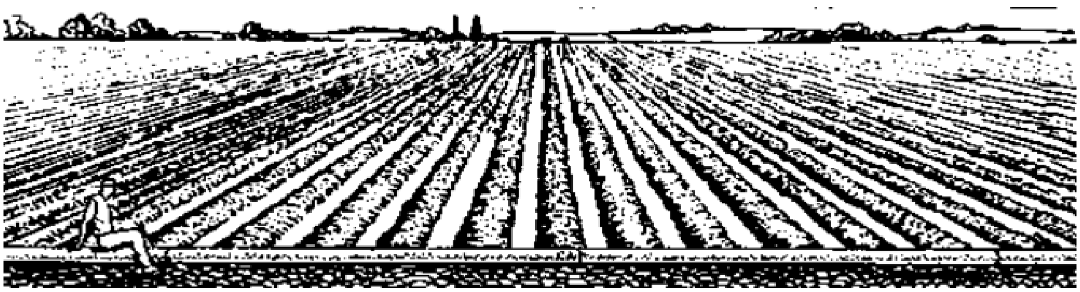

FIGURE 2. 8 Furrow Irrigation System

The last method of surface irrigation is the uncontrolled flooding type. This method is implemented to suits the cases where the horticulture's value is very small and the field has not been leveled or graded. This type of irrigation used low initial cost of land preparation and this is one of the reason why people still used this method. But this method requires lots of water sources and it is not advisable to use for a very large scale of agriculture.

FIGURE 2. 9 Uncontrolled Flooding Irrigation

Drip irrigation is one of the irrigation system that is used in agriculture sector. Drip irrigation works by allowing the water to drip slowly to the roots in two ways which is either from the soil surface or underground. Figure 2.10 and 2.11 below showed the surface drip irrigation and subsurface drip irrigation respectively.

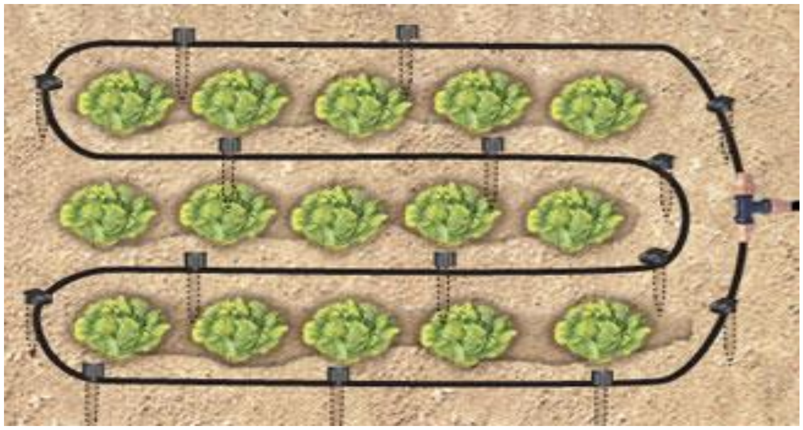

FIGURE 2. 10 Surface Drip Irrigation system

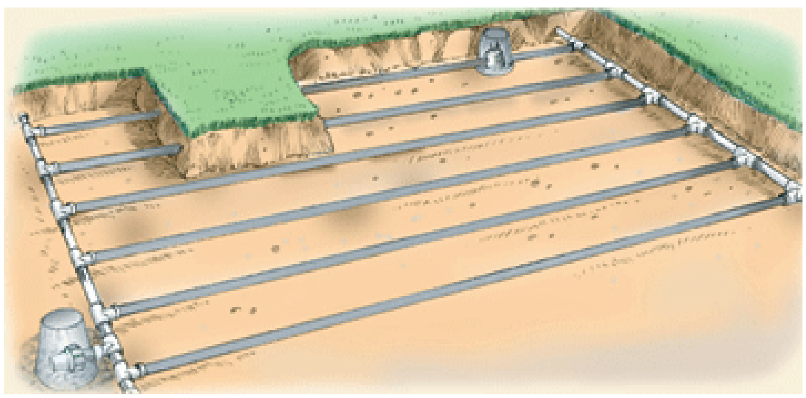

FIGURE 2. 11 Surface Drip Irrigation system

Drip irrigation has been regarded as a potentially efficient method of irrigation (Samadianfard et. al, 2012). Based on Ogaidi et. al (2016), drip irrigation is considered a priority rather than option in an arid area as it has many advantages such as saving water, yield growth, restraining evaporation and minimizing weeds development. Drip irrigation also has the potential of accurately applying water and chemicals in the field (Karimi et al, 2012). But Samadianfard et. al (2012) mentioned that despite of all positive traits, poor design and poor management can contributes to losses of water from drip irrigation comparable with the traditional irrigation systems.

Next and the last irrigation system is the sprinkler irrigation system. In this irrigation system, it uses the method of water spraying and the water will be allow to fall on the ground thus make it looks like rainfall. Based on Martin et. al (2007), sprinkler irrigation helps to reduced labor usage, lessen unintentional leaching and the potential to reserve precipitation rise in the crop root zone and thus satisfied the crop requirements. The water spraying is from the under pressure water flow that is through the small nozzles. The pressure is developed by the pump system which must be come along with the sprinkler system. There are also a few other components that mainline pipe, lateral pipe and of course, the sprinkler. Figure below showed the typical sprinkler irrigation system which consist of all the components stated above.

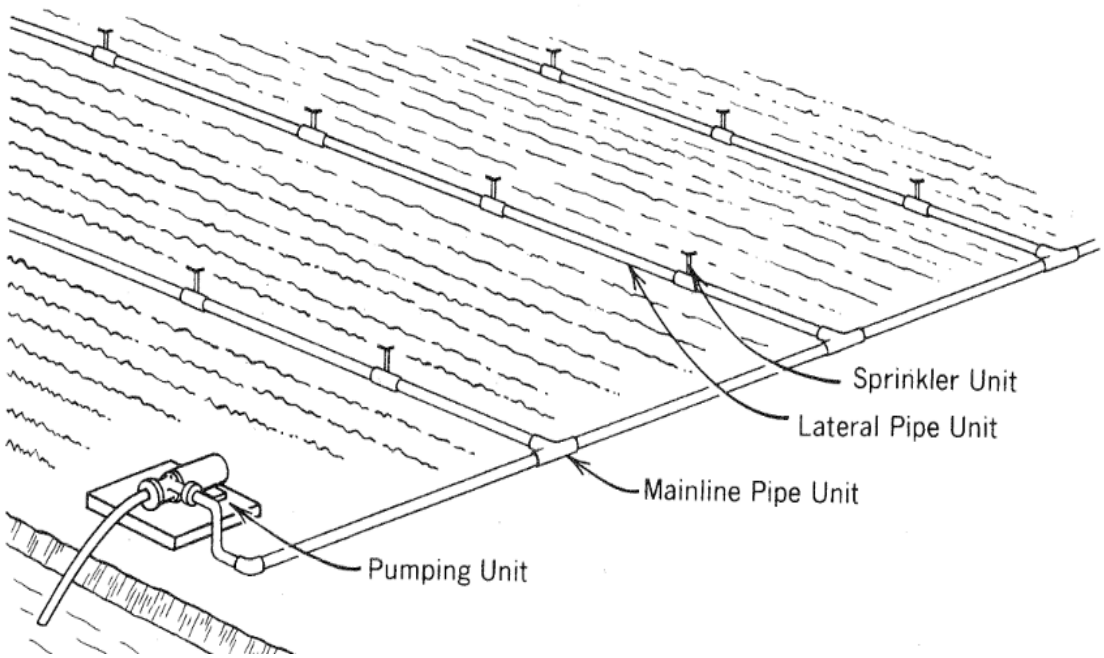

FIGURE 2. 12 Typical Sprinkler Irrigation System

In order to get the required amount of irrigation water, there are a few considerations that the farmer must take such as the selection of nozzle size. This is to ensure the operating pressure and sprinkler spacing gives out the uniform infiltration rate that is demanded by the soil.

2.4 WETTING PATTERN FOR EACH TYPE OF IRRIGATION

For each type of irrigation, the wetting pattern will appear differently due to the way of water being transferred and also the volume of water being applied on that particular time. In a simpler term, wetting pattern can be explained as the result of the irrigation system where it shows how the water infiltrated into the soil in various type of irrigation. Wetting pattern also shows different pattern for different type of soil. In order to maintain good crop growth, the right quantity of water must be supplied to the root zone and the root zone must be wetted uniformly. But according to Zhang (2015), research on the effects of irrigation parameters and soil physical properties on the wetted volume is restricted because of the hindrance of direct study of wetting patterns in the soil depth.

2.4.1. Wetting Pattern for Surface Irrigation

For surface irrigation, there are three methods which are basin irrigation, furrow irrigation and uncontrolled flooding as mentioned in Section 2.3. The ideal wetting pattern for basin irrigation can be seen in the figure below where the uniform wetted root zone is obtained and low percolation losses is achieved. To get the ideal wetting pattern, the basin surface must be elevated and the irrigation water must be spread in a very short time (Walker, 1989). The top part of basin which is located near the field channel is continuously on contact with the irrigation water longer than the bottom part of the basin. Thus, percolation losses will takes place near the field channel, if sufficient water is supplied to the opposite side of the basin.

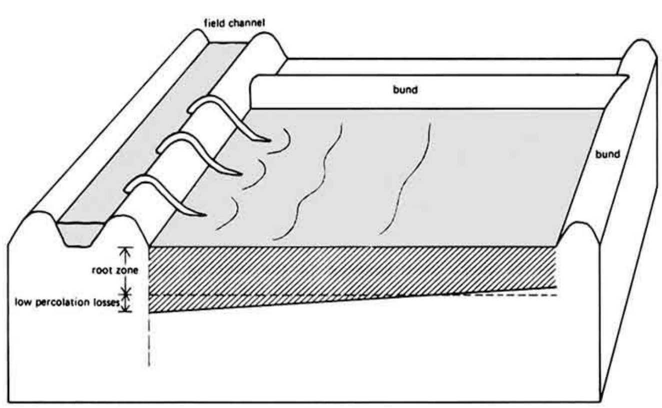

FIGURE 2. 13 Basin Irrigation Ideal Wetting Pattern

For basin irrigation, the causes for poor wetting patterns are unfortunate natural conditions such as compacted subsoil layer, or different soil types within one basin. The second cause is poor layout where the surface is poorly levelled and the third cause is poor water management like supplying incorrect stream size or applying too little or too much water (Walker, 1989).

For the furrow irrigation, the factors that determine the uniform wetted root zone are the spacing between the furrows, the slope of the furrows and the way irrigation water is being applied (Walker, 1989). Moreover, Zhang (2015) states that the design of a ridge-furrow irrigation system needs a precise estimation of the volume of wetted soil, the wetted lateral distance, and the soil water distribution. In order to get the uniformly wetted root zone, furrows has to be spaced accordingly, has a uniform slope and for the irrigation water, it has to be applied quickly.

In this type of irrigation, the downward movement of water in the soil is not as important as the lateral water movement (Walker, 1989). This is because the root zone in the ridge gets the water from the furrows. Furthermore, the depth dimension of water movement should coincide with the depth of the root system, while the lateral spreading distance can determine the optimum spacing and number of planting rows (Zhang, 2015). Zhang (2015) also added that subsoiling on ridges can promote the delivery of lateral water flow and improve irrigation uniformity.

Besides, to obtain a uniform water distribution along the furrow length, it is very important to have a uniform slope and a large enough stream size so that water advances rapidly down the furrow. In this way large percolation losses at the head of the furrow can be avoided (Walker, 1989). Zhang (2015) also mentioned that furrow irrigation should be implemented in finer soil as soil texture is primary indicator of soil water spreading and distribution in irrigated soil infiltration for this system.

Figure 2.14 below shows the ideal wetting pattern for the furrow irrigation where the adjacent wetting pattern overlap each other. There is also an upward movement of water as known as capillary rise that wets the entire ridge, thus supplying the root zone with water.

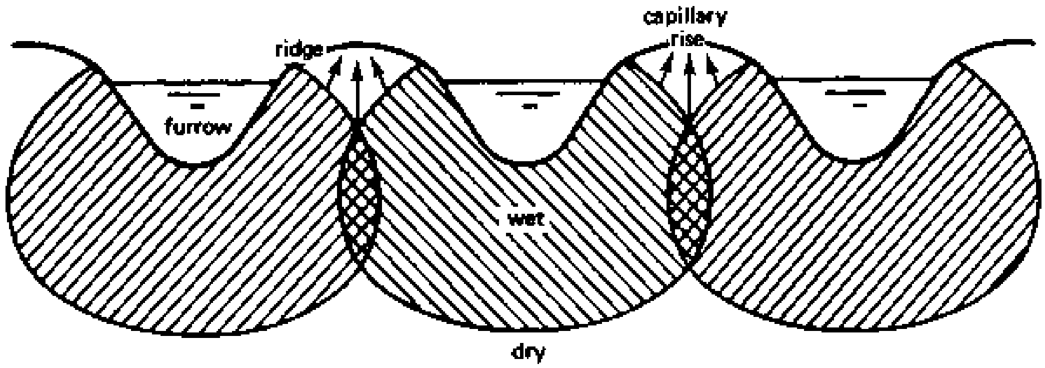

FIGURE 2. 14 Furrow Irrigation Ideal Wetting Pattern

2.4.2 Wetting Pattern for Drip Irrigation

Drip irrigation system is an automatic system that stays in the field and using this system, the water is directly being applied to the root zone. Because of the automatic system, it does not require a large number of workers to irrigate the plant. The idea of water is being saved if drip irrigation is used is not because of less water is being supplied to the horticulture because each plants needs right amount of water to support their growth. However, by using this system, the water can be save due to the reductions in deep percolation, in surface runoff and in evaporation from the soil (Elmaloglou & Diamantopoulus, 2009). The figures below show the wetting pattern of drip irrigation for two types of soil which is sand and clay.

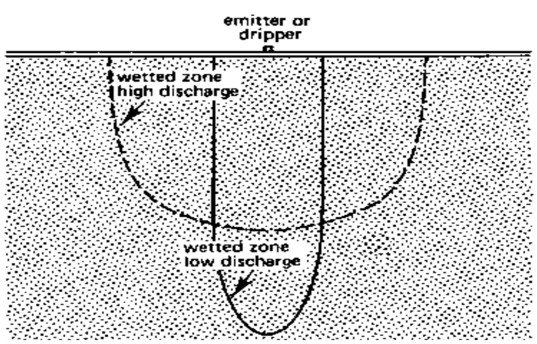

FIGURE 2. 15 Drip Irrigation Wetting Pattern - Sand

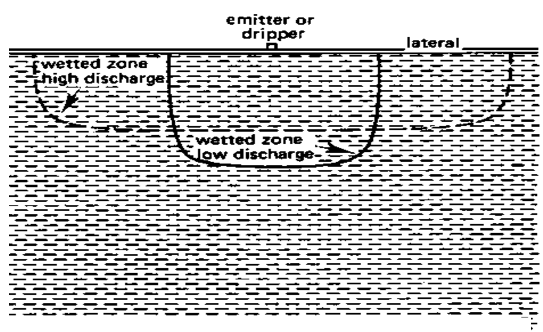

FIGURE 2. 16 Drip Irrigation Wetting Pattern - Clay

As for the wetting pattern that is for subsurface drip irrigation, Ogaidi et. al (2016) showed schematic drawing of the wetting pattern which is the figure below. They also stated that these patterns formed a wetted zone of truncated sphere or ellipsoid under surface emitter or of spherical or ellipsoidal shape under subsurface emitter.

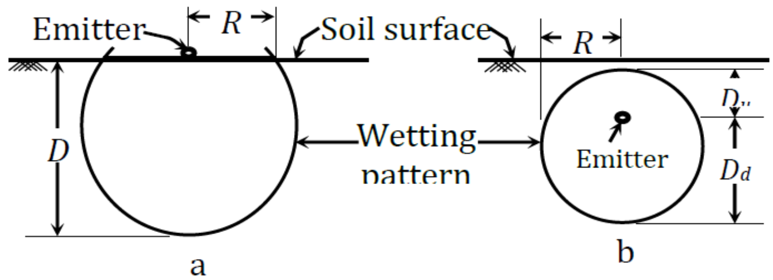

FIGURE 2. 17 Schematic Drawing of Surface (a) and Subsurface (b) Drip Irrigation

2.4.3 Wetting Pattern for Sprinkler Irrigation

For sprinkler irrigation, it is like the representation of rain water where the water is being distributed by a sprinkler. The wetting pattern for this irrigation needs to be observe from many rotary sprinkler because the wetting pattern form a single rotary sprinkler is not really uniform. The heaviest wetting is close to the sprinkler. These two figures are representing the single rotary sprinkler.

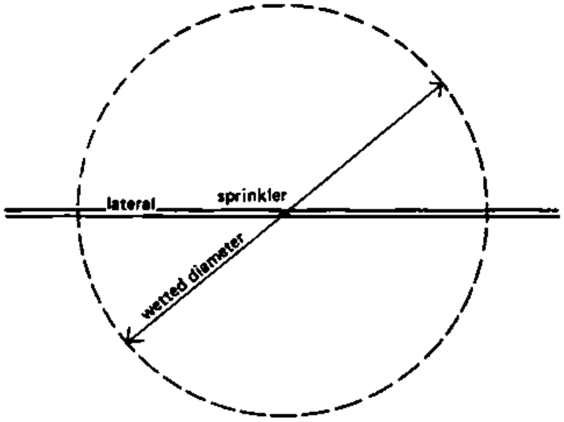

FIGURE 2. 18 Sprinkler Irrigation Wetting Pattern – Top view (Single)

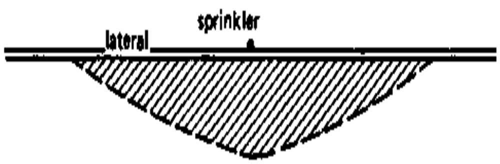

FIGURE 2. 19 Sprinkler Irrigation Wetting Pattern – Side view (Single)

In order to reach good uniformity, few sprinklers must be operated close together so that their patterns overlap. For good uniformity the overlap should be at least 65% of the wetted diameter, thus determining the spacing between the sprinklers (Walker, 1989).

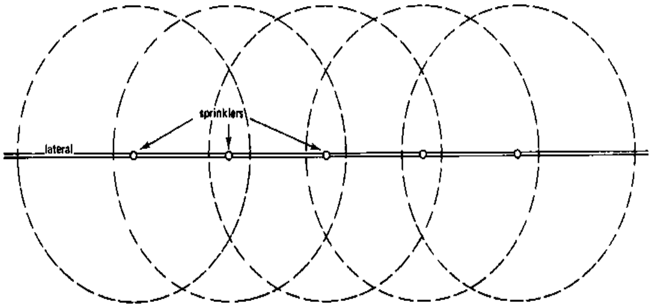

FIGURE 2. 21 Sprinkler Irrigation Wetting Pattern – Top view (Multiple)

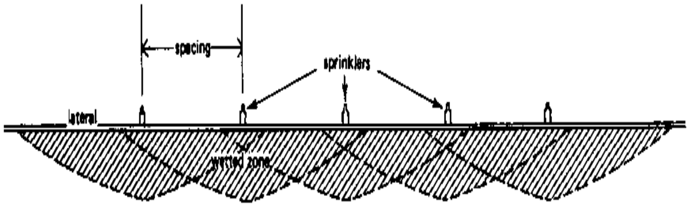

FIGURE 2. 20 Sprinkler Irrigation Wetting Pattern – Side view (Multiple)

2.5 PROBLEMS ASSOCIATED WITH IRRIGATION

The source of the irrigation is water and it uses lots of it. There are a few problems arises for the irrigation method problem that concern with the water. One of the problem is the use of excessive water and it becomes the norm in the agriculture field. Kavianand et. al (2016) mentioned in his paper that if the surface irrigation was used, there will lead to the infections by lead mould fungi which due to the saturation on the soil surface and the soil stays wet for quite long time.

There are also the case on the water deficiency. In the same paper, Kavianand et. al (2016) stated that the farmers still use manual control where from time to time, the farmers irrigate their land. This method consumes more water and the worst case is, if the water reaches late, the crops get dried. It will not give enough water to the plant and it will lead to the plant to be wilted. Besides that, Pereres & Soriano (2007) come out with the irrigation system that uses less water which called as deficit irrigation.

Moreover, there are also lots of barriers to irrigation growth that are the lack access of water, lack access to reliable energy and also lack of access to financing (Mashnik et. al, 2017). To cater this problem, there are lots of newest technology that are invented in order to increase the quality irrigation method hence increasing the crop production as Saranya and Amudha (2016) stated that irrigation water is one of the factor to crop planning optimization. By controlling and monitoring the irrigation water, the production of crop will increase and water can be save up to other usage. The example of the newest technology is the smart irrigation system that was invented in order to conserve water, to irrigate the plants with adequate water, come along with weather forecasting and lot more function (Namala et. al, 2016).

