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THESIS

**EFFECTS OF SOIL MOISTURE CONTENT ON WATER TABLE
UNDER DIFFERENT LAND USES AT BAN THUNG SOONG
VILLAGE, AO LUEK DISTRICT, KRABI PROVINCE,
THAILAND**

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**A Thesis Submitted in Partial Fulfillment of
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Sureeporn Khemmook 2009: Effects of Soil Moisture Content on Water Table under Different Land Uses at Ban Thung Soong Village, Ao Luek District, Krabi Province, Thailand. Master of Science (Watershed and Environmental Management), Major Field: Watershed and Environmental Management. Thesis Advisor: Associate Professor Wicha Niyom, Ph.D. 130 pages.

Study on effects of soil moisture content (SMC) affected on water table (WT) under different land use practices (oil palm plantation, para rubber plantation and mixed fruit orchard) was investigated at Ban Thung Soong, Ao Luek district in Krabi Province. SMC was studied by the gravimetric method expressed as percent of dry soil at various soil depth levels i.e., 0-25, 25-50, 50-75 and 75-100 cm, respectively. Water table (WT) was monthly measured to determine level of ground water table in shallow wells monthly during November 2006 to October 2007. The objectives of this study were to observe the dependence of monthly SMC on water table levels in different seasons in each land use types, to study the changing of water in shallow water wells.

Results showed that mixed fruit orchard had the highest SMC at all levels of soil depth while oil palm plantation had the lowest SMC. Water table under mixed fruit orchard was found the highest and para rubber plantation had been the lowest.

In dry seasons, the linear relationship between SMC and WT was found by which the R^2 of mixed fruit orchard, oil palm plantation and para rubber plantation were 0.98, 0.87 and 0.80 respectively. In wet season, the relationship was however insignificant. And in dry seasons, the highest value of relationship between total rainfall 5 days before data collection and WT. The R^2 of mixed fruit orchard, oil palm plantation and para rubber plantation were 0.98, 0.95 and 0.94 respectively.

The relationship of SMC and WT in dry season were highly significant in period lowest SMC and water table. Ground cover such as legume (*Pueraria phaseoloides*) and short grass should be used to protect water in soil and water table to decrease gradually in dry season.

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Student's signature Thesis Advisor's signature

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Ms. Sureeporn Khemmook

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EFFECTS OF SOIL MOISTURE CONTENT ON WATER TABLE UNDER DIFFERENT LAND USES AT BAN THUNG SOONG VILLAGE, AO LUEK DISTRICT, KRABI PROVINCE, THAILAND

INTRODUCTION

Climate changes and unexpected climatic condition during the present decade has recognized from the low annual rainfall and the increasing number of drought villages in different regions of Thailand. In another case, heavy rainfall has caused severe flood and caused landslides, mudslides, and also human lives. The central governments have to prepare contingency fund to tackle the problem of droughts and floods and this reflect the need of nature restoration and resources management through people participation.

Soil moisture is one of the important factors in watershed management. Because the water that keep in soil will be loosen to stream in the raining times and surface runoff don't have influence to this water flow. Not only, trees and plants that grow on soil but organic matters that accumulate on soil top has effected on soil moisture content. Different soil types has influenced on moisture availability differently through their water absorption and water holding capacity. Under the natural condition, trees and plants covering plants and litters is generally provide good water absorption and promote water holding capacity. The changing of forest cover and forest fire has given the bare soil has direct contact to rainfall and this cause erosion and siltation.

The disturbance of forest ecosystem has been reported to be caused by human factors through their involvements in shifting cultivation, slash and burn practices, changing forest land for farm practices by cultivating cash crops, illegal logging, and land settlement. The expansion of cultivated area also promoted more water uses. It is thus importance to study how different types of land uses have influenced to the water availability all year round.

In Andaman seacoast, flood and water shortage have been reported. In Khao Yai Subdistrict, only Ban Thung Soong Village (Village Number 4 of Ao Luek District in Krabi Province) has water availability all year round. Water supply from Ban Thung Soong Village is generally conducted in every summer to the nearby villages. The village has Ban Thung Soong Community Forest for Ecotourism and intensive agro-forestry farming practices as well as settled cash crop plantation of rubber, oil palm and mixed fruit orchards.

OBJECTIVES

1. To study soil moisture content under 3 land use types ; oil palm plantation, para rubber plantation and mixed fruit orchard.
2. To study the changing of water table in shallow wells under 3 land use types; oil palm plantation, para rubber plantation and mixed fruit orchard in different seasons.
3. To study relationship between soil moisture content and water table under 3 land use types; oil palm plantation, para rubber plantation and mixed fruit orchard.
4. To study relationship between accumulate rainfall and water table in each times under 3 land use types; oil palm plantation, para rubber plantation and mixed fruit orchard over the mentioned period.
5. To develop guidelines for water resource management practices for self reliance system and improving the people livelihood.

LITERATURE REVIEW

1. Soil Moisture Content

The soil moisture content has an important effect on soil thermal properties, soil heat flow, and vegetation. It is thus considered to be a critical parameter in analyzing the magnitude and variability of summer thaw. At many locations, and especially those with a thick organic materials or litter falls, the soil moisture content in the upper soil layer varies greatly over time (precipitation events, evaporation) and space. (Department of Soil, 1998)

Thus, most measurements of SMC should be collected beneath the organic matter, near the upper part of the mineral soil horizon. If possible, all measurements should be made at a depth of 15-20 cm. Water has a very different thermal conductivity than most soil particles and air (the thermal properties of the soil are determined by these three). The thermal conductivity of water is much greater than that of air, so the higher the soil moisture content the greater the thermal conductivity. The greater the soil moisture content, the more the soil thermal conductivity is like that of water. Therefore, a saturated soil has conductivity near that of water. However, just because the soil moisture content is high, doesn't mean that the soil will warm up faster in the sun than a dry soil. Evaporation of the water will remove much of the Sun's energy before the soil will have a chance to warm. Therefore, dry soils do warm up faster from sunlight and cool faster at night. This is assuming that there isn't a vegetation cover over the soil. Most wet soils evaporate the water, keeping the soil from warming as fast during the day, and cool more slowly at night because of their greater heat capacity (because of the higher water content). (Troeh and Donahue, 1999)

Soils that are better at holding water in them (reducing evaporation), such as clays and peat, are the exception to the above; they may not evaporate as much water and therefore do heat up in the sun, and do not loose as much energy at night. In the

swamp area, peat bogs are often very warm, although part of that energy comes from rapidly occurring rotting of organic matters.

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Soils that are better at holding water in them (reducing evaporation), such as clays and peat, are the exception to the above; they may not evaporate as much water and therefore do heat up in the sun and do not lose as much energy at night. Peat bogs are often very warm, although part of that energy comes from rapidly occurring rotting of organic matter. Wet clays can also become very warm in the sun.

Soil moisture content is appearing in 2 states such as liquid state or soil water and gas state or soil water vapor that in tropical area will meet in liquid state because of in the steam flow include a polar compound that made the molecular of water has cat ion and anion interaction (Department of Soil, 1998). Water in soil is not pure water because in molecule of water including of many compounds and ions. When the

water was full in the space of soil was called saturated soil and if the water fill in some of space was called unsaturated soil.

Water in soil can be divided in 2 parts consisting of the first part is the soil moisture. The water in this part is keeping by gravity of soil grain and the other part, water that soil can not be kept will be absorbed to ground water level that in this part was called gravitational water. In both parts water will be keeping in ground water level and can flow to basin by the gravity.

Department of Soil (1998) and Niyom (1992) classified soil moisture content into 4 types, as follows:

1) Chemical combined water was appearing in water of crystallization or water of hydration. It is the chemical combined in solid of soil. In oven dry soil at 105-110 °C in 24 hours can be still detected this moisture. This soil moisture content was not available to plant.

2) Hygroscopic water was appearing in layer of water molecule that made this soil moisture content was not available to plant.

3) Capillary water was appearing in the next layer of water molecule and in the micro pores of soil. This water was available to plant.

4) Gravitational water or drainage water was the water in macro pores. It's has influent of global graviton that made this water was not available to plant.

In fact, soil moisture content can not be estimated in all types (Chankao, 1996 and Niyom, 1992) as caused by the difference of soil level of each types (Figure 1), including:

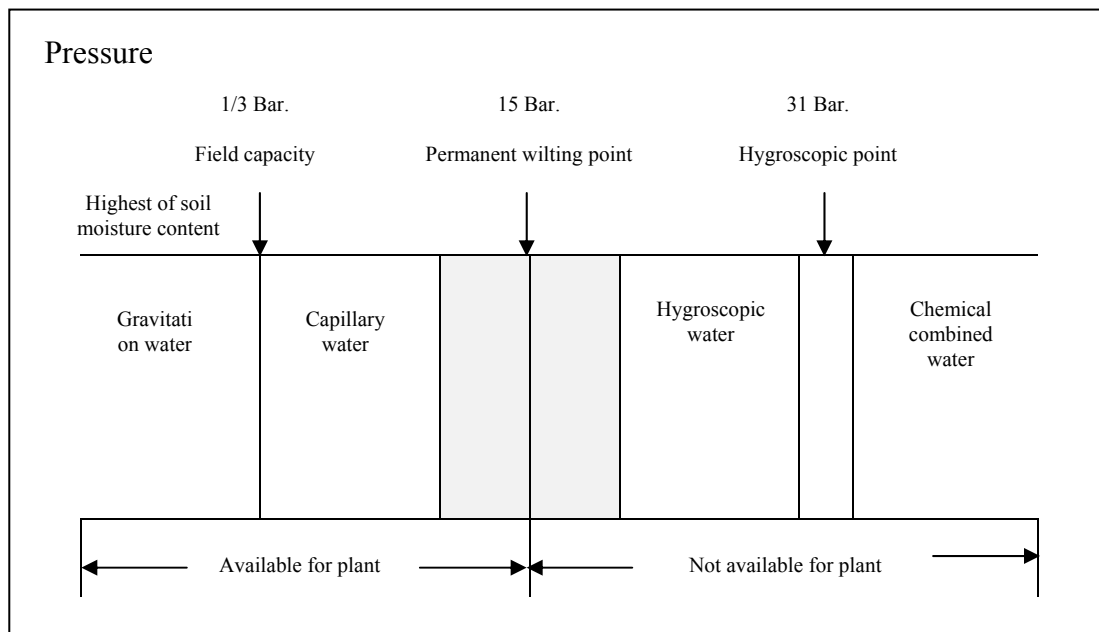


Figure 1 Characteristic of soil moisture content in available form and level.

Source : Applied from Tangtham (1999)

1) Hygroscopic coefficient is the hygroscopic water

The percentage of water that a soil will absorb and hold in equilibrium in a saturated atmosphere. After the soil has been air-dried and the soil has reached equilibrium with an unspecified environment of high relative humidity, usually near saturation, or with a specified relative humidity at a specified temperature.

2) Permanent Wilting Point (PWP)

Permanent Wilting Point (PWP) is defined as the minimal point of soil moisture the plant requires not to wilt. If moisture decreases to this or any lower point a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. The physical definition of the wilting point is defined as the water content at -1500 J/kg (or -15 bars) of suction pressure, or negative hydraulic head.

3) Field capacity

Field capacity is the amount of soil moisture or water content held in soil after excess water has drained away and the rate of downward movement has materially decreased, which usually takes place within 2–3 days after a rain or irrigation in previous soils of uniform structure and texture. The physical definition of field capacity is the bulk water content retained in soil at -33 J/kg (or -0.33 bar) of hydraulic head or suction pressure.

4) Maximum Water Holding Capacity (MWHC)

The water holding capacity is calculated based on the weight of the water held in the sample vs. the dry weight of the sample. The water holding capacity of a soil is a very important agronomic characteristic. Soils that hold generous amounts of water are less subject to leaching losses of nutrients or soil applied pesticides. This is true because a soil with a limited water holding capacity (i.e. a sandy loam) reaches the saturation point much sooner than a soil with a higher water holding capacity (i.e. a clay loam). After a soil is saturated with water, all of the excess water and some of the nutrients and pesticides that are in the soil solution are leached downward in the soil profile.

1.1 Measurement of soil moisture content

1.1.1 Gravimetric method

The soil moisture content may be expressed by weight as the ratio of the mass of water present to the dry to the dry weight of the soil sample, or by volume as ratio of volume of water to the total volume of the soil sample. To determine any of these ratios for a particular soil sample, the water mass must be determined by drying the soil to constant weight and measuring the soil sample mass after and before drying. The water mass (or weight) is the difference between the weights of the wet and oven dry samples. The criterion for a dry soil sample is the soil sample that has

been dried to constant weight in oven at temperature between 100 – 110 °C (105 °C is typical). It seems that this temperature range has been based on water boiling temperature and does not consider the soil physical and chemical characteristics. (Black, 1965). The procedure in determining the soil moisture content is shown below:

- 1) Weigh aluminum tin, and record this weight (tare).
- 2) Place a soil sample of about 10 gram in the tin and record this weight as wet soil plus tare.
- 3) Place the sample in the oven 110 °C and dry for 24 hours and leave it out the oven until the temperature release to the air temperature.
- 4) Weigh the sample and record this weight as weight of dry soil plus tare.
- 5) Return the sample to the oven and dry for several hours, and determine the weight of dry soil plus tare.
- 6) Repeat step 5 until there is no difference between any two consecutive measurements of the weight of dry soil plus tare.

The moisture content in dry weight basis may be calculated using the following formula:

$$\theta_d = \frac{(\text{wt of wet soil}) - (\text{wt of dry soil})}{(\text{wt of dry soil})}$$

In some literature the moisture content is expressed in wet weight basis that is defined as the ratio between water mass and the mass of wet soil (θ_w). (Black, 1965)

1.1.2 Tensiometer

A tensiometer is a device used to determine matric water potential

Ψ_m (soil moisture tension) in the vadose zone. The tensiometer consists of a glass or plastic tube with a porous ceramic cup, and is filled with water. The top of the tube has either a built-in vacuum gauge or a rubber cap used with a portable puncture tensiometer instrument, which uses a hypodermic needle to measure the pressure inside the tensiometer. The tensiometer is buried in the soil, and a hand pump is used to pull a partial vacuum. As water is pulled out of the soil by plants and evaporation, the vacuum inside the tube increases. As water is added to the soil, the vacuum inside the tube pulls moisture from the soil and decreases. The actual gauge reading will vary according to the type of soil, the moisture content, and due to hysteresis, according to the saturation history of the soil.

Tensiometers are used in irrigation scheduling to help farmers and other irrigation managers to determine when to water. In conjunction with a water retention curve, tensiometers can be used to determine how much to water. With practice, a tensiometer can be a useful tool for these purposes. Tensiometers can also be used in the scientific study of soils and plants

1.1.3 Electric resistance block

The Electrical Resistance Method uses a small block that changes resistance as soil moisture changes. The block is buried in the soil and lead wires connected to the block are brought above ground level. When the meter is connected to the wire leads, block resistance is read. The reading is related to the moisture content of the soil. The drier the soil, the greater the electrical resistance and vice-versa. Reading the resistance of the block with a portable meter gives the user a measure of the amount of water in the root zone.

Most blocks are constructed of wires or a wire grid embedded in a gypsum material. The block may be entirely gypsum or covered with a porous material such as sand, fiberglass, or ceramic. After burial, the moisture block comes to equilibrium with the soil moisture. Figure 1 is a diagram of a common block.

Meters are portable and are intended for use in reading a large number of blocks throughout one or more fields. The specially designed meters can be either analog or digital. The readings on the meter are calibrated to give reading that relate to the soil moisture content. One meter brand may not work with a different brand of block.

Resistance Block Methods are suitable for most soils, and the readings cover most of the soil moisture ranges of concern to irrigation management. The blocks tend to deteriorate over time, and it may be best to use them for only one season. Problems may occur with highly acid or highly saline soils.

1.1.4 Neutron Moisture Meter

The Neutron Moisture Meter consists of a probe connected by cabling to a logger. The probe is lowered down an access tube in contact with the surrounding soil. The tube is usually thin-walled aluminium but in this case it is thicker Polyvinyl Chloride (PVC).

The Neutron Moisture Meter probe contains a slow neutron detector and a radioactive source (Americium Berellium $^{241}\text{AmBe}$) that emits fast neutrons. These are absorbed, deflected and thermalised (slowed) by the surrounding material. Hydrogen (H) thermalises neutrons most effectively as the atoms' similar size results in an energy losing elastic collision. Oxygen (O), nitrogen (N) and carbon (C) are also relatively efficient thermalisers, however, roughly 6-8 times more collisions are required than hydrogen.

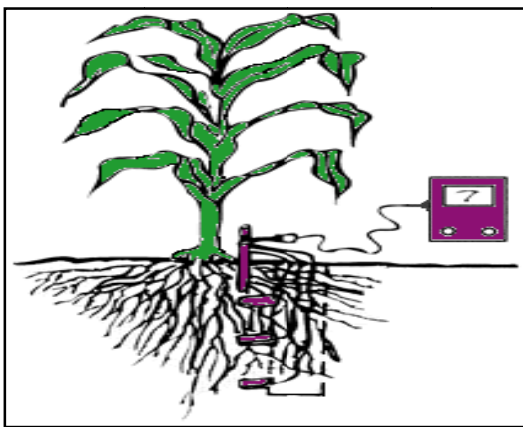
Consequently, the number of thermalised neutrons deflected back to the Neutron Moisture Meter is directly proportional to the amount of water (H_2O) present in the surrounding soil (but also depends on the presence of trace elements, tubing material, and soil density). The sphere of influence of the Neutron Moisture Meter depends on the wetness of the soil and varies from 15-50 centimeter in wet and dry conditions respectively.



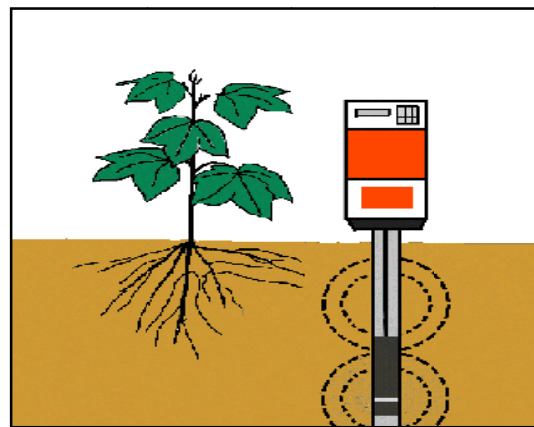
(a) Gravimetric Method



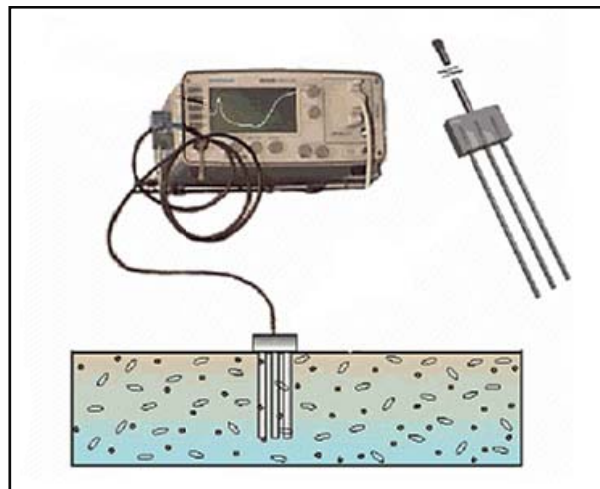
(b) Tensiometer



(c) Neutron Moisture Meter



(d) Electric Resistance Block



(e) Time Domain Reflectometry (TDR)

Figure 2 Materials for soil moisture content measurement.

Source: Rahula (2004).

1.1.5 Time Domain Reflectometry (TDR)

A time-domain reflectometer (TDR) is an electronic instrument used to characterize and locate faults in metallic cables (for example, twisted wire pairs, coaxial cables). It can also be used to locate discontinuities in a connector, printed circuit board (PCB), or any other electrical path. The equivalent device for optical fiber is an optical time-domain reflectometer.

A TDR transmits a short rise time pulse along the conductor. If the conductor is of a uniform impedance and properly terminated, the entire transmitted pulse will be absorbed in the far-end termination and no signal will be reflected toward the TDR. Any impedance discontinuities will cause some of the incident signal to be sent back towards the source. This is similar in principle to radar.

Increases in the impedance create a reflection that reinforces the original pulse whilst decreases in the impedance create a reflection that opposes the original pulse. The resulting reflected pulse that is measured at the output/input to the TDR is displayed or plotted as a function of time and, because the speed of signal propagation is relatively constant for a given transmission medium, can be read as a function of cable length.

Because of this sensitivity to impedance variations, a TDR may be used to verify cable impedance characteristics, splice and connector locations and associated losses, and estimate cable lengths.

1.2 Factor of Soil moisture content change

1.2.1 Soil Texture

Soil texture is a soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil. Particles are grouped according to their size into what are called soil separates. These separates are typically named clay, silt, and sand. Soil texture classification is based on the fractions of soil

separates present in a soil. The soil texture triangle is a diagram often used to figure out soil textures.

Soil separates are specific ranges of particle sizes. In the United States, the smallest particles are clay particles and are classified by the USDA as having diameters of less than 0.002 mm. The next smallest particles are silt particles and have diameters between 0.002 mm and 0.05 mm. The largest particles are sand particles and are larger than 0.05 mm in diameter. Furthermore, large sand particles can be described as coarse, intermediate as medium, and the smaller as fine. Other countries have their own particle size classifications.

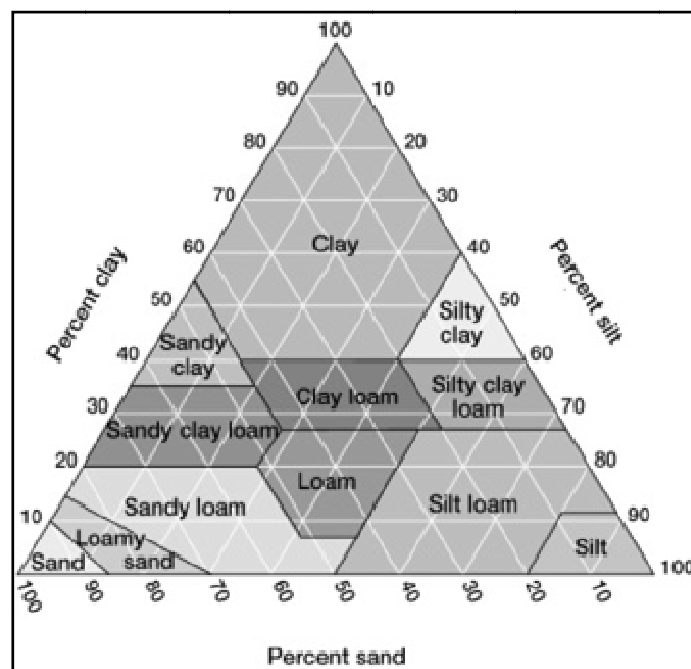


Figure 3 Soil texture classifications.

Source: Department of Soil (1998).

Soil texture triangle, showing the 12 major textural classes, and particle size scales as defined by the USDA.

Soil textures are classified by the fractions of each soil separate (sand, silt, and clay) present in a soil. Classifications are typically named for the primary constituent particle size or a combination of the most abundant particles sizes, e.g. sandy clay or silty clay. A fourth term, loam, is used to describe a roughly equal concentration of sand, silt, and clay, and lends to the naming of even more classifications, e.g. clay loam or silt loam.

In the United States, twelve soil texture classifications are defined by the USDA: Clay, Silt, Sand, Loam, Silty clay, Sandy clay, Clay loam, Silt loam, Sandy Loam, Loamy sand, Silty clay loam, Sandy clay loam. Determining the soil textures is often aided with the use of a soil texture triangle.

1.2.2 Soil Structure

Soil structure is determined by how individual soil granules clump or bind together and aggregate, and therefore, the arrangement of soil pores between them. Soil structure has a major influence on water and air movement, biological activities, root growth and seedling emergence.

Soil structure describes the arrangement of the solid parts of the soil and of the pore space located between them (Marshall & Holmes, 1979). It is dependent on: what the soil developed from; the environmental conditions under which the soil formed; the clay present, the organic materials present; and the recent history of land management.

Charman and Murphy (1998) considered soil to be of good structure, from an agricultural perspective, when it is of “an aggregated, low density/high porosity condition”. However, strict definition of good, from either an agricultural or catchment perspective, is not straight forward. We can say though that a well structured soil will enable robust biological activity by readily accepting, storing, and transmitting water, gases, nutrients, and energy; and by providing adequate and suitable surfaces and space for life and biochemical exchanges.

Aggregation of primary soil particles is a critical determinant of soil structure. Clay colloids - minute particles (diameters smaller than 2 micrometres) play a significant role in aggregation between the full range of soil particles (Leeper and Uren, 1993). Adhesion between particles is via electrostatic force (flocculation) or cementing substances, such as organic matter and minerals.

Other factors important in considering soil structure are: the stability of aggregates under wetting and drying conditions; the stability of aggregates to physical disturbance; the fabric and nature of the aggregates; and the profile form (referring to variation in the layers throughout the soil profile).

1.2.3 Organic Matter

Organic matter is matter that has come from a once-living organism; is capable of decay, or the product of decay; or is composed of organic compounds. The definition of organic matter varies upon the subject it is being used for.

Soil organic matter is mainly composed of minerals and organic matter, like decaying plants and animals, as well as living organisms. The minerals are derived from the weathering of parent material - bedrock and overlying sub-soil. The organic matter in soil derives from plants and animals. In a forest, for example, leaf litter and woody material falls to the forest floor. This is sometimes referred to as organic material. When it decays to the point in which it is no longer recognizable it is called soil organic matter. When the organic matter has broken down into a stable humic substances that resist further decomposition it is called humus. Thus soil organic matter comprises all of the organic matter in the soil exclusive of the undecayed material.

Organic matter may refer to materials either of plant or animal origin which were once part of a living organism or produced by a living organism. This definition is synonymous with biotic material, and would include a clam's shell and naturally produced urea, while excluding synthetically produced urea. While this

definition is useful for modeling nutrient flows, it is not useful in measuring the organic content of soil.

1.2.4 Soil Depth

The effective depth of a soil for plant growth is the vertical distance into the soil from the surface to a layer that essentially stops the downward growth of plant roots. The barrier layer may be rock, sand, gravel, heavy clay, or a cemented layer.

Soils that are deep, well-drained, and have desirable texture and structure are suitable for the production of most garden or landscape plants. Deep soils can hold more plant nutrients and water than can shallow soils with similar textures. Depth of soil and its capacity for nutrients and water frequently determine the yield from a crop, particularly annual crops that are grown with little or no irrigation. Plants growing on shallow soils also have less mechanical support than those growing in deep soils. Trees growing in shallow soils are more easily blown over by wind than are those growing in deep soils

1.2.5 Soil moisture

Soil moisture content is the quantity of water contained in a material, such as soil (called soil moisture), rock, ceramics, or wood on a volumetric or gravimetric basis. The property is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation.

Volumetric water content, θ , is defined mathematically as: where V_w is the volume of water and $V_T = V_s + V_v = V_s + V_w + V_a$ is the total volume (that is Soil Volume + Water Volume + Void Space). Water content may also be based on its mass or weight, thus the gravimetric water content is defined as: where m_w is the mass of water and m_b (or m_s for soil) is the bulk material mass. To convert

gravimetric water content to volumetric water, multiply the gravimetric water content by the bulk specific gravity of the material.

In saturated groundwater aquifers, all available pore spaces are filled with water (volumetric water content = porosity). Above a capillary fringe, pore spaces have air in them too.

Most soils have a water content less than porosity, which is the definition of unsaturated conditions, and they make up the subject of vadose zone hydrogeology. The capillary fringe of the water table is the dividing line between saturated and unsaturated conditions. Water content in the capillary fringe decreases with increasing distance above the phreatic surface.

One of the main complications which arises in studying the vadose zone, is the fact that the unsaturated hydraulic conductivity is a function of the water content of the material. As a material dries out, the connected wet pathways through the media become smaller, the hydraulic conductivity decreasing with lower water content in a very non-linear fashion.

A water retention curve is the relationship between volumetric water content and the water potential of the porous medium. It is characteristic for different types of porous medium. Due to hysteresis, different wetting and drying curves may be distinguished.

1.2.6 Land Cover

Land cover is the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. There are two primary methods for capturing information on land cover: field survey and thorough analysis of remotely sensed imagery. The nature of land cover is discussed in Comber *et al.* (2005). Land covers surrounding Madison, WI. Fields are colored yellow and brown, water is colored blue, and urban surfaces are colored red.

Land cover is distinct from land use despite the two terms often being used interchangeably. Land use is a description of how people utilize the land and socio-economic activity - urban and agricultural land uses are two of the most commonly recognised high-level classes of use. At any one point or place, there may be multiple and alternate land uses, the specification of which may have a political dimension. The origins of the land cover / land use couplet and the implications of their confusion are discussed in Fisher *et al.* (2005).

One of the major land cover issues (as with all natural resource inventories) is that every survey defines similarly named categories in different ways. For instance there are many definitions of Forest, sometimes within the same organization, that may or may not incorporate a number of different forest features (stand height, canopy cover, strip width, inclusion of grasses, and rates of growth for timber production). Areas without trees may be classified as forest cover if the intention is to re-plant areas with many trees may not be labeled as forest if the trees are not growing fast enough.

Per capita greenhouse gas emissions by country not including land use change. The extent and type of land use directly affects wildlife habitat and thereby impacts local and global biodiversity. Human alteration of landscapes from natural vegetation (e.g. wilderness) to any other use typically results in habitat loss, degradation, and fragmentation, all of which can have devastating effects on biodiversity. Land conversion is the single greatest cause of extinction of terrestrial species

Of particular concern is deforestation, where logging or burning are followed by the conversion of the land to agriculture or other land uses. Even if some forests are left standing, the resulting fragmented landscape typically fails to support many species that previously existed there.

1.2.7 Topography

Topography is the study of Earth's surface shape and features or those of planets, moons, and asteroids. It is also the description of such surface shapes and features (especially their depiction in maps).

The topography of an area can also mean the surface shape and features themselves. In a broader sense, topography is concerned with local detail in general, including not only relief but also vegetative and human-made features, and even local history and culture.

However, topography specifically involves the recording of relief or terrain, the three-dimensional quality of the surface, and the identification of specific landforms. This is also known as geomorphometry. In modern usage, this involves generation of elevation data in electronic form. It is often considered to include the graphic representation of the landform on a map by a variety of techniques, including contour lines, Hypsometric tints, and relief shading.

1.2.8 Rainfall

Rain is liquid precipitation. On Earth, it is the condensation of atmospheric water vapor into drops heavy enough to fall, often making it to the surface. Rain is the primary source of fresh water for most areas of the world, providing suitable conditions for diverse ecosystems, as well as water for hydroelectric power plants and crop irrigation. However, not all rain reaches the surface; some evaporates while falling through dry air. This is called virga, a phenomenon often seen in hot, dry desert regions. The METAR code for rain is RA.

Rain is also known or suspected on other worlds. On Titan, infrequent methane rain is thought to carve that moon's numerous surface channels. On Venus, sulfuric acid virga evaporates 25 km. from the surface. There is likely to

be rain of various compositions in the upper atmospheres of the gas giants, as well as precipitation of liquid neon and helium in the deep atmospheres.

Rain plays a role in the hydrologic cycle in which moisture from the oceans evaporates, condenses into drops, precipitates (falls) from the sky, and eventually returns to the ocean via rivers and streams to repeat the cycle again. The water vapor from plant respiration also contributes to the moisture in the atmosphere.

A major scientific explanation of how rain forms and falls is called the Bergeron process. More recent research points to the influence of Cloud condensation nuclei released as the result of biological processes.

Precipitation, especially rain, has a dramatic effect on agriculture. All plants need at least some water to survive; therefore rain (being the most effective means of watering) is important to agriculture. While a regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, even devastating to crops. Drought can kill crops in massive numbers, while overly wet weather can cause disease and harmful fungus. Plants need varying amounts of rainfall to survive. For example, cacti need small amounts of water while tropical plants may need up to hundreds of inches of rain per year to survive.

Agriculture of all nations at least to some extent is dependent on rain. Indian agriculture, for example, (which accounts for 25 percent of the GDP and employs 70 percent of the nation's population) is heavily dependent on the rains, especially crops like cotton, rice, oilseeds and coarse grains. A delay of a few days in the arrival of the monsoon can, and does, badly affect the economy, as evidenced in the numerous droughts in India in the 90s.

1.3 Related Study of Soil moisture content

Makarabhiromya (1979) study characteristic of soil hydrology that related with stream flow in dry season on evergreen forest in the north of Thailand and found that the highest of soil moisture content is in the 0 – 5 cm. and decrease with soil depth.

Khereemangkla (1999) study of soil moisture content variation under various ages of Teak Plantations at FIO Thong Pha Phum Plantation in Kanchanaburi Province. The result showed that Mixed Deciduous Forest had the highest soil moisture content at all levels of soil depth.

Rahula (2004) studied soil moisture variation under cassava field in Khon Buri District in Nakhon Ratchasima Province by using of TDR (Time Domain Reflectometry) to measure daily soil moisture at the depth levels of 0-5, 5-20, 20-60, 60-100, 100-160 and 160-220 cm respectively. Results showed that the average maximum daily soil moisture was 40.3 percent by volume in September, and the average minimum daily soil moisture was 18.4 percent by volume, in February. The greatest variation of daily soil moisture was found at 0-5 cm and 5-20 cm of soil depths.

2. Water Table

Most people know that the "water table" has something to do with ground water. The word table provides an image of a flat surface, like a tabletop, and it is commonly assumed that when a well is drilled it strikes water once it reaches below the water table. There is also a general understanding that in times of serious drought, water table levels may drop and wells may run dry. Understanding the terminology used to describe sub-surface water can help explain why water tables may rise and fall.

Ground water is sub-surface water, but not all sub-surface water is ground water. Having an appreciation of the types of sub-surface water and knowledge of local geology can explain why some water table levels may vary by tens of feet and others in the same area may only change by inches and some hardly at all. The upper surface of ground water is the water table. Below this surface, all the pore spaces and cracks in sediments and rocks are completely filled (saturated) with water. These saturated layers, known as the saturated zone (or the phreatic zone), are where ground water occurs. Strictly speaking only water found in the saturated zone is ground water. (Sriboonlue, 1987)

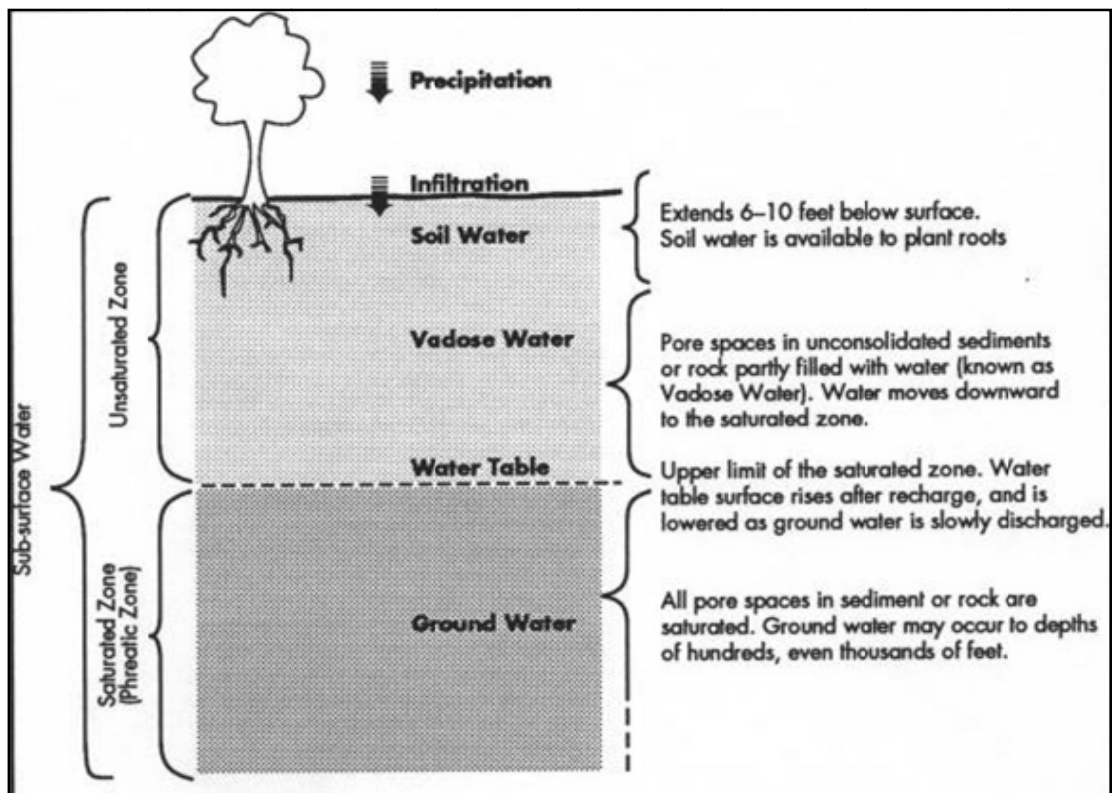


Figure 4 Sub-surface water zone and processes.

Source : Sriboonlue (1987).

In the top layers of soil, unconsolidated sediments or bedrock, pore spaces may not be completely filled with water. Some may contain water, some air, and some may only be partly filled with water. This is known as the unsaturated zone (also called the zone of aeration or the vadose zone). After heavy rainfall, this zone may be almost saturated, while during a long dry spell, it may become almost dry. Precipitation infiltrates downwards through the unsaturated zone. This infiltrating water is known as soil water when it is still shallow enough to be used by plants, and as vadose water when it is below root level, but still unsaturated. With further infiltration however, excess water will eventually reach the water table.

