IMPACT OF AGRICULTURAL LAND USE ON SOIL QUALITY, A CASE STUDY IN NAN PROVINCE, THAILAND

BY

CHAWANRUT TAMIKANON

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (ENGINEERING TECHNOLOGY)
SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY
THAMMASAT UNIVERSITY
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A Thesis Presented

By

CHAWANRUT TAMIKANON

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JULY 2018

Abstract

IMPACT OF AGRICULTURAL LAND USE ON SOIL QUALITY, A CASE STUDY IN NAN PROVINCE, THAILAND

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Changing land use practices are a current theme of scientific research. The recent report studying in Global forest resources assessment shows that the environment has been greatly changed from the past. Currently, Southeast Asian countries are facing geo-ecological problems from the environmental change. One of the most important problems in SEA is deforestation. However, the problem still exists in some regions of Thailand. The problem was found arisen rapidly in northern region where most area is containing of mountains, forested hills, dense jungle, and river valleys with fertile natural resources. The improper land use management can lead to plenty of problems such as deforestation, loss of wildlife habitat and environmental pollution. The soil degradation is also one of main problems. In this study focuses on soil quality changing by agricultural activities which proceeded to the mountainous area. The methods were used for this study are soil properties investigation; soil chemical properties and soil physical properties, another method is questionnaires to survey data of farming activities. All data analyzed and study of related effect. The examined result showed soil properties still suitable for planting when compared the result with the optimum standard except the abandoned field. The second part is survey study about agricultural activities in sample areas. The investigation found three improper farming activities which impact on soil quality; adding chemical fertilizer, adding chemical enhancer and planting in drought condition. However, the further study suggest a recommendation to manage problems are control fertilizer addition follows crop requirement, applying alternative crops, adopting terrace method, creating more water storage, replacing burning crop residue activity by tillage or burying.

Keywords: Land use, Agricultural land use, Soil qualities

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Chapter 1
Introduction

1.1 Introduction

Food and Agriculture Organization (FAO) defined land use as "the total of arrangements, activities, and inputs that people undertake in a certain land cover type"(IPCC, 2000). Land use is categorized according to the utility; agriculture, community, transportation, infrastructure and industry. Improper land use management will lead to environmental degradation, for example, deforestation, loss of wildlife habitat and environmental pollution.

Changing land use practices are a current theme of scientific research. The recent report studying in Global forest resources assessment (FAO, 2010) shows that the environment has been greatly changed from the past. Currently, Southeast Asian countries are facing geo-ecological problems from the environmental change. One of the most important geo-ecological problems in SEA is deforestation. Even though the rate of deforestation in SEA is not as high as it was in 1990-2005, the number is considered to be above the average in some countries e.g. Cambodia 1.22%, Myanmar 0.95% and Indonesia 0.71% per year. In contrast, the deforestation rate in Thailand has stopped. As a result, the area of forest has been slightly increasing at the rate 0.08% per year since 2005.

However, the problem still exists in some regions of Thailand. The problem was found arisen rapidly in northern region where most area is mountainous, forested hills, dense jungle, and river valleys with fertile natural resources. Thus, this area is an ideal location for farmers who live in mountainous areas to perform cultivation. Their agricultural areas consist of two parts; the lowland and highland agriculture. These agricultural activities influenced by different topography in each area. Therefore, the practice of shifting cultivation systems is different. (Choenkwan et al., 2014)

In highland, some farmers have limited understanding to proceeds agricultural activities on a mountain slope. The unsuitable agricultural procedures can be caused of land use problems. General causes of unsustainable land use are as followed.

The rapid expansion of upland plantation on steep slopes as a result from economic pressure on livelihood. Private sectors also offer convenient market that encourage local famers to perform innovative cultivation for example use of other alternative crops which can be grown under the rain-fed and steep slopes conditions in the highlands. Nevertheless, inappropriate agricultural practice in mountainous area can lead to land use problem such as soil surface runoff or loss of fertile soil nutrients which can be causes of land slide problem.

(1) The adoption of conservative agriculture practice is still low. This low rate of adoption is due to outdated forest regulation practices, which are inconsistent with highland livelihood patterns. Due to the enormous area in northern Thailand, all area cannot be taken care by small number of forest officers. That is the origin of deforestation issue in mountain.

(2) The limited water resource in highland is one of causes which lead to unsustainable land use problems. A lack of water resources and the steep slopes cultivation area lead to low soil fertility levels naturally and high rates of soil erosion. Thus, there is a loss of fertile space for plantation. (Kitchaicharoen et al., 2015)

(3) Due to the limited condition of conducting cultivation on the hilly terrain, agriculture patterns are not various. The widespread agricultural pattern which tropically practices is fire dependent agriculture, particularly mountainous agriculture because it can be proceeded without any technology, and it has low operation cost. Generally, land is cleared by cutting down trees, and remaining vegetation is burned. This method is used for a couple of years. In consequence, the nutrients in soil run out. Deteriorated land is abandoned, and farmer will move to a new plot. As a result, soil loses more nutrients through runoff and erosion.

From the deteriorated land situation, the agricultural terrace is suggested to solve problem of planting crop on mountainous terrain. Terraced landscapes have the potential to transform sloped terrains to efficient agricultural land by encourage humidity retention in soils and by reducing surface erosion, thus allowing long-term cultivation. In addition, this method allows soil sediments to accumulate between each terrace step. Thus, terraced fields are appropriate to be used to grow crops that require irrigation, such as rice. Terracing is long last agriculture which can retain the fertile soil properties for a long time and can be adopted to use with planting other crops.

Proper land use management is a necessary solution for dealing with soil problems in highland. Conducting right types of agriculture will benefits in many ways such as long last agricultural land usage, reducing deforestation rate and maintaining soil qualities.

This study aims to investigate about current land use situation in agricultural part of upper area in Nan Province, Thailand. The suitable and unsuitable land use can be categorized by some indicators. This research focuses on two major groups of parameter which are soil qualities and farming activities which are performed on mountain to explain cause of impact on soil qualities from current planting activities.

1.2 Objectives of the study

(1) To study and categorize various agricultural lands use types in Chalerm Phra Kiat district, Nan province.
(2) To investigate land management practice impact on soil qualities.
(3) To propose proper land use management that is suitable for highland agriculture.

1.3 Scope of the study

(1) Studying in land use from agriculture fields under the assistance of Pid Thong Royal Initiative Discovery Foundation in Chaloem Phra Kiat district, Nan province.
(2) The lands use types are paddy fields, maize field, economics crops, old - aged rice terrace, new - aged rice terrace, abandoned field and hilly paddy field**.**
(3) The data for investigation divide to 2 parts as the following:

- Agricultural activities from surveying agricultural activities by questionnaire survey and study in correlation of soil quality and cultivation income in each land use.
- Soil quality from investigation of soil properties which are physical properties and chemical properties

  Physical properties: soil texture, soil water holding capacity and soil temperature.