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CHAPTER 3

METHODOLOGY

3.1 PROJECT METHODOLOGY

Majority of the laboratory works are emphasis on the soil physical properties and its relationship with water. The whole research methodology is being shown in Figure 3.1. There are six types of soil that are being tested in this study which are sand, topsoil, soil form corn farm, vegetable farm, palm oil farm and peat soil. The soil were tested by using standard laboratories work for the preliminary experiment such as moisture content by oven drying, particle density by using pycnometer method, relationship between the dry density of soil and its moisture content using the compaction method, size distribution of soil using the dry sieving and hydrometer method and standard permeability test.

After the soil physical properties was known, the investigation of the wetting pattern for variation of soil can be proceed for the final experiment which to determine the purpose of this research. For this study, SOLTEQ Soil and Water Model Tank was used to investigate the topic that is mentioned above. This model is designed for the students to investigate several aspect of surface irrigation and drainage system. This equipment consist of a model tank, sump tank, a pump, emitters and a flowmeter. The soils will be filled in the model tank and when the water is being flowed, the observation will be done and the result can be tabulated.

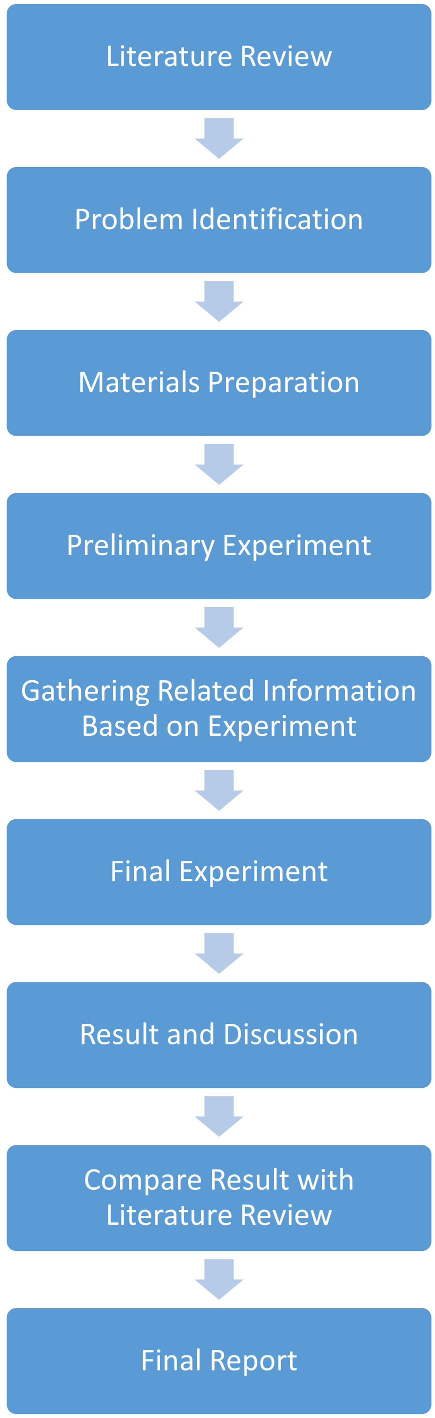


FIGURE 3. 1 Flow Chart of Research Methodology

3.2 EXPERIMENTAL WORK

3.2.1 Soil Selection

There are six different types of soil being tested in this project which are topsoil, sand, soil from corn farm, vegetable farm, palm oil farm and peat soil. Table 3.1 shows the details for each of the soil tested. Because this project related to irrigation which is closely associated with agriculture sector that is why most of the soil is from the agriculture filed.

TABLE 3. 1 Details of the Soil Selection

Type of soil	Location
Topsoil	Taken at Sewerage Treatment Plant (STP) in Universiti Teknologi Petronas (UTP) which is previously being used by one of final year student for his final year project.
Sand	Taken at Hydraulic Lab in Universiti Teknologi Petronas (UTP) which is previously being used by one of final year student for his final year project.
Soil (corn)	Taken from a corn farm at Kampung Gajah, Bota, Perak
Soil (vegetable)	Taken from a vegetable farm nearby Lafarge Chemor.
Soil (Palm oil)	Taken from a palm oil farm at Felcra Nasaruddin, Bota, Perak
Peat soil	Taken at a nearby palm oil farm at Felcra Nasaruddin, Bota, Perak

3.2.2 Soil Characteristic

The soil physical properties is significant to test because it is related on how the soil will react to water. The physical properties of soil consist of moisture content, specific gravity, bulk density, porosity, particle size distribution from sieve analysis and hydrometer analysis and the hydraulic conductivity. The method of tests was done by refer to BS 1377-2: 1990 Methods of test for soils in civil engineering world. In order to know the grain size of the six types of soil, sieve analysis method was conducted. This test was conducted in order to know the sizes of the particles which may influenced the performance of the wetting pattern. Moreover, the other soil characteristics such as specific gravity, maximum dry density, moisture content, bulk density and porosity of the soil sample also may effects the operation of the wetting pattern. To discover the hydraulic conductivity of the six soil sample, the standard permeability tests was done.

Preparation and Setup

For the soil characteristic, the preparation and setup for moisture content, specific gravity, bulk density, particle size distribution and permeability were identified by laboratory testing.

- Moisture Content

The moisture content experiment is done using BS 1377-2: 1990 Methods of test for soils for civil engineering purposes for reference. Classification tests, Clause 3.2 Moisture Content. In this test, the moisture content is determined by oven-drying method. The moisture content was obtained by subtracting the weight of the dry soil sample that was oven dried in a 110°C temperature oven for 24 hours with the wet soil sample initial weight. About 30g of the three different wet soil sample was placed into separate moisture can and was labelled. To increase the accuracy of the result, for each sample, three moisture can with the same sample were used and the average moisture content was calculated.

Thus, there are 18 samples of soil for the whole experiment. The equation for moisture content calculation is shown in Equation 3.1.

$$w = \left(\frac{m^2 - m^3}{m^3 - m^1}\right) 100 \qquad \text{Equation 3.1}$$

Where w = Moisture content (%)

m_1= Mass of moisture can (g)

m_2= Mass of dry sample + moisture can (g)

m_3= Mass of wet sample + moisture can (g)

- Specific Gravity

The specific gravity experiment is done using BS 1377-2: 1990 Methods of test for soils for civil engineering purposes for reference. Classification tests, Clause 8.3 Specific Gravity. The sand and undisturbed soil sample are tested using the small pycnometer method. The mass of the bottle with its cap is weighed. Next, soil specimen and bottle is weighed together and then the bottle was filled with water and they are being de-aired in the desiccator to eliminate all the air in the bottle. Then it is weighed again with water including the space of the cap. The bottle is weighed again by filling with only water in it.

FIGURE 3. 2 Small Pycnometer Method for Specific Gravity Experiment

The specific gravity of the soil can be determined by calculating the particle density in Equation 3.2 and the equation of the specific gravity is shown in Equation 3.3.

$$\rho_s = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)} \rho w \qquad \text{Equation 3.2}$$

$$G = \frac{\rho s}{\rho w} \qquad \text{Equation 3.3}$$

Where,

ρ_s = Particle density of soil (g/cm³)

ρ_w = Density of water at test temperature (g/cm³)

m_1 = Mass of bottle (g)

m_2 = Mass of bottle + soil (g)

m_3 = Mass of bottle + soil + water (g)

m_4 = Mass of bottle full of water (g)

- Bulk Density

The bulk density experiment is done using BS 1377-2: 1990 Methods of test for soils for civil engineering purposes for reference. Classification tests, Clause 7.2 Bulk Density. Bulk density indicates soil compaction for the particular soil that is being tested. It affects infiltration, rooting depth/restrictions, available water capacity and so on. After the particle density (3.2.2) was obtained, the bulk density was computed by using 2.5 kg automatic rammer. A mold which size is one liter was used to compact the soil. One third of the mold was filled with the soil and being compacted to 27 blows. The steps were repeated until the mold is filled. Thus, the bulk density of soil can be obtain by using Equation 3.4.

$$\rho = \frac{m_2 - m_1}{V} \quad \text{Equation 3.4}$$

Where,

ρ = Bulk Density (g/cm³)

m_1 = Mass of mold + base (g)

m_2 = Mass of mold + base + compacted soil (g)

V = Volume of mold (cm³)

FIGURE 3. 3 Equipment needed for Proctor Test

FIGURE 3. 4 Compaction machine for Proctor test

- Porosity

Water saturation method was used to obtain the porosity of soil. This method uses the calculation of ratio between pore volume and total volume of saturated soil. Basically, the pore volume is actually the volume of water available in the saturated soil sample. The porosity of the soil can be obtain by using Equation 3.5.

$$n = \frac{e}{1+e} \qquad \text{Equation 3.5}$$

Where,

n = Porosity (%)

e = void ratio = $\frac{\rho wG}{\rho d} - 1$

ρ_w = Water density

G = Specific Gravity

ρ_d = Dry Density

- Particle size Distribution

Dry Sieving

The particle size distribution was determine by the sieve analysis experiment is done using BS 1377-2: 1990 Methods of test for soils for civil engineering purposes for reference. Classification tests, Clause 9.3 Sieve analysis by dry sieving. The particle size distribution can be divide into two parts which are D_{10} (10% of material smaller) and D_{50} (mean) particle size. Based on Table 3.2 shown below, the minimum mass of test portion for sieve analysis is according to the maximum particle size of the soil sample.

TABLE 3. 2 Minimum Mass of Test Portion for Dry Sieving

Maximum Particle Size (mm)	Minimum Mass of Test Portion (kg)
28	5
20	2
14	1
10	0.5
5	0.2
3	0.2
<3	0.1

By computing the coefficient of uniformity, C_u and the coefficient of curvature, Cc, the uniformity and gradation of the soil sample can be obtain. For the well graded soil, the criteria is $1 < Cc < 3$; $C_u \geq 6$. While for the soil with only one grain size will have $C_u = 1$. By using the Equation 3.6 and Equation 3.7, the value for Cc and C_u can be determine.

$$Cc = \frac{(D_{30})^2}{(D_{10})(D_{60})} \quad \text{Equation 3.6}$$

$$C_u = \frac{D_{60}}{D_{10}} \quad \text{Equation 3.7}$$

Sedimentation Analysis

If more than 10% of soil passes through the 0.075mm sieve, then the sedimentation analysis using hydrometer test is necessary. Hydrometer test is the grain size analysis for fined grained soil. The test is done using BS 1377-2:1990 Methods of test for soils for civil engineering purposes as reference. Classification Tests, Clause 9.5 Sedimentation by hydrometer method. The soil particle diameter can be obtain from the Stoke's Law nomographic chart.

FIGURE 3. 5 Hydrometer Test for Particle Size Distributions

To use the chart, the corresponding K value need to be determine first and it can be calculated using Equation 3.8.

$$K = (\frac{100\rho s}{m(\rho s - 1)})Rd \qquad \text{Equation 3.8}$$

Where,

m = Mass of the dry soil used (g)

ρ_s = Particle density (Mg/m^3)

Rd = Modified hydrometer reading (mm)

- Permeability

Falling Head Permeability Test

The falling head permeability test is a common laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample. The test is done using BS 1377-5:1990 Methods of test for soils for civil engineering purposes as reference. Compressibility, permeability and durability tests, Clause 3: Determination of one-dimensional consolidation properties. This test is the continuation of the bulk density test where the optimum moisture content was used. Then, by flowing the water throughout the sample using the falling head apparatus, the sample was left for 72 hours to be fully saturated. The time required for the water in the standpipe to drop from the upper to the lower level is recorded. The test was repeated in order to get higher accuracy. By using Equation 10, the hydraulic conductivity, Kt can be obtained. The value is then corrected to the standard temperature of 27°C by using Equation 3.9.

$$Kt = \frac{a \times L \times (log_{10} h_1/h_2)}{A \times t} \qquad \text{Equation 3.9}$$

Where,

Kt = Hydraulic conductivity at water temperature of test (cm/s)

a = Area of standpipe (cm^2)

L = Length of soil column (cm)

A = Area of the soil column (cm^2)

h_1 = Initial reading of standpipe (cm)

h_2 = Final reading of standpipe (cm)

t = Time required to get head drop of Δh (s)

α = Ratio between viscosity of water at test temperature and at 27°C

FIGURE 3. 6 Falling Head Method Equipment

Constant Head Permeability Test

Constant head permeability test is conducted in the reference of BS 1377-5:1990 Methods of test for soils for engineering purposes. Compressibility, permeability and durability tests, Clause 5: Determination of permeability by the constant head method. The hydraulic conductivity, K was calculated using Equation 3.10.

$$K = \frac{qRt}{iA} \qquad \text{Equation 3.10}$$

Where,

K = Hydraulic conductivity (cm/s)

q = Rate of flow (mL/s)

Rt = Correction factor

A = Area of the soil column (cm^2)

i = Hydraulic gradient

3.2.3 Soil and Water Model tank (SOLTEQ)

The SOLTEQ® Soil and Water Model Tank (Model: FM 514) unit construction was shown in figure below is made in order to explore deeper in several aspects of surface irrigation and also drainage system. Based on the Figure 3.8, there are ten (10) specific components of this model tank which are the model tank, sump tank, pump, rotameter, drip emitter, flood emitter, overflow pipe, filter, model tank drain and sump tank drain.

FIGURE 3. 7 SOLTEQ® Soil and Water Model Tank (Model: FM 514)

This model tank will demonstrate the drip irrigation. Water is pumped through the flowmeter and discharged along the soil surface or directed to twin drip nozzles. To measure the water penetration rate into the soil and observe the wetting pattern of the pumped water, the narrow tank was used. It is easy to measure and observe because the tank is made of stainless steel and the front wall is a see-through wall. The other system in this model is overflow system. This system will help in gathering the surface water and send it back to the sump tank. This tank also has the removable end plates that can be use in changing the soil sample.

For this experiment, there are two types of irrigation that are going to be tested which are the normal irrigation and the surge irrigation. By using the normal irrigation, water can is flowed directly from the drip emitter. For the surge irrigation, the water will be flowed from the flood emitter that will give the soil the saturated and flooded condition.

Preparation and Setup

All six samples were dried beforehand and if the soil is not in its normal size after being dried, manual sieving using a tray was done to separate the bigger size of the soil. Then, the bigger soil will be break in order to get its normal size. Next step is to fill in the soil in the model tank. Based on the figure below, there are gridlines in the surface of the model tank and the soil was filled up until five layers of boxes as shown with the red line below.

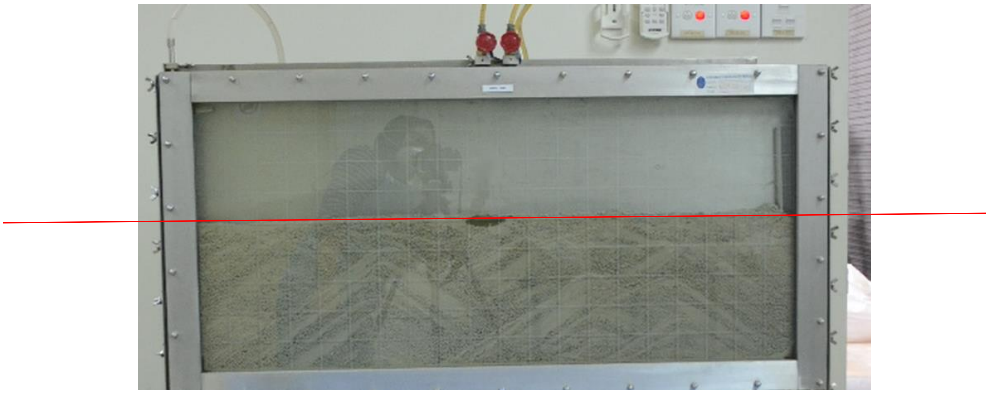


FIGURE 3. 8 Level of Soil fill in the Model Tank

1. Normal Irrigation

In order to demonstrate normal irrigation, drip emitter was used and the flowrate used is 0.1 LPM, 0.2 LPM, 0.4 LPM, 0.6 LPM, 0.8 LPM and 1.0 LPM. Each flowrate was given 25 minutes and the wetted pattern will be measured.

2. Surge Irrigation

In order to demonstrate surge irrigation, flood emitter was used and the flowrate used is 0.2 LPM, 0.4 LPM. 0.6 LPM, 0.8 LPM and 1.0 LPM. For flood emitter, flowrate of 0.1LPM was not used because of the water did not come out due not enough pressure. Each flowrate was given 25 minutes and the wetted pattern will be measured.

3.3 PROJECT MILESTONE

In order to make a project successful, proper planning should be implemented from the beginning of the project. The key milestone in Table 3.3 will show the process that have been done and the action that have been taken for the whole period in completing the project:

TABLE 3. 3 Project Milestone

No.	Plan of Action	Months							
		5	6	7	8	9	10	11	12
1	Literature Review 1. Soil-water Relationship 2. History of Irrigation System in Malaysia 3. Type of Irrigation System 4. Wetting Pattern for each type of Irrigation 5. Problems Associated with Irrigation								
2	Experimentation on the soil classification Moisture content & Specific Gravity Particle size distribution Bulk Density & Porosity Permeability								
3	Experimenting of the soil layering in the SOLTEQ's Soil and Water Model Tank by observing								
4	Comparing the result with literature review								

3.4 GANTT CHART

Table 3.4 and 3.5 show the flow of work for FYP1 and FYP2 respectively according to weekly basis.

TABLE 3. 4 Gantt Chart FYP1

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing on Final Year Project (FYP) course														
Selection on Project Topic 1. Meeting with supervisor 2. Understanding the FYP topic														
Preliminary Research Work 3. Identification of problem statement and literature review 4. Prepare research methodology 5. Registering for lab work														
Extended Proposal Submission														
Preparing for Proposal Defense 6. Do more research and preparing for slide presentation														
Proposal Defense														
Project work continues														
Interim Report Drafting														
Interim Report Submission														

TABLE 3. 5 Gantt Chart FYP2

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project work continues 7. Lab work														
Progress report Drafting 8. Consultation with supervisor														
Submission of Progress report														
Project work continues														
Pre-SEDEX														
Submission of Draft Final Report														
Submission of Dissertation (soft bound)														
Submission of Technical Paper														
Viva														
Submission of Project Dissertation (Hard Bound)														

CHAPTER 4

RESULTS AND DISCUSSION

4.1 SOIL CHARACTERISTICS

The result of the soil characteristic of variation soil types were being determined by the pycnometer test, sieve analysis, sedimentation analysis, proctor compaction test and permeability test. The calculation for each test are shown in Appendix A and B.

4.1.1 Specific Gravity

The result for the specific gravity of the six different types of soil which are sand, topsoil, soil from corn farm, vegetable farm, palm oil farm and peat soil was tabulated in Table 4.1 and was compared with the Field Manual for Material Testing by Department of the Army (DOA), Washington DOA (1999) which is based on ASTM D854-92 in table 4.3.

TABLE 4. 1 Specific Gravity – Result comparison with ASTM D854-92

Type of soil	Specific Gravity	
	Pycnometer test	ASTM D854-92 (1999)
Topsoil	2.66	2.6 - 2.8
Sand	2.59	2.65 - 2.67
Soil from corn farm	2.55	2.6 - 2.8
Soil from vegetable farm	2.64	2.6 - 2.8
Soil from palm oil farm	2.57	2.6 - 2.8
Peat soil	2.22	>2.6 or as low as 2.0

Based on ASTM D854-92 (1999), range specific gravity value of 2.6 to 2.8 is for the solid substance of most inorganic soil while for 2.65-2.67 is for the sand particles composed of quartz. For the specific gravity value of lower than 2.6 and can be as low as 2.0 is for the soils with large amount of organic matter or porous particle. The calculation for the specific gravity can be refer in Appendix A.

4.1.2 Dry Density and Moisture Content

The comparison between the optimum moisture content for all the samples that were resulted from the Proctor compaction test were showed in figure below. Peat soil has the most optimum moisture content which is 43.5%.