The vertical distance from the ground surface to the water table varies from place to place - it may be a few feet, or several hundred feet. Generally, the water table is deeper beneath hills and shallower beneath valleys. In any one place the water table usually rises with increased recharge from precipitation and declines in response to seasonally dry weather, drought, or excessive pumping of ground water. If however the water table is hundreds of feet down, it may take years for the infiltrating water to reach the saturated zone and there will be no seasonal change in water table levels. If ground water is "confined" by overlying impermeable rock formations, the well water levels represent a pressure level and not a water table level.

The spaces between soil or sediment particles and cracks in solid rock are called voids or pores. Each sediment and rock type has differences in porosity, (the amount of water a rock formation can hold). Porosity is expressed as the ratio of pore space to solid material per unit volume. For example, saturated sand may have 30% pore space to 70% solid material, while fractured granite may have 1% pore space to 99% solid rock. The sand is therefore more porous than the fractured granite.

Imagine a cubic foot of granite and a cubic foot of sand with porosity of 1% and 30%. Now add water to each. The granite will "fill up" first because there is less pore space. If it were a real aquifer, the water table level in the granite would rise faster. Similarly, because there is less storage than in the sand, the fractured granite water table would decline more rapidly in response to pumping or drought. Ground

water is always on the move, although usually very slowly. The discharge (or outflow) of water from aquifers occurs as part of the natural movement of water in the hydrologic system. Water table levels in aquifers therefore represent the combined effects of rates of recharge and rates of discharge. If pumping of aquifers takes place in excess of recharge then resource use will eventually not be sustainable. Careful monitoring of water levels in wells can show how water table levels change, and well data, with water levels and dates of the measurement are very important for ground water management. (Gardner, 1986)

For any well data however it is very important to know exactly which rock formations the well penetrates. There can be more than one aquifer beneath the surface! Water table information, in addition to other information about geology, precipitation and pumping rates are of great value when assessing ground water potential.

The water table is the level at which the ground water pressure is equal to the atmospheric pressure. It may be conveniently visualized as the 'surface' of the ground water in given vicinity. It usually coincides with the phreatic surface, but can be many feet above it. As water infiltrates through pore spaces in the soil, it first passes through the zone of aeration, where the soil is unsaturated. At increasing depths water fills in more spaces, until the zone of saturation is reached. This relatively horizontal plane atop this zone constitutes the 'water table'.

2.1 Ground Water and Subsurface Water

Most rock or soil near the earth's surface is composed of solids and voids. The voids are spaces between grains of sand, or cracks in dense rock. All water beneath the land surface occurs within such void spaces and is referred to as underground or subsurface water. Subsurface water occurs in two different zones. One zone, located immediately beneath the land surface in most areas, contains both water and air in the voids. This zone is referred to as the unsaturated zone. Other names for the unsaturated zone are zone of aeration and vadose zone. (GWAC, 1986)

The unsaturated zone is almost always underlain by a second zone in which all voids are full of water. This zone is defined as the saturated zone. Water in the saturated zone is referred to as ground water and is the only subsurface water available to supply wells and springs.

Water table is often misused as a synonym for ground water. However, the water table is actually the boundary between the unsaturated and saturated zones. It represents the upper surface of the ground water. Technically speaking, it is the level at which the hydraulic pressure is equal to atmospheric pressure. The water level found in unused wells is often the same level as the water table, as shown in Figure 5.

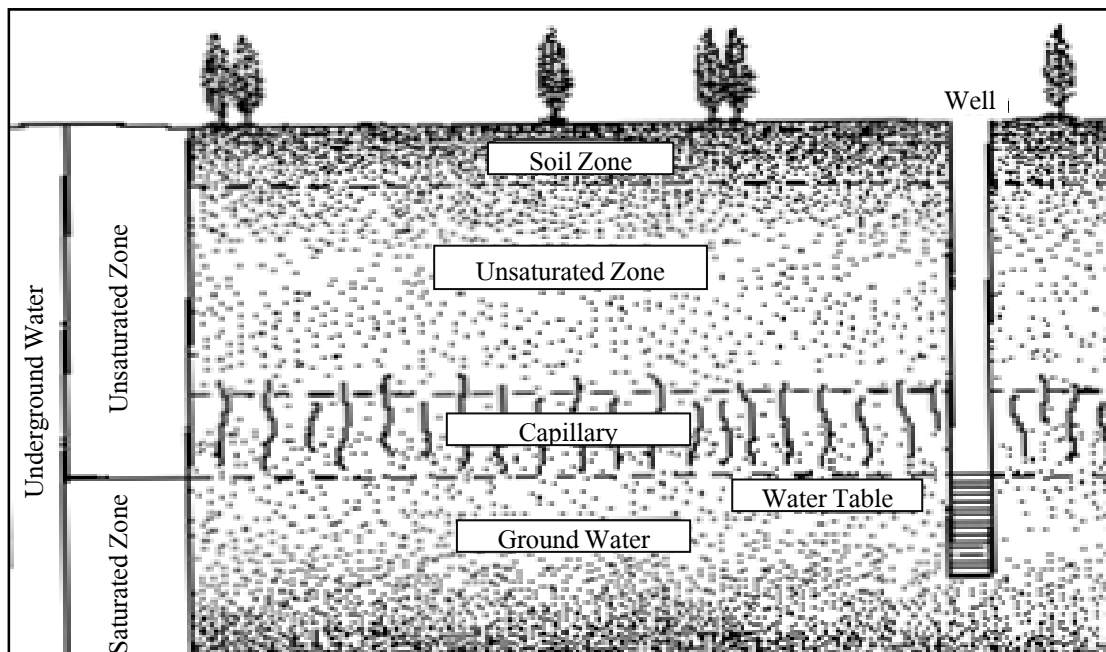


Figure 5 Zones of Underground Water.

Source: GWAC (1986).

2.2 Aquifers and Confining Beds

All geologic material beneath the earth's surface is either a potential aquifer or a confining bed. An aquifer is a saturated geologic formation that will yield a usable quantity of water to a well or spring. A confining bed is a geologic unit which is relatively impermeable and does not yield usable quantities of water. Confining beds also referred to as aquitards, restrict the movement of ground water into and out of adjacent aquifers.

Ground water occurs in aquifers under two conditions: confined and unconfined. A confined aquifer is overlain by a confining bed, such as an impermeable layer of clay or rock. An unconfined aquifer has no confining bed above it and is usually open to infiltration from the surface. Unconfined aquifers are often shallow and frequently overlie one or more confined aquifers. They are recharged through permeable soils and subsurface materials above the aquifer. Because they are usually the uppermost aquifer, unconfined aquifers are also called water table aquifers. (GWAC, 1986)

Confined aquifers usually occur at considerable depth and may overlie other confined aquifers. They are often recharged through cracks or openings in impermeable layers above or below them. Confined aquifers in complex geological formations may be exposed at the land surface and can be directly recharged from infiltrating precipitation. Confined aquifers can also receive recharge from an adjacent highland area such as a mountain range. Water infiltrating fractured rock in the mountains may flow downward and then move laterally into confined aquifers.

The water level in a confined aquifer does not rise and fall freely because it is bounded by the confining bed-like a lid. Being bounded causes the water to become pressurized. In some cases, the pressure in a confined aquifer is sufficient for a well to spout water several feet above the ground. Such wells are called flowing artesian wells. Confined aquifers are also sometimes called artesian aquifers.

When a well is drilled into an unconfined aquifer, its water level is generally at the same level as the upper surface of the aquifer. This is in most cases the water table. By contrast, when a well is drilled into a confined aquifer, its water level will be at some height above the top of the aquifer and perhaps above the surface of the land—depending on how much the water is pressurized. If a number of wells are drilled into a confined aquifer, the water level will rise in each well to a certain level. These well levels form an imaginary surface called the potentiometric surface. The potentiometric surface is to a confined aquifer what the water table is to an unconfined aquifer. It describes at what level the upper surface of a confined aquifer would occur if the confining bed were removed (Figure 6)

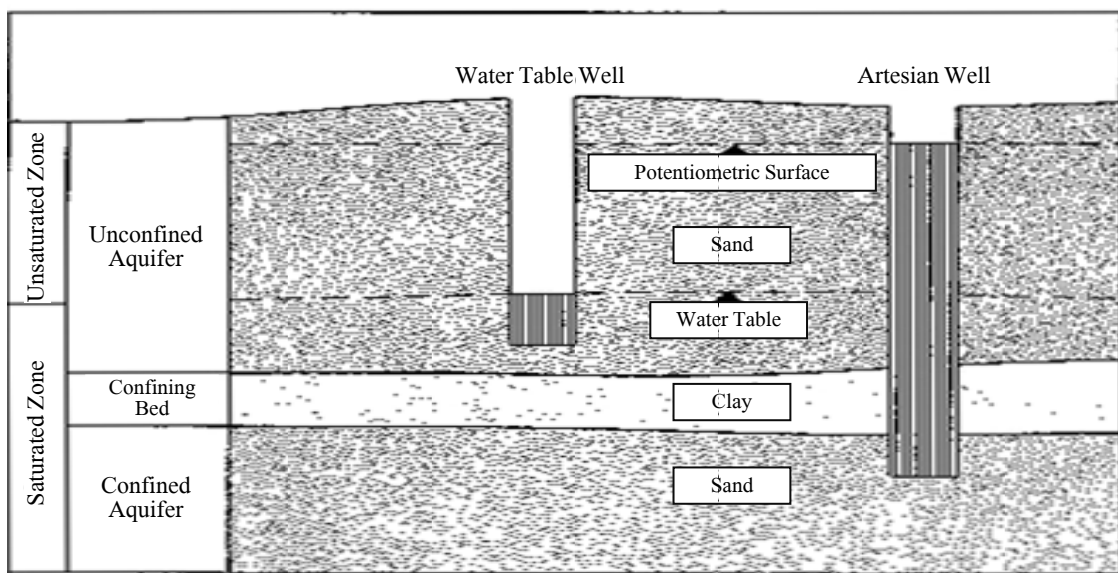


Figure 6 Aquifers and Confining Beds.

Source: GWAC (1986).

The most productive aquifers, whether confined or unconfined, are generally in sand and gravel deposits. These tend to have large void spaces for holding water. Rocks with large openings such as solution cavities or fractures can also be highly productive aquifers. Generally, the smaller the grain size or the less

fracturing, the less water and aquifer will produce. This is because there are fewer void spaces for holding water.

2.3 Ground Water Recharge and Discharge

Recharge is the process by which ground water is replenished. A recharge area is where water from precipitation is transmitted downward to an aquifer. Most areas, unless composed of solid rock or covered by development, allow a certain percentage of total precipitation to reach the water table. However, in some areas more precipitation will infiltrate than in others. Areas which transmit the most precipitation are often referred to as high or critical recharge areas.

Generally, how much water infiltrates depends on vegetation cover, slope, soil composition, depth to the water table, the presence or absence of confining beds and other factors. Recharge is promoted by natural vegetation cover, flat topography, permeable soils, a deep water table and the absence of confining beds.

Discharge areas are the opposite of recharge areas. They are the locations at which ground water leaves the aquifer and flows to the surface. Ground water discharge occurs where the water table or potentiometric surface intersects the land surface. Where this happens, springs or seeps are found. Springs and seeps may flow into fresh water bodies, such as streams, or they may flow into saltwater bodies.

Under the force of gravity, ground water generally flows from high areas to low areas. Consequently, high areas-such as hills or plateaus are typically where aquifers are recharged and low areas-such as river valleys-are where they discharge. However, in many instances aquifers occur beneath river valleys and can also be important recharge areas. Typical recharge and discharge areas are depicted in Figure

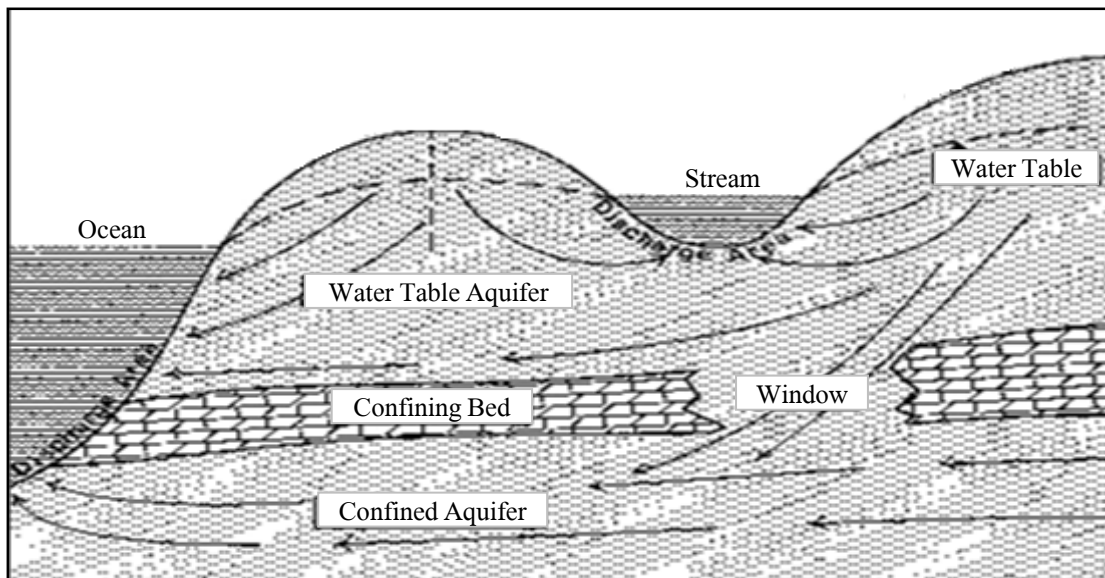


Figure 7 Recharge and Discharge Areas.

Source: GWAC (1986).

2.4 Ground Water Movement

Gravity is the force that moves ground water which generally means it moves downward. However, ground water can also move upwards if the pressure in a deeper aquifer is higher than that of the aquifer above it. This often occurs where pressurized confined aquifers occur beneath unconfined aquifers.

A ground water divide, like a surface water divide, indicates distinct ground water flow regions within an aquifer. A divide is defined by a line on the either side of which ground water moves in opposite directions. Ground water divides often occur in highland areas, and in some geologic environments coincide with surface water divides. This is common where aquifers are shallow and strongly influenced by surface water flow. Where there are deep aquifers, surface and ground water flows may have little or no relationship.

As ground water flows downwards in an aquifer, its upper surface slopes in the direction of flow. This slope is known as the hydraulic gradient and is determined by measuring the water elevation in wells tapping the aquifer. For confined aquifers, the hydraulic gradient is the slope of the potentiometric surface. For unconfined aquifers, it is the slope of the water table.

The velocity at which ground water moves is a function of three main variables: hydraulic conductivity, (commonly called permeability) porosity, and the hydraulic gradient. The hydraulic conductivity is a measure of the water transmitting capability of an aquifer. High hydraulic conductivity values indicate an aquifer can readily transmit water; low values indicate poor transmitting ability. Because geologic materials vary in their ability to transmit water, hydraulic conductivity values range through 12 orders of magnitude. Some clay, for example, have hydraulic conductivities of 0.00000001 centimeters per second (cm/sec), whereas gravel hydraulic conductivities can range up to 10,000 cm/sec. Hydraulic conductivity values should not be confused with velocity even though they appear to have similar units. Cm/sec, for example, is not a velocity but is actually a contraction of cubic centimeters per square centimeter per second ($\text{cm}^3/\text{cm}^2\text{-sec}$).

In general, coarse-grained sands and gravels readily transmit water and have high hydraulic conductivities (in the range of 50-1000 m/day). Fine grained silts and clays transmit water poorly and have low hydraulic conductivities (in the range of 0.001-0.1 m/day).

The porosity of an aquifer also has a bearing on its ability to transmit water. Porosity is a measure of the amount of open space in an aquifer. Both clays and gravels typically have high porosities, while silts, sands, and mixtures of different grain sizes tend to have low porosities.

The velocity at which water travels through an aquifer is proportional to the hydraulic conductivity and hydraulic gradient, and inversely proportional to the porosity. Of these three factors, hydraulic conductivity generally has the most effect

on velocity. Thus, aquifers with high hydraulic conductivities, such as sand and gravel deposits, will generally transmit water faster than aquifers with lower hydraulic conductivities, such as silt or clay beds.

Ground water velocities are typically very slow, ranging from around a centimeter per day to almost a meter per day. However, some very rapid flow can occur in rock with solution cavities or in fractured rock. Very high flow rates (more than 15 m/day) are also found in some areas. The volume of ground water flow is controlled by the hydraulic conductivity and gradient, and in addition is controlled by the volume of the aquifer. A large aquifer will have a greater volume of ground water flow than a smaller aquifer with similar hydraulic properties. But if the cross-sectional area—that is, the height and width—are the same for both aquifers, the aquifer with a greater hydraulic conductivity and hydraulic gradient will produce a greater volume of water. (Sriboonlue, 1987)

2.5 Shallow Water Wells

How aquifers respond when water is withdrawn from a well is an important topic in ground water hydrology. It explains how a well gets its water, how it can deplete adjacent wells, or how it can induce contamination. A person in Andaman has to rely on either rain water or shallow water well for their water uses and drinking water. When water is withdrawn from a well, its water level drops. When the water level falls below the water level of the surrounding aquifer, ground water flows into the well. The rate of inflow increases until it equals the rate of withdrawal.

The movement of water from an aquifer into a well alters the surface of the aquifer around the well. It forms what is called a cone of depression. A cone of depression is a funnel-shaped drop in the aquifer's surface. The well itself penetrates the bottom of the cone. Within a cone of depression, all ground water flows to the well. The outer limits of the cone define the well's area of influence (Figure 8).

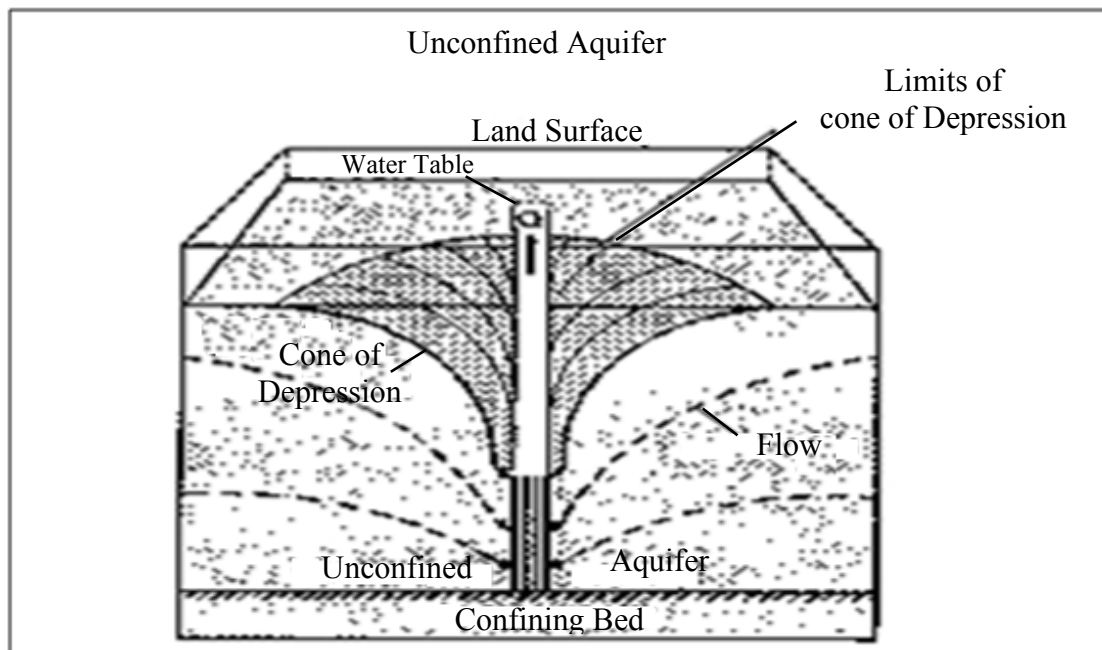


Figure 8 Cone of Depression.

Source: GWAC (1986).

3. Land use

Land use is the human modification of natural environment or wilderness into built environment such as fields, pastures, and settlements. The major effect of land use has been deforestation of tropical regions. More recent significant effects of land use include urban sprawl, soil erosion, soil degradation, salinization, and desertification. Land-use change, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide, a dominant greenhouse gas. (FAO, 1997a; FAO/UNEP, 1999).

Each designation, known as a parcel's zoning, comes with a list of approved uses that can legally operate on the zoned parcel. These are found in a government's ordinances or zoning regulations.

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals. Land use information can be used to develop solutions for natural resource management issues such as salinity and water quality. For instance, water bodies in a region that has been deforested or having erosion will have different water quality than those in areas that are forested.

According to a report by the United Nations' Food and Agriculture Organization, land degradation has been exacerbated where there has been an absence of any land use planning, or of its orderly execution, or the existence of financial or legal incentives that have led to the wrong land use decisions, or one-sided central planning leading to over-utilization of the land resources - for instance for immediate production at all costs. As a consequence the result has often been misery for large segments of the local population and destruction of valuable ecosystems. Such narrow approaches should be replaced by a technique for the planning and management of land resources that is integrated and holistic and where land users are central. This will ensure the long-term quality of the land for human use, the prevention or resolution of social conflicts related to land use, and the conservation of ecosystems of high biodiversity value

To regulate what can be built where; cities create comprehensive plans and zoning ordinances to create an order to the potential uses of land within their political boundaries. A municipality will spend thousands if not hundreds of thousands of dollars to determine where best to encourage industrial growth, allow residential building and permit commercial activity. These decisions have dramatic impacts on land values, safety and community interests. With so much at stake, the process of determining what can be built where has become extremely politicized.

Today active community groups wield much strength in the public land use approval process. Informed residents know the potential impacts of a large big box coming to their neighborhood or the opening of a quarry a mile down the road. When involved they shape the process and are more likely now than ever to actually impact

the process. Politics plays a big part in the approval process. But the reality is that mostly developers create the rules. In the absence of opposition, a developer can change the real estate landscape for years to come by successfully rezoning one large parcel in area. Where there is opposition, today's developers have to take heed and listen to their demands.

With financial stakes so high for developers and residents and the approval process being susceptible to public pressure and politics, it is no surprise that there is now a subset of political culture known as land use politics.

Patterns of land use arise naturally in a culture through customs and practices, but land use may also be formally regulated by land use planning through zoning and planning permission laws, or by private agreements such as restrictive covenants. For example, the setting aside of wilderness either publicly as a Wilderness Area or privately as a conservation easement.

Land in natural forests are used mainly for human lives such as agriculture, industries, business and settlement habitat (Watcharakitti, 1978) When the population increase human need more in land and habitat. Forest land will be changed to agriculture land, urban and water bodies. Theses changing do not have limit and caused land use many problems.

3.1 Classified of Land use types

Imphitak (1998) classified land use types into agriculture, industries, urbanization, forestry, recreation, wildlife conservation, mining, cemetery and others. This is confirmed well with Watcharakitti (1978) who classified land use into, topography, elevation, land suitability, land capability and sociology as following:

- 1) Urban land and buildings for such as settlement, commercial, industries, communication.
- 2) Agriculture land for crop, plantation and shifting cultivation

- 3) Forest land
- 4) Water bodies such as river, canal and lake.
- 5) Idle land such as bare land cover and flat field.

4. Oil Palm Plantation

The oil palms (*Elaeis*) comprise two species of the Arecaceae, or palm family. They are used in commercial agriculture in the production of palm oil. The African Oil Palm *Elaeis guineensis* is native to west Africa, occurring between Angola and Gambia, while the American Oil Palm *Elaeis oleifera* is native to tropical Central America and South America. The generic name of *Elaeis* is derived from the Greek for oil, elaion, while the species name refers to its country of origin.

Mature tree of oil palm has single-stemmed, and grow up to 20 meters tall. The leaves are pinnate, and may reach between 3-5 meters long. A young tree produces about 30 leaves a year. Well established trees over 10 years produce about 20 leaves a year. The flowers are produced in dense clusters; each individual flower is small, with three sepals and three petals. The fruit takes five to six months to mature from pollination to maturity; it comprises an oily, fleshy outer layer (the pericarp), with a single seed (kernel), also rich in oil. Unlike other relatives, the oil palm does not produce offshoots; propagation is by sowing the seeds.

Oil palms are grown for their clusters of fruit, which can weigh 40-50 kilogram. Upon harvest, the drupe, pericarp and seeds are used for production of soap and edible vegetable oil; different grades of oil quality are obtained from the pericarp and the kernel, with the pericarp oil used mainly for cooking oil, and the kernel oil used in processed foods.

For each hectare of oil palm, which is harvested year-round, the annual production averages 10 tones of fruit, which yields 3,000 kilogram of pericarp oil, and 750 kg of seed kernels, which yield 250 kilogram of high quality palm kernel oil as well as 500 kg of kernel meal. Palm fronds and kernel meal are processed for use as

livestock feed. Some varieties have even higher productivities which has led to their consideration for producing the vegetable oil needed for biodiesel.

The world's largest producer and exporter of palm oil today is Malaysia, producing about 47% of the world's supply of palm oil. Indonesia is the second largest world producer of palm oil producing approximately 36% of world palm oil volume. According to US Department of Agriculture, since 2005 Indonesia became the world's largest producer of Crude Palm Oil (CPO). Both nations are expanding their palm oil production capacity and the market continues to grow.

Worldwide palm oil production during the 2005-2006 growing season was 39.8 million metric tons, of which 4.3 million tons was in the form of palm kernel oil. It is thus by far the most widely-produced tropical oil, and constitutes thirty percent of total edible oil production worldwide.

Oil palm in Thailand is now increasingly noticed when the Thai government has set its policy on producing palm oil-based biodiesel as a renewable energy. An experiment of mixing 2% of the B2 biodiesel with 98% of diesel oil on trucks has undertaken during 2006-2010. After that, the B5 biodiesel will be used with other types of car in 2011 and the percentage of the biodiesel combination will rise to B10 in 2012.

Thailand's plantation areas are of lower quality than those of Malaysia's because of Thailand's lower humidity due to less rainfall. Also, the palm trees in many plantation areas receive less rain than what they need. The soil of Malaysia is much more fertile and suitable for oil palm plantation than that of Thailand's.

Additionally, Thailand has problem of the quality of seeds used for propagation. Many plantations were established by using unclassified seed sources.

5. Para Rubber Plantation

The Para rubber tree (*Hevea brasiliensis*), often simply called rubber tree, is a tree belonging to the family Euphorbiaceae and the most economically important member of the genus *Hevea*. It is of major economic importance because its sap-like extract (known as latex) can be collected and is the primary source of natural rubber.

The rubber tree can reach a height of over 30 m. The white or yellow latex occurs in latex vessels in the bark, mostly outside the phloem. These vessels spiral up the tree in a right-handed spiral which forms an angle of about 30 degrees with the horizontal.

Once the trees are 5-6 years old, the harvest can begin: incisions are made orthogonal to the latex vessels, just deep enough to tap the vessels without harming the tree's growth, and the sap is collected in small buckets. This process is known as rubber tapping. Older trees yield more latex, but they stop producing after 26-30 years.

The Para rubber tree initially grew only in the Amazon Rainforest. Increasing demand and the discovery of the vulcanization procedure in 1839 led to a boom in that region, enriching the cities of Belem and Manaus. The name of the tree derives from Para, the second largest Brazilian state, which contains Belem as capital, mainly city and tech-financial centre.

Rubbers are planting in many tropical countries including all nations in ASEAN. Thailand has now the world largest rubber plantation. It mainly grows in the southern peninsular and the eastern province. During the East decade, rubber in suggest to plant in North and Northeast regions.

6. Mixed Fruit Orchard

An orchard is an intentional planting of trees or shrubs maintained for food production. Orchards comprise fruit or nut-producing trees grown for commercial production. Orchards are also sometimes a feature of large gardens, where they serve an aesthetic as well as a productive purpose. A fruit garden is generally synonymous with an orchard, although it is set on a smaller non-commercial scale and may emphasize berry shrubs in preference to fruit trees.

Most temperate-zone orchards are laid out in a regular grid, with a grazed or mown grass or bare soil base that makes maintenance and fruit gathering easy.

Orchards are often concentrated near bodies of water, where climatic extremes are moderated and blossom time is retarded until frost danger is past.

The forest garden is a food production system that is closely related to the orchard. A move towards more ecologically-friendly coffee production has led to forest-garden production of coffee and rubber are being produced in such a method in some areas.

Mixed fruit orchard in southern Thailand especially in Andaman sea coast, include Krabi, Phang-Nga, Phuket, Ranong, Trang and Satun provinces. There are a variety of agricultural products, including: coconuts, durian, coffee, rose apple, Zapoda, pomelo, tangerine, papaya, banana, guava, mango, rambutan, mangosteen and langsung.

7. Related Research

S. Beldring, *et al.* (1998) studies contribution to the northern hemisphere climate processes land surface experiment (NOPEX). Its purpose is to investigate the spatial variability of groundwater levels and soil moisture content at different scales in a landscape dominated by boreal forest and till soils, which is characteristic of the

Nordic countries. The analysis of data from the NOPEX area is based on a review of previous studies on the spatial distribution of these state variables and their significance for runoff formation. Soil moisture content in the unsaturated zone and depth to the groundwater table show characteristic patterns which are related to the landscape elements (patches) of the drainage basins. Similar behavior is observed in different parts of the NOPEX region. The variability of average values between areas decreases to a minimum for catchments with size larger than 1km^2 . It can therefore be concluded that the main part of the spatial variability of soil moisture content and depth to the groundwater level in the till soils of the NOPEX area is found within small drainage basins. Based on a physical description of the soil, distribution functions of soil moisture content conditioned on the depth to the groundwater table have been developed, both for the patch scale and the catchment scale.

Kang (2001) studied partial root zone irrigation and it was tested for its soil water distribution, water uptake, and water use efficiency (WUE) on pear trees in a commercial orchard (Goulburn Valley, central Victoria, Australia) in 1998–1999. Irrigation was applied through in three ways: conventional flood irrigation (CFI), fixed partial root zone irrigation (FPI), and alternate partial root zone irrigation (API). CFI means that both sides of the root zone were flood-irrigated. Under FPI, flood irrigation was fixed to one side of the root zone, and the other side was kept dry. The API means that one of the two sides of the root zone was alternately flood-irrigated during consecutive watering. A total of four irrigations were applied for all treatments during the pear fruit-growing season.

Kumar (1999) study of the amount of water that may be extracted from an aquifer without causing depletion is primarily dependent upon the ground water recharge. Thus, a quantitative evaluation of spatial and temporal distribution of ground water recharge is a pre-requisite for operating ground water resources system in an optimal manner. This paper presents a methodology with step-by-step procedure to determine the ground water recharge by soil moisture balance in the unsaturated zone.

MATERIALS AND METHODS

Materials

In this study, materials used consist of hardware and software for computerized analysis and equipments for soil sample and water table data collections, as follows:

1. Global Positioning System (GPS)
2. Disturbed and undisturbed soil sample i.e. soil pH test kit, soil core, plastic knock, plastic bag, pickax or digging tool etc.
3. Oven
4. Digital balance
5. Probe, tendon and meter tapes.
6. Topographic map scale 1: 50,000 from Royal Thai Survey Department
7. Soil map from Land Development Department
8. Land use map years 2007 from Land Development Department
9. Water resource data in Ban Thung Soong Village
10. Personal computer
11. Microsoft excel program
12. Statistical package program

Methods

1 Data collection

In this study, the quantitative and qualitative measurements method will be conducted. There are two types of method that will be used first; quantitative method for collecting data of water table, and soil moisture content. Qualitatively, the study will be conducted by using Global Positioning System (GPS) to locate the position of well and the study site.

1.1 Climatic data

The meteorological data was collected from Univanich Palm Oil Public Co.,Ltd. at Ban Thung Soong and the Meteorological Department for amount of rainfall, air temperature, relative humidity data.

1.2 The determination of soil moisture content (SMC)

Variation in SMC in different farming practices at Ban Thung Soong can be done as follows,

1) Sampling the sample areas of 3 land uses, including oil palm plantation, para rubber plantation and mixed fruit orchard. Position of soil sample data based on the percent of land use types area and 6 samples of shallow wells were oil palm plantation (P) 3 samples, para rubber (R) 2 samples and mixed fruit orchard (G) 1 sample.

2) Soil sample collection

Soil samples were collected monthly by digging soil at level of soil depth 0-25, 25-50, 50-75, and 75-100 cm. from surface soil respectively.

Analysis of the SMC was determined by the Gravimetric Method. Fresh soil sample and oven-dried soil at 110 °C for 24 hours were weighed and calculated based on the following formula:

$$\% \text{ SMC by weight} = \left[\frac{\text{Wet weight} - \text{Oven dried weight}}{\text{Oven dried weight}} \right] \times 100$$

1.3 The determination of water table

Water table data was measured by drop a probe down the well on a wire to sense the water level and collect data once a month for measure water table in different level to do rating curve and calculate quantity of water table in each month.

2. Data analysis

2.1 Monthly and annual trend of SMC and water table in each types of land uses.

2.2 Relationship between SMC and water table data.

2.3 Relationship between water table and rainfall data.

3. Time table for conducting proposed research: October 2007-April 2009.

| Activities | Months | | | | | | | | | | | | | | | | | | |
|--|--------|----|----|------|---|---|---|---|----|---|---|---|----|----|----|------|---|---|---|
| | 2007 | | | 2008 | | | | | | | | | | | | 2009 | | | |
| | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| 1. Preliminary visit to the study area | ←→ | | | | | | | | | | | | | | | | | | |
| 2. Collection Secondary data | ←→ | | | | | | | | | | | | | | | | | | |
| 3. Writing thesis proposal | ←→ | | | | | | | | | | | | | | | | | | |
| 4. Field visit for data collection | ←→ | | | | | | | | | | | | | | | | | | |
| 5. Additional literature review | ←→ | | | | | | | | | | | | | | | | | | |
| 6. Data reduction into figure, table and graph | | | | | | | | | ←→ | | | | | | | | | | |
| 7. Data analysis | | | | | | | | | ←→ | | | | | | | | | | |
| 8. Thesis writing | | | | | | | | | | | | | ←→ | | | | | | |

Remarks: 1-12 = Jan.-Dec.

