SOIL MOISTURE DISTRIBUTION FROM CHECK DAMS USING GEO-INFORMATION TECHNOLOGY AT HUAY SAI ROYAL DEVELOPMENT STUDY CENTER, THAILAND

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ABSTRACT

This study aims to examine physical characteristics, including altitude, slope, geographical aspects and soil texture that affect the distribution, amount, and the pattern of soil moisture from check dams at Huay Sai Royal Development Study Center, Phetchaburi Province. The survey and data collection were conducted in two seasons, namely Summer (April-May) and the rainy season, June-July 2011 at the depths of 5-15 centimeters and 15-30 centimeters of locations with and without a check dam. Soil moisture was measured using the gravimetric method. Statistical correlations and physical characteristics were analyzed. Geo-information technology was applied for soil moisture distribution analysis.

The results showed that moisture values in summer were 0.32-11.26 percent by weight and 0.15-10.55 percent by weight according to the depth. In the rainy season, moisture values were 2.16-23.82 percent by weight and 1.31-14.09 percent by weight according to the depth. About physical characteristics, it was found that the geographical aspects had an impact on soil moisture in summer. Altitude had an impact on soil moisture in the rainy season at significance level of 0.05. For area estimation using Thiessen Polygon and Co-Kriging methods, it was found that soil moisture was mostly distributed in the north and the northeast of the study center in summer. In the rainy season, soil moisture was widely distributed. Particularly in mountain areas with check dams, soil moisture values increased during summer. Corresponding to vegetation diversity value (NDVI) obtained from a satellite photograph taken by Landsat-5 TM during April-August 2011, the area showed higher vegetation density in August compared to April.

KEY WORDS: SOIL MOISTURE/ CHECK DAM/ DISTRIBUTION/ THE ROYAL PROJECT/ GEO-INFORMATION TECHNOLOGY

129 pages

การแพร่กระจายความชื้นในดินจากฝายชะลอน้ำโดยใช้เทคโนโลยีภูมิสารสนเทศ บริเวณศูนย์ศึกษาการพัฒนาห้วยทราย อันเนื่องมาจากพระราชดำริ ประเทศไทย

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาลักษณะทางกายภาพ ได้แก่ ความสูงจากระดับน้ำทะเลปานกลาง ความ ลาดชัน ทิศทางลาด และลักษณะเนื้อดิน ที่มีผลต่อการแพร่กระจายความชื้นในดิน และปริมาณลักษณะการกระจายความชื้นจากฝายชะลอน้ำ บริเวณศูนย์ศึกษาการพัฒนาห้วยทราย อันเนื่องมาจากพระราชดำริ จังหวัดเพชรบุรี สำรวจและเก็บข้อมูลใน 2 ฤดูกาล คือฤดูร้อนเดือนเมษายน-พฤษภาคม และฤดูฝนเดือนมิถุนายน-กรกฎาคม ปี 2554 ที่ระดับความลึก 5-15 และ 15-30 เซนติเมตร ตำแหน่งที่มีฝายชะลอน้ำและไม่มีฝายชะลอน้ำ วัดค่าความชื้นในดินด้วยวิธีวัดโดยน้ำหนัก (Gravimetric Method) และวิเคราะห์ความสัมพันธ์ทางสถิติกับลักษณะทางกายภาพ พร้อมทั้งประยุกต์ใช้เทคโนโลยีภูมิสารสนเทศเพื่อการวิเคราะห์การแพร่กระจายความชื้นในดิน

ผลการศึกษา พบว่าฤดูร้อนมีค่าความชื้นอยู่ระหว่าง 0.32-11.26 เปอร์เซ็นต์โดยน้ำหนัก และ 0.15-10.55 เปอร์เซ็นต์โดยน้ำหนัก ตามระดับความลึก ช่วงฤดูฝน ค่าความชื้นอยู่ระหว่าง 2.16-23.82 เปอร์เซ็นต์โดยน้ำหนัก และ1.31-14.09 เปอร์เซ็นต์โดยน้ำหนัก ตามระดับความลึก ลักษณะทางกายภาพ พบว่าทิศทางลาด มีผลต่อความชื้นในดินฤดูร้อน ระดับความสูงจากระดับทะเลปานกลาง มีผลต่อความชื้นในดินฤดูฝน อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 สำหรับการประมาณค่าเชิงพื้นที่แบบ Thiessen Polygon และ Co-Kriging พบว่าฤดูร้อนความชื้นในดินแพร่กระจายมากที่สุดทางทิศเหนือและทิศตะวันออกเฉียงเหนือ ช่วงฤดู ความชื้นในดินแพร่กระจายเป็นบริเวณกว้าง โดยเฉพาะพื้นที่ภูเขาและมีฝายชะลอน้ำ ค่าความชื้นในดินเพิ่มขึ้นจากฤดูร้อน เช่นเดียวกับค่าความแตกต่างพืชพรรณ (NDVI) ของข้อมูลภาพถ่ายดาวเทียม Landsat 5 TM ระหว่างเดือนเมษายน-สิงหาคม ปี 2554 พบว่าในเดือนสิงหาคมพื้นที่มีความหนาแน่นพืชพรรณมากกว่าในเดือนเมษายน

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CHAPTER I
INTRODUCTION

1.1 Reasonable

Up to now, natural resources in Thailand especially forestry area has been greatly destroyed by deforestation and illegal intruding. Consequently, imbalance ecology and lacking of water absorption could cause barren ground and effect on organism in that area. H.M.King Bhumibol Adulyadej deeply concerned this issue and thought the solution for protecting and conservation natural resources in Thailand. "Small dam" or "weir" has been invented by the Royal thought. It can revive degraded forest, retain moisture during dry season and retard the water flow which can fulfill amount of water in creek or stream. The speech of H.M.King Bhumibol Adulyadej about rehabilitation of degraded forests on, 21 March 1978 at Mae La District, Mae Hong Sorn Province as this following;

"For the trees which grow along the creek should be maintained in a good way, because they will retain soil moisture. Moreover, the watercourse should create weir for reserving the water. However, it seemed to be such a tiny reservoir but it could irrigate to agricultural area.

Another speech of H.M.King Bhumibol Adulyadej was declared on 11 March 1989 at Doi Ang Khang, Fang District, Chiang Mai Province, his speech was presented as this following;

"At downstream should build the small dam which can retard the water flow and reserve the water for the upper stream".

According to the Royal speeches, both of government (Department of National Park, Wildlife and Plant Conservation, Ministry of Natural Resources and Environment) and private organization (The Siam Cement Public Company Limited; (SCG), Siam City Cement Public Company; (SCCC)) and the another public sectors have created building weir project which have built about thousand weir in difference places. However, some places received more benefit than the others which depended on objective of project, topography and weir pattern. The most benefit of weir is to retard water flow in creek or stream, to increases the soil moisture, and to raise the abundance of water.

The Huay Sai Royal Development Study Center in Phetchaburi is one of His Majestic weir project succeeded. This area encountered drought consistently. The King realized this problem as well. After that, the king thought and created check dam or called “Fai Maew” which was created from natural materials. His idea brought resourcefulness and moisture back to Huay Sai again. For this succession, it lead attention to study of soil moisture diffusion. About physical characteristics, the study included altitude, slope and soil texture influenced on soil moisture diffusion and the diffusion of soil moisture from Check Dam which could revive drought area to become productive area.

1.2 Objectives

The objectives of this study are:

1.2.1 to study the physical characteristics; altitude, slope aspects and soil texture, which could effect on the diffusion of soil moisture, and

1.2.2 to determine the amount and the distribution patterns of Check Dam.

1.3 Study Area

1.3.1 Spatial Scoping

Study the diffusion of moisture at Huay Sai Royal Development Study Center in Phetchaburi

1.3.2 Timing Scoping

Study the diffusion of moisture in 2 seasonal which cover dry season (April- May) and rainy season (June-July).

1.3.3 Data Scoping

1) Physical data included altitude, slope and soil texture.
2) Geographic Information from Satellite LANDSAT (5 TM system)

1.4 Study Framework

At present, forest in Thailand has been continuously deforested. For reviving ecosystem back to resourcefulness, it must restore natural resourceful. Water is the most vital natural resource for living organisms. Therefore, it is unlikely to require treatment in an area as long as possible. H.M.King Bhumibol Adulyadej has an idea for water and soil conservation and revives drought area back to productive area. Check Dam has been built for creating and distributing the moisture to drought area by the government and the private organizations.

As well as, Huay Sai Royal Development Study Center project was occurred by the King thinking when he visited the people who lived in this area and saw many problems such as lacking of water. The King decided to create “Check Dam” for distributing moisture. As a result, ecosystem at Huay Sai area became alive again. Soil moisture leaded the attention to study of soil moisture diffusion. The study was about physical characteristics included altitude, slope and soil texture which influenced soil moisture distribution. Moreover, the Remote Sensing was applied in this study. The principle of remote sensing was studied about reflection materials, plant, water and soil and relationship between plant density and actual soil moisture in the study area which effected on soil moisture distribution.

1.5 Definition Terms

1.5.1 Soil Moisture

After raining, dry soil will absorb water and keep it between spaces of soil particles and air will be expelled. If the water was increasingly kept, this absorption by gravity will be still continues and reach to the saturated soil by water that is called "filed Capacity". Properties of soil structure have different filed Capacity. Grained soils are saturated by water faster than clay. In contrast, clay is easily to loss water faster grained soil. If the water keeps flowing, clay cannot absorb it anymore, the water will flow around soil surface. The filed capacity is useful for agriculture but somehow the water cannot be refilled until plant's root cannot take in. It will consequence on plant withering. This point will be called "wilting point" and plant will not be able to maintain life. If no water is added to soil, the plant will eventually die due to withering. The study of wilting point at plant root is very important for agriculture.

1.5.2 Check Dam

Check Dam refers to the building of obstacle in stream, creek or river where the water flows from the upstream or slope area. It can trap sediment, retard the water flow and storage of sediment deposition.

1.5.3 The Royal Projects

The Royal Projects have been created by H.M.King Bhumibol Adulyadej and operated with government, private organizations and another sectors. The Royal Projects have been scattered all over country which various aspects of project development such as education, experiment etc. The project had completed in the short term and long term with more than 5 years.

1.5.4 Geo-Information Technology

Geo-Information Technology is technology which integrates Remote Sensing, Geo-Information System and Global Positioning System for more efficient and effective.

1.6 Expected Outcome

1.6.1 For knowing of physical characteristics including altitude, slope, aspects and soil texture can affect the diffusion of moisture in the soil at "Check Dam" building area.

1.6.2 For knowing of the amount and how to soil moisture spread which is occurred from "Check Dam".

CHAPTER II
LITERATURE REVIEW

Related study, literature review and theories were gathered for study about classification of soil moisture distribution from check dam by using Geo Information Technology at Huay Sai Royal Development Study Center in Phetchburi Province. The literature review was consisted of at this following;

1. Soil Moisture
2. Soil texture
3. Check Dam
4. Huay Sai Royal Development Study Center
5. Geo-Information System (GIS)

2.1 Soil Moisture

Soil moisture refers to water is located in zone of aeration or unsaturated zone which is refers to underground. Between soil pores have space that contain water and air. Soil pores that contain water cause soil moisture (Niwat Ruengpanit, 2004). When rain starts falling to the ground, some of them will be absorbed by soil particles. This water is kept by soil gradient and is considered that is the first part of water in soil (Wicha Niyom, 1992). When soil cannot absorb water anymore, the remaining of water will flow down to bigger space between soil particles by earth gravity. This part of water is called “Gravitational Water”, which do not useful for plant growth. This water will seep through another soil layers until underground water.

2.1.1 Water Content

Soil moisture or water in soil is commonly contained between soil particles. In this space, it does not contain only water but it is also fulfilled by air. Both of two components significantly relate each other. If the gap is fulfilled by water, the air will not be trapped. In contrast, if the gap is filled by air, there is no place or less for containing water. Status of water in soil depends on different types of water available in the soil and can be divided into this following; (Kasensri Subson, 1998)

1) Saturated soil refers to soil has reached maximum water containing and proportion of water and air contain in space is 100 % of water. In this status, soil is surrounded by water and percent of soil moisture is 100%. Saturated soil can find in lowland or paddy field.

2) Unsaturated Soil refers to water contain apart of soil pores and can be found in hill topography.

3) Field Capacity, FC refers to the amount of water contain held in the soil which the highest of field capacity found in depth 6 m. and tended to be stable. It means that soil pores will be saturated by water, the excess water will flow by gravity.

4) Hygroscopic Coefficient refers to the condition of soil water content is very low and look like gossamer in soil. Plant cannot use for living.

5) Permanent Wilting Point, PWP is defined as the minimal point of water contain in soil and adhesive force between water and soil increase. As a result, the amount of water does not enough for plant requirement. When daytime, plant has transpiration rate more than water transportation. Resulting on plant temporary wilting. If water is added in soil, this symptom will disappear. In contrast, soil does not filled by water, it will become dry and eventually plant will permanently wilt.

2.1.2 Types of Soil Moisture

The water in soil can move from one point to another point by gravity force, between ions in solution and the forces between molecules of water. Water in the soil may appear in many form (Faculty of the Department of Soil Science, 2005). Soil Moisture can be divides into 4 types as this following (Niyom Boonpikham, 2000)

1) Water or moisture in the mineral composition of the chemical compound (Chemical Combined Water), it will be crystalline form in solid component such as limonite and gypsum. This kind of soil has been dried by oven at 105-110 ° C for less than 15 hours. Moisture still remain in soil, however, it does not benefit to the plant.

2) Hydroscopic Water refers to water forms very thin films about 2-3 of water molecule (layer of water molecule) around soil particles. Adhesive force between soil particles and humidity increase from 31 to 10,000 atmosphere. Moisture is still remain in air dry soil. Plants cannot absorb this type of moisture because it is firmly attached to soil particles in steam form.

3) Capillary Water describes water (very thin membrane) is absorbed outside of soil particles which stay next Hydroscopic Water layer. Adhesive force of soil particles are between 0.5- 31 atmosphere. If soil is saturated with water and then left under the influence of gravity for a period of 2-3 days and prevent the water drainage until there is no drip out from soil. This kind of moisture does not available for plant and permeating water is available for plant. This kind of water keeps changing and depends on soil type and water.

4) Gravitational Water or Drainage Water describes occupies the larger soil pores which is less of adhesive force. Adhesive force is between 0.1- 0.5 atmosphere. Water will flow through the ground by gravity force which makes it move from soil or seep and leach plant nutrient from upper to lower soil. Plant can use this kind of water very few.

2.1.3 Losing of Soil Moisture

Losing of soil moisture refers to the amount of soil moisture decreases which can be lost in many ways. Soil moisture deficit can cause from 3 reasons as this following; (Dusit Manajuti, 1992)

2.1.3.1 Run off

Runoff occurs when the rate of water infiltration rate is lower than the surface water which causes water losing from the soil, soil erosion and soil fertility declines.

2.1.3.2 Evapotranspiration

Losing water by evaporation can evaporate from the soil directly or transpiration by plants. Soil moisture deficit is directly influenced from climate such as solar radiation, temperature, wind and humidity.

2.1.3.3 Deep Percolation

Losing of water content in soil occurs when the water seeps out around the plant root, it decreases opportunity for plant using. Moreover, seeping water can leach and dissolve nutrition in soil. Deep percolation occurs when heavy rain or irrigated soil more than the ability of soil can absorb water. Deep percolation is mostly influenced from amount of rainfall, soil properties, evaporation and ground covered.

2.1.4 Soil Water Content

Measurement of soil water content mostly measures level of humidity (Water Content). It refers to measure ratio between the amount of water and amount of water contained soil. It can be measured as this following; (Faculty of the Department of Soil Science, 2005)

2.1.4.1 Mass Water Content

Mass Water Content refers to ratio between the mass of water and mass of dried soil which contain water. It can be described as this following equation;

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

Whereas; θ_m = Mass Water Content

m_w = Mass of water

m_s = Mass of dried soil

Dried soil refers to soil has been dried in an oven at a temperature of 105-110 ◦ C until constantly mass.

2.1.4.2 Volume Water Content

Volume Water Content refers to ratio between volume of water in soil and volume of bulk. The bulk volume means total of solid volume and pore volume. It can be described as this following equation;

$$\theta_v = \frac{v_w}{v_b}$$

Where; θ_v = Volume Water Content

v_w = Volume of water

v_b = Bulk volume

When considering relationship between volume water content θv and mass water content is shown in following equation.

$$\theta_v = \frac{P_b \, . \theta_m}{P_w}$$

Where; P_b = Bulk Density

P_w = Water Density

For estimating moisture content by calculating the first equation is very intricacy. Therefore, assessing the moisture content mostly figure out from the second equation when mass water content and bulk density is known.

2.1.4.3 Depth Water Content

Depth water content refers to the volume of water in soil per unit area of soil. When considering soil area is equal A and soil depth is Z. So equation of Depth Water Content can be written as this following;

$$V_w = \theta_v \mathrm{Az}$$

Where; V_w = Volume of water

θ_v = Volume Water Content

Az = Total Volume of soil

Due to depth water content refers depth of water which means volume of water in soil per area, hence;

$$h_w = \frac{\theta_v Az}{A} = \theta_v z$$

Where; h_w = Depth Water Content

2.1.5 Measuring Soil Water Content

Measuring soil water content is used for determining the amount of soil moisture changes. Measurement can be classified into two methods which comprises of directly method and indirect method. Directly method applies by weighting and indirect method uses instrument (Faculty of the Department of Soil Science, 2005). Several commonly methods for measuring soil water content consists of as this following;

2.1.5.1 Gravimetric Method

Gravimetric method refers to soil is collected and dried and weighted directly. The procedure conducts as this following step;

1) Collecting soil samples from targeted area in moisture can which is already know mass, or wrap it in a sheet of aluminum foil which also know mass precisely.

2) Collecting soil samples in a plastic bag which seal tightly for preventing leakage of moisture.

3) Weighting soil samples 1 time before put them to the oven in laboratory room.

4) Put soil samples with container into oven with temperature of 105-110°C for about 24 hours.

5) When dried soil become cooler, weight them again.

The entire of results are calculated by using equation 2.1.4.1 for finding mass water content. In this method, soil samples must be collected many samples which may damage on sampling area. This method is properly used in small sampling area and used for calibration with other methods. Therefore, in order to minimize disturbing impact in sampling area, it must conduct as shown in Figure 2-1.

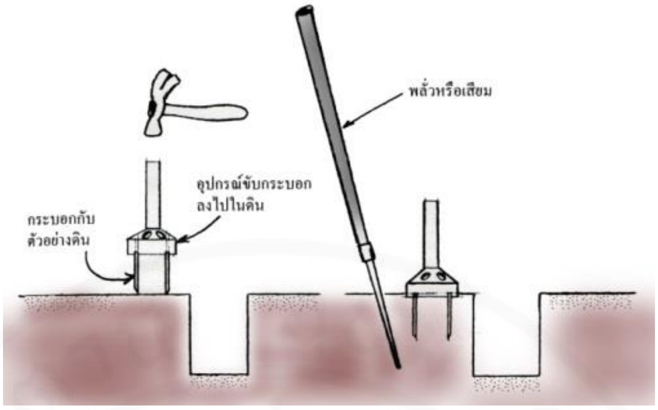
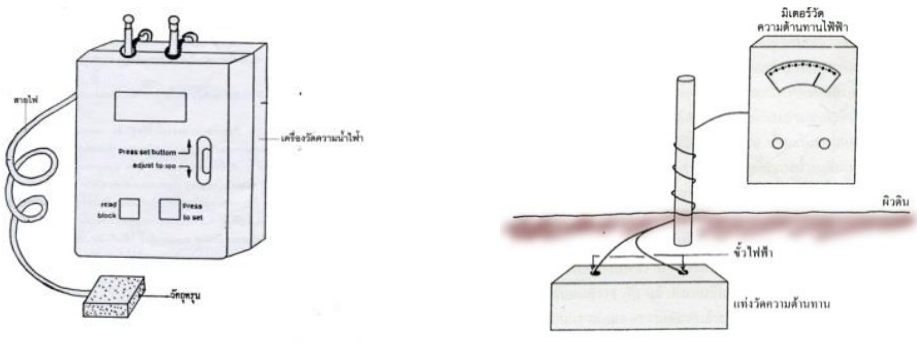


Figure 2-1 Soil sampling equipment does not disturb soil structure.
Source: Faculty of the Department of Soil Science (2005)

2.1.5.2 Electrical Resistance Block

Electrical Resistance Block is used for indirectly measuring soil water content. It uses variation of conductivity (Electrical Conductivity) or Electrical Resistance. The Electrical Resistance Block is shown in figure 2-2. This method must create “Calibration Curve” which presents relationship between the Electrical resistance and soil water content. For creating a good calibration curve, soil which surround electrical probe, must be dug for finding soil water content and also measure electrical resistance as well. The result will nearly resemble the natural. This method is useful for measuring plants’ growth more than the amount of soil water content.



(A) (B)

Figure 2-2 Electrical Resistance Block (A) and Usability (B)
Source: Faculty of the Department of Soil Science (2005)

2.1.5.3 Tensiometer

Another indirect method for finding soil water content, this instrument looks like long tube as presented in figure 2-3 and using of tensiometer is presented in figure 2-4. The component of tensiomenter comprises of 4 part as this following;

1) Porous Ceramic Cup is buried in soil depths to measure soil water stress.

2) Plastic tube connects between Porous Ceramic Cup and Stress meter.

3) Stress meter can be Vacuum Gauge, Mercury Manometer, or another device.

4) Cap is fulfilled by water and displaces air out of Tensiometer while it is working. Every part of Tensiometer is fulfilled by water.

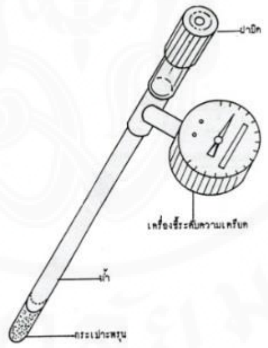


Figure 2-3 Component of Tensiometer

Source: Faculty of the Department of Soil Science (2005)

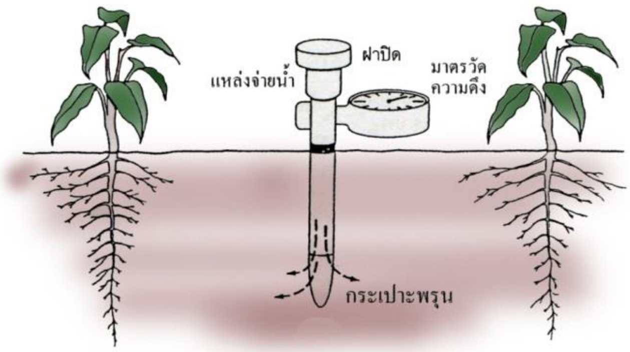


Figure 2-4 Using of Tensiometer

Source: Faculty of the Department of Soil Science (2005)

2.1.5.4 Neutron Moisture Gauge

Another indirect method for finding soil moisture, soil water content is measured by Radio Isotopes. The amount of Hydrogen is detected by neutron, because hydrogen in soil relates with groundwater. Installing Neutron Moisture Gauge is presented in figured 2-5. Detecting soil moisture with this method, result is more accurate than the others. Moreover, this method will slightly damage soil, convenience but it is expensive instrument. The proper depth for measuring is more than 30 cm. and does not suitable for measuring moisture in soil surface because the value is inaccurate, and the user may be harmed by neutron radiation.

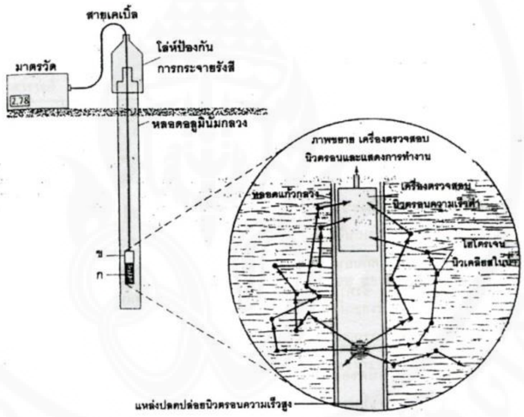


Figure 2-5 Measuring soil moisture by Neutron Moisture Gauge Instrument
Source: Faculty of the Department of Soil Science (2005)

2.1.5.5 Time Domain Reflectometer

Soil moisture is detected by using radio wave or microwave (100 - 1000 MHz). It will measure electrical properties of water molecules and it will be used for estimating soil moisture.

2.1.6 Soil Moisture Factors

Soil moisture in each area is difference from each other. It depends on the penetration of water or movement of water into soil. The most important factor of infiltration depends on soil properties and texture. If soil is loam and contains many pores and if soil is covered with high organic matter and leaf debris densely, it will increase water infiltration rate to soil (Niwat Ruengpanit, 2004). Donahue et al. (1971) mentioned that soil moisture was influenced by soil particles (percentage of sand, silt and clay), soil structure, soil organic matter, soil depth to Lithosphere, amount of water in soil, amount of ground cover, topography and amount of rainfall. As well as documents from Department of Landscaping and Environmental Conservation, Faculty of Architecture and Environmental Design, Mae Jo University concluded that the amount of groundwater was influenced from rainy period (time). If rain period is short, will result rate of water flow is fast and rate of water infiltration decreases. In contrast, if rain period is longer, rate of water infiltration increases. Slope, if the area is steep, water infiltration is less. Porosity refers to ratio between the volume of pores and volume of the rock. Permeability refers to ability of rock that permits water flow through it. Permeability depends on size of pores but does not rely on volume of gaps. Amount of tree can retard surface water flowing and it is consequence on increasing of water infiltration. Finally, slope steepness can influence the amount of ground water. If slope steepness is very steep, water flows very fast.

Wicha Niyom (1992) mentioned the crucial soil moisture process was infiltration. If soil has highly water permeability, it will have highly moisture. Therefore, factor that affected infiltration was weather such as rain. If it heavily rain and take long period, soil will receive much more water. In contrast, if rains take short period, soil will receive less of water. Seasonal, during dry season, water will seep through the first stage higher than rainy season. If snow gradually melts, soil will absorb water more than heavily rain. Moreover, rate of evaporation could affect the amount of groundwater. If highly evaporation, the rate of water infiltration is low. Soil properties were also affected soil water content too. Coarse texture had rate of water infiltration more than fine texture. For example, Sandy soil is more permeability than clay. Land use, soil and water conservation and also vegetation cover could impact soil moisture. Land use which do not covered by vegetation, when it rain, soil pores were filled by water. It caused runoff at soil surface and consequence on decreasing infiltration. Another factor which was topography could influence soil moisture. Water flows by gravity is an important impact on permeability. Soil moisture in plain area will have soil moisture more than slope area. Soil moisture in ridge has water content less than soil where locates near river or foothill.

Another study of factors that influenced soil moisture such as Payap Paoprajak (1967) who studied about influence of difference of slope direction impact on soil moisture in Teak forest. Soil samples were collected in difference direction of slope. Each of the slopes were divided into 4 directions (North, South, West and East) and each direction took soil samples 5 levels with the similar slope. The result presented that moisture content in soil from northern slope was the highest and moreover, comparison of soil moisture in differences slope showed that the slope level 3, 6, 9 and 12% was the most humidity.

Rommanee Thongdara (1997) studied about application of Geo Information Technology (GIS) and remote sensing for creating soil moisture in Khaohinsorn Royal development study. Factors that could effect on soil moisture consisted of as this following;

- Altitude: Soil moisture is inversely proportional to the height of sea level. When height of sea level rise, soil moisture decreases. Slope was less influence soil moisture than height of sea level.
- Depth: soil moisture was conjugated with depth. Soil moisture at 60 cm. depth had more moisture than soil depth 15 cm.
- Soil texture: soil moisture varied with the amount of clay particle. Sandy clay was apparently had moisture more than sandy loam.
- Land use: Types of land use resulted on soil moisture. Due to plant physiology, Crop Evapotranspiration, Life-cycle of plant and root system.
- Seasonal: seasonal could influence soil moisture. This study conducted during dry season, which started from October to March. Result presented that soil moisture in October was higher than November. And humidity gradually decreased until October.
- Rainfall: soil moisture depended on the amount of rainfall in each area.

Amonrat Leamtrakulpanit (2001) studied about soil moisture variation in Mixed Deciduous Forest at Mae Klong watershed Research Station, Thongpaphum District, Kanchanaburi Province. The objective aimed to study about changing soil moisture which impact from elevation of the area such as slope and soil depth in days and month and also studied factors that affected soil moisture in Mixed Deciduous

Forest. Measuring soil moisture by using TDR (Time Domain Reflectometry) measured every day in areas with high sea level along the slope and divided into 4 levels, included lower, upper middle and the upper part which soil depth was range between 0-15, 15-30, 30-60, 60-90 and 90-120 cm. Results reveled that soil moisture was influenced by seasonal changing. Soil moisture in rainy season had more moisture than dry season and then it gradually decreased in the end of rainy season and reduced constantly in dry season. The most variation presented in depth 0-15 and 15-30 cm. From this study concluded that the factors that determine the amount of moisture were amount of rainfall and clay particle, and also included location.

Ratchaneewan Rahula (2004) investigated the variation of soil moisture in cassava plantation Khon Buri district, Nakorn Srithamarat province. The objective of study was study about variation of soil moisture in various depths from surface in daily and monthly. Measuring soil moisture applied TDR (Time Domain Reflectometry) and measured at depth of 0-5, 5-20, 20-60, 60-100, 100-160, and 160-220 cm. Moreover, relationship between soil moisture and evapotranspiration value were investigated by using Bowen Ratio. Result revealed that the average daily humidity is 40.3 percent by volume, maximum and minimum of 18.4 percent by volume. The most variation found at depth of 0-5 and 5-20 cm, and was changed by seasonal and the time of cultivation. Analysis of the relationship at depth 0-5 cm between the soil moisture content (MC) and evapotranspiration (Et) found that the linear equation which could be written as this following, Et = 0.1635MC – 1.4598 (R2 = 0.55, F = 181.6).

Suda Saikrajang (2007) studied the variation of soil moisture in paddy field at Muang District, Sukhothai Province. The aim of study was study the variation and rate of reduction of moisture in soil after planting rice in various depths of the soil in daily and monthly. Moreover, relationship between soil moisture and meteorological factors were investigated in this study. By using a TDR (Time Domain Reflectometry) technique, soil samples were collected in different month. Result revealed that variability and rates of soil moisture decreasing after planting both daily and monthly. For studying the relationship between soil moisture and meteorological factors such as temperature (Ta), relative humidity (RH) and wind speed (Ws) found that air temperature and wind speed. Both of temperature and wind speed negatively affected on soil moisture. In contrast, relative humidity was positively on soil moisture.

Panittha Saard (2007) studied about identity equation of soil water contain for estimating soil moisture changing in Mae Sa watershed at Chiang Mai Province. The objective was study about relationship between soil moisture and soil lumps directed energy levels and also found properly pattern that suited for Mae Sa watershed. By comparison Brooks and Corey's equation ,Campbell's equation and the equation of Van Genuchten, Soil samples were taken from 7 stations and different depth which total of soil samples were 21 samples, then analyzed in the laboratory. Result revealed that soil moisture changed in same direction, when pressure push water out of soil water content, it resulted on soil moisture reduced. Comparison in depth of each station found that soil moisture in 5 station levels considerably were higher than the energy directed at the deeper layers and another 2 stations found that subsoil was higher than the topsoil. The equation for finding the identity of the water in the soil of the three equations showed that R2 did not different. However, equation of Van Genuchten was the most similar with laboratories resulting. Hence, it was applied to model of Nash and Sutclife (EFF) and was calibrated by using Generalized Reduced Gradient, revealed that porosity and thermal conductivity of water saturated, making the EFF had maximum value (0.9397) was 0.4988 and. 0.0001 cm per second.

2.2 Soil Texture

One of the most important of physical soils properties is soil texture. Soil texture relates to other physical soil properties such as size and distribution porosity which involves water movement, solution, ventilation and the ability of soil to absorb water. Soil texture represents of soil properties coarse and fine texture which can be classified soil many types.

2.2.1 Soil Component

Faculty of the Department of Soil Science (2548) has classified soil texture into three groups which depends on soil component.

1) Sand or sand particle is the biggest size of soil particle.

2) Silt or silt particle sediment or sand particles is moderate size of soil particle.

3) Clay or clay particle is the smallest size of soil particle.

Each group has a different specificity as this following;

2.2.1.1 Sand

- It looks like grainy which decay from parent matter.
- Larger size and ability to visible. Except very fine sand. When touch this sand, will feel itchy.
- Joint incoherent granular soil. If there is no other soil particle, it appears single grain.
- Sand formations with larger pore size, well drainage and ventilation and water retention is low.
- This group has specific surface area which has less area for water and nutrients absorption.

2.2.1.2 Silt

- A group of medium-sized particle
- Smaller particle and invisible. Edges of the particle are less and feel slippery like flour when touch it.
- Crumbly
- Silt formation in a clod with properly size will associate hydroscopic.

2.2.1.3 Clay

- Clay particle which decay from mineral dissolution.
- The smallest particles and invisible with a microscope. Particle has a sheets stacked layers. When it dry, it feels rough. However, if it wet is sticky, feel slippery fingers and sticks.
- Clay particle is connected tightly (cohesion) when it dried. Clay particle is connected loose (adhesion) well when it wet. Because of highly specific surface area, clay will not

appear as single particle. But it appears cluster. Some clay can swell when absorb water and shrink when losing water.

- When particulate formations it will have porosity between particles. Water retention is high and pool drainage and ventilation.
- Clay particle have surface area more than other soil particle and unneutral particles. It can absorb water and nutrient well which is more fertility than the others.

2.2.2 Textural Classes

According to 3 groups of soil particle, which differently geology and topography or even climate, result to proportion of soil particles and soil texture. Aerb Keawruenrom (2005) classified soil texture into 12 types as this following, Sand, Loamy Sand, Sandy Loam, Loam Silt Loam,Silt, ,Sandy Clay Loam,Clay Loam,Silty Clay Loam,Sandy Clay,Silty Clay and Clay.

According to 12 types of soil texture, could be written as a triaxial diagram which presented proportions of three particles as shown in Figure 2-6. Moreover, faculty of Department of Soil Science (2005) divided soil texture into 3 groups, as shown in Figure 2-7. They explained as this following;

2.2.2.1 Coarse texture soils

This group consists of three types of sand, loamy and sandy loam. It is diatomite and its advantages and disadvantages of this group are;

- The advantage is porosity between soil particles is small. Infiltration and water redistribution are well.
- The disadvantage is less surface area and does not have an Ion. Resulting to less absorb water and nutrients.

2.2.2.2 Medium texture soils

This group consists of four types of soil, includes loam, silt loam), silt and sandy clay loam. Characteristic of this group is moderately drainage, well ventilate and available water capacity which is useful for plant growth.

2.2.2.3 Fine texture soils

This group consists of clay loam, silty clay loam, sandy clay, silty clay and clay. Specialty characteristic of this group is;

- The advantage is highly specific surface area and porosity between particles is small which can absorb more water and nutrients.
- The disadvantage is porosity between particles is small and highly total volume of porosity. Moreover, infiltration and drainage is low which can cause flood and bad ventilation.