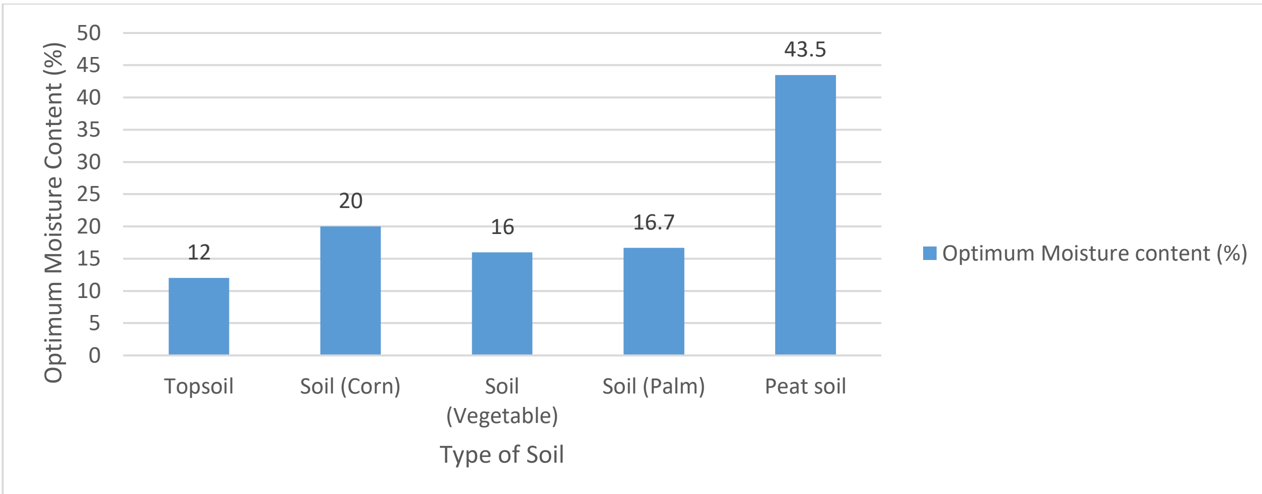


FIGURE 4. 1 Optimum Moisture Content vs Type of Soil

The value of bulk density, void ratio and porosity of the topsoil, soil from corn farm, vegetable farm, palm oil farm and peat soil are tabulated below.

TABLE 4. 2 Result for Various Soil Parameter for each soil tested

Soil Parameter	Topsoil	Soil (Corn)	Soil (Vegetable)	Soil (Palm)	Peat soil
Bulk density, ρ (g/cm^3)	0.935	0.919	1.032	0.984	0.660
dry density , pd (Mg/m^3)	0.834	0.764	0.886	0.843	0.460
Void ratio, e $= \frac{\rho w G}{\rho d} - 1$	2.175	2.325	1.967	2.060	4.759
Porosity, n $= \frac{e}{1+e}$	0.685	0.699	0.663	0.673	0.826

4.3 PARTICLE SIZE DISTRIBUTION

For the particle size distribution, there are two parts of the sieving which is wet sieving using hydrometer and dry sieving using the sieve machine. Figure below showed the combination of both experiment which are the hydrometer and dry sieving. From this graph, the soil characteristic such as its size and composition in the soil can be known.

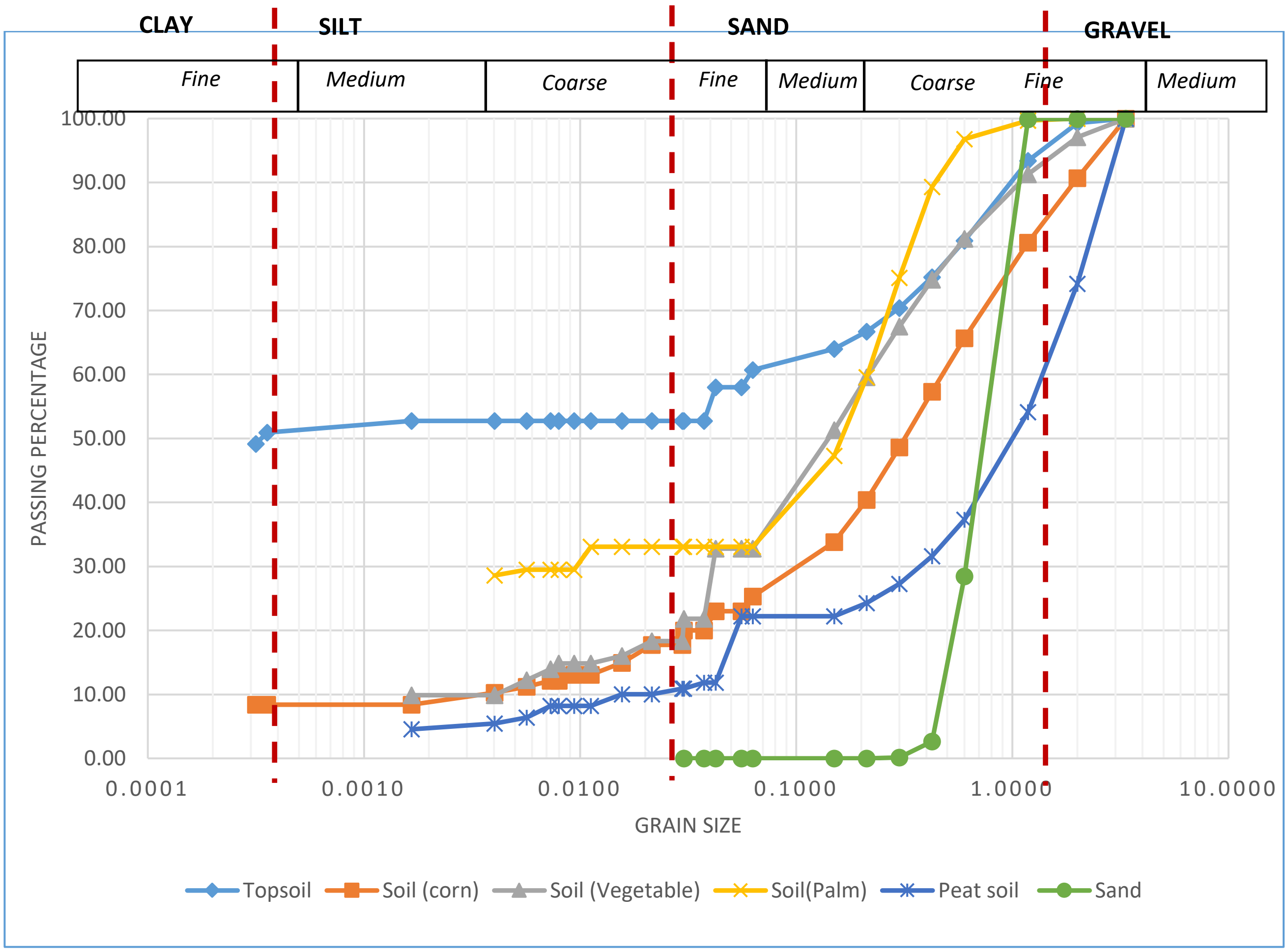


FIGURE 4. 2 Particle size distribution for six types of soil

The soil texture classification for each soil can be determine by referring to the soil texture classification triangle which is from USDA. This triangle was shown in Figure 2.1. This triangle can be referred if the percentage for the sand, silt and clay are known. This information can be obtained from the Figure 4.2 and is being interpreted in table below.

TABLE 4. 3 Soil Composition and Soil Texture Classification

Type of soil	Soil composition (%)				Soil texture classification (USDA)
	Gravel	Sand	Silt	Clay	
Topsoil	0	51	3	51	Sandy clay
Sand	0	100	0	0	Sand
Soil (corn)	18	70	30	8	Sandy loam
Soil (vegetable)	7	73	20	0	Sandy loam
Soil (palm)	0	70	30	0	Sandy loam
Peat soil	45	55	6	5	Sand

By knowing the soil texture of each soil types, the information regarding the water content can easily be obtained based on Figure 2.2 which is the graph of soil texture vs water content. Based on that figure, the water content for the sandy loam soil is 11% to 23%. Moreover based on Malaysia Department of Irrigation and Drainage (DID) Volume 5 Irrigation and Agricultural Drainage (2009), for fine-textured soil which has large portion of clay and silt particles they detain water very well but drain badly. As for the coarse-textured soils which has large portion of sand and gravel particles, they can drain well but have very bad water holding capacity. DID (2009) also mentioned about the suitability for the crops to undergo the irrigation system. Based on the sample from this project, table below will show the suitability irrigation system for each crop.

TABLE 4. 4 Crop with suitable Irrigation system (DID, 2009)

Type of crop	Suitable irrigation system (DID,2009)
Corn	Surface and Sprinkler Irrigation
Vegetable (Depends on type of vegetable) - Chilli - Spinach	 Surface and Drip irrigation Surface and Sprinkler Irrigation
Palm oil	Sub-irrigation, micro-irrigation and Sprinkler irrigation

4.4 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity is a significant parameter describing the ease with which flow takes place through a porous medium (Schwartz & Zhang, 2003). Based on Leiveci et. al (2016) mentioned that there are several factors that affecting the hydraulic conductivity of the soil such as the viscosity of the fluid moving through the soil, shape, size and the particle size of the soil, amount of soil particles and void spaces and also the degree of saturation of the soil. Hydraulic conductivity can be determined using two methods which are falling head method and constant head method. These two methods depends on the type of soil where falling head method for the soil that has smaller particle and constant head method is generally for sand particle. But in the case of peat soil, based on Table 4.3 it stated that peat soil is classify as sand by using the Soil Textural Classification Triangle by USDA in Figure 2.1. After testing the peat soil with the constant head method, the water did not managed to flow out and as there is some silt and clay present in the soil. Therefore, falling head method was used to measure the hydraulic conductivity of the peat soil. This K value can be compared with the values given in the Malaysia Department of Irrigation and Drainage (DID) Volume 5 Irrigation and Agricultural Drainage (2009) which is Table 4.5 which is shown below.

TABLE 4. 5 Recommended Range of K values in DID (2009)

Soil Type (Texture)	Hydraulic conductivity (m/day)	Hydraulic Conductivity (mm/hr)
Dense clay (no cracks, pores)	< 0.002	< 0.08333
Clay loam, clay (poorly structured)	0.002-0.2	0.08333 – 8.333
Loam, clay loam, clay (well structured)	0.5-2.0	20.8333 – 83.333
Sandy loam, fine sand	1-3	41.6667 - 125
Medium sand	1-5	41.6667 - 208.333
Coarse sand	10-50	416.667 – 2083.33
Gravel	100-1000	4166.67 – 41666.7

Figure 4.4 and 4.5 showed the comparison of the hydraulic conductivity values for all the soil. From this, the relationship between hydraulic conductivity and particle size distribution can be concluded as the bigger the particle size, the bigger the hydraulic conductivity of the soil.

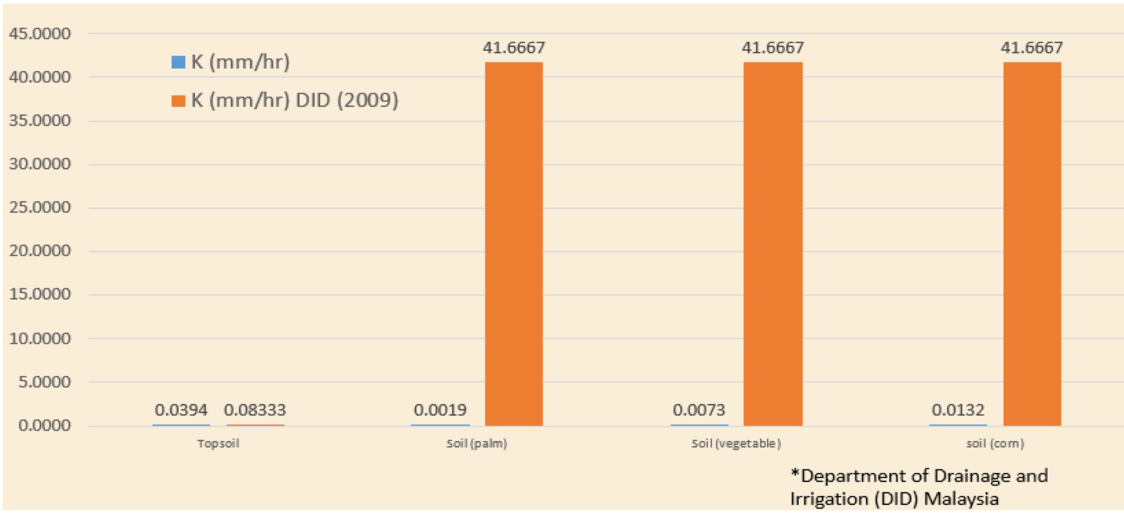


FIGURE 4. 3 K value compared with DID (2009) for soils

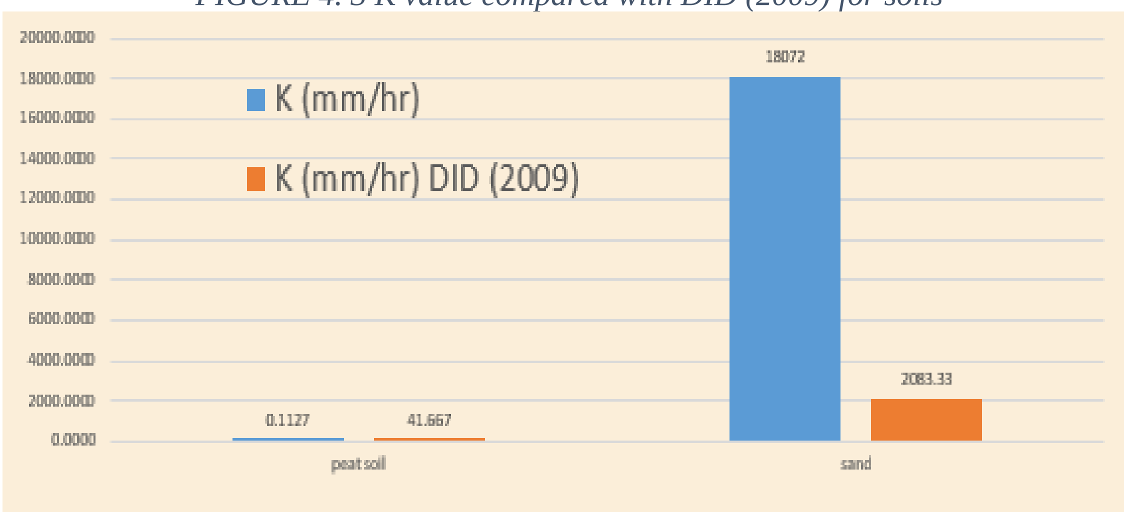


FIGURE 4. 4 K value compared with DID (2009) for sand

The comparison between the value of the hydraulic conductivity from the experiment and also the value from DID (2009) showed a very huge difference. This huge differences may be because of the different gradation of the particle size used in DID (2009) where it did not mentioned about the exact gradation size for each of the soil types. The difference also due to the different compaction effort on the soil sample.

Infiltration rate for the soil can be related to the soil hydraulic conductivity. Infiltration rate can be calculated by using Darcy's Law equation and the data such as the length of the soil and the time taken for the water to infiltrate are from Appendix C. Darcy's Law Equation;

$$f = \frac{dL}{dt} = -Ki \qquad \text{Equation 4.1}$$

Where;

f = Infiltration rate (mm/hr)

L = Length of the water infiltrated

t = time taken for the water to infiltrate

Table below shows the infiltration rate for each soil tested.

TABLE 4. 6 Infiltration Rate of the Soil (Experimental)

Type of soil	Soil Texture	Infiltration rate (mm/hr)	Infiltration rate (mm/day)
Topsoil	Sandy clay	1153.85	27692.31
Sand	Sand	7500	180000
Soil (corn)	Sandy loam	480	11520
Soil (vegetable)	Sandy loam	750	18000
Soil (palm)	Sandy loam	1250	30000
Peat soil	Sandy gravel	5000	120000

Note: The value of L and t are taken from the wetting pattern experiment for normal irrigation at 0.1LPM

Table 4.7 states about the infiltration rate for type of soil which recommended by DID (2009).

TABLE 4. 7 Infiltration Rate Recommended by DID (2009)

Types of Soil	q_s(mm/day)
Cemented gravel and hard pan with sandy loam	100
Clay and clayey loam	120
Sandy loam	200
Sand clay	360
Sandy soil with rock	510
Sandy and gravelly soil	670

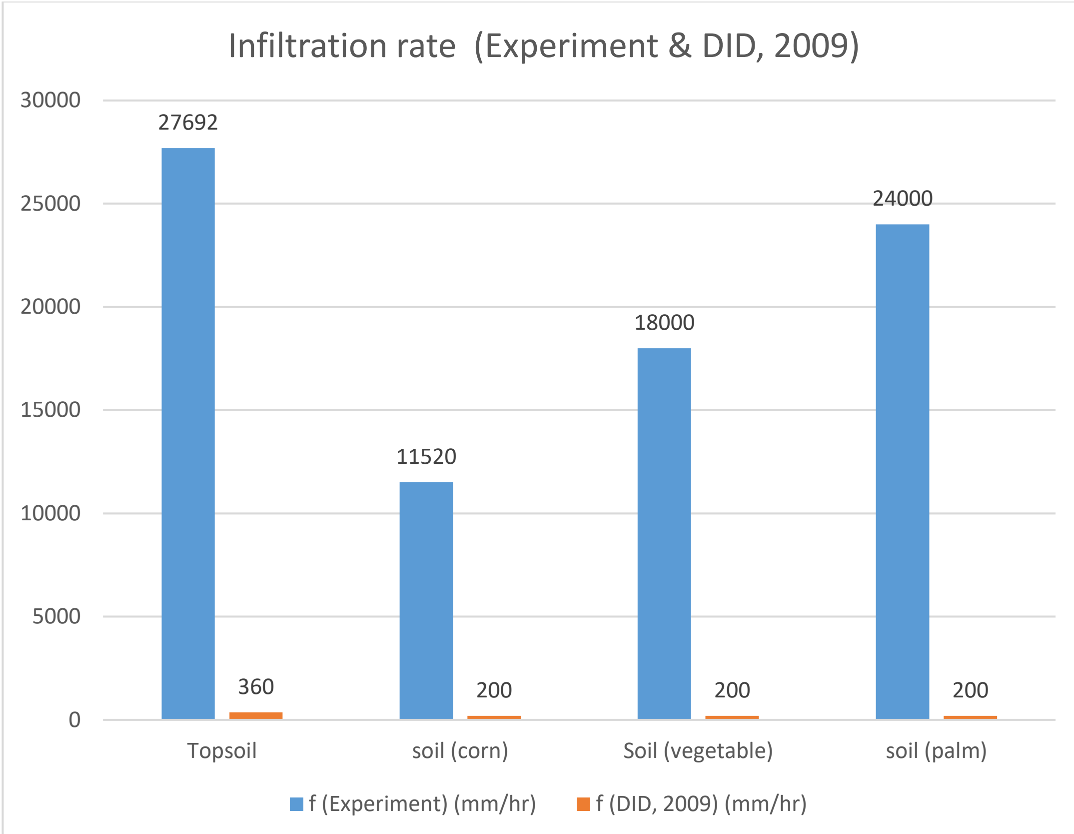


FIGURE 4. 5 Comparison of Infiltration rate - Experiment vs DID for soils

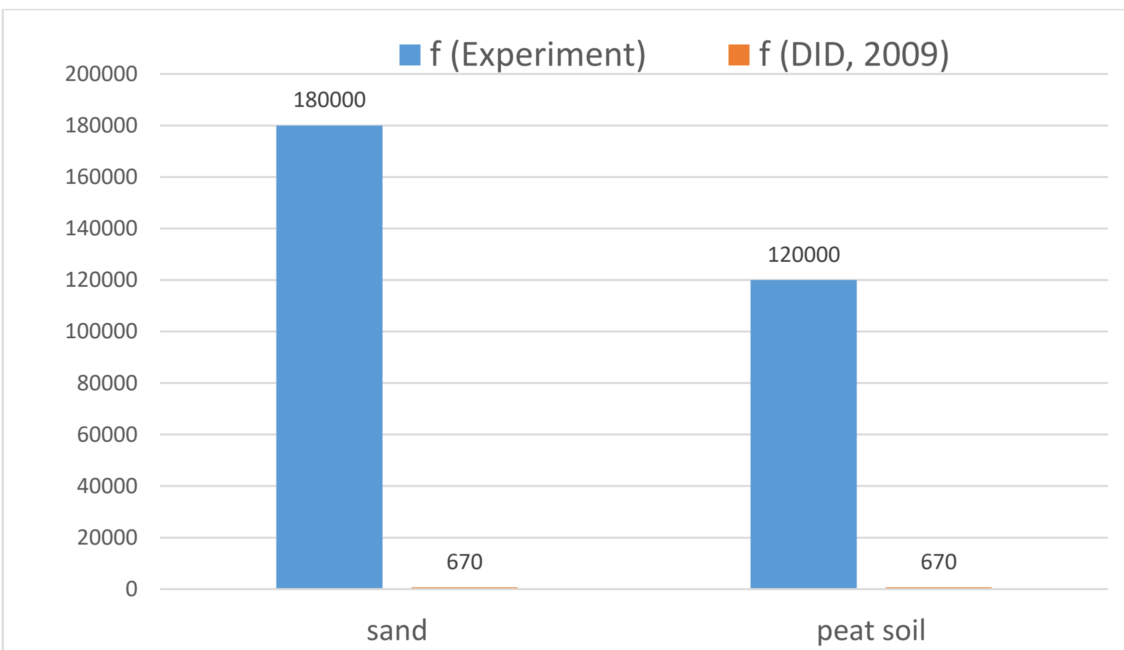


FIGURE 4. 6 Comparison of Infiltration rate - Experiment vs DID for sands

To compare the result from the experiment and also the actual value, Figure 4.5 and 4.6 shows the comparison where the values have very big difference but the sequence for both values are quite the same where sand and sandy gravel has the highest value of infiltration rate, followed by the sandy clay and the last one is sandy loam. For the experiment, sandy loam soils such as soil from corn farm, soil from vegetable farm and also soil from palm oil farm differ in their infiltration rate even though they have the same soil texture. Soil from palm oil farm has the highest infiltration rate, followed by soil from vegetable and lastly soil from corn farm. This big difference is most probably due to the soil compaction as the table from DID (2009) take the infiltration rate from the field experiment.