Study Area

In this study, the data will be collected at Ban Thung Soong (BTS) in Krabi province. Krabi is one of the Southern Provinces of Thailand and located at the Andaman Sea coast. Krabi area is approximately about 4,708.5 square kilometers with about 336,210 people (with population density 71 in/km²). Krabi is located 814 kilometers South of Bangkok and local between latitude 7° 30' and 8° 30' North and 98° 30' and longitude 99° 30' East with height about 6 meters or 19 feet above mean sea level (Figure10). The province consists of mountains, hills (solitary limestone hills, plains and mangrove forest, including more than 130 large and small islands. Natural forest near sea shore mostly consists of mangrove and casuarinas. Krabi's sandy clay soil conditions are perfect for a variety of agricultural products, including: para rubber trees, oil palms, pomelo, tangerine, rambutan, mangosteen, coconuts, durian and coffee. Figure 11 and Table 1 showed land use types at Ban Thung Soong such as forest, oil palm plantation, para rubber plantation and institution land.

| | |
|---------------|--|
| On the North: | Lies Phang-nga and Surat Thani Provinces |
| On the South: | Lies Trang province and the Andaman Sea |
| On the East: | Lies Trang and Nakhon Si Thammarat provinces |
| On the West: | Lies Phang-nga Province and the Andaman Sea |

Krabi is subdivided into 8 districts (Amphoe) Muang Krabi, Khao Phanom, Ko Lanta, Khlong Thom, Ao Luek, Plai Phraya, Lam Thap and Nuea Khlong 53 communes (Tambon) and 374 villages (Mubaan). Recently, there are 66 Community Forest (CF) areas in Krabi Province, which are scatterly distributed in various districts, including Muang Krabi (17 CFs), Khao Phanom (11 CFs), Ko Lanta (8 CFs), Khlong Thom (7 CFs), Ao Luek (12 CFs), Plai Phraya (1 CFs), Lam Thap (2 CFs) and Nuea Khlong (8 CFs). (Yahya, 2006)

BTS is one of the five villages in Tambon Khao Yai and part of Ao Luek district. BTS village landscapes are classified into a flat and hill terrain with the ground surface in the 30-350 meters mean sea level (MSL). There are three hills that

bordered BTS landform which are, on the north, northeast and northwest village area, namely Khuan Ying Wua Hill, Khao Yai Hill and Khao Lang Tang Hill. Khuan Ying Wua Forest was the site for BTS community forest. People in BTS village were conserved and protected Khuan Ying Wua Hill Forest for 50 years. Barrebo (2004) indicated that the community forest in the BTS village was established in 1998 and consist of 236 families (approximately 1,053 people) living in only one village with a total protected forest area of 7,300 rai (1,168 hectares). According to Sawatdee (2002), the total area of the village was approximately 16,336 rai (26.14 km²). The land use type of village was comprised the forest 7,300 rai (1,168 hectares), para rubber plantation 1,866 rai (298.56 hectares), oil palm plantation 5,600 rai (896 hectares) and other land use 1,270 rai. (203.2 hectares) (Figure11)

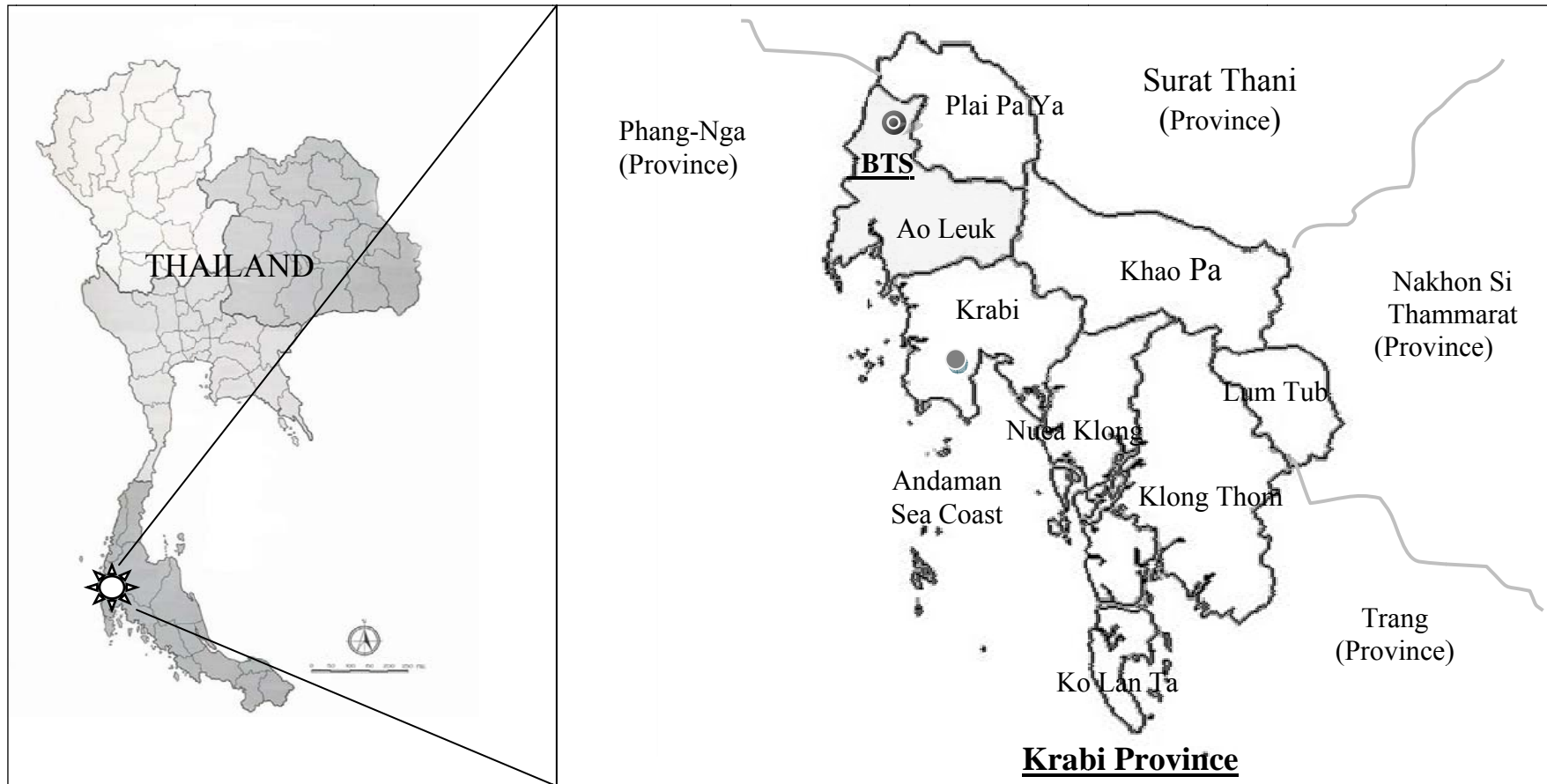


Figure 10 Location of study area in Ban Thung Soong, Ao Luek district in Krabi province.

Source : Thai Map (2004).

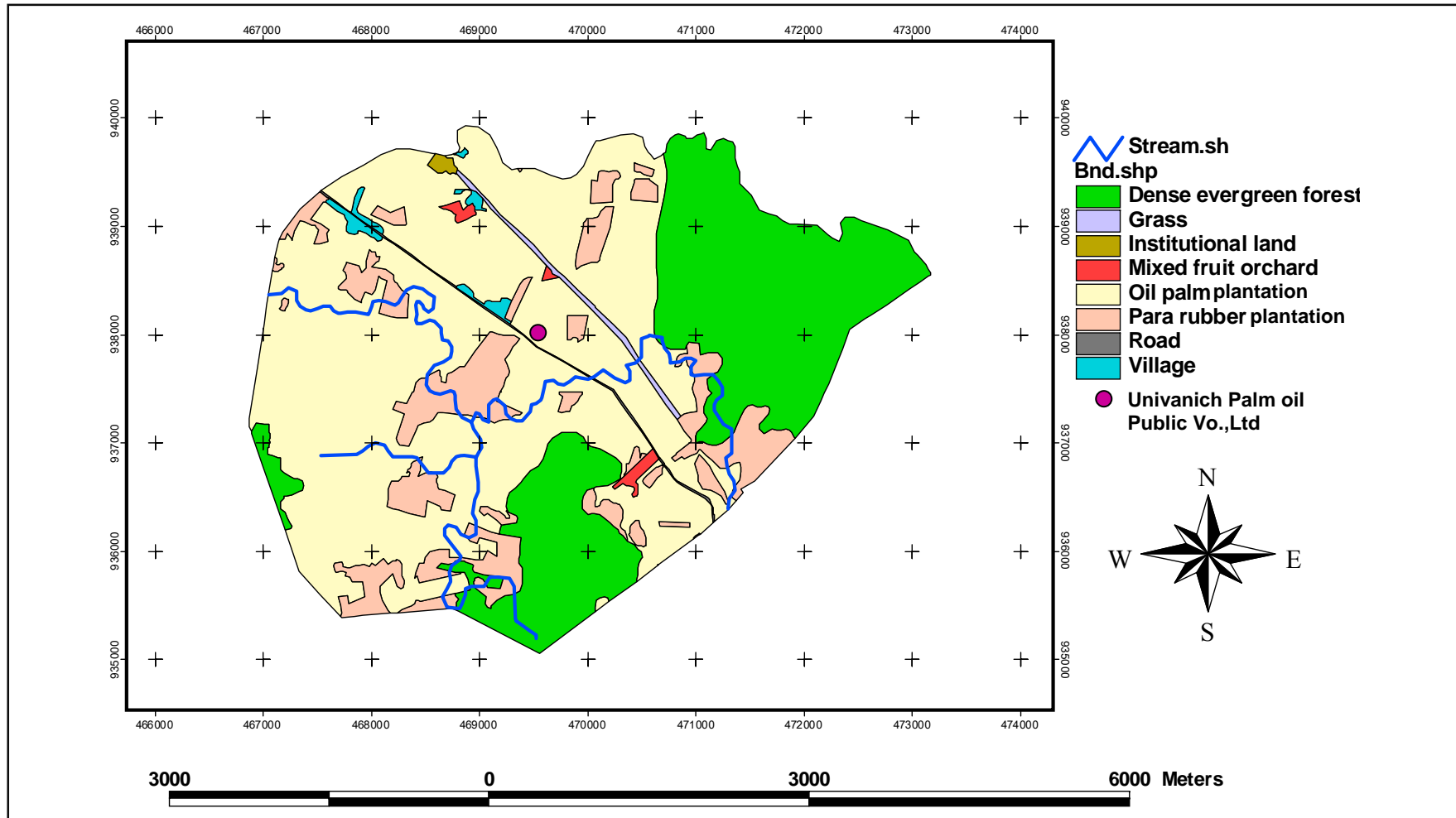


Figure 11 Land use types and Univanich Palm oil Public Vo.,Ltd at Ban Thung Soong, Ao Luek district in Krabi province.

Table 1 Land use types at Ban Thung Soong, Ao Luek district in Krabi province.

| Land Use Types | Area | | |
|------------------------|-----------|-----------------|--------|
| | Rai | Km ² | % |
| Oil Palm Plantation | 8,964.75 | 14.34 | 69.46 |
| Community Forest | 7,300.03 | 11.68 | 16.12 |
| Natural Forest | 683.53 | 1.09 | 5.30 |
| Para Rubber Plantation | 589.41 | 0.94 | 4.56 |
| Mixed Fruit Orchard | 185.21 | 0.30 | 1.43 |
| Others | 403.79 | 0.65 | 3.13 |
| Total | 18,126.72 | 29.00 | 100.00 |

Remarks: Others mean of factory, school and institution land.

**Figure 12** Landscape of Ban Thung Soong, Ao Luek district in Krabi province.

1.1 Elevation

Elevation of study area was analyzed by using topographic map scale 1: 50,000 from Royal Thai Survey Department (4725 I, 4725 IV, 4726 II, 4726 III). From this study with contour interval of 0.20 meters, It was found the contour 0.20-360 meters is the homestead, contoured 20-80 meter is farming area and contoured 80-360 meters is a reserved forest area (Figure 13). (Tunsin, 2004)

1.2 Climate

The climate classified by Koppen's system at Ban Thung Soong (BTS) was characterized by tropical monsoon climate. The area is influence by two monsoon namely southwest and northeast monsoons (Figure 14), and occasionally by the cyclone and depression storms. Thus the climate in this area is different from the other regions (Figure 17). There are two seasons in this area as follows: (Sawatdee, 2002)

1) During late May to December was rainy season, approximately 8 months. It was divided into two periods. The first period (May to September) was called northeast monsoon and second period (October to December or January) was called southwest monsoon. Northeast monsoon was caused by the air mass move from the South China Sea; during this period the rainfall occur continuously. The second period was influenced by the southwest monsoon. During this period the air mass moved from the Indian Ocean and brings few rainfalls.

The first period was prevented the rain to Ban Thung Soong by the Khao Phanom Benja and Nakorn Sri Thammarat Mountain Range and the second period were prevented by Phuket Mountain Range.

2) Dry season from January to April. This season was influenced from southeast monsoon; the air mass moved from the high pressure in the South China Sea and with brought slightly rain. The average monthly rainfall ranged from 3.2

millimeters to 412.8 millimeters with the annual rainfall of 2,224.5 millimeters (Table 2 and Figure 15).

1.3 Temperature and Relative Humidity

The annual temperature of the area exhibited variation (Table 1). Annual temperatures range between 16.9° and 37.3° C. The highest temperature of 36.6 °C was recorded in February and May (mean maximum temperature 32.3 °C). The lowest temperature of 19.5 °C occurred during December (mean minimum temperature 23.6 °C). The highest average relative humidity occurred similarly both in October (87.2%) and November (87.2%) and the lowest relative humidity occurred in February (76.7%) while the average relative humidity was 82.67 % (Table 2 and Figure 16).

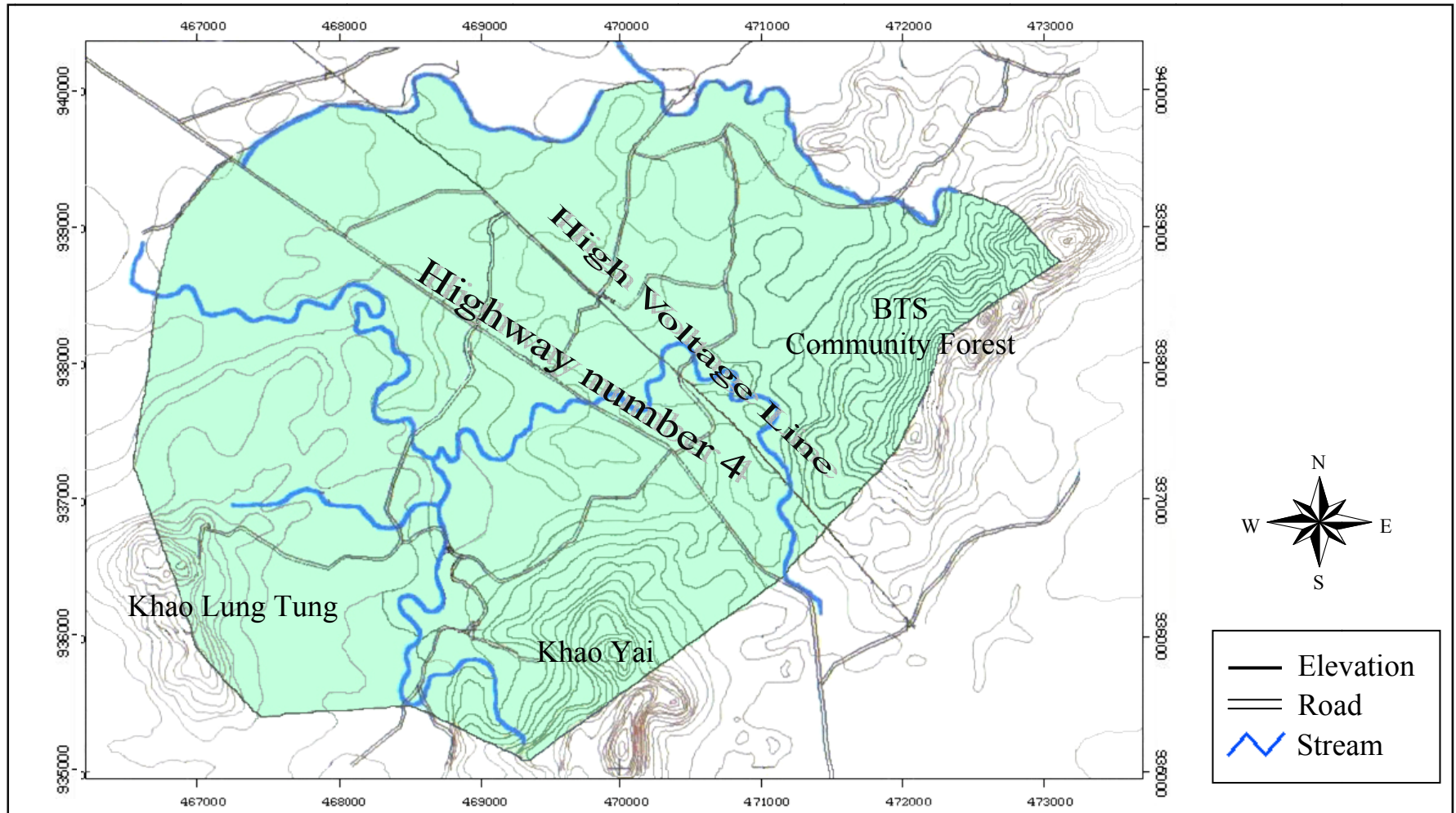


Figure 13 Elevation of Ban Thung Soong, Ao Luek district in Krabi province.

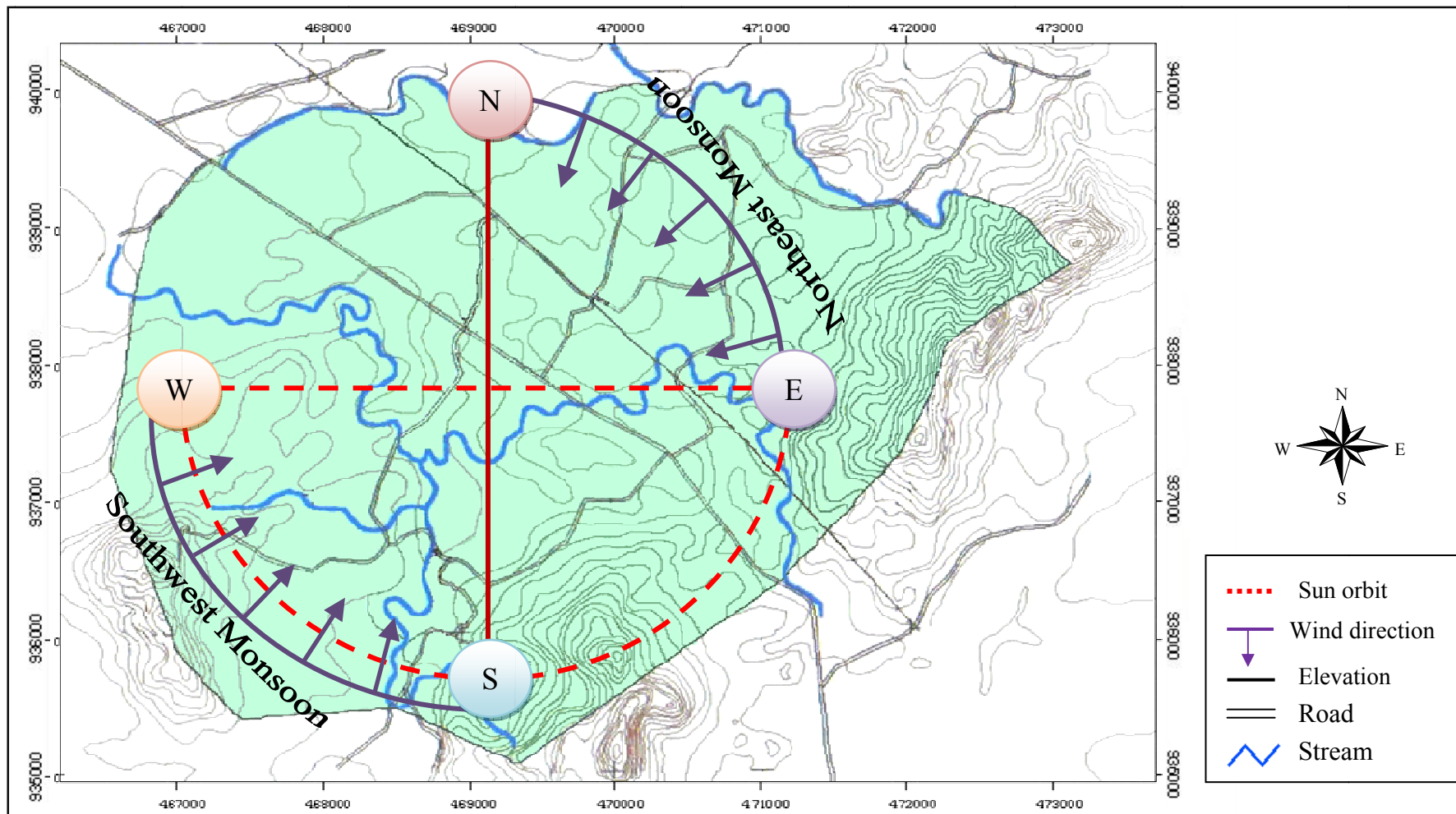


Figure 14 Wind direction map of Ban Thung Soong, Ao Luek district in Krabi province.

Table 2 Amount of Rainfall and air temperature at Krabi Station (1994-1995).

| Item | | | | | | | | | | | | | Total |
|-----------------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|---------|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | |
| Rainfall (mm) | | | | | | | | | | | | | |
| Mean | 3.2 | 33.8 | 136.6 | 172.7 | 191.2 | 203.2 | 214.2 | 264.2 | 412.8 | 338.3 | 26.4 | 47.9 | 2224.5 |
| Mean Rainy Day | 1.5 | 2.5 | 12.0 | 14.0 | 17.0 | 15.5 | 20.5 | 21.0 | 21.0 | 20.0 | 20.5 | 7.0 | 172.5 |
| Daily maximum | 3.8 | 60.1 | 60.1 | 57.7 | 54.9 | 65.4 | 54.2 | 44.7 | 75.5 | 75.9 | 56.5 | 35.9 | - |
| Temperature (Celsius) | | | | | | | | | | | | | Average |
| Mean | 28.0 | 28.6 | 28.7 | 29.0 | 28.6 | 28.2 | 27.7 | 27.3 | 27.1 | 27.4 | 27.0 | 27.3 | 28.0 |
| Mean max. | 33.3 | 34.1 | 33.7 | 34.0 | 32.7 | 32.1 | 31.5 | 30.7 | 30.8 | 31.7 | 30.9 | 32.1 | 32.3 |
| Mean min. | 22.7 | 23.2 | 23.7 | 24.1 | 24.5 | 24.4 | 23.9 | 23.9 | 23.4 | 23.1 | 23.2 | 22.5 | 23.6 |
| Ext. max. | 34.9 | 36.3 | 35.5 | 36.3 | 36.6 | 34.6 | 33.9 | 33.4 | 32.6 | 34.0 | 33.8 | 33.6 | 33.6 |
| Ext. min. | 20.2 | 21.5 | 22.5 | 22.7 | 23.0 | 22.2 | 22.1 | 21.8 | 22.0 | 21.7 | 22.1 | 19.5 | 19.5 |
| Wind (Knot) | | | | | | | | | | | | | |
| Mean wind speed | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Prevailing wind | NE | NE | NE | W | W | W | W | W | W | W | NE | NE | - |
| Max. wind speed | 20 | 30 | 25 | 28 | 22 | 30 | 42 | 26 | 26 | 43 | 25 | 33 | 43 |

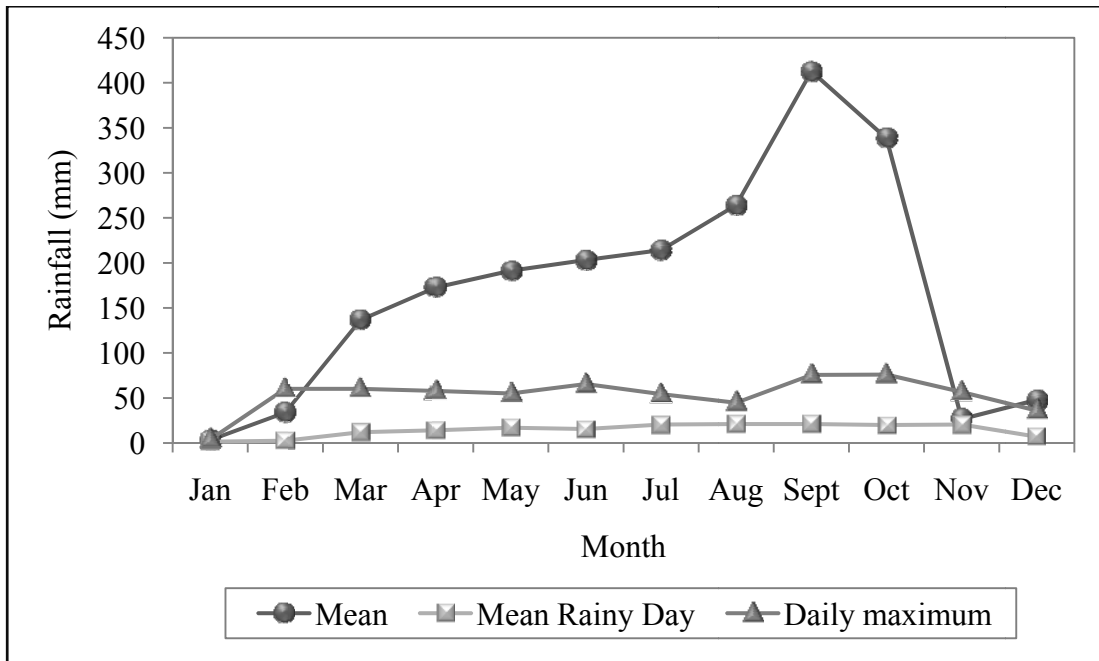


Figure 15 The average monthly rainfall at Ao Luek district (9 km from BTS).

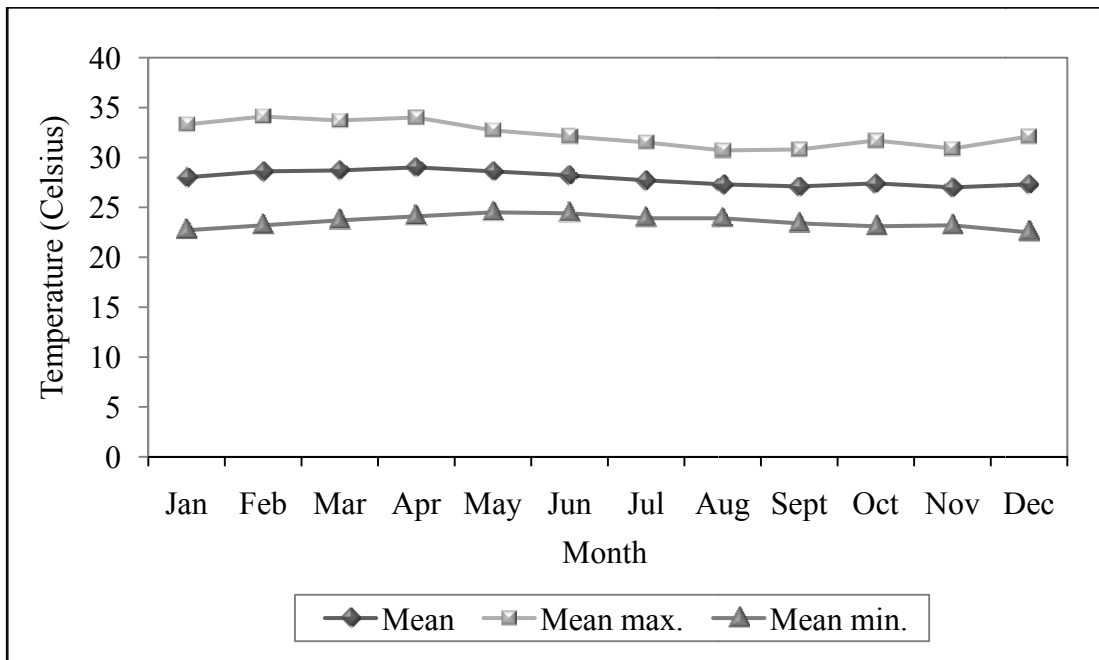


Figure 16 The average monthly temperature at Ao Luek district (9 km from BTS).

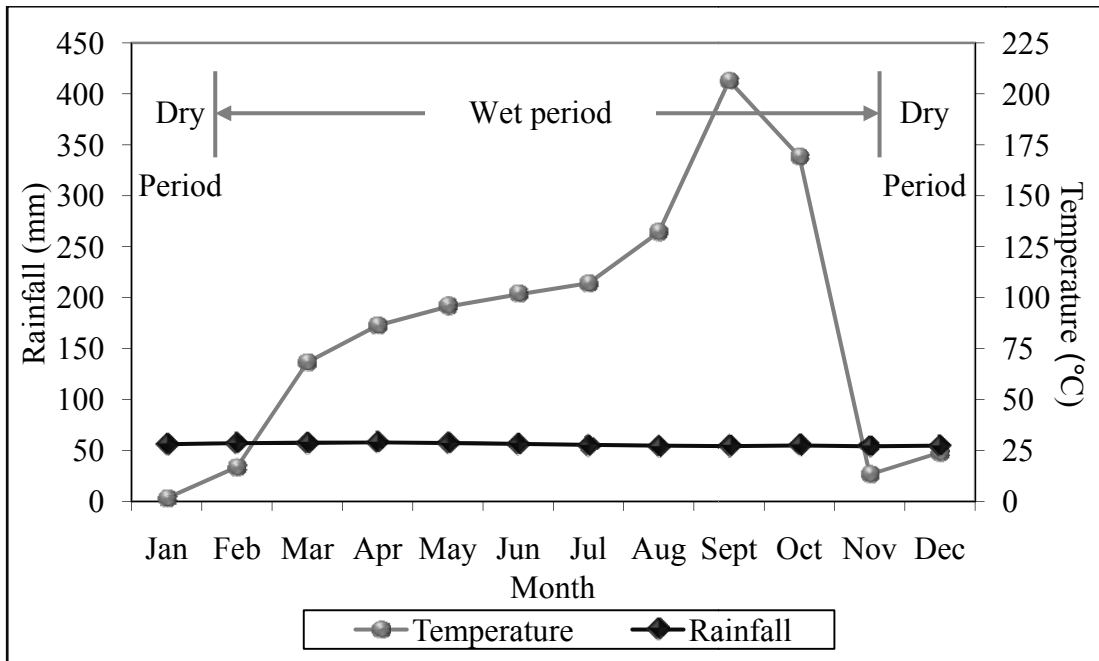


Figure 17 Wet and dry period at Ao Luek district (9 km from BTS).

1.4 Watershed and natural water resources

Characteristic of BTS area was a valley plain include of lowland and upland. In BTS village natural water resources that important for agricultural is Klong Thom. It is the main of water resource of BTS because of this canal was flow through the village and flow from northeast direction. Next canal was Klong Bang Nam Sai that flow direction from northwest and origin of this canal was a spring from Khao Yai that the finally flow to Klong Thom. The small canal in the north of village was name Klong Bang Mud that now was filled for agricultural area. And the last was Klong Bang Nam Dum. This canal was in the top of village. The origin of this canal was from the BTS community Forestry. Main water resources and flow direction in each canal at BTS was shown in Figure 18

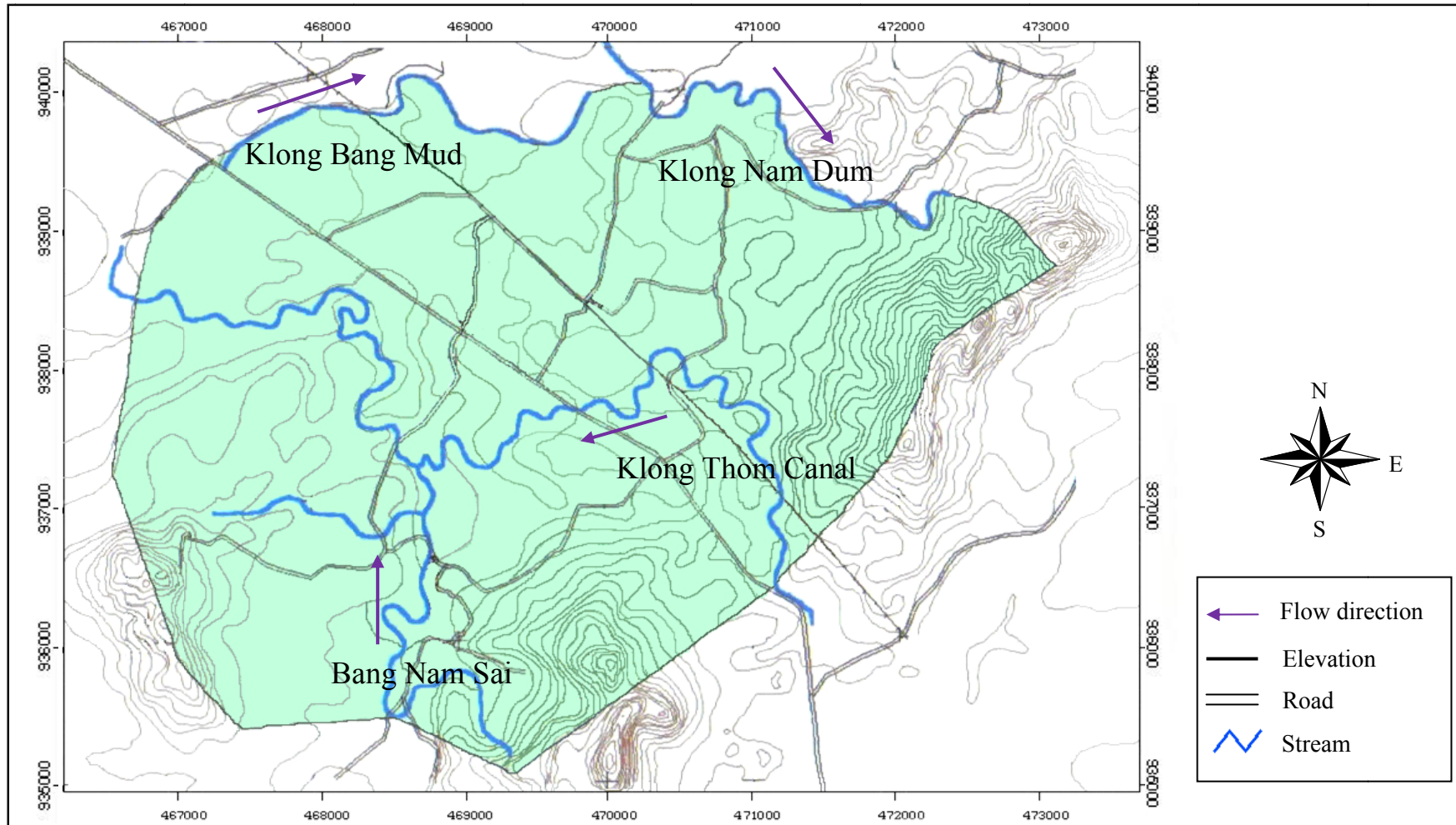


Figure 18 Map of natural water resource at Ban Thung Soong, Ao Luek District in Krabi province.

1.5 Geological Characteristics

Geological Characteristics of Ban Thung Soong has 5 characteristics (Charoenpong *et al.*, 1986) following:

1.5.1 Sediment Group feature of pebble, sand, silt and clay found in Khao Mai Kaew – Koun Ying Wua Hill that have an age in Quaternary.

1.5.2 Korat Group feature of sandstone, shale etc. found in Khao Yai Hill and Khao Lang Tang Hill that has an age in Triassic to Cretaceous.

1.5.3 Ratchaburi Group feature of gray limestone found in Khao Mai Kaew – Kuan Ying Wua Hill, Khao Yai Hill and Khao Lang Tang Hill that have an age in Permian.

1.5.4 Tanaosic Group feature of sandstone, shale, graywacki etc. found in Khao Mai Kaew – Kuan Ying Wua Hill that have an age in Carboniferous to Permian.

1.5.5 Igneous rock develop to granite found at Khao Yai Hill that have an age in Triassic.

1.6 Soil Characteristics

Soil characteristics influence by relief parent materials climate timing and organism. In fact, soil characteristics were directly controlled by relief, parent materials, climate, timing and organism, Soil texture origins by decomposition of parent materials of Ban Thung Soong was mainly silt, silty clay and silty sand in topsoil and 28 clay in subsoil. Soil colors were brown, yellow and red. So there are well drainage and moderate to low fertility. Soil pH was approximately 4.5-5.5 (Sawatdee, 2002). Soil characteristic in BTS can be classified in to 5 group (Figure 19) and 16 soil series (Anurakpongton *et.al.*, 1991) i.e. Ao Luek series (AK), Bang Nara series (Ba-ow), Krabi series (Kbi), Klaeng series (Kl), Kantang series (Kat),

Khlong Thom series (Km), Lamphu La series (Ll \$ LI-g), Lamphu La series (Ll \$ Pac), Na Tham series (Ntm), Pak Chan series (Pac), Phak Kat (Pat), Phattalung series (Ptl), Ruso series (Ro), Tha Sae series (Te/Te-m), Tha Sae series (Te-m) and Steep Complex series (Sc) that this series was a data base for decide activity pattern. Classified of soil series was show in Figure 20.

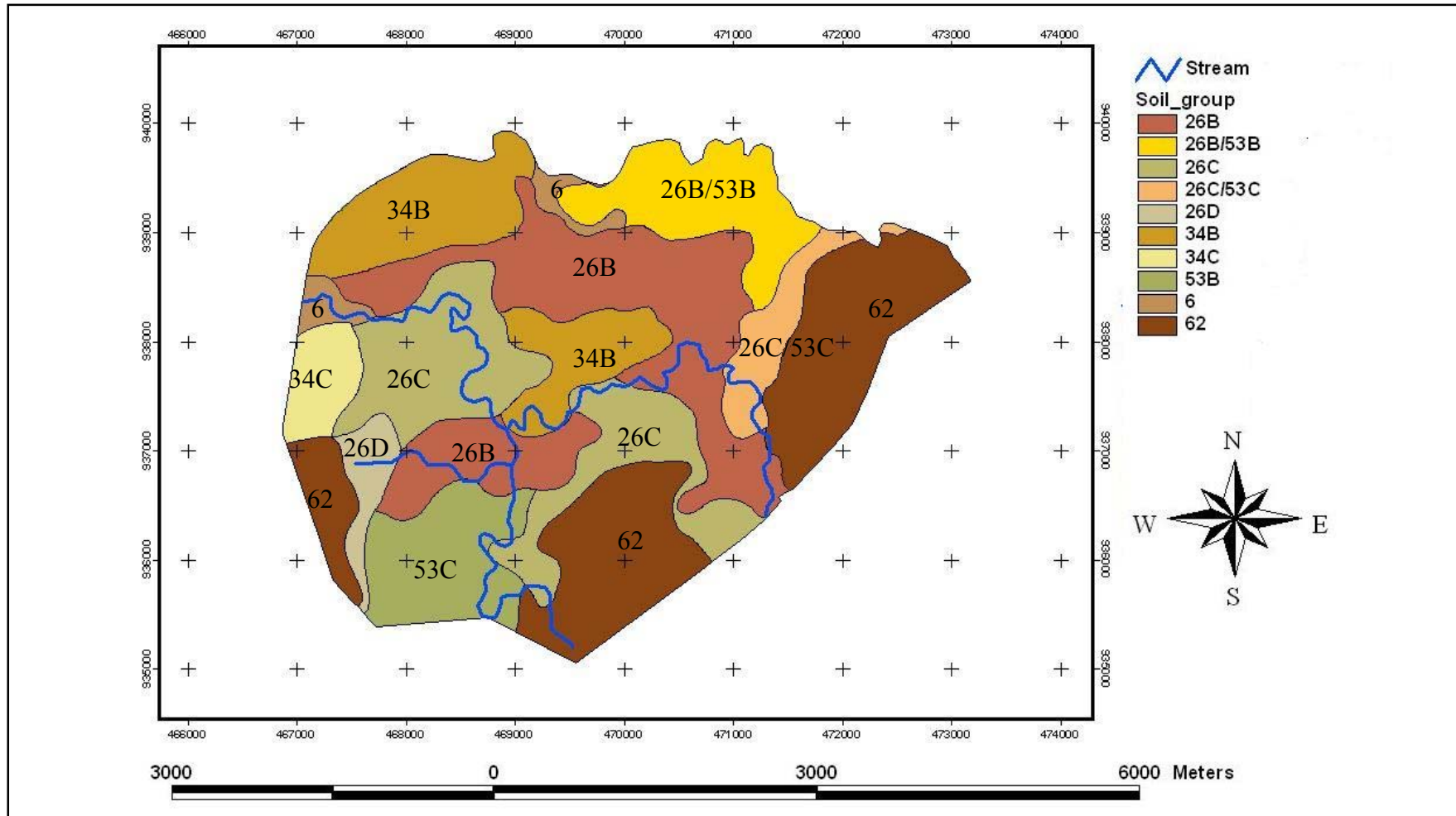


Figure 19 Classification of Soil Group at BTS.