  Chemical properties: soil pH, soil organic matter, soil exchange cation capacity and soil nutrient (NPK)

(4) All data will be analyzed and explained about current situations and impact of land use on soil qualities.

(5) Suitable land use management practices were proposed.

Chapter 2
Literature Review

2.1 Land use

The definition of land use given by FAO is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Land use means using area on the ground for conducting any human activities such as commerce, industry, resident and cultivation. The land use pattern and its usage are depended on land cover composition.

Soil quality depends on the proper soil maintenance, improper activities that are operated with soil can cause soil deterioration problem, and land use area can be converted to be a wasteland. In Thailand, land use is classified in 5 categories as followed:

(1) **Urban and built- up land**; resident, building, shopping center, industry, and transportation

(2) **Forest land;** tropical rain forest, dry evergreen forest, hill evergreen forest, coniferous forest, swamp forest, mangrove swamp forest, mixed deciduous forest, dry deciduous dipterocarp forest and grassland forest.

(3) **Water bodies**; river, steam, cannel, pond, lake and dam.

(4) **Agricultural land**; cultivation, husbandry, fishing and plantation

(5) **Idle land;** champaign and wasted land

Land use changing pattern depends on 3 main factors which are human needs, technology and economic.(Waipreechee, 2006)

2.1.1 Land use change

Description of land use change is the transformation of land from one pattern to another pattern for the benefit of the land cover. Since human consumption increase rapidly in many directions, the expansion of agricultural area to produce more crops is necessary. As the result, some areas are converted in respond to economic, industry and transportation system. Common land use change occurs by converting forest area to human livelihood area. Some studies indicated that changing land use without the adoption of conservative policy might have an effect on soil erosion, soil degradation, and soil qualities (Hanaček & Rodríguez-Labajos, 2018; Paz González et al., 2014).

2.1.2 Agricultural land

Definition of agricultural land from Organization for Economic Co-operation and Development (OECD) is “The land area that is either arable, under permanent crops, or under permanent pastures. Arable land includes land under temporary crops such as cereals, temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow”.

Abandonment of land is a result from conducting shifting cultivation, and proper management is excluded. However, in mountainous area, terracing agricultural method can be used instead of shifting cultivation to solve this problem. (OECD, 2013)

(1) Fire dependent agriculture

Fire dependent agriculture is commonly practiced in mountainous agriculture because the procedure does not require any technology and cost. Generally, land is cleared by cutting down trees, and remaining vegetation is burned. The consequent layer of ash furnishes the newly-cleared land with a nutrient-rich layer which helps fertilize crops. However, the land that applied this method fertility of nutrient for a couple of years after those nutrients are used up finally. Deteriorated land abandoned and farmers will move to a new plot. For example, maize plantation is one type of fire-dependent agriculture. As a result, conducting without proper management can cause nutrient loss through runoff and erosion.

(2) Terracing agriculture

An agricultural method uses for controlling water erosion and maintaining surface runoff water. It is well known from the ancient history that terracing method can adjust the steep landscape systems such as hilly or mountainous terrain. Terracing agriculture is also commonly used in Asia, for example, China, Thailand, India and also some developing countries in Africa. Moreover, terracing method is applied for solving arid environmental problems in Ethiopia, Rwanda, Tanzania and others.(Balbo & Puy, 2017)

The proposition of terracing appliance improves the utility of steep slope and develops the agricultural potential. This method is actualized by creating the level surface following to contour line of slope. The benches allow the spreading of soil surface runoff and also reduce soil loss by runoff water (Arnáez et al., 2015). Terraces are reported as a successful application to control soil erosion and appreciably adopted in the region with climatic conditions, steep slopes and erodible soil. However, in some areas, the effectiveness is limited by planting combination of sparse vegetation.

Before conducting the terrace cultivation farmers have to use mechanical equipment adjust agricultural area. As the result, terraces have expensive cost to construct and maintain. They have many well-known types which are; bench terraces, back-sloping, stone-wall terraces and Fanya juu terraces (Widomski 2011).

(3) Bench terraces

Bench terrace (Figure 2.1) consists of a set of platforms and it is constructed along the terrace slope, embankments known as risers are created for separating the platforms in each level of terrace. The purpose of benches is to reduce slope and length of steepness. The reduction of surface runoff velocity contributes to the retention of surface water and allows water to infiltrate into topsoil.

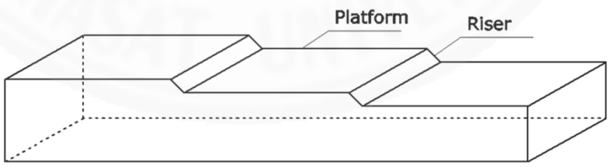


Figure2.1 Pattern of typical bench terraces.(Widomski, 2011)

(4) Back-sloping

Back-sloping terrace (Figure2.2) contains of toe drain which is placed near the riser and a bed slope is located at the back towards the toe drain. The steeper slope of terrace riser is approximately 35-50^{o}. The 0.3-0.4 m. width of toe drain is put slightly inclined 1-3^{o} towards the end of terrace. This positioning helps surface water runoff to redirect the parallel flow through the central drain parallel with the contour line of slope. This terrace is suggested to proceed in the regions which have high precipitation.

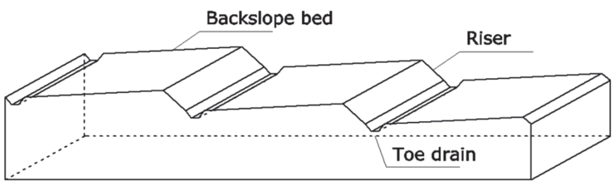


Figure2.2 Back-sloping bench terraces (Van Dijk & Bruijnzeel 2003)

(5) Stone-wall terraces

Stone bunds (Figure 2.3) are deployed along the slope. The level of the terraces platform usually place closely with stone walls (or stone bunds). At the same time, the deposit sediments create terrace platform. Stone wall terrace can be properly used where there is steeper slope covered by shallow soil. Furthermore, it is a permanent structure and has high self-stabilizing. However, the construction cost is higher than other terrace types.

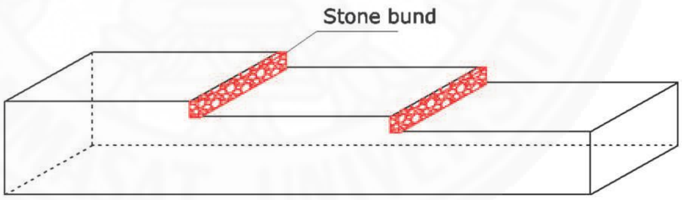


Figure2.3. Stone bund terraces (Widomski, 2011)

(6) Fanya juu terraces

Fanya juu terrace can be constructed by digging the small channel along the contour lines of the slope. The excavated soil is thrown up to create soil embankments. The sediment gradually accumulates on upper part and adjusts the cannel which will later become a terral. Accordingly, the long slope it is divided into 2 parts which are the short segment and the accumulated ditch for infiltrating surface water.