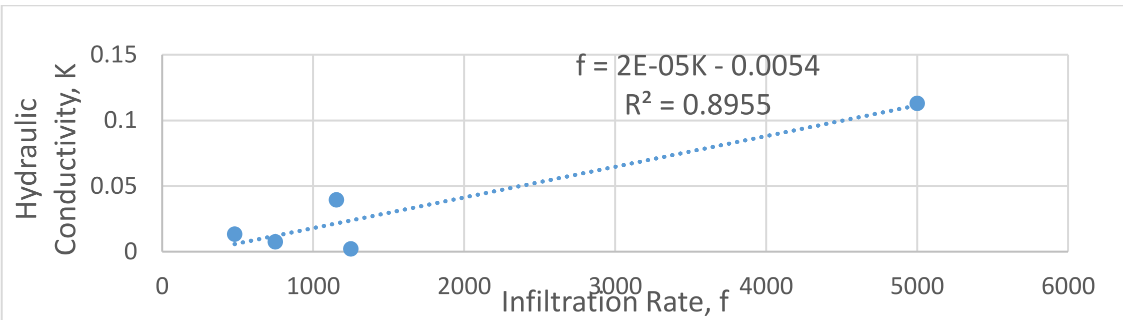


FIGURE 4. 7 Relationship of Hydraulic Conductivity, K and Infiltration Rate, F

Figure 4.7 showed the relationship between the experimental result of hydraulic conductivity and also the infiltration rate. From the figure, it is stated that f = 2E-05K - 0.0054 is the equation obtained from the relationship of K and f. The R^2 value is the coefficient of determination which showed the strength of this relationship. If the value is more than 0.7, it can be said that this relationship is strong. For the infiltration rate suitability of type of irrigation used, DID (2009) also stated that for surface irrigation which is for basin, the suitable infiltration rate is moderate. For drip irrigation which used micro-irrigation, any infiltration rate is okay. Lastly for sprinkler irrigation, there are three types of sprinkler irrigation based on site and situation factors which are intermittent mechanical move, continuous mechanical move and solid-set and permanent. As for intermittent mechanical move and solid set and permanent sprinkler, all infiltration rate is okay but for continuous mechanical move, the suitable infiltration rate is from medium to high.

4.5 WETTING PATTERN BY SOLTEQ FM 514

4.5.1 Normal Irrigation

Wetting pattern for each type of soil can be observed by using the Soil and Water model tank, FM 514. Appendix C shows the pictures and description regarding the wetting pattern of each soil tested. From the wetting pattern, there are few parameters that have been extracted to compute a relationship such as wetted area of soil, volume of water discharged and volume of water retained against the flowrate of water. The water was discharged around 25 minutes for each of the flowrate.

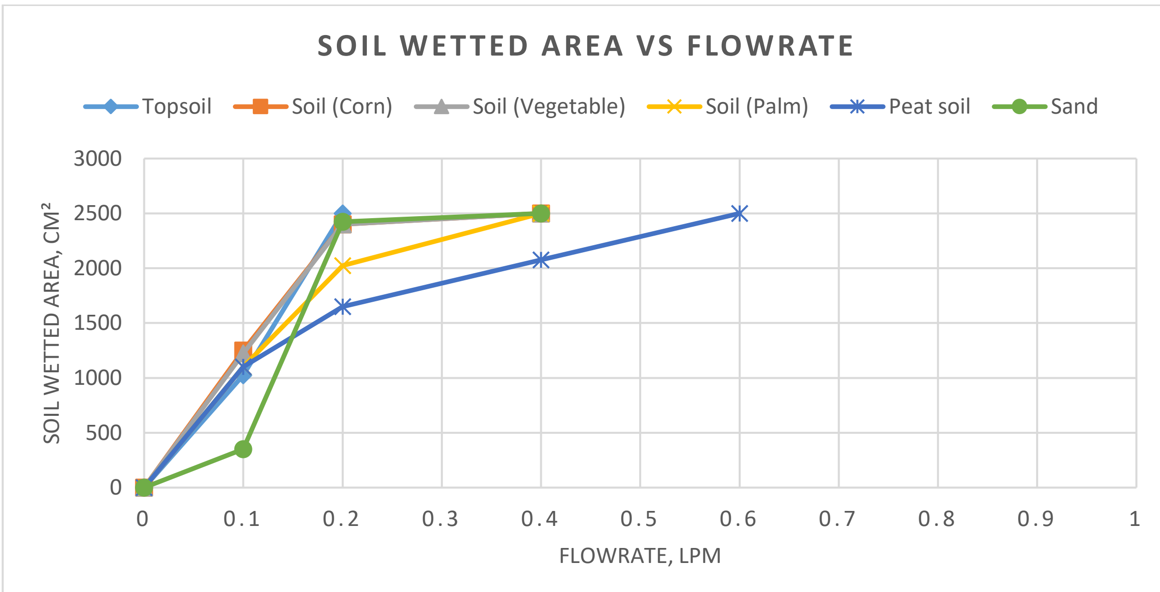


FIGURE 4. 8 Wetted Area of Soil VS Flowrate - Normal Irrigation

Figure 4.8 above shows the relationship between wetted areas of soil when the drip emitter start emitting the water at 0.1 LPM until 1 LPM. This wetted area represents how much soil wet when certain amount of water being discharge at different flowrate and this resemble the wetting pattern of the soil. As shown in the graph, the sand has the least wetted area at the beginning of 0.1 LPM whereas the highest wetted area goes to soil from corn farm. As the flowrate increase, topsoil is the first soil that fully wetted at 0.2 LPM, meanwhile other soil like soil (corn), soil (vegetable), soil (palm) and sand are fully wetted at 0.4 LPM. Only peat soil fully wetted at 0.6 LPM. As for peat soil, due to its color the calculation to know the wetted area is a bit difficult.

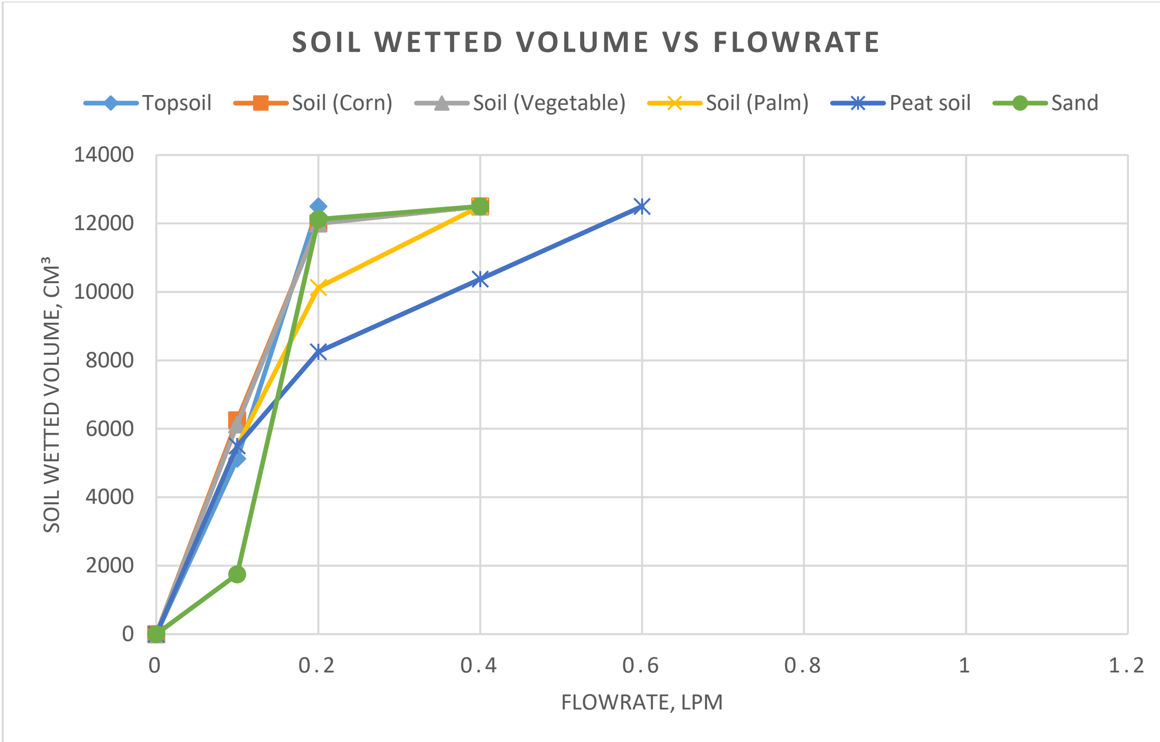


FIGURE 4. 9 Soil Wetted Volume vs Flowrate

The wetted soil volume is depended on the hydraulic conductivity of the soil, the emitter discharge and on the total amount of water in the soil. The wetted soil volume has no regular geometric shape. The best way of estimating wetting volume is a local field experimentation of the chosen emitter in undisturbed soil in the specified field (DID, 2009). But in this case, the soil wetted volume was just calculated by using soil wetted area that was obtained in Figure 4.8.

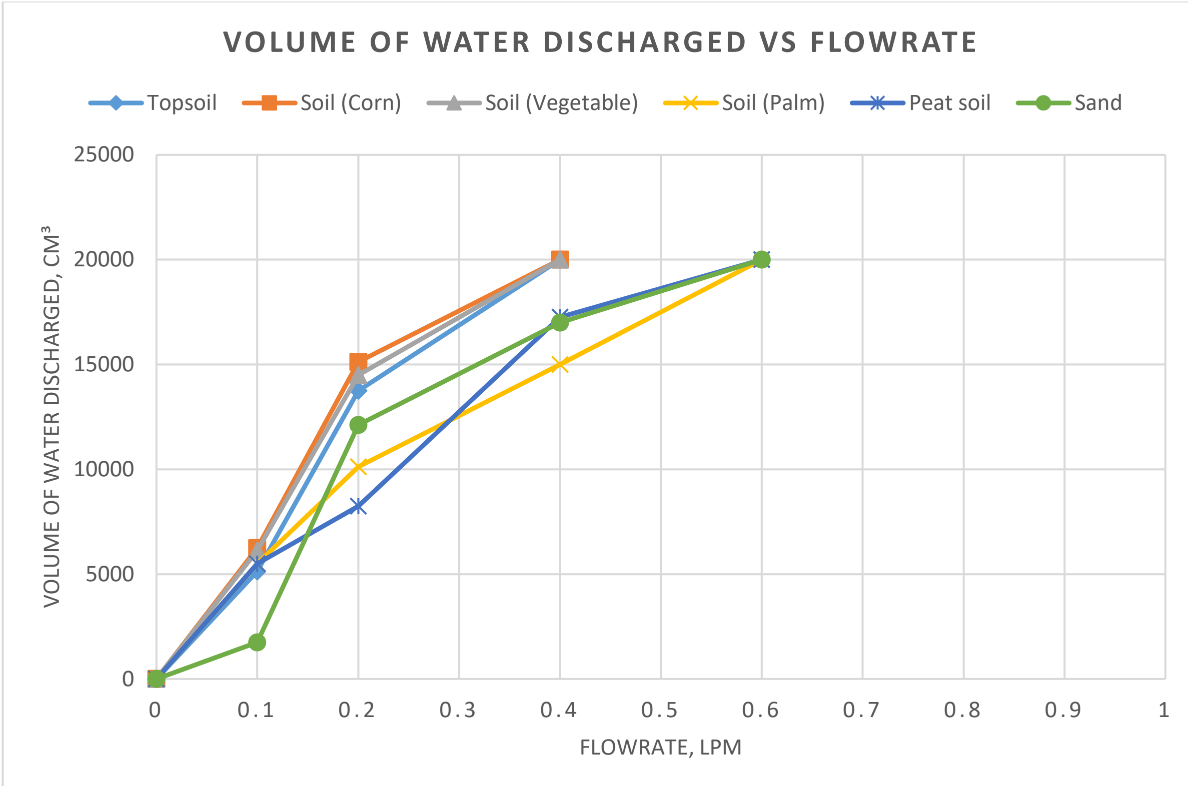


FIGURE 4. 10 Volume of Water Discharge of Soil VS Flowrate - Normal Irrigation

Volume of water discharged means that how much water was being supplied to the soil at that particular flowrate. This volume of water discharged can be divided into two parts which are the water that went into the soil and also the water that retained on top of the soil. Based on figure above, sand has the least volume of water discharge and soil from corn has the most water discharge at 0.1 LPM. But as for sand, it is rapidly increase from 0.1LPm to 0.2 LPM. The difference between the three types of agriculture soil not so big and it is quite the same as they have same soil texture. But for soil from corn farm and vegetable farm which is the sandy loam, the soil is fully wetted at 0.4 LPM and as for soil from palm oil farm, it takes until 0.6 LPM to be fully wetted.

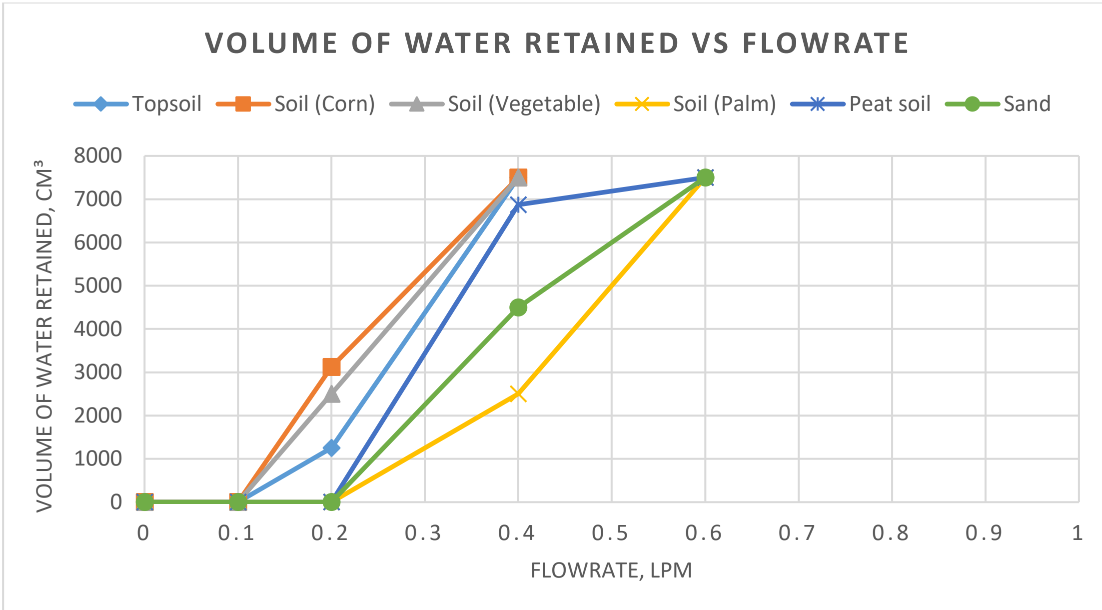


FIGURE 4. 11 Volume of water Retained of Soil VS Flowrate - Normal Irrigation

As for the volume of water retained, this information was extracted to show the ability of the soil to retain the water which can help in the irrigation conveyance. The fastest soil to retain the water are topsoil, soil from corn and vegetable farm. But soil from corn farm tend to retain the most water at 0.2 LPM. The volume of water retained can be relate with the field capacity which is shown in Figure 2.2. DID (2009) also mentioned about field capacity that is defined as the amount of water retained by a soil after saturated condition and has drained freely by gravity. Table 4.8 shows the typical results for field capacity, permanent wilting point and available water for different soil types based on DID (2009).

TABLE 4. 8 Typical Results for Field Capacity, Permanent Wilting Point and Available Water for Different Soil Types.

Soil Type	Total Pore Space (%)	Moisture (% by weight)		Available Water (mm/m of soil)
		Field Capacity (%)	Permanent Wilting Point (%)	
Clay	51-55	45	30	135
Clay Loam	47-51	40	25	120
Sandy Loam	40-47	28	18	120
Fine Sand	35-40	15	8	80
Sandy	32-42	8	4	55

4.5.2 Surge Irrigation

For surge irrigation, it was done to demonstrate the maximum water being applied in irrigation by using the flood emitter. Therefore, it only needed less time compared to the normal irrigation which is using drip emitter. It is just the same as normal irrigation but for surge irrigation, when tested with 0.1 LPM, the water is not coming out. This is most likely because of the potential head is not enough to push the water out. Therefore, for this experiment, the flowrate starts at 0.2 LPM.

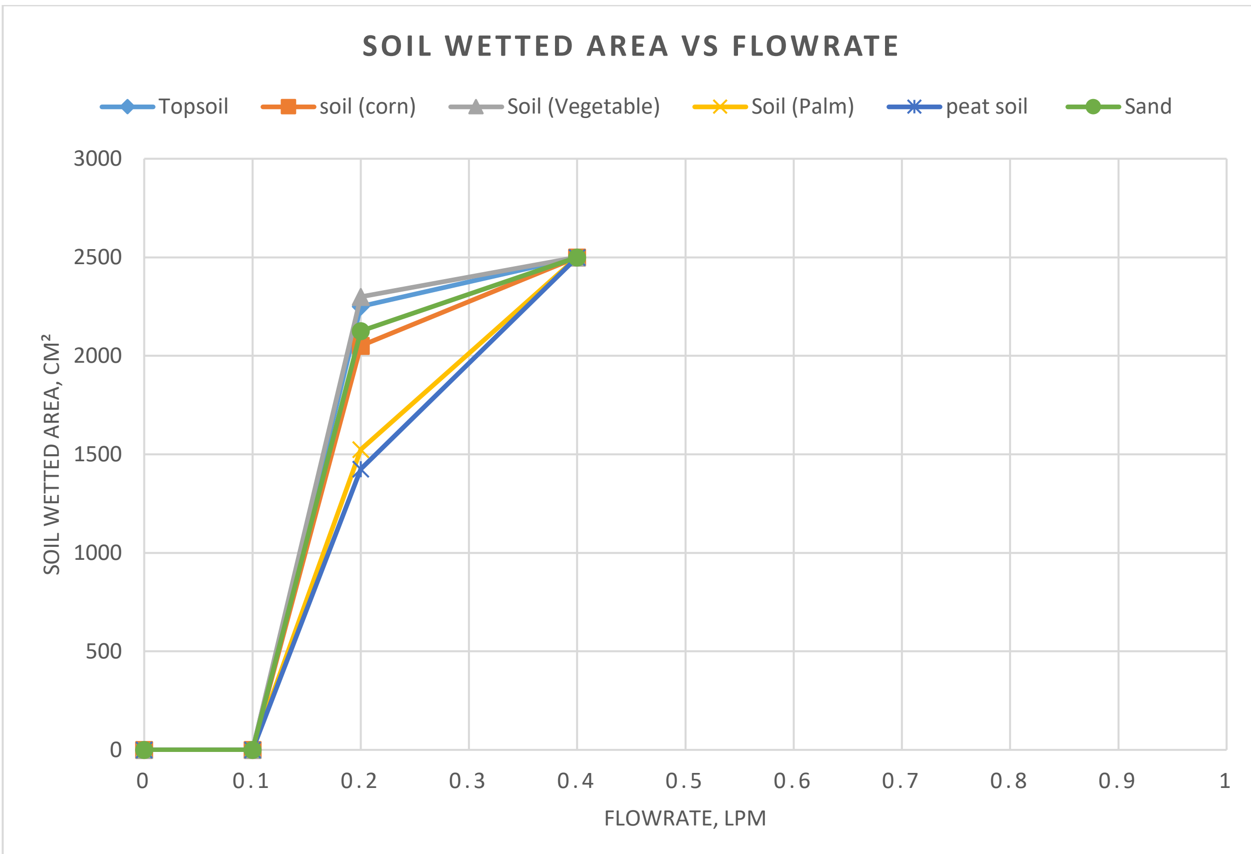


FIGURE 4. 12 Wetted Area of Soil VS Flowrate - Surge Irrigation

As shown in the figure above, the soil that has most wetted area on 0.2 LPM is soil from vegetable farm and followed by topsoil, sand and also soil from corn farm. And the least wetted area is soil from palm oil farm and also peat soil. Despite their differences in the starting point, the finishing result is just the same as the soil are fully saturated on 0.4 LPM.