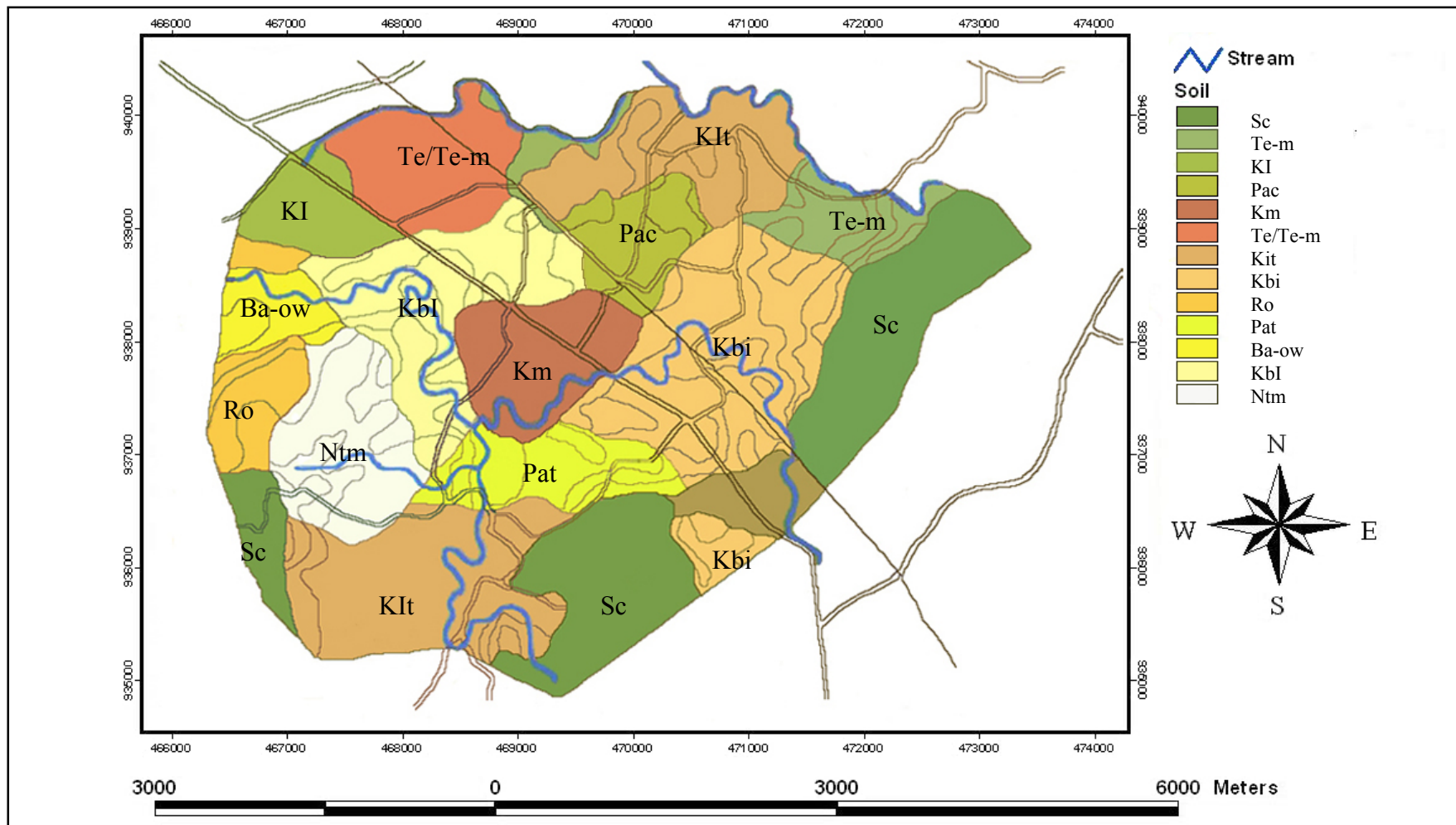


Figure 20 Classification of Soil Series at BTS.

1.7 Status of Natural Resources

Sawatdee (2002) studied plant biodiversity and ecotourism resource potential in the community forest (Khao Mai Kaew-Kuan Ying Wua). These studies consist of 2 plots and each plot is 40 m. x 40 m. The result showed 61 species (1,638 trees/ha.) and biodiversity was similar to the natural forest when comparing with the Evergreen Forest.

Tansupanon and Palawoot (1999) studied of local herbals at Khao Mai Kaew-Kuan Ying Wua and about 90 species was monocotyledon 23 species, dicotyledonous 63 species and fern 3 species.

Faculty of Forestry (2000) studied of wildlife resources at agricultural area and community forest (Khao Mai Kaew-Kuan Ying Wua) by survey and interviewing villagers. The result showed Amphibians with 2 orders, 6 families, and 24 species. Reptiles was 2 orders, 8 families, 14 species and Mammals was 5 orders, 11 families, 17 species. Protected animals such as Gould's Frogmouth (*Batrachostomus steilatus*), White-fronted Scops-Owl (*Otus sagittatus*), Green Broadbill (*Calypomena viridis*) and Thick-thumbed myotis (*Myotis rosseti*) were listed.

1.8 Vegetation

Ban Thung Soong community forest has comprised of 3 hills, Khao Mai Kaew-Kuan Ying Wua, Khao Yai and Khao Lang Tang. There are covered by Moist Tropical Forest, which slightly different in structure and species composition. Kuan Ying Wua and Khao Lang Tang hill was the secondary forest that succeeded from logging and from setting telecommunication station, respectively. The home garden is mostly situated at the foot hill or the low land of the 3 hills. Forest areas were dominated by Yang-na (*Dipterocarpus atatus*), Ta-kean thong (*Hopea odorata*), Teen-ped (*Alstonia scholars*), Plong (*Memecylon sp.*), Wha-dong (*Eugenia sp.*), Sai (*Ficus sp.*) etc. and the homegarden dominated by Durian (*Durio zibethinus*), Langsat (*Aglaia domestica*), Longkong (*Lansium domesticum*), Mang-kood (*Garcinia*

mangostana), Ka-noon (*Artocarpus heterophyllus*), Ma-praw (*Cocos nucifera*), Mhark (*Areca catechu*), Stink bean (*Parkia speciosa*) etc.

1.9 Demographic Information

Ban Thung Soong Village is one of the village of Khao Yai Sub-districts, Ao Luck district in Krabi province. Community started with 6 families settling in this area before 100 years ago. As living place Ban Thung Soong is suitable for people so that population is increasing. New comers are allowed to settle here and live in harmony with early settlers. The total area of the village is approximately 18,126.72 Rai (2,900.28 ha). According to the village committee office's information, about 253 families are living in this area. Total population is 336 people. The women and men percentage are 51% and 49%. Women percentage is slightly higher than men. All women of Ban Thung Soong village are eager to hard work like the men. (Roksena, 2006)

1.10 Education

Increased education in the village gives villagers the ability to control their economic, social, cultural and environmental situation in the future. Ban Thung Soong village has only one primary school and rely on old temples in the adjacent villages for formal and religious education. To create awareness about conservation of forest and protection of environment, environmental education is included along with formal education. According to the village information centre, about 100% villagers are literate. (Roksena, 2006)

1.11 Background of Ban Thung Soong Community Forest

Enamul (2006) studied background of Ban Thung Soong Community Forest that it was flourished from Khao Mai Kaew hill and Kuan Ying Wua Reserved Forest, a part of the mountain range passed beside the village, which has been conserved, protected and rehabilitated by the villager for more than 10 years. The

forest is mainly divided into two portions as high land and low land. The total area of the forest is 7,300 rai (1,168 ha). It was the secondary forest that succeeded from logging. Forest type of Khao Mai Kaew is tropical moist forest on the limestone mountain forest. These forest areas are dominated by Yang-na (*Dipterocarp sp.*), Ta-kean (*Hopea sp.*), Plong (*Memecyclon sp.*), Wha-dong (*Eugenia sp.*), Sai (*Ficus sp.*), etc. In addition, non-timber forest products like bamboo, edible mushrooms, rattan, medicinal plants are available in the forest. There was national reserved forest before establishing community forest. More than 100 years ago, only 6 families lived in this village. In the old days, the villagers grow upland rice, maize, pumpkin, long bean, taro and sago palm in lower part of the forest. They also raised pigs, water-buffaloes, and chicken as a way of their life. They collect timber from the forest to construct their houses, make furniture and other utensils. Fuel wood was collected mainly for cooking purpose. People used to collect resin from trees of Yang-na (*Dipterocarpus alatus*). This resin was used for making torch. They sold the product in nearby village market Pak Lao and purchased their essential things. From the history, it was known that a devastating natural disaster caused the severe damage of big trees in Kuan Ying Wua Forest in 1961. It resulted in a decreasing diversity of wildlife and important plants in the forest. The situation also opens to access the sawmill owners to log the felled trees. This way, the commercial trees were felled over the area very rapidly.

More than two years after the storm, the people of Ban Thung Soong started to realize that valuable forest resources were rapidly disappearing from the area which was the source of food, medicine, water for their livelihood. So, they took necessary initiative for controlling the logging operation in the forest. They also protested against the government policy of giving lease to the private company for raising oil palm plantation as well as they organized themselves in protecting the forest from the destruction done by illegal loggers and influential people of adjacent area. A Forest Protection Committee was formed by the then head of the village for the control of the forest resources. They coordinated with their own members, government agencies and local welfare organizations to help them for safeguard of the forest. At present, Ban Thung Soong Community Forest can be put forward to be a good community forest in conserving the forest resources in the Andaman region.

The community is well organized and has developed necessary management skills to sustain their activities in community forest conservation. They have established a committee named as “Community Forest Committee” to run the activities concerning forestry issues in the village. The committee consists of 15 members. The main responsibility of the committee is to ensure the restoration of the forest. During the visit to community forest, it was observed that different species were present and density of the present stock is increasing satisfactorily. The people of the village are very aware of their forest and they always keep their attention for its protection.

People participated in almost all of the forest conservation activities such as cleaning the forest, tree planting and campaign, forest protection duty. Besides this they attend in village forest committee meeting and exchange ideas and views with the villagers for the improvement of the forest. They provided cooperation with the researchers, students, nature-lovers, tourists as well as any outsiders who came to visit and develop their forest. They also play a supportive role in creating awareness among their children about the significance of forest and trees in human life.

They have a good communication network ranging from their own members of 252 families, local government agencies, research agencies and educational institutes. In the year of 2001, Her Majesty Queen Sirikit came to visit Ban Thung Soong village to recognize the people of the village for contributing their efficient participatory approach in forest conservation. She emphasized on wildlife conservation and released mouse deer, 4 kinds of tortoise, wild fowls to the Ban Thung Soong Community Forest. In addition, she donated 100,000 Baht (2,850 US\$), and was suggested about villagers using the money for protection of forest and wildlife.

The village is rich in forest resources and agriculture related farming. The forest is restored and has good condition. The villagers are being proud of this forest. The village is also the “Center of Agricultural Technological Transfer” in Khao Yai Sub-district where demonstration and training are given to the people.

Moreover, active people participation and communication in implementing development activities of the village are also present among villagers. This is a good indication of social cohesiveness and understands the common property concept among the members in the community.

RESULTS AND DISCUSSION

1. Climatic Data

1.1 Rainfall/Day of rainfall

Climate in Krabi Province and Ban Thung Soong village typically characteristic of tropical monsoon climate (AM) and was influenced mainly by two monsoons which are southwest and northeast monsoon and also by cyclone and depression storms. There are two seasons in this area, as follows:

1) During late May to December is rainy season, approximately eight months. It was divided in two periods. The first period (May to September) is called northeast monsoon and second period (October to December or January) is called southwest monsoon.

2) Dry season from January to April. This season was influenced from southeast monsoon; the air mass moved from the high pressure in the South China Sea and brought slightly rain.

Regarding Table 3 the average monthly rainfall ranges 51.6 mm to 384.7 mm while average annual rainfall 2,428.3 mm. The average air temperature is the highest in April (29.12°C) and lowest in November (26.97°C) while average annual temperature is (28.08°C). The annual average of relative humidity is 82.67%. The highest and lowest average of relative humidity occurs in October, November and February respectively.

Table 3 Average monthly rainfall, air temperature and relative humidity at the study area during 1976-2005.

| Month | Average of | | | |
|-----------|------------------|---------------------|---------------------|-----------------------------|
| | Rainfall (mm) | Rainy days (Day) | Temperature (°C) | Relative humidity (%) |
| January | 51.60 | 3.10 | 27.72 | 78.20 |
| February | 33.90 | 2.20 | 28.23 | 76.70 |
| March | 83.80 | 5.80 | 28.76 | 79.10 |
| April | 100.30 | 7.60 | 29.12 | 81.20 |
| May | 179.30 | 10.00 | 28.90 | 82.90 |
| June | 312.70 | 12.10 | 28.37 | 84.80 |
| July | 342.20 | 13.00 | 28.34 | 83.70 |
| August | 384.70 | 12.50 | 28.23 | 84.40 |
| September | 350.40 | 14.00 | 27.60 | 86.40 |
| October | 320.10 | 14.20 | 27.28 | 87.20 |
| November | 180.80 | 9.50 | 26.97 | 87.20 |
| December | 88.50 | 6.30 | 27.54 | 82.30 |
| Total | 202.36 | 110.30 | 28.08 | 82.67 |

Source: The Meteorological Department, Ministry of Transport and Communications (2006).

The rainfall data during November 2006–October 2007 was collected from Univanich Palm Oil Public Co.,Ltd at Phuket Rubber Estate in Ban Thung Soong. The detail of the meteorological data in BTS was shown in Table 4.

Table 4 Rainy day during November 2006–October 2007.

| Day | Years | | | | | | | | | | | |
|-------|-------|------|------|------|------|------|-----|------|------|------|------|------|
| | 2006 | | 2007 | | | | | | | | | |
| | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. |
| 1 | 8 | - | - | - | 10 | - | 22 | - | - | - | 13 | - |
| 2 | - | - | - | - | 35 | 9 | 31 | - | - | - | 14 | - |
| 3 | 8 | - | - | - | - | - | - | - | - | 25 | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | 4 | - |
| 5 | - | - | - | - | - | - | - | - | 16 | - | 6 | - |
| 6 | - | - | - | - | - | 18 | - | - | 16 | 14 | 8 | - |
| 7 | - | - | 4 | - | - | - | 36 | - | 29 | 10 | 6 | - |
| 8 | - | - | - | 51 | - | - | 14 | - | 20 | - | 8 | 7 |
| 9 | - | - | - | - | - | - | 58 | 8 | 58 | - | 15 | - |
| 10 | - | - | - | - | 27 | - | 35 | 5 | 26 | - | 19 | 3 |
| 11 | - | 20 | - | - | - | 20 | 16 | - | 20 | - | 8 | 18 |
| 12 | 10 | 13 | - | - | - | - | - | 5 | 6 | - | - | - |
| 13 | - | - | - | - | - | 17 | 5 | 9 | - | - | - | - |
| 14 | - | - | - | - | - | 15 | 9 | - | - | - | 3 | 4 |
| 15 | - | - | 15 | 35 | - | 14 | 28 | 10 | 9 | - | - | 66 |
| 16 | 12 | - | - | - | - | - | - | - | - | - | 25 | 17 |
| 17 | - | - | - | - | - | - | - | - | - | - | - | 11 |
| 18 | - | - | - | - | - | - | - | 50 | - | - | 10 | 60 |
| 19 | - | - | 9 | - | 23 | 20 | - | 20 | - | - | - | 8 |
| 20 | 10 | - | - | - | - | - | - | - | 30 | - | - | 9 |
| 21 | - | - | - | - | 4 | 13 | - | - | - | 14 | - | - |
| 22 | 8 | - | - | 16 | - | 4 | - | - | 15 | - | - | - |
| 23 | 43 | - | - | 9 | - | 34 | - | - | - | - | - | - |
| 24 | - | - | - | - | - | 19 | - | - | - | - | - | - |
| 25 | - | - | - | - | - | 7 | - | 31 | 30 | - | - | - |
| 26 | - | - | - | - | - | - | - | 22 | - | 19 | 52 | - |
| 27 | 18 | - | - | - | - | - | - | - | - | - | - | - |
| 28 | - | 3 | - | 9 | 14 | 40 | - | - | 20 | 17 | - | - |
| 29 | - | - | - | - | 15 | 41 | - | - | - | 15 | - | - |
| 30 | - | - | - | - | - | - | 15 | - | 5 | - | - | - |
| 31 | - | - | - | - | - | - | - | - | - | - | - | - |
| Total | 117 | 36 | 28 | 120 | 128 | 271 | 269 | 160 | 300 | 114 | 191 | 203 |

From Table 4, it was shown the total rainfalls in each month. The result showed the maximum rainfall is in June and minimum rainfall is in January. The day that has maximum rainfall is in the 15 October 2007 (66 mm). From this study can showed total rainfall in each month in Figure 21.

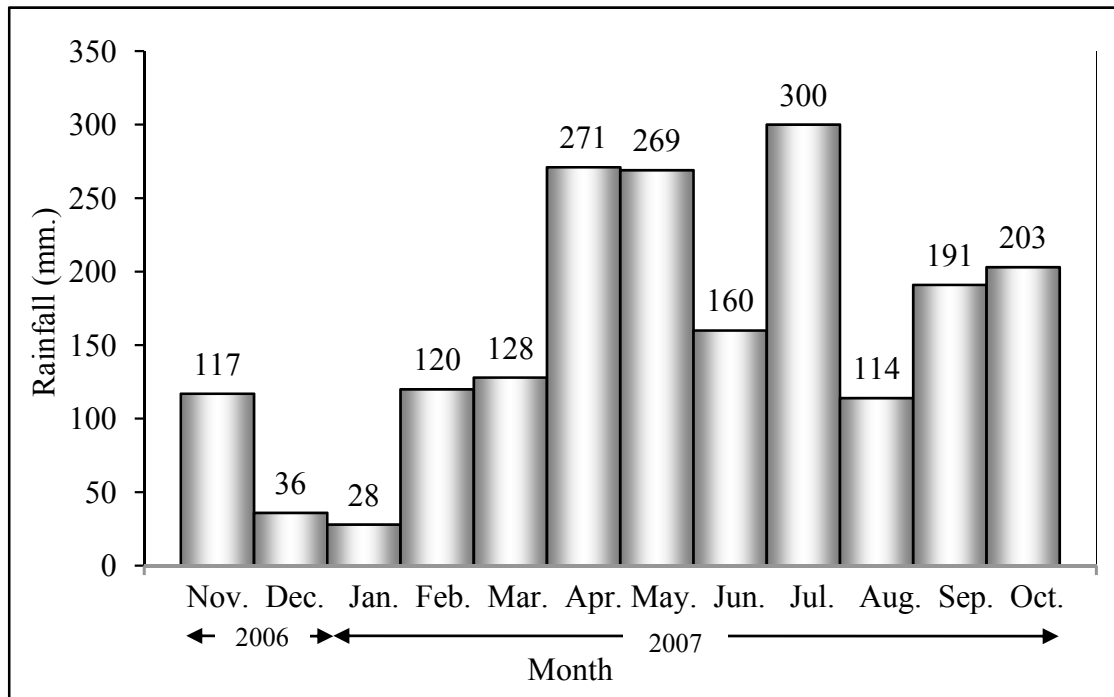


Figure 21 Monthly rainfall during November 2006–October 2007.

Total rainfall in each month was studied and classified accumulate of rainfall in 5 days, 10 days, 15 days, 20 days, 25 days and more than 25 days (Table 5)

Table 5 Accumulate of rainfall before data collection.

| Total rainfall (Days) | Years | | | | | | | | | | | |
|-----------------------------|-------|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|
| | 2006 | | | | | | 2007 | | | | | |
| | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct |
| 5 | 61 | 0 | 0 | 25 | 27 | 77 | 0 | 70 | 45 | 14 | 28 | 105 |
| 10 | 79 | 0 | 9 | 25 | 27 | 97 | 0 | 94 | 60 | 14 | 84 | 193 |
| 15 | 91 | 33 | 24 | 60 | 54 | 163 | 58 | 107 | 213 | 24 | 102 | 203 |
| 20 | 101 | 33 | 24 | 111 | 54 | 181 | 201 | 107 | 245 | 63 | 129 | 203 |
| 25 | 109 | 33 | 28 | 111 | 99 | 190 | 254 | 122 | 245 | 88 | 180 | 255 |
| > 25 | 117 | 33 | 31 | 111 | 108 | 219 | 335 | 122 | 298 | 118 | 180 | 265 |

Table 5 showed total rainfall in each range and the rainfall sum in 5, 10, 15, 20, 25 days and more than 25 days as following:-

(1) Accumulate rainfall 5 days before data collection

The result of this study showed maximum accumulate rainfall 5 days before data collection is in October at accumulate rainfall 105 mm and minimum accumulate rainfall 5 days before data collection is in December, January and May at 0 mm as because there was no rain in 3 month (Figure 22).

(2) Accumulate rainfall 10 days before data collection

The result of this study showed maximum accumulate rainfall 10 days before data collection is in October at accumulate of rainfall 193 mm and minimum accumulate rainfall 10 days before data collection is in December and May at 0 mm because in 2 month there was no influence of rainfall. Result of this study was shown in Figure 23.

(3) Accumulate rainfall 15 days before data collection

The result of this study showed maximum accumulate rainfall 15 days before data collection is in July at accumulate rainfall 213 mm and minimum accumulate rainfall 15 days before data collection is in January and August at 24 mm. Result of this study was shown in Figure 24.

(4) Accumulate rainfall 20 days before data collection

The result of this study showed maximum accumulate rainfall 20 days before data collection is in July at accumulate rainfall 245 mm and minimum accumulate rainfall 20 days before data collection is in January at 24 mm. Result of this study was shown in Figure 25.

(5) Accumulate rainfall 25 days before data collection

The result of this study showed maximum accumulate rainfall 25 days before data collection is in October at accumulate rainfall 255 mm and minimum accumulate rainfall 25 days before data collection is in January at 28 mm. Result of this study was shown in Figure 26.

(6) Accumulate rainfall more than 25 days before data collection

The result of this study showed maximum accumulate rainfall more than 25 days before data collection is in May at accumulate rainfall 335 mm and minimum accumulate rainfall more than 25 before data collection is in January at 31 mm. Result of this study was shown in Figure 27.

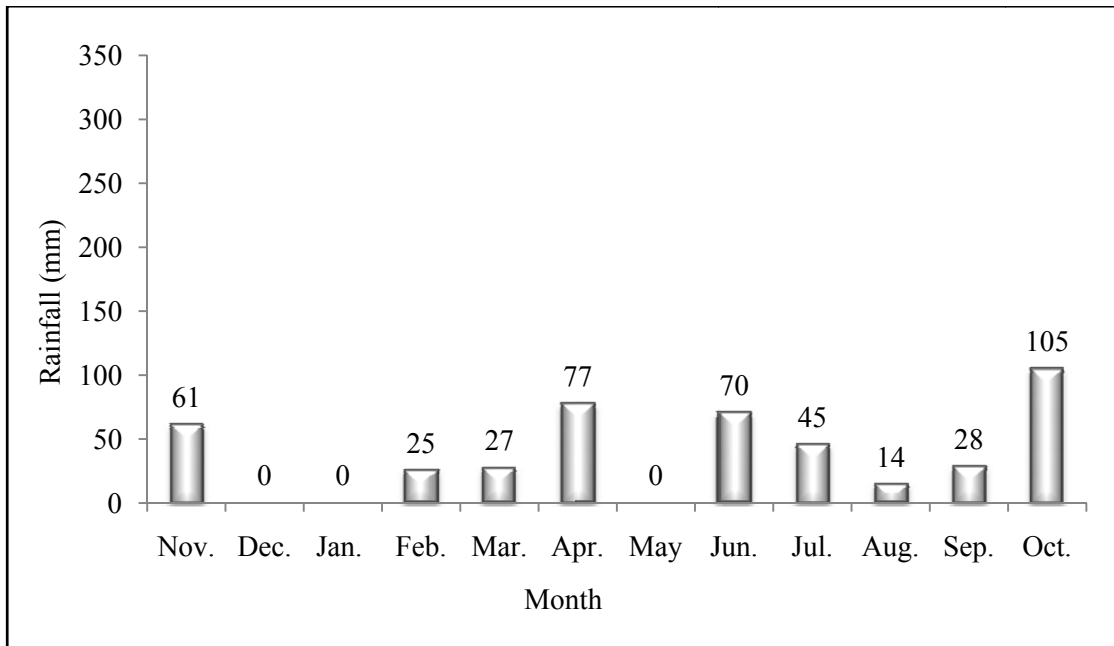


Figure 22 Accumulate rainfall of 5 days before data collection.

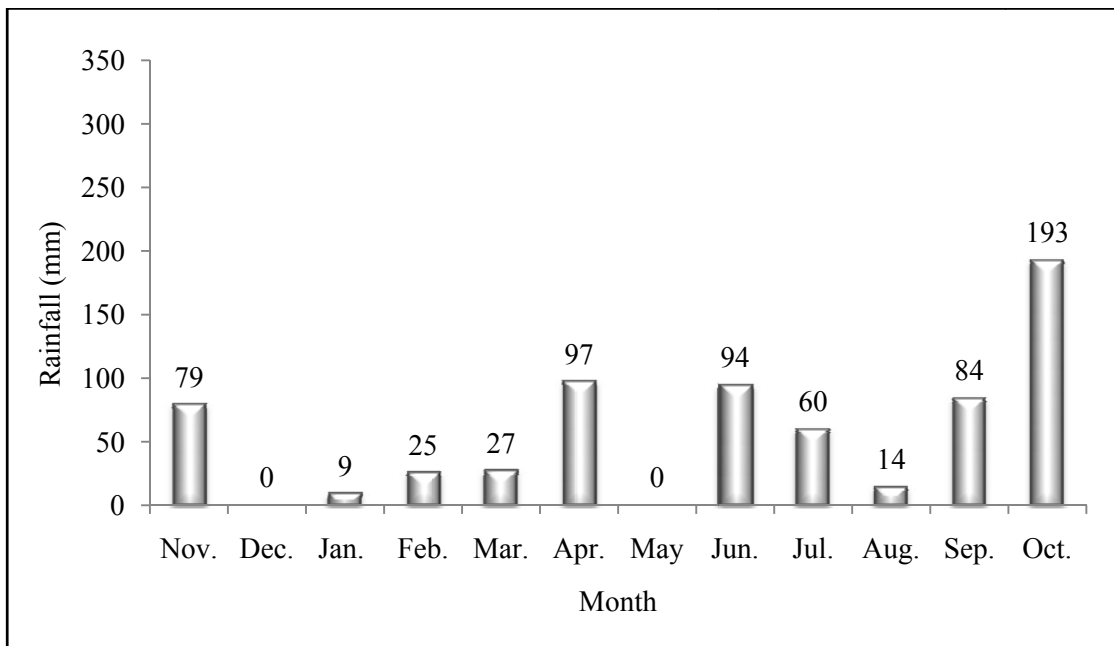


Figure 23 Accumulate rainfall of 10 days before data collection.

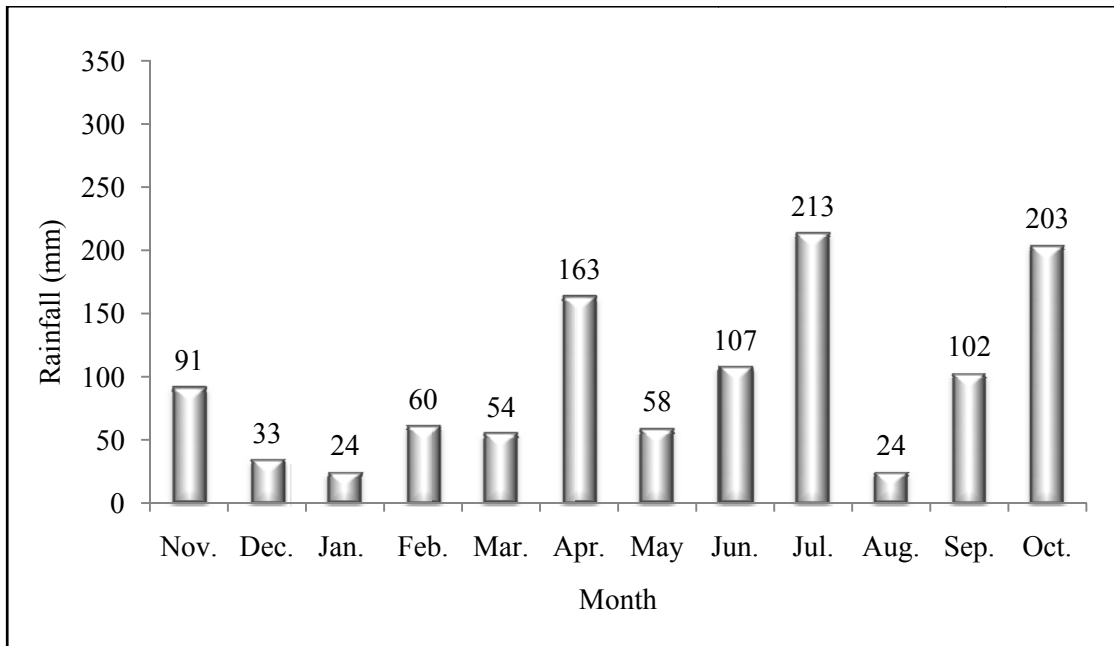


Figure 24 Accumulate rainfall of 15 days before data collection.

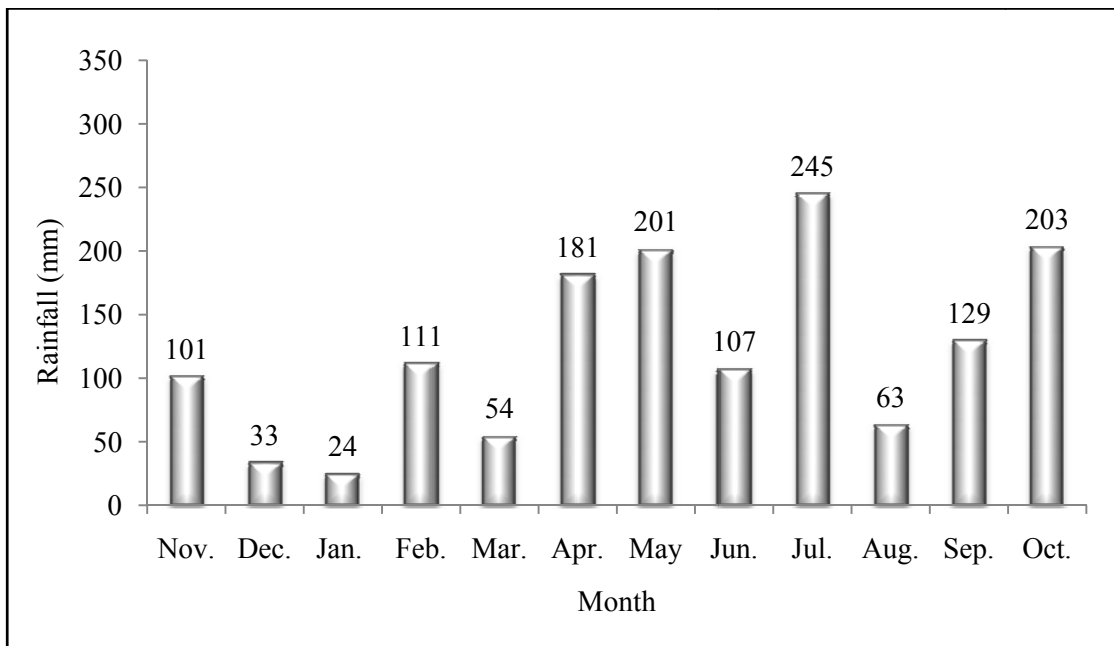


Figure 25 Accumulate rainfall of 20 days before data collection.

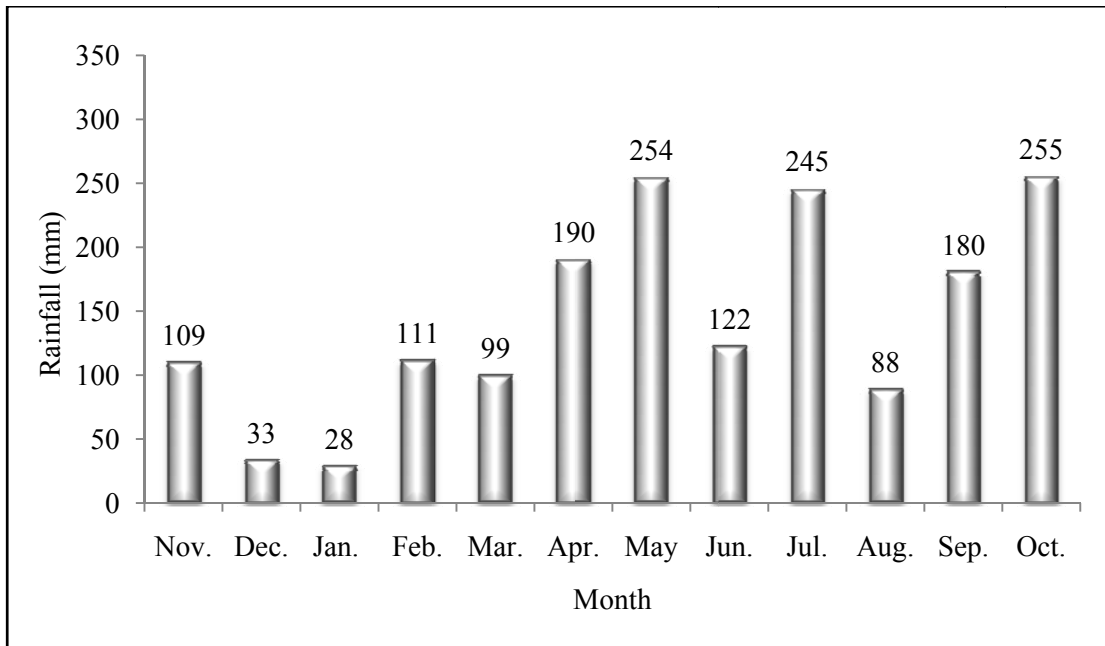


Figure 26 Accumulate rainfall of 25 days before data collection.

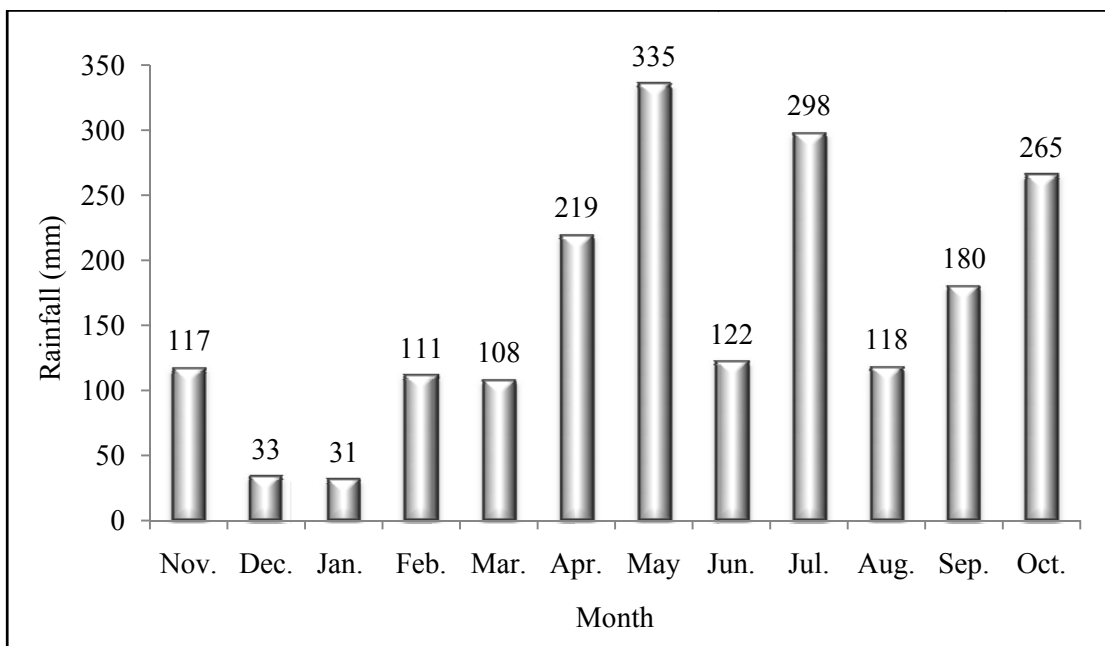


Figure 27 Accumulate rainfall more than 25 days before data collection.

2. Characteristic of data collected area.

Characteristic in each data collected areas in BTS include of area for soil sample data based on the percent of land use types and position of shallow well. In this study 6 sample sites were chosen for data collection including 3 sample of oil palm plantation (P) 2 samples for para rubber (R) 1 samples for mixed fruit orchard (G). The characteristic and soil characteristic in each study area was reported in Figure 28 and Table 6.