Fanya juu terrace is not labor-intensive. This terrace is applicable in the regions with thin soil cover.

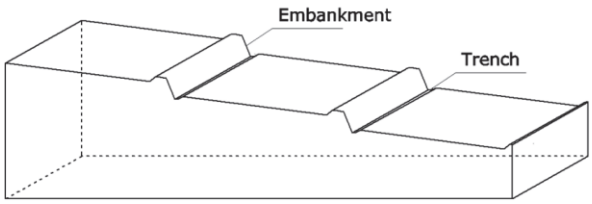


Figure2.4 Fanya juu terraces (Widomski, 2011)

2.2 Soil quality

The three components of environmental quality to concern while conducting agriculture activities are air, water, and soil quality. For both water and air quality, the degree of pollution can be detected by the impacts on human and animal health and consumption, or on the natural ecosystems. Whereas, the investigation of soil qualities is used to indicate the potential of soil properties that promotes plant growth. The concept of soil quality investigation is acquired from two parts; soil properties and the effects of management. Limitation of general management can stand only short-term to maintain the inherent soil properties. For the long-term beneficial usage of soil needs to adopt proper soil management along with usual soil quality investigation.

Therefore, the important component of soil quality assessment is the identification of soil properties those are the indicators of soil function (Bünemann et al., 2018).

2.2.1 Soil properties

2.2.1.1 Soil physical properties

(1) Soil texture

Soil texture is a parameter to inspect the relative proportion of particles; sand, silt and clay. The grain size distribution is measured for determining soil texture.

Particles larger than 2.0 mm are classified as gravels and stones. Particles with diameter less than 2.0 mm are classified as sand. Particles having size between 0.002-0.05 mm are classified as silt. The size of particles less than 0.002 mm is clay. (Thien, 1979).

The relative soil particles (Figure2.5) can be used for determining soil factors such as water holding capacity, drainage, and plant rooting depth. All soil textures are further divided into subclasses (Table 2.1); sands (S), loamy sands (LS) and sandy loams (SL) are dominantly composed of sand particles.(School of Plant, 2011)

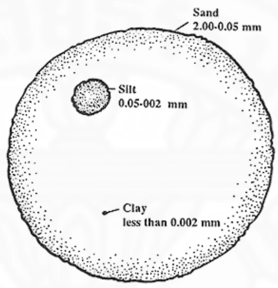


Figure2.5 Size of sand, silt, and particle relative to each other (Thien, 1979).

Table2.1 Size of sand particle (School of Plant, 2011).

Sand subclasses	Particle size (mm)
Very coarse sand (VCoS)	2.0 - 1.0
Coarse sand (CoS)	1.0 - 0.5
Medium sand (S)	0.5 - 0.25
Fine sand (FS)	0.25 - 0.10
Very fine sand (VFS)	0.10 - 0.05

(2) Soil water holding capacity

The soil water holding capacity is the quantity of water that soil can hold against the force of gravity or amount of water soil can absorb. The key for approximation of soil water holding capacity are soil texture and organic matter components. Soil containing small particles such as, silt and clay, has more surface area which indicates the ability to retain water. Compared to sand which has larger particle size, it consequential has less surface area.

This research shows the relevance of increasing water holding capacity ability due to increasing level of organic matter. Therefore, water holding capacity is the measurement of soil potentiality to maintain moisture content. (Wilke, 2005)

(3) Soil temperature

Soil temperature is major key of plant growth and decomposition process. Soil temperature affects many dimensions of cultivation such timing of budburst leaf or fall, biogeochemical activities chemical and impact on all of physical practices that occur in soil. (Volz & DeMoss, 2002)

The major impacts of soil temperature on the composition and activity of soil are microbial groups; root respiration processes and the rate organic matter decompose in soil. (Willis & Power, 1973)

2.2.1.2 Soil chemical properties

(1) Soil pH

Soil pH is an indicator of acid or base forming cations. Generally acid cation forms are H^+ (hydrogen), Fe^{2+} or Fe^{3+} (iron) and Al^{3+} (Aluminium). Whereas, normal base cation forms are Mg^+ (Magnesium), Na^+ (Sodium), Ca^{2+} (Calcium) and K^+ (Potassium) (McCauley et al., 2017).

The lowest unit of pH start from 0 to 14, thus the neutral pH is 7 (Table2.2). Commonly, plants optimal growth condition in soil has pH between 5.2 to 8.0. The influence from soil pH value from 5.0 to 7.0 is microbial activity. Various species of earthworms and nitrifying bacteria disappear from the areas where it is extremely acidic or alkaline. Soil nutrients may be affected by soil pH. Some nutrients available to plant, for example, phosphorus, molybdenum, calcium, and magnesium when pH changes. (Lake, 2000)

Table 2.2 Soil classification based on pH value. (Land Development Department, 2010)

Degree of acidity and alkalinity	pH Ranges
Ultra acid	<3.5
Extremely acid	3.5 -4.4
Very strongly acid	4.5-5.0
Strongly acid	5.0-5.5
Moderately acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Slightly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	>9.0

(2) Organic matter

Soil organic matter occurred by the decomposition process of plant and animal residues. The consistent benefit of soil organic matter value (Table.2.3) is the indicator of changing soil pH. While organic matter begins to decay, soil organic matter releases anions and cations. Thus, the soil pH value rises in the first few weeks of decaying process. From this activity, nitrogen rise affects on the accretion of soil pH and also the reduction of H^+. Aluminum and manganese can cause directly impact to seed and plant root.

Organic matter in soil helps to protect soil from the natural effects such as rainfall, sun, and wind removing. As much as soil accumulates OM, that influence to the higher potential water holding capacity. In addition humus can absorb and hold nutrients in plant-available form. Burning crop residues exposes the negative impact. This procedure removes and deprives soil organism energy source (McCauley et al., 2017).

Table 2.3 Rating of OM value in soil (Land Development Department, 2010)**.**

Rating	Range (%)
Very low	<0.5
Low	0.5-1.0
Slightly low	1.0-1.5
Moderate	1.5-2.5
Slightly high	2.5-3.5
High	3.5-4.5
Very high	>4.5

(3) Soil exchange cation capacity

CEC (Cation exchange capacity) is ability of soil to transfer cation. The positive cations are Ca^{2+} (calcium), K^{+} (potassium), Mg^{2+} (magnesium), Na^{+} (sodium), Al^{3+} (Aluminum), H^{+} (hydrogen), Fe^{2+} (iron), Zn^{2+} (Zinc) and Cu^{2+} (copper). All these cations are caught by negative cations and organic matter content in soil through electrostatic energies.