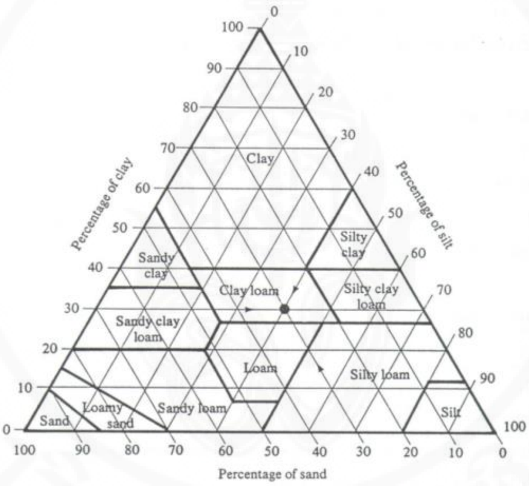


Figure 2-6 Triaxial Diagram present proportion of soil particle

Source: Aerb Keawruenrom (2005)

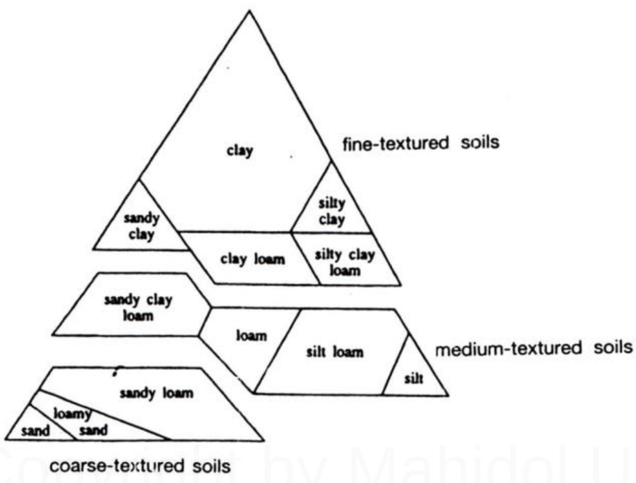


Figure 2-7 New Triaxial Diagram which Divided soil into 3 groups

Source: Aerb Keawruenrom (2005)

2.2.3 Relationships with soil texture

2.2.3.1 Relationships between Permeability Classes and soil texture

The relationships between permeability classes and soil texture were presented in Table 2-1, revealed that areas with consists of coarse sand or gravel. The water permeability is very high and rapid. In contrast, silt and clay particle do not have porosity.

Table 2-1 Relationships between Permeability Classes and soil texture

Permeability Classes	**Hydraulic Conductivity**		**Soil texture**
	in/h	**cm/h**	
Very rapid	>20	>60	coarse sand or gravel
Rapid	6.3-20	16-60	Sandy Loam
Moderately rapid	2.0-6.3	5-16	Loamy Sand
Moderate	0.63-2.0	1.6-5	Soils with good structure such as loam, silt loam or clay loam
Moderately slow	0.2-0.63	0.5-1.6	Loam, silt or clay with have suitable structure
Slow	0.063-0.2	0.16-0.5	Soil texture with consists of silt or clay particle which have bad structure
Very slow	<0.063	<0.16	Silt or clay particle arranged in a vertical or pan

Source: Aerb Keawruenrom (2005)

2.2.3.2 Relationships between soil texture and soil moisture

Soil texture influences soil moisture directly, which is retention of soil moisture. Due to soil surface area can absorb molecule of water and retain water by porosity. For example, clay particle can absorb water by ion and porosity is small. Resulting water can be more absorbed than coarse soil which has larger porosity and soil particles adherence is bigger.

2.3 Check Dam

2.3.1 Definition

The Royal thinking about development and re-habitation forestry theory by using natural resources which provides beneficial for each other. The H.M.King Bhumibol Adulyadej recognized the importance of the survival of forests which vital parameters of the survival of the forest is "water". Hence, the King crated Check Dam for helping and conserving of forest re-habitation. Check Dam can describe a weir or small dam is constructed for obstacle in stream, creek or river where the water flows from the upstream or slope area. It can trap sediment, retard the water flow and storage of sediment deposition. This method is can conserve soil and water as well.

Watershed Conservation and Management Office (2010) explains Check Dam as a small dam is constructed obstructive gully erosion or tiny stream or creek. The objectives of construction dam comprise of trapping sediment which occur from upper stream run off and preserve gully erosion to do not expand. As well as, Royal Irrigation Department describes as a building is built to irrigate at upper stream and its function is distribute water in to canal and provide water to agricultural area. The excess water will flow over the weir. Mostly, dam height does not high too much and it’s shaped like a trapezoid.

2.3.2 Check Dam Types

According to Royal Thinking about constructing Check Dam, it could be divided into 3 types at this following;

2.3.2.1 Local Weir (Combination Pattern)

Local weir or is called “Fai Maew” as shown in figure 2-8, is built from natural materials such as wood, branches. It is a simply way to construct. Mostly find this weir at the upper stream or watercourse. It can trap sediment, retard the water flow and add moisture to the area around the dam as well.

Figure 2-8 Local Weir (Combination Pattern)
Source: Watershed Conservation and Management Office, Department of National Park, Wildlife and Plant Conservation

2.3.2.2 Check Dam with constructed by stone (Semi-permanent)

Check Dam with constructed by stone (Semi-permanent) was shown in figure 2-9. The water wall is constructed by stone and can be found in middle stream and downstream. It can trap sediment, store some of water during dry season

Figure 2-9 Check Dam with constructed by stone (Semi-permanent)
Source: Watershed Conservation and Management Office, Department of National Park, Wildlife and Plant Conservation

2.3.2.3 Check Dam with constructed by reinforced concrete (permanent)

Check Dam with constructed by reinforced concrete (permanent) was shown in figure 2-10. The permanent construction is often carried out in the area at the end of the creek or ditch it creek or watercourse. It can trap sediment and water storage in the dry season as well. But the cost is rather higher than the other.

Figure 2-10 Check Dam with constructed by reinforced concrete (permanent)
Source: Watershed Conservation and Management Office, Department of National Park, Wildlife and Plant Conservation

2.3.3 Useful of Check Dam

Natural rehabilitation by building Check Dam could bring abundance Back to area again. According to study of Maliwan Maneeso (2007) examined impact of Check dam to soil moisture. A case study of Tha Shea's watershed, Ta Mod sub-district, Ta Mod District, Phatthalung Province. Soil moisture from Check dam in Huay Na was compared with soil moisture from Huay Sun which did not construct Check Dam by using Gravimetric Method. Result revealed that soil moisture in Hyua Na where check dam was constructed had moisture more than Hyua. Moreover, result presented that soil moisture was obviously limited by the rain regularly.

Pisut Saengmanee (2007) studied about effect of Check Dam to runoff, result to soil moisture in riverbank changing at Karnjanaburi Province, by using Electric Resistance Block for investigating moisture content in the soil at depth of 5, 30, 60 and 80 cm in the rainy season. The Result revealed that Check Dam did not affect the retention of soil moisture. In dry season, soil at depth 5 cm, the moisture content remaining approximately 5% , compared with weir. The soil moisture at depth of 30 cm with was higher than 60 and 80 cm soil depth. Comparing Check Dam for retarding runoff revealed that dry season could reserve water more than creek that did not build Check Dam.

2.4 Huay Sai Royal Development Study Center

2.4.1 Background

The Huay Sai Royal Development Study Centre is located in the area of Mrigadayavan Palace, Sam Phraya Sub-district, Chaum District, Phetchburi Province, where was belong King Rama IV. He declared this area was animal sanctuary area about 22,627 Rai on 7 May 1924. In the past, this area was abundant natural resources. There were many wildlife, especially " Hog deer" and as well as water resources. Later on, people had started intruding this area and turned to pineapples area. During planting, farmers had used chemical fertilizing hardly. Resulting to rain did not fall in seasonal, decreasing rainfall and soil erosion. It was also consequence on ecosystem deteriorated sharply. Within less than 40 years of forest had been destroyed completely, making rain did not fall in seasonal, the amount of rainfall decreased which were resulted highly soil erosion and degradation. When the His Majesty came to visit people in this area on April 5, 1983, he saw many problems that occurred in this area. He said that "If the area was abandoned, it would become a desert. It should develop area to become multipurpose and focused on agricultural area and conservation forest at the same time. It should also develop water resources and agricultural for protecting and preventing forest intruding by local people". Finally, he decided to establish this center after that and named Huay Sai Royal Development Study Center.

2.4.2 Topography

The topography of Huay Sai Royal Development Study Centre consists of at this following;

- The upper of center, especially at the western is closed to river source.
- The middle of center at the eastern is plain area
- At the lower part is closed to mangrove forest.

Moreover, in center area consists of many reservoirs such as Huay Tapaet Reservoir, Khao Kapuk Reservoir, Huay Sai Reservoir and is surrounded by Khao Sawoei Kapi, Khao Rang Raeng, Khao Kapuk, Khao Noi, Khao Thong, Khao Dong Dam, Khao Bo Khing and Khao Tao Pun. The study area located at the western part of this study where near Khao Noi , Khao Bo Khing and Khao Dong Dam. The elevation of the study area was approximately 290 meters from sea level. Geology in this area, mostly locates on igneous rock and sedimentary rock. In addition, this area is located in soil series which consists of Hup Krapong Series: Hg, Nong Kae Series: Nk and slope complex.

2.4.3 Climate

Huay Sai Royal Development Study Centre stands in Rain Shadow with less rainfall. According to amount of rainfall report during 1992-2009 found that average of rainfall was 75.86 mm per year.

2.4.4 Re-habitation

The succession of operating Huay Sai Royal Development Study Centre such as recovery of soil using vetiver grass as natural wall, and moisture distribution. This area used to drought and located in Rain shadow , therefore King decided to distribute moisture by using method at this following;

2.4.4.1 Construction Check Dam by using natural materials are available in the area such as falling tree or branches. Check Dam is constructed in watercourse, valley or at slope complex. The useful of Check Dam comprises of protect soil erosion, slow down water flow, trap sediment and reserve moisture in soil. Moreover, it can increase and retain underground water. The figure of construction Check Dam is shown in figure 2-11

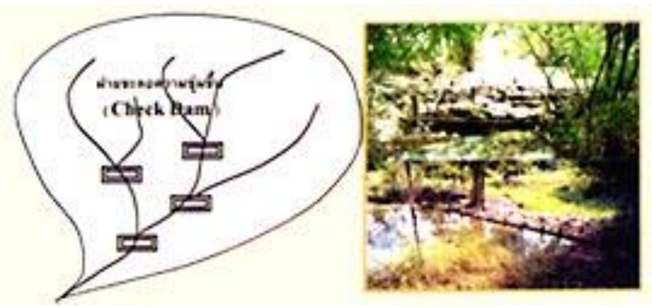


Figure 2-11 The impressionist of Construction Check Dam

Source: Huay Sai Royal Development Study Centre, 2007

2.4.4.2 Terracing and Diversion

Terracing refers to create a transversely earthen dike in slope area. Some area is dug for reserving water which maintains and distributes moisture to soil. Some of water can seep to underground and keep groundwater level. After that plant vegetation around earthen dike, it will re-habituate forest in that area.

Diversion refers to earthen dike is elevated by digging. It is constructed for seaming 2 earthen dikes together. When rainfall is heavily, water will flow along the earthen dike. If the amount of water is exceed more than the capacity of water reservoirs, it will have pipe line which can distribute water to Terracing and Diversion (Figure 2-12). It can control water distribution in the area thoroughly. Terracing and Diversion can be also used for road and fire line.

Figure 2-12 The impressionist of Construction Terracing and Diversion

Source: Huay Sai Royal Development Study Centre, 2007

2.5 Geo-Information System

2.5.1 Definition

According to Geo-Informatics and Space Technology Development Agency (Public Organization) defines that integration of knowledge and technologies in remote sensing, which obtains information about the object, space and phenomena from sensing and without access to object. Remote sensing detects object by using Electromagnetic wave. Geo-Information System (GIS) is spatial data, consists of Graphic Data and Attribute Data. Data structure is Vector Data, Grid or Raster Data and Global Positioning System (GPS) which is used to find position on the Earth's surface from satellites. The definition of Geo-Information Technology which comprises of 3 pars, is called 3S Technology (Supetch Jirakajornkul. 2012).

2.5.2 Application of Geo-Information Technology and Soil Moisture

Application of Geo-Information Technology is used for managing natural resources and environmental monitoring which causes from both of natural and man-made. Studying soil moisture can be investigated by using Geo-Information Technology.

2.5.2.1 Application of Remote Sensing in Soil moisture distribution

Sainam Audpuay (2008) studied soil moisture distribution during dry season in Kularonghai by using Remote Sensing. The aims of this study were study the potential of remote sensing techniques to assess soil moisture distribution during the dry season and to obtain information of the soil moisture during the dry season in Kularonghai. Soil samples were analyzed water content by Gravimetric and converted value into volume by using Bulk Density. In sampling area, soil moisture by volume was analyzed relation with Rader Backscatter, (dB) in same position, by using Single Liner Regression Analysis. Results presented that all of relation was low (R2<0.18) and soil moisture assessment was divided into 0-10, 10-30, and 0-30 depth and Radersat-1 SAR information had 3 sets , which were crops after the middle age, crops after the end season and crops was between late summer and early winter. Data was analyzed by Maximum Likelihood from Supervised Classification which consisted 3 classes, were 0-5%, >5-15% and >15% by volume.

Suphaporn Kukhamsai (2005) created soil moisture mapping in Lam Dome Watershed in UbonRatchathani Province by applying remote sensing and Geo-Information Technology. The main objective was to assess the quantity and soil moisture mapping for planning and land use in targeted area. This study gathered factors that could influence soil moisture, included land use, soil, elevation, slope and satellite Landsat. Normalized Difference Vegetation Index (NDVI) was calculated and then overlay on soil moisture factors which could define sampling area. Soil sampling area was determined as the same period that satellite recorded which was December 2003 and February 2004. The average of soil moisture was 10.48 and 6.92 percent by volume. After that, soil moisture was calculated for finding relation with reflectivity of the object by using Multiple Regression. Result revealed that the suitable equation as this following;

December $Y = 56.816 – 0.00267(DN_{B1})^2 – 1.079(DN_{B4}) + 0.008334(DN_{B4})^2$ and

February $Y = 35.45 – 0.286(DN_{B1}) – 0.0744(DN_{B5}) + 0.0008309(DN_{B4})^2$

Where R2 was 0.698 and 0.685 at the level of significance was 0.01. Assessments of soil moisture from equations were 8.91 and 5.10 percent by volume, respectively.

Sophota Khanom (1999) studied the influence of groundwater against moisture by applying GIS and geophysical exploration in Khaohinsorn Royal development study. The objectives of this study consisted of studying influence of groundwater and soil moisture factors by preparing spatial database for planning soil sampling area. Soil samples were analyzed for finding relationship between soil moisture, sediment thickness and other factors which were calculated by mean and multiple regression analysis. For created soil moisture distribution mapping, it had done by application of GIS combined with geophysical exploration, which measured electrical resistance. Creating mapping, ILWIS program was used in this study. Factors were investigated, included altitude, geology, hydrogeology soil series, land use and depth. Result presented that correlation between 6 factors and soil moisture significantly correlated at level of confidence 95 percent. The 6 variables were ground cover by rice, soil depth, soil texture with mostly contain clay particle, all those factors were directly variation with soil moisture. In contrast, soil texture with mostly contain sand particle, ground cover by Eucalyptus and altitude were reverse variation with water content. It could be written as this following equation;

$$Y = 11.493 - 0.068\,(\%sand) + 5.305(rice) + 0.029(depth) + 0.127(\%clay) - 1.266\,(eucalyptus) - 0.037\,(high\ of\ mean\ sea\ level)$$

It could explain the variation of soil moisture is 75.3 percent, and the error of the forecast 2.03. The thickness of sediment had no significantly relationship with soil moisture at level of confidence 95%. According to cross section presented that geology and hydrogeology and altitude found that thickness of sediments were reverse variation soil moisture.

2.5.2.2 Application of Remote Sensing with Normalized Difference Vegetation Index (NDVI)

Plant reflection in the near-infrared (0.7-1.3 micron) plants have high reflectivity at wavelength of approximately 0.75 to 1.3 microns. Energy is reflected by approximately 45-50 percent of the incident energy and will be delivered over approximately 45-50 percent of the energy is absorbed only have 5 percent or lower. Plant reflection is influenced by plant structure and the amount of left or density of the leaves. If plants have many leaves which arrange in single layer, reflect light is less than areas with dense by foliage. Moreover, reflected light in near-infrared of plants with foliar symptoms can vary from completely plants. In Shortwave Infrared (1.30-3.00 microns), most of energy is absorbed or reflected by the leaves. Wavelengths are less reflected light, include 1.4, 1.9 and 2.7 microns. All those wavelengths are absorbed by water in leaves, which is called Water Absorption Bands. This band, leaves become an important role and result to reflect light is low.

For the most wavelengths that plants can reflect, consist of 1.6 and 2.2 microns. An important element of reflection and absorption in the wave is moisture in plants. If moisture content in leaves decrease, the reflected light will increase. Moisture in leaves can mainly cause different reflective when moisture content reduces to only 5.4 percent or lower. At low humidity, dry leaves are highly reflected light and chlorophyll production is low. Chlorophyll can influence absorption and reflection light in visible range. Difference vegetation was exposed to different reflections of the satellite images were used to assess dryness in study area. By adjusting the information called Index. Study of the wavelength index which correlates with physical condition of vegetation, water content in plants and soil can indicate drought conditions of the area. Report of analyzing drought in the Northeast concluded indices as shown in Table 2-2. (Chanchai Thanawut et al, 2008)

Table 2-2 Indices correlated with physical of vegetation and drought

Drought Indices	Source and Reference
1. Normalized Difference Vegetation Index (NDVI)	Lawrence&Ripple, 1998. Chen et al.,2005 Volcani et al.,2005. Gu et al., 2007. Shakya&Yamaguchi, 2007. Bayarjargal et al., 2006. Cheng et al., 2008
2. Normalized Difference Water Index (NDWI)	Gao, 1996. Chen et al., 2005. Gu et al., 2007. Cheng et al., 2008
3. Enhanced Vegetation Index (EVI)	Huete et al., 2002. Cheng et al., 2008
4. The difference of index (dINDEX) & The difference of NDVI	Volcani et al., 2005
5. Simple Ratio (SR) & Modified SR	Lawrence&Ripple, 1998. Sims&Gamon, 2002
6. The Normalized Difference Index (NDindex) & The Modified of Normalized Difference Index (mNDindex)	Sims&Gamon, 2002
7. Normalized Difference Drought Index (NDDI)	Gu et al., 2007
8. Vegetation Condition Index (VCI)	Kogan, 2000. Bayarjargal et al., 2006
9.Temperature Condition Index (TCI)	Kogan, 2000. Bayarjargal et al., 2006
10. Vegetation and Temperature Index (VT)	Kogan, 2000. Bayarjargal et al., 2006
11. Vegetation Heslth Index (VT)	Bayarjargal et al., 2006
12. Land Surface Temperature (LST)	Bayarjargal et al., 2006. Shakya&Yamaguchi, 2007
13. Vegetation Temperature Condition Index (VTCI) & Vegetation Water Temperature Condition Index (VWTCI)	Shakya&Yamaguchi, 2007
14. Soil-Adjusted Vegetation Index (SAVI)	Huete et al., 1997. Lawrence&Ripple, 1998

Table 2-2 Indices correlated with physical of vegetation and drought (cont.)

Drought Indices	Source and Reference
15. Modified Soil-Adjusted Vegetation Index (MSAVI)	Lawrence&Ripple, 1998
16. Optimized Soil-Adjusted Vegetation Index (OSAVI	Lawrence&Ripple, 1998
17.Transformed Soil-Adjusted Vegetation Index (TSAVI)	Lawrence&Ripple, 1998
18. Perpendicular Drought Index (PDI)	Ghulam et al., 2007
19. Modified Perpendicular Drought Index (MPDI)	Ghulam et al., 2007

Source: Chanchai Thanawut et al, 2008

Kaesad Mongkhonsawad (2009) studied satellite data of vegetation index and humidity over time to monitor drought conditions phenology of tropical monsoon forest. Data from the Terra satellite system's with highly time resolution was appropriate for using in study of spatial patterns and timing and phenology of forests. The objective of this study was measurement and evaluation phenology of tropical monsoon forest changing which result from drought in Phukhiao Wildlife Sanctuary where is located in northeast of Thailand. In this place consists of many types of vegetation. Different types of vegetation were analyzed by Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Enhanced Vegetation Index (EVI). All those indices were used for studying phenology, or seasonal growth cycle of the plant for finding relationship between rainfall and index changing in project area. Assessment by determination of threshold or the beginning of a change from the average, hierarchy of standard deviations from the mean of the difference image index determined the magnitude of the change. Result indicated that phenology changing of vegetation could present drought and spatial data which presented in the dNDVI dNDWI and dEVI photos in difference days on project area. Dry Dipterocarp Forest and Mixed Deciduous Forest were sensitive to drought and caused defoliate leaves. Difference resulting from NDVI and EVI (dNDVI and dEVI) indicated difference between area and vegetation cover.

Highly DNDVI and dEVI value referred to level of changing was higher. The dNDWI presented relation between vegetation cover and water content in plant. Spatial data and drought could be achieved from dNDWI, dNDVI and dEVI , instead of using meteorological data, or in case of climate data did not sufficient.

Chenglin et al. (2004) monitored drought by using Normalized Difference Vegetation Index (NDVI) for studying relationship between vegetation and moisture Normalized Difference Water Index (NDWI) in agricultural areas where was located in the northern of China. Result could precisely and accurately monitor drought situation in study area.

Chanchai Thanawut et al. (2002) studied drought situation in Songkhla watershed by applying GIS and remote sensing. Factors were used for study, included annual rainfall, number of rainy days per year, distance from water resources, groundwater, ground cover, soil texture, slope and density of river. After that, all of factors were weighted and scored in each factor which could be determined 3 ranges. Risky drought area presented that the west side of this watershed was highly risk area.

Pornsiri Khanayai (2009) said that coagulation is process that occurs naturally, as a result of the renewal process of the reservoir sediment reservoir capacity surveys and found that it took longer duration for survey. Currently, remote sensing has been used in water management research, which is intended to assess the amount of sediment in reservoirs. Study area located in Lamprapleng and Lamtakong reservoir Nakhon Ratchasima Province. 6 images were archived from Landsat for calculating water surface area at Lamprapleng reservoir and 5 images were archived from satellite IRS-1D, LISS III for finding water surface area at Lamtakong reservoir. After that, calculating water surface by comparison water pixel which includes Density Slicing, NDWI and MNDWI. Surface area was calculated by multiplying water pixels resolution with satellite imageries and analyzed water surface with reservoir elevation. Result found that the relationship was Exponential curve which could be used to calculate water surface area at the height of 1 meter in each reservoir surface area at various altitudes which was used to calculate the capacity of the reservoir.

Jaranya Kittiphaisannon (2005) classified palm oil generation by generating from regression equation which calculated by the relationship of palm oil age and Water Index (WI) , Bare Soil Index (BI), Normalized Difference Vegetation Index (NDVI) and Advance Vegetation Index(AVI). The entries of indices were used to predict the age range which divided into 4 ranges in possibly area.

2.5.2.3 Application of Remote Sensing in Soil Moisture Distribution

It is one of method for studying spatial interpolation which refers to process is used for estimating value in unknown area. Mostly, data is used for estimating spatial interpolation, is meteorological data which includes rainfall, temperature. Topography includes altitude, snow accumulation, water table and population density. For applying spatial interpolation must set Control Points, which is already known values for estimating other areas and it is divided into 2 types as this following;

1) Global Method: It is estimated by using the value of the control points to create an equation or model for the calculation or estimation in unknown area. The Global method consists of two methodologies which are Trend Surface Analysis and Regression Method.

2) Local Method: It uses value from control point to calculate values in unknown area. Mostly, 5 techniques of local method commonly use, include Thiessen Polygon, Density Estimation, Inverse Distance Weight, Thin-plate Splines (Regularized Spline) or Regularized Spline with Tension), Kriging

Thiessen Polygon is estimated value by constructing polygons surround set of sample which is known values and computed delta from the known value and then draw a line perpendicular to the center of each side of triangle. Sometimes is called Voronoi Polygon. The characteristic of Thiessen Polygon consists of

1) It can reduce problem from Non-recording Rain Gauge.

2) When used in large areas, if rainfall measurement errors. Calculated the amounts of rainfall will discrepancy.

3) The line in polygons disregards topography such as mountain or undulating area. The average of rainfall can error. If rain gauge stations change, it needs to create a new polygon every time which does not flexibility for using.

CHEPTER III
METHODOLOGY

3.1 Data and Equipments

According to study, soil moisture distribution from check dam by using Geo Information Technology at Huay Sai Royal Development Study Center in Phetchburi Province. Data and equipments were used in this study, included as this following;

3.1.1 Data and Map

Table 3-1 Information for the study

Data	Detail	Source	data sample
1. Topography Map	1:50,000 scale of Royal Thai Survey Department, series L7018, sheet name 4934 II.	Royal Thai Survey Department	• Topo_49342 .img
2. Scoping of Huay Sai Royal development study in Phetchburi Province	Spatial Data in polygon pattern	Huay Sai Royal Development Study Center in Phetchburi Province	• Huaisai.shp • BND.sho
3. Altitude	The different heights of 5 meters in a digital file.	Geo-Informatics In Resource and Environment Research and Training Center, Mahidol University	• DEMn12.tif

Table 3-1 Information for the study (cont.)

Data	Detail	Source	data sample
4. Water Resources	Spatial Data in polygon pattern	Huay Sai Royal Development Study Center in Phetchburi Province	• Water_body .shp Stream.shp
5. Rainfall	Spatial Data, the amount of rainfall had gathered from 2000-2010	The Thai Meteorological Department	• Rainfall 2001-2010.xlsx
6. Check Dam Location	Spatial Data in point pattern	Field Survey	• Survey Point.shp • Survey Point2.shp

3.1.2 Geographic Information

Geographic Information from Satellite LANDSAT (5 TM system) from Geo-Informatics and Space Technology Development Agency (Public Organization): GISTDA covered the study area at Path 129, Row 051 and recorded during March to August 2011

3.1.3 Equipments

3.1.3.1 Computers software and data processing system, such as geographic application (Geographic Information System: GIS) and applications of remote sensing (Remote Sensing: RS).

3.1.3.2 Soil sampling instrument (such as shovel, pickax, soil containing tape pen oven and weighing machine) and soil moisture Devices.

3.1.3.3 Global Positioning System: GPS

3.2 Methodology

The study the distribution of soil moisture from Check Dam and physical characteristics that affect to soil moisture at at Huay Sai Royal Development Study Center conducted in this following;

3.2.1 Collecting data as database system was done by inputting Spatial Data and Non-Spatial Data, including topography data, soil profile, land used, scoping study area and rainfall data.

3.2.2 Preparing soil moisture mapping from 3.2.1 was conducted by collecting data and applying with geographic information program to create a map of soil moisture sampling.

3.2.3 Gathering Landsat data covered the study area recorded time with the same study time for deciding field survey date.

3.2.4 Soil moisture sampling followed the soil moisture mapping which created from 3.2.2 and 3.2.3.

3.2.5 Analysis of soil moisture and analyze the physical characteristics influenced the distribution of soil moisture in at Huay Sai Royal Development Study Center.

3.2.6 Creating soil moisture distribution mapping from Check Dam in at Huay Sai Royal Development Study Center was done.

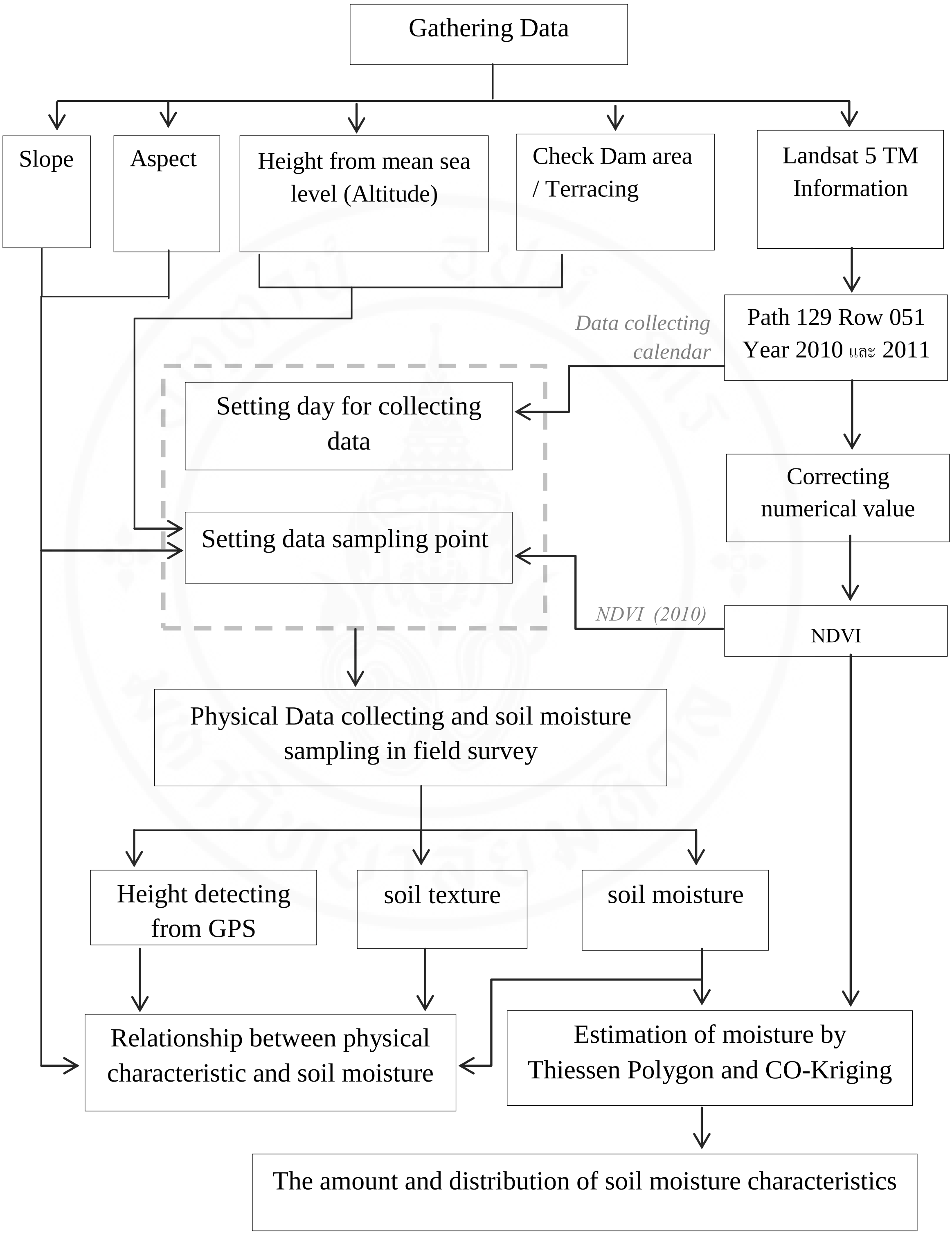


Figure 3-1 Study method diagram

3.3 Study Procedure

The study of the soil moisture distribution from Check Dam and physical characteristics influenced to soil moisture at Huay Sai Royal Development Study conducted in this following;

3.3.1 Preparing Database

The entire of data were collected from several sectors and field survey data. The coordinates had differences from each other. Therefore, before using data, it needed to adjust data to same format. By specific types of data, two types of spatial data (Spatial Data) and attribute data (Non-Spatial Data) coordinate system, the coordinate reference was UTM grid system (Universal Transverse Mercator Co-ordinate System) Zone 47 N.

3.3.2 Soil Moisture Sampling

3.3.2.1 Determination of Soil Moisture sampling considered by this following;

1) Triangulated Irregular Network

Height from sea level was difference in each 5 meters by applying geographic information program. Height was analyzed by Triangulated Irregular Network (TIN). This methodology would provide realistic topography study area which could make more understanding about structure study area.