1) Oil Palm Plantation (P1)

Characteristic of this area was a plantation of oil palm, about 7 years old and planted with spacing 4m x 8m. Soil characteristic of this area was a sandy clay loam, Soil color was dark red brown, amount of organic matters was 0.61 percent, Particle density was 2.59 g/cm^3 , Average pH was 5.2 and well graded soil. (Figure 28 (a))

2) Oil Palm Plantation (P2)

Characteristic of this area was a plantation of oil palm, about 15 years old which was and planted with spacing 4m x 7m. Soil characteristic of this area was a sandy loam, Soil color was red brown, Organic matters was 1.15 percent, Particle density was 2.6 g/cm^3 , average pH was 6.1 and well graded soil. (Figure 28 (b))

3) Oil Palm Plantation (P3)

Characteristic of this area was a plantation of oil palm about 15 years old which was and planted with spacing 5m x 8m. Soil characteristic of this area was a loam, Soil color was dark red brown, Organic grew in matters were 1.18 percent, Particle density was 2.68 g/cm^3 , Average pH was 4.9 and well graded soil. (Figure 28 (c))

4) Para Rubber Plantation (R1)

Characteristic of this area was a plantation of para rubber around 25 years old which was and planted with spacing 6m x 4m. Soil characteristic of this area was a sandy loam, Soil color was dark brown, Organic matter around 0.61 percent, Particle density was 2.59 g/cm³, Average pH was 5.2 and being well graded soil. (Figure 28 (d))

5) Para Rubber Plantation (R2)

Characteristic of this area was a plantation of para rubber around 25 years old which was and planted with spacing 6m x 4m. Soil characteristic of this area was sandy loam, Soil color was brown, Organic matter around 1.36 percent, Particle density was 2.51 g/cm³, Average pH was 5.4 and being well graded soil. (Figure 28 (e))

6) Mixed Fruit Orchard

Characteristic of this area include many species of plant such as *Durian* (*Durio zibethinus*), Langsat (*Aglaia domestica*), Longkong (*Lansium domesticum*), Mangosteen (*Garcinia mangostana*), Jackfruit (*Artocarpus heterophyllus*), Coconut (*Cocos nucifera*), Betel nut (*Areca catechu*), Stink bean (*Parkia speciosa*) etc. All fruit trees were planted in mixing each others. Soil characteristic of this area was the sandy clay loam, Soil color was dark brown, Organic matter around 1.18 percent, Particle density was 2.64 g/cm³, average pH was 5 and being well graded soil. (Figure 28 (f))



(a) Oil palm plantation (P1)



(b) Oil palm plantation (P2)

Figure 28 Characteristic of data collection area in each land use types.



(c) Oil palm plantation (P3)



(d) Para rubber plantation (R1)

Figure 28 (Continued)



(e) Para rubber plantation (R2)



(f) Mixed fruit orchard (G1)

Figure 28 (Continued)

Table 6 Soil characteristic in each study area.

| Sample Name | Soil Texture | | | | Organic matter | Particle Density |
|-----------------------------|--------------|--------|--------|-----------------|----------------|----------------------|
| | Sand % | Silt % | Clay % | Texture | % | (g/cm ³) |
| Oil Palm Plantation (P1) | 52 | 25 | 23 | Sandy clay loam | 0.61 | 2.59 |
| Oil Palm Plantation (P2) | 56 | 27 | 17 | Sandy loam | 1.15 | 2.6 |
| Oil Palm Plantation (P3) | 44 | 35 | 21 | Loam | 1.18 | 2.68 |
| Para rubber Plantation (R1) | 62 | 24 | 14 | Sandy loam | 1.12 | 2.53 |
| Para rubber Plantation (R2) | 60 | 27 | 13 | Sandy loam | 1.36 | 2.51 |
| Mixed Fruit Orchard | 58 | 22 | 20 | Sandy clay loam | 1.18 | 2.64 |

3. Variation of SMC and water table in different land use types

This study was carried out under the southern climate condition of the Andaman seacoast. A characteristic feature of until soil is the drastic decrease in porosity depth. This has the consequence that the water table level follows the land surface at a shallow depth, which in turn leads to close relationship between water table and SMC in the unsaturated zone. This is due to the capillary transport of water and means that the water table level determines the possible range of fluctuations of the soil moisture content. The result of this study was shown in the Tables 2, 3 and Figure 4, 5 respectively

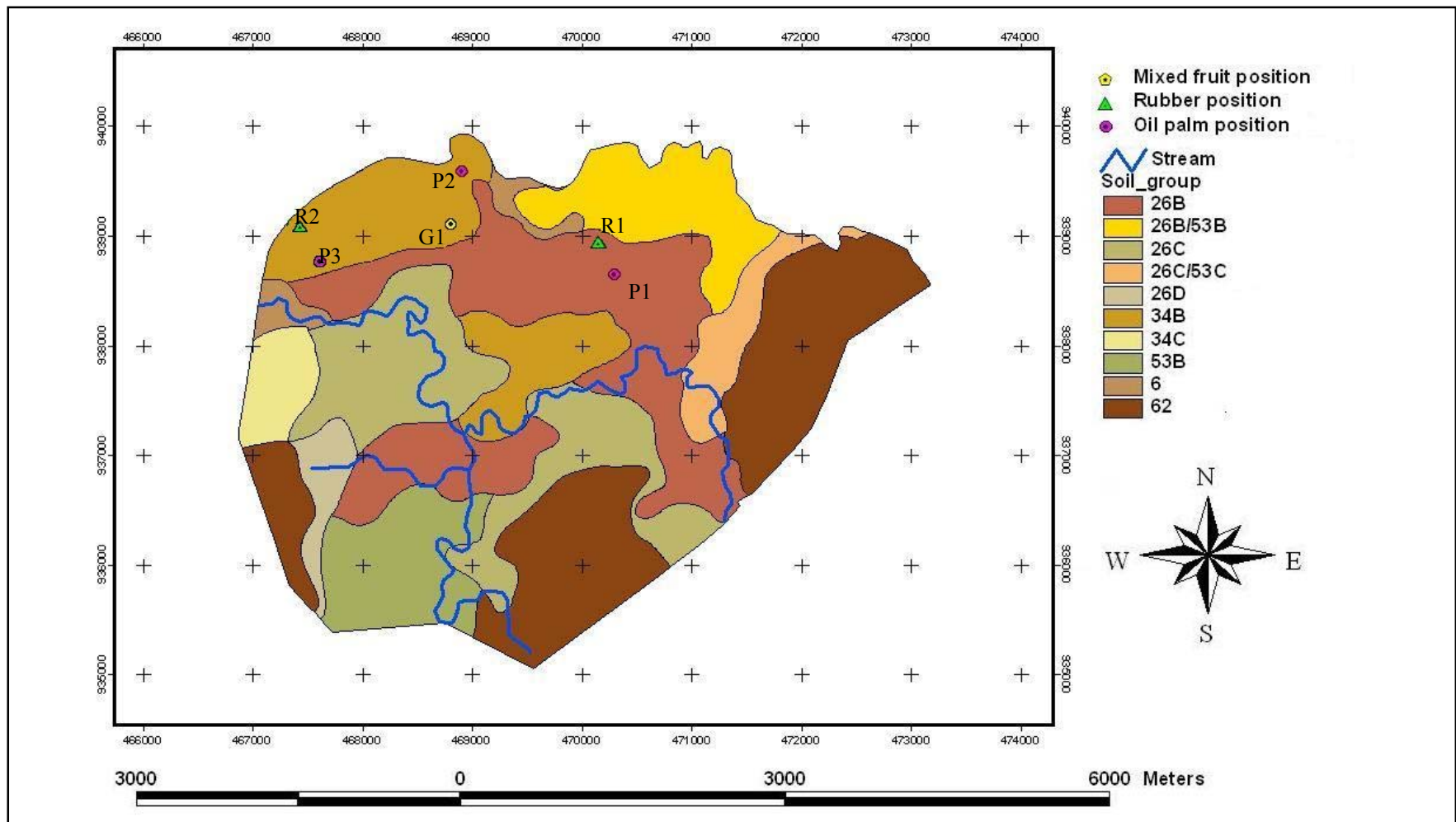


Figure 29 Position of data collection in soil groups.

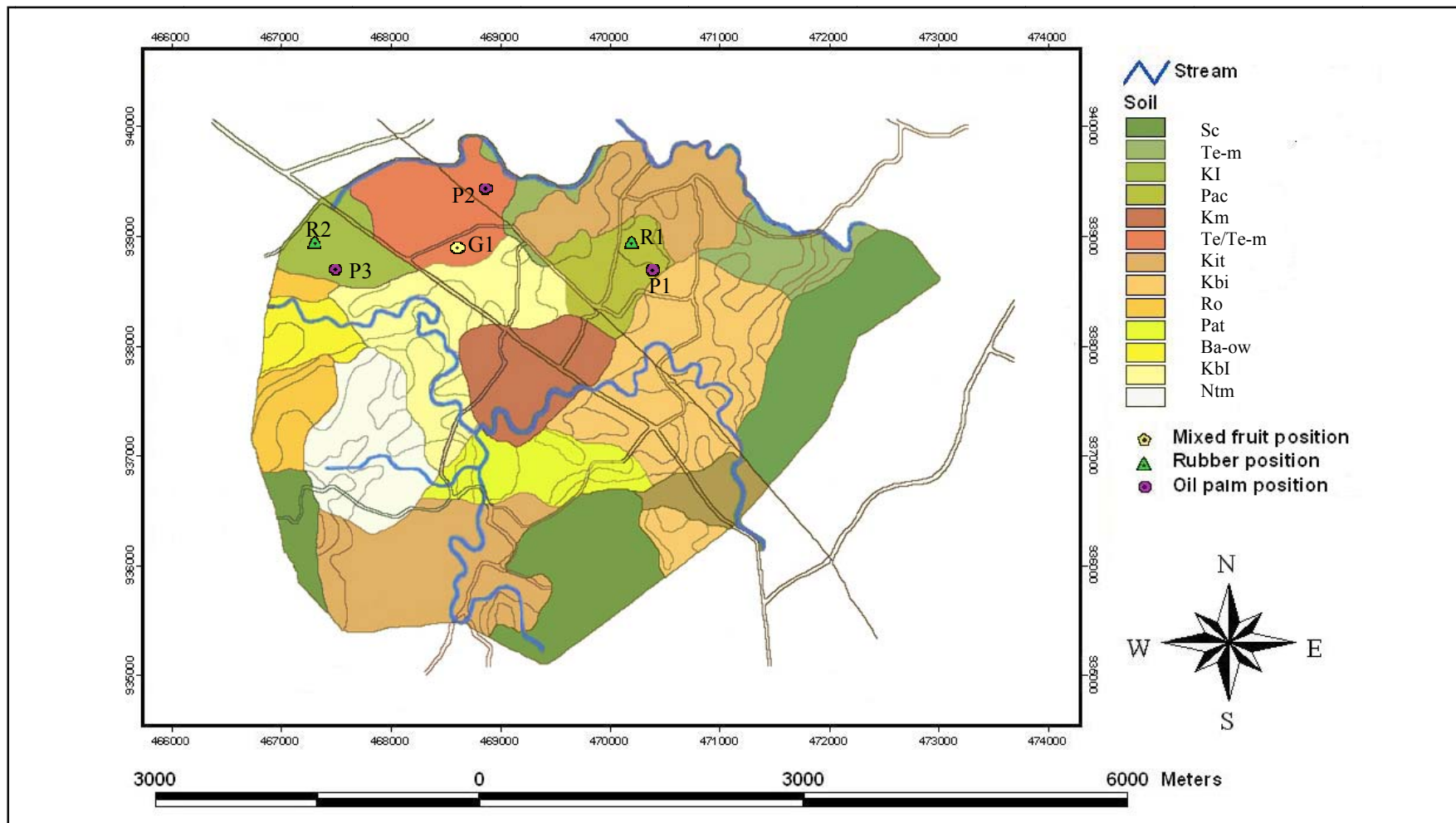


Figure 30 Position of data collection in soil series.

Table 7 Soil moisture content in oil palm plantation, para rubber plantation and mixed fruit orchard during Nov. 2006–Oct. 2007.

| Land use types | Soil depth | Soil moisture content (% by weight) | | | | | | | | | | | |
|--------------------------|------------|-------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | 2006 | | | | 2007 | | | | | | | |
| | | Nov. | Dec. | Jan | Feb | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. |
| Oil palm plantation (P1) | 0-25 | 13.13 | 12.51 | 13.55 | 11.89 | 10.21 | 18.59 | 17.06 | 16.46 | 16.99 | 18.50 | 21.53 | 16.77 |
| | 25-50 | 11.31 | 11.53 | 10.69 | 8.77 | 5.90 | 10.76 | 16.98 | 16.70 | 16.68 | 18.31 | 22.33 | 15.10 |
| | 50-75 | 12.10 | 11.52 | 11.79 | 9.21 | 7.46 | 7.23 | 16.77 | 16.82 | 12.92 | 22.02 | 17.70 | 16.08 |
| | 75-100 | 13.12 | 10.10 | 13.32 | 10.02 | 6.93 | 7.14 | 14.23 | 18.36 | 13.91 | 24.19 | 16.27 | 16.08 |
| | Mean | 12.42 | 11.42 | 12.34 | 9.97 | 7.63 | 10.93 | 16.26 | 17.09 | 15.13 | 20.76 | 19.46 | 16.01 |
| Oil palm plantation (P2) | 0-25 | 19.75 | 14.52 | 14.90 | 12.33 | 11.74 | 15.60 | 10.25 | 16.93 | 18.11 | 18.25 | 26.81 | 15.13 |
| | 25-50 | 16.00 | 14.46 | 10.43 | 10.56 | 11.19 | 16.86 | 12.96 | 19.71 | 18.91 | 15.98 | 29.52 | 17.71 |
| | 50-75 | 14.17 | 12.32 | 10.90 | 9.96 | 9.33 | 14.44 | 11.25 | 18.43 | 19.28 | 18.61 | 23.94 | 15.89 |
| | 75-100 | 16.19 | 12.91 | 11.79 | 10.05 | 9.26 | 15.26 | 11.03 | 18.11 | 19.67 | 18.68 | 25.46 | 15.09 |
| | Mean | 16.53 | 13.55 | 12.01 | 10.73 | 10.38 | 15.54 | 11.37 | 18.30 | 18.99 | 17.88 | 26.43 | 15.96 |
| Oil palm plantation (P3) | 0-25 | 10.14 | 16.30 | 10.82 | 14.06 | 17.56 | 19.44 | 19.29 | 20.36 | 20.35 | 20.10 | 25.36 | 21.20 |
| | 25-50 | 14.88 | 15.24 | 12.39 | 13.33 | 14.50 | 19.99 | 18.90 | 21.73 | 20.69 | 23.48 | 24.45 | 22.51 |
| | 50-75 | 17.65 | 11.79 | 14.64 | 12.17 | 12.34 | 15.00 | 17.14 | 20.16 | 22.88 | 21.83 | 27.83 | 20.17 |
| | 75-100 | 16.68 | 10.98 | 15.32 | 12.54 | 12.07 | 16.15 | 16.26 | 19.81 | 24.6 | 22.23 | 28.88 | 20.53 |
| | Mean | 14.84 | 13.58 | 13.29 | 13.03 | 14.12 | 17.65 | 17.90 | 20.52 | 22.13 | 21.91 | 26.63 | 21.10 |
| Grand mean | | 14.59 | 12.85 | 12.55 | 11.24 | 10.71 | 14.71 | 15.18 | 18.63 | 18.75 | 20.18 | 24.17 | 17.69 |

Table 7 (Continued)

| Land use types | Soil depth | Soil moisture content (% by weight) | | | | | | | | | | | |
|-----------------------------|------------|-------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | 2006 | | | | 2007 | | | | | | | |
| | | Nov. | Dec. | Jan | Feb | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. |
| Para rubber plantation (R1) | 0-25 | 23.02 | 15.68 | 11.30 | 14.83 | 19.15 | 22.23 | 13.9 | 23.29 | 22.45 | 21.93 | 20.55 | 22.13 |
| | 25-50 | 13.66 | 16.03 | 10.27 | 12.98 | 17.26 | 16.69 | 13.10 | 17.90 | 16.66 | 15.82 | 19.77 | 16.09 |
| | 50-75 | 14.66 | 13.15 | 10.00 | 12.23 | 17.02 | 17.34 | 15.33 | 19.93 | 18.09 | 15.80 | 17.58 | 17.11 |
| | 75-100 | 16.71 | 13.22 | 11.94 | 13.01 | 17.89 | 16.55 | 14.21 | 19.59 | 19.36 | 15.96 | 21.33 | 17.41 |
| | Mean | 17.01 | 14.52 | 10.88 | 13.26 | 17.83 | 18.20 | 14.14 | 20.18 | 19.14 | 17.38 | 19.81 | 18.19 |
| Para rubber plantation (R1) | 0-25 | 16.61 | 19.45 | 12.33 | 14.96 | 16.95 | 27.07 | 16.09 | 28.61 | 25.39 | 24.70 | 30.02 | 23.48 |
| | 25-50 | 14.38 | 19.24 | 11.62 | 12.32 | 14.98 | 19.04 | 16.00 | 18.29 | 18.98 | 19.09 | 22.04 | 17.57 |
| | 50-75 | 14.88 | 16.61 | 11.95 | 13.75 | 16.47 | 17.89 | 16.22 | 21.46 | 20.84 | 19.37 | 24.01 | 17.97 |
| | 75-100 | 14.80 | 16.32 | 10.94 | 13.17 | 16.22 | 18.01 | 14.74 | 21.97 | 20.25 | 18.24 | 24.67 | 17.71 |
| | Mean | 15.17 | 17.91 | 11.71 | 13.55 | 16.16 | 20.50 | 15.76 | 22.58 | 21.37 | 20.35 | 25.19 | 19.18 |
| Grand mean | | 16.09 | 16.21 | 11.29 | 13.41 | 16.99 | 19.35 | 14.95 | 21.38 | 20.25 | 18.86 | 22.50 | 18.68 |
| Mixed fruit orchard (G1) | 0-25 | 23.27 | 19.65 | 10.73 | 13.44 | 22.36 | 21.25 | 20.19 | 24.93 | 20.51 | 21.06 | 28.36 | 17.29 |
| | 25-50 | 20.49 | 18.39 | 14.54 | 15.45 | 19.10 | 18.54 | 20.80 | 18.79 | 19.67 | 17.67 | 26.85 | 16.28 |
| | 50-75 | 21.40 | 18.34 | 17.14 | 17.84 | 18.96 | 17.32 | 19.35 | 22.26 | 20.31 | 20.01 | 23.40 | 17.59 |
| | 75-100 | 24.26 | 17.00 | 17.66 | 17.26 | 18.88 | 16.89 | 20.07 | 25.49 | 21.63 | 21.94 | 27.05 | 17.69 |
| Mean | | 22.36 | 18.35 | 15.02 | 16.00 | 19.83 | 18.50 | 20.10 | 22.87 | 20.53 | 20.17 | 26.42 | 17.21 |

Table 7 showed trend of percent of SMC during November 2006 – October 2007 based on oil palm plantation, para rubber plantation and mixed fruit orchard. Details of this study were shown below:

3.1 Variation of SMC in each land use types

(1) Oil palm plantation (P1)

Soil moisture content in oil palm plantation (P1) (Figure 31) showed that in soil depth 0-25 cm. the highest SMC was 18.59% in April and the lowest SMC was 10.21% in March. In soil depth 25-50 cm. the highest SMC was 22.33 % in September and the lowest SMC was 5.90 % in March. In soil depth 50-75 cm. the highest SMC was 22.02 % in August and the lowest SMC was 7.23 % in April. And in soil depth 75-100 cm. the highest SMC was 24.19 % in August and the lowest SMC was 7.14 % in April. An average of soil moisture content in oil palm plantation (P1) showed that in all of soil depth (0-100 cm) the highest SMC was 20.76% in August and the lowest SMC was 7.63% in March.

(2) Oil palm plantation (P2)

Soil moisture content in oil palm plantation (P2) (Figure 32) showed that in soil depth 0-25 cm. the highest SMC was 26.81 % in September and the lowest SMC was 10.25% in May. In soil depth 25-50 cm. the highest SMC was 29.52 % in September and the lowest SMC was 10.56 % in February. In soil depth 50-75 cm. had the highest SMC was 23.94 % in April and the lowest SMC was 9.33 % in March. And in soil depth 75-100 cm. the highest SMC was 25.46 % in April and the lowest SMC was 9.26 % in March. An average of soil moisture content in oil palm plantation (P2) showed that in all of soil depth (0-100 cm) the highest SMC was 26.43% in September and the lowest SMC was 10.38% in March.

(3) Oil palm plantation (P3)

Soil moisture content in oil palm plantation (P3) (Figure 33) showed that in soil depth 0-25 cm. the highest SMC was 25.36% in September and the lowest SMC was 10.14% in November. In soil depth 25-50 cm. the highest SMC was 24.45% in September and the lowest SMC was 12.39% in January. In soil depth 50-75 cm. the highest SMC was 27.83% in September and the lowest SMC was 11.79% in December. And in soil depth 75-100 cm. the highest SMC was 28.88% in September and the lowest SMC was 10.98% in December. An average of soil moisture content in oil palm plantation (P3) showed that in all of soil depth (0-100 cm) the highest SMC was 26.63% in September and the lowest SMC was 13.03% in February.

Study in oil palm plantation (Figure 34) showed average of SMC in oil palm plantation at all soil depth (0-100 cm) and the highest SMC was 24.17% in September and the lowest SMC was 10.71% in March.

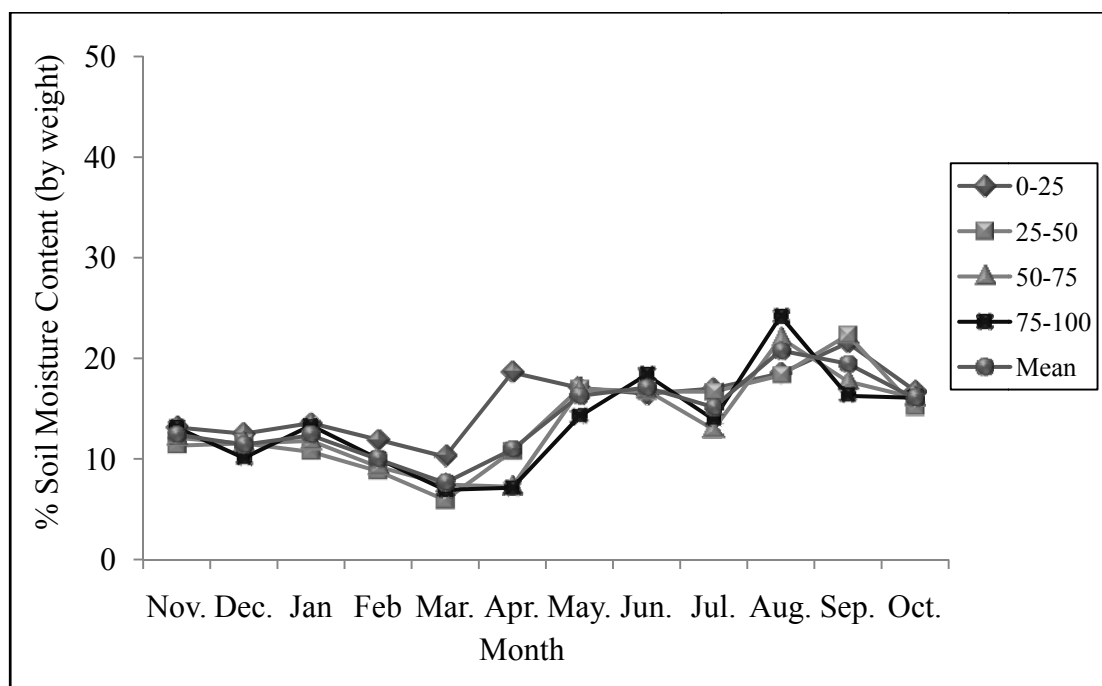


Figure 31 Variation of soil moisture content (SMC) in each depth of oil palm plantation (P1).

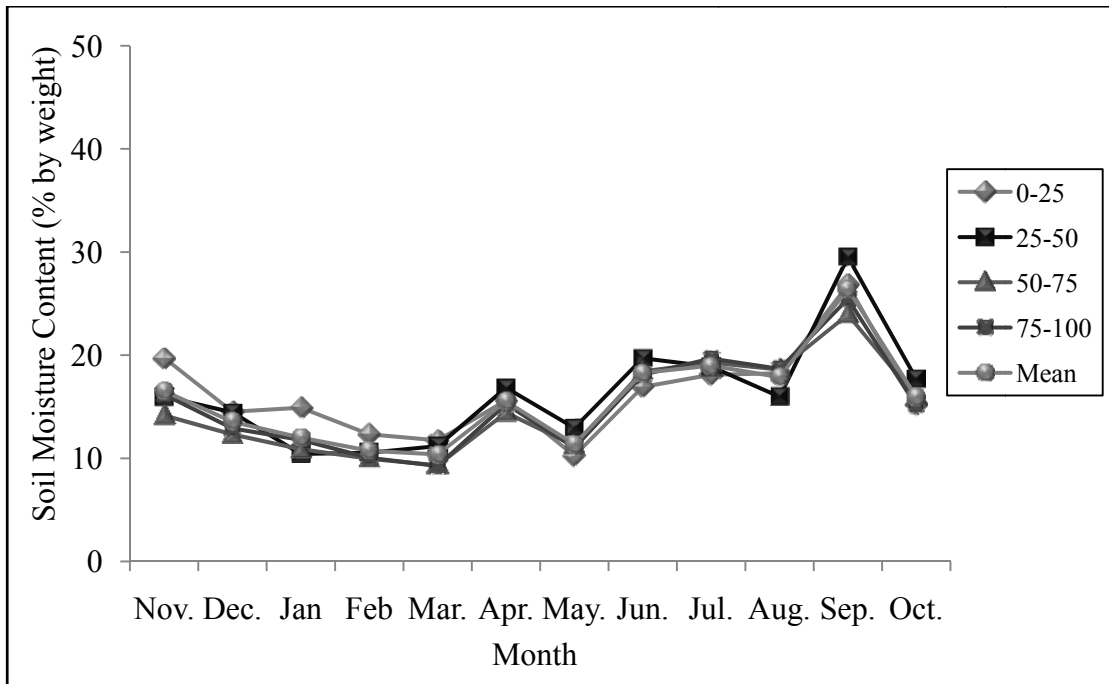


Figure 32 Variation of soil moisture content (SMC) in each depth of oil palm plantation (P2).

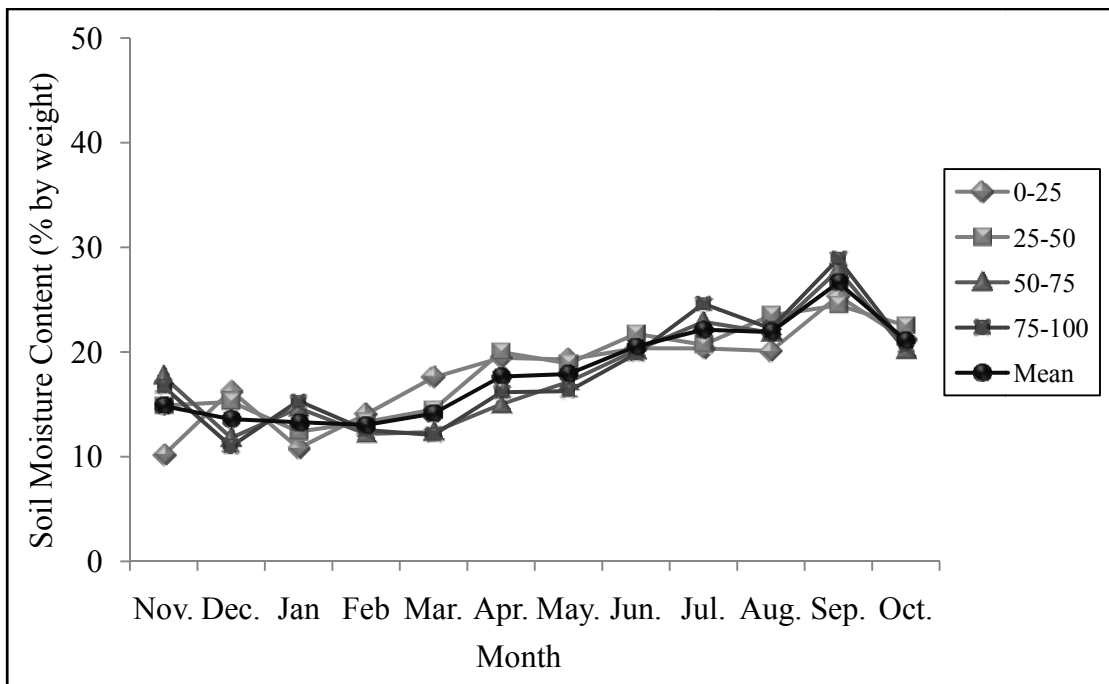


Figure 33 Variation of soil moisture content (SMC) in each depth of oil palm plantation (P3).

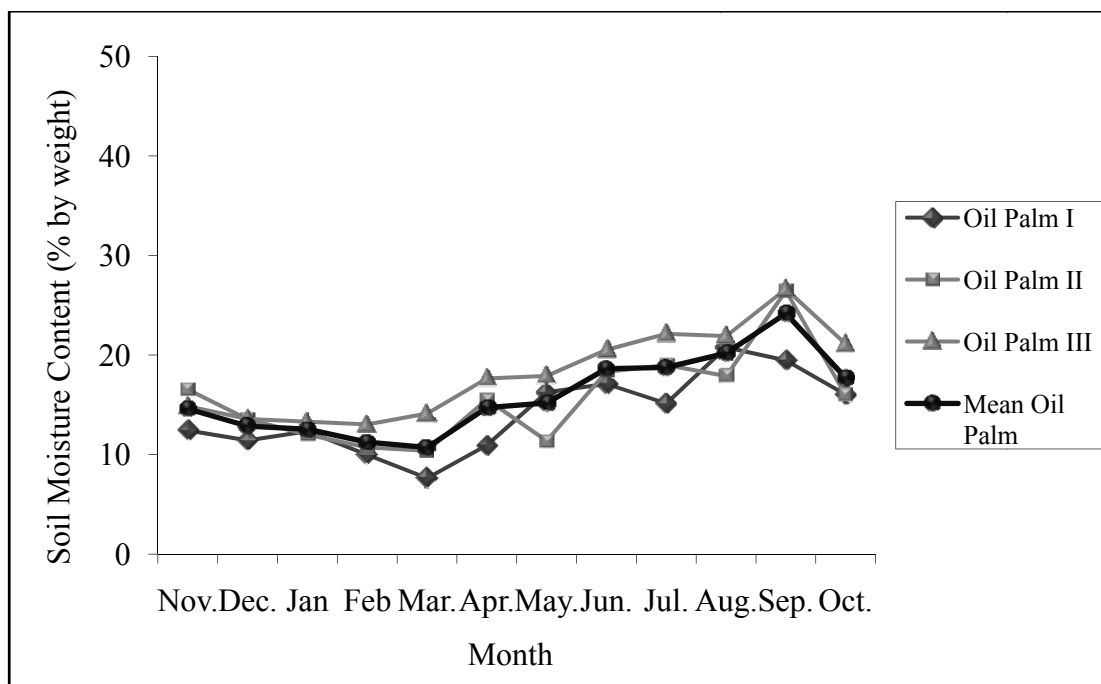


Figure 34 Variation of soil moisture content (SMC) in oil palm plantation at BTS.

(4) Para rubber plantation (R1)

Soil moisture content in para rubber plantation (R1) (Figure 35) showed that in soil depth 0-25 cm. the highest SMC was 23.29% in June and the lowest SMC was 11.30% in January. In soil depth 25-50 cm. the highest SMC was 19.77% in September and the lowest SMC was 10.27% in January. In soil depth 50-75 cm. the highest SMC was 19.93% in June and the lowest SMC was 10.00% in January. And in soil depth 75-100 cm. the highest SMC was 21.33% in September and the lowest SMC was 11.94% in January. An average of soil moisture content in para rubber plantation (R1) showed that in all of soil depth (0-100 cm) the highest SMC was 20.18% in June and the lowest SMC was 10.88% in January.

(5) Para rubber plantation (Para rubber plantation 2)

Soil moisture content in para rubber plantation (R2) (Figure 36) showed that in soil depth 0-25 cm. the highest SMC was 30.02% in September and

the lowest SMC was 12.33% in January. In soil depth 25-50 cm. the highest SMC was 22.04% in September and the lowest SMC was 11.62% in January. In soil depth 50-75 cm. the highest SMC was 24.01% in September and the lowest SMC was 11.95% in January. And in soil depth 75-100 cm. the highest SMC was 24.67% in September and the lowest SMC was 10.94% in January. An average of soil moisture content in para rubber plantation (R2) showed that in all of soil depth (0-100 cm) the highest SMC was 25.19% in September and the lowest SMC was 11.71% in January.

Para rubber plantation (Figure 37) showed average SMC in para rubber plantation at all soil depth (0-100 cm) and the highest SMC was 22.50% in September and the lowest SMC was 11.29% in January.

(6) Mixed fruit orchard (G1)

Soil moisture content in mixed fruit orchard (G2) (Figure 36) showed that in soil depth 0-25 cm. the highest SMC was 28.36% in September and the lowest SMC was 10.73% in January. In soil depth 25-50 cm. the highest SMC was 26.85% in September and the lowest SMC was 14.54% in January. In soil depth 50-75 cm. the highest SMC was 23.40% in September and the lowest SMC was 17.14% in January. And in soil depth 75-100 cm. the highest SMC was 27.05% in April and the lowest SMC was 16.89% in January. Average of soil moisture content in mixed fruit orchard in all of soil depth (0-100 cm) the highest SMC was 26.42% in September and the lowest SMC was 15.02% in January.

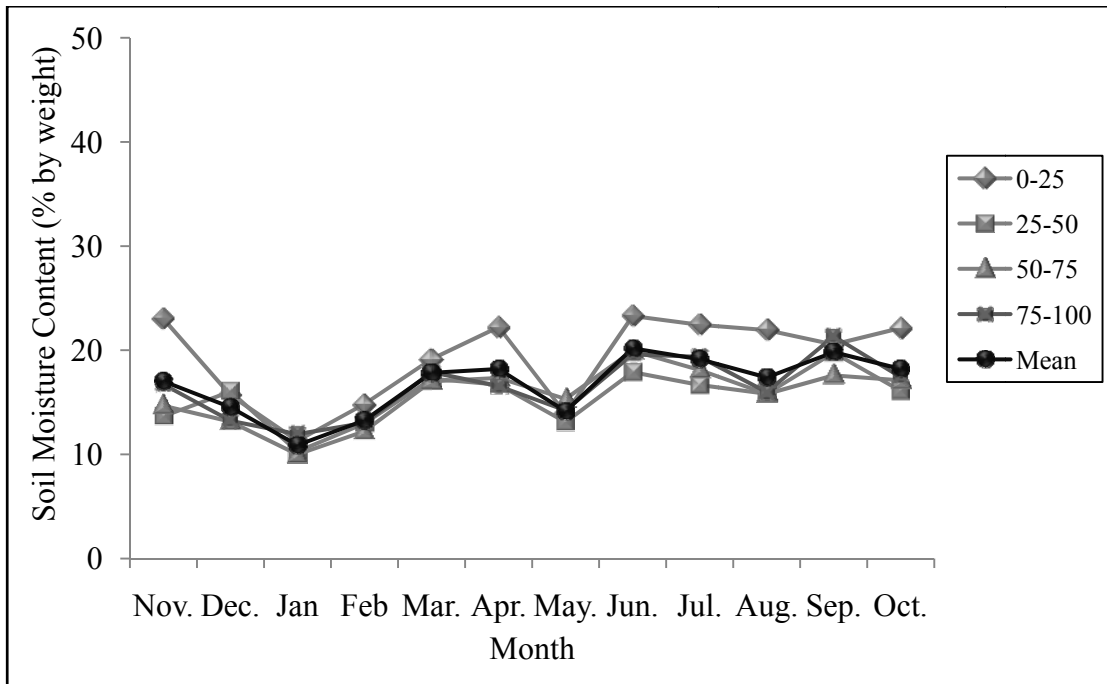


Figure 35 Variation of soil moisture content (SMC) in each depth of para rubber plantation (R1).