The rate of soil cation exchange capacity represents the total capacity of exchangeable cations that the soil can captivate.

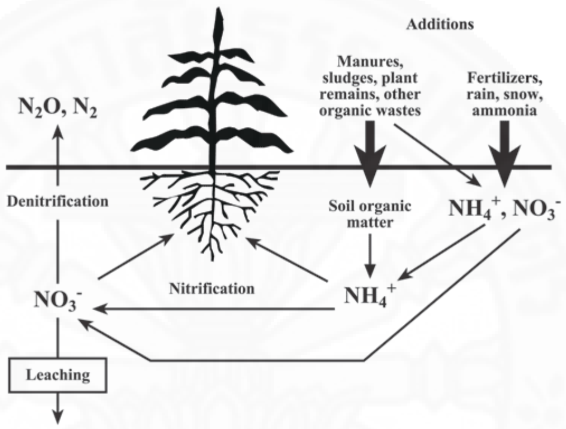
(4) Soil nutrients

- **Nitrogen(N)**

Nitrogen is most demanded plant nutrient. However, the excess amount of nitrogen has negative impacts on plant grown. Nitrogen in plant and animal residues must be decayed to become organic material form by microbial decomposition process (mineralization).

The ending of nitrogen is ammonium (NH^{4+}) form that can transform into gas state under alkaline conditions. Nitrification is a process to turn ammonium into nitrate (Figure2.6) by aerobic condition. Detection of nitrogen is not simple to be conducted. Thus, the best measurement to inspect nitrogen value is to detect overall nitrogen value or total nitrogen because nitrate molecules are negatively cations which are repelled from soil particles by similar charged ions. If plants do not take up nitrogen materials, nitrogen will move along with water by infiltration. The following result is that nitrates inhabit with groundwater. Nitrogen losses can happen via harvested plants and animals and become nitrogen gas.

Nitrogen is the part of chlorophyll molecule which helps plant growth and creates food for plant. It performs green color of leaf involved in the photosynthesis process. Chlorosis is a plant disease occurred when there is lack of nitrogen in plant. Nitrogen molecules can move to any part of the plant. Consequently, the new growth not often turn yellow easily than the older plant (Frate, 2008).



(Source: http//:nevegetable.org)

Figure2.6 Nitrogen cycle

- **Phosphorus (P)**

Phosphorus is one of essential nutrient for plant requirement. Phosphorus operates a critical role in cell development and the main element of molecules that store energy, such as DNA, lipids and ATP.(Grant et al., 2005)

Lacking of phosphorus in soil is the source of decreasing crop production. Roots act as reception for phosphorus uptake. The potentiality of phosphorus absorption depends on root surface and phosphorus concentration.

Phosphorus is found in soil both of organic form and inorganic form. The form good for plant uptake is solution form. When plant root absorbs from the solution into plant root, the rest of phosphorus solution becomes solid phase to maintain soil nutrient equilibrium.

Soil acidity tends to react with aluminum, manganese, and iron. More soil acidity more encouraging of phosphorus reaction that impacts on available phosphorus decreasing.

Decomposition of organic content and crop residue contribute to available phosphorus in soil. The explanation of phosphorus process is in the phosphorus cycle (Figure2.7) (Lajtha et al., 1999).

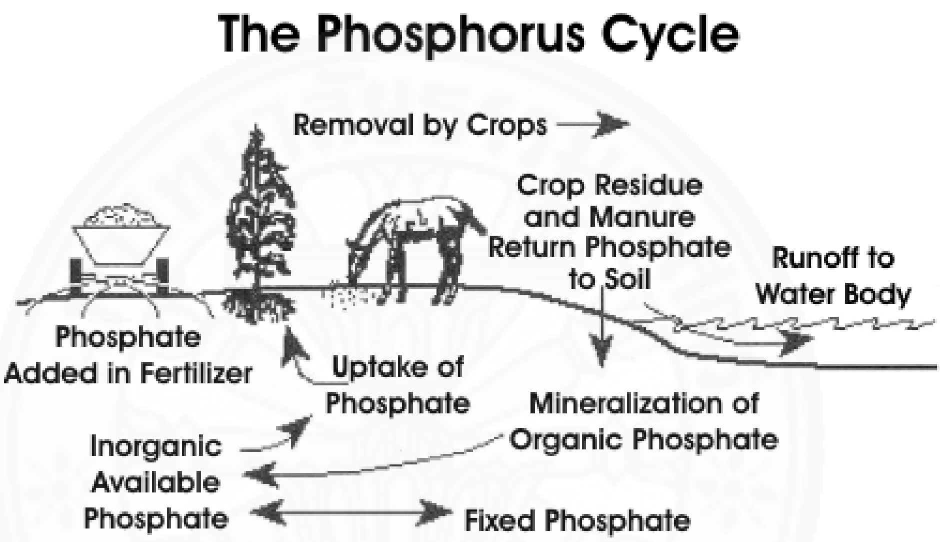


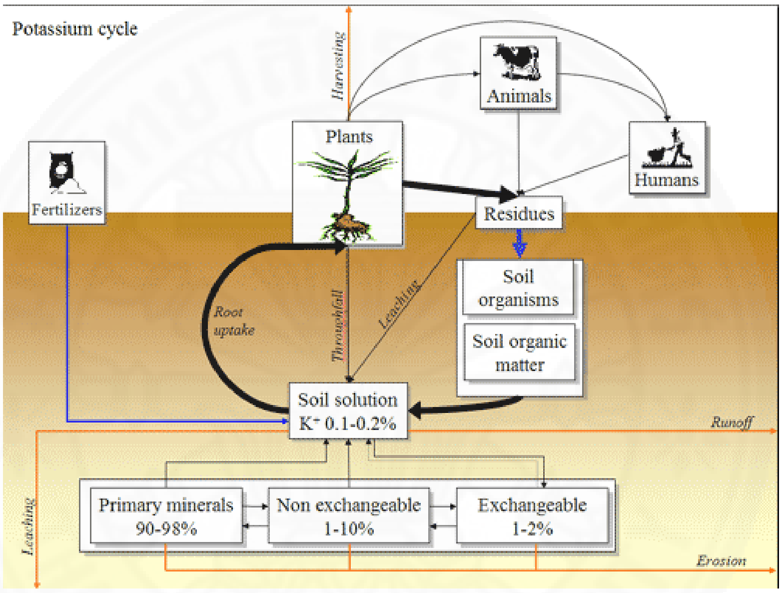
Figure2.7. Phosphorous cycle (Lajtha et al., 1999)

- **Potassium(K)**

Potassium is one of the three main essential nutrients for plant growth. Potassium can be revealed in many forms such as exchangeable, non- exchangeable, mineral form and water-soluble depending on availability of plant uptake. (Figure.2.8) Whatever potassium form can be defined as exchangeable and non-exchangeable. Potassium is used up by leaching, exchange reactions with other cations or plant removal. Adding crop residues and soil fertilizer distributes potassium to gradually spread in soil. Thereby, potassium in soil can be available through long- term soil weathering. Wet, dry, freeze and melted thaw conditions influence on the transformation of potassium. Therefore, the rate of potassium uptake is differed by K phase (nonexchangeable, exchangeable, and solution phases) that affects plant growth and crop yield.