2) Slope Data

TIN would be analyzed for creating slope data by applying geographic information program. Slope was the one of factors that influences moisture distribution. According to Office of Soil Survey and Planing, Land Development Department Annual Report 2005 revealed that slope can influence movement and retention of water, movement of soil materials, accelerated rate and volume of runoff and soil flow potential and water condition in soil. Land Development Department classified of slope as shown in Table 3-2 and figure 3-2

Table 3-2 Slope Levels

Slope Level	Detail
0-2 %	Smooth and rather flatten
2-12%	Slightly slope
12-20%	Highly slope
20-35%	Moderately steep
35-50%	Steep
50-75%	Highly steep
More than 75	Extremely steep

Source: Land Development Department, 2005

3) Aspect

Aspect is another factor that influences soil moisture. Analyzing of aspect applied by using TIN data from height analyzing, as a result could divided direction into 45 degree and 8 direction, included north northeast east southeast south southwest west and northwest. All of directions were presented in figure 3-3

4) Check Dam and Terracing

Determination of Check Dam area and terracing by translating Landsat 5 satellite images combined with field data from staff at the center. Terracing is earthen dyke and watercourse across area aspect and is divided into many phases for retaining water and protecting flashflood. Terracing in study area was built at slope between 2-12%. Check Dam was built for retarding water flow and retain water as much as it ability. Check Dam could be found in hills or mountain, especially, in study area found in slope area less than 35%. The study area could be divided into two parts as shown in figure 3-4

5) Classification of Plant Density

Areas with vegetation and no vegetation areas were another of study scoping for determining the position of soil moisture storage, by using Landsat-

5 satellite images recording in last year as well as collecting data month. Calculating of Normalized Difference Vegetation Index (NDVI) followed this equation;

$$NDVI = \frac{NIR-RED}{NIR+RED}$$

Whereas; NDVI = Normalized Difference Vegetation Index

NIR = The spectral reflectance measurements acquired near- infrared regions

RED = The spectral reflectance in the visible (Red)

The value of NVDI is between - 1to +1. If NVDI presents negative value, refers to water area. If NVDI is nearly to zero represents an area with covered few of vegetation and it will become greener which means that area is covered densely of plant. The value of NVDI will result more than +1, as shown in figure 3-5

After finishing 5 steps and applying geographic information program were used overlay technique, finally position of soil moisture sampling consisted of 57 sampling as shown in figure 3-6

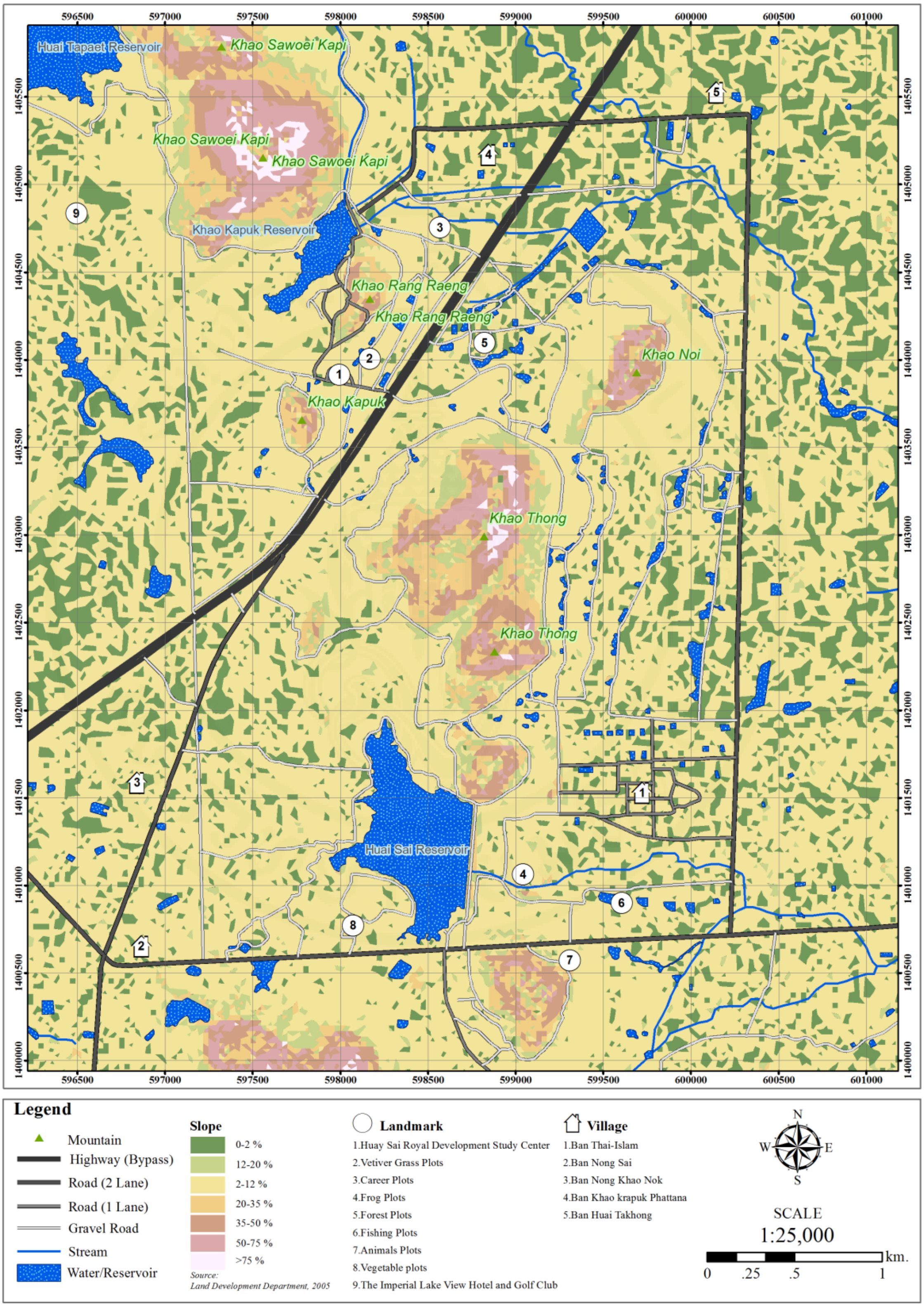


Figure 3-2 Map showing slope

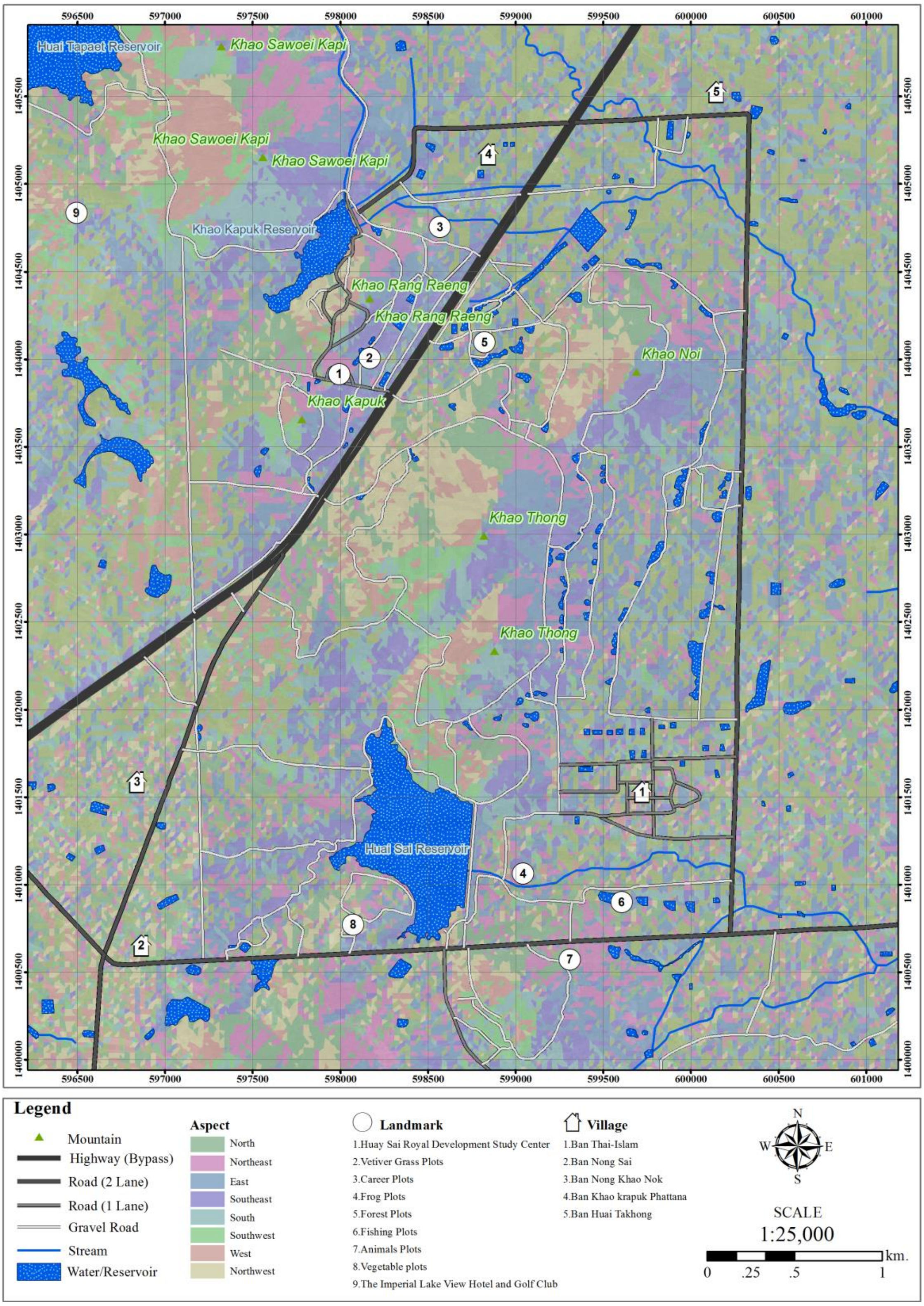


Figure 3-3 Map showing aspects

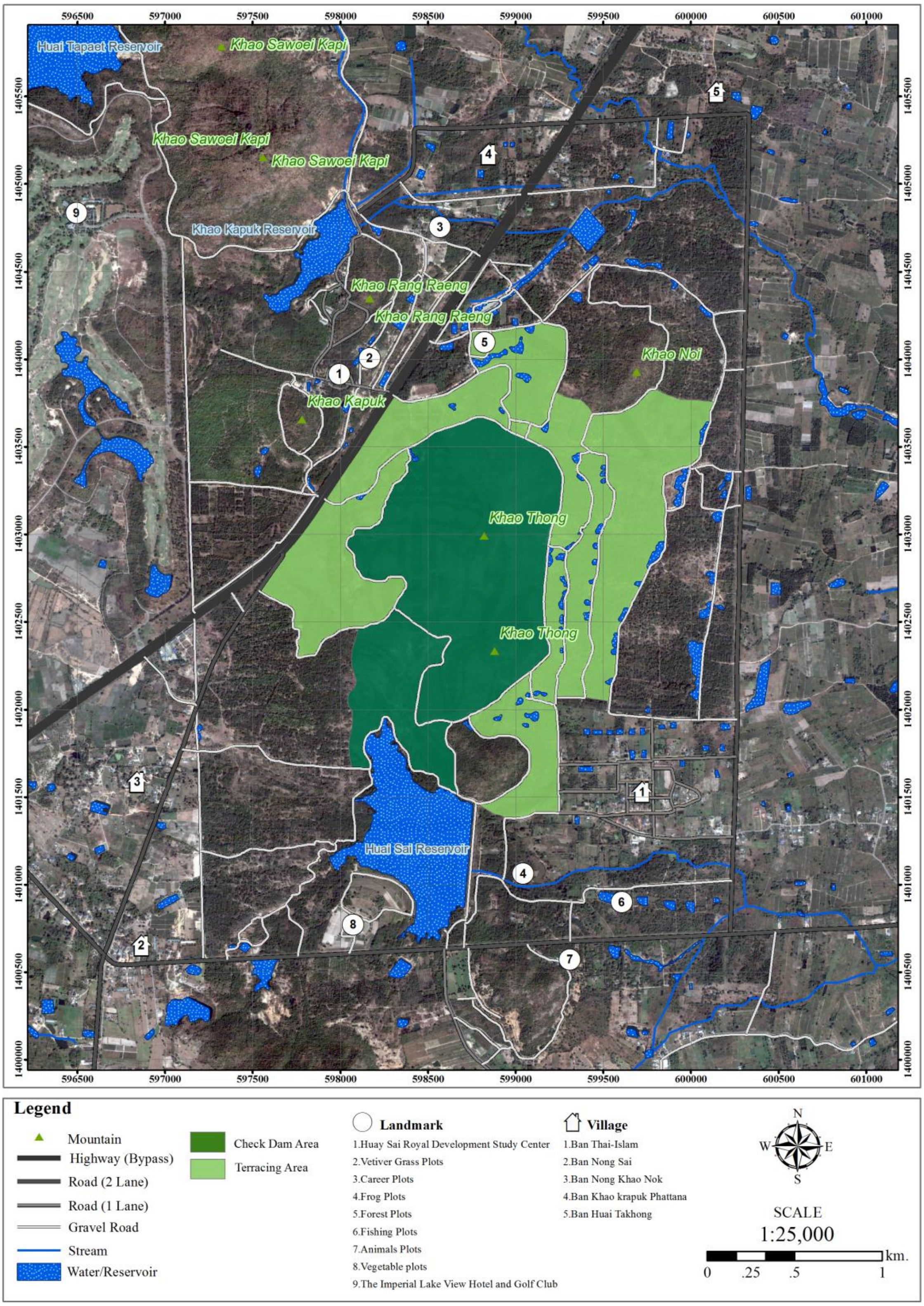


Figure 3-4 Map showing construction of check dam and terracing

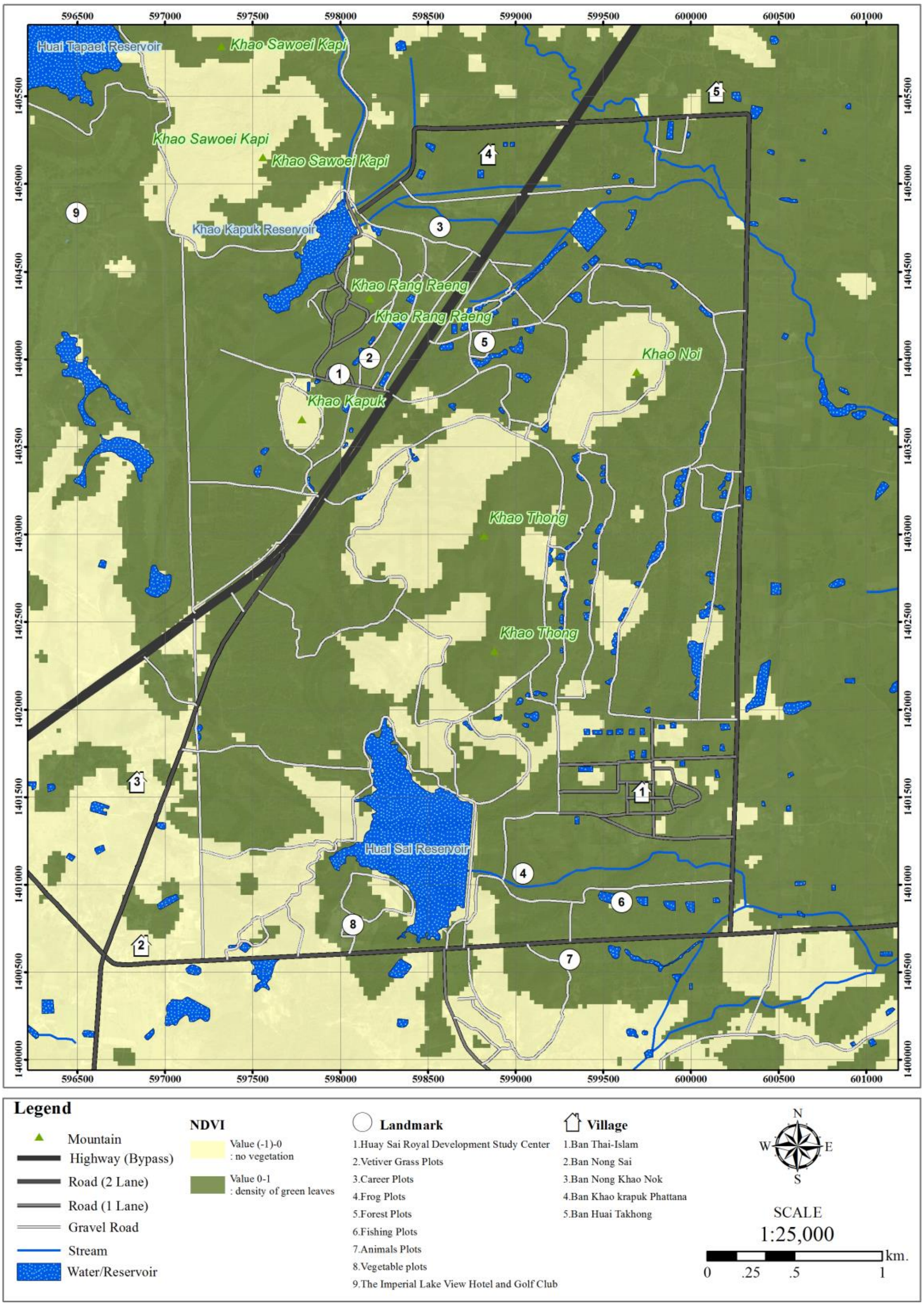


Figure 3-5 Map showing vegetation diversity classification NDVI

Figure 3-6 Map showing 57 soil moisture sample locations

3.3.2.2 Determination of Soil Depth and Soil Sampling

The 57 soil samplings position located on with Check Dam area and without Check Dam area. Taking soil sampling in Check Dam area would collect in 3 directions, including row 1 above the check dam, row 2 on the check dam and row 3 under the check dam. Each direction would collect left and right of water course and far from it about 1 m. Hence, soil collecting in check dam would have 6 soil samples and tasted for moisture in 2 differences of depth, were between 5-15 cm. and 15-30 cm. As shown in figure 3-7

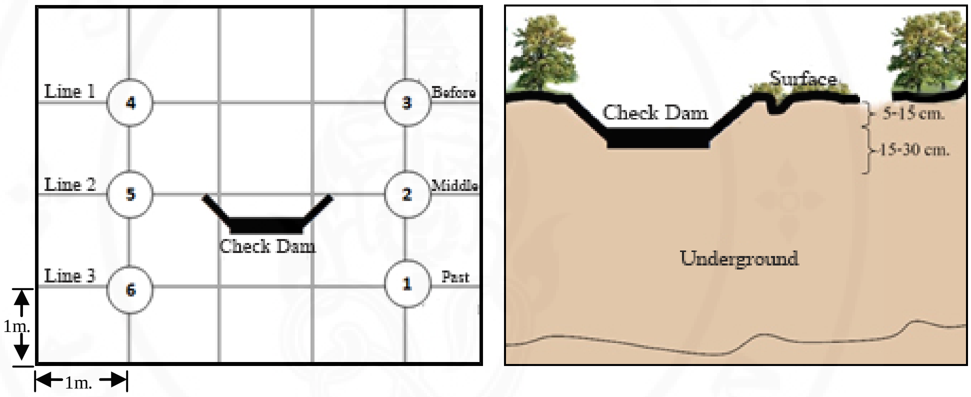


Figure 3-7 Soil moisture collecting method in Check Dam area

3.3.3 Field Survey

3.3.3.1 Soil Moisture Sampling

The 376 samples were collected from 2 depths and took them during April 2011 to July 2011, represented dry season to rainy season. All of soil samples were analyzed moisture in soil by using Gravimetric Method. Soil samples were weighted before dried them by oven at 105 Celsius degree for 24 hour. After that, calculating soil moisture was done by using equation;

$$\textit{Percent of soil moisture} = \frac{\textit{soil weighted} - \textit{dried soil}}{\textit{dried soil}} \times 100$$

3.3.3.2 Soil Texture Survey

Classification soil texture by using Visual Soil Classification was followed by Classification Soil Texture in Field Survey Guidebook, written by Assoc. Prof. Charlie Navanugrah, Ph.D. (As shown figure 3-8)

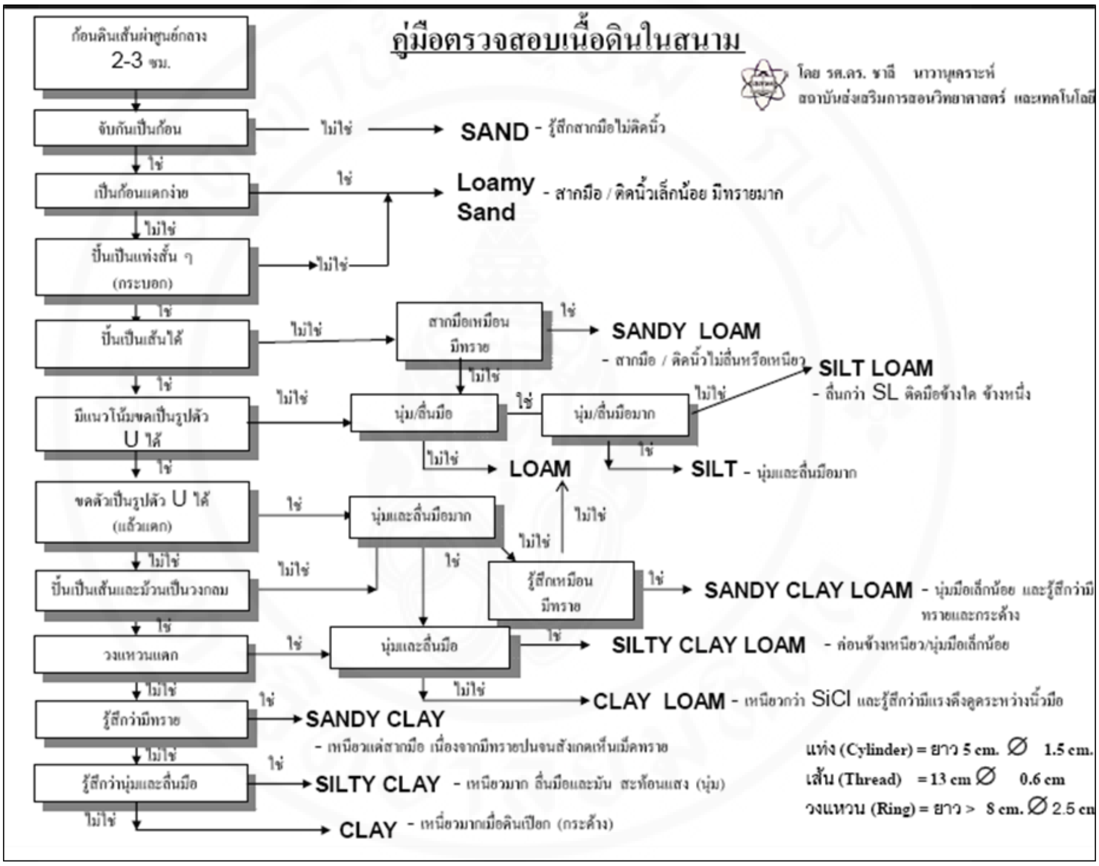


Figure 3-8 Classification Soil Texture in Field Survey Guidebook.

Source: Assoc. Prof. Charlie Navanugrah, Ph.D. "Classification Soil Texture in Field Survey Guidebook", Department of Environmental Quality Promotion and associated with Faculty of Environment and Resource Studies, Mahidol University

3.3.4 Data Analysis

3.3.4.1 Analysis of soil moisture and Physical Characteristics

Calculating by using statistical methodology, aimed to find correlation between soil moisture and physical factors (such as altitude, slope, aspects and soil texture).

3.3.4.2 Estimation of Spatial Analysis

Soil moisture data from filed survey was changed into Spatial Data and then analyzed moisture by THIESSEN POLYGON and Co-Kriging, which applying ArcGIS Program.

3.3.4.3 Classification of Plant Density

According to satellite images from Landsat 5, TM system of GISTDA were the original images and without correction of wave and geometric. All of them were brought to adjust ground error by using ground control point and referencing by topography map with 1:50,000 scale of Royal Thai Survey Department, series L7018, sheet name 4934 II. Adjusted satellite images were calculated for finding difference of vegetation by using NDVI equation;

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Whereas; NDVI = Normalized Difference Vegetation Index

NIR = The spectral reflectance measurements acquired near- infrared regions

RED = The spectral reflectance in the visible (Red)

3.3.4.4 Soil Moisture Map

Analysis of soil moisture from humidity in field survey and humidity from Thiessen Polygon and Co-Kriging were done. After that, creating amount and diffusion of moisture in the soil feature were done, and then were analyzed for finding relationship with physical factors (including; slope, aspects, altitude and soil moisture). Moreover, satellite images which had already analyzed difference vegetation, resulted soil moisture map at Huay Sai Royal Development Study Center.

CHAPTER IV
RESULTS AND DISCUSSION

The study of soil moisture distribution from check dam by using Geo-Information technology aims to examine physical characteristics, including altitude, slope, aspects, and soil texture, which have the impact on the distribution of soil moisture. It also examines the amount and pattern of the distribution of moisture from check dam in Huay Sai Royal Development Study Center, Sam Phraya Sub-district, Cha-Am District, Phetchaburi Province. The results of the study are as follows.

4.1 Soil moisture and physical characteristics

4.2 Physical characteristics that affect to the distribution of soil moisture

4.3 The pattern of the distribution of soil moisture

4.1 Soil moisture and physical characteristics

In the analysis of soil moisture, the samples were collected according to the specific location in the position of 3.2.2. Those locations are distributed in 2 types of the area that were namely the area with check dam and the area without check dam. Soil sample collection varies depending on the area. In the area with check dam, the samples from 6 locations were collected. These are separated into 3 rows, including row 1 above the check dam, row 2 on the check dam and row 3 under the check dam as shown in figure 3-7. In item 3.3.2.2, 144 samples were collected. In the area without check dam, 44 samples were collected. The samples were collected at 2 levels of depth, 5-15 and 15-30 centimeters. The sample collection for soil moisture analysis was performed during April to May and June to July. Soil moisture was measured by using gravimetric method. Physical characteristics, which affect the distribution of soil moisture according to study objectives, were analyzed, including altitude, slope, aspects, and soil texture. The results of soil moisture and physical characteristics are shown in Table A. Soil moisture and physical characteristics are presented (Appendix).

4.1.1 Soil moisture

From soil moisture analysis in laboratory, it was found that during April-May, the soil at the depth of 5-15 centimeters had soil moisture at 0.32-11.26 percent by weight. The soil at the depth of 15-30 centimeters had soil moisture at 0.15-10.55 percent by weight. The graph is shown in figure 4-1. During June to July, the soil at the depth of 5-15 centimeters had soil moisture at 2.16-23.82 percent by weight. The soil at the depth of 15-30 centimeters had soil moisture at 1.31-14.09 percent by weight. The graph is shown in figure 4-2. Soil moisture from 2 periods of time shows that soil moisture at the depth of 5-15 centimeters was higher than soil at the depth of 15-30 centimeters. When considered on moisture of the soil at the same depth, it was found that at the depth of 5-15 centimeters during June-July, soil moisture was higher than that during April-May. The graph is shown in figure 4-3. At the depth of 15-30 centimeters, soil moisture during June-July was higher than that during April-May. The graph is shown in figure 4-4. It is apparent that during April-May, soil moisture was higher than that during June-July.

When considered on moisture of soil samples obtained from the area with check dam and the area without check dam, it was found that during April-May at the depth of 5-15 centimeters, the moisture of the area with check dam was between 0.45-7.49 percent by weight. The moisture of the area without check dam was between 0.32-11.26 percent by weight as shown in figure 4-5. At the depth of 15-30 centimeters, the moisture of the area with check dam was between 0.57-5.22 percent by weight. The moisture of the area without check dam was between 0.15-10.55 percent by weight as shown in figure 4-6. During June-July at the depth of 5-15 centimeters, the moisture of the area with check dam was between 3.05-23.82 percent by weight. The moisture of the area without check dam was between 2.16-17.48 percent by weight as shown in figure 4-7. At the depth of 15-30 centimeters, the moisture of the area with check dam was between 1.50-14.09 percent by weight. The moisture of the area without check dam was between 1.31-11.20 percent by weight as shown in figure 4-8. It can be seen that soil moisture during April-May was high in the area without check dam. During June-July, soil moisture was high in the area with check dam.

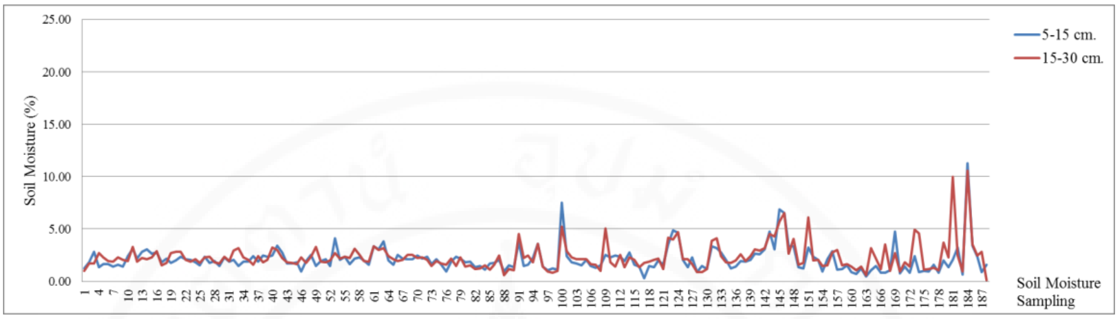


Figure 4-1 Graph showing soil moisture during April - May

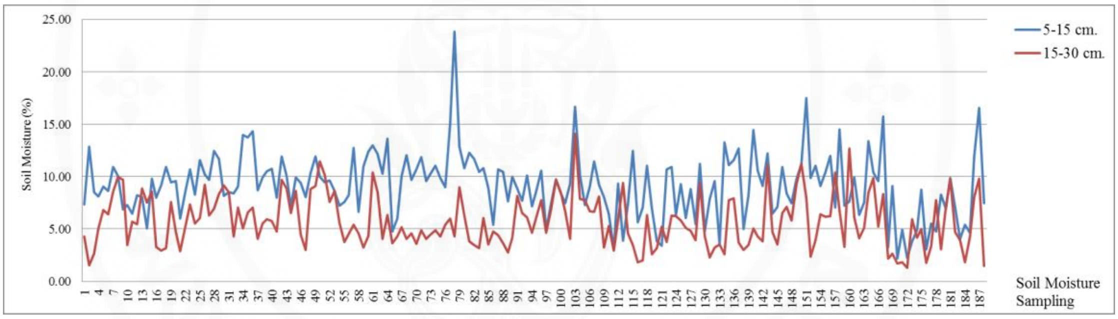


Figure 4-2 Graph showing soil moisture during June – July

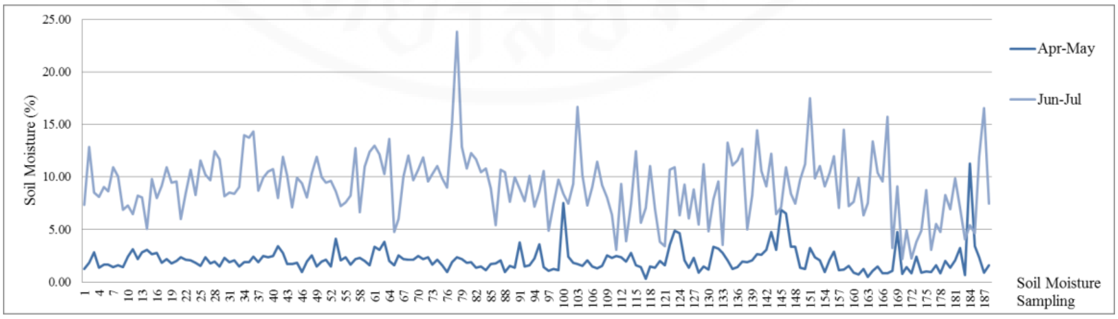


Figure 4-3 Graph showing soil moisture at the depth of 5-15 centimeters

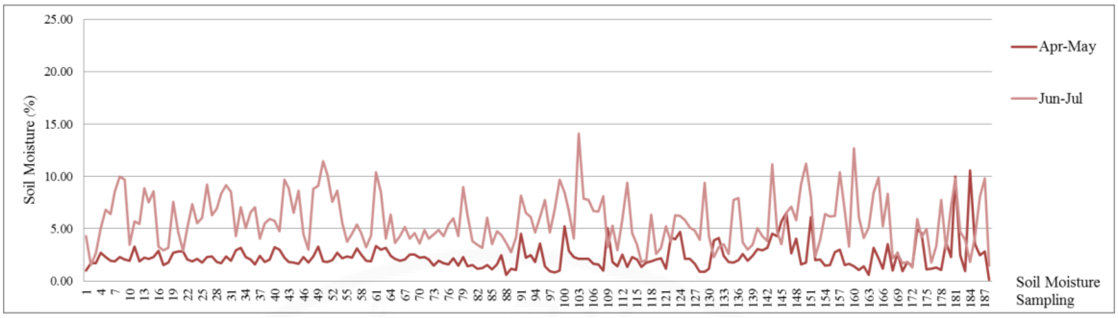


Figure 4-4 Graph showing soil moisture at the depth of 15-30 centimeters

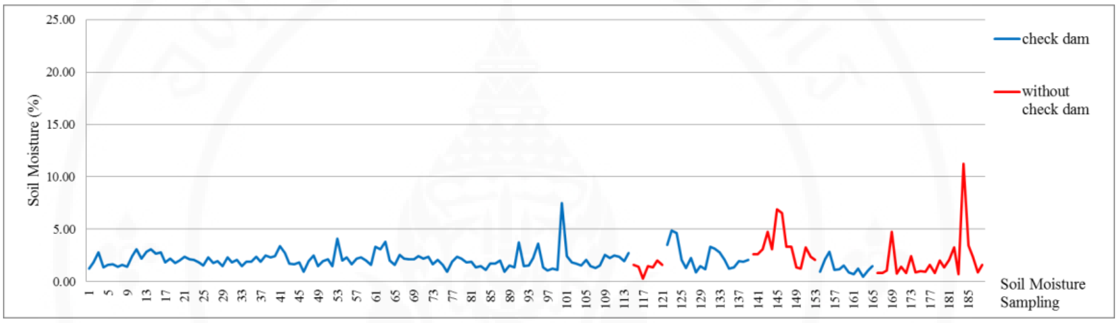


Figure 4-5 Graph showing soil moisture during April - May at the depth of 5-15 centimeters classified by locations with and without check dam

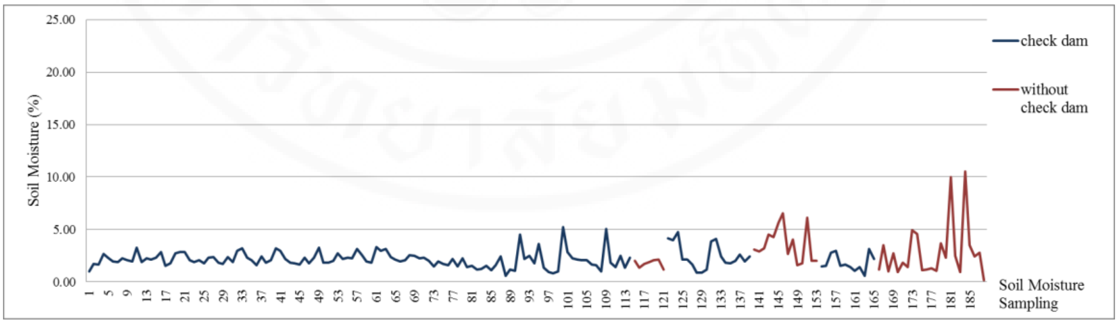


Figure 4-6 Graph showing soil moisture during April - May at the depth of 15-30 centimeters classified by locations with and without check dam

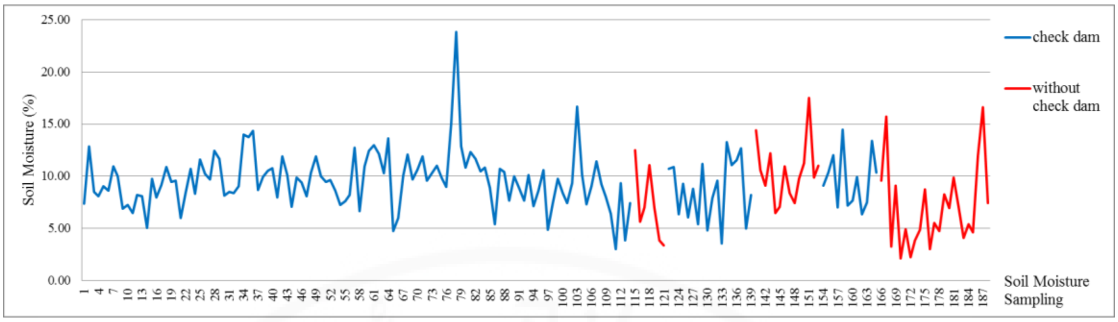


Figure 4-7 Graph showing soil moisture during June - July at the depth of 5-15 centimeters classified by locations with and without check dam

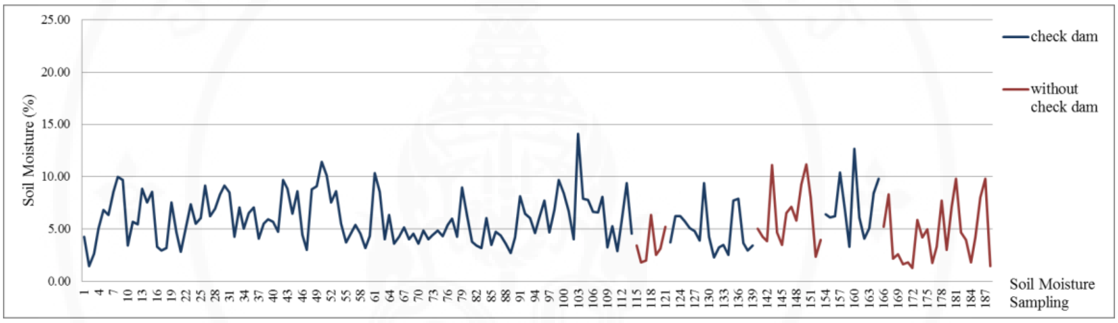


Figure 4-8 Graph showing soil moisture during June - July at the depth of 15-30 centimeters classified by locations with and without check dam

4.1.2 Physical characteristics

In the study on physical characteristics, this study examines physical characteristics of study area, including altitude, slope, aspects and soil texture. The results of such physical characteristics can be summarized as follows.

4.1.2.1 Altitude

Altitude of the locations, where soil samples were collected, was measured using Global Positioning System (GPS). It was found that all 188 soil samples had altitude between 31-85 meters. The location with check dam had altitude minimum level at 44 meters and maximum level at 85 meters. The area without check dam had minimum altitude level at 31 meters and maximum altitude level at 82 meters. The locations of soil samples and altitude are shown in figure 4-9.

4.1.2.2 Slope

Land Development Department classified the slope into 7 levels. In the study on slope, it was found that all 188 sample locations had 4 slope levels as follows: Slope level 0-2% means smooth to rather smooth. Slope level 2-12% means minor slope. Slope level 12-20% means high slope. Slope level 20-35% means moderate slope. When considered on the locations with check dam, most of them had slope level at 2-12% or minor slope. For the locations non check dam, most of them had slope level at 2-12%. The locations with check dam and the area non check dam, where samples were collected, had minor slope. The soil samples and slope are shown in figure 4-10.

4.1.2.3 Aspects

Aspects of sample locations in this study are separated into 8 directions, namely north, northeast, east, southeast, south, southwest, west and northwest. From data collection, it was found that most locations with check dam had aspect toward the east and there was no aspect toward the north. Most locations non check dam had aspect toward the east. Among the aspects of locations, where soil samples were collected, the most aspects direct toward the east and the least aspects direct toward the west. The soil samples and aspects are shown in figure 4-11.

4.1.2.4 Soil texture

This study examined soil texture by using visual soil classification. In this study, soil texture can be classified into 7 types, including sand, sandy loam, loamy sand, sandy clay loam, silty clay, sandy clay and silty clay loam. When considered on locations with check dam, it was found that soil texture at the depth of 5-15 centimeter was mostly loamy sand. At the depth of 15-30 centimeters, soil texture was mostly loamy sand too. For locations non check dam at the depth of 5-15 centimeters, soil texture was mostly sand. At the depth of 15-30 centimeters, soil texture was mostly sand too. It can be seen that soil texture at the depth of 5-15 centimeters and 15-30 centimeters is loamy sand and sand.