Figure 4.14 below shows the soil wetted volume against the flowrate. As mentioned in Section 4.5.1, soil wetted volume is supposed to test in field with the undisturbed soil so that the result is more accurate. In this project, soil wetted volume was calculated the wetted area based on figure above. Therefore, the sequence of the increment of the soil wetted volume would be just the same as the soil wetted area.

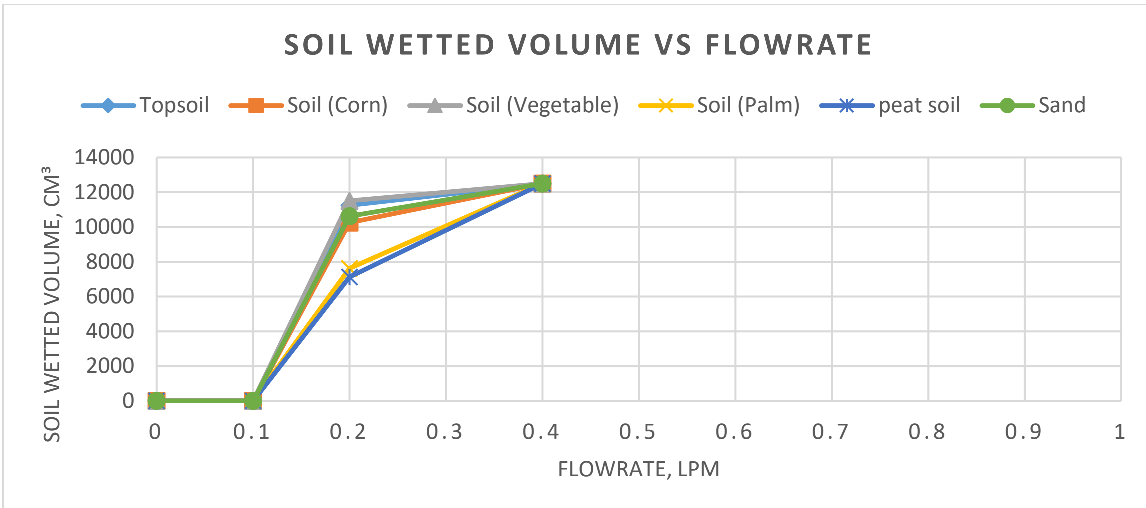


FIGURE 4. 13 Soil Wetted Volume vs Flowrate

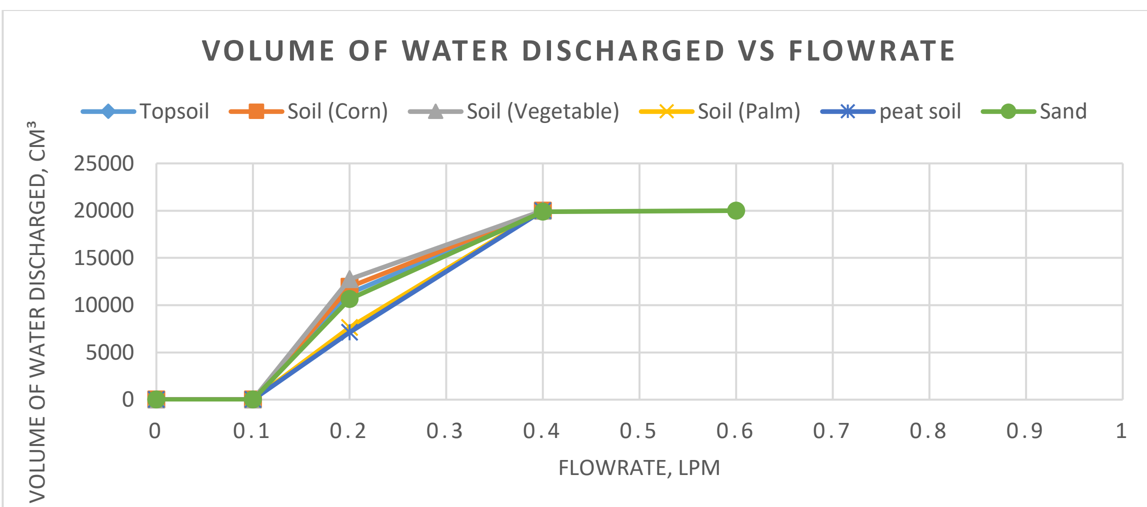


FIGURE 4. 14 Volume of Water Discharged of Soil VS Flowrate - Surge Irrigation

As mentioned above, volume of water discharged represent the summation of soil wetted volume and volume of water retained. At 0.2 LPM, the soil that taken the most water is the soil from vegetable farm, followed by the soil from corn farm, topsoil and sand. Then the least is peat soil followed by soil from palm oil farm.

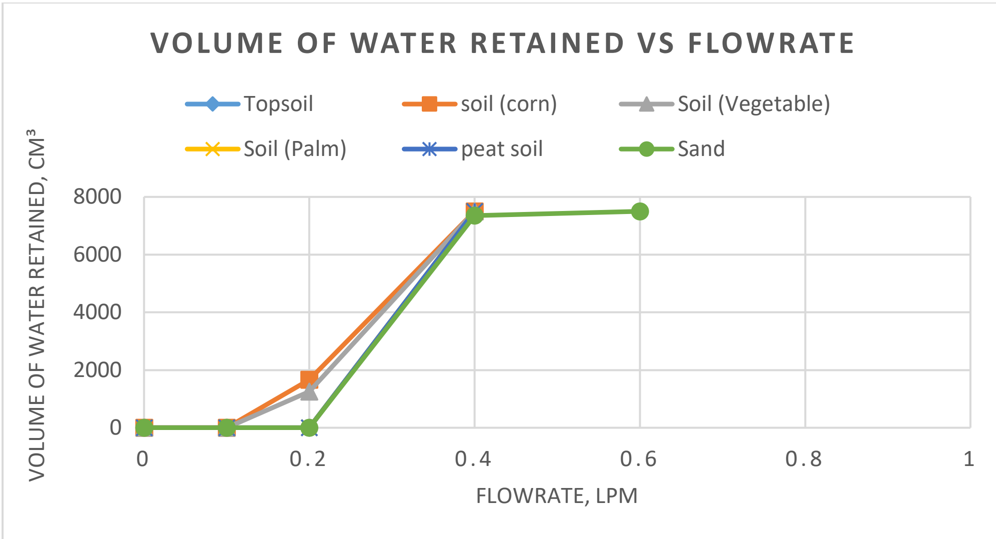


FIGURE 4. 15 Volume of Water Retained of Soil VS Flowrate - Surge Irrigation

Figure 4.16 showed the result for soil that retained water at top of the soil. The best water that managed to retain water at as early as 0.2LPM is soil from corn farm and soil from vegetable farm. The other soil such as topsoil, soil from palm oil farm, peat soil and sand retained water at 0.4 LPM and the soils also experiencing overflowing at 0.4LPM with different time except for sand. Sand overflowed at 0.6 LPM after 3 minutes. And for other soil, the overflow time is recorded in the table below.

TABLE 4. 9 Type of soil with Time taken to Overflow

Type of soil	Time taken to overflow at 0.4LPM
Topsoil	15 minutes
Soil(corn)	20 minutes
Soil (Vegetable)	19 minutes
Soil (palm)	25 minutes
Peat soil	25 minutes

The water overflow means that the soil has already saturated and the volume of water discharged has already exceed the required volume of the soil.

4.5.3 Comparison between Normal Irrigation and Surge Irrigation

The comparison between normal and surge irrigation can be made based on the soil volume or water discharged, volume of water retained, adequate infiltration rate and ability to retain water. Adequate infiltration rate means not too high and not too low. This is required in order to avoid flood from happening

TABLE 4. 10 Comparison based on Normal and Surge Irrigation

Characteristics	Normal Irrigation	Surge Irrigation
Volume of Water Discharge	Lower because using drip emitter	Higher because using flood emitter
Water Retain	Lower because water infiltrated directly after the water being applied	Higher because water tend to move horizontally
Flowrate	Started from 0.1LPM	Started from 0.2LPM
Infiltration rate and Ability to transport water	High as the water infiltrated directly after the water being applied, only retained after the water is fully saturated in the model tank.	Moderate as the water tend to move horizontally which showing its ability to transport water
The best soil in giving adequate infiltration rate, ability to retain water	Infiltration rate:. Soil from corn farm and vegetable farm Ability to retain water: Soil from corn farm and vegetable farm	Infiltration rate:. Soil from corn farm and vegetable farm Ability to retain water: Soil from corn farm and vegetable farm

CHAPTER 5

CONCLUSION AND RECOMMENDATION

As for conclusion, this project is proposing to investigate the wetting pattern of normal and surge irrigation for variation soil types is basically valid to do and will benefit agricultural sector especially. There are six types of soil being tested in this project and the main idea is to investigate the wetting pattern for each of the soil types. To know which soil is the best to use for irrigation purposes quite a number of test being done to satisfy all the objectives mentioned in Chapter 1. By doing all of the experiments from moisture content, specific gravity, particle size distribution, compaction, permeability and also the wetting pattern, the soil that is most suitable for irrigation purposes is soil from corn and vegetable farm because it has the most suitable and adequate infiltration rate and the ability to retain water is really good.

As for the project recommendation, to get more accurate data especially for the bulk density values, the soil must be taken as an undisturbed soil by taking the soil as a whole or bringing the mould to the site and take the soil by using that mould. With that, the exact value for the bulk density can be obtain and that value also can be compared with the calculation from the compaction test. Next is to add more parameter for the soil characteristic such as the plastic limit and liquid limit and also the pH value of the soil. This is because plastic limit and liquid limit can enable us to group the type of soil more precisely because both test can determine the soil classification more accurately. For the pH value of the soil, it will help to determine whether the soil is high in acidity or alkali and therefore will decide which soil is good or bad or does the soil requires treatment for it to be helpful for irrigation system.

Furthermore, this project closely related with the agriculture sector thus, it is quite important in order to know which soil is okay to use in helping with the irrigation system. So, the future work that can be done is to do the testing at the field and compare it with the wetting pattern that have been tested in the lab. This is also due to the soil wetted volume is most accurate when tested on the undisturbed soil. As for future plan, the field test can be done in order to get more accurate result in order to know which soil is good in irrigation conveyance. Moreover, in order to give more concrete evidence on the standard values for hydraulic conductivity, infiltration rate and so on, refer to another manual. This is because, in this project only manual from Department of Irrigation and Drainage (DID) (2009) has been used.

As for the SOLTEQ, there are few problems regarding SOLTEQ which is not user friendly for cleaning purposes. In order to ease the user in cleaning the model tank especially for the clayey soil, this SOLTEQ must come with a cleaning tool that suits with the model tank size so that no injuries happen to the user's hands while cleaning the model tank. Moreover, the soil that is being filled not fully compacted so this will not really showed the real soil behaviour which is really compacted. Therefore the result will not be that precise. In order to make sure that the soil is compacted inside the model tank, this equipment must provide a tool that can help with the compactions for example maybe a hammer that fits the size of the model tank. Besides, SOLTEQ comes with both end that can be open which used removable end plate. This plate can be removed to get the soil out from the model tank but there is a major problem occur with the both end which is leaking. When leaking happen, the result for volume of water retained may be not fully correct because there is some losses in water due to leakage. The leakage is due to the method use to attach the end plate is by putting screws. The water started to leak when the end plate is not replaced properly or when the screw is not properly installed. Therefore, instead of using screw, use something else which that can control the water from leaking.

REFERENCES

Anees. T., Abdullah. K., Nawawi. M., & Abd. Kadir O. (2015). Morphometric Analysis for Delineation Flood Hazard Zone of Batang Padang Catchment, Perak, Peninsular Malaysia. *International Conference on Space Science and Communication (IconSpace),* 231-23.

Bai, M. J., Xu, D., Li, Y. N., & Pereira, L. S. (2011). Impacts of spatial variability of basins micro-topography on irrigation performance. Irrigation Science, 29, 359-368.

Department of the Army Washington. (1999). Field Manual No. 5-472: Material Testing, 62-159. ASTM D854-92.

Department of Irrigation and Drainage (DID) of Malaysia (2009). Volume 5. Irrigation and Agricultural Drainage.

Easton. Z., & Bock. E. (2016). Soil and Soil Water Relationship. *Communication and Marketing, College of Agricuture and Life Sciences, Virginia Tech*.

Elmagloglou. S., & Diamantopoulos. E. (2010). Soil Water Dynamics under Surface Trickle Irrigation as affected by Soil Hydraulic Properties, Discharge rate, dripper spacing and Irrigation Duration. *Irrigation and Drainage. Volume 59, Issue 3.*

Food and Agriculture Organization of United Nations. (2017). What is Soil? Retrieved June 20, 2017, from http://www.fao.org/soils-portal/about/all-definitions/en/

Ismail. N, & Yusoff. K. (2009). The Modernized and Higher Technology Agriculture of Malaysia: Development of Livestock Industry. *Ministry of Agriculture (MoA).*

Kara. T., Temizel. KE., & Apan. M. (2008). Using Empirical Equations to Determine Appropriate Furrow Length under Field Condition. *Pakistan Journal of Biological Sciences 11 (2): 220-225*

Karimi. B., Teymour. S., Mirzaei. F., & Sinobas. LR. (2012). Evaluation of Wetting Area and Water Distribution on Different Soils in Subsurface Drip Irrigation Emitters. Retrieved from Research Gate https://www.researchgate.net/publication/258614925_Evaluation_of_wetting_area_and_water_distribution_on_different_soils_in_subsurface_drip_irrigation_emitters?enrichId=rgreq-c3bcd6d1af3e097946c2b950b26ac72b-XXX&enrichSource=Y292ZXJQYWdlOzI1ODYxNDkyNTtBUzoxOTQ4NDI0MDg4MjA3MzZAMTQyMzQ2NTQ1ODE2Ng%3D%3D&el=1_x_2&_esc=publicationCoverPdf at 26/11/2017.

Kavianand. G., Nivas. V., Kiruthika. R., & Lalitha. S. (2016). Smart Drip Irrigation System for Sustainable Agriculture. *IEEE International Conference on Technological Innovations in ICT for Agriculture and Rural Development (TIAR)*, 19-22

Leiveci. KS., Kazemi. GA., & Damough. N. (2016). Measuring Infiltration Rate and Hydraulic Conductivity in a Dry Well in a Thin Overburden. *JGeope 6(1) PP 63-73.*

Malaysia - Agriculture. (n.d.). Retrieved June 16, 2017, from http://www.nationsencyclopedia.com/economies/Asia-and-the-Pacific/Malaysia-AGRICULTURE.html

Mancosu. N., Snyder. RL., Kyriakakis. G., & Spano. D. (2015). Water Scarcity and Future Challenges for Food Production. *Water* **2015**, *7*, 975-992; doi:10.3390/w7030975

Martin. DL., Kincaid. DC., & Lyle WM. (2014). Design and Operation of Sprinkler Sytem. Retrieved from Research Gate https://www.researchgate.net/publication/43265028_Design_and_operation_of_sprinkle r_systems?enrichId=rgreq-ef21e061e48ffcc4fd8c6615e75958a0-XXX&enrichSource=Y292ZXJQYWdlOzQzMjY1MDI4O0FTOjk5NjI4NzI4OTc5NDYzQDE0MDA3NjQ3NDg5MzI%3D&el=1_x_2&_esc=publicationCoverPdf at 21/11/17

Mashnik. D. et. al (2017). Increasing Productivity through Irrigation : Problems and Solutions Implemented in Africa and Asia. *Sustainable Energy Technologies and Assessments*.

Miao. Q., Shi. H., Goncalves. JM., & Pereira LS. (2015). Field Assessment of Basin Irrigation Performance and Water Saving in Hetao, Yellow River Basin: Issue to Support Irrigation Systems Modernization. *Biosystems Engineering 1 36 (2015) 102-116*

Namala. K., Krishna. K., Math. A., Kumari. A., & Kulkarni. S. (2016). Smart Irrigation with Embedded System. *IEEE Bombay Section Symposium (IBSS)*.

Nyvall. J. (2002). Soil Water Storage Capacity and Available Soil Moisture. *Ministry of Agriculture, Food and Fisheries*.

Ogaidi. AAM., Aimrun. W., Rowshon. MK., & Abdullah AF. (2016). WPEDIS – Wetting Pattern Estimator under Drip Irrigation Systems. *International Conference on Agricultural and Food Engineering. 23-25 August 2016*

Pereres. E., & Soriano. M. (2007). Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany, 58*(2), 147-159

Ramya. A., & Ravi. G. (2016). Efficient Automatic Irrigation System using Zigbee. *International Conference on Communication and Signal Processing*

Samadianfard. S., Sadraddini. AA., Nazemi. AH., Provenzano. G., & Kisi. O. (2012). Estimating Soil Wetting Patterns for Drip Irrigation Using Genetic Programming. *Spanish Journal of AgriculturalResearch 2012 10(4), 1155 – 1166*

Saranya. S., & Amudha. T. (2016). Crop Planning Optimization Research - A Detailed Investigation. *IEEE International Conference on Advances in Computer Applications (ICACA),* 202-208

Shirsath. P. (2009). Irrigation Development: History and Impact. Retrieved October 28, 2017, from http://indiairrigation.blogspot.my/

Soulis. K., Elmaloglou. S., & Dercas. N. (2014). Investigating the Effects of Soil Moisture Sensors Positioning and Accuracy on Soil Moisture based on Drip Irrigation scheduling System. *Agricultural Water Management, 148,* 258-26

Valera. A., & Desa. M. N. (1992). Design-Management Interactions of Malaysia's Kerian Irrigation Scheme. *International Irrigation Management Institute*

Walker. W. R., & Skogerboe. G. V. (1987). Surface Irrigation: Theory and practice. *Englewood Cliffs, NJ, USA: Prentice-Hall Inc. xiii, 386p*

Walker. W. R. (1989). Guidelines for designing and evaluating surface irrigation systems. *Food and Agriculture Organization of United Nations. Irrigation And Drainage Paper 45*

Walker. W. R. (2003). Surface Irrigation Simulation, Evaluation and Design. *Biological and Irrigation Engineering, Utah State University.*

Zhang. YY., Zhao. XN., & Wu. PT (2015). Soil Wetting Patterns and Water Distribution as Affected by Irrigation for Uncropped Ridges and Furrows. *Soil Science Society of China. Pedosphere 25 (3): 468-477*

APPENDIX A: SOIL CLASSIFICICATION TESTS

MOISTURE CONTENT BY OVEN DRYING METHOD

Location : STP, UTP [**Topsoil**]		Sample No:	1	
Soil Description : Sandy Clay		Date	29/5/17	
Test Method : BS 1377 : Part 2 : 1990 : 3.2				
Related Test				
Specimen reference		T	T	T
Container no:		1	2	3
Mass of wet soil + container (m_2)	(g)	49.2	38.4	38.0
Mass of dry soil + container (m_3)	(g)	44.1	33.4	32.9
Mass of container (m_1)	(g)	19.2	8.4	8.0
Mass of moisture (m_2 - m_3)	(g)	5.1	5.0	5.1
Mass of dry soil (m_3 - m_1)	(g)	24.9	25.0	24.9
Moisture content , $W = \frac{(m2 - m3)}{(m3 - m1)}$ x 100%	(%)	20.48	20.0	20.48
Average value w	(%)	20.32		

Location : Hydraulic Lab, UTP [**Sand**]		Sample No:	2	
Soil Description : Sand		Date	29/5/17	
Test Method : BS 1377 : Part 2 : 1990 : 3.2				
Related Test				
Specimen reference		S	S	S
Container no:		1	2	3
Mass of wet soil + container (m_2)	(g)	48.9	51.2	38.4
Mass of dry soil + container (m_3)	(g)	48.9	51.1	38.3
Mass of container (m_1)	(g)	18.9	21.2	8.4
Mass of moisture (m_2 - m_3)	(g)	0.0	0.1	0.1
Mass of dry soil (m_3 - m_1)	(g)	30	29.9	29.9
Moisture content , $W = \frac{(m2 - m3)}{(m3 - m1)}$ x 100%	(%)	0	0.33	0.33
Average value w	(%)	0.22		