This nutrient promotes plant to use water in food production, resist drought and enhances crop yield. If potassium is deficient in soil, there will be an occurrence of some crop diseases.

Potassium promotes robust stem and deep root and also develops flowers. K nutrient is necessary for potatoes, the rich carbohydrate plant, for tuber growth.



(source: http://wiki.ubc.ca/Category:SoilWeb)

Figure2.8 Potassium cycle.

2.3 Information of Nan.

Nan is a province which is located in northern Thailand. The distance is approximately 668 kilometers away from Thai capital city. The other information of Nan province is described as follows.

2.3.1 Location

Nan is located in north of Thailand's border which is connected to Laos (Figure2.9) PDR. Nan province elevation is higher than 2,112 meters above mean sea level. Total area of this province is 7,170,045 Rai.

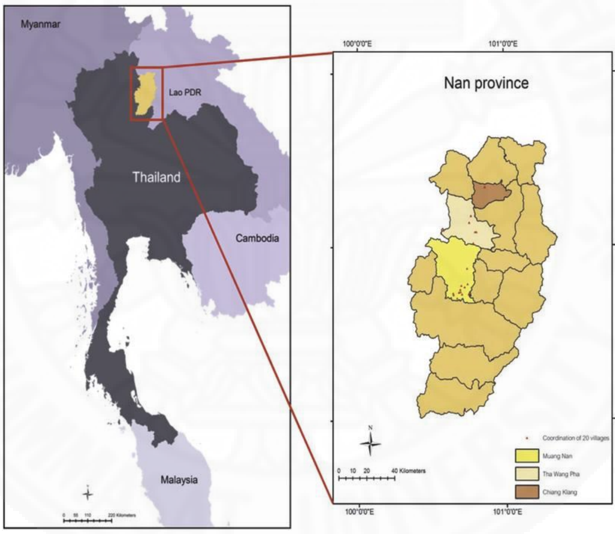


Figure2.9. The location of Nan province in Thailand (Alongkorn Kurilung et al., 2017).

2.3.2 Topography

A series of mountain ranges in the province are at an elevation of approximately 600 to 2,000 meters above mean sea level. Most of the land (about 85%) in Nan has a slope greater than 35%. The main river is Nan river. Narrow plain space near the basin is suitable to conduct cultivation

2.3.3 Population

From 2014 information of Nan province shows the number of population is 478,264 people(Office of the National Economic and Social Development Board, 2014). Local people for 80% live in the lowland areas and the most of rest population for 20% who lives in the mountainous areas is ethnic groups (Mlabri, Mien, Khmu, Lau and Hmong). Most people are between working age, and they work and live outside the municipal district (Kitchaicharoen et al., 2015).

2.3.4 Occupations

In 2014, a gross provincial product at Current Market Price per capita of Nan province is 23,049.9 million baht. The major gross provincial products percentage comes from agricultural division which is 39.3%. The second one is education industry for 17 % (Office of the National Economic and Social Development Board, 2014). Normally, Nan citizens practice agriculture as the main job and doing a handicraft and weaving for a second job. The occupations in Nan are described as following;

Industry: wood carving, Mauhom fabrication, and making teak furniture.

Commerce: small business and agricultural purchasing business.

Agriculture: cultivation (rice, corn, cotton, and tobacco) husbandry, and fishery

2.3.5 Climate

The climate in this province is tropical. It is cold in winter. The Köppen climate classification categorize the climate in Nan is tropical savanna climate or tropical wet and dry climate (AW). The average temperature in Nan province is 25.8^{o}C. (Figure 2.10)

In recent 10 years, average rainy day per year is approximately 180 mm and average rainfall per year is 1,304 mm (Figure2.11). The highest volume of rainfall is August and the lowest is January.

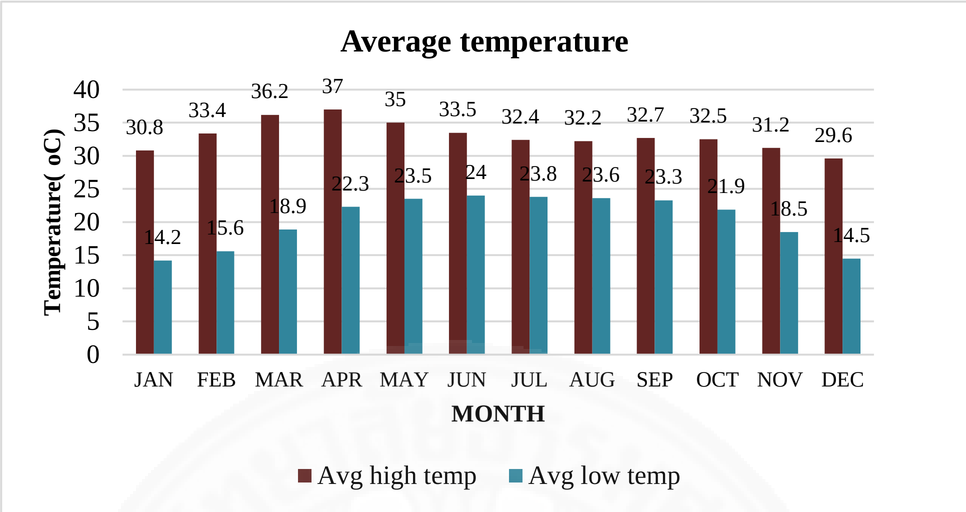


Figure 2.10 The average monthly temperature

(Thai Meteorological Department, 2018).