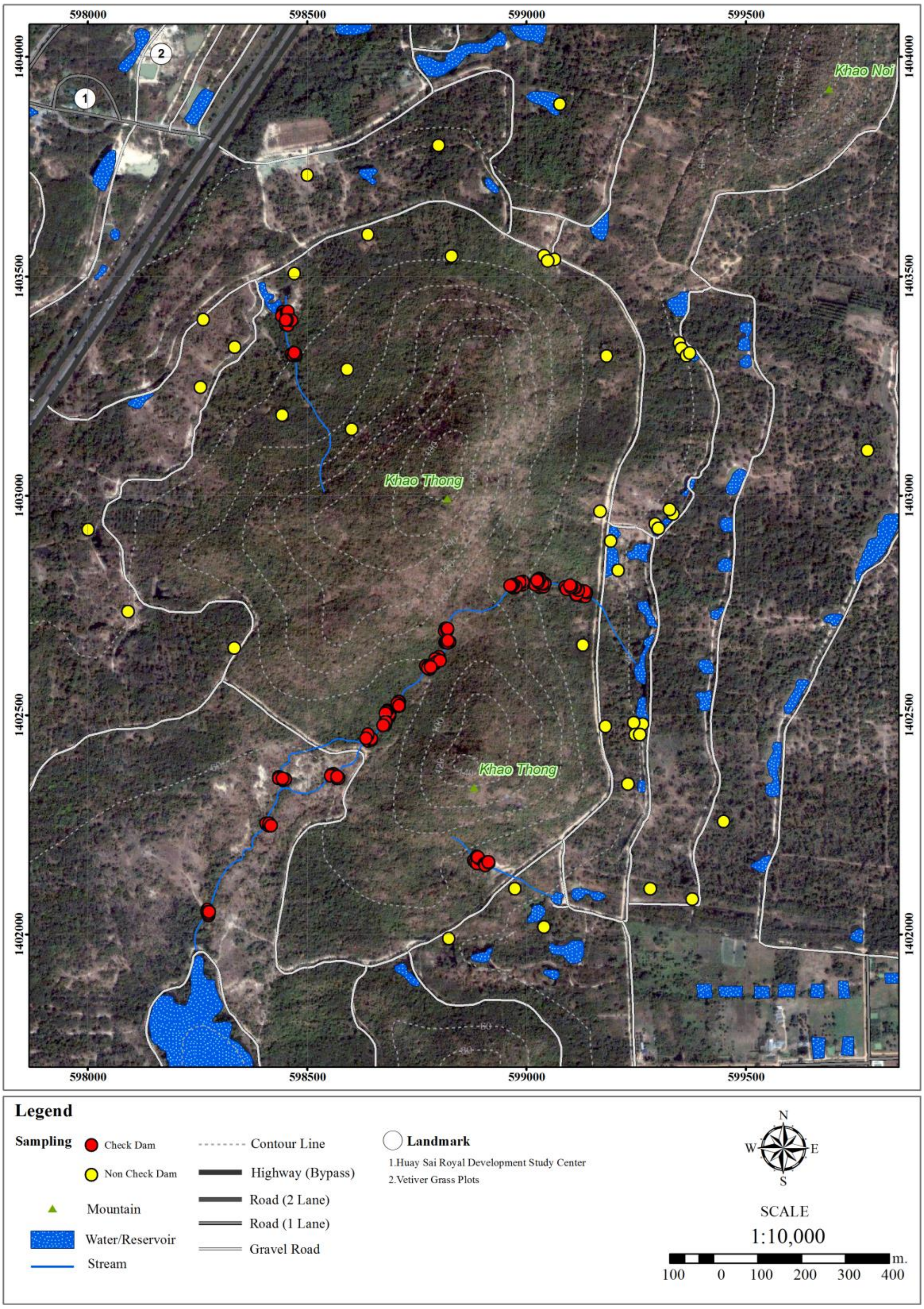


Figure 4-9 Map showing the Altitude of soil moisture sample locations

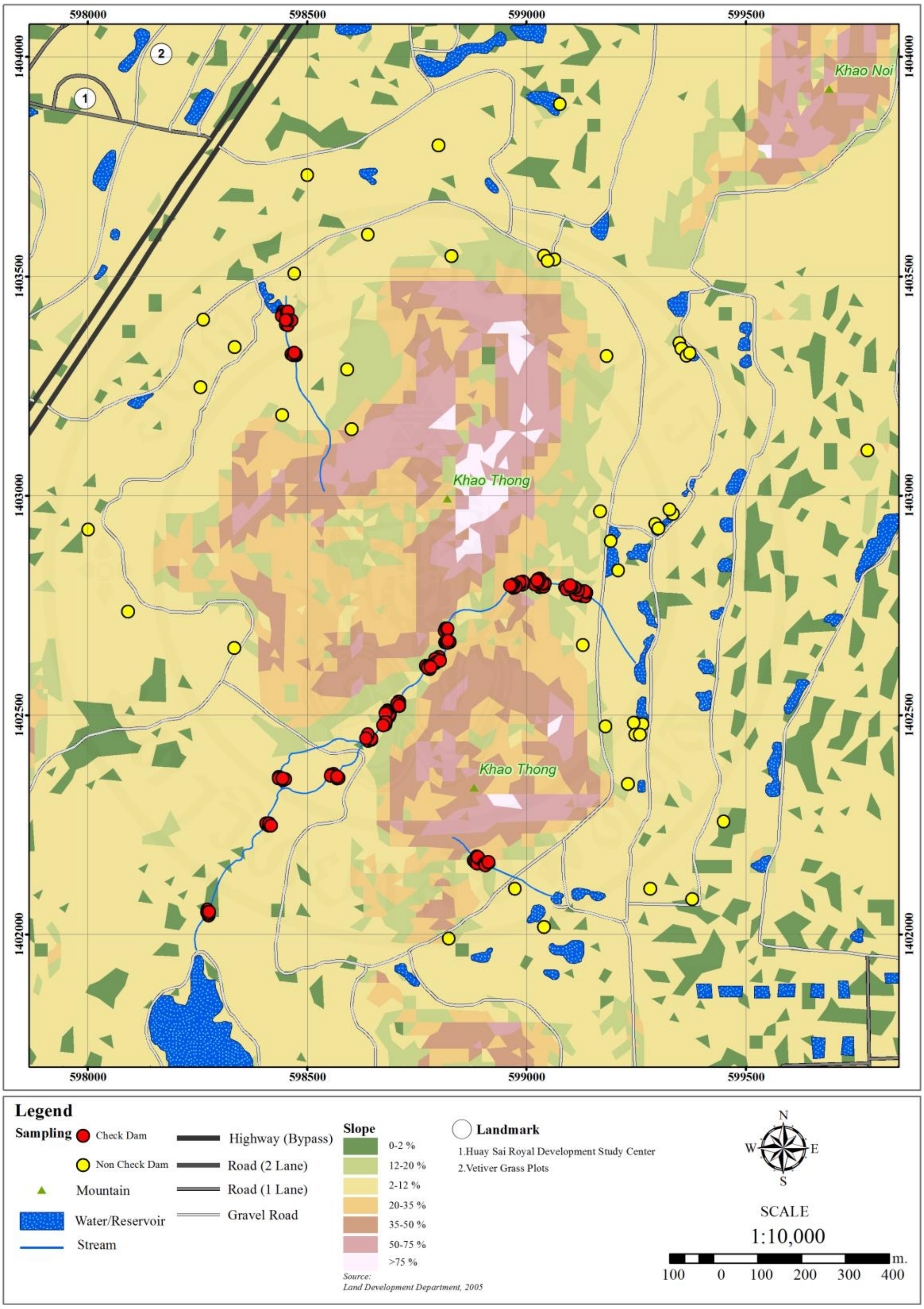


Figure 4-10 Map showing the Slope of soil moisture sample locations

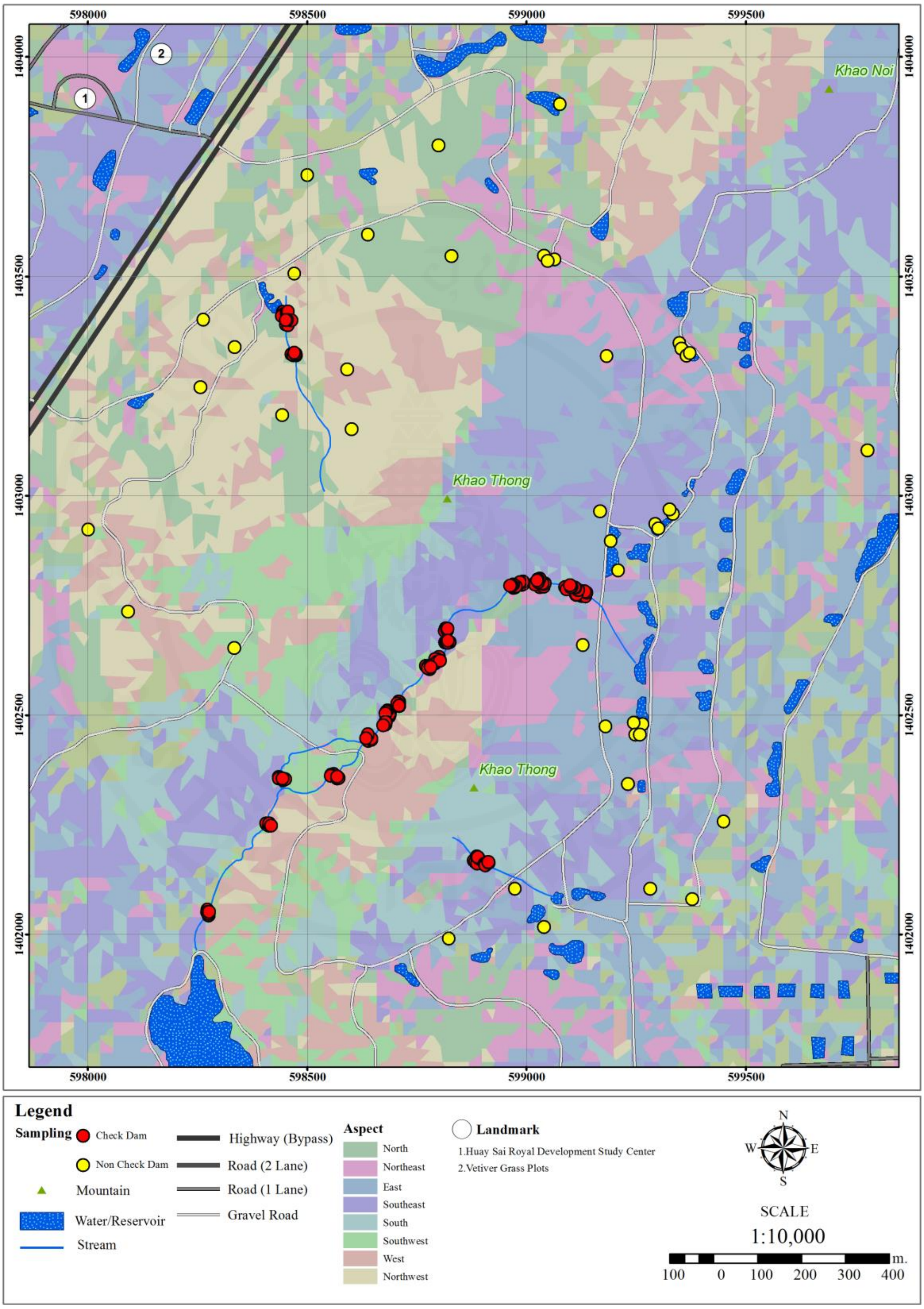


Figure 4-11 Map showing the Aspects of soil moisture sample locations

4.2 Physical characteristics that affect to the distribution of soil moisture

The information of soil moisture and physical characteristics including altitude, slope, aspects, and soil texture was obtained from data collection and field survey during two seasons, namely summer, from April to May and rainy season, from June to July. The data collection was conducted at the areas with and without check dam at 2 levels of depth, namely 5-15 centimeters and 15-30 centimeters. Therefore, this study utilized these two factors to examine physical characteristics that have the impact on the distribution of soil moisture. Statistical analysis was performed separately in order to test relationship of different factors with soil moisture.

4.2.1 Analysis on average soil moisture and season

From the analysis in comparison of average soil moisture and season by using t-test, it was found that soil moisture during summer was 2.23 percent by weight and soil moisture during rainy season was 7.45 percent by weight.

When compared average soil moisture, it was found that soil moisture during rainy season was higher than that during summer at significance level of 0.05 (sig = 0.00) as shown in Table 4-1. According to the study of Amonrat Leamtrakulpanit (2001) and Department of Landscape and Environment, Faculty of Agricultural Production, Mae Jo University, soil moisture changes depending on season. In other words, moisture in rainy season is higher than that in summer. The decrease is gradual. The value is low at the end of rainy season and becomes stable in dry season. From rainfall information in 2010 collected by Meteorological Department, the area of Huay Sai Royal Development Study Center (Khao Kapuk), Phetchaburi, it was found that the average rainfall during summer was 18.2 milimeters and the average rainfall during rainy season was 72.25 milimeters. Due to higher average rainfall during rainy season, average soil moisture during rainy season is higher than that in summer.

Table 4-1 Analysis on average soil moisture and season

	Rainy season			Summer			t	Sig.
	Amount of sampling points	Average soil moisture (%)	Standard deviation	Amount of sampling points	Average soil moisture (%)	Standard deviation		
Average soil moisture and season	376	7.45	3.27	376	2.23	1.28	-28.87	0.00

4.2.2 Analysis on average soil moisture and characteristics of sample locations

This study of soil moisture classifies sample locations into 2 types, namely locations with and without check dam. At each location, data collection was conducted at 2 levels of depth, including 5-15 centimeters and 15-30 centimeters. The test of sample locations with average soil moisture was separated into 2 seasons as shown in figure 4-12.

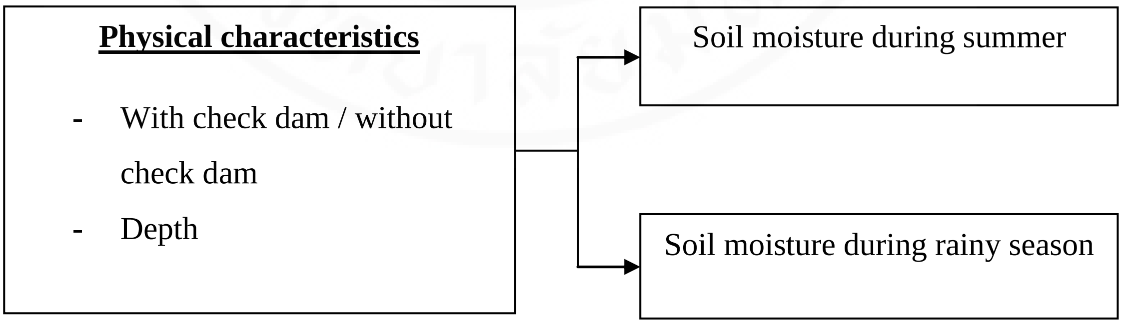


Figure 4-12 represents the diagram of average soil moisture test and data collection method

From the analysis on the difference of soil moisture during 2 seasons and characteristics of sample locations as shown in figure 4-12 by using statistical method, analysis results show that:

- In summer, characteristic of having check dam/ not having check dam resulted in the difference of average soil moisture. However, depth did not result in the difference of average soil moisture.

- In rainy season, both characteristic of having check dam/ not having check dam and depth resulted in the difference of average soil moisture.

4.2.2.1 The analysis on average soil moisture and characteristics of sample locations during summer

In statistical analysis on average soil moisture and characteristics of sample locations during summer, it was found that having check dam/not having check dam had the difference of average soil moisture. The average soil moisture at the area with check dam was 2.10 percent by weight. The average soil moisture at the area without check dam was 2.64 percent by weight.

When compared average soil moisture by using t-test, it was found that soil moisture of the area with check dam was lower than that of the area non check dam at significance level of 0.05 (sig = 0.02) as shown in Table 4-2.

Table 4-2 The analysis on average soil moisture and having check dam/not having check dam during summer

	Having Check Dam			Not having Check Dam			t	Sig.
	Amount of sampling points	Average soil moisture (%)	Standard deviation	Amount of sampling points	Average soil moisture (%)	Standard deviation		
Average soil moisture and having check dam/non check dam	288	2.10	0.85	88	2.64	2.11	-2.32	0.02

4.2.2.2 The analysis on average soil moisture and characteristics of sample locations during rainy season

1) The analysis on average soil moisture and having check dam/not having check dam.

In the analysis on average soil moisture and having check dam/not having check dam during rainy season, it was found that the average soil moisture at the area with check dam was 7.73 percent by weight. The average soil moisture at the area without check dam was 6.51 percent by weight.

When compared the average soil moisture by using t-test, it was found that the average soil moisture at the area with check dam was higher than that of the area without check dam at significance level of 0.05 (sig = 0.005) as shown in Table 4-3.

Table 4-3 The analysis on average soil moisture and having check dam/not having check dam during rainy season

	Having Check Dam			Not having Check Dam			t	Sig.
	Amount of sampling points	Average soil moisture (%)	Standard deviation	Amount of sampling points	Average soil moisture (%)	Standard deviation		
Average soil moisture and having check dam/non check dam	288	7.73	3.08	88	6.51	3.68	2.83	0.005

2) Analysis on average soil moisture and depth

In analysis on average soil moisture and depth during rainy season, it was found that the average soil moisture at the depth of 5-15 centimeters was 9.18 percent by weight. The average soil moisture at the depth of 15-30 centimeters was 5.72 by weight.

When compared the average soil moisture by using t-test, it was found that the average soil moisture at the depth of 5-15 centimeters was higher than that at the depth of 15-30 centimeters at significance level of 0.05 (sig = 0.005) as shown in Table 4-4. This does not correspond to the study of Rommanee Thongdara (1997), who concluded that soil moisture would be higher as the depth increases. In other words, soil moisture at the depth of 60 centimeters is higher than that at the depth of 15 centimeters. Soil samples in this study were collected at the depth of 5-15 centimeters and 15-30 centimeters. Such depths were only at surface level. Due to the difference of physical characteristics in each area, soil moisture values in this study did not correspond to the study in other areas. When considered on soil texture of the area, it was found that most soil samples in the area were rough. These soils have little specific surface area, thus they have no space to absorb water. There are big pores among the grains of sand, facilitating drainage and ventilation. At the depth of 5-15 centimeters, most soil textures were loamy sand. At the depth of 15-30 centimeters, most soil textures were sand. Soil texture in the study area was sand at the depth of 5-15 centimeters. It had lesser percentage of sand than that at the depth of 15-30 centimeters. It had better water absorption. There were a great number of weeds on the ground.

Table 4-4 The analysis on average soil moisture and soil depth during rainy season

	5-15 centimeters			15-30 centimeters			t	Sig.
	Amount of sampling points	Average soil moisture (%)	Standard deviation	Amount of sampling points	Average soil moisture (%)	Standard deviation		
Average soil moisture and depth	188	9.18	3.05	188	5.72	2.47	12.09	0.000

Statistical analysis was applied to find average soil moisture and characteristics of sample locations during both seasons. It was found that the areas with and without check dam were statistically significant in both seasons. In other words, during April-May, soil moisture in the areas with check dam was lesser than that of the areas without check dam. In rainy season, during June-July, soil moisture in the area with check dam was higher than that of the areas without check dam. The study in summer did not correspond to Pisut Saengmanee (2007) and Maliwan Maneeso (2007), who stated that soil moisture around watercourse with check dam was higher than that of watercourse the areas without check dam. This was due to the difference of landscape and climate of study area. Its western coast was water source. Its middle part was plain inclining toward the east. The area was dry and it did not rain seasonably due to rain barrier. There was little rainfall. Furthermore, natural resources of the study area are promoted and restored. There are planning and 3 parts of moisture distribution system, including check dam, terracing and diversion. Such moisture distribution system slows down water flow, maintaining soil moisture in the area during summer. Moreover, the moisture here is higher than the areas with check dam.

The objective of this study is to examine the distribution of soil moisture from the check dam. In data collection of soil moisture around the check dam, more data was collected than the areas without check dam. That means the samples were collected from 6 locations in the areas with check dam as specified in item 3.3.2.2. The determination of depth and soil sample locations was assigned as follows.

- Row 1 above the check dam : The right is location 3, the left is location 4
- Row 2 on the check dam : The right is location 2, the left is location 5
- Row 3 under the check dam : The right is location 1, the left is location 6

Statistical analysis showed that average soil moisture at the areas with check dam, all 6 soil sample locations, had no difference of soil moisture in both seasons.

4.2.3 The analysis on average soil moisture and physical characteristics

The analysis on average soil moisture and physical characteristics includes altitude, slope, aspects, and soil texture. It aims to examine physical characteristics that affect to the distribution of soil moisture by testing physical characteristics with average soil moisture in 2 seasons as shown in figure 4-13.

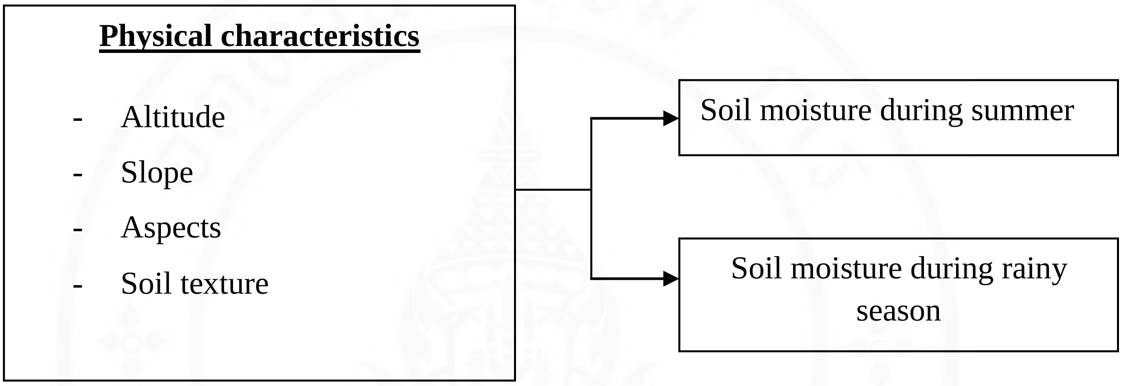


Figure 4-13 Diagram showing the test of average soil moisture and physical characteristics

In analysis on the difference of soil moisture in 2 seasons and physical characteristics by using statistical method as shown in figure 4-13, the result showed that:

- In summer, physical characteristic that showed the difference of average soil moisture was aspects.

- In rainy season, physical characteristic that showed the difference of average soil moisture was altitude.

4.2.3.1 The analysis on average soil moisture and physical characteristics during summer

The analysis showed that slope was physical characteristic that contributed to the difference of average soil moisture. When compared by using One Way Analysis of Variance (ANOVA), it was found that different slope had different average soil moisture at significance level of 0.05 (F = 5.40, Sig. = 0.00) as shown in Table 4-5.

Table 4-5 The analysis on average soil moisture and slope during summer

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	64.35	8	8.04	5.40	0.000
Within Groups	546.98	367	1.49		
Total	611.32	375			

When compared average soil moisture at different slopes, it was found that the average soil moisture of northeastern slope was different from that of southwestern slope. The average soil moisture of northeastern slope was different from that of northwestern slope as shown in Table 4-6. It can be seen that different slope causes different soil moisture. Corresponding to the study of Payap Paoprajak (1967), soil moisture changes according to different slope direction. Soil moisture of northern slope was higher than that of southern slope, eastern slope and western slope. However, due to different landscape, the slopes in each area do not match. The study showed that the average soil moisture of northern slope was the highest. The next one was northeastern slope. The lowest average soil moisture belonged to southern slope. This is because of the landscape, where the range of mountains lies from northeast to southwest, causing southeastern slope and southwestern slope to be more affected by sunlight than other slopes.

Table 4-6 Comparison on average soil moisture of each slope during summer

Aspects	Amount of sampling points	Average soil moisture (%)	Difference between slopes							
			N	S	E	W	NE	SE	NW	SW
N	10	3.21	-	1.16	1.08	1.22	0.18	1.32	0.85	1.39
S	30	2.05	-1.16	-	-0.08	0.06	-0.98	0.16	-0.31	0.24
E	62	2.13	-1.08	0.08	-	0.14	-0.89	0.24	-0.22	0.32
W	93	1.99	-1.22	-0.06	-0.14	-	-1.04	0.09	-0.37	0.18
NE	50	3.03	-0.18	0.98	0.89	1.04	-	1.14*	0.67	1.22
SE	60	1.89	-1.32	-0.16	-0.24	-0.09	-1.14	-	-0.46	0.08
NW	61	2.36	-0.85	0.31	0.22	0.37	-0.67	0.46	-	0.54
SW	10	1.81	-1.40	-0.24	-0.32	-0.18	-1.22*	-0.08	-0.54	-

Remark: ** Significance level of 0.05*

N = North, S = South, E = East, W = West, NE = Northeast, SE = Southeast, NW = Northwest and SW = Southwest

4.2.3.2 Analysis on average soil moisture and physical characteristics during rainy season

The analysis showed that altitude was physical characteristic that contributed to the difference of average soil moisture. The average soil moisture and altitudes were analyzed. The altitudes were classified into 4 groups. Each group was spaced for 20 meters height according to height contours of topographic map at the scale 1:50,000 created by Royal Thai Survey Department. The resulting altitudes included 21-40 meters, 41-60 meters, 61-80 meters, and 81-100 meters. When compared average soil moisture and altitude by using One Way Analysis of Variance (ANOVA), it was found that different altitudes caused different average soil moisture at significance level of 0.05 (F = 6.49, Sig. = 0.00) as shown in Table 4-7.

Table 4-7 The analysis on average soil moisture and altitude during rainy season

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	198.77	3	66.26	6.49	0.00
Within Groups	3800.63	372	10.22		
Total	3999.40	375			

When compared the average soil moisture with different altitudes, it was found that average soil moisture at the altitude of 21-40 meters was different from the altitude of 41-60 meters, 61-80 meters, and 81-100 meters as shown in Table 4-8. Different altitude causes different soil moisture. Corresponding to Rommanee Thongdara (1997), the altitude is an influencing factor for soil moisture. Soil moisture changes as the altitude changes. In soil drainage theory for hill and plain landscape, the soil's drainage capability decrease as the hight goes down. Underground water level differs by drainage level. In other words, for the soil with good drainage, the underground water is deep down from the surface. For the soil with bad drainage, the underground water is close to the surface. From the information of average soil moisture during rainy season at altitude of 21-40 meters, the average soil moisture was lowest. The average soil moisture increases and altitude increases. This does not correspond to the drainage of different locations. When considered on locations, it was found that the locations at the altitude of 21-40 meters were plain without check dam in contrast to the altitude of 41-60 meters, 61-80 meters, and 81-100 meters. These altitudes are where the check dams are built. The check dam helps slow down water flow and moisten the soil.

Table 4-8 Comparison of average soil moisture at each altitude during rainy season

Altitude (meter)	Amount of sampling points	Average soil moisture (%)	Difference between altitudes			
			21-40	41-60	61-80	81-100
21-40	40	5.38	-	-2.20*	-2.53*	-2.33*
41-60	214	7.58	2.20*	-	-0.32	-0.13
61-80	108	7.91	2.53*	0.32	-	0.19
81-100	14	7.71	2.33*	0.13	-0.19	-

Remark: ** Significance level of 0.05*

4.3 The pattern of the distribution of soil moisture

4.3.1 The analysis on vegetation diversity

The analysis on vegetation diversity was performed by calculating vegetation diversity value using normalized differential vegetation index (NDVI) from satellite photograph of Landsat-5 TM Path 129 Row 051 taken on 15th April 2011 and 5th August 2011 at the area of Huay Sai Royal Development Study Center. The analysis on satellite photograph taken on 15th April 2011 showed maximum vegetation diversity (Max) at 0.5862. The mean of density was 0.3361. Vegetation diversity value can be presented in figure 4-14. The analysis on satellite photograph taken on 5th August 2011 showed maximum vegetation diversity at 0.7279. The mean of diversity was 0.4919. Vegetation diversity value can be presented in figure 4-15. From the analysis on vegetation diversity by using NDVI in April and August, it can be seen that most of the study area is covered by vegetation, especially on the mountain area as shown in figure 4-16. Vegetation is denser in August as shown in figure 4-17.

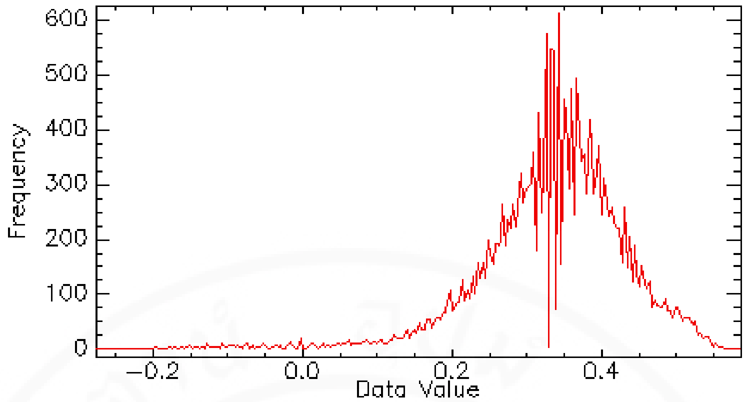


Figure 4-14 Graph showing the distribution of normalized differential vegetation index (NDVI) from Landsat-5 TM satellite images recorded on April 15, 2011

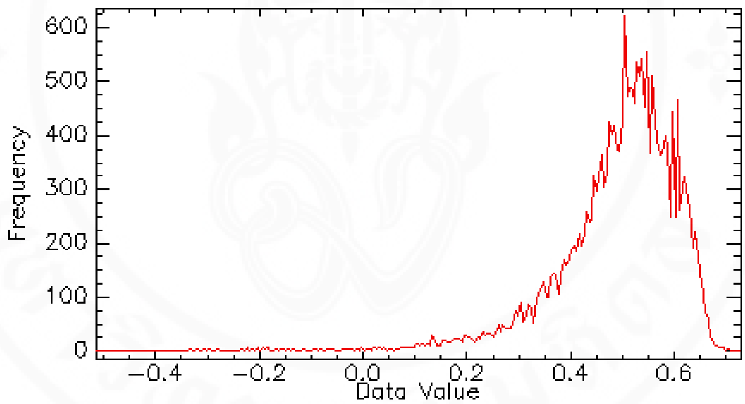


Figure 4-15 Graph showing the distribution of normalized differential vegetation index (NDVI) from Landsat-5 TM satellite images recorded on August 5, 2011

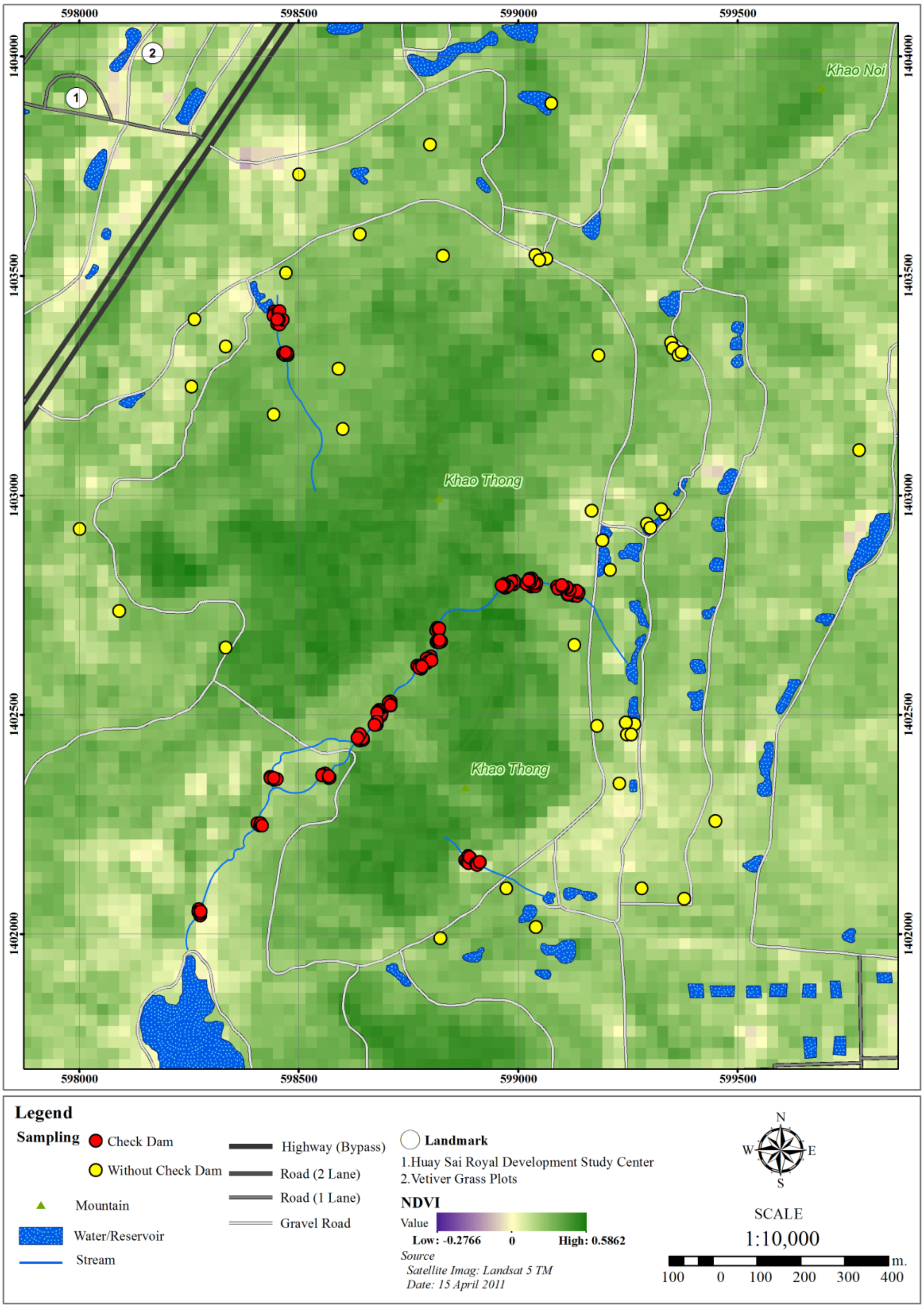


Figure 4-16 Map showing the distribution of normalized differential vegetation index (NDVI) from Landsat-5 TM satellite images recorded on April 15, 2011

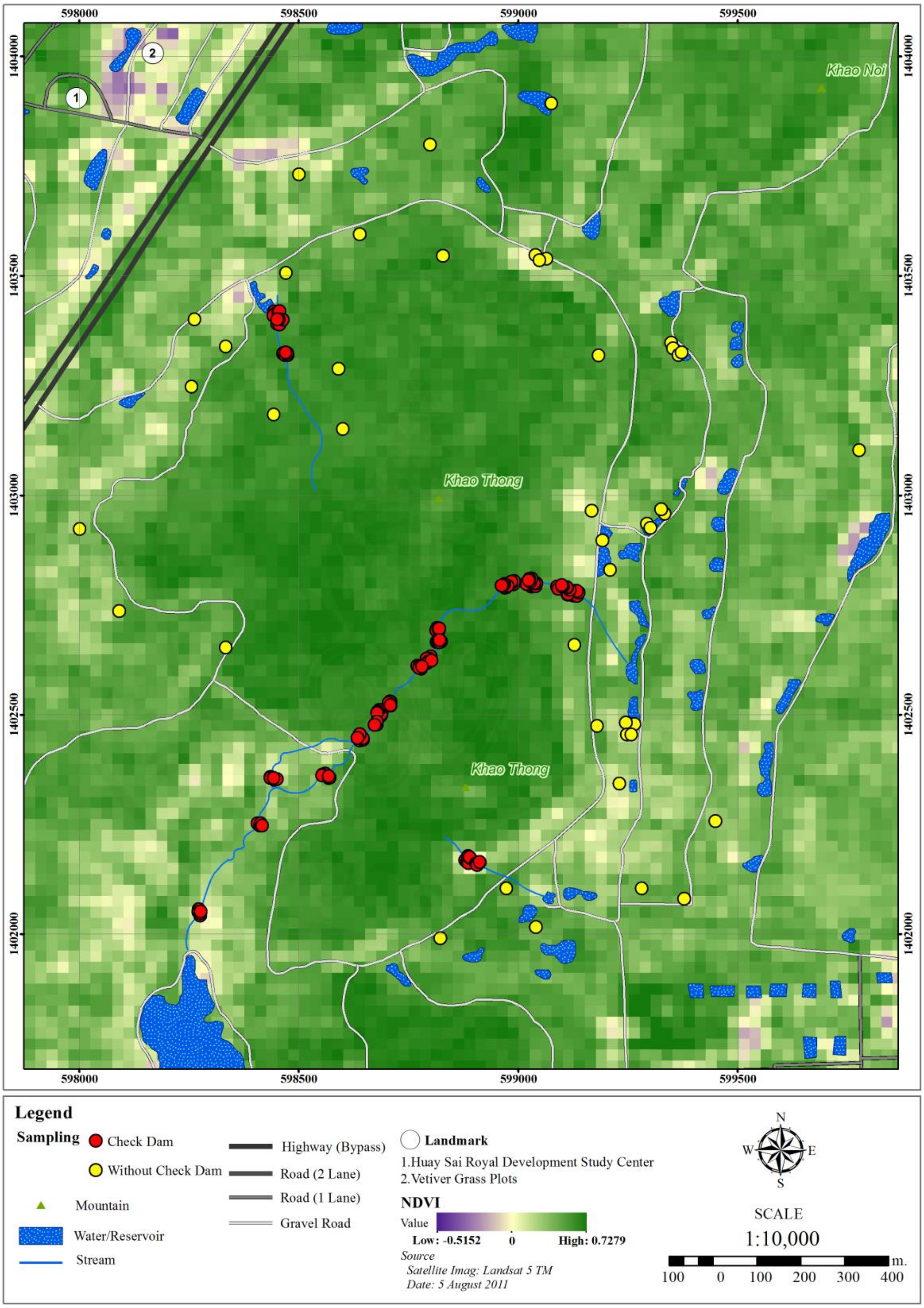


Figure 4-17 Map showing the distribution of normalized differential vegetation index (NDVI) from Landsat-5 TM satellite images recorded on August 5, 2011

4.3.2 The estimation of soil moisture in area aspect

Soil moisture values collected from field survey are shown in item 4.1, Table A (Appendix). They identify soil moisture, physical characteristics and estimation on soil moisture. This study examines the distribution of soil moisture of study area by applying geoinformatic software (ArcGIS) to analyze area estimation (Interpolation) using Thiessen Polygon and Co-Kriging methods. Soil moisture at both depths was estimated during April-May. In soil moisture estimation using Thiessen Polygon method, it was found that soil moisture at the north and northeast of the area spread more than other directions as shown in figure 4-19. From the estimation of soil moisture using Co-Kriging method at both depths, it was found that soil moisture at the north and northeast spread more than other directions, especially the southeast and the west as shown in figure 4-20. However, at the depth of 15-30 centimeters, soil moisture spread throughout the area as shown in figure 4-21. From the analysis on area estimation for both types, it can be seen that the distribution of soil moisture at both depth in the northeast is higher than the southwest. Corresponding to the analysis on average soil moisture and physical characteristics, it was found that north aspects and northeast aspects had the highest average soil moisture.