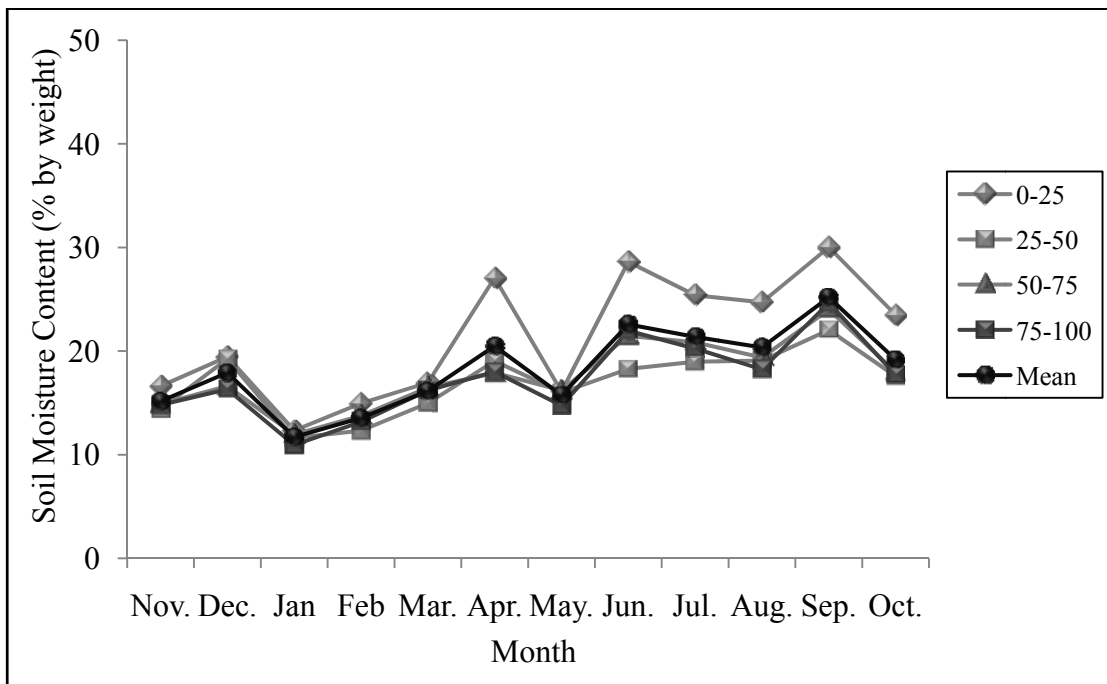


Figure 36 Variation of soil moisture content (SMC) in each depth of para rubber plantation (R2).

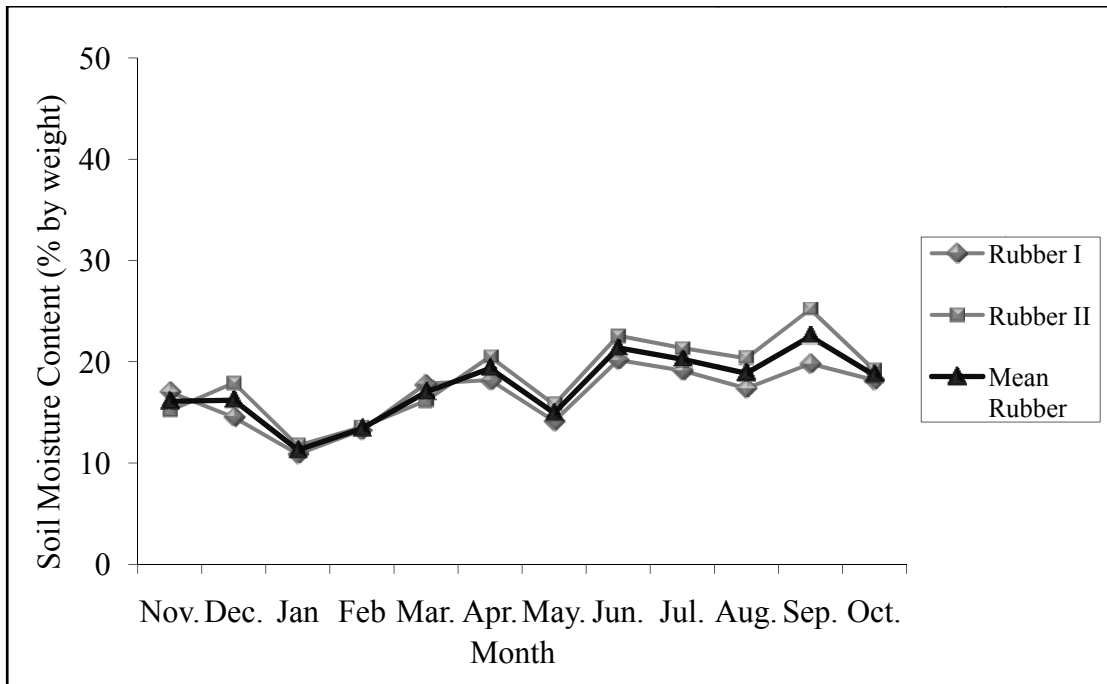


Figure 37 Variation of soil moisture content (SMC) in para rubber plantation at BTS.

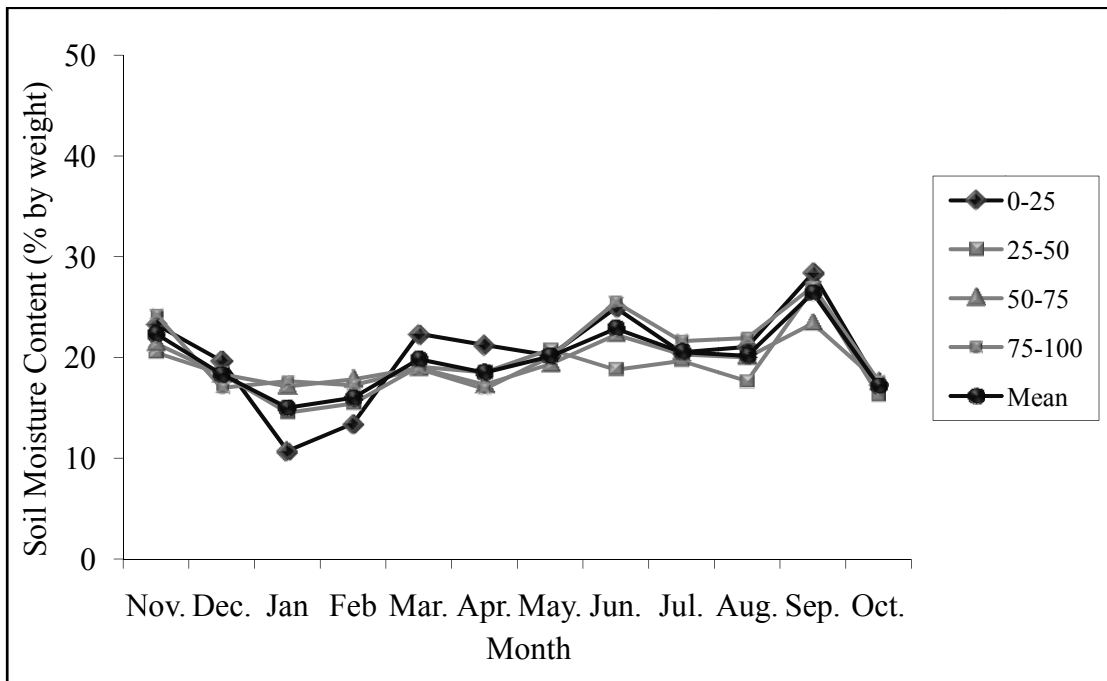


Figure 38 Variation of soil moisture content (SMC) in mixed fruit orchard (G1).

Result showed that mixed fruit orchard had the highest SMC in all levels of depth because the nature of this area had multiple type of tree and all of tree is an evergreen type that had many stage of crown cover that can protect water in soil better than oil palm plantation and para rubber plantation which growing in a plot. The second best is in rubber plantation and oil palm plantation had the lowest SMC in all levels of soil depth because of the nature of oil palm plantation is monocotyledon that used a lot of water to produce a product and include of size of plot is very large when comparing with plot of rubber plantation because palm leaf is expand in a lateral that made the space between tree is large (Figure 39).

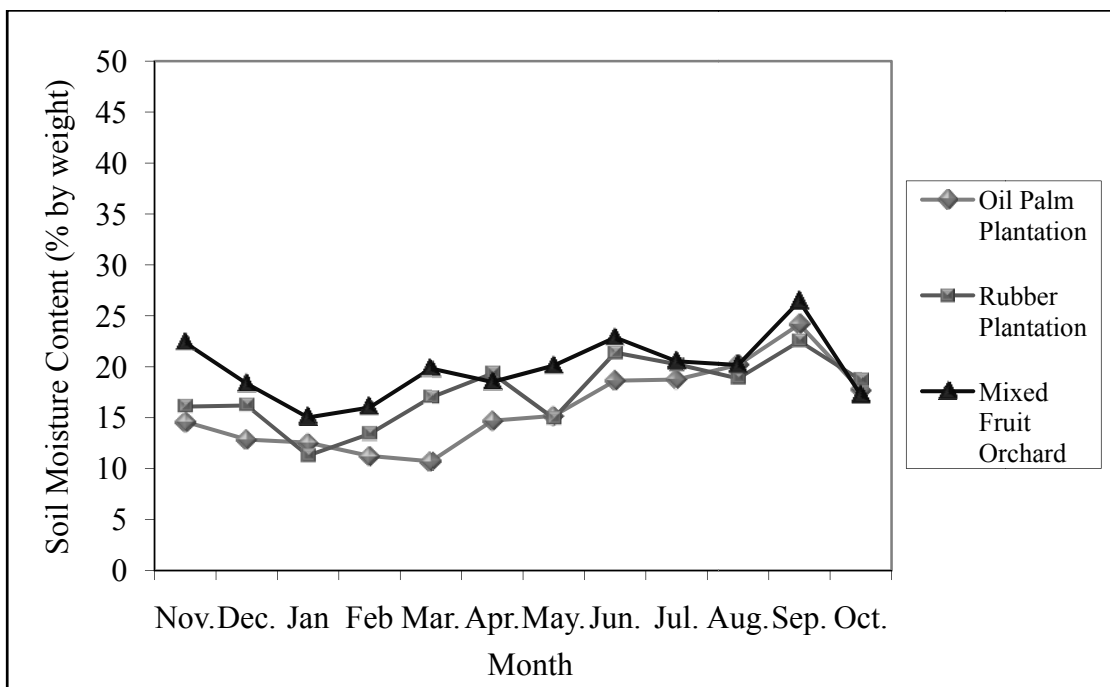


Figure 39 SMC in oil palm, para rubber plantation and mixed fruit orchard.

3.2 Variation of SMC percentage in each soil depth (0-25 cm, 25-50 cm, 50-75 cm and 75-100 cm) of oil palm plantation, para rubber plantation and mixed fruit orchard was reported below:

The study of soil moisture content in oil palm plantation, para rubber plantation and mixed fruit orchard in various soil depth 0-25 cm (Figure 40), 25-50 cm (Figure 41), 50-75 cm (Figure 42) and 75-100 cm (Figure 43). In all cases, highest value of SMC was found in mixed fruit orchard, followed by para rubber plantation and oil palm plantation. In mixed fruit orchard, SMC was ranged between 18.88% at 0-25 cm and 20.49 % at 75-100 cm while SMC in para rubber plantation varied between 16.24% (at 25-50 cm) and 20.26 % (at 0-25 cm) and SMC in oil palm plantation, SMC was ranged between 15.38% at 50-75 cm and 16.57 % at 0-25 cm.

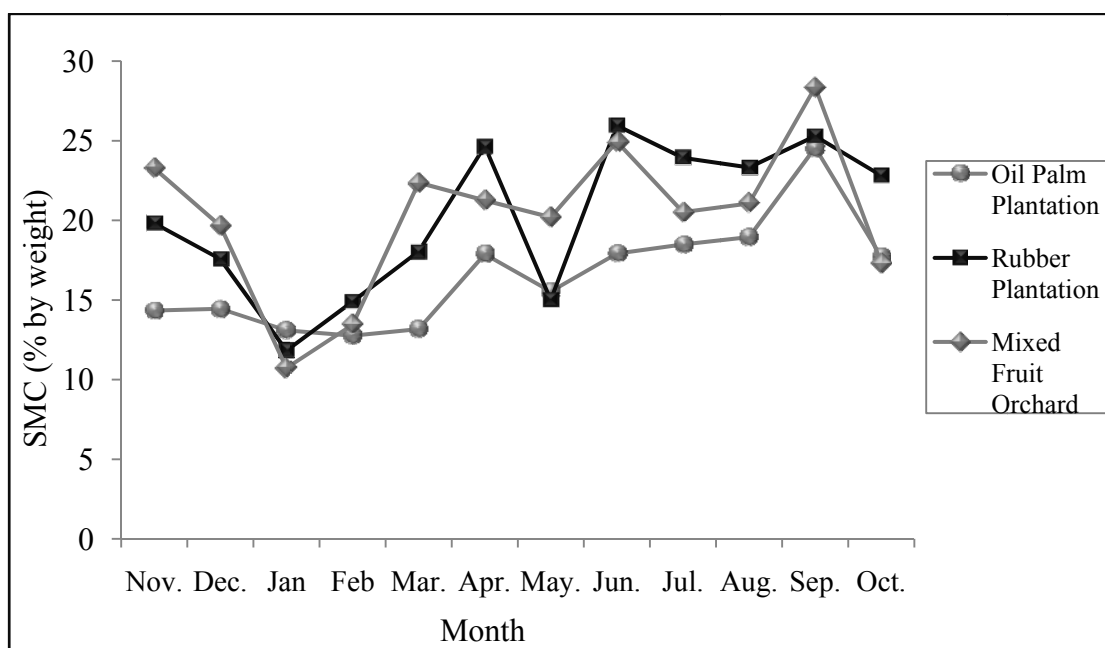


Figure 40 Variation of soil moisture content (SMC) at 0-25 cm in each land use at BTS.

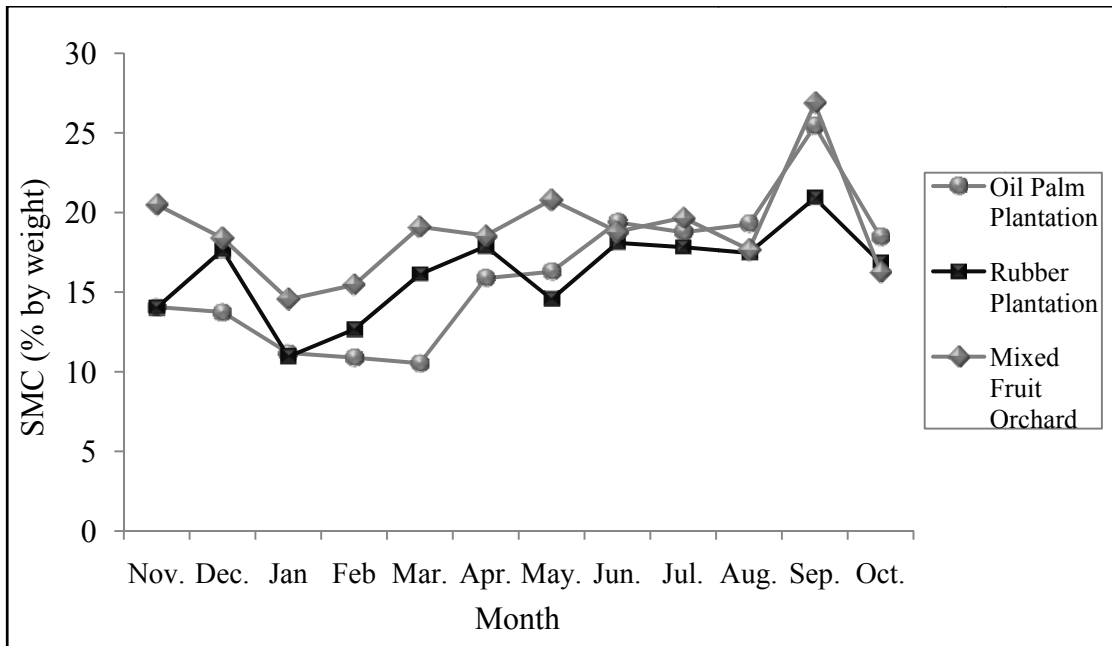


Figure 41 Variation of soil moisture content (SMC) at 25-50 cm in each land use at BTS.

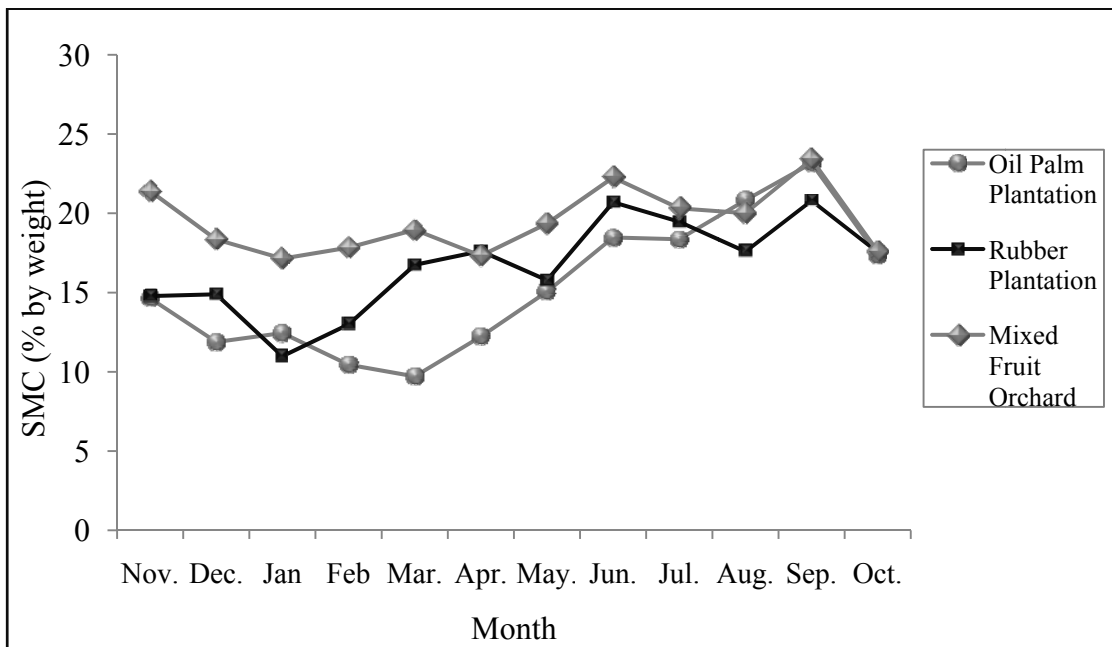


Figure 42 Variation of soil moisture content (SMC) at 50-75 cm in each land use at BTS.

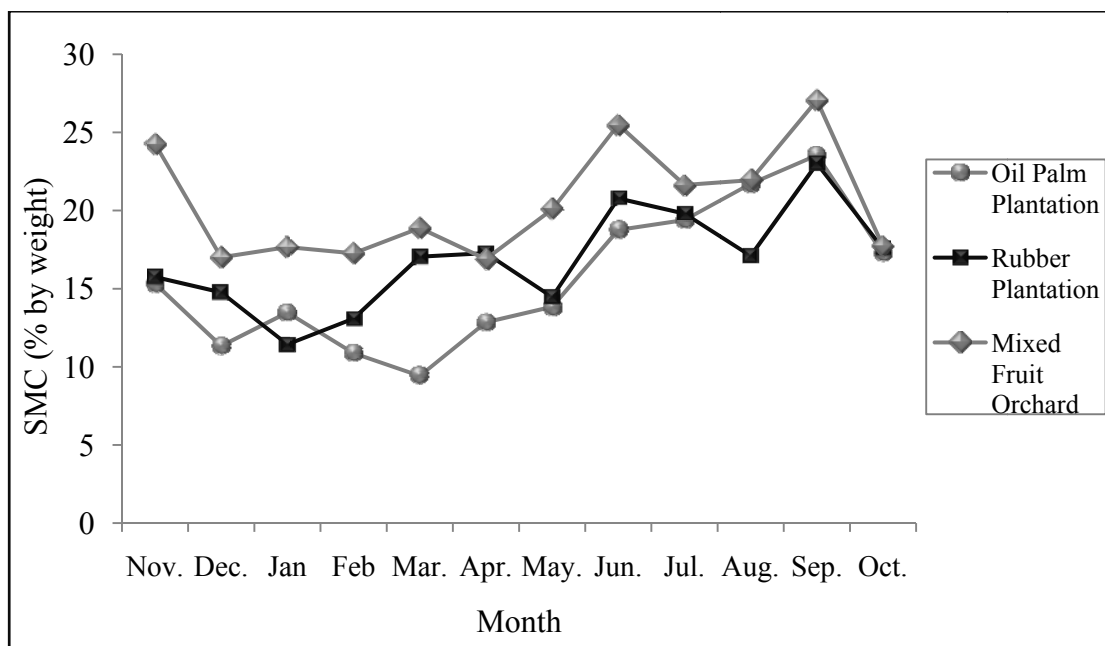


Figure 43 Variation of soil moisture content (SMC) at 75-100 cm in each land use at BTS.

Considering in variation of soil moisture content in each soil depth, it was found that mixed fruit orchard has highest more than oil palm plantation and para rubber plantation in both wet and dry period. From this study can conclude that mixed fruit orchard can collected soil moisture content better than another land use types in each soil depth. Oil palm plantation can be collected water in soil because oil palm plantation is a monocotyledon plant and used water in producing product process more than in mixed fruit orchard and para rubber plantation.

4. Variation of Water Table in different land use types

Ban Thung Soong Village is a village that long term used water well for their livelihood prior to the common water supply that was recently established. The villagers of Ban Thung Soong use water well for consumption, farming etc. For long term security, water well was constructed in or close to the house. As the common water supply has just established to provide water for consumption and household uses but the water quality is uncertain. There 39 wells scatterly distribute in the

village, including two artesian wells and 37 shallow wells (Figure 46 and appendix Table 1).



Figure 44 An artesian well from the Office of Accelerated Rural Development (ARD) established in the north of BTS.



Figure 45 The second artesian well constructed by the Office of Accelerated Rural Development (ARD) in the middle of BTS.

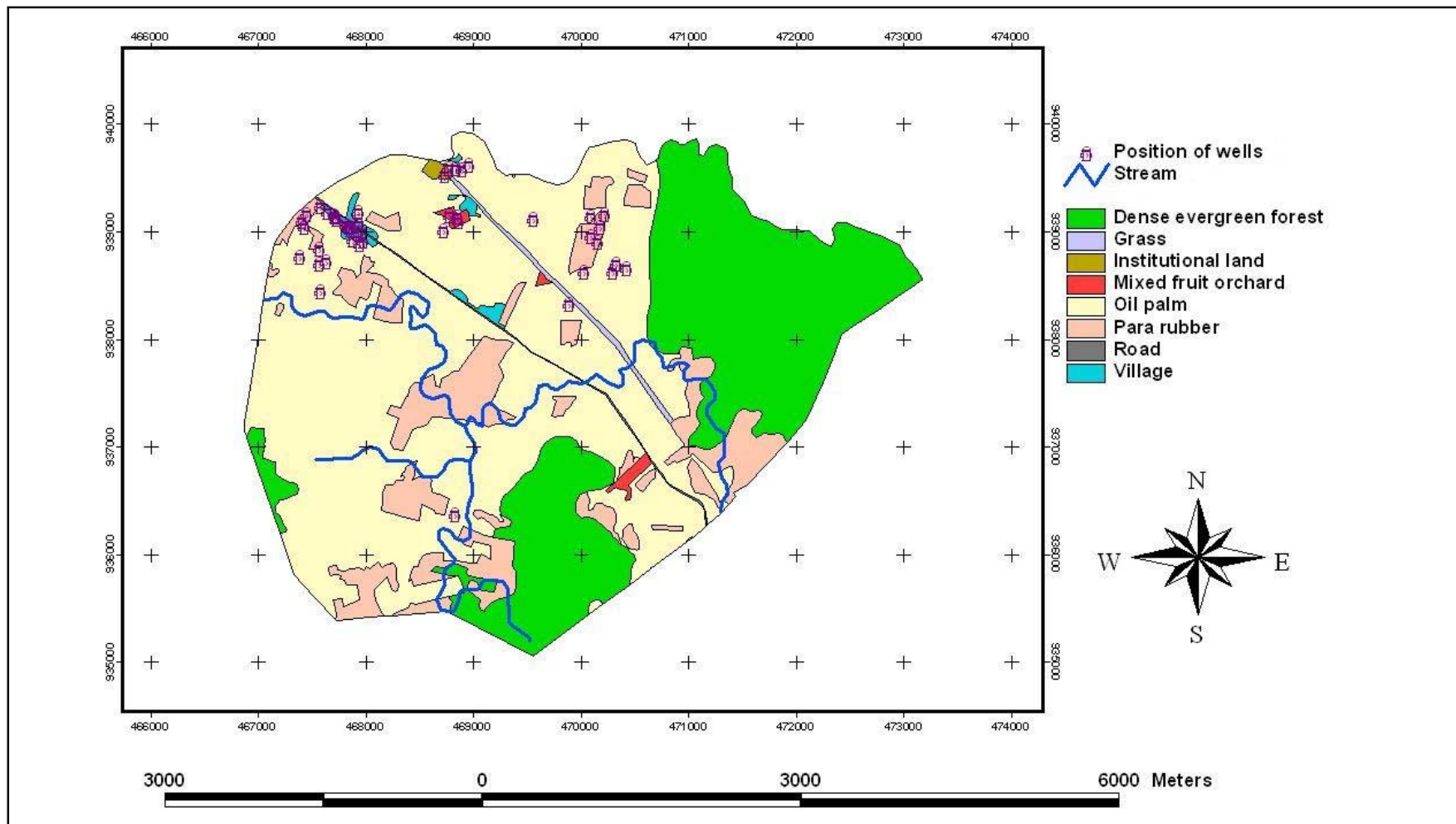


Figure 46 Distribution of shallow wells at BTS.

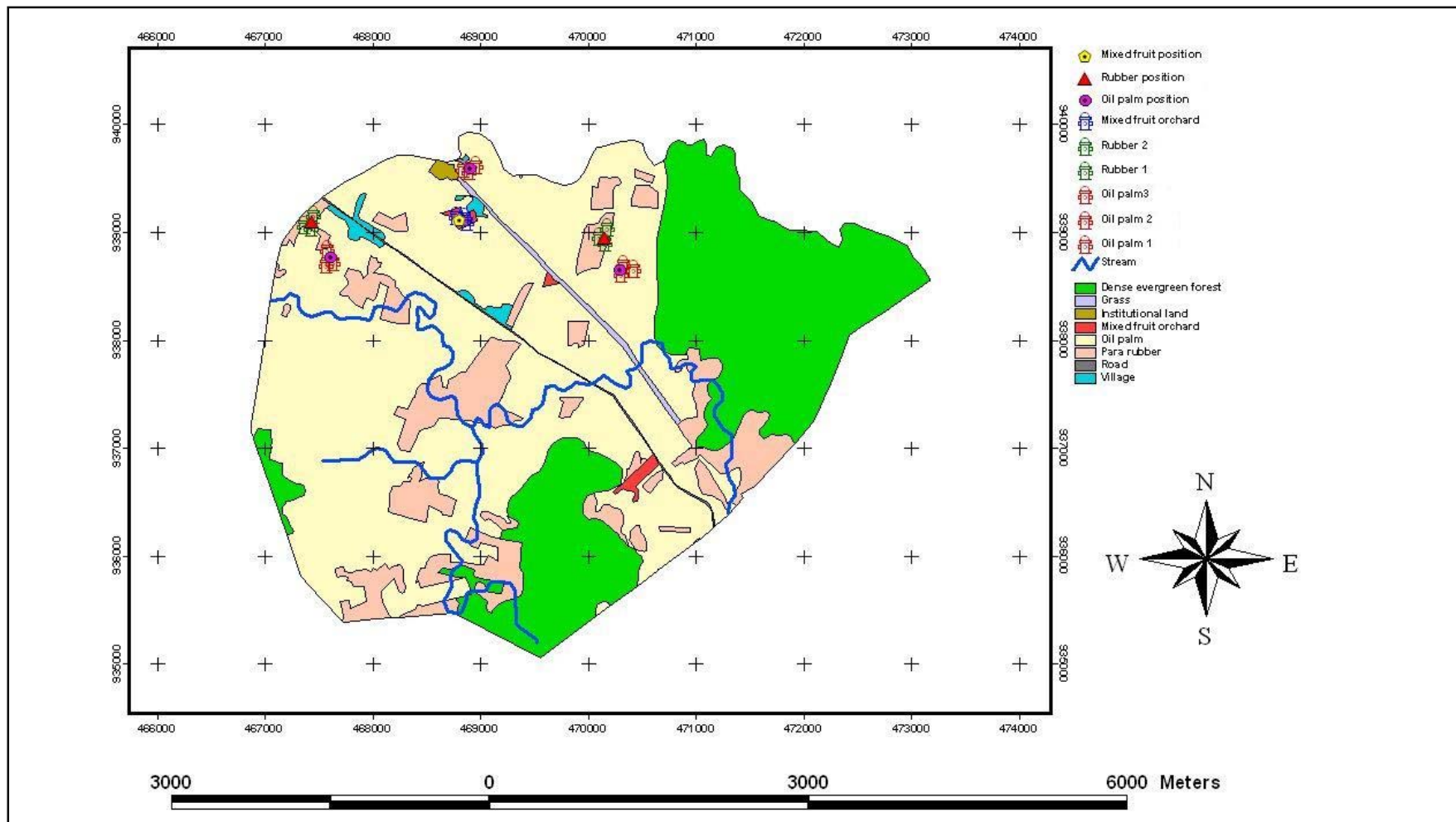


Figure 47 Distribution of selected shallow wells in each land use type in the present study.

Table 8 Water table in oil palm plantation, para rubber plantation and mixed fruit orchard during November 2006–October 2007.

| Land use types | Positions | Level of Water table (m.) | | | | | | | | | | | |
|--------------------------|-----------|---------------------------|------|------|------|------|------|------|------|------|------|------|------|
| | | 2006 | | | | 2007 | | | | | | | |
| | | Nov. | Dec. | Jan | Feb | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. |
| Oil palm plantation (P1) | Well 1 | 2.05 | 3.55 | 4.38 | 4.36 | 4.33 | 3.96 | 2.67 | 2.40 | 2.66 | 3.05 | 3.25 | 2.87 |
| | Well 2 | 1.40 | 3.03 | 4.20 | 3.45 | 2.98 | 1.45 | 1.47 | 0.93 | 1.33 | 1.70 | 2.01 | 1.32 |
| | Well 3 | 2.8 | 3.50 | 3.96 | 4.01 | 4.20 | 3.10 | 2.70 | 2.60 | 2.99 | 3.10 | 3.50 | 3.20 |
| | Mean | 2.08 | 3.36 | 4.18 | 3.94 | 3.84 | 2.84 | 2.28 | 1.98 | 2.33 | 2.62 | 2.92 | 2.46 |
| Oil palm plantation (P2) | Well 1 | 4.10 | 4.05 | 4.75 | 4.97 | 5.21 | 3.94 | 4.35 | 4.30 | 4.26 | 4.10 | 4.10 | 3.3 |
| | Well 2 | 3.20 | 4.02 | 4.57 | 4.61 | 4.75 | 2.20 | 2.95 | 2.50 | 3.02 | 3.60 | 3.75 | 2.52 |
| | Well 3 | 3.10 | 3.82 | 4.45 | 4.48 | 4.50 | 2.35 | 2.80 | 2.32 | 3.01 | 3.43 | 3.50 | 2.39 |
| | Mean | 3.47 | 3.96 | 4.59 | 4.69 | 4.82 | 2.83 | 3.37 | 3.04 | 3.43 | 3.71 | 3.78 | 2.74 |
| Oil palm plantation (P3) | Well 1 | 2.80 | 3.75 | 4.32 | 4.33 | 4.30 | 2.52 | 2.90 | 2.30 | 2.88 | 3.35 | 3.55 | 2.51 |
| | Well 2 | 2.80 | 3.75 | 4.29 | 4.55 | 4.82 | 2.43 | 2.85 | 2.30 | 2.79 | 3.22 | 3.51 | 2.45 |
| | Well 3 | 2.75 | 3.64 | 4.25 | 4.20 | 4.25 | 2.49 | 2.84 | 2.39 | 2.92 | 3.25 | 3.54 | 2.33 |
| | Mean | 2.78 | 3.71 | 4.29 | 4.36 | 4.46 | 2.48 | 2.86 | 2.33 | 2.86 | 3.27 | 3.53 | 2.43 |
| Grand mean | | 2.78 | 3.68 | 4.23 | 4.29 | 4.37 | 2.72 | 2.84 | 2.45 | 2.87 | 3.20 | 3.41 | 2.54 |

Table 8 (Continued)

| Land use types | Positions | Level of Water table (m.) | | | | | | | | | | | |
|-----------------------------|-----------|---------------------------|------|------|------|------|------|------|------|------|------|------|------|
| | | 2006 | | 2007 | | | | | | | | | |
| | | Nov. | Dec. | Jan | Feb | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. |
| Para rubber plantation (R1) | Well 1 | 4.29 | 7.51 | 9.82 | 9.65 | 8.11 | 1.85 | 4.60 | 2.05 | 3.46 | 4.90 | 3.44 | 1.70 |
| | Well 2 | 3.95 | 5.86 | 7.32 | 7.02 | 6.65 | 1.83 | 4.80 | 2.15 | 3.52 | 4.01 | 3.05 | 2.16 |
| | Well 3 | 4.52 | 6.05 | 6.95 | 6.63 | 6.20 | 3.84 | 6.35 | 4.52 | 5.14 | 5.95 | 6.21 | 2.54 |
| | Mean | 4.25 | 6.47 | 8.67 | 7.77 | 6.99 | 2.51 | 5.25 | 2.91 | 4.04 | 4.95 | 4.23 | 2.13 |
| Para rubber plantation (R2) | Well 1 | 4.42 | 4.88 | 5.21 | 5.81 | 6.28 | 4.43 | 4.22 | 4.24 | 4.32 | 4.66 | 5.06 | 4.32 |
| | Well 2 | 4.39 | 4.52 | 4.83 | 5.06 | 5.76 | 4.02 | 3.97 | 4.02 | 4.11 | 4.35 | 4.76 | 3.99 |
| | Well 3 | 4.35 | 4.76 | 4.95 | 5.42 | 5.8 | 4.20 | 4.08 | 4.08 | 4.23 | 4.53 | 4.97 | 4.12 |
| | Mean | 4.39 | 4.72 | 5.00 | 5.43 | 5.95 | 4.22 | 4.09 | 4.11 | 4.22 | 4.51 | 4.93 | 4.14 |
| Grand mean | | 4.32 | 5.60 | 7.26 | 6.60 | 6.00 | 3.30 | 4.69 | 3.51 | 4.13 | 4.73 | 4.58 | 3.47 |
| Mixed fruit orchard (G1) | Well 1 | 1.66 | 2.49 | 2.93 | 2.90 | 2.75 | 1.54 | 1.70 | 1.10 | 1.44 | 1.90 | 2.02 | 1.42 |
| | Well 2 | 1.53 | 2.22 | 2.65 | 2.59 | 2.52 | 1.37 | 1.54 | 1.02 | 1.45 | 1.72 | 1.85 | 1.12 |
| | Well 3 | 1.70 | 2.10 | 2.30 | 2.34 | 2.30 | 1.36 | 1.40 | 1.05 | 1.34 | 1.70 | 1.87 | 1.23 |
| | Mean | 1.63 | 2.27 | 2.63 | 2.61 | 2.52 | 1.42 | 1.55 | 1.06 | 1.41 | 1.77 | 1.91 | 1.26 |

From Table 3, result showed the trend of monthly water table level recorded during November 2006 – October 2007 in oil palm plantation, para rubber plantation and mixed fruit orchard. Result showed variation of water table in selected shallow wells in Figures 48 -56 as follows:

Shallow wells P1-P3 in oil palm plantation, results showed differences in water table. Highest water table was found in June in P1 (1.98 m) and P3 (2.33 m) while P2 was found in October (2.74 m). The lowest water tables of shallow well were found in January (4.82 m, P1) and in March (4.82 m, P2 and 4.46, P3). Figure 51 showed the highest and lowest water table of shallow wells in oil palm plantation.

In rubber plantation, shallow wells (R1-R2) showed the highest and lowest water table in October (2.13 m) and January (8.67 m), see Figure 52. However, R2 showed highest and lowest water table in May (4.09 m) and March (5.95 m) respectively. Figure 54 showed the trend of water table changing and the average highest and lowest water table were observed in April (3.30 m) and March (7.26 m) respectively.

As regards mixed fruit orchard, the highest and lowest water table in June (1.06 m) and January (2.63 m). As shown in Figure 56, high water level was observed in mixed fruit orchard when comparing to para rubber plantation and oil palm plantation.

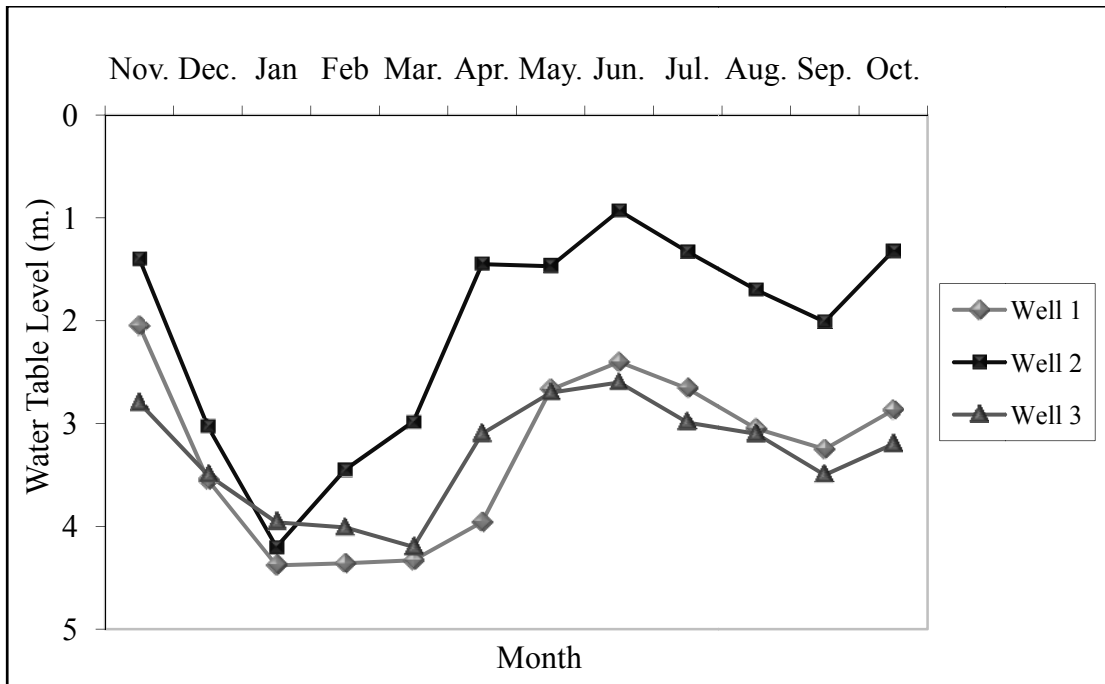


Figure 48 Variation of water table level in oil palm plantation (P1) in BTS.