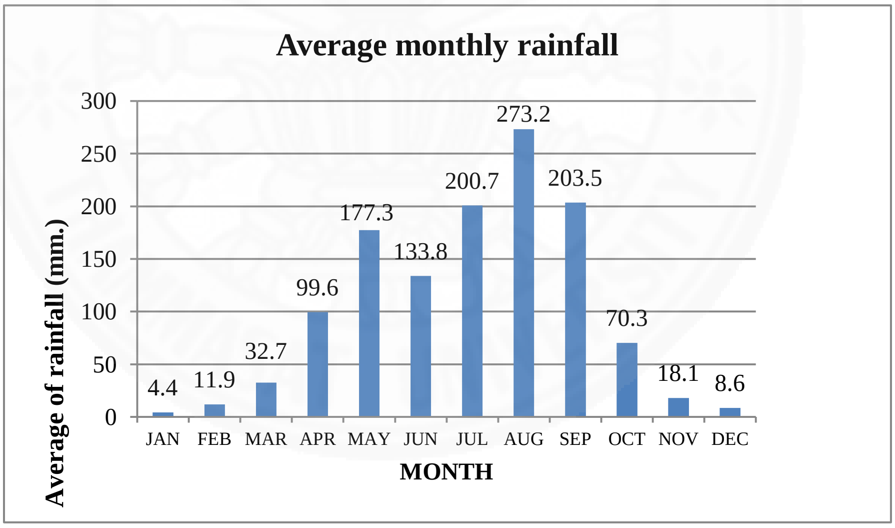


Figure 2.11 The average monthly rainfall

(Thai Meteorological Department, 2018).

2.3.6 Agricultural production and Market.

The whole agriculture area in Nan is 846,043 Rai. In the past, most cultivation conducted on plain area. The major crops are rice, maize, tobacco, beans, cassava, and so on. Besides, the hilly field mostly planted crops e.g. maize, cotton, bean, and chili (Figure2.12). Since 2014 the proportion of planting has changed especially in upland which increased maize and rice production and most economics crop still planted in lowland area (Figure2.13)(Nan provincial Industry office, 2014).

Furthermore, the recent information from Ministry of Agriculture and Cooperative reveals data of average yield from crop production in Nan province (Table 2.14)(Ministry of Agriculture and Cooperatives, 2015, 2017).

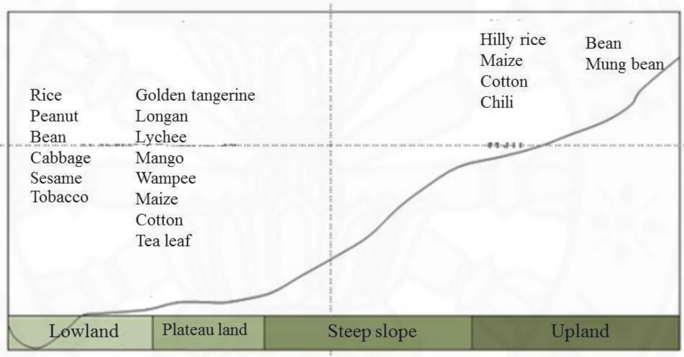


Figure 2.12 Agricultural patterns in the past (Nan provincial Industry office, 2014).

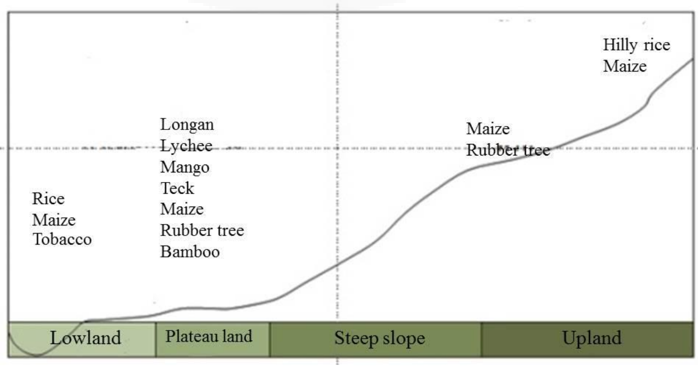


Figure 2.13 Agricultural patterns in the 2014 (Nan provincial Industry office, 2014).

Table 2.14 The data of average yield from major crop of Nan province (Ministry of Agriculture and Cooperatives, 2015, 2017).

Crop	Average yield (kg/Rai)	Average total profit/Rai (baht)
Maize	593	3,690
Rice	507	6,084
Banana	315	1,899
Coffee	43	872
Cashew nut	28	1,017

The major market of vegetables is the local markets in the province. Some famers sell their products to local entrepreneurs or agricultural cooperatives. Vegetable market is separated into fresh vegetable market and agro-product processing market. Local middlemen who buy most fruit will sell them with profitable price. The well-known market that products will be sold in Bangkok are Talad Thai and Talad Si Mum Muang and including abroad markets (Kitchaicharoen et al., 2015).

2.3.7 Current land use in Nan

A significant part of Nan province is covered by natural forests. The keys of land use change in this area include the damage of forests, the expansion of cultivated lands, the transition from slash and burning agricultural crop remain, and various applications of agrochemicals (Kitchaicharoen et al., 2015).

In the research which studies land use dynamics is land cover structure change in Thailand (Baicha, 2016). The study presents that the area of natural forests decreased the period 1995-2012 approximate 41.5%. Whereas, the proportion of agricultural area which are perennial crops, slash and burn agriculture, fields of unirrigated crops, pastures, paddy fields, and orchards increased by 51.1 % (Figure2.13) and the update information of 2016. (Figure2.14)

The cultivation of fire-dependent changes negatively influences the land use. The obvious effect is the ecological environment, and this issue causes many problems such as an increase in soil erosion, a deterioration of the quality of water resources, and biodiversity losses. Although, the major agricultural problem from practicing fire-dependent agriculture is officially prohibited by national parks. However, soil pollution problems are occupied by agricultural crops which are the application of high agrochemicals.

Nan province needs proper management and elaboration of policies which aim at a rational utilization of natural resources.