When considered on the distribution of soil moisture of study area and characteristics and properties of soil series, it was found that 3 soil series in study area, including Hup Kapong series, Nong Kae series, and Slope Complex can be presented in figure 4-22. It can be seen that soil moisture mostly spreads over slope complex. This is because of characteristics and properties of the slope complex are mountain area with over 35% slope. Soil texture and natural abundance vary depending on the area. Most of this soil series are in natural forest area. The area, where litte soil moisture is spread, is the area with Hup Kapong series. The characteristics and properties of Hup Kapong series are deep soil and sandy loam. The grain of sand is rough depending on depth. Its drainage is good. The speed of water flow on its surface is medium to fast. The water can penetrate it quickly. Its limit is that it is sandy with low capability in absorption. Therefore, it has relatively low soil moisture distribution.

For the distribution of soil moisture during June-July, the estimation of soil moisture using Thiessen Polygon method showed that the study area had more moisture at the depth of 5-15 centimeters. The moisture spread over large area. Especially the areas with check dam, soil moisture value here was higher than that of the areas without check dam as shown in figure 4-23. At deeper level, 15-30 centimeters, s soil moisture spread throughout the area similarly to the depth of 5-15 centimeters. However, soil moisture was lower as shown in figure 4-24. From the estimation of soil moisture using Co-Kriging method for both depths, it was found that soil moisture of the areas with check dam spread more than that of the areas without check dam as shown in figure 4-25. Soil moisture at the depth of 15-30 centimeters spread throughout the area as shown in figure 4-26. Especially at the western mountain, soil moisture spread more than the eastern area. This is because the area is under influence of southwest monsoon. Therefore, western area receives rainfall more than eastern area.

When considered on soil moisture from the analysis of area estimation using Thiessen Polygon and Co-kriging methods during April-May and vegetation diversity value (NDVI) from satellite photograph taken by Landsat-5 TM on 15th April 2011, it was found that soil moisture from the estimation using Thiessen Polygon method at the depth of 5-15 centimeters had linear correlation with vegetation diversity (NDVI) at $R^2 = 0.0006$ as shown in figure 4-27. (1) Soil moisture from area estimation using Co-Kriging method had linear correlation with vegetation diversity (NDVI) at $R^2 = 0.0038$ as shown in figure 4-27. (2) For area estimation during June-July on vegetation diversity (NDVI) from satellite photograph taken by Landsat-5 TM on 5th August 2011, it was found that soil moisture from area estimation using Thiessen Polygon at the depth of 5-15 centimeters had linear correlation with vegetation diversity (NDVI) at $R^2 = 0.0355$ as shown in figure 4-27. (3) Soil moisture from area estimation using Co-Kriging method had linear correlation with vegetation diversity (NDVI) at $R^2 = 0.13$ as shown in figure 4-27. (4) From the study on soil moisture distribution by using differential vegetation index analysis and soil moisture estimation using Thiessen Polygon and Co-kriging methods at the depth of 5-15 centimeters of both seasons, it can be seen that study area had increasing soil moisture from April to July. Similarly to vegetation diversity (NDVI) from satellite photograph taken by Landsat 5 TM in April and August, vegetation density in study area also increased as shown in figure 4-28 to figure 4-39. Three-dimension map shows perspective of the study area in 4 directions, including north, east, south and west respectively.

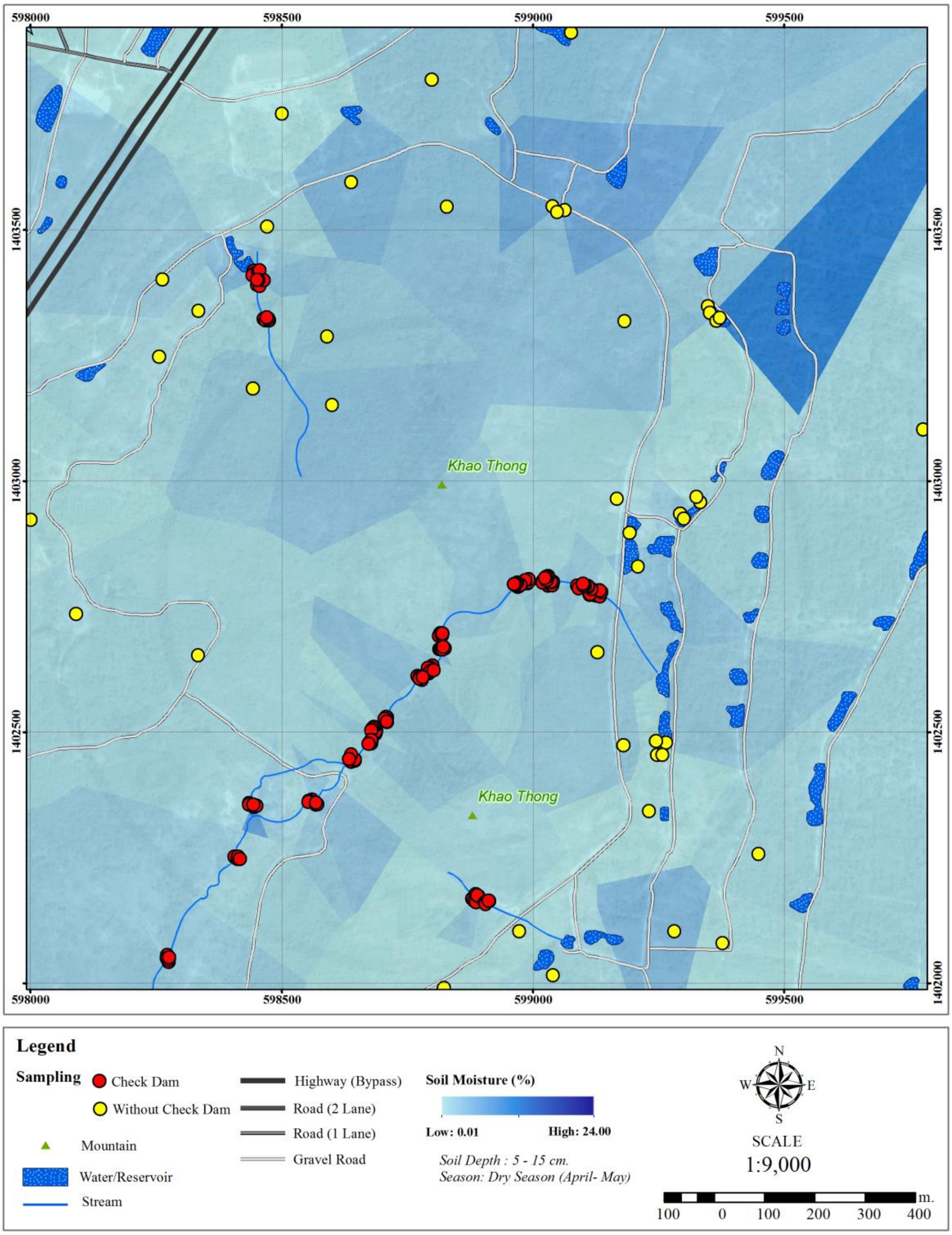


Figure 4-18 Map showing the soil moisture estimation using Thiessen Polygon method during April-May at the depth of 5-15 centimeters

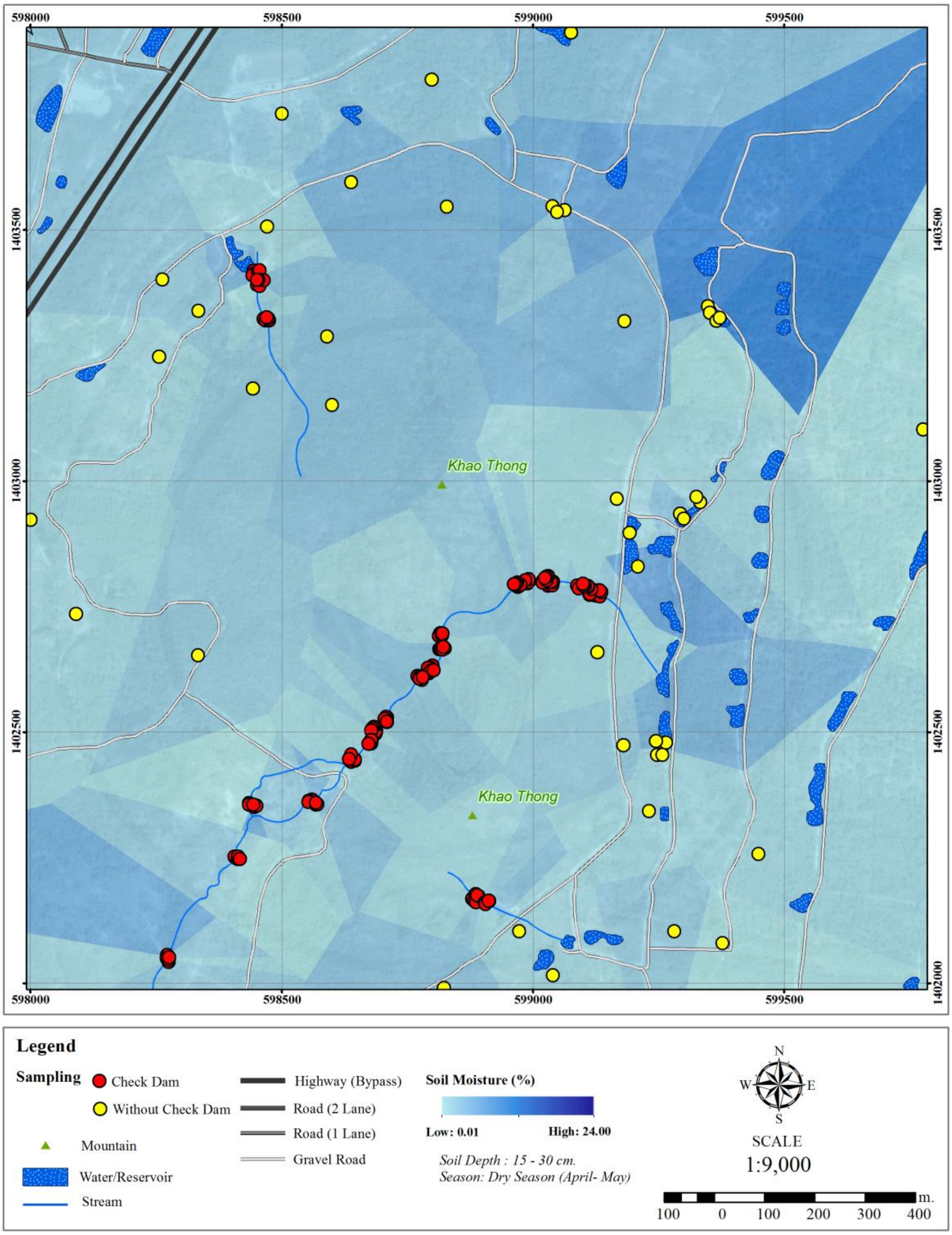


Figure 4-19 Map showing the soil moisture estimation using Thiessen Polygon method during April-May at the depth of 15-30 centimeters

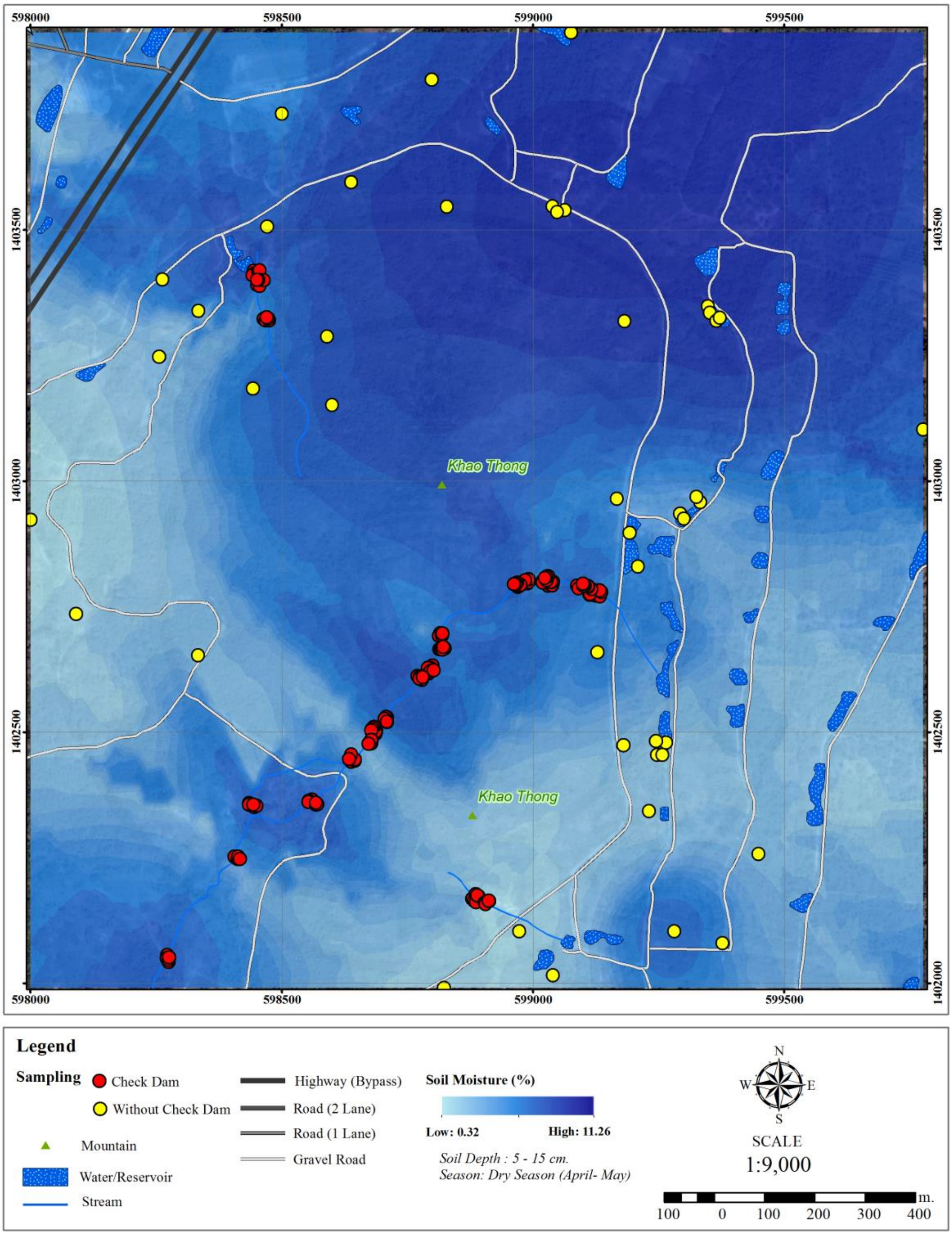


Figure 4-20 Map showing the soil moisture estimation using Co-Kriging method during April-May at the depth of 5-15 centimeters

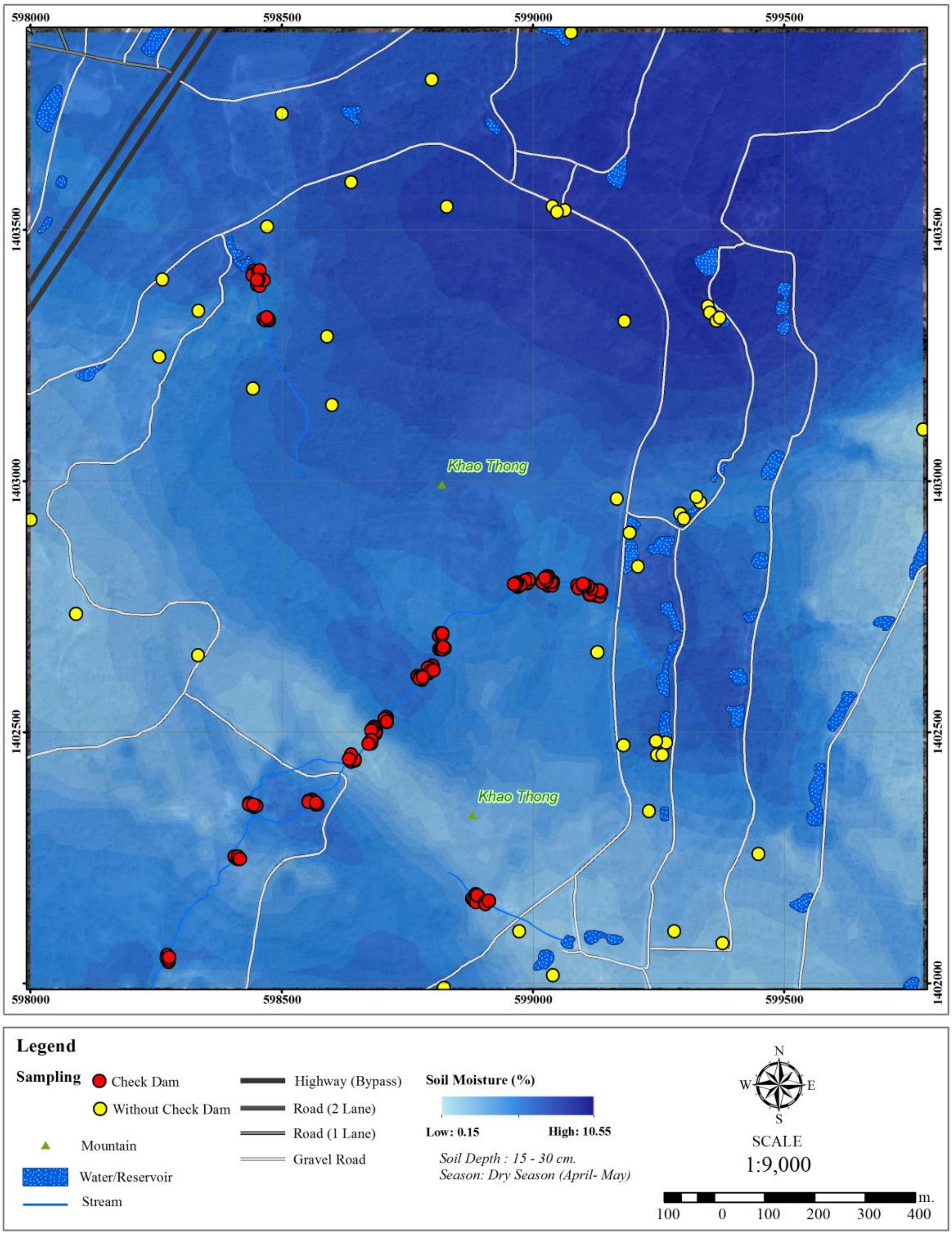


Figure 4-21 Map showing the soil moisture estimation using Co-Kriging method during April-May at the depth of 15-30 centimeters

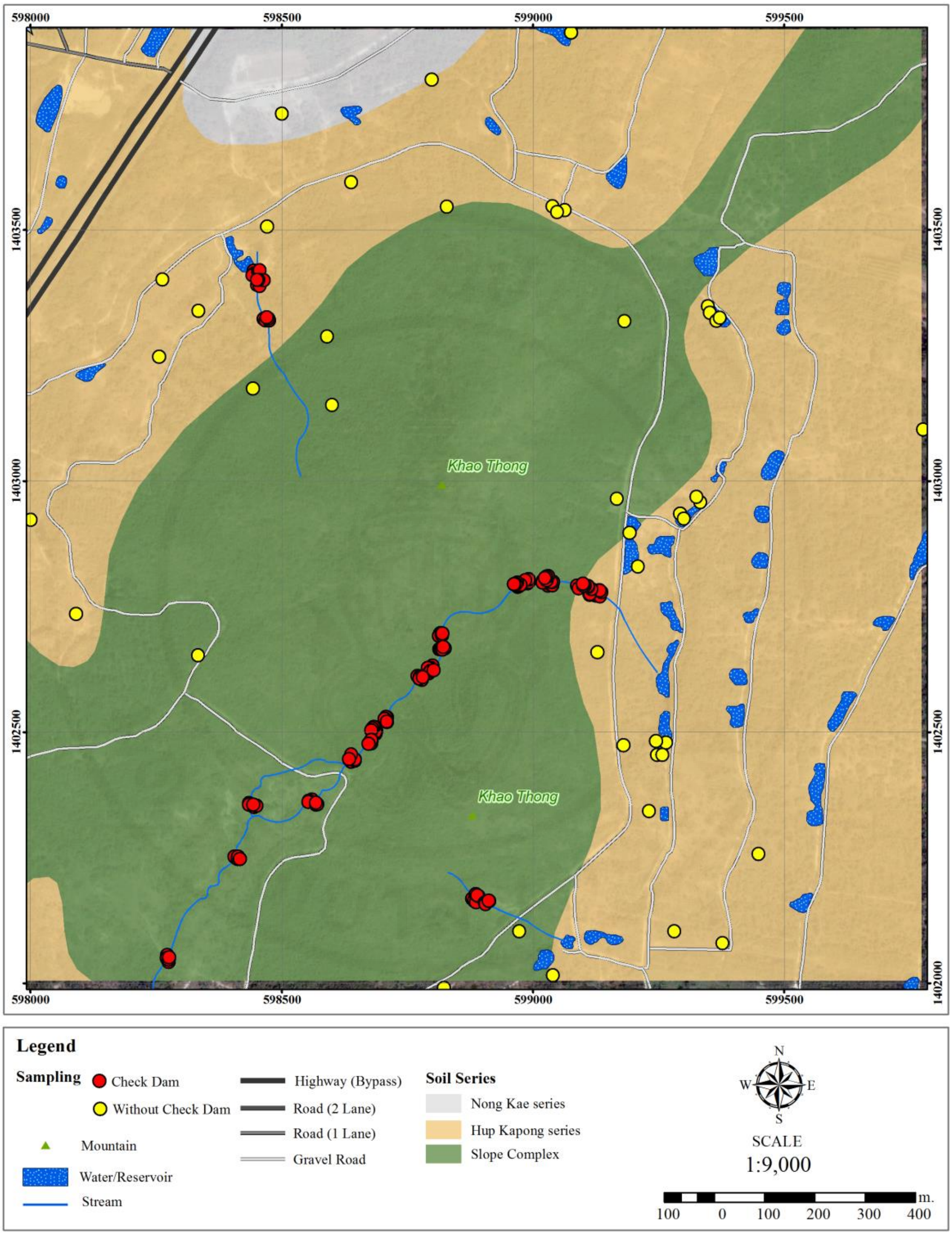


Figure 4-22 Map showing soil series in study area

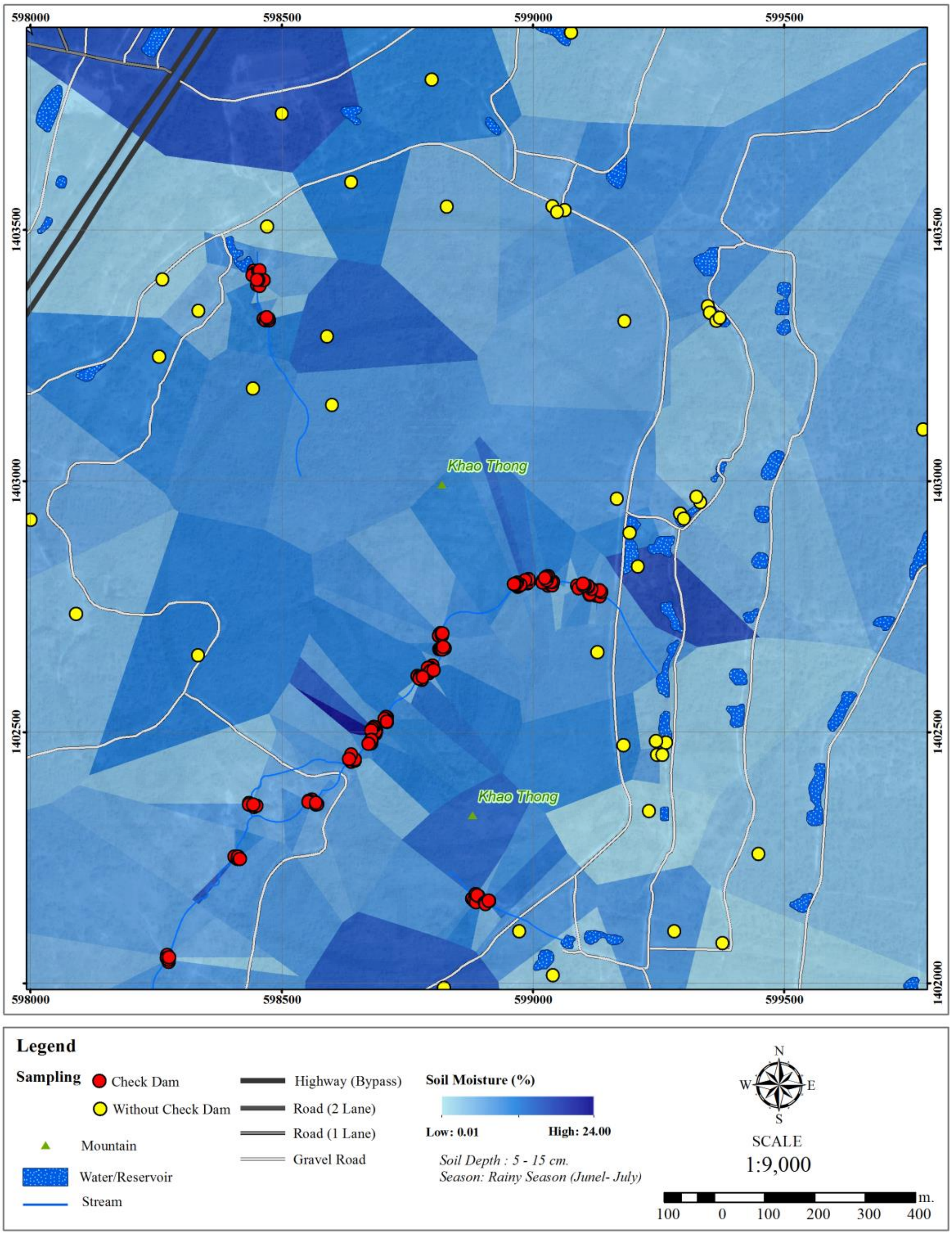


Figure 4-23 Map showing the soil moisture estimation using Thiessen Polygon method during June-July at the depth of 5-15 centimeters

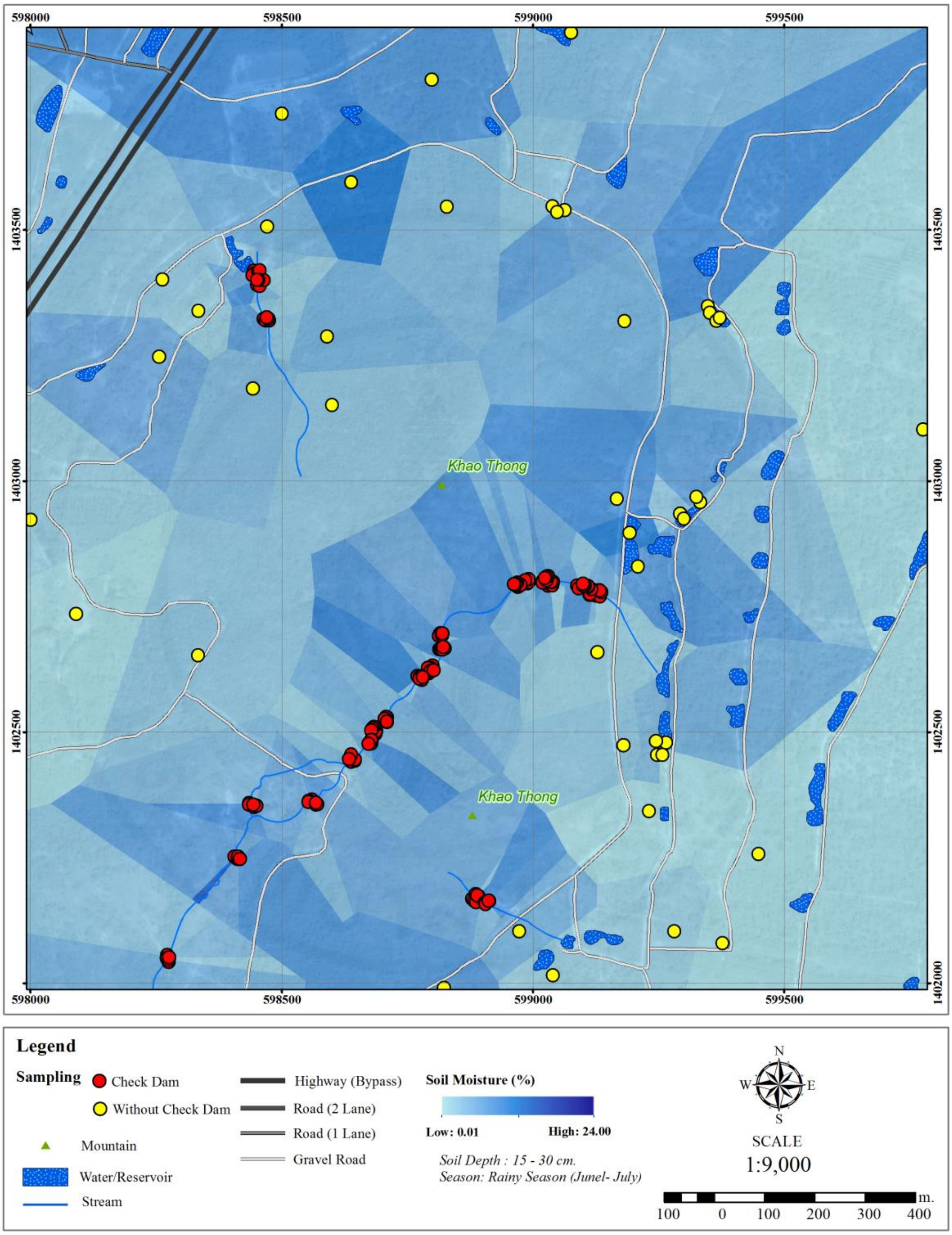


Figure 4-24 Map showing the soil moisture estimation using Thiessen Polygon method during June-July at the depth of 15-30 centimeters

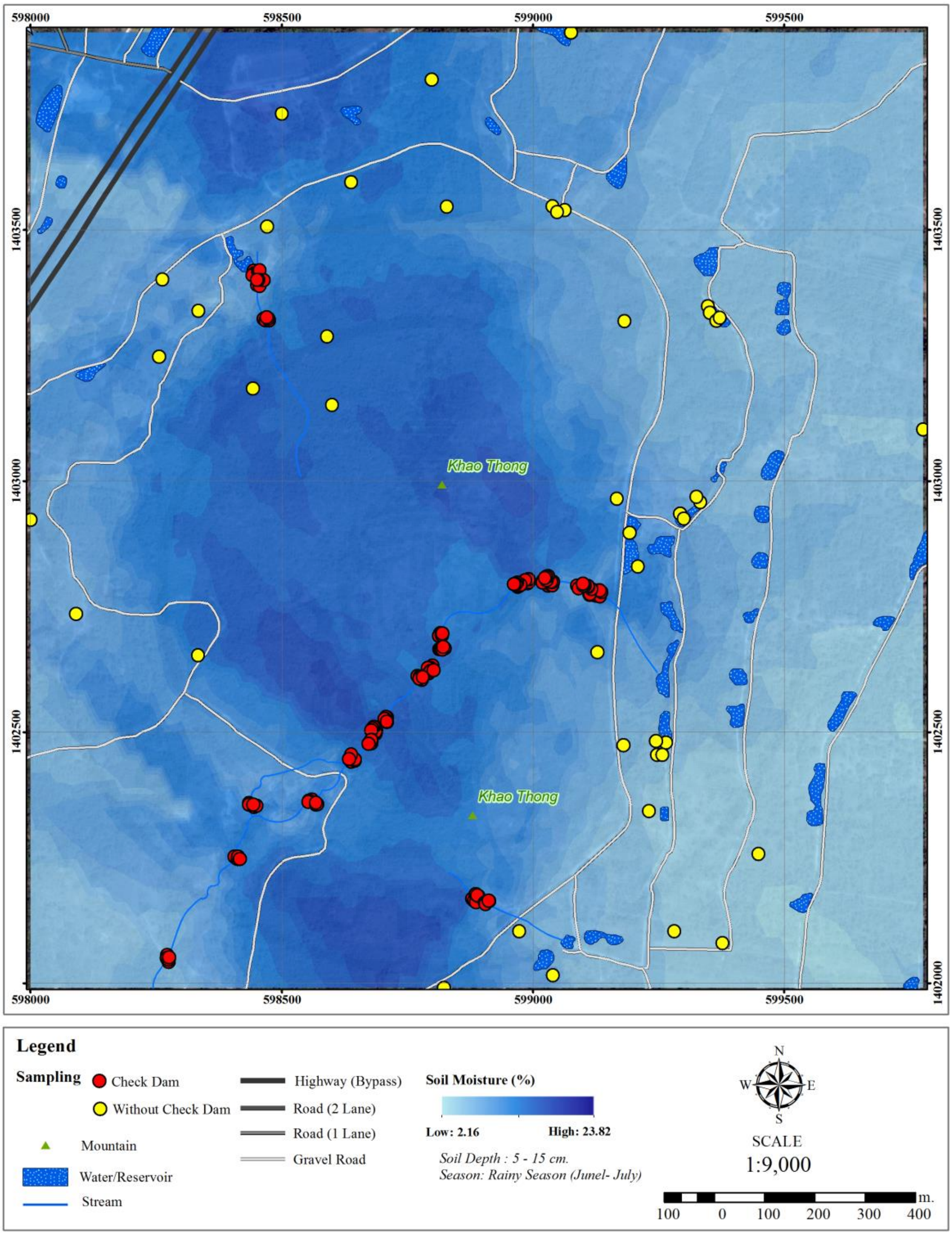


Figure 4-25 Map showing the soil moisture estimation using Co-Kriging method during June-July at the depth of 5-15 centimeters