Location : Corn Farm at Kampung Gajah, Tronoh [**Soil (corn)**]		Sample No:	3	
Soil Description : Sandy Loam		Date	29/5/17	
Test Method : BS 1377 : Part 2 : 1990 : 3.2				
Related Test				
Specimen reference		CF	CF	CF
Container no:		1	2	3
Mass of wet soil + container (m_2)	(g)	50.7	49.0	38.3
Mass of dry soil + container (m_3)	(g)	49.2	47.5	36.9
Mass of container (m_1)	(g)	20.7	19.0	8.3
Mass of moisture (m_2 - m_3)	(g)	1.5	1.5	1.4
Mass of dry soil (m_3 - m_1)	(g)	28.5	28.5	28.6
Moisture content , $W = \frac{(m2 - m3)}{(m3 - m1)}$ x 100%	(%)	5.26	5.26	4.90
Average value w	(%)	5.14		

Location : Vegetable farm around Mining Area at Ipoh [**Soil(Vegetable)]**		Sample No:	4	
Soil Description : Sandy Loam		Date	29/5/17	
Test Method : BS 1377 : Part 2 : 1990 : 3.2				
Related Test				
Specimen reference		FM	FM	FM
Container no:		1	2	3
Mass of wet soil + container (m_2)	(g)	49.8	50.9	51.4
Mass of dry soil + container (m_3)	(g)	45.6	46.7	47.4
Mass of container (m_1)	(g)	19.8	20.9	21.4
Mass of moisture (m_2 - m_3)	(g)	4.2	4.2	4.0
Mass of dry soil (m_3 - m_1)	(g)	25.8	25.8	26.0
Moisture content , W = $\frac{(m2 - m3)}{(m3 - m1)}$ x 100%	(%)	16.27	16.27	15.38
Average value w	(%)	15.98		

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Soil (Palm)]**		Sample No:	5	
Soil Description : Sandy Loam		Date	29/5/17	
Test Method : BS 1377 : Part 2 : 1990 : 3.2				
Related Test				
Specimen reference		PF	PF	PF
Container no:		1	2	3
Mass of wet soil + container (m_2)	(g)	50.5	51.0	51.3
Mass of dry soil + container (m_3)	(g)	45.7	46.2	46.4
Mass of container (m_1)	(g)	20.5	21.0	21.3
Mass of moisture (m_2 - m_3)	(g)	4.8	4.8	4.9
Mass of dry soil (m_3 - m_1)	(g)	25.2	25.2	25.1
Moisture content , W = $\frac{(m2 - m3)}{(m3 - m1)}$ x 100%	(%)	0.19	0.19	0.20
Average value w	(%)	0.193		

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Peat Soil**]		Sample No:	6	
Soil Description : Sandy Gravel		Date	29/5/17	
Test Method : BS 1377 : Part 2 : 1990 : 3.2				
Related Test				
Specimen reference		PFP	PFP	PFP
Container no:		1	2	3
Mass of wet soil + container (m_2)	(g)	47.8	49.7	51.5
Mass of dry soil + container (m_3)	(g)	36.6	38.0	38.5
Mass of container (m_1)	(g)	17.8	19.7	21.5
Mass of moisture (m_2 - m_3)	(g)	11.2	11.7	13.0
Mass of dry soil (m_3 - m_1)	(g)	18.8	18.3	17.0
Moisture content , W = $\frac{(m2 - m3)}{(m3 - m1)}$ x 100%	(%)	59.57	63.93	76.47
Average value w	(%)	66.66		

SPECIFIC GRAVITY BY SMALL PYCNOMETER METHOD

Location: STP, YTP [**Topsoil**]		Sample No.	1
Soil description: Sandy clay		Date	5/6/17
Test Method			
Method of Preparation			
Specimen Reference		T	T
Container No.		1	2
Mass of jar + glass + cap + soil + water (m_3)	(g)	90.1	89.9
Mass of jar + glass + cap + soil (m_2)	(g)	46.0	45.6
Mass of jar + glass + cap + water (m_4)	(g)	80.73	80.54
Mass of jar + glass + cap (m_1)	(g)	31.0	30.6
Mass of soil ($m_2 - m_1$)	(g)	15.0	15.0
Mass of water in glass ($m_4 - m_1$)	(g)	49.73	49.94
Mass of water used ($m_3 - m_2$)	(g)	44.1	44.3
Volume of soil particles ($m_4 - m_1$) - ($m_3 - m_2$)	(g)	5.63	5.64
Particle density $\wp_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$	ML	2.66	2.66
Average value $\wp_s$	Mg/m^3	2.66	

Location: Hydraulic Lab, UTP [**sand**]		Sample No.	2
Soil description: Sand		Date	5/6/17
Test Method			
Method of Preparation			
Specimen Reference		S	S
Container No.		1	2
Mass of jar + glass + cap + soil + water (m_3)	(g)	57.8	58.3
Mass of jar + glass + cap + soil (m_2)	(g)	38.8	39.5
Mass of jar + glass + cap + water (m_4)	(g)	48.6	49.1
Mass of jar + glass + cap (m_1)	(g)	23.8	24.5
Mass of soil ($m_2 - m_1$)	(g)	15.0	15.0
Mass of water in glass ($m_4 - m_1$)	(g)	24.8	24.6
Mass of water used ($m_3 - m_2$)	(g)	19.0	18.8
Volume of soil particles ($m_4 - m_1$) - ($m_3 - m_2$)	(g)	5.8	5.8
Particle density $\wp_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$	ML	2.59	2.59
Average value $\wp_s$	Mg/m^3	2.59	

Location: Corn Farm at Kampung Gajah, Tronoh [**Soil (corn)]**	Sample No.	3

Soil description: Sandy Loam		Date	5/6/17
Test Method			
Method of Preparation			
Specimen Reference		CF	CF
Container No.		1	2
Mass of jar + glass + cap + soil + water (m_3)	(g)	89.4	89.9
Mass of jar + glass + cap + soil (m_2)	(g)	46.9	46.7
Mass of jar + glass + cap + water (m_4)	(g)	80.31	80.75
Mass of jar + glass + cap (m_1)	(g)	31.9	31.7
Mass of soil (m_2 - m_1)	(g)	15	15
Mass of water in glass (m_4 - m_1)	(g)	48.41	49.05
Mass of water used (m_3 - m_2)	(g)	42.5	43.2
Volume of soil particles (m_4 - m_1) - (m_3 - m_2)	(g)	5.91	5.85
Particle density $\wp_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$	ML	2.538	2.564
Average value $\wp_s$	Mg/m^3	2.55	

Location: Vegetable farm around Mining Area at Ipoh [**Soil (Vegetable**)]		Sample No.	4
Soil description: Sandy Loam		Date	5/6/17
Test Method			
Method of Preparation			
Specimen Reference		FM	FM
Container No.		1	2
Mass of jar + glass + cap + soil + water (m_3)	(g)	57.0	90.3
Mass of jar + glass + cap + soil (m_2)	(g)	39.0	46.7
Mass of jar + glass + cap + water (m_4)	(g)	47.65	81.02
Mass of jar + glass + cap (m_1)	(g)	24.0	31.7
Mass of soil (m_2 - m_1)	(g)	15.0	15.0
Mass of water in glass (m_4 - m_1)	(g)	23.65	49.32
Mass of water used (m_3 - m_2)	(g)	18.0	43.6
Volume of soil particles (m_4 - m_1) - (m_3 - m_2)	(g)	5.65	5.72
Particle density $\wp_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$	ML	2.65	2.62
Average value $\wp_s$	Mg/m^3	2.64	

Location: Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Soil (Palm)]**		Sample No.	5
Soil description: Peat Soil		Date	5/6/17
Test Method			
Method of Preparation			
Specimen Reference		PFP	PFP
Container No.		1	2
Mass of jar + glass + cap + soil + water (m_3)	(g)	76.2	77.6
Mass of jar + glass + cap + soil (m_2)	(g)	46.4	46.9
Mass of jar + glass + cap + water (m_4)	(g)	81.7	69.34
Mass of jar + glass + cap (m_1)	(g)	31.4	31.9
Mass of soil (m_2 - m_1)	(g)	15.0	15.0
Mass of water in glass (m_4 - m_1)	(g)	50.3	37.44
Mass of water used (m_3 - m_2)	(g)	29.8	30.7
Volume of soil particles (m_4 - m_1) - (m_3 - m_2)	(g)	6.75	6.74
Particle density $\wp_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$	ML	2.22	2.22
Average value $\wp_s$	Mg/m^3	2.22	

Location: Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Peat soil**]		Sample No.	6
Soil description: Sandy Gravel		Date	5/6/17
Test Method			
Method of Preparation			
Specimen Reference		PF	PF
Container No.		1	2
Mass of jar + glass + cap + soil + water (m_3)	(g)	90.1	89.8
Mass of jar + glass + cap + soil (m_2)	(g)	46.8	46.6
Mass of jar + glass + cap + water (m_4)	(g)	80.94	80.65
Mass of jar + glass + cap (m_1)	(g)	31.8	31.6
Mass of soil (m_2 - m_1)	(g)	15.0	15.0
Mass of water in glass (m_4 - m_1)	(g)	49.14	49.05
Mass of water used (m_3 - m_2)	(g)	43.3	43.2
Volume of soil particles (m_4 - m_1) - (m_3 - m_2)	(g)	5.84	5.85
Particle density $\wp_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$	ML	2.568	2.562
Average value $\wp_s$	Mg/m^3	2.57	

PARTICLE SIZE DISTRIBUTION BY DRY SIEVING METHOD

Location : STP, UTP [**Topsoil**]		Sample No	1
Soil Description : Sandy Clay		Date	26/6/17
Test Method : BS 1377-2: 1990 :9.3			
Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Passing (%)
3.35	0.0	0.0	100.0
2.00	0.7	0.7	99.3
1.18	5.9	5.9	93.4
0.600	12.5	12.5	80.9
0.425	5.7	5.7	75.2
0.300	4.8	4.8	70.4
0.212	3.7	3.7	66.7
0.150	2.7	2.7	64.0
0.063	3.3	3.3	60.7
Pan	0.1	0.1	60.6

Location : Hydraulic Lab, UTP [**Sand**]		Sample No	1
Soil Description : Sand		Date	26/6/17
Test Method : BS 1377-2: 1990 :9.3			
Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Passing (%)
3.35	0.0	0.0	100.0
2.00	0.1	0.0	99.967
1.18	0.2	0.1	99.9
0.600	14.3	71.4	28.467
0.425	77.5	25.8	2.633
0.300	7.5	2.5	0.133
0.212	0.4	0.1	0.0
0.150	0.0	0.0	0.0
0.063	0.0	0.0	0.0
Pan	0.0	0.0	0.0

Location : Corn Farm at Kampung Gajah, Tronoh [**Soil(Corn)]**		Sample No	3
Soil Description : Sandy Loam		Date	26/6/17
Test Method : BS 1377-2: 1990 :9.3			
Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Passing (%)
3.35	0.0	0.0	100.0
2.00	9.3	9.3	90.7
1.18	10.1	10.1	80.6
0.600	14.9	14.9	65.7
0.425	8.4	8.4	57.3
0.300	8.7	8.7	48.6
0.212	8.2	8.2	40.4
0.150	6.6	6.6	33.8
0.063	8.5	8.5	25.3
Pan	1.7	1.7	23.6

Location : Vegetable farm around Mining Area at Ipoh [**Soil(Vegetable)]**		Sample No	4
Soil Description : Sandy Loam		Date	26/6/17
Test Method : BS 1377-2: 1990 :9.3			
Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Passing (%)
3.35	0.0	0.0	100.0
2.00	2.9	2.9	97.1
1.18	5.8	5.8	91.3
0.600	10.1	10.1	81.2
0.425	6.4	6.4	74.8
0.300	7.3	7.3	67.5
0.212	7.9	7.9	59.6
0.150	8.3	8.3	51.3
0.063	18.5	18.5	32.8
Pan	1.9	1.9	30.9

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Soil(Palm)]**		Sample No	5
Soil Description : Sandy Loam		Date	26/6/17
Test Method : BS 1377-2: 1990 :9.3			
Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Passing (%)
3.35	0.0	0.0	100.0
2.00	0.0	0.0	100.0
1.18	0.3	0.3	99.7
0.600	2.9	2.9	96.8
0.425	7.5	7.5	89.3
0.300	14.2	14.2	75.1
0.212	15.5	15.5	59.6
0.150	12.3	12.3	47.3
0.063	14.2	14.2	33.1
Pan	0.7	0.7	32.4

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Peat Soil**]		Sample No	46
Soil Description : Sandy Gravel		Date	26/6/17
Test Method : BS 1377-2: 1990 :9.3			
Sieve size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Passing (%)
3.35	0.0	0.0	100.0
2.00	25.8	25.8	74.2
1.18	20.1	20.1	54.1
0.600	16.8	16.8	37.3
0.425	5.7	5.7	31.6
0.300	4.3	4.3	27.3
0.212	.0	.0	24.3
0.150	2.1	2.1	22.2
0.063	2.9	2.9	19.3
Pan	1.0	1.0	18.3

PARTICLE SIZE DISTRIBUTION BY HYDROMETER METHOD (BS1377-2:1990:9.6)

Location : STP, UTP [**Topsoil**]		Sample No	1
Soil Description : Sandy Clay		Date	20/6/17
Meniscus Correction (m)		Cm	0.5
Reading in dispersant (cm)		Ro’	0.5
Dry mass of soil (g)		M	100.0
Particle Density Measured/Assumed		$\wp_s$	0.76
Viscosity of Water at 25°C		η	0.891

Test Data

Date	t min	T°C	Reading Rn’	Rn’ + Cm Rn	Hr (mm)	D (mm)	Rn’- Ro’ Rd	% finer K%
20/6	0.5	25	30.0	30.5	72.8	0.056	29.5	52.73
20/6	1	25	30.0	30.5	72.8	0.040	29.5	52.73
20/6	2	25	30.0	30.5	72.8	0.028	29.5	52.73
20/6	4	25	30.0	30.5	72.8	0.020	29.5	52.73
20/6	8	25	30.0	30.5	72.8	0.014	29.5	52.73
20/6	15	25	30.0	30.5	72.8	0.010	29.5	52.73
20/6	30	25	30.0	30.5	72.8	0.007	29.5	52.73
20/6	60	25	30.0	30.5	72.8	0.005	29.5	52.73
20/6	120	25	30.0	30.5	72.8	0.004	29.5	52.73
20/6	240	25	30.0	30.5	72.8	0.003	29.5	52.73
20/6	1440	25	30.0	30.5	72.8	0.001	29.5	52.73
21/6	2880	25	30.0	30.5	72.8	0.001	29.5	52.73
22/6	4320	25	30.0	30.5	72.8	0.001	29.5	52.73
23/6	5760	25	30.0	30.5	72.8	0.001	29.5	52.73
24/6	7200	25	30.0	30.5	72.8	0.000	29.5	52.73
25/6	8640	25	30.0	30.5	72.8	0.000	29.5	52.73
26/6	10080	25	30.0	30.5	72.8	0.000	29.5	52.73
27/6	11520	25	29.0	29.5	72.8	0.000	28.5	52.73
28/6	12960	25	29.0	29.5	76.6	0.000	28.5	50.94
29/6	14400	25	29.0	29.5	76.6	0.000	28.5	50.94
30/6	15840	25	29.0	29.5	76.6	0.000	27.5	50.94
31/6	17280	25	28.0	28.5	80.5	0.000	27.5	49.15
1/7	18720	25	28.0	28.5	80.5	0.000	28.5	49.15

Location : Corn Farm at Kampung Gajah, Tronoh [**Soil(corn)**]	Sample No	3

Soil Description : Sandy Loam						Date		20/6/17
Meniscus Correction (m)							Cm	0.5
Reading in dispersant (cm)							Ro’	0.5
Dry mass of soil (g)							M	100.0
Particle Density Measured/Assumed							$\wp_s$	2.155
Viscosity of Water at 25°C							η	0.891
Test Data								
Date	t min	T°C	Reading Rn’	Rn’ + Cm Rn	Hr (mm)	D (mm)	Rn’- Ro’ Rd	% finer K%
20/6	0.5	25	11.0	11.5	145.6	0.083	10.5	19.59
20/6	1	25	11.0	11.5	145.6	0.059	10.5	19.59
20/6	2	25	11.0	11.5	145.6	0.041	10.5	19.59
20/6	4	25	10.0	10.5	149.4	0.030	9.5	17.73
20/6	8	25	10.0	10.5	149.4	0.021	9.5	17.73
20/6	15	25	8.5	9.0	155.2	0.016	8.0	14.93
20/6	30	25	7.5	8.0	159.0	0.011	7.0	13.06
20/6	60	25	7.0	7.5	160.9	0.008	6.5	12.13
20/6	120	25	6.5	7.0	162.8	0.006	6.0	11.19
20/6	240	25	6.0	6.5	164.8	0.004	5.5	10.26
21/6	1440	25	5.0	5.5	168.6	0.002	4.5	8.40

Location : Vegetable farm around Mining Area at Ipoh						Sample No		4
Soil Description : Sandy Loam						Date		20/6/17
Meniscus Correction (m)							Cm	0.5
Reading in dispersant (cm)							Ro’	0.5
Dry mass of soil (g)							M	100.0
Particle Density Measured/Assumed							$\wp_s$	2.34
Viscosity of Water at 25°C							η	0.891
Test Data								
Date	t min	T°C	Reading Rn’	Rn’ + Cm Rn	Hr (mm)	D (mm)	Rn’- Ro’ Rd	% finer K%
20/6	0.5	25	15.0	15.5	130.3	0.073	14.5	25.32
20/6	1	25	15.0	5.5	130.3	0.051	14.5	25.32
20/6	2	25	13.0	13.5	137.9	0.037	12.5	21.83
20/6	4	25	11.0	11.5	145.6	0.027	10.5	18.34
20/6	8	25	10.0	10.5	149.4	0.019	9.5	16.59
20/6	15	25	10.0	10.5	149.4	0.014	9.5	16.59
20/6	30	25	9.0	9.5	153.3	0.010	8.5	14.84
20/6	60	25	8.5	9.0	155.2	0.007	8.0	13.97
20/6	120	25	7.5	8.0	159.0	0.005	7.0	12.22
20/6	240	25	7.0	7.5	164.8	0.004	6.5	11.35
21/6	1440	25	6.0	6.5	164.8	0.002	5.5	9.60

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Soil(Palm)]**						Sample No		5
Soil Description : Sandy Loam						Date		20/6/17
Meniscus Correction (m)							Cm	0.5
Reading in dispersant (cm)							Ro'	0.5
Dry mass of soil (g)							M	100.0
Particle Density Measured/Assumed							ρ_s	2.27
Viscosity of Water at 25°C							η	0.891
Test Data								
Date	t min	T°C	Reading Rn'	Rn' + Cm Rn	Hr (mm)	D (mm)	Rn'- Ro' Rd	% finer K%
20/6	0.5	25	17.5	18.0	120.7	0.072	17.0	30.39
20/6	1	25	17.5	18.0	120.7	0.051	17.0	30.39
20/6	2	25	17.5	18.0	120.7	0.036	17.0	30.39
20/6	4	25	17.5	18.0	120.7	0.025	17.0	30.39
20/6	8	25	17.0	17.5	122.6	0.018	16.5	29.49
20/6	15	25	17.0	17.5	122.6	0.013	16.5	29.49
20/6	30	25	17.0	17.5	122.6	0.009	16.5	29.49
20/6	60	25	16.5	17.0	124.5	0.007	16.0	28.60
20/6	120	25	16.5	17.0	124.5	0.005	16.0	28.60
20/6	240	25	16.0	16.5	126.4	0.003	15.5	27.70
21/6	1440	25	15.5	16.0	128.4	0.001	15.0	26.81