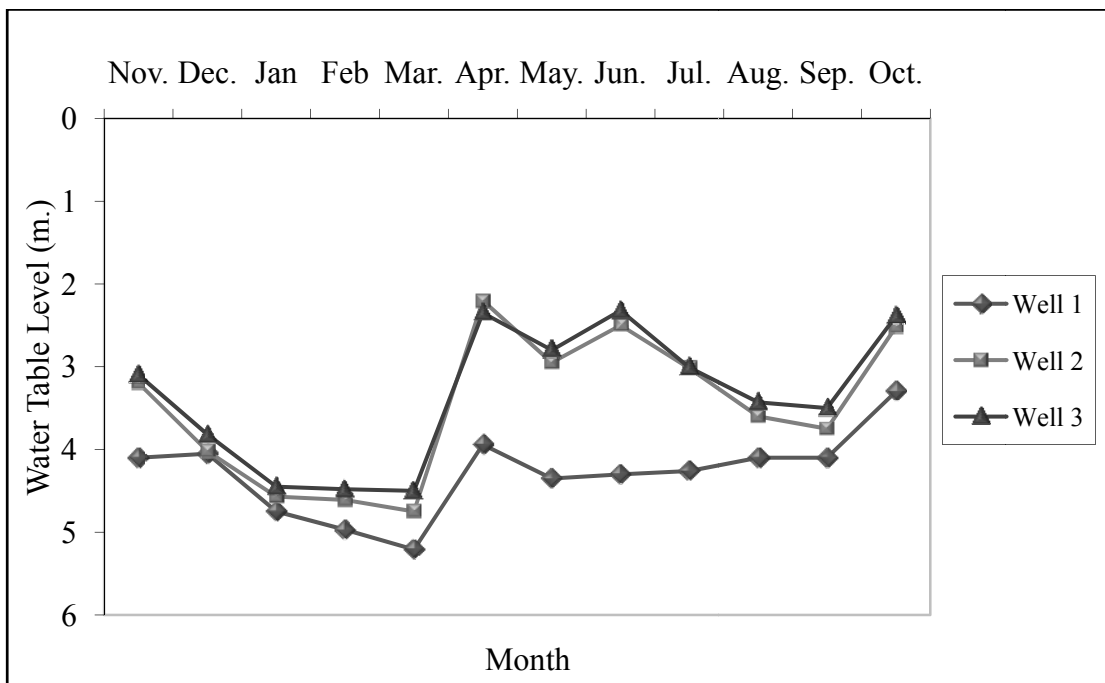


Figure 49 Variation of water table level in oil palm plantation (P2) in BTS.

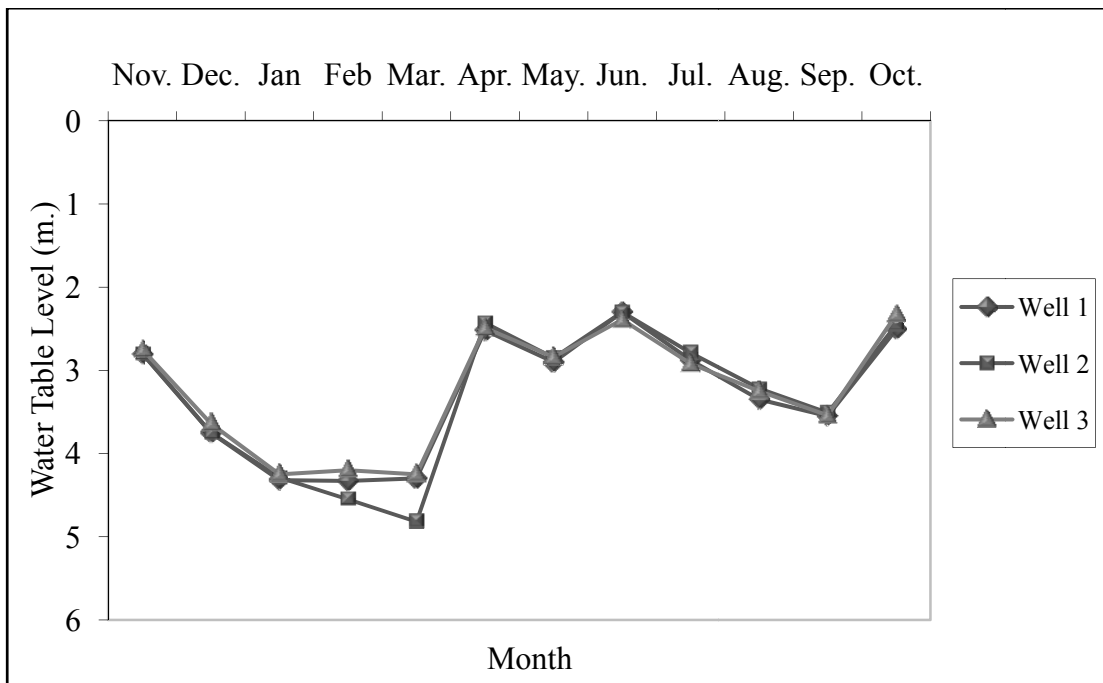


Figure 50 Variation of water table level in oil palm plantation (P3) in BTS.

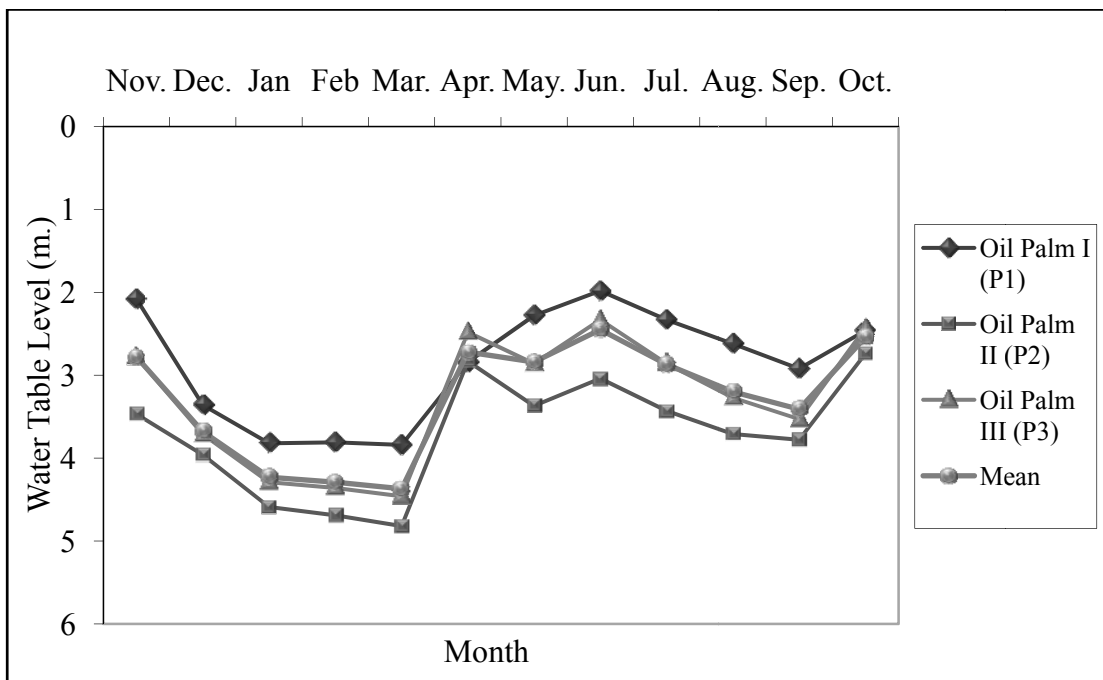


Figure 51 Variation of water table level in total oil palm plantation in BTS.

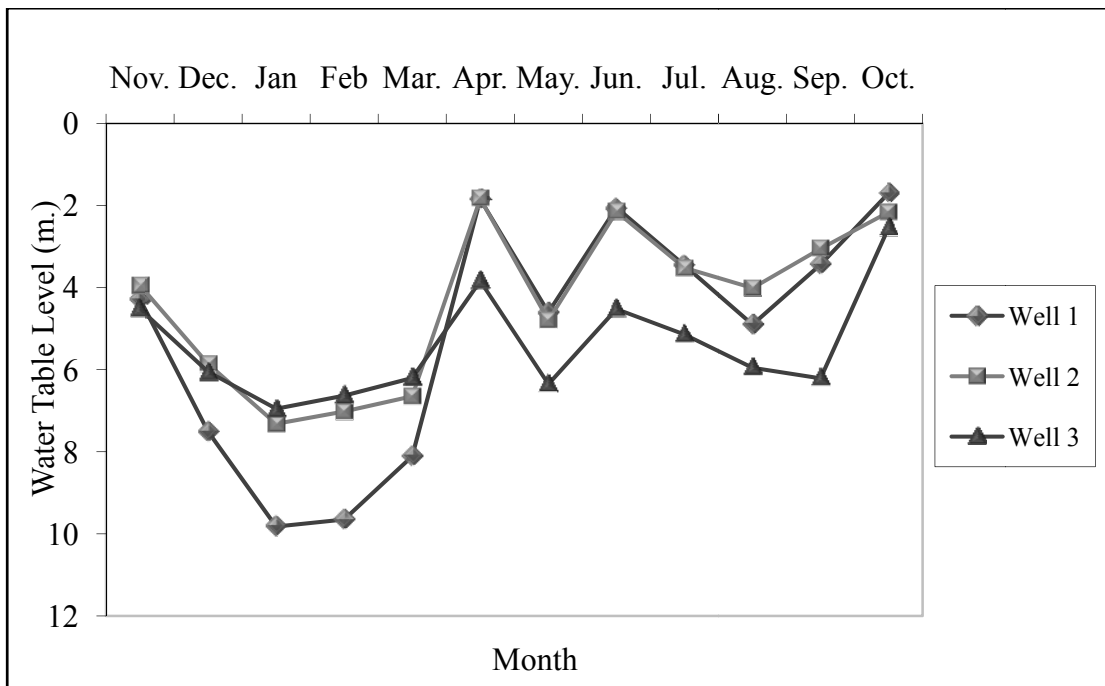


Figure 52 Variation of water table level in para rubber plantation (R1) in BTS.

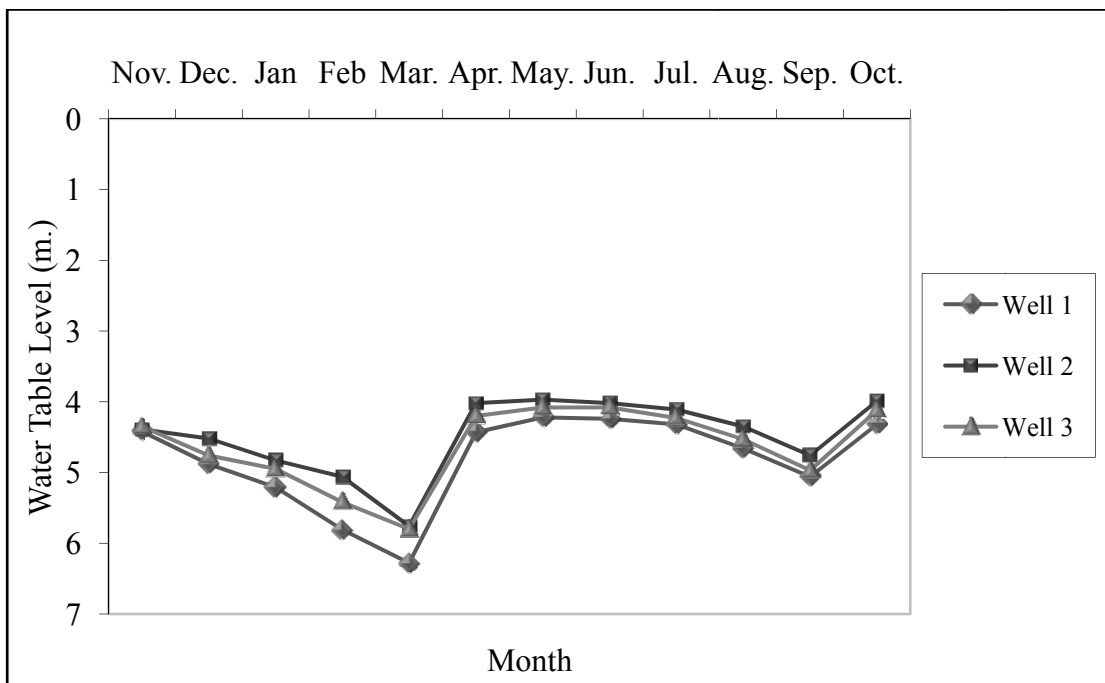


Figure 53 Variation of water table level in para rubber plantation (R2) in BTS.

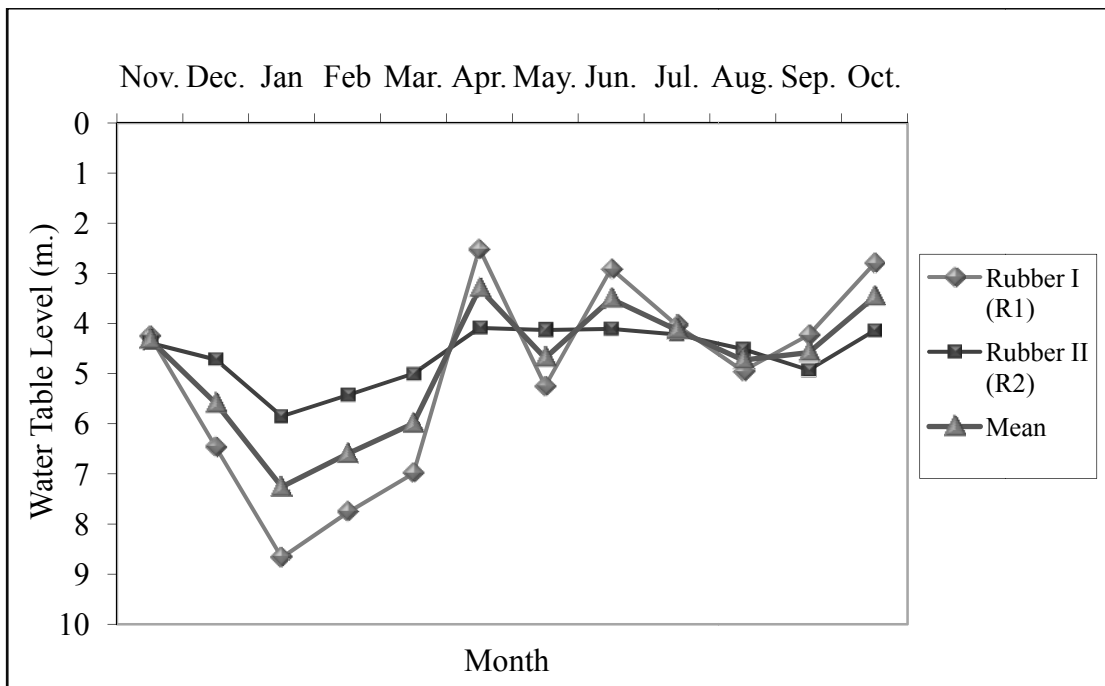


Figure 54 Variation of water table level in total para rubber plantation in BTS.

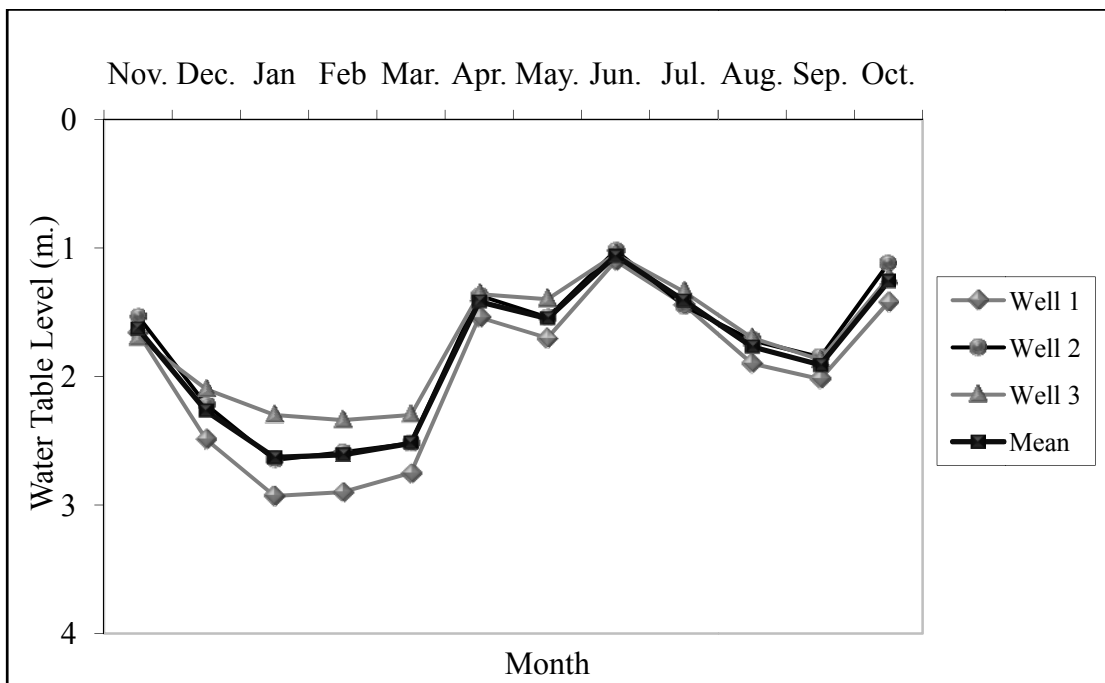


Figure 55 Variation of water table level in mixed fruit orchard in BTS.

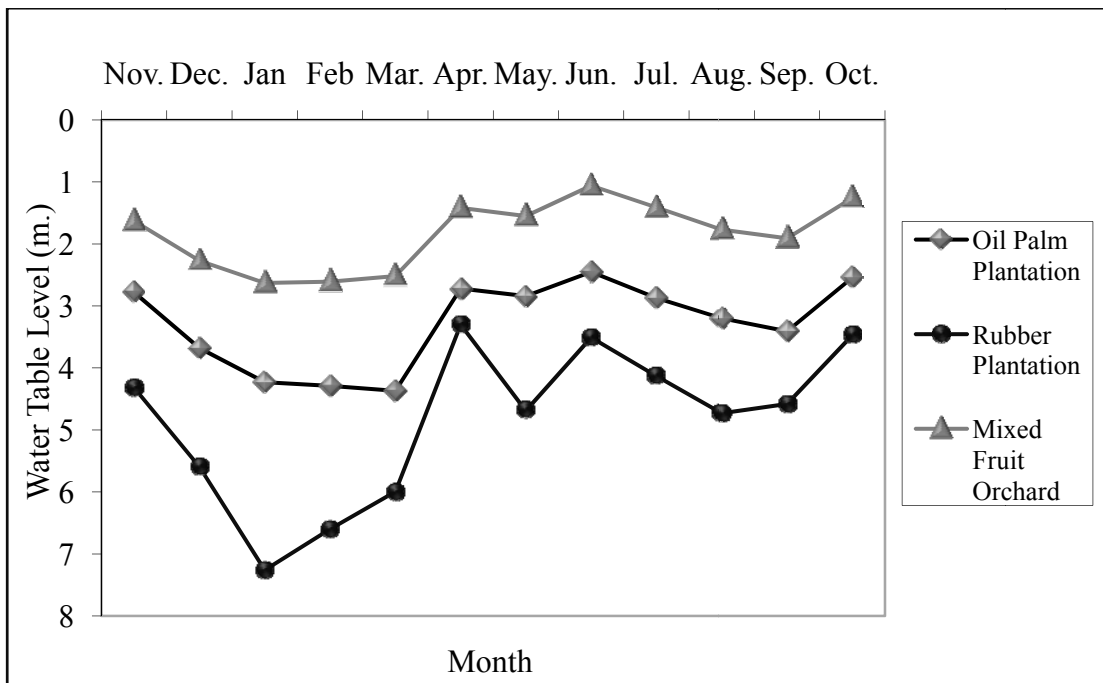
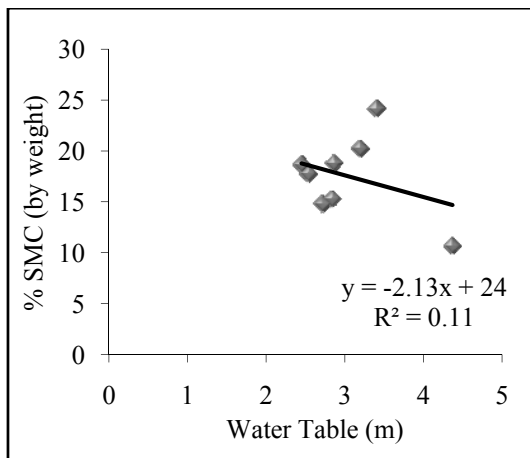


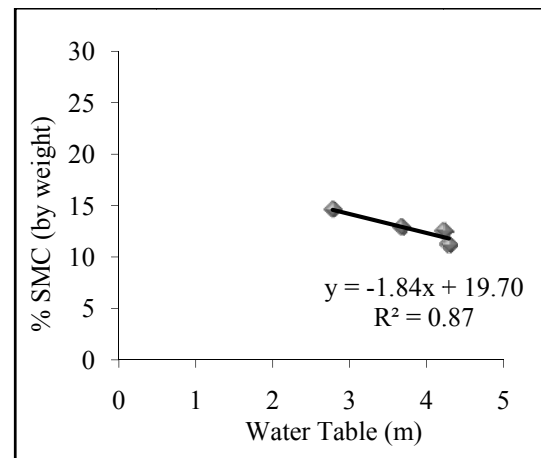
Figure 56 Variation of water table level in oil palm plantation, para rubber plantation and mixed fruit orchard in BTS.

5. Relationships between SMC and Water Table in different land use types

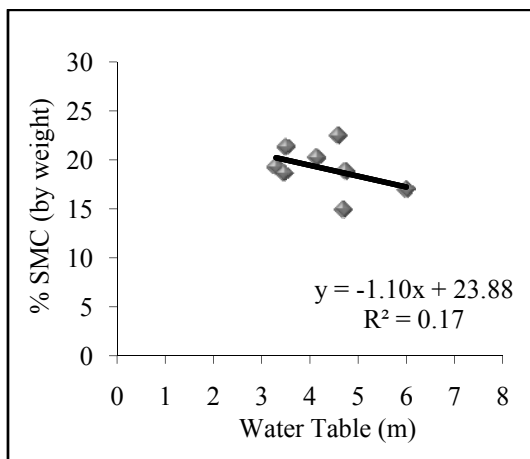
Relationships between SMC and water table were linear pattern (Figure 57); for oil palm plantation (Figure 57 (a) and (b)), para rubber plantation (Figure 57 (c) and (d)) and mixed fruit orchard (Figure 57 (e) and (f)) in a respective wet and dry periods as follows.



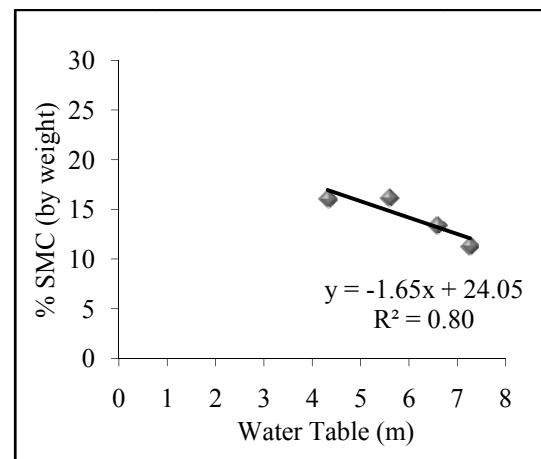
(a) Wet period of oil palm plantation



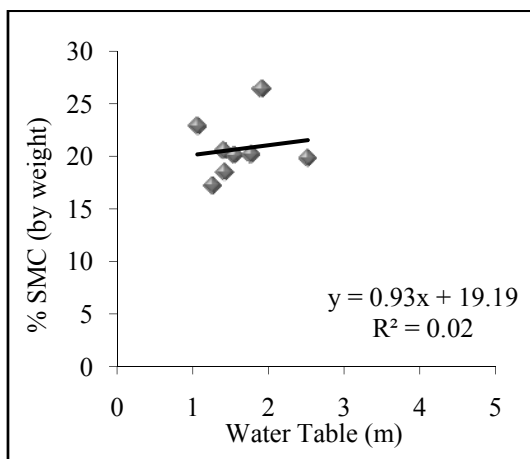
(b) Dry period of oil palm plantation



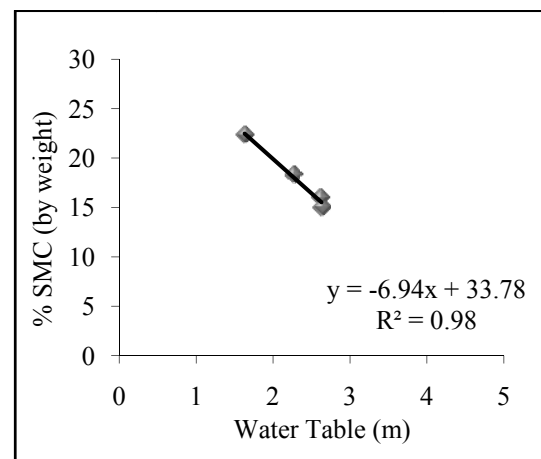
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation



(e) Wet period of mixed fruit orchard



(f) Dry period of mixed fruit orchard

Figure 57 Relationships between SMC and water table in 3 land use types.

From Figures 57 (a) to (f) showed relationship between SMC and water table that in oil palm plantation, para rubber plantation and mixed fruit orchard. It might be seen from the figures that there was a weak relation between SMC and water table level during the wet period of the year. However, the situation was different for the dry period where strong relationship between the two variables was detected.

Linear equations describing the relations between SMC and water table level for oil palm plantation, para rubber plantation, mixed orchard were:

$$y = - 1.84x + 19.70; \quad R^2 = 0.87$$

$$y = - 1.65x + 24.05; \quad R^2 = 0.80$$

$$y = - 6.94x + 33.79; \quad R^2 = 0.98$$

Where, $y = \text{SMC}$

$x = \text{depth of water table in meters.}$

It can be explained that SMC depended significantly on level of water table is quite explicit since during dry period the only source of moisture in soil derived solely by capillary movement from water table. However, during wet period the main source of soil moisture was from rain whereas upward capillary rise from water table was an auxiliary source. Therefore, the relationships between SMC and water table level during wet period was in-significant because in this period has an influence from rainfall that several fall in every day. In dry period the differences has highly significant in the absence influence from rainfall.

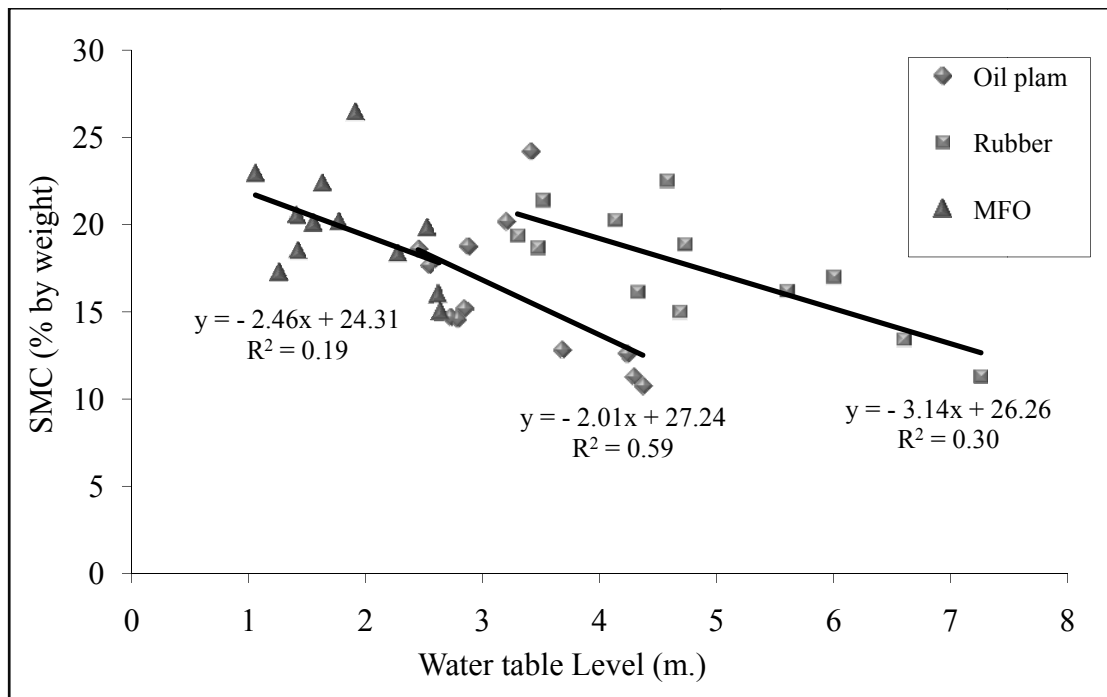
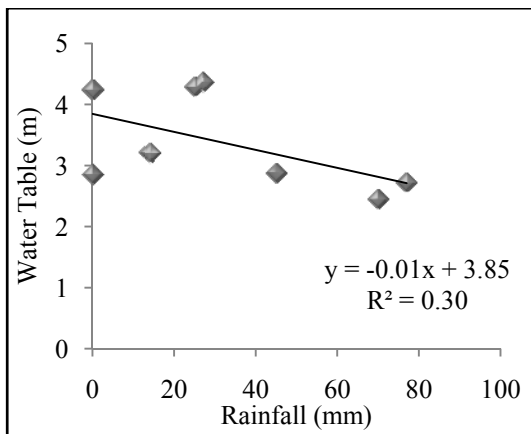


Figure 58 Linear relationship between SMC and water table in BTS.

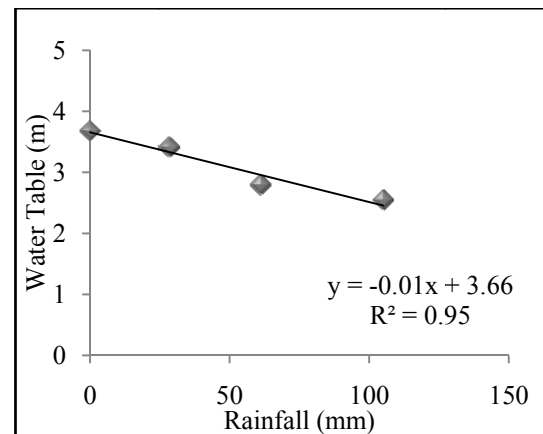
From Figure 58, the equations for annual relationship between SMC and level of water table for oil palm plantation, para rubber plantation, and mixed orchard were in-significant.

6. Relationships between accumulate rainfall and water table in different land use types

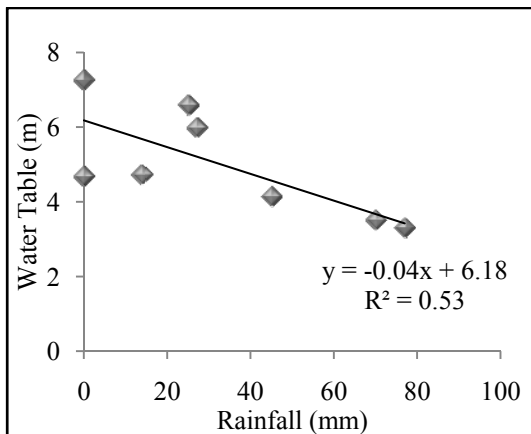
Relationship between rainfall and water table that in oil palm plantation, para rubber plantation and mixed fruit orchard was showed in Figures 59 to 64



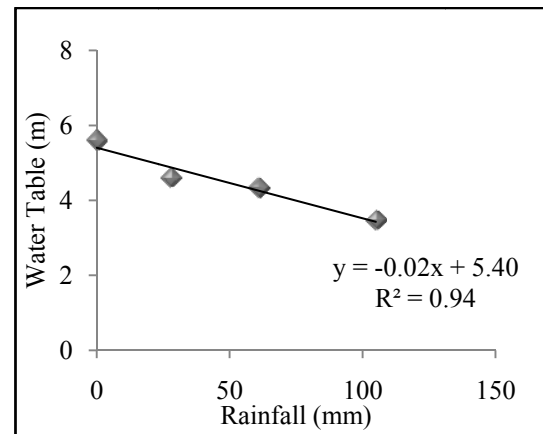
(a) Wet period of oil palm plantation



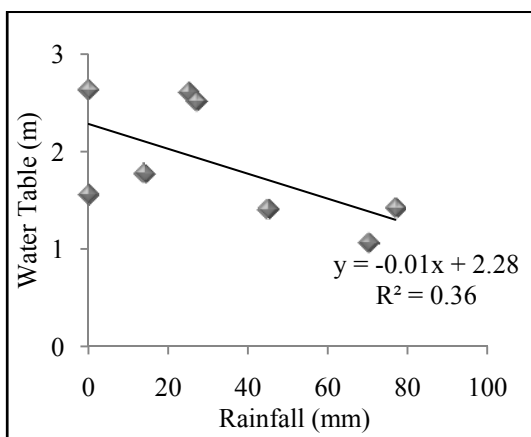
(b) Dry period of oil palm plantation



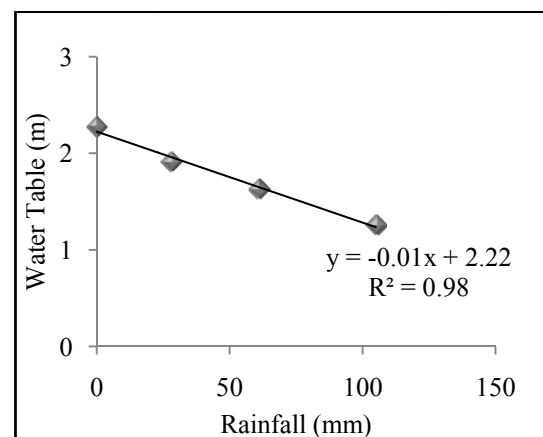
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation

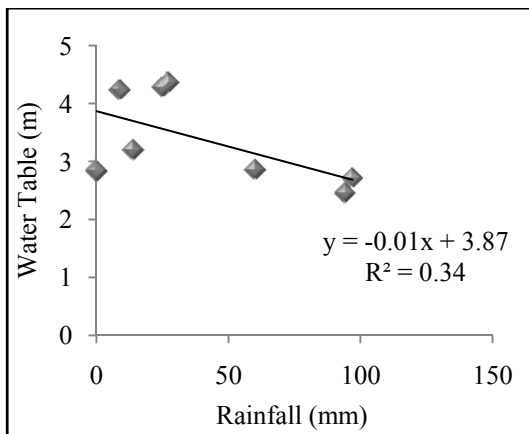


(e) Wet period of mixed fruit orchard

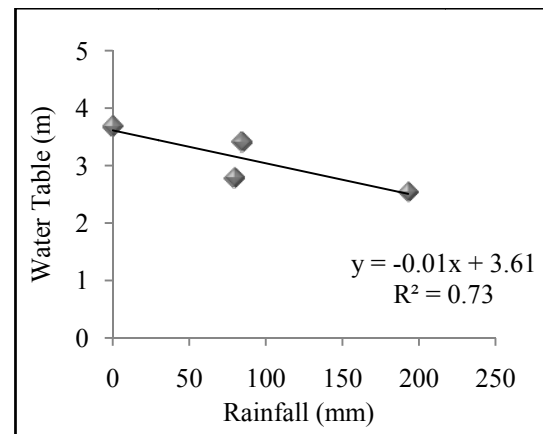


(f) Dry period of mixed fruit orchard

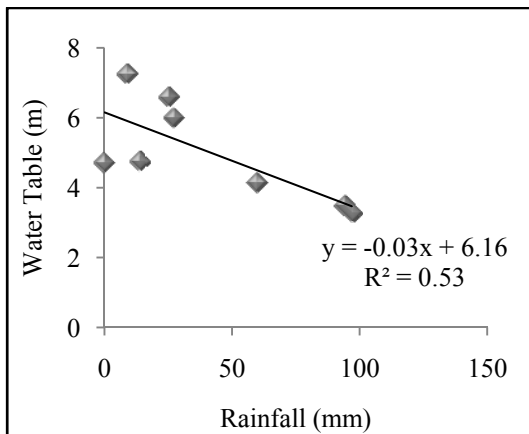
Figure 59 Relationships between water table and accumulate rainfall 5 day before data collection in each land use types.