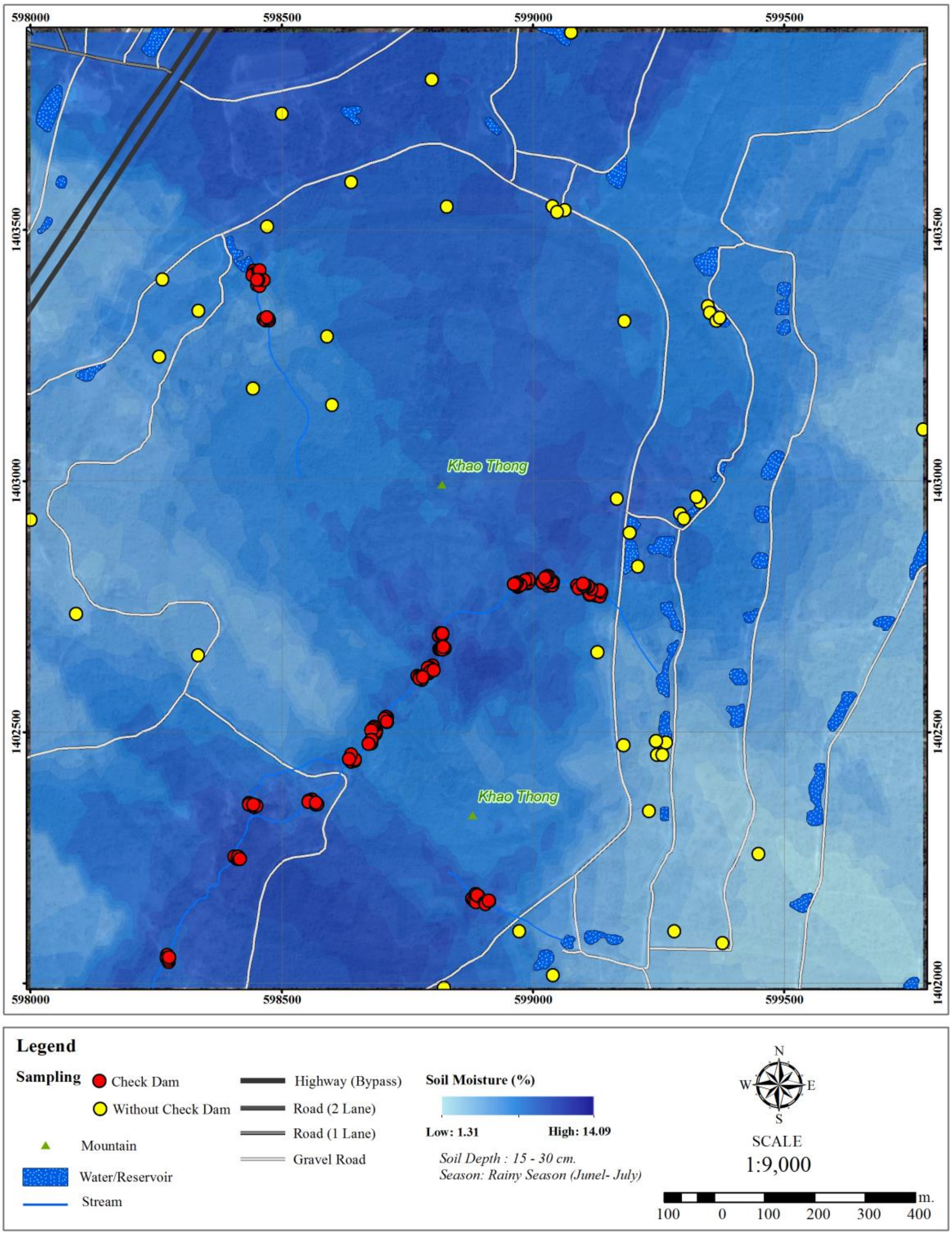
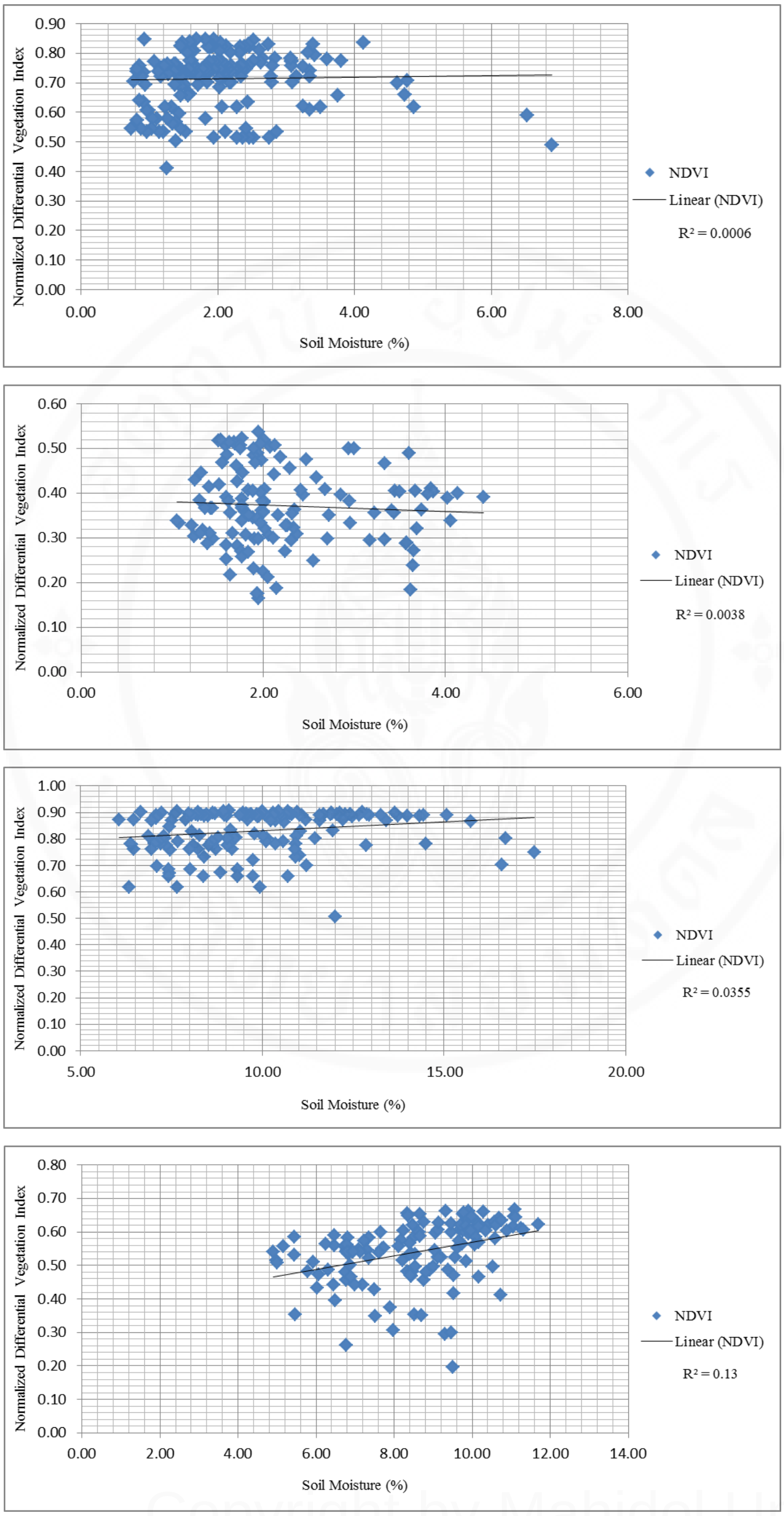


Figure 4-26 Map showing the soil moisture estimation using Co-Kriging method during June-July at the depth of f 15-30 centimeters



(1) (2) (3) (4)

Figure 4-27 Distribution of area estimation using Thiessen Polygon method and Co-Kriging method and vegetation diversity (NDVI)

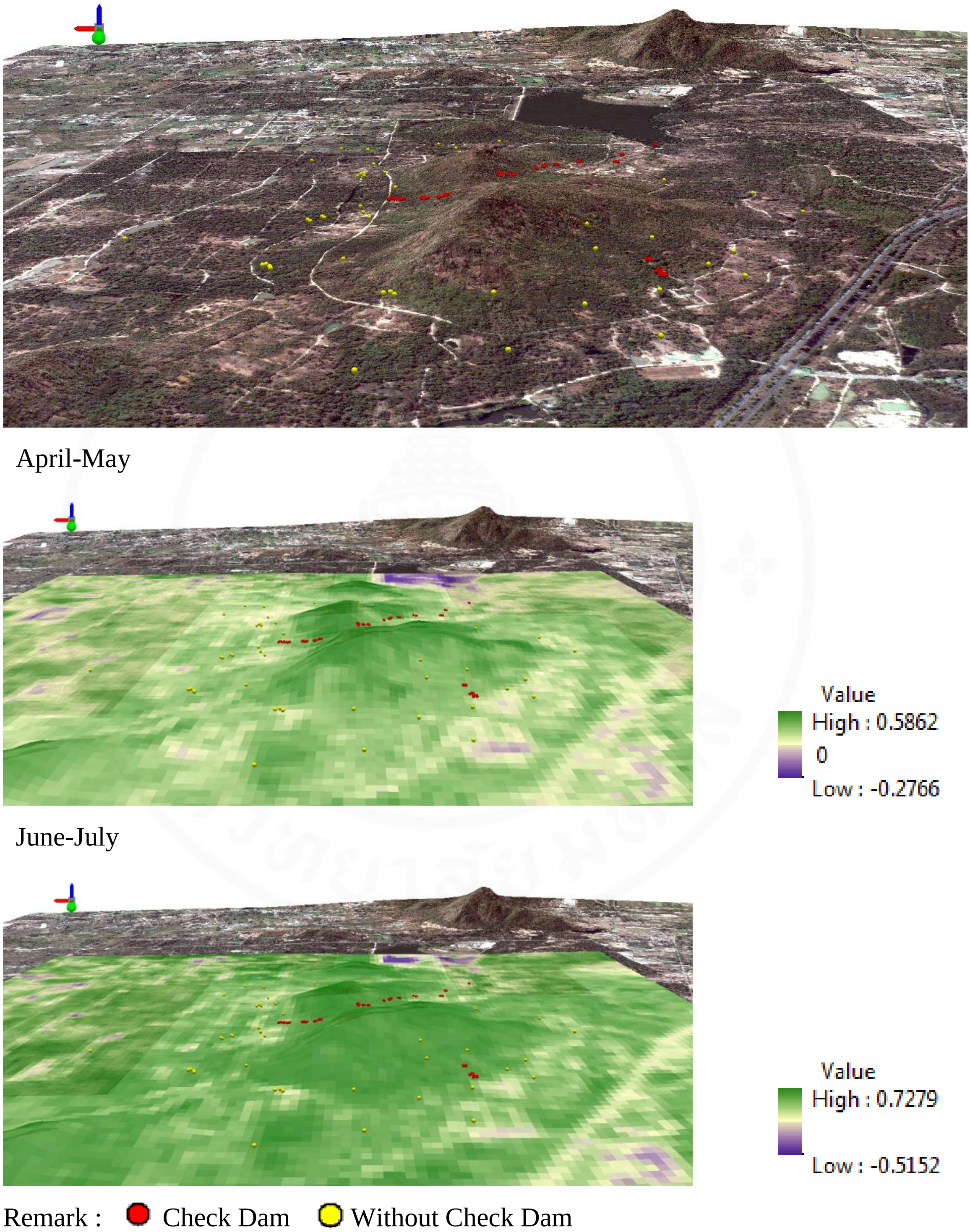


Figure 4-28 Three-dimension map showing north perspective of the study area: NDVI data

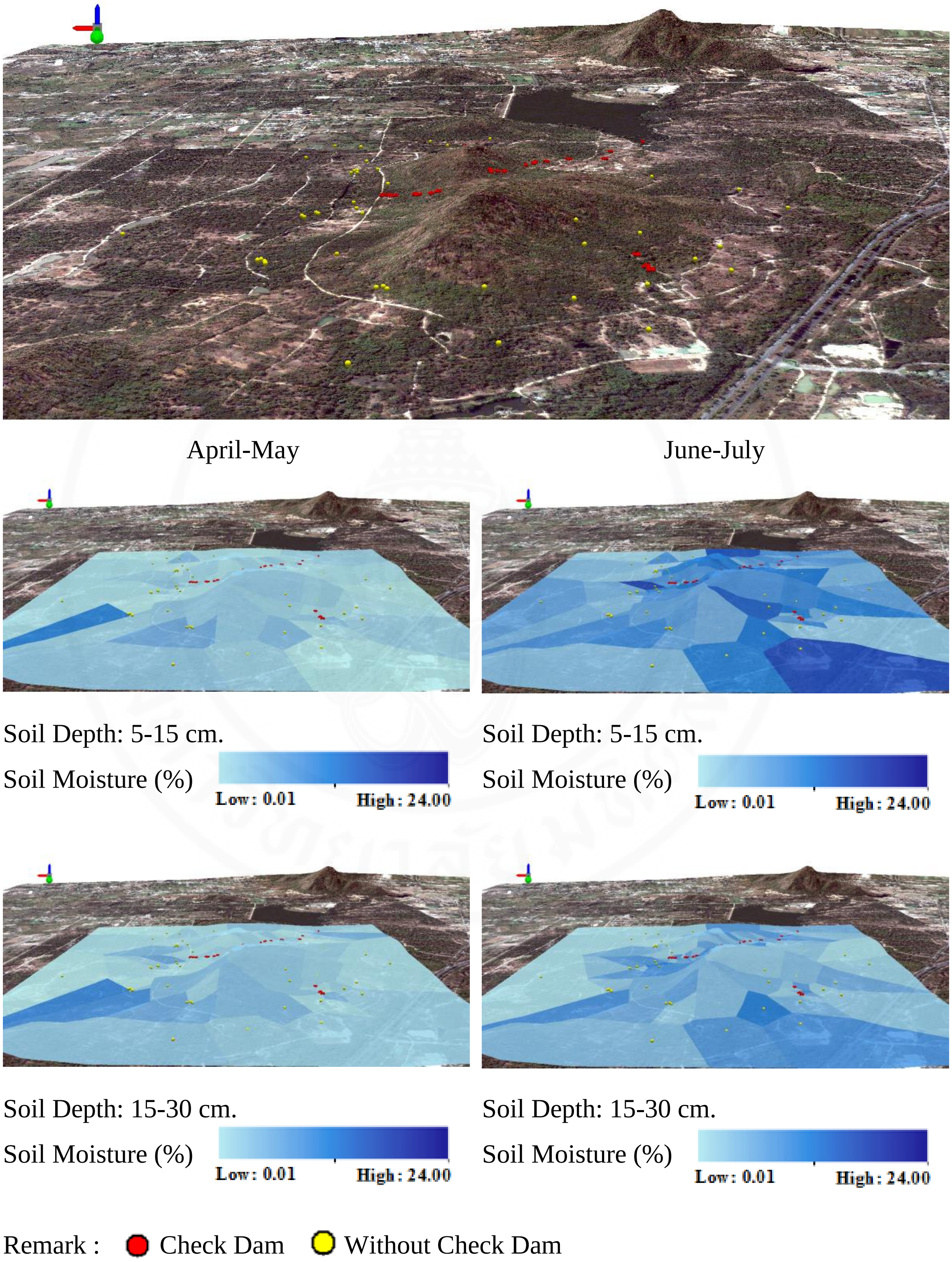


Figure 4-29 Three-dimension map showing north perspective of the study area: Information of area estimation using Thiessen Polygon method

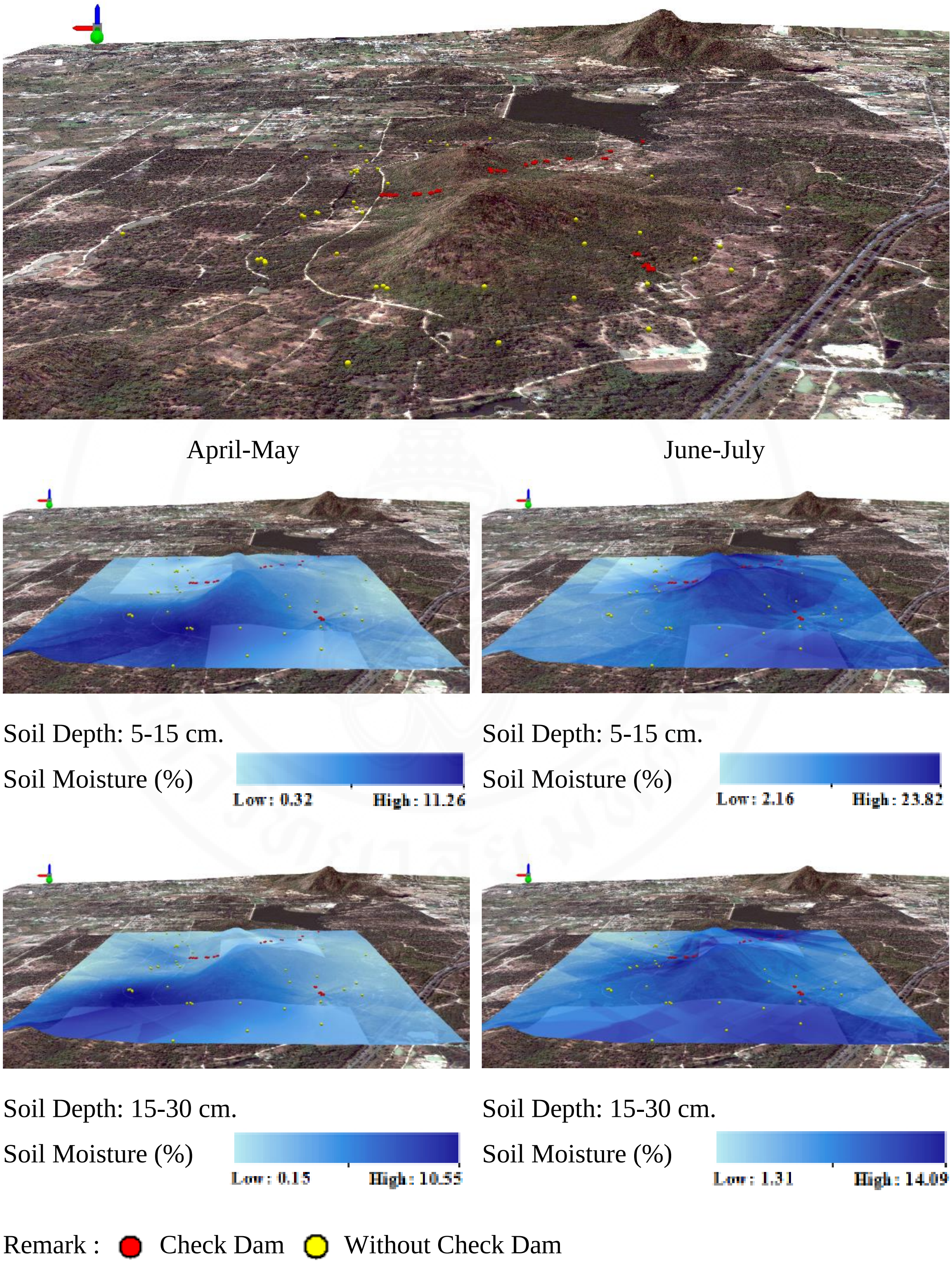
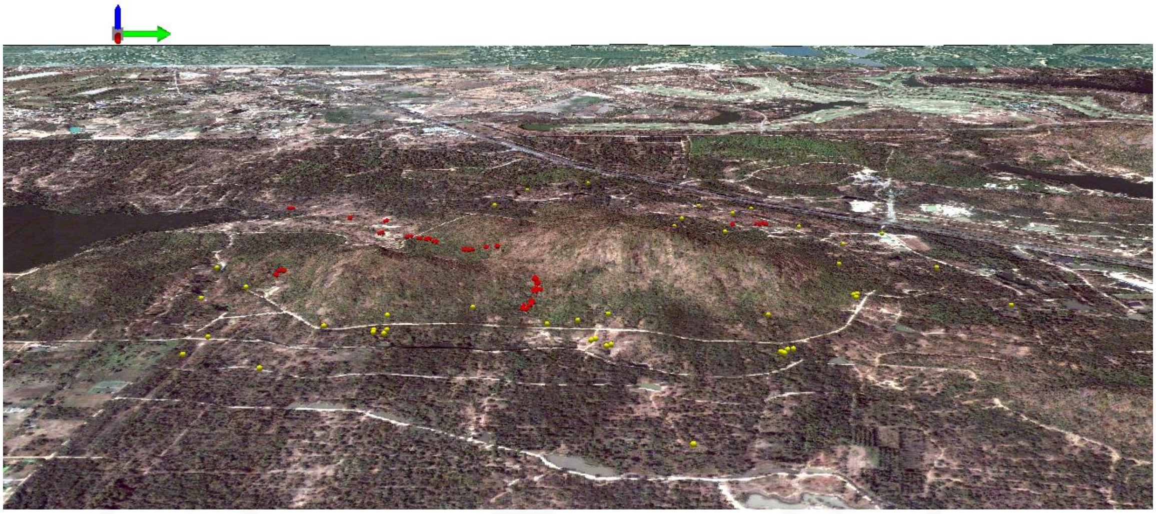
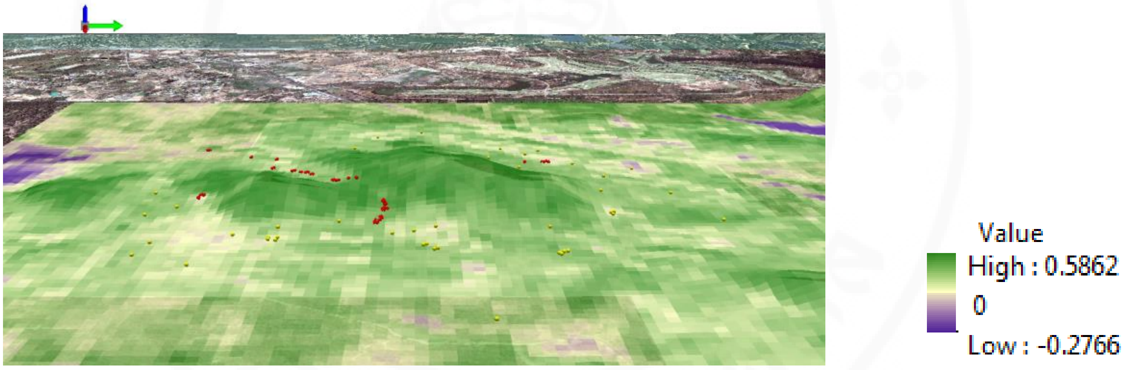


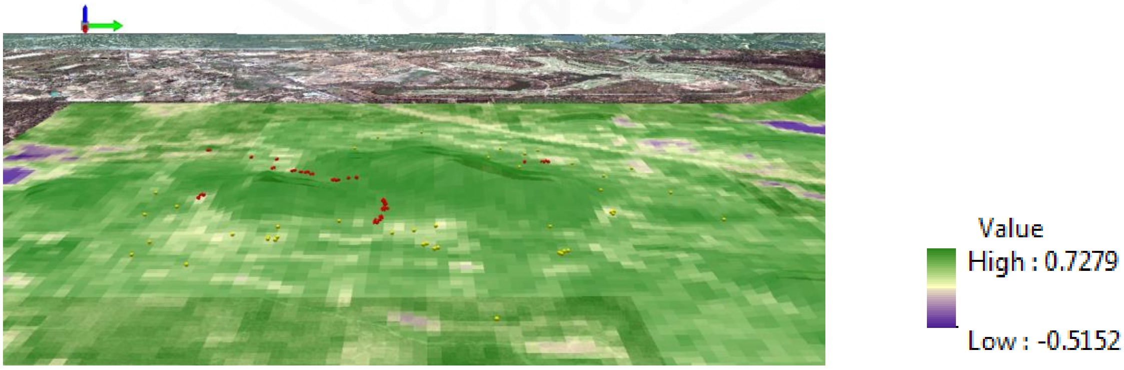
Figure 4-30 Three-dimension map showing north perspective of the study area: Information of area estimation using Co-Kriging method



April-May



June-July



Remark : Check Dam Without Check Dam

Figure 4-31 Three-dimension map showing east perspective of the study area: NDVI data

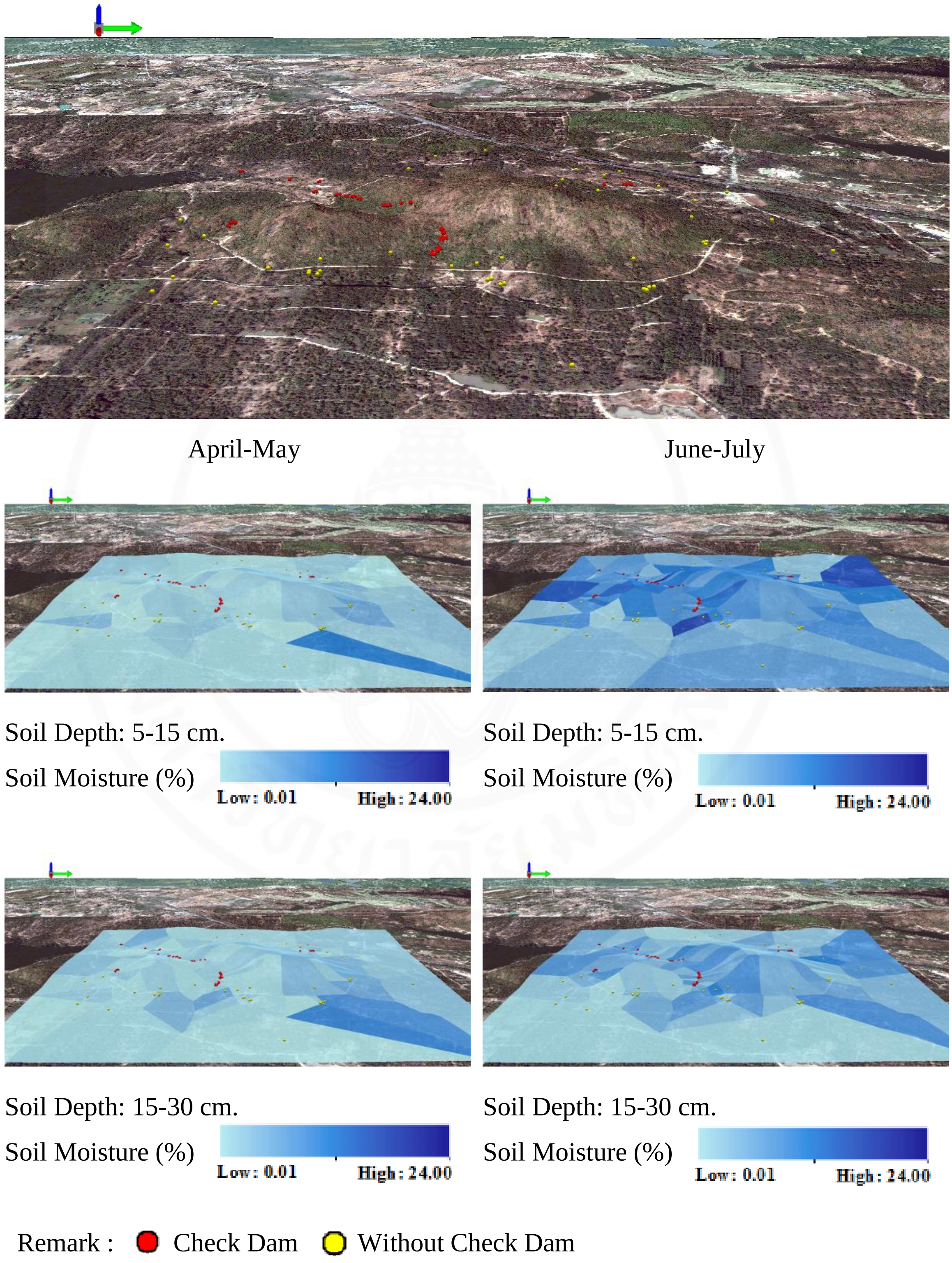


Figure 4-32 Three-dimension map showing east perspective of the study area: Information of area estimation using Thiessen Polygon method

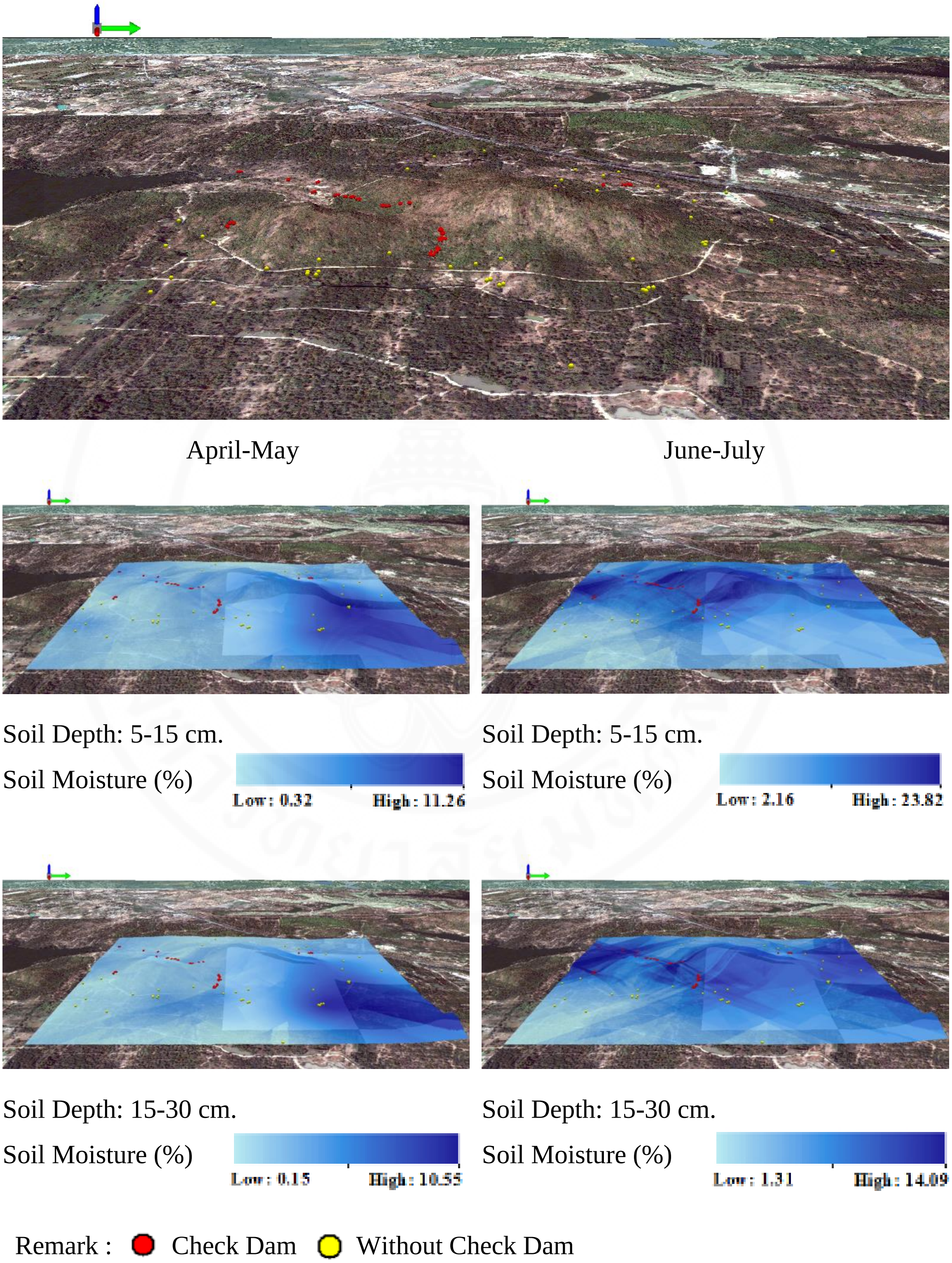
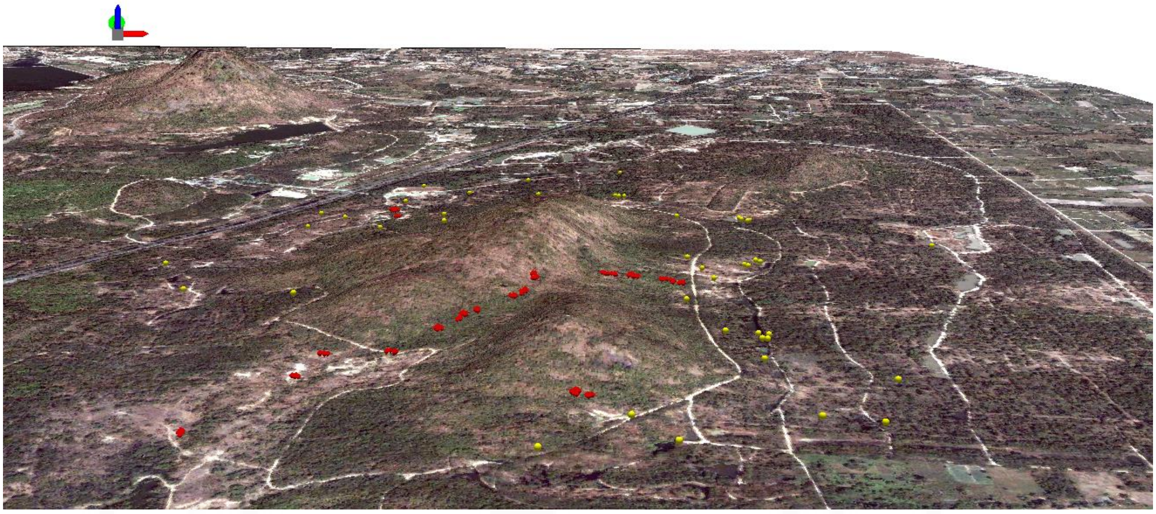
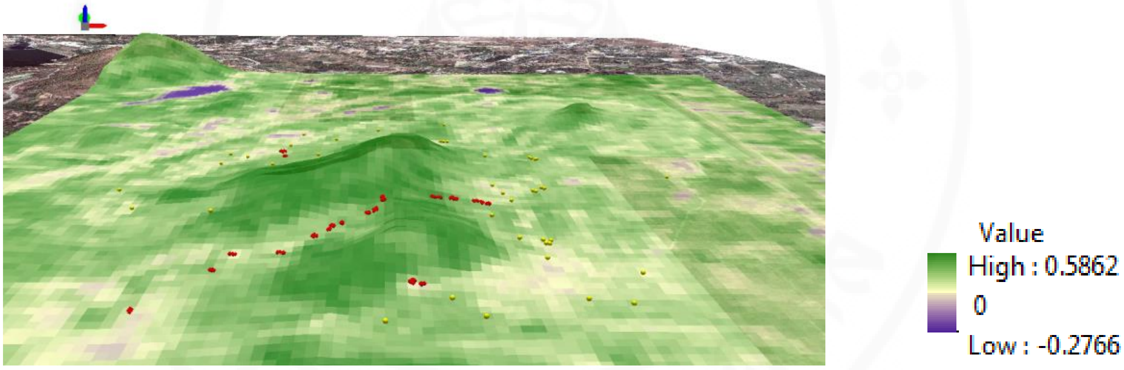