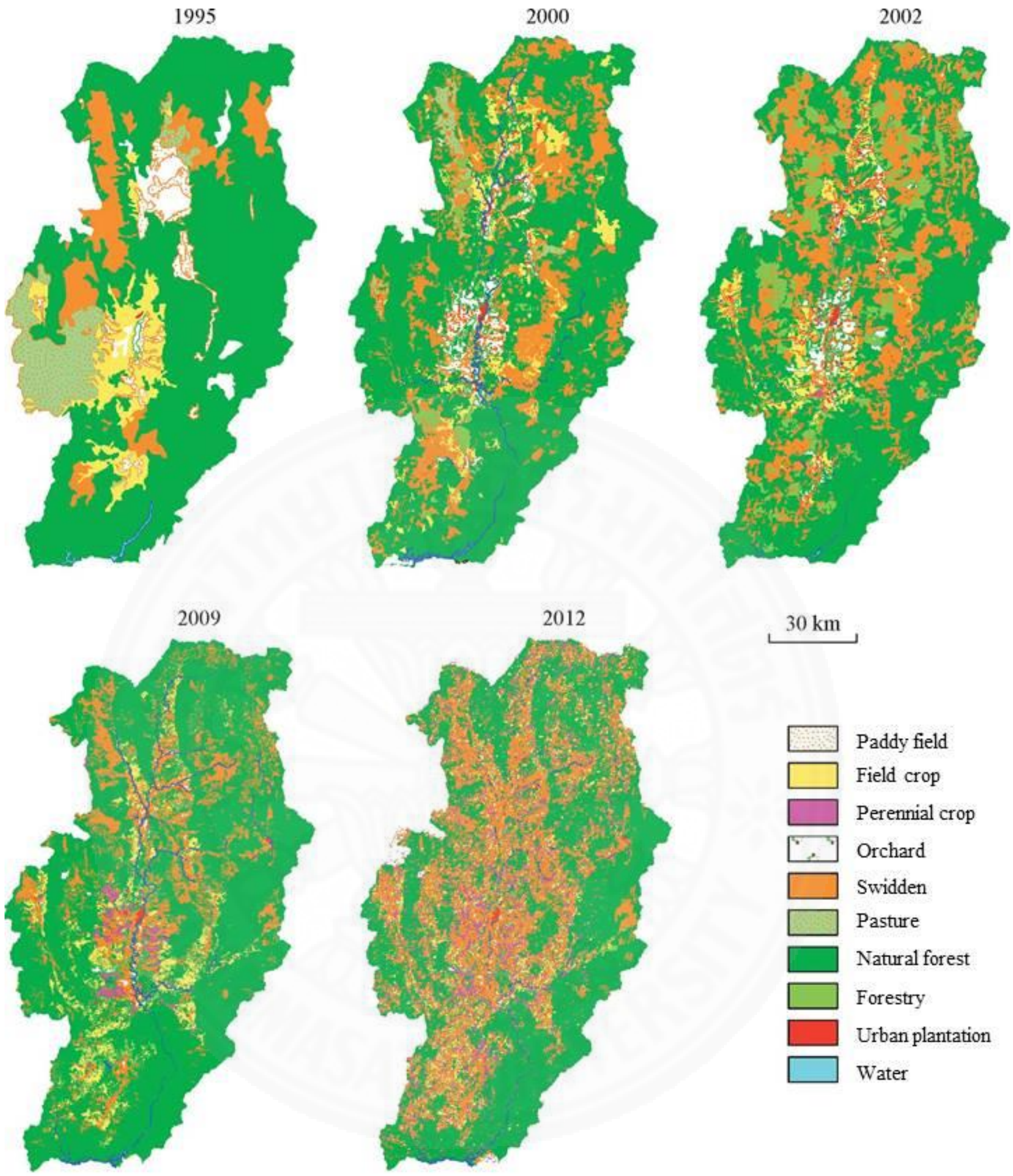


Figure2.14 Land cover structure change in Nan province between 1995–2012 (Baicha, 2016).

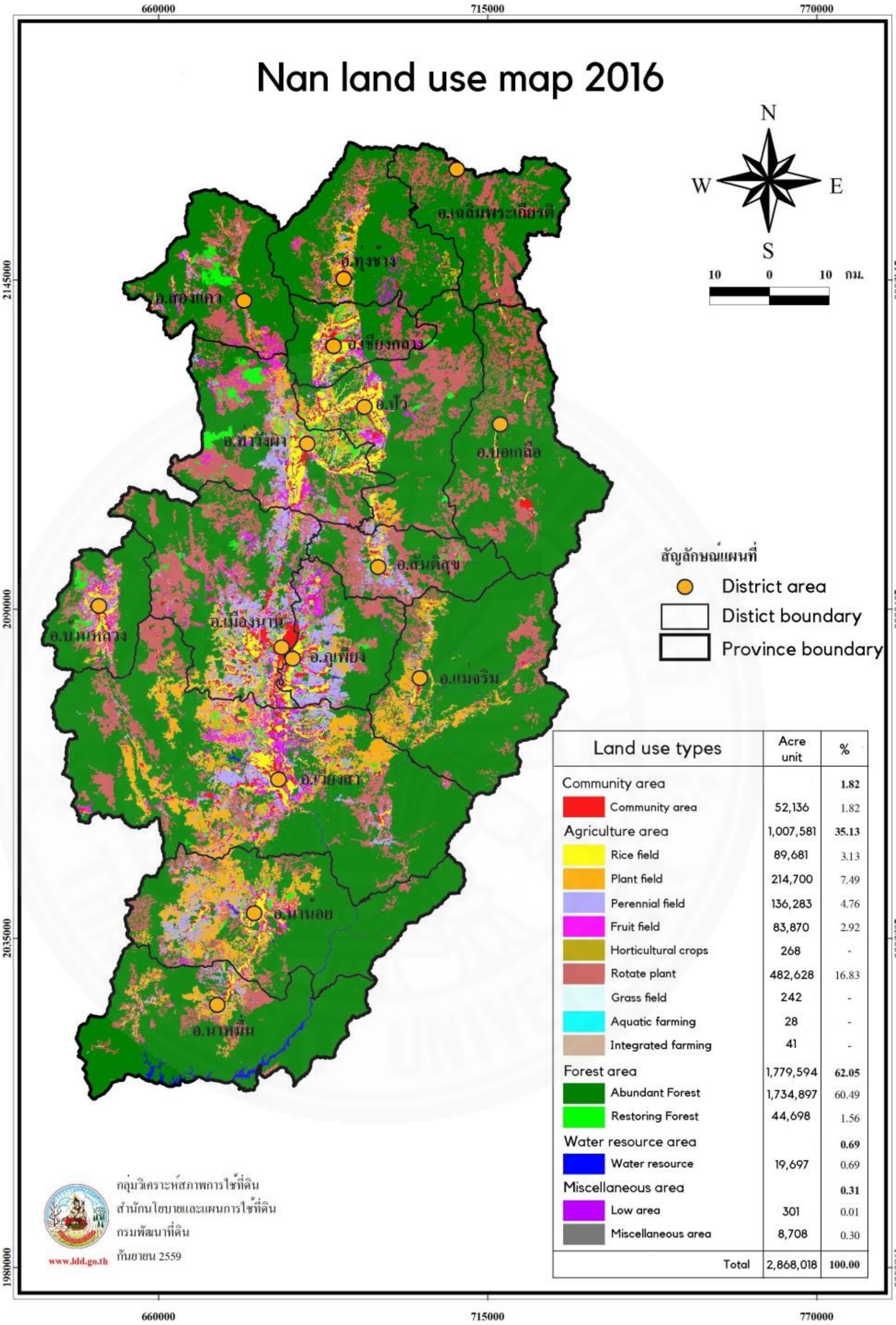


Figure2.15 The latest map of land use situation in Nan province (Land Development Department. 2016).

2.4 Major crops planting in Nan province.

2.4.1 Maize

Maize is also called corn. Maize is important because it is the main staple of multiple food from agriculture, livestock feed products and serves as a major component for various industrial products. The biological research reveals that maize is produced annually more than 1016.73 million metric tonnes.