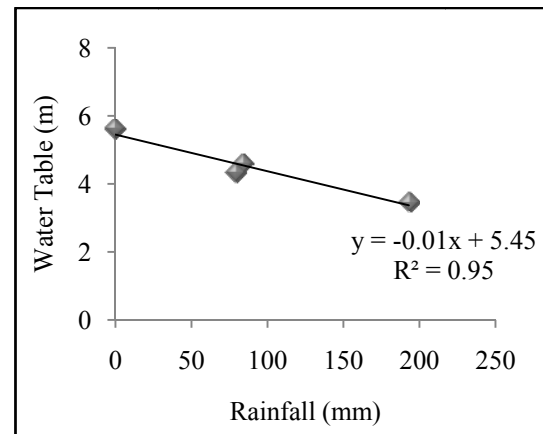
(a) Wet period of oil palm plantation



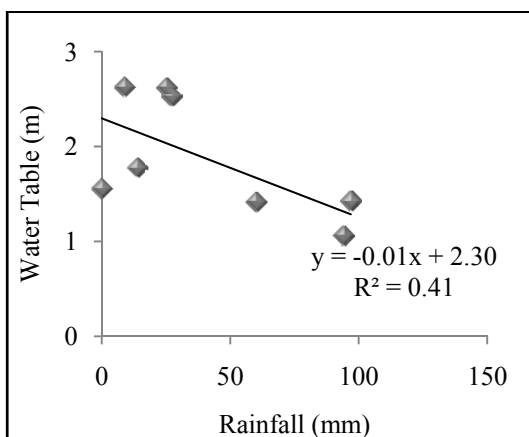
(b) Dry period of oil palm plantation



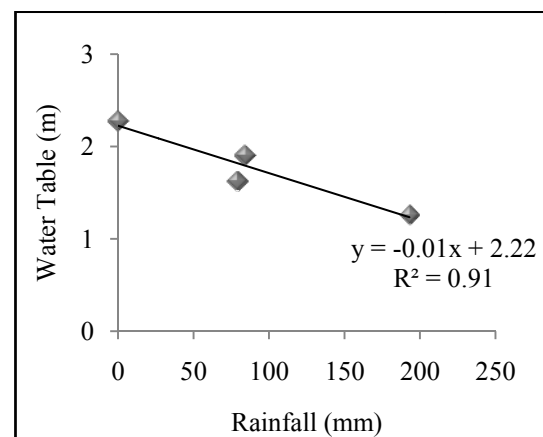
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation

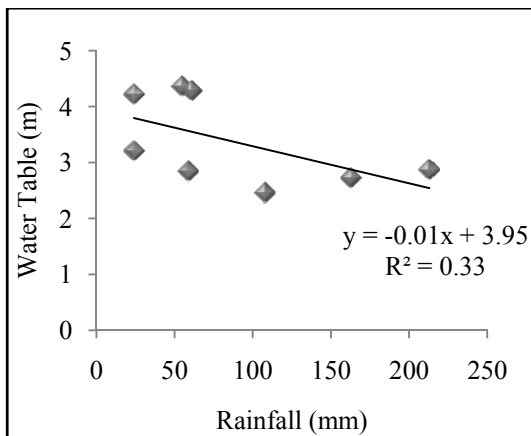


(e) Wet period of mixed fruit orchard

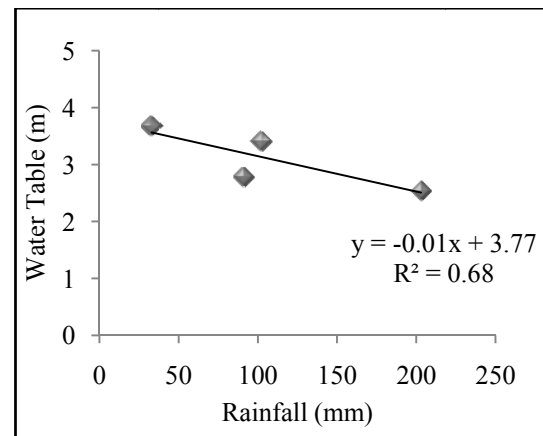


(f) Dry period of mixed fruit orchard

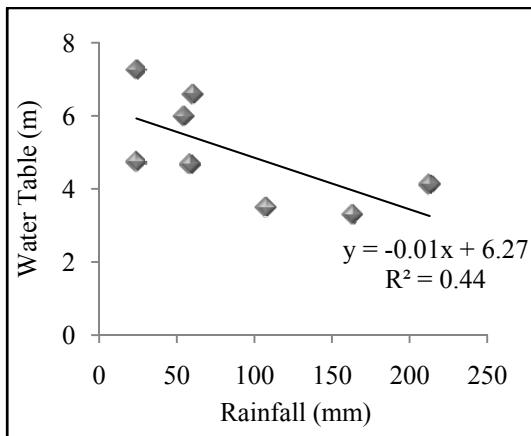
Figure 60 Relationships between water table and accumulate rainfall 10 day before data collection in each land use types.



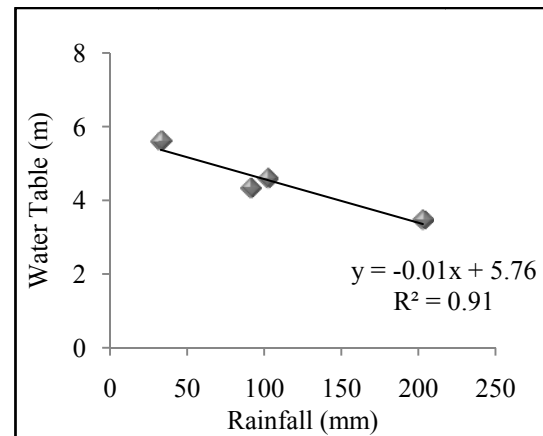
(a) Wet period of oil palm plantation



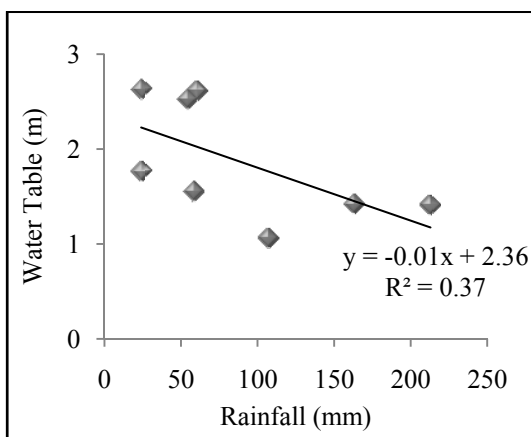
(b) Dry period of oil palm plantation



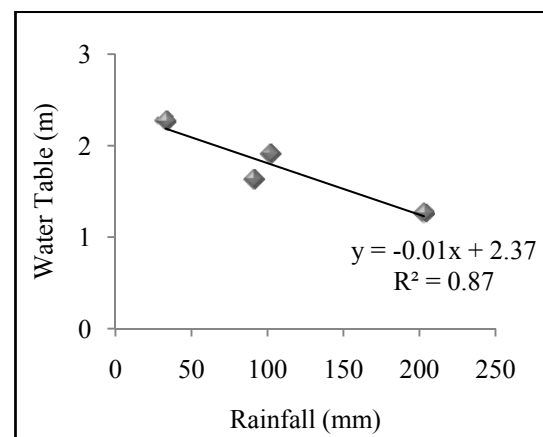
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation

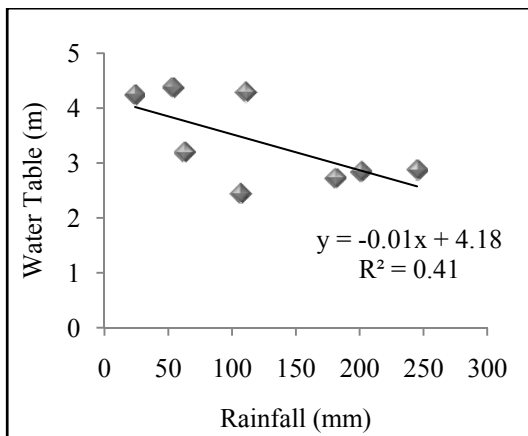


(e) Wet period of mixed fruit orchard

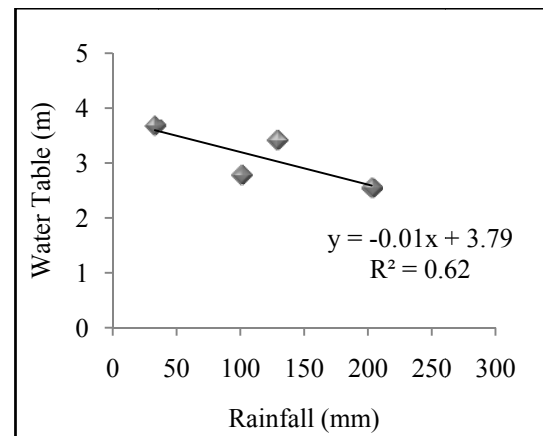


(f) Dry period of mixed fruit orchard

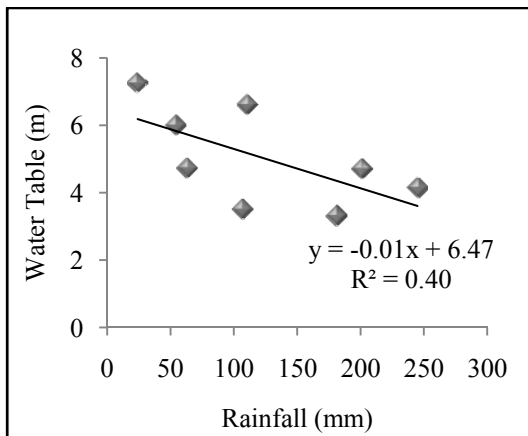
Figure 61 Relationships between water table and accumulate rainfall 15 day before data collection in each land use types.



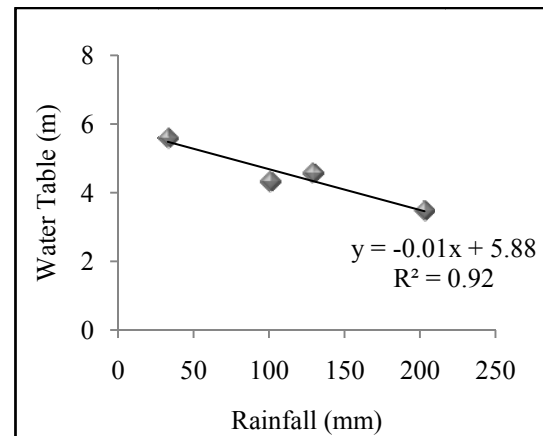
(a) Wet period of oil palm plantation



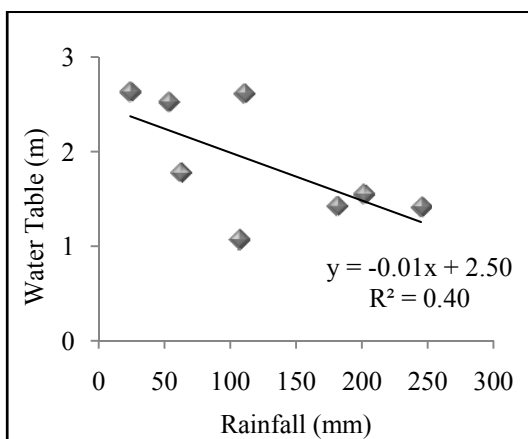
(b) Dry period of oil palm plantation



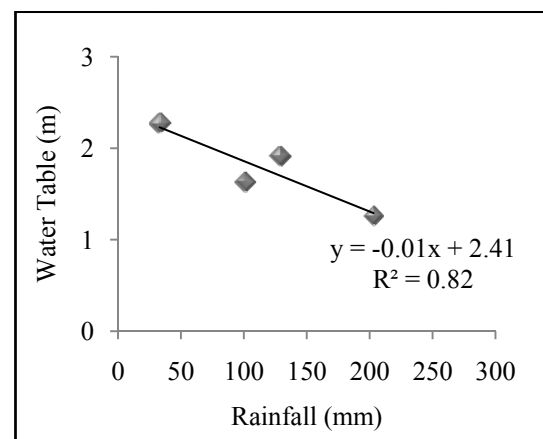
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation

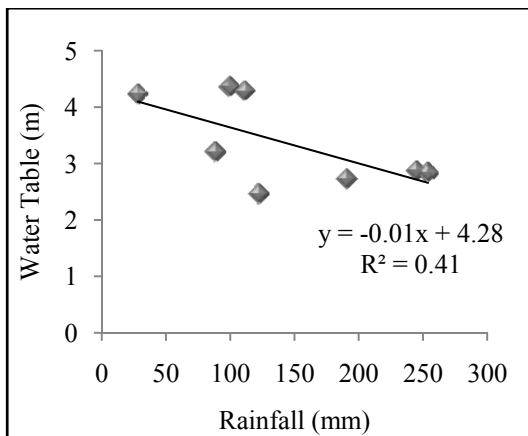


(e) Wet period of mixed fruit orchard

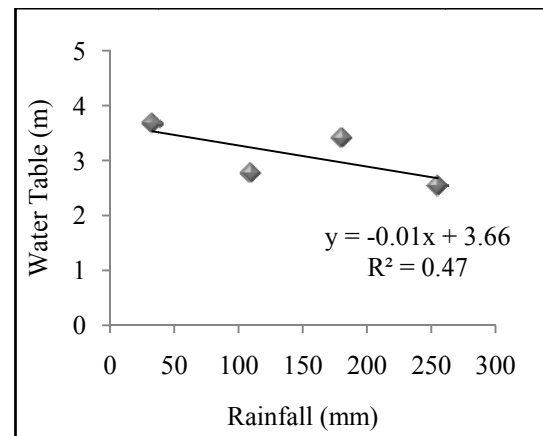


(f) Dry period of mixed fruit orchard

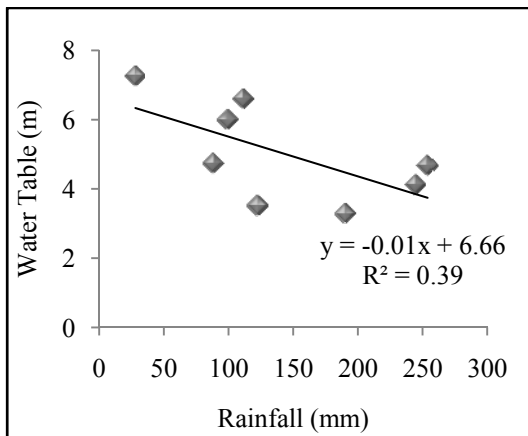
Figure 62 Relationships between water table and accumulate rainfall 20 day before data collection in each land use types.



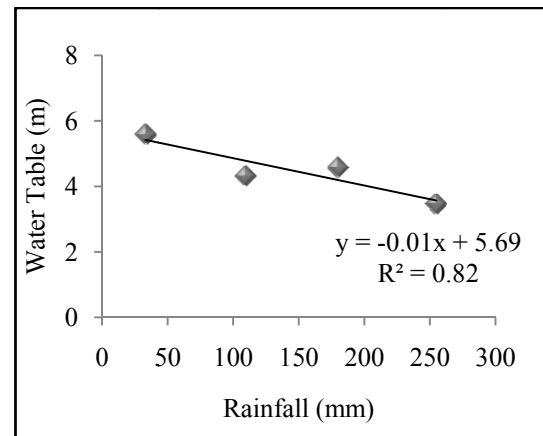
(a) Wet period of oil palm plantation



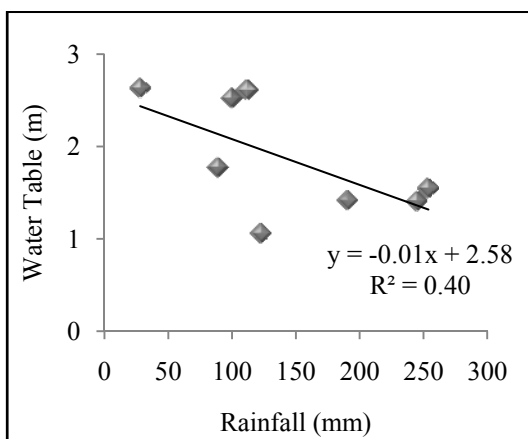
(b) Dry period of oil palm plantation



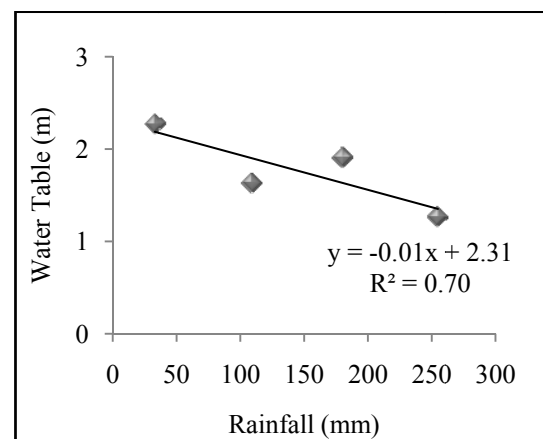
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation

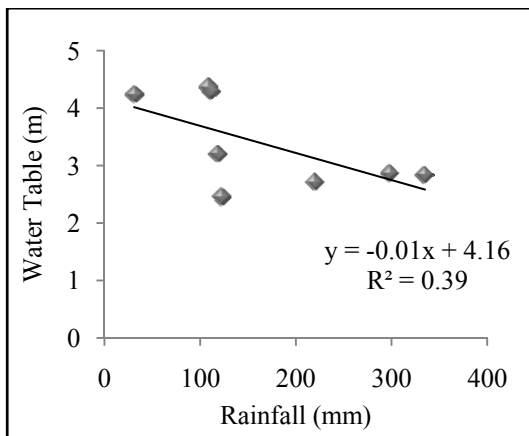


(e) Wet period of mixed fruit orchard

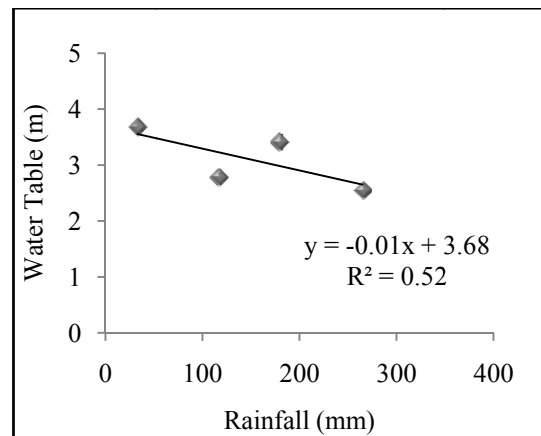


(f) Dry period of mixed fruit orchard

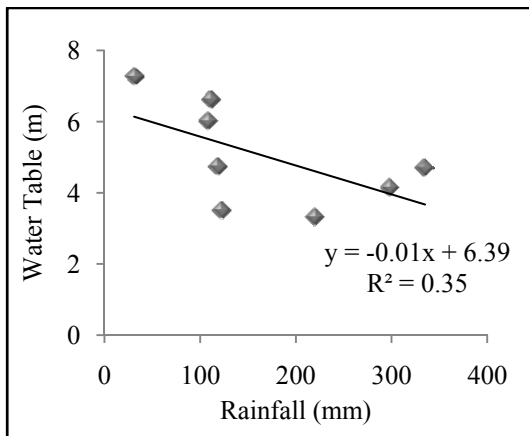
Figure 63 Relationships between water table and accumulate rainfall 25 day before data collection in each land use types.



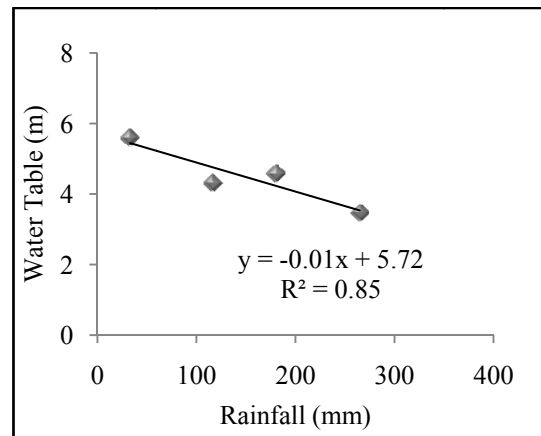
(a) Wet period of oil palm plantation



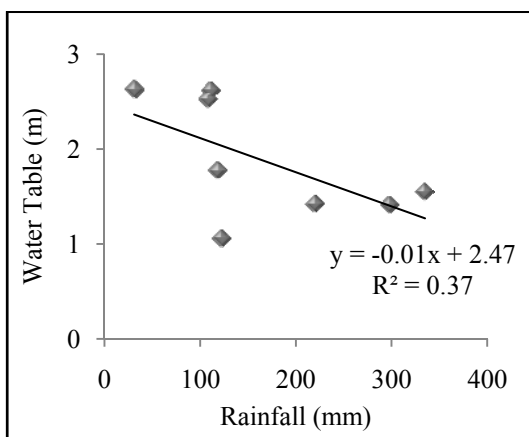
(b) Dry period of oil palm plantation



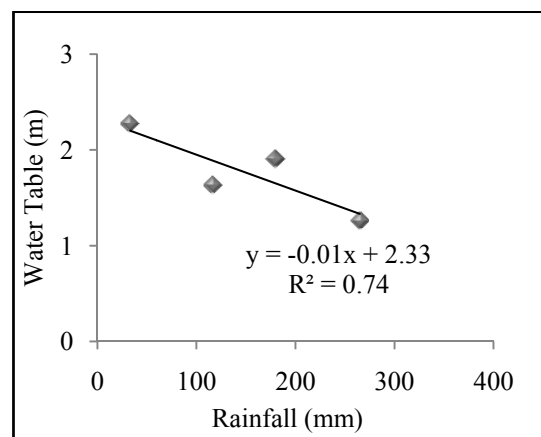
(c) Wet period of para rubber plantation



(d) Dry period of para rubber plantation



(e) Wet period of mixed fruit orchard



(f) Dry period of mixed fruit orchard

Figure 64 Relationships between water table and accumulate rainfall more than 25 days before data collection in each land use types.

From Figures 59 – 64, result showed relationships between rainfall and water table that in oil palm plantation, para rubber plantation and mixed fruit orchard. It might be seen from the figures that there was a weak relation between rainfall and water table level during the wet period of the year. However, the situation was different for the drying period where strong relationship between the two variables was detected.

Linear equations describing the relationships between rainfall and water table level at 5 days before data collection for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = - 0.01x + 3.66; \quad R^2 = 0.95$$

$$y = - 0.02x + 5.40; \quad R^2 = 0.94$$

$$y = - 0.01x + 2.22; \quad R^2 = 0.98$$

Where, y = depth of water table in meters

x = accumulate rainfall in millimeters

Linear equations describing the relationship between rainfall and water table level at 10 days before data collection for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = - 0.01x + 3.61; \quad R^2 = 0.73$$

$$y = - 0.01x + 5.45; \quad R^2 = 0.95$$

$$y = - 0.01x + 2.22; \quad R^2 = 0.91$$

Where, y = depth of water table in meters

x = accumulate rainfall in millimeters

Linear equations describing the relationship between rainfall and water table level at 15 days before data collection for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = - 0.01x + 3.77; \quad R^2 = 0.68$$

$$y = - 0.01x + 5.76; \quad R^2 = 0.91$$

$$y = - 0.01x + 2.37; \quad R^2 = 0.87$$

Where, y = depth of water table in meters

x = accumulate rainfall in millimeters

Linear equations describing the relationship between rainfall and water table level at 20 days before data collection for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = - 0.01x + 3.79; \quad R^2 = 0.62$$

$$y = - 0.01x + 5.88; \quad R^2 = 0.92$$

$$y = - 0.01x + 2.41; \quad R^2 = 0.82$$

Where, y = depth of water table in meters

x = accumulate rainfall in millimeters

Linear equations describing the relationship between rainfall and water table level at 25 days before data collection for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = -0.01x + 3.66; \quad R^2 = 0.47$$

$$y = -0.01x + 5.69; \quad R^2 = 0.82$$

$$y = -0.01x + 2.31; \quad R^2 = 0.70$$

Where, y = depth of water table in meters

x = accumulate rainfall in millimeters

Linear equations describing the relationship between rainfall and water table level at more than 25 days before data collection for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = -0.01x + 3.68; \quad R^2 = 0.52$$

$$y = -0.01x + 5.72; \quad R^2 = 0.85$$

$$y = -0.01x + 2.33; \quad R^2 = 0.74$$

Where, y = depth of water table in meters

x = accumulate rainfall in millimeters

Linear equations between rainfall and water table at the accumulate rainfall 5 days before data collection was highly significant than other period (10, 15, 20, 25 and more than 25 days before data collection). This may be caused by the evaporation into atmosphere or the water was recharged to the nearly basin.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Results presented in this study shown the average monthly rainfall ranging from 3.2 mm to 412.8 mm (with the annual rainfall of 2,224.5 mm). The minimum rainfall occurred during January as influencing from the northeast monsoon. The maximum rainfall normally occurred in September due to the southwest monsoon from the Indian Ocean. The highest and the lowest SMC were found in September and January, respectively, for all type of land uses. Mixed fruit orchard had the highest SMC in all levels of depth and oil palm plantation had the lowest SMC. The mixed fruit orchard keeps water in soil more than oil palm and para rubber plantation. Mixed fruit orchard had the highest water table level in each well and para rubber plantation had the lowest. The close linear relationships were found between SMC and water table level during the dry period for all types of land uses. The equations for mixed orchard, oil palm and para rubber plantations were, respectively:

$$y = - 6.94x + 33.79; \quad R^2 = 0.98$$

$$y = - 1.84x + 19.70; \quad R^2 = 0.87$$

$$y = - 1.65x + 24.05; \quad R^2 = 0.80$$

Where, y = soil moisture content (SMC)

x = depth of water table in meters.

Closed linear equations between rainfall and water table level in dry period for all types of land uses in 5 days before data collection was found. The equations for oil palm plantation, para rubber plantation, mixed orchard were, respectively:

$$y = - 0.01x + 3.66; \quad R^2 = 0.95$$

$$y = - 0.02x + 5.40; \quad R^2 = 0.94$$

$$y = - 0.01x + 2.22; \quad R^2 = 0.98$$

Where, y = soil moisture content (SMC)
 x = depth of water table in meters.

The relation between SMC and water table level and rainfall during wet period was insignificant for at all locations. Such relationships may be use as a guideline for land use management under the similar environment.

Recommendations

The study on variation of soil moisture content affected by water table under different types of land use at Ban Thung Soong, Ao Luek district in Krabi Province are useful for the future researches in Thailand. The recommendation on variation of soil moisture content and water table, as follows:

- 1) From this study showed relationship of SMC and water table in dry period has highly significant in lowest SMC and water table. Ground cover such as legume (*Pueraria phaseoloides*) and short grass should be use to reduce water loss from soil and water table during dry season.
- 2) New technique like Time Domain Reflectometer (TDR) and water level sensor are recommended to facilitate field data collection.
- 3) Quantitative effect of rainfall on the relationship between SMC and level of water table should be assessed in future experiment.

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APPENDIX

Appendix Table 1 Location of shallow wells in Ban Thung Soong, Ao Luek District in Krabi Province.

| No | Name | UTM | | Type | Level of water table (m.) | | | | | | | | | | | | * |
|----|------------------------|--------|--------|------|---------------------------|-------|-------|-------|-------|------|-------|------|-------|-------|-------|------|----|
| | | | | | 2006 | | | | 2007 | | | | | | | | |
| | | X | Y | | Nov. | Dec. | Jan | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | |
| 1 | Mr. Pramote Predapol | 469932 | 939194 | C | 4.29 | 7.51 | 9.82 | 9.65 | 8.11 | 1.85 | 4.60 | 2.05 | 3.46 | 4.90 | 3.44 | 1.70 | R1 |
| 2 | Mr. Pramote Predapol | 469394 | 939171 | C | 3.95 | 5.86 | 7.32 | 7.02 | 6.65 | 1.83 | 4.80 | 2.15 | 3.52 | 4.01 | 3.05 | 2.16 | R1 |
| 3 | Mr. Juti Predapol | 470008 | 939194 | C | 8.40 | 10.90 | 12.46 | 12.11 | 11.97 | 3.28 | 11.75 | 9.90 | 10.02 | 10.70 | 11.05 | 4.20 | - |
| 4 | Mr. Juti Predapol | 469981 | 939226 | C | 4.52 | 6.05 | 6.95 | 6.63 | 6.20 | 3.84 | 6.35 | 4.52 | 5.14 | 5.95 | 6.21 | 2.54 | R1 |
| 5 | Mrs. Sumang Meepol | 470172 | 939414 | S | 3.71 | 4.02 | 4.33 | 4.29 | 4.25 | 3.25 | 4.32 | 3.50 | 4.00 | 4.30 | 4.10 | 2.31 | - |
| 6 | Mr. Sakorn Predapol | 470273 | 938731 | C | 7.67 | 8.05 | 8.53 | 8.86 | 9.20 | 8.69 | 8.10 | 8.25 | 8.53 | 8.60 | 8.85 | 8.68 | - |
| 7 | Mrs. Kwanjai Boonjun | 469866 | 938670 | S | 5.55 | 6.20 | 6.96 | 6.84 | 6.70 | 5.87 | 6.07 | 4.95 | 5.52 | 6.25 | 6.46 | 2.54 | - |
| 8 | Mr. Jaroan Thongsiri | 469725 | 938366 | C | 5.00 | 6.10 | 6.33 | 5.64 | 5.05 | 3.58 | 4.87 | 4.22 | 4.71 | 4.90 | 5.05 | 2.26 | - |
| 9 | Mr. Somboon Kaewsawang | 468670 | 939749 | S | 2.05 | 3.55 | 4.38 | 4.36 | 4.33 | 3.96 | 2.67 | 2.40 | 2.66 | 3.05 | 3.25 | 2.87 | P1 |
| 10 | Mrs. Suda Phetkray | 468763 | 939830 | C | 1.40 | 3.03 | 4.20 | 3.45 | 2.98 | 1.45 | 1.47 | 0.93 | 1.33 | 1.70 | 2.01 | 1.32 | P1 |
| 11 | Mr. Sawat Choomphan | 468602 | 939762 | C | 2.80 | 3.50 | 3.96 | 4.01 | 4.20 | 3.10 | 2.70 | 2.60 | 2.99 | 3.10 | 3.50 | 3.20 | P1 |
| 12 | Mr. Viroje Koomkrong | 468590 | 939652 | S | 4.39 | 5.80 | 6.33 | 6.49 | 6.60 | 5.30 | 5.05 | 5.16 | 5.42 | 5.70 | 6.08 | 5.45 | - |
| 13 | Mrs. Tin Kaemuang | 468553 | 939582 | C | 4.95 | 6.00 | 6.42 | 6.58 | 6.85 | 5.26 | 5.05 | 5.10 | 5.44 | 5.65 | 6.10 | 5.56 | - |
| 14 | Mr. Anan Suttisan | 467753 | 938930 | C | 4.25 | 4.95 | 6.75 | 6.32 | 5.70 | 4.00 | 4.50 | 4.50 | 5.17 | 5.25 | 5.45 | 4.96 | - |
| 15 | Mr. Prawit Sornkaew | 467773 | 939041 | C | 4.70 | 5.00 | 6.82 | 6.44 | 5.40 | 3.55 | 4.10 | 3.60 | 3.77 | 3.82 | 4.70 | 2.74 | - |
| 16 | Mr. Sombat Prabpracha | 467733 | 939047 | C | 3.95 | 4.78 | 5.20 | 5.26 | 5.30 | 4.18 | 3.67 | 4.15 | 4.17 | 4.32 | 4.68 | 3.25 | - |
| 17 | Mr. Wai Choompan | 467671 | 939076 | C | 2.80 | 3.75 | 4.32 | 4.33 | 4.30 | 2.52 | 2.90 | 2.30 | 2.88 | 3.35 | 3.55 | 2.51 | P3 |
| 18 | Mr. Suthep Praditkarn | 467658 | 939092 | C | 2.80 | 3.75 | 4.29 | 4.55 | 4.82 | 2.43 | 2.85 | 2.30 | 2.79 | 3.22 | 3.51 | 2.45 | P3 |

Remarks: * = Selected shallow wells in each land use type, S = Soil well, C = Cement well.

Appendix Table 1 (Continued)

| No | Name | UTM | | Type | Level of water table (m.) | | | | | | | | | | | | * |
|----|---------------------------|--------|--------|------|---------------------------|------|------|------|------|------|------|------|------|------|------|------|----|
| | | | | | 2006 | | 2007 | | | | | | | | | | |
| | | | | | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | |
| 19 | Mr. Panit Raksakoon | 467652 | 939100 | C | 2.75 | 3.64 | 4.25 | 4.20 | 4.25 | 2.49 | 2.84 | 2.39 | 2.92 | 3.25 | 3.54 | 2.33 | P3 |
| 20 | Mr. Amnuay Kaosa-ard | 467649 | 939105 | C | 2.53 | 3.38 | 3.92 | 3.95 | 4.05 | 2.05 | 2.48 | 2.05 | 2.65 | 3.00 | 3.14 | 2.08 | - |
| 21 | Mr. Suchart Tippayangkoon | 467625 | 939114 | C | 2.60 | 3.65 | 4.12 | 4.12 | 4.10 | 2.42 | 2.83 | 2.25 | 2.42 | 3.20 | 3.44 | 2.35 | - |
| 22 | Mrs. Pad Plodboot | 467531 | 939174 | C | 2.65 | 2.85 | 3.32 | 3.21 | 3.15 | 2.06 | 2.78 | 1.05 | 1.76 | 2.17 | 2.50 | 1.80 | - |
| 23 | Mrs. Uraiwan Thoomtuma | 467527 | 939193 | C | 2.02 | 2.74 | 3.27 | 3.20 | 3.12 | 1.87 | 2.05 | 1.30 | 1.61 | 2.04 | 2.26 | 1.75 | - |
| 24 | Mr. Prayut Marknui | 467516 | 939208 | C | 1.66 | 2.49 | 2.93 | 2.90 | 2.75 | 1.54 | 1.70 | 1.10 | 1.44 | 1.90 | 2.02 | 1.42 | G1 |
| 25 | Mrs. Tanorm Plaichana | 467746 | 930238 | C | 1.53 | 2.22 | 2.65 | 2.59 | 2.52 | 1.37 | 1.54 | 1.02 | 1.45 | 1.72 | 1.85 | 1.12 | G1 |
| 26 | Mr. Prasit Plodboot | 467451 | 939240 | C | 1.70 | 2.10 | 2.30 | 2.34 | 2.30 | 1.36 | 1.40 | 1.05 | 1.34 | 1.70 | 1.87 | 1.23 | G1 |
| 27 | Mr. Sawang Kourpol | 467385 | 939265 | C | 1.60 | 2.63 | 3.90 | 5.20 | 6.00 | 2.20 | 2.15 | 1.60 | 2.02 | 2.30 | 2.39 | 1.75 | - |
| 28 | Mr. Charad Paklao | 466780 | 939328 | C | 4.42 | 4.88 | 5.21 | 5.81 | 6.28 | 4.43 | 4.22 | 4.24 | 4.32 | 4.66 | 5.06 | 4.32 | R2 |
| 29 | Mr. Tud Tudsee | 466871 | 939288 | C | 4.39 | 4.52 | 4.83 | 5.06 | 5.76 | 4.02 | 3.97 | 4.02 | 4.11 | 4.35 | 4.76 | 3.99 | R2 |
| 30 | Mrs. Aree Kwanprom | 466879 | 939455 | C | 4.35 | 4.76 | 4.95 | 5.42 | 5.80 | 4.20 | 4.08 | 4.08 | 4.23 | 4.53 | 4.97 | 4.12 | R2 |
| 31 | Sahakarn Palm Company | 467383 | 938498 | C | 2.71 | 3.20 | 4.04 | 4.25 | 4.55 | 2.40 | 2.48 | 1.63 | 2.35 | 2.95 | 3.16 | 1.98 | - |
| 32 | Mr. Keattisak Praditkarn | 467371 | 938754 | C | 3.70 | 5.00 | 5.61 | 6.03 | 6.85 | 3.90 | 4.75 | 4.60 | 5.42 | 5.02 | 5.05 | 5.08 | - |
| 33 | Mrs. Tu Sritip | 467436 | 938775 | C | 3.90 | 4.25 | 5.63 | 6.47 | 7.02 | 5.45 | 5.05 | 4.95 | 5.08 | 5.15 | 5.83 | 5.16 | - |
| 34 | Mr. Sawang Sornkaew | 467376 | 938890 | S | 4.10 | 4.05 | 4.75 | 4.97 | 5.21 | 3.94 | 4.35 | 4.30 | 4.26 | 4.10 | 4.10 | 3.30 | P2 |
| 35 | Public hall | 467746 | 939151 | C | 3.20 | 4.02 | 4.57 | 4.61 | 4.75 | 2.20 | 2.95 | 2.50 | 3.02 | 3.60 | 3.75 | 2.52 | P2 |
| 36 | Mrs. Sangam Thongsrion | 467745 | 939120 | C | 3.10 | 3.82 | 4.45 | 4.48 | 4.50 | 2.35 | 2.80 | 2.32 | 3.01 | 3.43 | 3.50 | 2.39 | P2 |
| 37 | Mr. Tan Ratthakoon | 468652 | 936377 | S | 4.35 | 6.01 | 6.17 | 6.11 | 6.05 | 3.55 | 6.00 | 5.10 | 5.12 | 5.25 | 6.00 | 4.00 | - |

Remarks: * = Selected shallow wells in each land use type, S = Soil well, C = Cement well.

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