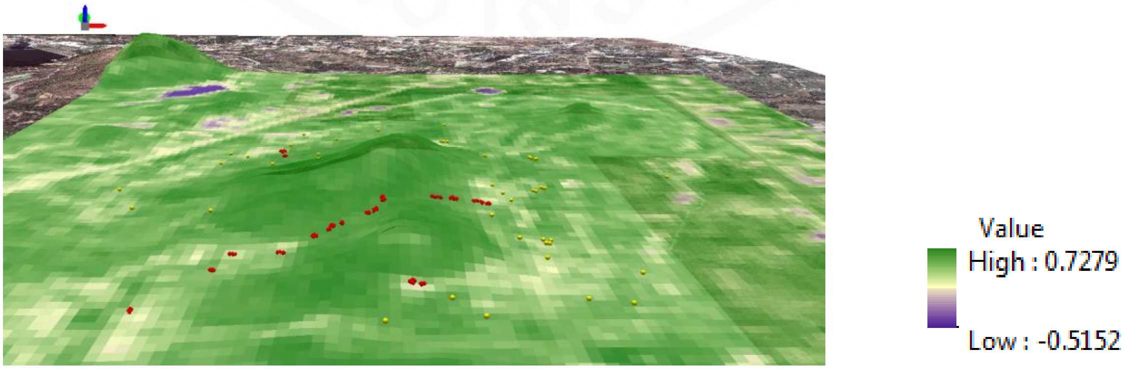
Figure 4-33 Three-dimension map showing east perspective of the study area: Information of area estimation using Co-Kriging method



April-May



June-July



Remark : ● Check Dam ○ Without Check Dam

Figure 4-34 Three-dimension map showing south perspective of the study area: NDVI data

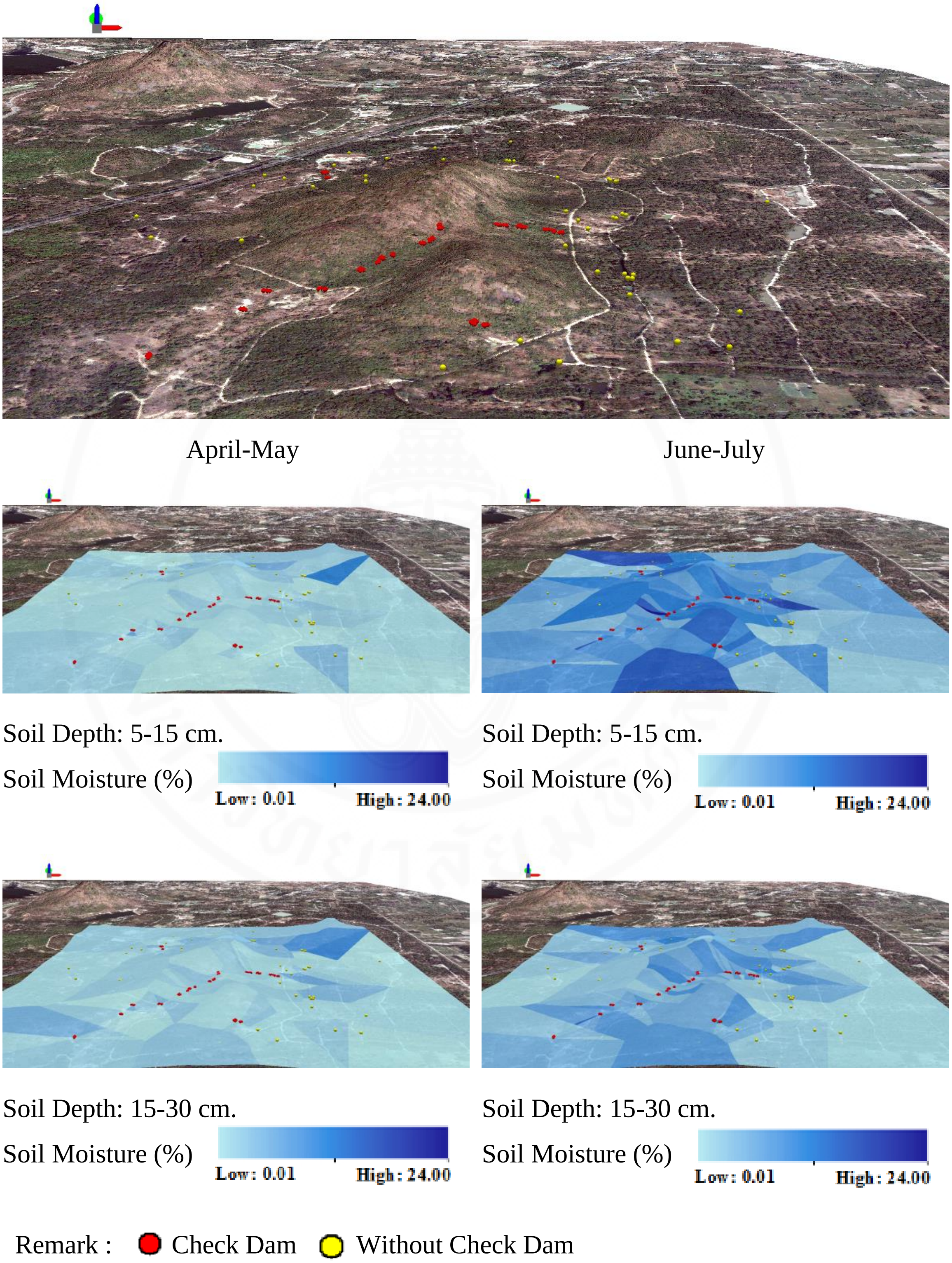


Figure 4-35 Three-dimension map showing south perspective of the study area: Information of area estimation using Thiessen Polygon method

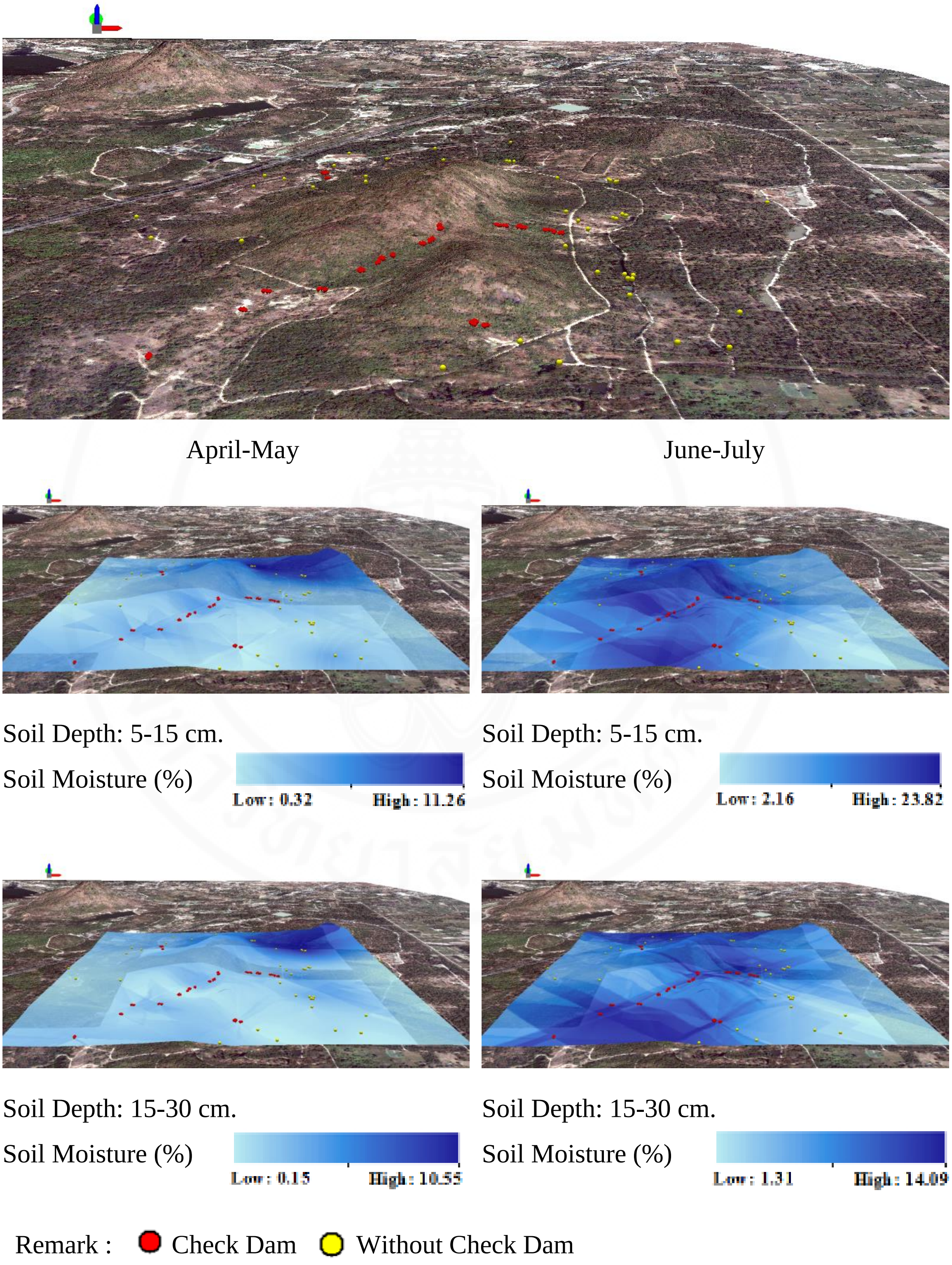
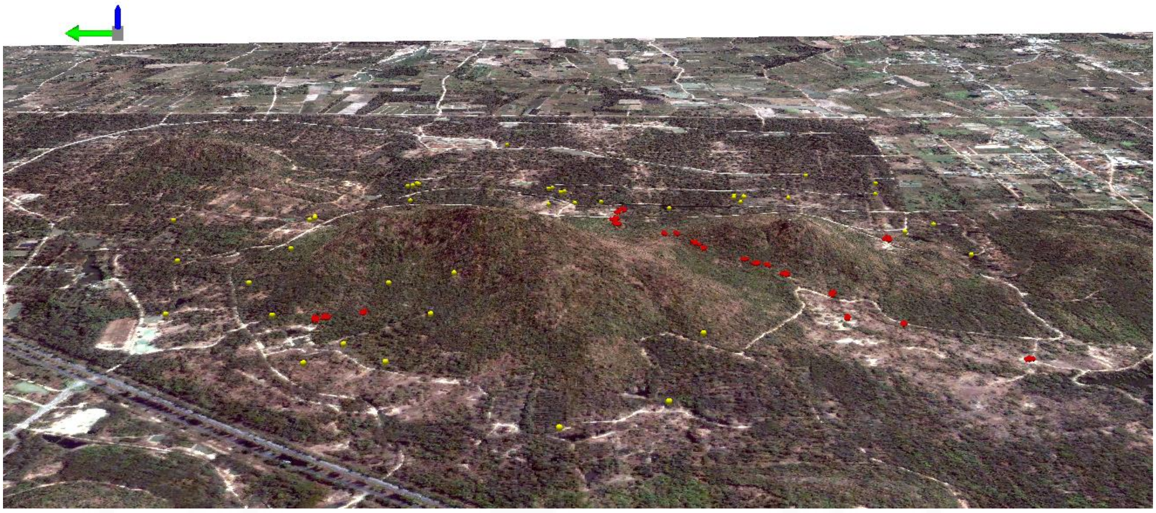
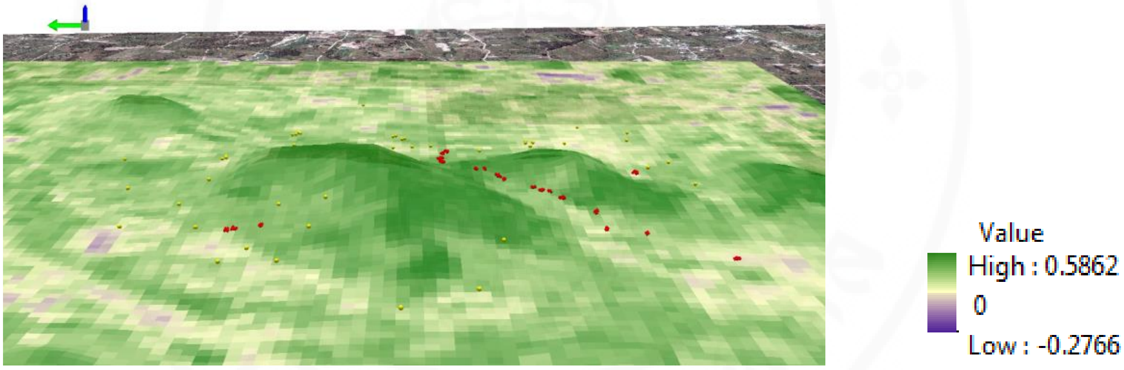


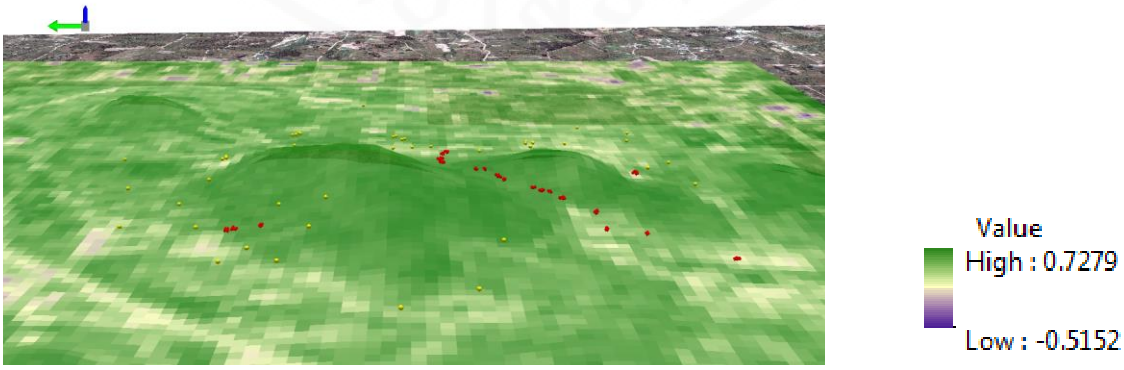
Figure 4-36 Three-dimension map showing south perspective of the study area: Information of area estimation using Co-Kriging method



April-May



June-July



Remark : Check Dam Without Check Dam

Figure 4-37 Three-dimension map showing west perspective of the study area : NDVI data

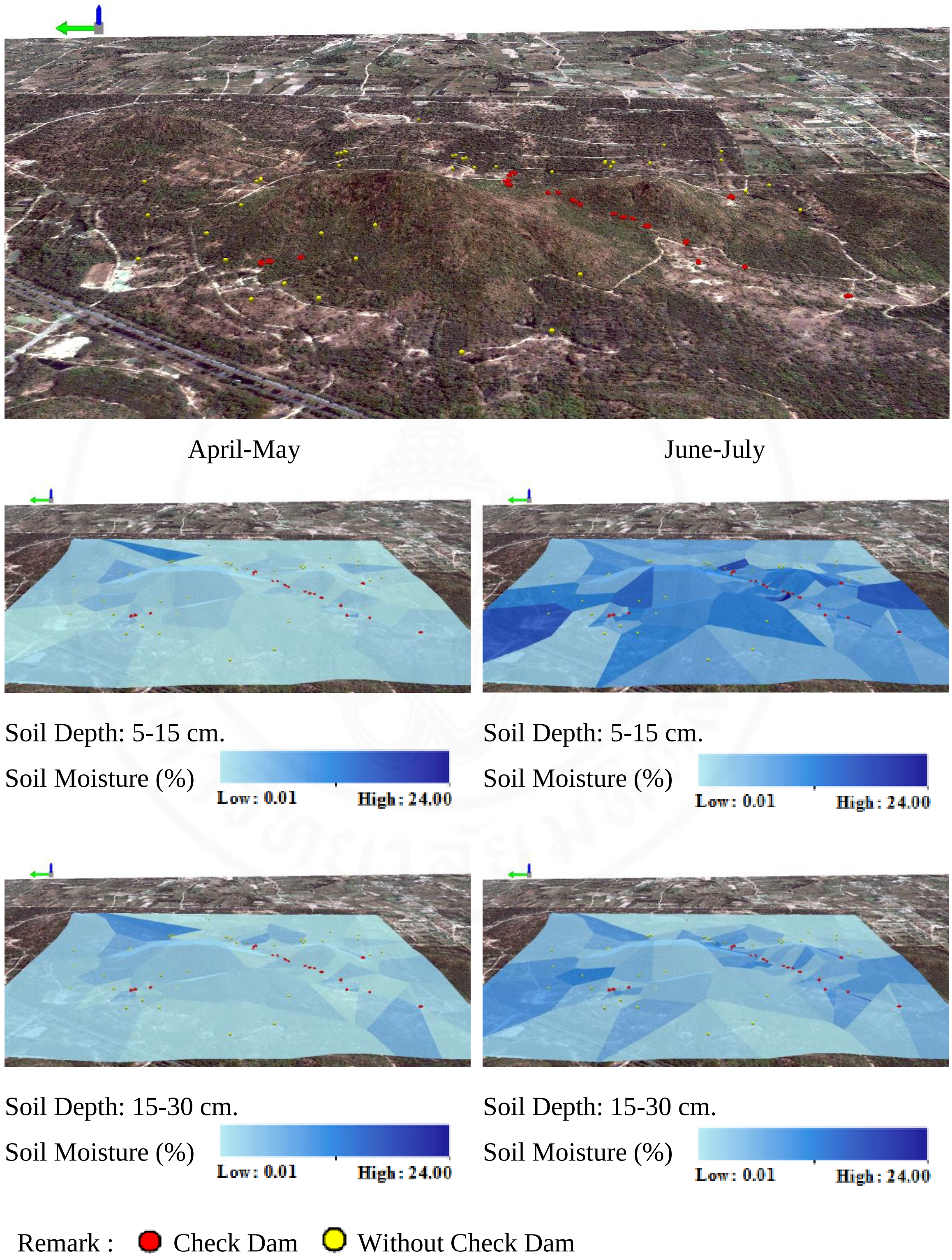


Figure 4-38 Three-dimension map showing west perspective of the study area: Information of area estimation using Thiessen Polygon method

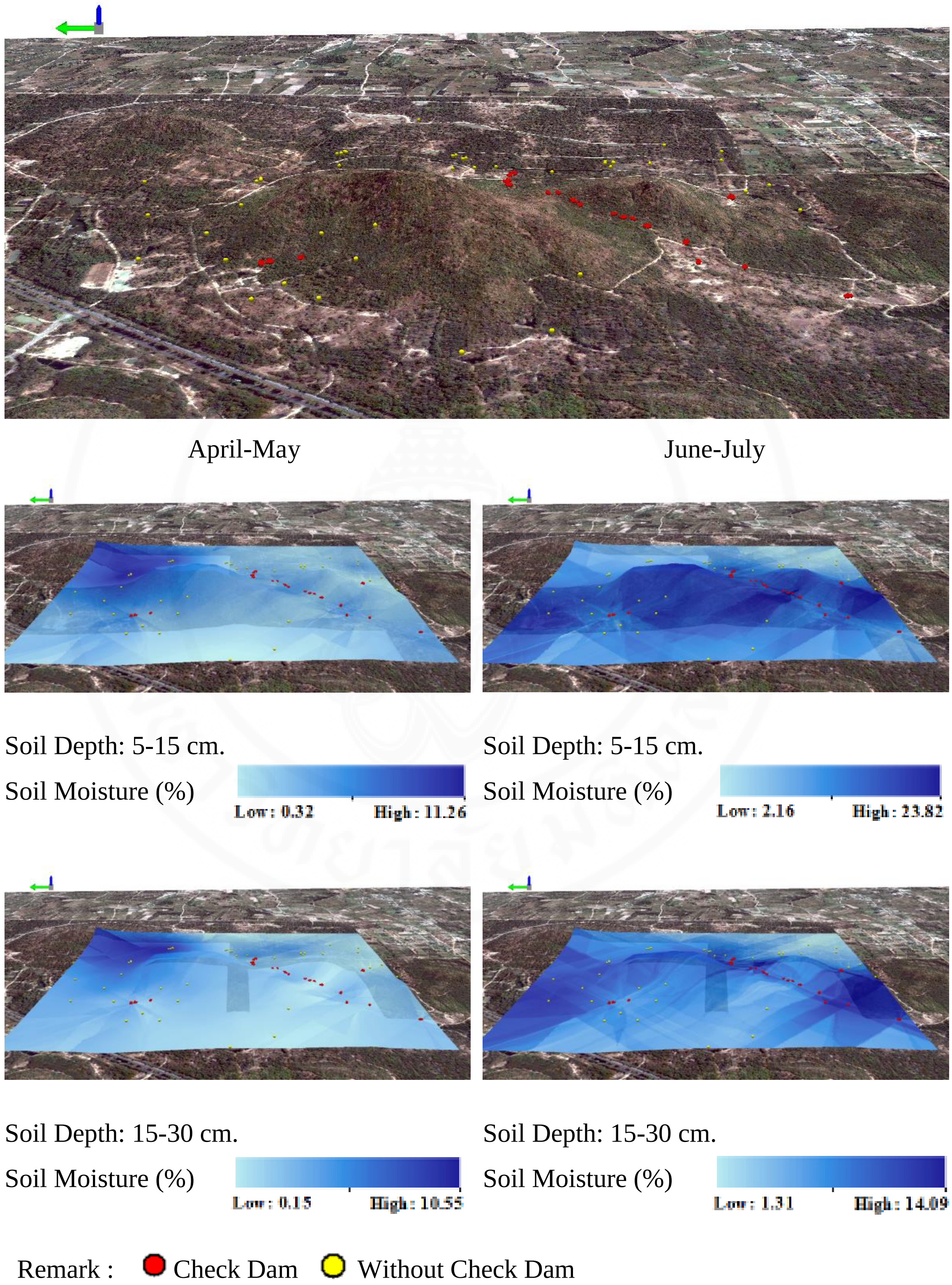


Figure 4-39 Three-dimension map showing west perspective of the study area: Information of area estimation using Co-Kriging method

CHAPETER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The data collection on soil moisture and physical characteristics of the study area, Huay Sai Royal Development Study Center, aims to examine physical characteristics, including altitude, slope, aspects, and soil texture that have the impact on soil moisture distribution and to examine the amount and form of moisture distribution from the check dam. The results can be concluded as follows.

5.1.1 Soil moisture and physical characteristics

In summer, April-May, soil moisture was 0.32-11.26 percent by weight and 0.15-10.55 percent by weight according to the depth. Soil moisture was lesser than rainy season, June-July, where soil moisture was 2.16-23.82 percent by weight and 1.31-14.09 percent by weight according to the depth. At the depth of 5-15 centimeters, soil moisture was higher than that at the depth of 15-30 centimeters. The altitude was 31-85 meters. Most of the area had northeast aspects. The slope was at the level of 2-12, minor slope. Most of soil texture was loamy sand and sand.

5.1.2 Physical characteristics that affect to the distribution of soil moisture

From statistical analysis on physical characteristics that affect to the distribution of soil moisture, it was found that different altitude during June-July related to different average soil moisture at significance level of 0.05 (F=6.49 sig=0.00). At the altitude of 21-40 meters, the average soil moisture was lower than that at the altitude of 41-100 meters. For different aspects of the soil during April-May, the average soil moisture was different at significance level of 0.05 (F=5.40 sig=0.00). At northeast aspect, the average soil moisture was different from the southwest and northwest aspects. For different aspects and soil texture, the average soil moisture was not different in both seasons.

Furthermore, in statistical analysis, sample locations included the areas with and without check dam. For the depth and season, it was found that the average soil moisture during summer was 2.23 percent by weight and that of rainy season was 7.45 percent by weight. The average soil moisture in rainy season was higher than that in summer at significance level of 0.05 (sig=0.000). When considered on the depth, it was found that the average soil moisture in rainy season, June-July, was different. In other words, the soil moisture at the depth of 5-15 centimeters was 9.18 percent by weight. The average soil moisture at the depth of 15-30 centimeters was 5.72 percent by weight. The average soil moisture at the depth of 5-15 centimeters was higher than that at the depth of 15-30 centimeters at significance level of 0.05 (sig=0.00).

For the locations with and without check dam, it was found that the average soil moisture was different. In summer, April-May, the average soil moisture at the locations with check dam was 2.10 percent by weight and that of locations without check dam was 2.64 percent by weight. It can be seen that the average soil moisture of locations without dike was higher than that of the locations with check dam at significance level of 0.05 (sig=0.02). In rainy season, June-July, the average soil moisture of the locations with check dam was 7.73 percent by weight. Soil moisture of the locations without check dam was 6.51 percent by weight. It can be seen that average Soil moisture of the locations with check dam was higher than that of the locations without check dam at significance level of 0.05 (sig=0.005). When considered on the area of Huay Sai Royal Development Study Center, this study area soil moisture distribution system according to royal idea in order to restore deteriorated land. This soil moisture distribution system consists of check dam, terracing, and diversion. This distribution system starts from check dam, which was built on watercourses, mountain pass, and the slopes at the upper part of the mountain. The dam helps slows down water flow. When water level is high it will flows over to the terracing, which is similarly to small reservoir. When the reservoir is full, it will flow along the diversion, which is built as canal or lifted as row around the mountain. When water level is excess, the water will be pumped through the pipe to the terracing and the diversion at the next row. Such moisture distribution system can help maintain soil moisture during summer, April-May. It can be seen that the average soil moisture of the areas without check dam was higher than that of the areas with check dam.

5.1.2 The study on the pattern of soil moisture distribution

From the analysis on area estimation using Thiessen Polygon and Co-Kriging methods, it was found that during April-May, the soil moisture at the depth of 5-15 centimeters was higher than that at the depth of 15-30 centimeters. The moisture spread more in northern and northeastern areas than other study areas. The areas with the least soil moisture distribution were southeastern and western areas. In June-July, soil moisture at the depth of 5-15 centimeters was higher than that at the depth of 15-30 centimeters. Moisture particularly spread more at the areas with check dam. When considered on Normalized Difference Vegetation Index (NDVI) using satellite photograph taken by LANDSAT 5 TM on 15th April 2011, the maximum density (Max) was 0.5862. On 5th August 2011, the maximum density (Max) was 0.7279. When considerd on linear correlation of Thiessen Polygon area estimation with vegetation density (NDVI), it was found that s soil moisture during April-May, had linear correlation at $R^2 = 0.0006$. During June-July, linear correlation was at $R^2 = 0.0038$. For Co-Kriging area estimation, it was found that soil moisture during April-May had linear correlation at $R^2 = 0.0355$. During June-July, linear correlation was at $R^2 = 0.13$.

In this study, satellite photograph taken by Landsat 5 TM on 15th April 2011 was analyzed for vegetation density (NDVI). The photograph was taken 15 days before data collection date during April-May. The satellite photograph on 5th August 2011 was recorded 15 days after data collection date during June-July. From area estimation during April-July, it was found that s soil moisture distribution increased as well as vegetation density (NDVI). In August, the area had more vegetation density than that in April.

5.2 Benefits from the study

From the study on soil moisture distribution from the check dam by using Geo-information technology at the area of Huay Sai Royal Development Study Center, physical factors affecting soil moisture distribution, soil moisture amount, and soil moisture distribution were identified. Such results can be utilized as follows.

5.2.1 Soil moisture distribution, it was found that aspects and altitude were physical characteristics affecting soil moisture distribution of the study area. This is due to the model scheme of Huay Sai Royal Development Study Center, 5th edition (2012-2016). The 3rd strategic plan regarding natural resources and environment conservation and development contains the plan/project for maintaining and building soil and water management system (Check Dam, Terracing, Diversion, and Sediment Trap). The results of this physical characteristics study can be used as the information for designing and selecting the area with physical characteristics appropriate for building check dam or soil moisture distribution system in the future according to the model scheme. This is to assure the effectiveness of soil moisture distribution system resulting abundant area.

5.2.2 From the study on soil moisture distribution by using Geo-information technology to analyze Thiessen Polygon and Co-Kriging area estimation methods, the results showed the values of soil moisture distributed across different areas of the study area. They identified the areas with maximum and minimum soil moisture distribution. The results can be used as a guideline for selecting the area for promotion and natural resources restoration to become more perfect. Especially for the areas with low soil moisture distribution, they can be prioritized for restoration in order that those areas will have increased moisture. In addition, soil moisture value attained from the analysis is also the indicator of the strategy in the balance and support between soil, water and the forest corresponding to 3rd strategic plan regarding natural resources and environment conservation and development.

5.2.3 The objectives of the study on soil moisture distribution from the check dam can be applied with the areas, where check dam construction or soil moisture distribution system is planned, for restoring natural resources in the areas. The study will help in the design and selection on the areas with physical characteristics appropriate for soil moisture distribution, contributing to the actual benefit of soil moisture distribution system.

5.2.4 In this study, soil samples were collected from 3 locations in the areas with check dam. This reveals the values of soil moisture around the dike. In data collection, the area was separated into 3 rows, namely in front of check dam, on the check dam and behind the check dam. For the literatures regarding soil moisture around the check dam, the researcher recommends data collection method presented in this study. However, for soil moisture measurement, the researcher does not recommend using Gravimetric Method. Although it is simple and convenient, the errors in moisture values might be occurred.

5.3 Problems and suggestions

In the study on soil moisture distribution from check dam by using Geo-information technology at the area of Huay Sai Royal Development Study Center, problems, obstacles and suggestions are provided for further study as follows.

5.3.1 Problems and obstacles

1) In soil moisture collection in this study, the researcher used Gravimetric Method for soil moisture measurement. This method measures soil moisture directly. It contains many steps in measuring soil moisture as follows. First, collect soil samples according to assigned locations. Dig the soil at different levels, put the soil in the can quickly and close it tightly. Then weigh the soil sample instantly. After obtaining soil weight, put the soil into the oven at 105 Celsius degree for 24 hours. After that, weigh the soil again after baking. This method is appropriate for small area with small size of samples. In this study 376 soil samples were collected. The researcher must finish soil collection within the period, when satellite photograph was taken. Soil weighting must be performed quickly before the soil losses its moisture. Due to large number of the samples, the researcher could not bake and weigh all soil samples at the same time, the researcher had to separate soil samples for soil moisture analysis based on the researcher’s available time, which was weekend only. Therefore, it took a long time for laboratory operation.

2) In this study, vegetation density (NDVI) was examined by using satellite photograph taken by Landsat 5 TM. The satellite uses passive remote sensing system for photography. This is one system in remote sensing category based on power source. This system consumes natural power source, the sun, which

generates electromagnetic power (EM). It acts as medium transmitting information between the object and data storage. This system mostly receives and records information at daytime since it requires EM energy from the sun. Make the ground objects reflect the signal back to the atmosphere, and then applies sensor to measure reflecting energy. Therefore, this system is not appropriate for receiving information in rainy season due to the limitation from weather, cloud and rain. The signal cannot pass through the cloud. For this reason, this study lacks of satellite photograph for examining vegetation density (NDVI) in rainy season. Apart from the lack of satellite photograph in rainy season, this study also lacks of satellite photograph in summer. From satellite photograph on the date of soil moisture data collection, such area was covered by cloud. Thus, this study requires satellite photograph taken 15 days before the date of data collection in summer and rainy season.

3) The year of this data collection had fluctuate weather because the study area was located in rain shadow area. Therefore, there was little rainfall. However, the year of such data collection had fluctuate weather and there was higher rainfall than the previous years, which can be seen in the information of increasing rainfall in 2011, this weather fluctuation affected to field data collection. The data collection was delayed from the schedule. The data was collected after raining, causing soil moisture at some locations higher than other locations in the same season.

5.3.2 Suggestions

1) The study on soil moisture by using gravimetric method is direct moisture measurement. There are many steps in collecting moisture values, which could to error. Regarding this, there are several methods for soil moisture data collection, such as Electrical Resistance Block, Tensiometer, and Neutron Moisture Gauge. All these are indirect moisture measurement. However, there is another method the research would like to recommend. That is measuring soil moisture using time domain reflectometer (TDR). This is indirect moisture measurement. This method relies on water molecule’s electrical property for evaluating soil moisture. This tool consists of rods, transmission lines, and TDR cable tester. It works by transmitting electric current into the soil, which will return to the tip of the line. Soil

moisture measurement using TDR equipment is popular in measuring water amount in the soil. It is less disturbing for the soil than gravimetric method.

2) Due to the problem and obstacle in the lack of satellite photograph for vegetation density analysis (NDVI), for further study that applies satellite photograph for soil moisture study, the researcher suggests using satellite photograph taken by active remote sensing system. This is one type of remote sensing category. The power source of this system is generated and transmitted to the object. It can be used in both daytime and nighttime. For example, radar system uses the equipment to generate microwave and lidar system generate radio wave or laser. In the function of this system, it transmits the energy to the object area. The energy then backscattered to the receiver. This is because the system has no limitation regarding time and weather since such wave bandwidth is long. It can penetrate cloud, fog and rain, thus there is no obstacle for the study during rainy season, allowing more complete information for the study.

3) In soil moisture data collection in this study, the soil samples were collected at 2 levels of depth, including 5-15 centimeters and 15-30 centimeters. These are considered as ground surface depths. Therefore, the values obtained had little difference. Since the soil in the area of Huay Sai Royal Development Study Center was shallow, the researcher chose to study at 2 levels. For further study, the researcher recommends collecting soil moisture data at 3 levels or above or at the depth beyond 30 centimeters in order to see soil moisture value more clearly.

4) In the study on physical characteristics affecting soil moisture distribution, physical characteristics brought into the study included altitude, slope, aspects and soil texture. There are other factors affecting soil moisture distribution, such as rainfall, land utilization, weather, relative moisture, wind speed and vaporization. The researcher would like to suggest further study on such factors in addition to physical factors examined in this study.