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Peat Soil**]						Sample No		6
Soil Description : Sandy Loam						Date		20/6/17
Meniscus Correction (m)							Cm	0.5
Reading in dispersant (cm)							Ro'	0.5
Dry mass of soil (g)							M	100.0
Particle Density Measured/Assumed							ρ_s	1.13
Viscosity of Water at 28°C							η	0.891
Test Data								
Date	t min	T°C	Reading Rn'	Rn' + Cm Rn	Hr (mm)	D (mm)	Rn'- Ro' Rd	% finer K%
20/6	0.5	28	7.0	7.5	160.9	0.260	6.5	56.50
20/6	1	28	7.0	7.5	160.9	0.184	6.5	56.50
20/6	2	28	7.0	7.5	160.9	0.130	6.5	56.50
20/6	4	28	6.5	7.0	162.8	0.092	6.0	52.15
20/6	8	28	6.0	6.5	164.8	0.066	5.5	47.81
20/6	15	28	6.0	6.5	164.8	0.048	5.5	47.81
20/6	30	28	5.0	5.5	168.6	0.034	4.5	39.12
20/6	60	28	5.0	5.5	168.6	0.024	4.5	39.12
20/6	120	28	4.0	4.5	172.4	0.017	3.5	30.42
20/6	240	28	3.5	4.0	174.3	0.012	3.0	26.08
21/6	1440	28	3.0	3.5	176.3	0.005	2.5	21.73

SOIL COMPOSITION BASED ON DRY SIEVING AND HYDROMETER WASHING

Location : STP, UTP [**Topsoil**]		Sample	1
Test method			
Particle size (mm)	Cumulative percentage passing (%)	Soil proportion (%)	
3.3500	100.00	Gravel (5%)	
2.0000	99.30		
1.1800	93.40	Sand (51%)	
0.6000	80.90		
0.4250	75.20		
0.3000	70.40		
0.2120	66.70	Silt (3%)	
0.1500	64.00		
0.0630	60.70		
0.0559	52.73		
0.0004	50.94	Clay (51%)	
0.0003	49.15		
Soil Classification based on USDA		Sandy Clay	

Location : Hydraulic lab, UTP [**Sand**]		Sample	2
Test method			
Particle size (mm)	Cumulative percentage passing (%)	Soil proportion (%)	
3.3500	100.00	Gravel (0%)	
2.0000	99.97		
1.1800	99.90	Sand (100%)	
0.6000	28.47		
0.4250	2.63		
0.3000	0.13		
0.2120	0.00		
0.1500	0.00		
0.0630	0.00		
Soil Classification based on USDA		Sand	

Location : Corn Farm, Kampung gajah [**Soil(Corn)**]		Sample	3
Particle size (mm)	Cumulative percentage passing (%)	Soil proportion (%)	
3.3500	100.00	Gravel (18%)	
2.0000	90.70		
1.1800	80.60	Sand (70%)	
0.6000	65.70		
0.4250	57.30		
0.3000	48.60		
0.2120	40.40	Silt (30%)	
0.1500	33.80		
0.0630	25.30		
0.0297	17.73		
0.0156	14.93		
0.0112	13.06		
0.0080	12.13		
0.0057	11.19		
0.0040	10.26		
0.0017	8.40	Clay (8%)	
Soil Classification based on USDA		Sandy Loam	

Location : Vegetable farm around Mining Area at Ipoh [**Soil(Vegetable)]**		Sample	4
Test method			
Particle size (mm)	Cumulative percentage passing (%)	Soil proportion (%)	
3.3500	100.00	Gravel (7%)	
2.0000	97.10		
1.1800	91.30	Sand (73%)	
0.6000	81.20		
0.4250	74.80		
0.3000	67.50		
0.2120	59.60	Silt (20%)	
0.1500	51.30		
0.0630	32.80		
0.0375	21.83		
0.0270	18.34		
0.0195	16.59		
0.0102	14.84		
0.0073	13.97		
0.0052	12.22		
0.0037	9.88		
Soil Classification based on USDA		Sandy Loam	

Location : Palm Oil Farm, Felcra nasaruddin [**Soil(Palm)]**		Sample	5
Test method			
Particle size (mm)	Cumulative percentage passing (%)	Soil proportion (%)	
3.3500	100.00	Gravel (0%)	
2.0000	100.00		
1.1800	99.70	Sand (70%)	
0.6000	96.80		
0.4250	89.30		
0.3000	75.10		
0.2120	59.60	Silt (30%)	
0.1500	47.30		
0.0630	33.10		
0.0094	29.49		
0.0047	28.60		
Soil Classification based on USDA		Sandy Loam	

Location : Palm Oil Farm, Felcra nasaruddin [**Peat Soil**]		Sample	6
Test method			
Particle size (mm)	Cumulative percentage passing (%)	Soil proportion (%)	
3.3500	100.00	Gravel (45%)	
2.0000	74.20		
1.1800	54.10	Sand (55%)	
0.6000	37.30		
0.4250	31.60		
0.3000	27.30		
0.2120	24.30		
0.1500	22.20		
0.0630	19.30		
Cannot define using USDA			

DRY DENSITY/MOISTURE CONTENT RELATIONSHIP BY 2.5KG RAMMER PROCTOR TEST [BS 1377-4:1990:3.3]

Location : STP, UTP [**Topsoil**]										Sample no			1	
Soil Description: Sandy Clay										Date			25/9/17	
Volume of Mould	2066.01 cm^3	Water Temperature				25°C				Specific Gravity				2.66
Initial Sample Mass	2569 g	Water Density				0.9962 kg/m^3				Mass of mould + base (M1)				4187g
Test no.		1	2	3	4	5	6	7	8	9	10	11	12	13
Mass of mould + base + compacted specimen (M2)	g	5572	5662	5714	5736	5765	5792	5817	5826	5830	5886	6085	6114	6118
Mass of compacted specimen (M2-M1)	g	1385	1475	1527	1549	1578	1605	1630	1639	1643	1699	1898	1927	1931
Bulk Density, ρ	g/cm^3	0.67	0.71	0.74	0.75	0.76	0.78	0.79	0.79	0.80	0.82	0.92	0.93	0.94
Moisture content container no		1	2	3	4	5	6	7	8	9	10	11	12	13
Moisture content, w	%	0	1.56	3.18	4.11	4.81	4.94	6.37	6.98	7.96	10.17	10.52	10.96	12.00
Dry density, ρd	g/cm^3	0.67	0.70	0.72	0.72	0.73	0.74	0.74	0.74	0.74	0.75	0.83	0.84	0.83
Void Ratio, *e*		2.95	2.77	2.70	2.68	2.64	2.58	2.57	2.57	2.60	2.55	2.19	2.15	2.18
Dry density (theoretical), $\rho d.max$	g/cm^3	2.65	0.51	0.28	0.22	0.19	0.19	0.15	0.14	0.12	0.09	0.09	0.09	0.08
Degree of Saturation, S	%	0.00	149.99	313.64	407.60	485.67	509.19	659.05	721.17	814.88	1061.04	1279.02	1354.88	1467.55
Porosity, n		0.747	0.735	0.730	0.728	0.725	0.721	0.720	0.720	0.722	0.718	0.686	0.683	0.685

Location : Corn Farm at Kampung Gajah, Tronoh [**Soil (corn)]**										Sample no		2	
Soil Description: Sandy Loam										Date		26/9/17	
Volume of Mould	2066.01 cm³		Water Temperature			25°C				Specific Gravity			2.55
Initial Sample Mass	2939 g		Water Density			0.9962 kg/m³				Mass of mould + base (M1)			4187g
Test no.			1	2	3	4	5	6	7	8	9		
Mass of mould + base + compacted specimen (M2)	g		5574	5642	5717	5777	5833	5878	5945	6028	6086		
Mass of compacted specimen (M2-M1)	g		1387	1455	1530	1590	1646	1691	1758	1841	1899		
Bulk Density, ρ	g/cm³		0.671	0.704	0.741	0.770	0.797	0.818	0.851	0.891	0.919		
Moisture content container no			1	2	3	4	5	6	7	8	9		
Moisture content, w	%		0	1.854	2.916	8.412	9.203	12.903	15.326	19.476	20.307		
Dry density, ρd	g/cm³		0.671	0.691	0.720	0.710	0.730	0.725	0.738	0.746	0.764		
Void Ratio, *e*			2.784	2.674	2.530	2.579	2.482	2.504	2.443	2.406	2.325		
Dry density (theoretical), ρd.max	g/cm³		2.540	0.444	0.301	0.113	0.104	0.075	0.063	0.050	0.048		
Degree of Saturation, S	%		0	177	294	832	946	1314	1600	2064	2227		
Porosity, n			0.736	0.728	0.717	0.721	0.713	0.715	0.710	0.706	0.699		

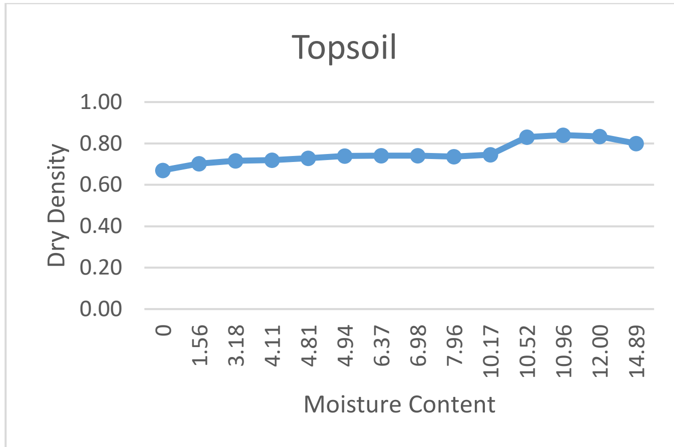
Location : Vegetable farm around Mining Area at Ipoh [**Soil(Vegetable)]**						Sample no		3
Soil Description: Sandy Loam						Date		27/9/19
Volume of Mould	2066.01 cm³	Water Temperature		25°C		Specific Gravity		2.64
Initial Sample Mass	2681 g	Water Density		0.9962 kg/m³		Mass of mould + base (M1)		4187g
Test no.		1	2	3	4	5	6	7
Mass of mould + base + compacted specimen (M2)	g	5831	6003	6036	6095	6183	6219	6319
Mass of compacted specimen (M2-M1)	g	1644	1816	1849	1908	1996	2032	2132
Bulk Density, ρ	g/cm³	0.796	0.879	0.895	0.924	0.966	0.984	1.032
Moisture content container no		1	2	3	4	5	6	7
Moisture content, w	%	0.000	2.041	5.263	8.460	10.865	13.143	16.414
Dry density, ρd	g/cm³	0.796	0.861	0.850	0.851	0.871	0.869	0.886
Void Ratio, *e*		2.305	2.053	2.093	2.089	2.018	2.025	1.967
Dry density (theoretical), ρd.max	g/cm³	2.630	0.412	0.177	0.113	0.089	0.074	0.059
Degree of Saturation, S	%	0	262	664	1069	1421	1713	2203
Porosity, n		0.697	0.672	0.677	0.676	0.669	0.669	0.663

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Soil(Palm)**]								Sample no		4
Soil Description: Sandy Loam								Date		28/9/17
Volume of Mould	2066.01 cm³	Water Temperature				25°C		Specific Gravity		2.27
Initial Sample Mass	2345 g	Water Density				0.9962 kg/m³		Mass of mould + base (M1)		4187g
Test no.		1	2	3	4	5	6	7	8	9
Mass of mould + base + compacted specimen (M2)	g	5656	5737	5772	5778	5851	5943	6063	6200	6220
Mass of compacted specimen (M2-M1)	g	1469	1550	1585	1591	1664	1756	1876	2013	2033
Bulk Density, ρ	g/cm³	0.711	0.750	0.767	0.770	0.805	0.850	0.908	0.974	0.984
Moisture content container no		1	2	3	4	5	6	7	8	9
Moisture content, w	%	0	1.833	4.135	5.925	8.889	11.426	12.301	14.337	16.701
Dry density, ρd	g/cm³	0.711	0.737	0.737	0.727	0.740	0.763	0.809	0.852	0.843
Void Ratio, *e*		2.629	2.502	2.502	2.549	2.488	2.383	2.191	2.028	2.060
Dry density (theoretical), ρd.max	g/cm³	2.580	0.449	0.220	0.158	0.107	0.084	0.079	0.068	0.058
Degree of Saturation, S	%	0	190	428	602	925	1242	1454	1831	2100
Porosity, n		0.724	0.714	0.714	0.718	0.713	0.704	0.687	0.670	0.673

Location : Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Peat Soil**]									Sample no		5			
Soil Description: Sandy Gravel									Date		29/9/17			
Volume of Mould	2066.01 cm³	Water Temperature				25°C			Specific Gravity				2.22	
Initial Sample Mass	2345 g	Water Density				0.9962 kg/m³			Mass of mould + base (M1)				4187g	
Test no.		1	2	3	4	5	6	7	8	9	10	11	12	13
Mass of mould + base + compacted specimen (M2)	g	5080	5160	5218	5247	5250	5292	5335	5345	5403	5435	5492	5522	5551
Mass of compacted specimen (M2-M1)	g	893	973	1031	1060	1063	1105	1148	1158	1216	1248	1305	1335	1364
Bulk Density, ρ	g/cm³	0.432	0.471	0.499	0.513	0.515	0.535	0.556	0.560	0.589	0.604	0.632	0.646	0.660
Moisture content container no		1	2	3	4	5	6	7	8	9	10	11	12	13
Moisture content, w	%	14.81	18.18	20.51	22.22	22.64	27.78	30.43	31.11	35.71	37.25	40.78	42.86	43.48
Dry density, ρd	g/cm³	0.38	0.40	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.44	0.45	0.45	0.46
Void Ratio, *e*		6.04	5.65	5.40	5.31	5.32	5.33	5.22	5.20	5.11	5.02	4.91	4.86	4.76
Dry density (theoretical), ρd.max	g/cm³	0.07	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02
Degree of Saturation, S	%	652	856	1010	1113	1133	1386	1551	1592	1859	1973	2211	2347	2430
Porosity, n		0.858	0.850	0.844	0.842	0.842	0.842	0.839	0.839	0.836	0.834	0.831	0.829	0.826

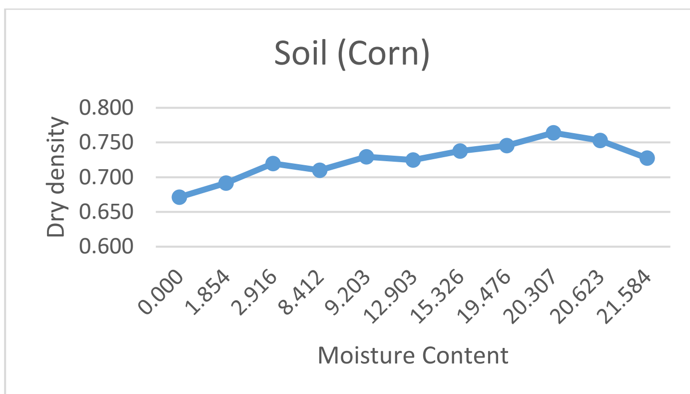
GRAPH FOR DRY DENSITY AGAINST MOISTURE CONTENT

Sample 1: Topsoil



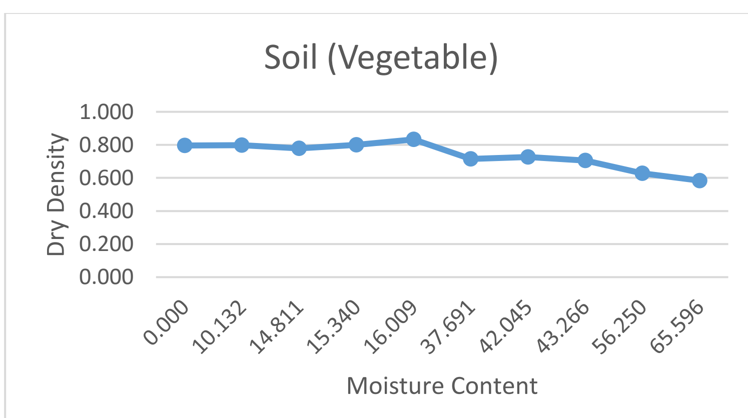
Dry Density vs Moisture Content - Topsoil

Sample 2: Soil from Corn Farm



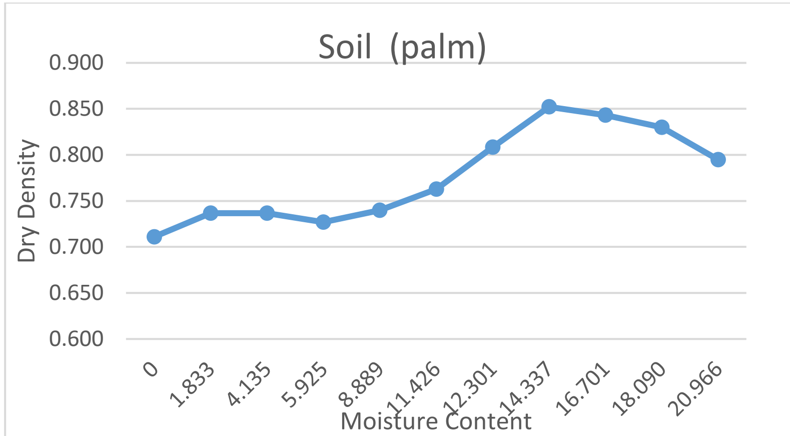
Dry Density vs Moisture Content - Soil from Corn Farm

Sample 3: Soil from Vegetable farm



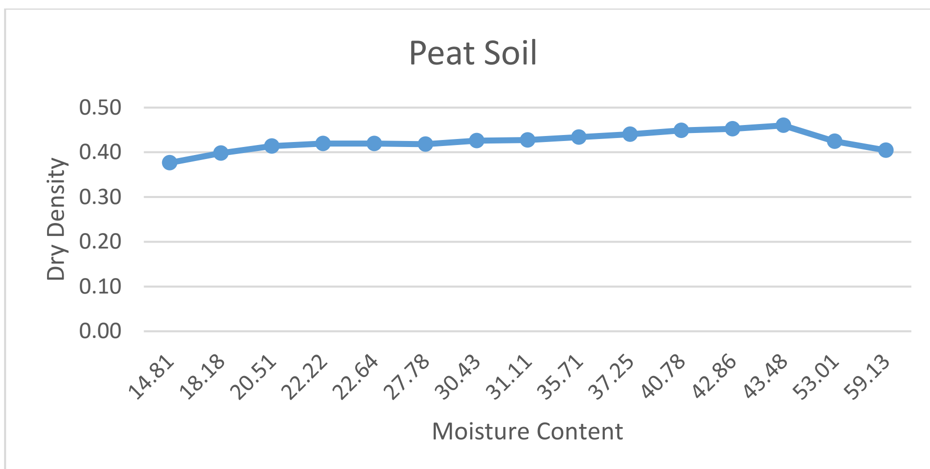
Dry Density vs Moisture Content - Soil from Farm at Mining Area

Sample 4: Soil from Palm oil



Dry Density vs Moisture Content - Soil from Palm Oil Farm

Sample 5: Peat Soil



Dry Density vs Moisture Content - Peat Soil

APPENDIX B: STANDARD PERMEABILITY TEST

Permeability by Falling Head Test Method [BS 1377-5:1990]

Location: STP, UTP [**Topsoil**]				Sample No	1
Soil Description: Sandy Clay				Date	2/10/17
Details of sample					
Length of sample	L	cm	29.629		
Diameter of sample	D	cm	27.314		
Area of sample	A	cm²	585.95		
Mass of compacted specimen	m	g	1445		
Bulk density	ρ	g/cm³	0.94		
Dry density	ρd	g/cm³	0.83		
Void ratio	e		2.18		
Test					
Area of Standpipe, a (mm²)	Initial reading of standpipe, h1 (mm)	Final reading of standpipe, h2 (mm)	Time, t (hour)	Hydraulic conductivity, K (mm/h)	
17	975	575	`0.5230556	0.037690445	

Location: Corn Farm at Kampung Gajah, Tronoh [**Soil (corn)**]				Sample No	2
Soil Description: Sandy loam				Date	3/10/17
Details of sample					
Length of sample	L	cm	29.629		
Diameter of sample	D	cm	27.314		
Area of sample	A	cm²	585.95		
Mass of compacted specimen	m	g	1522		
Bulk density	ρ	g/cm³	0.919		
Dry density	ρd	g/cm³	0.764		
Void ratio	e		2.325		
Test					
Area of Standpipe, a (mm²)	Initial reading of standpipe, h1 (mm)	Final reading of standpipe, h2 (mm)	Time, t (hour)	Hydraulic conductivity, K (mm/h)	
23	920	380	3.383333	0.01320005	

Location: Vegetable farm around Mining Area at Ipoh [**Soil(Vegetable)**]				Sample No	3
Soil Description: Sandy loam				Date	4/10/17
Details of sample					
Length of sample	L	cm	29.629		
Diameter of sample	D	cm	27.314		
Area of sample	A	cm²	585.95		
Mass of compacted specimen	m	g	1540		
Bulk density	ρ	g/cm³	1.032		
Dry density	ρd	g/cm³	0.886		
Void ratio	e		1.967		
Test					
Area of Standpipe, a (mm²)	Initial reading of standpipe, h1 (mm)	Final reading of standpipe, h2 (mm)	Time, t (hour)	Hydraulic conductivity, K (mm/h)	
28	715	580	1.766667	0.007283143	