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APPENDIX

Table A: Soil moisture and physical characteristics are presented

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
1	1	5-15	Check Dam	1.22	7.35	45	2-12	East	Loamy Sand	599125	1402772	
		15-30	Check Dam	1.02	4.30	45	2-12	East	Loamy Sand			
	2	5-15	Check Dam	1.84	12.85	45	12-20	East	Loamy Sand	599127	1402772	
		15-30	Check Dam	1.70	1.50	45	12-20	East	Loamy Sand			
	3	5-15	Check Dam	2.80	8.53	45	12-20	East	Loamy Sand	599134	1402771	
		15-30	Check Dam	1.69	2.65	45	12-20	East	Loamy Sand			
	4	5-15	Check Dam	1.38	8.10	44	12-20	East	Loamy Sand	599137	1402779	
		15-30	Check Dam	2.69	5.04	44	12-20	East	Loamy Sand			
	5	5-15	Check Dam	1.62	9.05	44	12-20	East	Sandy Loam	599132	1402783	
		15-30	Check Dam	2.29	6.84	44	12-20	East	Sandy Loam			
	6	5-15	Check Dam	1.67	8.64	44	12-20	East	Loamy Sand	599133	1402782	
		15-30	Check Dam	1.95	6.39	44	12-20	East	Loamy Sand			
2	1	5-15	Check Dam	1.39	10.94	45	2-12	East	Loamy Sand	599113	1402774	
		15-30	Check Dam	1.89	8.55	45	2-12	East	Loamy Sand			
	2	5-15	Check Dam	1.58	10.02	44	2-12	East	Loamy Sand	599112	1402775	
		15-30	Check Dam	2.28	9.97	44	2-12	East	Loamy Sand			
	3	5-15	Check Dam	1.44	6.87	44	2-12	East	Loamy Sand	599114	1402775	
		15-30	Check Dam	2.08	9.72	44	2-12	East	Loamy Sand			
	4	5-15	Check Dam	2.42	7.29	44	12-20	East	Loamy Sand	599117	1402785	
		15-30	Check Dam	1.94	3.46	44	12-20	East	Loamy Sand			
	5	5-15	Check Dam	3.10	6.46	44	12-20	Southeast	Loamy Sand	599111	1402790	
		15-30	Check Dam	3.29	5.69	44	12-20	Southeast	Sand			
	6	5-15	Check Dam	2.17	8.23	44	12-20	Southeast	Sand	599110	1402791	
		15-30	Check Dam	1.89	5.49	44	12-20	Southeast	Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
3	1	5-15	Check Dam	2.83	8.07	46	20-35	East	Sand	599094	1402793	
		15-30	Check Dam	2.24	8.87	46	20-35	East	Sand			
	2	5-15	Check Dam	3.07	5.08	46	20-35	East	Sandy Loam	599088	1402792	
		15-30	Check Dam	2.15	7.53	46	20-35	East	Loamy Sand			
	3	5-15	Check Dam	2.65	9.79	46	20-35	East	Sandy Loam	599091	1402787	
		15-30	Check Dam	2.32	8.58	46	20-35	East	Loamy Sand			
	4	5-15	Check Dam	2.79	7.99	46	20-35	Southeast	Sandy Clay Loam	599103	1402792	
		15-30	Check Dam	2.85	3.31	46	20-35	Southeast	Sandy Clay Loam			
	5	5-15	Check Dam	1.85	9.17	46	20-35	East	Sandy Clay Loam	599100	1402792	
		15-30	Check Dam	1.54	2.95	46	20-35	East	Loamy Sand			
	6	5-15	Check Dam	2.20	10.90	46	20-35	Southeast	Sandy Clay	599099	1402796	
		15-30	Check Dam	1.76	3.19	46	20-35	Southeast	Loamy Sand			
4	1	5-15	Check Dam	1.78	9.45	54	12-20	Northeast	Sand	599030	1402792	
		15-30	Check Dam	2.72	7.58	54	12-20	Northeast	Sand			
	2	5-15	Check Dam	2.03	9.57	54	12-20	Northeast	Loamy Sand	599034	1402795	
		15-30	Check Dam	2.83	4.72	54	12-20	Northeast	Sand			
	3	5-15	Check Dam	2.35	5.99	54	12-20	Northeast	Silty Clay Loam	599039	1402793	
		15-30	Check Dam	2.85	2.87	54	12-20	Northeast	Loamy Sand			
	4	5-15	Check Dam	2.15	8.46	54	12-20	Northeast	Loamy Sand	599038	1402799	
		15-30	Check Dam	2.07	5.12	54	12-20	Northeast	Loamy Sand			
	5	5-15	Check Dam	2.08	10.70	54	12-20	Northeast	Loamy Sand	599041	1402800	
		15-30	Check Dam	1.90	7.37	54	12-20	Northeast	Loamy Sand			
	6	5-15	Check Dam	1.84	8.31	54	12-20	Northeast	Sandy Loam	599036	1402800	
		15-30	Check Dam	2.10	5.51	54	12-20	Northeast	Sandy Loam			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
5	1	5-15	Check Dam	1.55	11.58	59	12-20	Northeast	Loamy Sand	599019	1402801	
		15-30	Check Dam	1.76	6.06	59	12-20	Northeast	Sand			
	2	5-15	Check Dam	2.32	10.24	59	12-20	Northeast	Loamy Sand	599019	1402798	
		15-30	Check Dam	2.30	9.19	59	12-20	Northeast	Loamy Sand			
	3	5-15	Check Dam	1.78	9.68	54	12-20	Northeast	Loamy Sand	599027	1402803	
		15-30	Check Dam	2.37	6.26	54	12-20	Northeast	Loamy Sand			
	4	5-15	Check Dam	1.94	12.44	53	20-35	Southeast	Silty Clay Loam	599030	1402811	
		15-30	Check Dam	1.82	6.95	53	20-35	Southeast	Silty Clay Loam			
	5	5-15	Check Dam	1.46	11.69	53	20-35	Southeast	Sandy Clay	599026	1402810	
		15-30	Check Dam	1.71	8.35	53	20-35	Southeast	Sandy Clay Loam			
	6	5-15	Check Dam	2.29	8.17	53	20-35	Southeast	Sandy Clay Loam	599024	1402807	
		15-30	Check Dam	2.35	9.15	53	20-35	Southeast	Sandy Clay Loam			
6	1	5-15	Check Dam	1.89	8.50	59	20-35	Northeast	Loamy Sand	598993	1402800	
		15-30	Check Dam	1.92	8.51	59	20-35	Northeast	Loamy Sand			
	2	5-15	Check Dam	2.06	8.40	62	20-35	Northeast	Loamy Sand	598989	1402797	
		15-30	Check Dam	2.94	4.30	62	20-35	Northeast	Loamy Sand			
	3	5-15	Check Dam	1.47	9.03	59	20-35	Northeast	Loamy Sand	598992	1402799	
		15-30	Check Dam	3.18	7.06	59	20-35	Northeast	Loamy Sand			
	4	5-15	Check Dam	1.90	13.99	55	20-35	East	Sandy Loam	598991	1402805	
		15-30	Check Dam	2.31	5.06	55	20-35	East	Loamy Sand			
	5	5-15	Check Dam	1.88	13.73	59	20-35	East	Silty Clay Loam	598991	1402804	
		15-30	Check Dam	2.07	6.57	59	20-35	East	Sandy Loam			
	6	5-15	Check Dam	2.40	14.33	62	20-35	East	Sand	598984	1402803	
		15-30	Check Dam	1.60	7.07	62	20-35	East	Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
7	1	5-15	Check Dam	1.87	8.70	62	20-35	Northeast	Sandy Clay Loam	598970	1402790	
		15-30	Check Dam	2.42	4.08	62	20-35	Northeast	Sandy Clay Loam			
	2	5-15	Check Dam	2.47	9.91	62	20-35	Northeast	Silty Clay	598973	1402791	
		15-30	Check Dam	1.84	5.50	62	20-35	Northeast	Silty Clay			
	3	5-15	Check Dam	2.33	10.53	62	20-35	Northeast	Silty Clay	598976	1402794	
		15-30	Check Dam	2.05	5.95	62	20-35	Northeast	Silty Clay			
	4	5-15	Check Dam	2.45	10.77	62	20-35	East	Sandy Loam	598969	1402798	
		15-30	Check Dam	3.23	5.73	62	20-35	East	Loamy Sand			
	5	5-15	Check Dam	3.39	7.97	62	20-35	Northeast	Loamy Sand	598966	1402795	
		15-30	Check Dam	2.98	4.74	62	20-35	Northeast	Loamy Sand			
	6	5-15	Check Dam	2.74	11.93	62	20-35	Northeast	Loamy Sand	598962	1402795	
		15-30	Check Dam	2.22	9.68	62	20-35	Northeast	Loamy Sand			
8	1	5-15	Check Dam	1.69	10.10	85	12-20	South	Loamy Sand	598815	1402697	
		15-30	Check Dam	1.83	8.87	85	12-20	South	Sand			
	2	5-15	Check Dam	1.68	7.08	85	12-20	South	Loamy Sand	598816	1402698	
		15-30	Check Dam	1.76	6.49	85	12-20	South	Loamy Sand			
	3	5-15	Check Dam	1.82	9.90	85	12-20	South	Loamy Sand	598813	1402692	
		15-30	Check Dam	1.66	8.61	85	12-20	South	Loamy Sand			
	4	5-15	Check Dam	0.93	9.39	85	12-20	South	Loamy Sand	598818	1402695	
		15-30	Check Dam	2.31	4.44	85	12-20	South	Loamy Sand			
	5	5-15	Check Dam	1.95	8.07	85	12-20	South	Loamy Sand	598819	1402693	
		15-30	Check Dam	1.76	3.01	85	12-20	South	Sand			
	6	5-15	Check Dam	2.52	10.33	85	12-20	South	Loamy Sand	598820	1402697	
		15-30	Check Dam	2.33	8.79	85	12-20	South	Loamy Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
9	1	5-15	Check Dam	1.46	11.90	80	12-20	West	Loamy Sand	598814	1402666	
		15-30	Check Dam	3.28	9.09	80	12-20	West	Loamy Sand			
	2	5-15	Check Dam	1.93	9.99	80	12-20	West	Loamy Sand	598817	1402667	
		15-30	Check Dam	1.86	11.43	80	12-20	West	Loamy Sand			
	3	5-15	Check Dam	2.13	9.47	80	12-20	West	Loamy Sand	598817	1402666	
		15-30	Check Dam	1.84	10.14	80	12-20	West	Loamy Sand			
	4	5-15	Check Dam	1.48	9.64	80	12-20	West	Loamy Sand	598824	1402667	
		15-30	Check Dam	1.99	7.58	80	12-20	West	Loamy Sand			
	5	5-15	Check Dam	4.13	8.63	80	12-20	West	Loamy Sand	598820	1402665	
		15-30	Check Dam	2.72	8.65	80	12-20	West	Sand			
	6	5-15	Check Dam	2.04	7.23	80	12-20	West	Loamy Sand	598821	1402670	
		15-30	Check Dam	2.19	5.55	80	12-20	West	Sand			
10	1	5-15	Check Dam	2.34	7.59	77	12-20	West	Sandy Clay Loam	598800	1402633	
		15-30	Check Dam	2.34	3.77	77	12-20	West	Loamy Sand			
	2	5-15	Check Dam	1.66	8.24	77	12-20	West	Loamy Sand	598796	1402628	
		15-30	Check Dam	2.23	4.52	77	12-20	West	Sandy Loam			
	3	5-15	Check Dam	2.18	12.75	77	12-20	West	Loamy Sand	598791	1402628	
		15-30	Check Dam	3.12	5.41	77	12-20	West	Sand			
	4	5-15	Check Dam	2.32	6.65	80	12-20	Northwest	Sand	598792	1402618	
		15-30	Check Dam	2.55	4.60	80	12-20	Northwest	Sandy Loam			
	5	5-15	Check Dam	2.03	10.97	80	12-20	Northwest	Sandy Clay	598796	1402622	
		15-30	Check Dam	1.95	3.23	80	12-20	Northwest	Loamy Sand			
	6	5-15	Check Dam	1.60	12.41	77	12-20	West	Sandy Clay	598802	1402624	
		15-30	Check Dam	1.86	4.37	77	12-20	West	Sandy Clay			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
11	1	5-15	Check Dam	3.32	12.95	73	20-35	West	Sandy Clay Loam	598770	1402612	
		15-30	Check Dam	3.33	10.37	73	20-35	West	Sandy Clay Loam			
	2	5-15	Check Dam	3.08	12.13	73	20-35	West	Sandy Clay Loam	598778	1402611	
		15-30	Check Dam	2.99	8.54	73	20-35	West	Sandy Clay Loam			
	3	5-15	Check Dam	3.80	10.30	73	20-35	West	Sandy Clay Loam	598775	1402611	
		15-30	Check Dam	3.17	4.03	73	20-35	West	Sandy Clay Loam			
	4	5-15	Check Dam	2.00	13.64	73	20-35	West	Sandy Clay Loam	598779	1402605	
		15-30	Check Dam	2.39	6.35	73	20-35	West	Sandy Clay Loam			
	5	5-15	Check Dam	1.61	4.74	73	20-35	West	Silty Clay Loam	598774	1402607	
		15-30	Check Dam	2.11	3.64	73	20-35	West	Silty Clay Loam			
	6	5-15	Check Dam	2.53	5.98	73	20-35	West	Silty Clay Loam	598781	1402610	
		15-30	Check Dam	1.97	4.27	73	20-35	West	Silty Clay Loam			
12	1	5-15	Check Dam	2.20	10.06	72	2-12	Northwest	Sandy Clay Loam	598710	1402530	
		15-30	Check Dam	2.06	5.16	72	2-12	Northwest	Sandy Loam			
	2	5-15	Check Dam	2.13	12.05	72	2-12	Northwest	Silty Clay Loam	598708	1402531	
		15-30	Check Dam	2.53	4.03	72	2-12	Northwest	Sandy Loam			
	3	5-15	Check Dam	2.13	9.70	72	2-12	Northwest	Silty Clay Loam	598705	1402527	
		15-30	Check Dam	2.52	4.60	72	2-12	Northwest	Sandy Loam			
	4	5-15	Check Dam	2.45	10.67	72	2-12	Northwest	Silty Clay Loam	598709	1402521	
		15-30	Check Dam	2.23	3.61	72	2-12	Northwest	Sandy Loam			
	5	5-15	Check Dam	2.20	11.88	72	2-12	Northwest	Silty Clay Loam	598710	1402521	
		15-30	Check Dam	2.32	4.87	72	2-12	Northwest	Sandy Loam			
	6	5-15	Check Dam	2.34	9.57	72	2-12	Northwest	Sandy Clay Loam	598709	1402522	
		15-30	Check Dam	2.03	4.06	72	2-12	Northwest	Sandy Clay Loam			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
13	1	5-15	Check Dam	1.63	10.29	70	2-12	West	Silty Clay Loam	598687	1402497	
		15-30	Check Dam	1.47	4.45	70	2-12	West	Silty Clay Loam			
	2	5-15	Check Dam	2.10	11.02	69	12-20	Southwest	Silty Clay Loam	598689	1402503	
		15-30	Check Dam	1.95	4.89	69	12-20	Southwest	Silty Clay Loam			
	3	5-15	Check Dam	1.60	9.84	70	12-20	West	Silty Clay Loam	598687	1402501	
		15-30	Check Dam	1.69	4.32	70	12-20	West	Sandy Loam			
	4	5-15	Check Dam	0.92	8.96	69	12-20	Southwest	Loamy Sand	598683	1402511	
		15-30	Check Dam	1.59	5.39	69	12-20	Southwest	Sand			
	5	5-15	Check Dam	1.88	15.07	69	2-12	Southwest	Silty Clay	598680	1402508	
		15-30	Check Dam	2.20	5.98	69	2-12	Southwest	Sandy Clay			
	6	5-15	Check Dam	2.36	23.82	69	2-12	Southwest	Sandy Clay	598678	1402504	
		15-30	Check Dam	1.50	4.27	69	2-12	Southwest	Sandy Clay			
14	1	5-15	Check Dam	2.19	12.88	70	2-12	West	Sandy Loam	598678	1402478	
		15-30	Check Dam	2.28	9.01	70	2-12	West	Sand			
	2	5-15	Check Dam	1.85	10.80	70	2-12	West	Sandy Loam	598679	1402484	
		15-30	Check Dam	1.44	6.30	70	2-12	West	Loamy Sand			
	3	5-15	Check Dam	1.87	2.29	70	2-12	West	Sandy Clay	598679	1402485	
		15-30	Check Dam	1.56	3.81	70	2-12	West	Sandy Clay			
	4	5-15	Check Dam	1.36	11.69	70	2-12	West	Sandy Clay	598677	1402484	
		15-30	Check Dam	1.19	3.45	70	2-12	West	Loamy Sand			
	5	5-15	Check Dam	1.48	10.46	70	2-12	West	Sandy Clay	598678	1402485	
		15-30	Check Dam	1.22	3.18	70	2-12	Wes	Loamy Sand			
	6	5-15	Check Dam	1.13	10.81	70	2-12	West	Sandy Loam	598673	1402477	
		15-30	Check Dam	1.55	6.06	70	2-12	West	Loamy Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
15	1	5-15	Check Dam	1.72	8.94	67	2-12	West	Loamy Sand	598639	1402441	
		15-30	Check Dam	1.11	3.51	67	2-12	West	Loamy Sand			
	2	5-15	Check Dam	1.74	5.43	67	2-12	West	Sandy Loam	598646	1402444	
		15-30	Check Dam	1.58	4.74	67	2-12	West	Sandy Loam			
	3	5-15	Check Dam	2.04	10.71	67	2-12	West	Silty Clay Loam	598646	1402447	
		15-30	Check Dam	2.46	4.39	67	2-12	West	Silty Clay Loam			
	4	5-15	Check Dam	0.94	10.44	67	2-12	West	Sandy Loam	598638	1402454	
		15-30	Check Dam	0.57	3.64	67	2-12	West	Sandy Loam			
	5	5-15	Check Dam	1.51	7.66	67	2-12	West	Sandy Loam	598638	1402456	
		15-30	Check Dam	1.20	2.75	67	2-12	West	Sandy Loam			
	6	5-15	Check Dam	1.37	9.99	65	2-12	West	Sandy Loam	598634	1402447	
		15-30	Check Dam	1.09	4.20	65	2-12	West	Sandy Loam			
16	1	5-15	Check Dam	3.75	8.86	60	0-2	West	Sandy Loam	598560	1402366	
		15-30	Check Dam	4.51	8.16	60	0-2	West	Sandy Loam			
	2	5-15	Check Dam	1.46	7.67	60	2-12	West	Loamy Sand	598554	1402364	
		15-30	Check Dam	2.21	6.50	60	2-12	West	Loamy Sand			
	3	5-15	Check Dam	1.56	10.12	60	2-12	West	Sandy Loam	598553	1402362	
		15-30	Check Dam	2.47	6.09	60	2-12	West	Sand			
	4	5-15	Check Dam	2.23	7.15	60	2-12	West	Loamy Sand	598568	1402356	
		15-30	Check Dam	1.80	4.63	60	2-12	West	Sandy Loam			
	5	5-15	Check Dam	3.60	8.61	60	2-12	West	Loamy Sand	598571	1402357	
		15-30	Check Dam	3.61	6.11	60	2-12	West	Sand			
	6	5-15	Check Dam	1.39	10.57	60	0-2	West	Sandy Loam	598568	1402360	
		15-30	Check Dam	1.39	7.74	60	0-2	West	Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
17	1	5-15	Check Dam	1.04	4.88	55	2-12	South	Silty Clay Loam	598435	1402359	
		15-30	Check Dam	0.92	4.67	55	2-12	South	Silty Clay Loam			
	2	5-15	Check Dam	1.27	7.42	55	2-12	South	Silty Clay Loam	598437	1402356	
		15-30	Check Dam	0.81	6.87	55	2-12	South	Silty Clay Loam			
	3	5-15	Check Dam	1.11	9.75	55	2-12	South	Loamy Sand	598435	1402356	
		15-30	Check Dam	0.98	9.72	55	2-12	South	Loamy Sand			
	4	5-15	Check Dam	7.49	8.39	55	2-12	South	Sand	598445	1402352	
		15-30	Check Dam	5.22	8.45	55	2-12	South	Sand			
	5	5-15	Check Dam	2.41	7.44	55	2-12	South	Sand	598450	1402354	
		15-30	Check Dam	2.86	6.72	55	2-12	South	Sand			
	6	5-15	Check Dam	1.82	9.32	55	2-12	South	Loamy Sand	598443	1402356	
		15-30	Check Dam	2.27	4.04	55	2-12	South	Loamy Sand			
18	1	5-15	Check Dam	1.71	16.70	52	2-12	West	Sandy Loam	598407	1402252	
		15-30	Check Dam	2.12	4.09	52	2-12	West	Sandy Loam			
	2	5-15	Check Dam	1.53	10.13	52	2-12	West	Sand	598407	1402253	
		15-30	Check Dam	2.09	7.90	52	2-12	Wes	Sand			
	3	5-15	Check Dam	2.08	7.31	52	2-12	West	Sand	598406	1402253	
		15-30	Check Dam	2.10	7.78	52	2-12	West	Sand			
	4	5-15	Check Dam	1.47	9.05	52	2-12	West	Loamy Sand	598412	1402248	
		15-30	Check Dam	1.63	6.67	52	2-12	West	Sand			
	5	5-15	Check Dam	1.28	11.46	52	2-12	West	Loamy Sand	598413	1402253	
		15-30	Check Dam	1.60	6.62	52	2-12	West	Loamy Sand			
	6	5-15	Check Dam	1.52	9.23	52	2-12	West	Loamy Sand	598417	1402248	
		15-30	Check Dam	0.99	8.09	52	2-12	West	Loamy Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
19	1	5-15	Check Dam	2.53	8.03	47	0-2	Southeast	Sandy Clay Loam	598272	1402057	
		15-30	Check Dam	5.08	3.24	47	0-2	Southeast	Loamy Sand			
	2	5-15	Check Dam	2.28	6.39	47	0-2	Southeast	Sand	598271	1402051	
		15-30	Check Dam	1.85	5.29	47	0-2	Southeast	Sand			
	3	5-15	Check Dam	2.46	3.05	47	0-2	Southeast	Sand	598276	1402051	
		15-30	Check Dam	1.44	2.92	47	0-2	Southeast	Loamy Sand			
	4	5-15	Check Dam	2.37	9.32	46	0-2	South	Loamy Sand	598275	1402043	
		15-30	Check Dam	2.52	5.85	46	0-2	South	Loamy Sand			
	5	5-15	Check Dam	1.95	3.86	47	0-2	Southeast	Sandy Clay Loam	598275	1402048	
		15-30	Check Dam	1.35	9.41	47	0-2	Southeast	Sandy Clay Loam			
	6	5-15	Check Dam	2.76	7.43	47	0-2	Southeast	Sandy Loam	598276	1402052	
		15-30	Check Dam	2.31	4.57	47	0-2	Southeast	Sandy Clay Loam			
20	1	5-15	Without Check Dam	1.59	12.48	73	2-12	Southwest	Loamy Sand	598333	1402653	
		15-30	Without Check Dam	2.04	3.47	73	2-12	Southeast	Loamy Sand			
21	1	5-15	Without Check Dam	1.39	5.65	62	2-12	West	Loamy Sand	598091	1402736	
		15-30	Without Check Dam	1.33	1.81	62	2-12	West	Loamy Sand			
22	1	5-15	Without Check Dam	0.32	7.05	56	2-12	West	Sand	598001	1402923	
		15-30	Without Check Dam	1.75	2.00	56	2-12	West	Sand			
23	1	5-15	Without Check Dam	1.46	11.05	52	2-12	West	Sand	598256	1403248	
		15-30	Without Check Dam	1.90	6.36	52	2-12	West	Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
24	1	5-15	Without Check Dam	1.34	6.94	52	2-12	Northwest	Sand	598334	1403339	
		15-30	Without Check Dam	2.08	2.57	52	2-12	Northwest	Sand			
25	1	5-15	Without Check Dam	2.03	3.84	48	2-12	Northwest	Sand	598263	1403401	
		15-30	Without Check Dam	2.15	3.16	48	2-12	Northwest	Sand			
26	1	5-15	Without Check Dam	1.59	3.40	48	2-12	Northwest	Sandy Clay Loam	598471	1403507	
		15-30	Without Check Dam	1.20	5.22	48	2-12	Northwest	Sandy Loam			
27	1	5-15	Check Dam	3.50	10.71	50	2-12	Northwest	Loamy Sand	598444	1403419	
		15-30	Check Dam	4.15	3.77	50	2-12	Northwest	Loamy Sand			
	2	5-15	Check Dam	4.86	10.92	50	2-12	Northwest	Loamy Sand	598446	1403414	
		15-30	Check Dam	3.98	6.26	50	2-12	Northwest	Loamy Sand			
	3	5-15	Check Dam	4.62	.37	50	2-12	Northwest	Loamy Sand	598442	1403410	
		15-30	Check Dam	4.73	6.23	50	2-12	Northwest	Loamy Sand			
	4	5-15	Check Dam	2.07	9.28	50	2-12	Northwest	Sandy Clay Loam	598453	1403417	
		15-30	Check Dam	2.13	5.79	50	2-12	Northwest	Loamy Sand			
	5	5-15	Check Dam	1.33	6.06	51	2-12	Northwest	Sandy Loam	598455	1403413	
		15-30	Check Dam	2.11	5.10	51	2-12	Northwest	Sandy Loam			
	6	5-15	Check Dam	2.28	8.79	51	2-12	Northwest	Sandy Clay Loam	598456	1403420	
		15-30	Check Dam	1.67	4.79	51	2-12	Northwest	Sandy Clay Loam			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
28	1	5-15	Check Dam	0.89	5.44	52	12-20	Northwest	Sandy Clay Loam	598453	1403397	
		15-30	Check Dam	0.90	3.91	52	12-20	Northwest	Sandy Clay Loam			
	2	5-15	Check Dam	1.46	11.19	52	2-12	Northwest	Sandy Loam	598451	1403391	
		15-30	Check Dam	0.87	9.41	52	2-12	Northwest	Sandy Loam			
	3	5-15	Check Dam	1.17	4.81	55	2-12	Northwest	Sandy Clay Loam	598456	1403389	
		15-30	Check Dam	1.20	4.28	55	2-12	Northwest	Sandy Clay Loam			
	4	5-15	Check Dam	3.35	7.90	55	12-20	Northwest	Sand	598464	1403400	
		15-30	Check Dam	3.88	2.31	55	12-20	Northwest	Sand			
	5	5-15	Check Dam	3.15	9.60	52	12-20	Northwest	Sand	598454	1403401	
		15-30	Check Dam	4.10	3.24	52	12-20	Northwest	Loamy Sand			
	6	5-15	Check Dam	2.77	3.55	52	12-20	Northwest	Loamy Sand	598451	1403401	
		15-30	Check Dam	2.43	3.50	52	12-20	Northwest	Loamy Sand			
29	1	5-15	Check Dam	2.08	13.27	58	2-12	Northwest	Loamy Sand	598465	1403324	
		15-30	Check Dam	1.85	2.57	58	2-12	Northwest	Sand			
	2	5-15	Check Dam	1.26	11.09	58	2-12	Northwest	Sand	598464	1403323	
		15-30	Check Dam	1.75	7.72	58	2-12	Northwest	Sand			
	3	5-15	Check Dam	1.39	11.57	58	2-12	Northwest	Loamy Sand	598468	1403320	
		15-30	Check Dam	2.03	7.92	58	2-12	Northwest	Sand			
	4	5-15	Check Dam	1.95	12.67	58	2-12	Northwest	Sandy Loam	598475	1403320	
		15-30	Check Dam	2.61	3.70	58	2-12	Northwest	Loamy Sand			
	5	5-15	Check Dam	1.88	4.99	58	2-12	Northwest	Loamy Sand	598474	1403324	
		15-30	Check Dam	1.96	2.98	58	2-12	Northwest	Loamy Sand			
	6	5-15	Check Dam	2.06	8.23	58	2-12	Northwest	Loamy Sand	598470	1403326	
		15-30	Check Dam	2.43	3.47	58	2-12	Northwest	Loamy Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
30	1	5-15	Without Check Dam	2.63	14.43	70	12-20	West	Sandy Loam	598591	1403288	
		15-30	Without Check Dam	3.08	5.04	70	12-20	West	Loamy Sand			
31	1	5-15	Without Check Dam	2.61	10.59	65	2-12	Northwest	Loamy Sand	598443	1403184	
		15-30	Without Check Dam	2.92	4.26	65	2-12	Northwest	Loamy Sand			
32	1	5-15	Without Check Dam	3.08	9.09	82	20-35	Northwest	Loamy Sand	598600	1403152	
		15-30	Without Check Dam	3.18	3.83	82	20-35	Northwest	Loamy Sand			
33	1	5-15	Without Check Dam	4.78	12.23	48	2-12	North	Sandy Clay Loam	598638	1403595	
		15-30	Without Check Dam	4.52	11.15	48	2-12	North	Sandy Clay Loam			
34	1	5-15	Without Check Dam	3.08	6.45	57	12-20	North	Silty Clay Loam	598829	1403546	
		15-30	Without Check Dam	4.30	4.70	57	12-20	North	Silty Clay Loam			
35	1	5-15	Without Check Dam	6.88	7.11	48	2-12	Northeast	Loamy Sand	599039	1403547	
		15-30	Without Check Dam	5.67	3.51	48	2-12	Northeast	Sand			
	2	5-15	Without Check Dam	6.52	10.93	46	2-12	Northeast	Loamy Sand	599063	1403539	
		15-30	Without Check Dam	6.54	6.52	46	2-12	Northeast	Loamy Sand			
	3	5-15	Without Check Dam	3.35	8.40	46	2-12	Northeast	Sandy Loam	599048	1403536	
		15-30	Without Check Dam	2.66	7.12	46	2-12	Northeast	Sandy Loam			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
36	1	5-15	Without Check Dam	6.88	7.11	48	2-12	Northeast	Loamy Sand	599039	1403547	
		15-30	Without Check Dam	5.67	3.51	48	2-12	Northeast	Sand			
37	1	5-15	Without Check Dam	6.52	10.93	46	2-12	Northeast	Loamy Sand	599063	1403539	
		15-30	Without Check Dam	6.54	6.52	46	2-12	Northeast	Loamy Sand			
38	1	5-15	Without Check Dam	3.35	8.40	46	2-12	Northeast	Sandy Loam	599048	1403536	
		15-30	Without Check Dam	2.66	7.12	46	2-12	Northeast	Sandy Loam			
39	1	5-15	Without Check Dam	3.35	7.45	51	2-12	East	Sandy Clay Loam	599183	1403319	
		15-30	Without Check Dam	4.04	5.84	51	2-12	East	Sandy Clay Loam			
40	1	5-15	Without Check Dam	1.38	9.75	47	2-12	Southeast	Sand	599167	1402965	
		15-30	Without Check Dam	1.59	9.30	47	2-12	Southeast	Sand			
41	1	5-15	Without Check Dam	1.23	11.22	42	12-20	East	Loamy Sand	599192	1402897	
		15-30	Without Check Dam	1.79	11.20	42	12-20	East	Sandy Loam			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
42	1	5-15	Check Dam	0.97	9.11	48	12-20	East	Loamy Sand	598879	1402169	
		15-30	Check Dam	1.49	6.41	48	12-20	East	Loamy Sand			
	2	5-15	Check Dam	2.12	10.37	48	12-20	East	Loamy Sand	598883	1402165	
		15-30	Check Dam	1.51	6.15	48	12-20	East	Loamy Sand			
	3	5-15	Check Dam	2.86	12.00	48	12-20	East	Loamy Sand	598887	1402162	
		15-30	Check Dam	2.78	6.26	48	12-20	East	Sand			
	4	5-15	Check Dam	1.14	7.04	49	20-35	Southeast	Sand	598891	1402174	
		15-30	Check Dam	2.97	10.41	49	20-35	Southeast	Sand			
	5	5-15	Check Dam	1.20	14.49	49	20-35	Southeast	Sandy Clay Loam	598886	1402178	
		15-30	Check Dam	1.53	6.77	49	20-35	Southeast	Loamy Sand			
	6	5-15	Check Dam	1.53	7.21	49	20-35	Southeast	Sandy Clay Loam	598889	1402176	
		15-30	Check Dam	1.64	3.32	49	20-35	Southeast	Sandy Clay Loam			
43	1	5-15	Check Dam	0.88	7.65	44	2-12	Southeast	Sandy Loam	598904	1402161	
		15-30	Check Dam	1.43	12.66	44	2-12	Southeast	Sand			
	2	5-15	Check Dam	0.73	9.94	44	2-12	Southeast	Sand	598907	1402161	
		15-30	Check Dam	1.07	6.12	44	2-12	Southeast	Loamy Sand			
	3	5-15	Check Dam	1.26	6.34	44	2-12	Southeast	Loamy Sand	598906	1402158	
		15-30	Check Dam	1.42	4.12	44	2-12	Southeast	Loamy Sand			
	4	5-15	Check Dam	0.45	7.52	44	2-12	Southeast	Loamy Sand	598912	1402165	
		15-30	Check Dam	0.59	5.09	44	2-12	Southeast	Loamy Sand			
	5	5-15	Check Dam	1.04	13.40	44	2-12	Southeast	Sandy Loam	598913	1402164	
		15-30	Check Dam	3.17	8.44	44	2-12	Southeast	Loamy Sand			
	6	5-15	Check Dam	1.46	10.37	44	2-12	Southeast	Loamy Sand	598912	1402165	
		15-30	Check Dam	2.20	9.84	44	2-12	Southeast	Loamy Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
44	1	5-15	Without Check Dam	0.82	9.55	40	2-12	Southeast	Loamy Sand	598973	1402104	
		15-30	Without Check Dam	1.16	5.21	40	2-12	Southeast	Loamy Sand			
45	1	5-15	Without Check Dam	0.85	15.73	40	12-20	South	Sandy Loam	598823	1401991	
		15-30	Without Check Dam	3.52	8.33	40	12-20	South	Sandy Loam			
46	1	5-15	Without Check Dam	1.07	3.24	37	2-12	Northeast	Sand	599040	1402017	
		15-30	Without Check Dam	1.03	2.17	37	2-12	Northeast	Sand			
47	1	5-15	Without Check Dam	4.73	9.13	32	2-12	Southeast	Sandy Clay Loam	599282	1402104	
		15-30	Without Check Dam	2.72	2.63	32	2-12	Southeast	Loamy Sand			
48	1	5-15	Without Check Dam	0.78	2.16	31	12-20	South	Sand	599378	1402081	
		15-30	Without Check Dam	0.95	1.69	31	12-20	South	Sand			
49	1	5-15	Without Check Dam	1.43	4.96	32	0-2	Southeast	Loamy Sand	599449	1402258	
		15-30	Without Check Dam	1.83	1.81	32	0-2	Southeast	Loamy Sand			
50	1	5-15	Without Check Dam	0.82	2.26	41	2-12	Southeast	Loamy Sand	599231	1402343	
		15-30	Without Check Dam	1.39	1.31	41	2-12	Southeast	Loamy Sand			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
51	1	5-15	Without Check Dam	2.44	3.83	38	2-12	East	Sandy Loam	599265	1402479	
		15-30	Without Check Dam	4.92	5.91	38	2-12	East	Sandy Clay Loam			
	2	5-15	Without Check Dam	0.91	4.86	40	2-12	East	Sand	599245	1402483	
		15-30	Without Check Dam	4.58	4.20	40	2-12	East	Sand			
	3	5-15	Without Check Dam	0.99	8.72	40	2-12	East	Sand	599247	1402455	
		15-30	Without Check Dam	1.13	4.98	40	2-12	East	Loamy Sand			
	4	5-15	Without Check Dam	0.97	3.04	40	2-12	East	Loamy Sand	599258	1402455	
		15-30	Without Check Dam	1.19	1.77	40	2-12	East	Sand			
52	1	5-15	Without Check Dam	1.61	5.53	38	2-12	Southeast	Loamy Sand	599334	1402958	
		15-30	Without Check Dam	1.32	3.35	38	2-12	Southeast	Loamy Sand			
	2	5-15	Without Check Dam	0.81	4.74	38	2-12	Southeast	Sand	599326	1402969	
		15-30	Without Check Dam	1.07	7.75	38	2-12	Southeast	Sand			
	3	5-15	Without Check Dam	2.03	8.27	38	2-12	Southeast	Loamy Sand	599293	1402936	
		15-30	Without Check Dam	3.69	3.05	38	2-12	Southeast	Loamy Sand			
	4	5-15	Without Check Dam	1.37	6.94	38	2-12	Southeast	Sand	599301	1402926	
		15-30	Without Check Dam	2.32	7.12	38	2-12	Southeast	Sandy Loam			

Table A: Soil moisture and physical characteristics are presented (cont.)

Sample	Position	Levels of Depth (cm)	Type of Sample	Soil Moisture (%)		Altitude (m)	Slope (%)	Aspects	Soil texture	Coordinates		Remark
				April – May 2011	June – July 2011					East	North	
53	1	5-15	Without Check Dam	2.07	9.85	38	2-12	Northeast	Sand	599348	1403348	
		15-30	Without Check Dam	9.98	9.81	38	2-12	Northeast	Sand			
	2	5-15	Without Check Dam	3.25	7.08	38	2-12	Northeast	Sand	599353	1403335	
		15-30	Without Check Dam	2.48	4.72	38	2-12	Northeast	Sand			
	3	5-15	Without Check Dam	11.26	5.40	38	2-12	Northeast	Loamy Sand	599365	1403320	
		15-30	Without Check Dam	10.55	1.84	38	2-12	Northeast	Loamy Sand			
	4	5-15	Without Check Dam	0.68	4.07	38	2-12	Northeast	Sand	99372	1403326	
		15-30	Without Check Dam	0.95	3.96	38	2-12	Northeast	Sand			
54	1	5-15	Without Check Dam	3.42	4.63	36	2-12	North	Sandy Loam	599076	1403893	
		15-30	Without Check Dam	3.51	4.20	36	2-12	North	Sandy Loam			
55	1	5-15	Without Check Dam	2.35	11.93	43	2-12	North	Sandy Loam	598799	1403799	
		15-30	Without Check Dam	2.46	8.02	43	2-12	North	Sandy Loam			
56	1	5-15	Without Check Dam	0.86	16.58	42	2-12	North	Sand	598500	1403731	
		15-30	Without Check Dam	2.80	9.82	42	2-12	North	Sand			
57	1	5-15	Without Check Dam	1.60	7.46	31	12-20	East	Sand	599777	1403103	
		15-30	Without Check Dam	0.15	1.47	31	12-20	East	Loamy Sand			

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