Location: Palm Oil Farm at Felcra Nasaruddin, Tronoh [**Soil(Palm)**]				Sample No	4
Soil Description: Sandy loam				Date	5/10/17
Details of sample					
Length of sample	L	cm	29.629		
Diameter of sample	D	cm	27.314		
Area of sample	A	cm²	585.95		
Mass of compacted specimen	m	g	1420		
Bulk density	ρ	g/cm³	0.984		
Dry density	ρd	g/cm³	0.843		
Void ratio	e		2.060		
Test					

Area of Standpipe, a (mm²)	Initial reading of standpipe, h1 (mm)	Final reading of standpipe, h2 (mm)	Time, t (hour)	Hydraulic conductivity, K (mm/h)
23	990	770	19.08	0.000665285

Location: Palm Oil Farm at Felcra Nasaruddin, Tronoh[**Peat soil**]				Sample No	5
Soil Description: Sandy loam				Date	5/10/17
Details of sample					
Length of sample	L	cm	29.629		
Diameter of sample	D	cm	27.314		
Area of sample	A	cm²	585.95		
Mass of compacted specimen	m	g	1366		
Bulk density	ρ	g/cm³	0.660		
Dry density	ρd	g/cm³	0.460		
Void ratio	e		4.759		
Test					

Area of Standpipe, a (mm²)	Initial reading of standpipe, h1 (mm)	Final reading of standpipe, h2 (mm)	Time, t (hour)	Hydraulic conductivity, K (mm/h)
23	1000	800	0.1	0.112707545

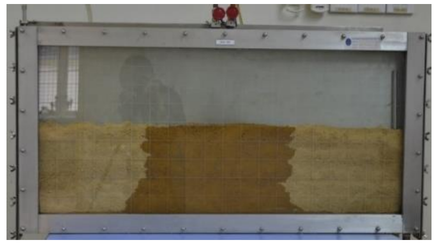
Permeability by Constant Head Test Method [BS 1377-5:1990]

Location: Hydraulic Lab [**Sand**]				Sample No	1
Soil Description: Sand				Date	6/10/17
Details of sample					
Length of sample before saturation	L1	cm	12.503		
Length of sample after saturation	L2	cm	12.501		
Average length of sample	L	cm	12.502		
Diameter of sample	D	cm	9.028		
Area of sample	A	cm²	64.01		
Test					

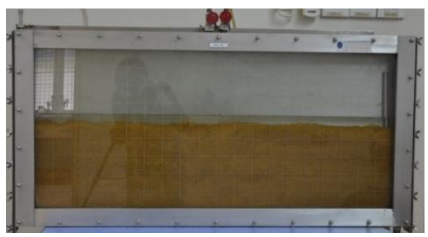
Time interval, t	h	y	Hydraulic gradient, i=h/y	Flow, Q	Rate of flow, q=Q/t	Temperature, T	Correction factor, Rt	Permeability, K
s	cm	cm		mL	mL/s	°C		cm/s
41	8.7	13.82	0.63	1000	24.39	28	0.83	0.502

APPENDIX C: WETTING PATTERN EXPERIMENT BASED ON SOLTEQ FM514
NORMAL IRRIGATION

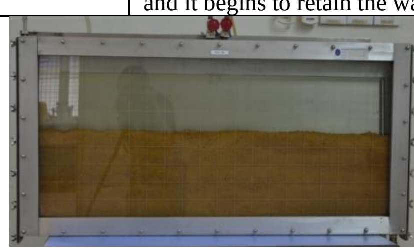
Sample 1: Topsoil



Type of Sample	Topsoil
Volume of sample	12500cm³
Water Flow rate	0.1 LPM
Wetted area after 25 minutes	1025cm²
Volume of water discharged after 25 minutes	5125 cm³
Volume of Water Retained	0 cm³
Discussion	The water started to flow from top to bottom and the shape of a cylinder was formed

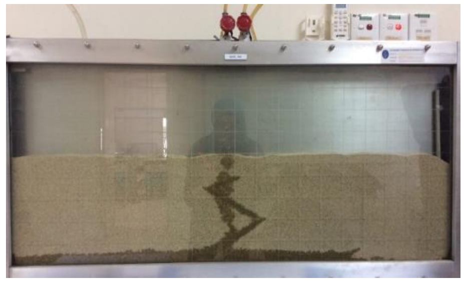


Type of Sample	Topsoil
Volume of sample	12500cm³
Water Flow rate	0.2 LPM
Wetted area after 25 minutes	2500 cm²
Volume of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	1250 cm³
Discussion	At 0.2LPM, the water has already flow throughout the topsoil and it begins to retain the water.



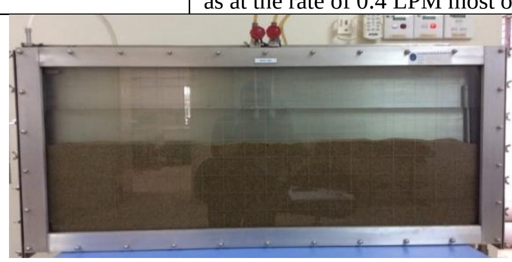
Type of Sample	Topsoil
Volume of sample	12500cm³
Water Flow rate	0.4 LPM
Wetted area after 25 minutes	2500 cm²
Volume of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	7500 cm³
Discussion	At 0.4LPM, the water has already overflowed.

[Sample 2: Sand

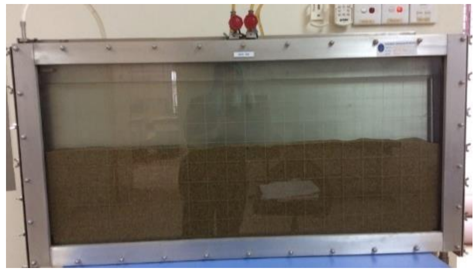


Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.1 LPM
Wetted area after 25 minutes	350cm²
Volume of water discharged after 25 minutes	1750 cm³
Volume of Water Retained	0 cm³
Discussion	The water flows from the drip emitter which is located on top of the model tank. The water flows throughout the sand by the gravitational force and it is flowing through the sand particle because the sand particle is quite big. Moreover the sand particle just have to undergo the dry sieving particle distribution size.

Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.2 LPM
Wetted area after 25 minutes	2425cm²
Volume of water discharged after 25 minutes	12125 cm³
Volume of Water Retained	0 cm³
Discussion	Most of the area is wet and the sand infiltration takes place really quick as at the rate of 0.4 LPM most of the sand is already filled with water.

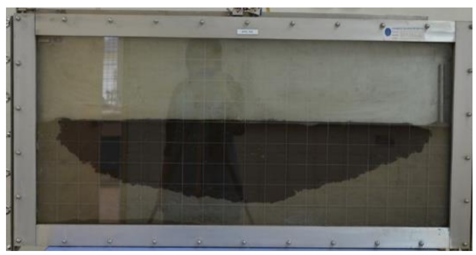


Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.4 LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	12500
Volume of Water Retained	4500cm³
Discussion	At 0.4 LPM, the water started to retain as all the sand has already been saturated. After 25 minutes, the volume of water retained is as stated as above.



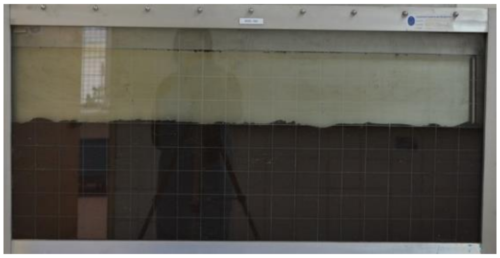
Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.6 LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	7500cm³
Discussion	After around 10minutes of 0.6LPM of flowrate started, the water begin to overflow.

3. Soil from Corn Farm, Kampung Gajah



Type of Sample	Soil from Corn Farm
Volume of sample	12500cm³
Water Flow rate	0.1 LPM
Wetted area after 25 minutes	1250cm²
Volume of water discharged after 25 minutes	6250 cm³
Volume of Water Retained	0 cm³
Discussion	For corn soil, the water flowed from top to bottom and the shape formed is a half oval shape.

Type of Sample	Soil from Corn Farm
Volume of sample	12500cm³
Water Flow rate	0.2 LPM
Wetted area after 25 minutes	2400cm²
Volume of water discharged after 25 minutes	12000 cm³
Volume of Water Retained	3125 cm³
Discussion	Even the water has already retained, but there is stills some area that is not wet yet.

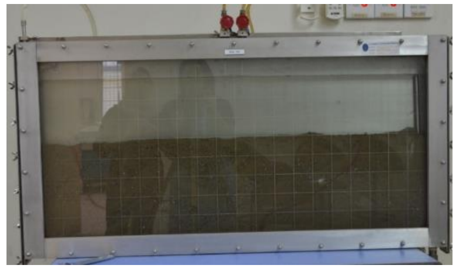


Type of Sample	Soil from Corn Farm
Volume of sample	12500cm³
Water Flow rate	0.4 LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	12500cm³
Volume of Water Retained	7500cm³
Discussion	The water has already overflow at 0.4LPM

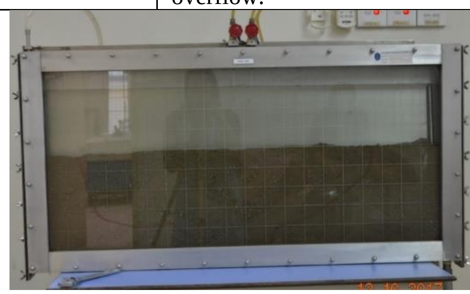
Sample 4: Soil from Vegetable farm at Mining area, Lafarge

Type of Sample	Soil from Mining Area
Volume of sample	12500cm³
Water Flow rate	0.1 LPM
Wetted area after 25 minutes	1225cm²
Volume of water discharged after 25 minutes	6125 cm³
Volume of Water Retained	0 cm³
Discussion	The water infiltration went downwards then it spreads to the left and also to the right in the top of the soil.

Type of Sample	Soil from Mining Area
Volume of sample	12500cm³
Water Flow rate	0.2 LPM
Wetted area after 25 minutes	2400cm²
Volume of water discharged after 25 minutes	12000 cm³
Volume of Water Retained	2500cm³
Discussion	The water started to retain on top of the soil but there are certain areas that was not been wetted yet.

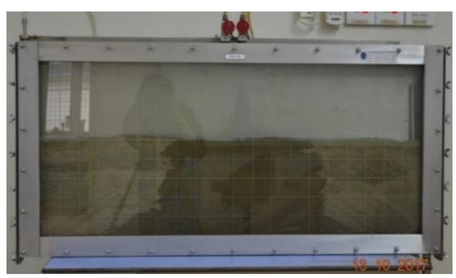


Type of Sample	Soil from Mining Area
Volume of sample	12500cm³
Water Flow rate	0.4 LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	7500cm³
Discussion	At the end of 25 minutes with 0.4LPM, the water started to overflow.

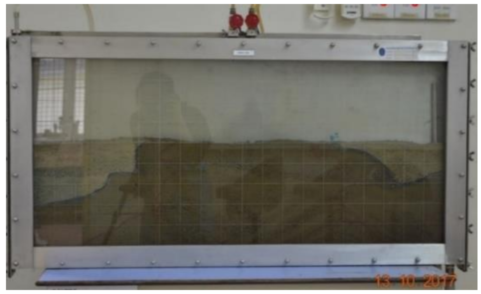


Type of Sample	Soil from Mining Area
Volume of sample	12500cm³
Water Flow rate	0.6 LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	7500cm³
Discussion	The water continued to overflow at 0.6LPM, therefore for 0.8LPM the experiment was not continued.

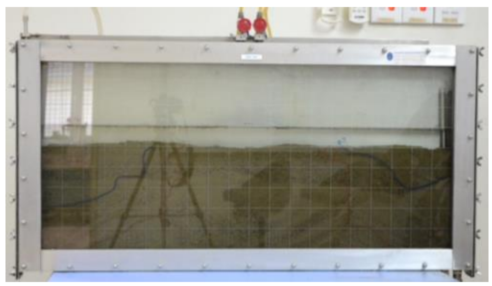
Sample 5: Soil from Palm Oil Farm, Felcra Nasaruddin



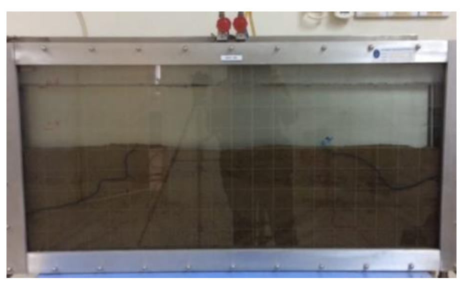
Type of Sample	Soil from Palm Oil Farm
Volume of sample	12500cm³
Water Flow rate	0.1 LPM
Wetted area after 25 minutes	1100cm²
Volume of water discharged after 25 minutes	5500 cm³
Volume of Water Retained	0 cm³
Discussion	For this type of soil, the water infiltrated downwards first then the water spreads at the bottom part of the soil.



Type of Sample	Soil from Palm Oil Farm
Volume of sample	12500cm³
Water Flow rate	0.2 LPM
Wetted area after 25 minutes	2025cm²
Volume of water discharged after 25 minutes	10125 cm³
Volume of Water Retained	0 cm³
Discussion	This soil practically absorb the water from the bottom part first, then only the water moves upwards.



Type of Sample	Soil from Palm Oil Farm
Volume of sample	12500cm³
Water Flow rate	0.4 LPM
Wetted area after 25 minutes	2500cm²
Volum9e of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	2500cm³
Discussion	At 0.4LPM, the water has already retained and all the soil has already in contact with water.



Type of Sample	Soil from Palm Oil Farm
Volume of sample	12500cm³
Water Flow rate	0.6 LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	12500 cm³
Volume of Water Retained	7500cm³
Discussion	During this water flowrate, the water has already overflow.

Sample 6: Peat Soil

Type of Sample	Peat soil
Volume of sample	12500cm³
Water Flow rate	0.1 LPM
Wetted area after 25 minutes	1100cm²
Volume of water discharged after 25 minutes	5500cm³
Volume of Water Retained	0cm³
Discussion	The water flow downwards first then only spread to the left and right at bottom part.

Type of Sample	Peat soil
Volume of sample	12500cm³
Water Flow rate	0.2LPM
Wetted area after 25 minutes	1650cm²
Volume of water discharged after 25 minutes	8250cm³
Volume of Water Retained	0cm³
Discussion	The water spread from bottom to top part of the model tank.

Type of Sample	Peat soil
Volume of sample	12500cm³
Water Flow rate	0.4 LPM
Wetted area after 25 minutes	2075cm²
Volume of water discharged after 25 minutes	17250cm³
Volume of Water Retained	6874cm³
Discussion	Most of the water has already retain but not yet overflow.

Type of Sample	Peat soil
Volume of sample	12500cm³
Water Flow rate	0.6LPM
Wetted area after 25 minutes	2500cm²
Wetted volume after 25 minutes	20000cm³
Volume of Water Retained	7500cm³
Discussion	In 3 minutes of the 0.6LPM, the water already overflow,

SURGE IRRIGATION

Sample 1: Topsoil

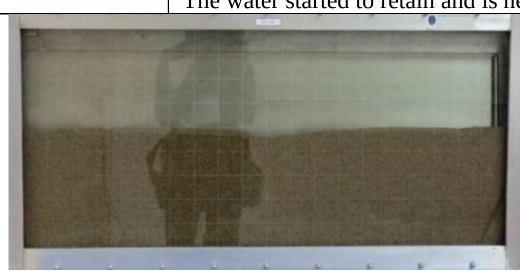
Type of Sample	Topsoil
Volume of sample	12500cm³
Water Flow rate	0.2LPM
Wetted area after 25 minutes	2250cm²
Volume of water discharged after 25 minutes	11250cm³
Volume of Water Retained	0cm³
Discussion	The water come out from the flood emitter is on the left side of the model tank so the wetted area started from left to right.

Type of Sample	Topsoil
Volume of sample	12500cm³
Water Flow rate	0.4LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	20000cm³
Volume of Water Retained	7500cm³
Discussion	After 15 minutes of 0.4LPM, the water has retained and also overflow.

Sample 2: Sand

Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.2LPM
Wetted area after 25 minutes	2125cm²
Volume of water discharged after 25 minutes	10625cm³
Volume of Water Retained	0cm³
Discussion	The water started to flow downwards and to the top.

Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.4LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	20000cm³
Volume of Water Retained	7350cm³
Discussion	The water started to retain and is near to the overflow level.



Type of Sample	Sand
Volume of sample	12500cm³
Water Flow rate	0.6LPM
Wetted area after 25 minutes	2500cm²
Wetted volume after 25 minutes	20000cm³
Volume of Water Retained	7500cm³
Discussion	The water overflow just after 3 minutes of 0.6LPM.

Sample 3: Soil from corn farm

Type of Sample	Soil (Corn)
Volume of sample	12500cm³
Water Flow rate	0.2LPM
Wetted area after 25 minutes	2050cm²
Volume of water discharged after 25 minutes	11916.67cm³
Volume of Water Retained	1666.67 cm³
Discussion	The water spreads throughout the soil and while spreading the water also retaining at the top of the soil.

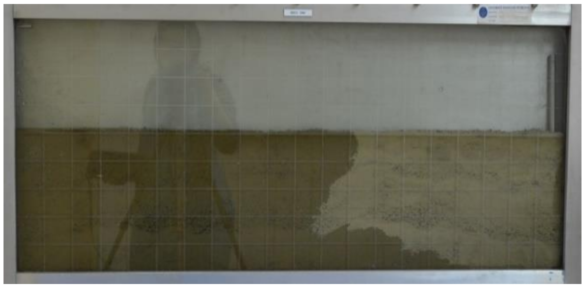
Type of Sample	Soil (Corn)
Volume of sample	12500cm³
Water Flow rate	0.4LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	20000cm³
Volume of Water Retained	7500cm³
Discussion	The water are fully wetted and retained. And at 21 minutes of 0.4LPM, the water started to overflow.

Sample 4: Soil from Vegetable farm

Type of Sample	Soil (Vegetable)
Volume of sample	12500cm³
Water Flow rate	0.2LPM
Wetted area after 25 minutes	2300cm²
Volume of water discharged after 25 minutes	12750 cm³
Volume of Water Retained	1250cm³
Discussion	There are still some area that is not fully wet but the water has already retain.

Type of Sample	Soil (Vegetable)
Volume of sample	$12500cm^3$
Water Flow rate	0.4LPM
Wetted area after 25 minutes	$2500\ cm^2$
Volume of water discharged after 25 minutes	$20000cm^3$
Volume of Water Retained	$7500cm^3$
Discussion	The water started to overflow after 19minutes of 0.4LPM.

Sample 5: Soil from Palm oil farm

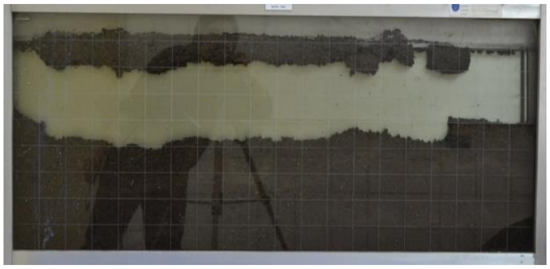


Type of Sample	Soil (palm)
Volume of sample	$12500cm^3$
Water Flow rate	0.2LPM
Wetted area after 25 minutes	$1525cm^2$
Volume of water discharged after 25 minutes	$7625\ cm^3$
Volume of Water Retained	$0cm^3$
Discussion	Water spreads from left to right due to position of the flood emitter. But the water started to flow downwards first then only they spread to the right.

Type of Sample	Soil (palm)
Volume of sample	$12500cm^3$
Water Flow rate	0.4LPM
Wetted area after 25 minutes	$2500cm^2$
Volume of water discharged after 25 minutes	$20000cm^3$
Volume of Water Retained	$7500cm^3$
Discussion	The water started to overflow at the end of 25minutes of 0.4LPM.

Sample 6: Peat Soil

Type of Sample	Peat soil
Volume of sample	12500cm³
Water Flow rate	0.2LPM
Wetted area after 25 minutes	1425cm²
Volume of water discharged after 25 minutes	7125cm³
Volume of Water Retained	0cm³
Discussion	The water spread begin from bottom to top.



Type of Sample	Peat soil
Volume of sample	12500cm³
Water Flow rate	0.4LPM
Wetted area after 25 minutes	2500cm²
Volume of water discharged after 25 minutes	20000cm³
Volume of Water Retained	7500cm³
Discussion	There are some peat soil being lifted up by the water. This may be because of the low compaction of the soil inside the model tank.