Maize grows well in various agro-ecosystems, especially, tropical condition. The suitable temperature for maize growth is approximately 23- 27 ^{o}C. Maize plantation can be conducted above sea level to higher than 2,000-3,000 m. Average rainfall requirement for maize during growing period is 350 - 600 mm per year (Department Of Agriculture, 2005).

Soil property is one factor for encouraging maize growth. Therefore, the appropriate soil properties for maize plantation are described as the followings. Clay loam is very suitable for maize growth. In case of soil which has much clay particle, clay particle promotes soil water retention and too moist can lead to flooding in cultivation area. The result is crop damaged. The optimal rate of soil water holding capacity in sandy loam for growing maize is 30.5 %(Charles A. Shapio et al., 2008).

Soil acidity for planting maize should be 4-9 of the pH level. The optimum range of organic matter content in soil is around 1.8-3.0 %. The three major soil nutrients are nitrogen, phosphorus, and potassium. Nitrogen plays a key role to build a strong structure of plant and produces grain. Nitrogen appears in soil in many forms such as NH^{4+} or No^{3-}, thus, it is easier to detect total nitrogen. Total nitrogen required for maize growth is more than 50 ppm. Phosphorus is also important for fertilizer seeding of crops. The optimum range is 10-20 ppm. One of three proportion of available potassium in soil is used for seeding and the remaining retains in maize stalk. The potassium lack of problem is barely found in Thailand. However, the optimum rate of potassium in maize field ought to be 40-60 ppm. Cation exchange capacity is the key to measure ability of soil to transfer nutrient into plant tissue, and 10-25 meq/100g is good for maize (Field and renewable energy crops research institute, 2005).

2.4.2 Rice

Rice has the large crop production in Thailand. Rice generally grown in Thailand is separated to many breeds. Normally rice cultivation needs irrigation system. Nonetheless, limitation of proceeding rice field in hilly topography is insufficient water resource. The regular breeds which are selected to make rice field on mountains are Jaokowchiangmai, Jaoleesanpathong, R-258, Namroo, Kowpongkrai, and Kowluangsanpathong. These rice breeds need 60% lower amount of water than typical paddy field rice (Rice Department, 2008).

The optimum conditions for growing rice are identified. Clay, clay loam and loam are suitable soil for growing rice. Clay particles promote soil to retain water content and some nutrients. Water holding capacity of these soils is approximately 23-30.5%. Average rainfall quantity during planting season is 1,400 - 1,600 mm. per year. Lacking of water during rice growth can lead to weed disturbance and losing rice grain quality problems. Temperature for rice growth varies between 18-30^{o}C. (Auttanun, 2007)

Soil pH is suggested to be 5-8. The organic matter in soil serves around 1.7-3.4 %. For soil nutrients requirement, optimal rate of nutrient such as nitrogen is 1,000-2,000 ppm (Keulen, 1977), 5-10 ppm for phosphorous and more than 78 ppm for potassium. Soil potentiality to exchange nutrients or CEC ought to be 14.4 meq/100g (Haifa Chemicals group, 2014).

Rice harvesting can be conducted 25-30 days after rice produces grains, and the threshing rice step will be operated afterwards until rice moisture remains only 14% (Bureau of Agricultural Commdities Promotion and Management, 2010).

2.4.3 Banana

Banana is a tropical fruit. The origin of banana is from South East Asia. Human can get benefits from banana in many parts of it, such as fruit for food and leaf for container. Banana plantation has low cost to conduct, and banana is also fast growing plant. Moreover, it is the plant that creates market flexibility. The general breeds of banana in Thailand are Cavendish Banana, Ducasse Banana, and Golden Banana (Posomboon, 2001).

Banana is an annual crop which grows well in tropical climate condition and it can produce crop yield for the whole year. A couple of months in winter are an exception because banana produces fewer yields in cool weather. Conversely, too warm weather can lead to some symptoms e.g. leaf blight, low nutrient uptake and poor yield quality. The well growing condition for banana is under temperature around 20-27 ^{o}C. Loam soil and clay loam is very suitable to plant banana because of their great water holding capacity about 28.2-30.5%. The average annual rainfall required for planting is 1,200 – 2500 mm per year, thus, banana needs steady irrigation system.

For soil chemical properties, pH value should be 4.5-7. The percentage of organic matter is 1.8%. The optimal rate of soil nutrients are nitrogen more than 700 ppm, phosphorus more than 40 ppm, and potassium 144 ppm that strengthen plant during fructification process, and cation exchange capacity more than 12.4 meq/100g (Pattison et al., 2008).

The suggestion of banana planting is that soil should not be too dried or wet , and planting area should not be located in the area which has strong wind flow because it can damage banana tree or leaf (Department Of Agriculture, 2005).

2.4.4 Coffee

The famous breeds of coffee are Robusta, Arabica, Excelsa, and Liberica because they are only 2 types of coffee that are planted for sale. Farmers commonly grow Robusta and Arabica because they have good taste (Masterpiece Coffee Roasting House, 2011).

Arabica is known to be one of the most important coffees worldwide due to more than 80% of coffee production. Arabica is native to south western highland of Ethiopia. Coffee is not only used for a beverage but it is also used in the ingredient of plenty products e.g. beauty, dessert and so on. In order to the manufacture the products, coffee beans need to pass through many complex processes. One step of plantation is controlling the suitable environmental factors providing the coffee growth.

Most coffee cultivation is planted in the beginning of rainy season. Arabica grows best with 1,000-1,500 mm of rainfall through the year. Two to three months in dry season, these time suites this species growth. Arabica coffee is usually cultivated between 700 – 2,800 m. altitude above the sea level. Elevated area influences on coffee taste. However, planting process has no difference in varied altitude.

Arabica grows well with temperature approximately 15-24 ºC. This plant excellently rises in low climate but not frost. Furthermore, both of Robusta and Arabica dislike too strong sunlight. Therefore, the shade is necessary to shield them (Casasbuenas, 2017).

Loam and clay loam are a good soil for planting coffee. The range of water holding capacity is between 28.0-30.5 %. For chemical properties, pH value should be 5.5 - 6.0, OM is set between 1.0-3.0%. Coffee tree intensely requires soil nutrients. Agriculturists rather put fertilizer many times. The optimal range of nitrogen is not less than 20 ppm. Phosphorus is 60-80 ppm and potassium is very important for fructification process serve as 100-130 ppm and cation exchange capacity is over 0.75 meq/100g (Abayneh Melke & Ittana, 2015; Ministry of Agriculture and Cooperatives, 2014).

The caution to produce coffee mentioned about if coffee fruit too many berries it can lead to some problems are a coffee bean low quality or coffee produces fewer yield crops. To avoid the issue, trimming is suggested to solve this problem. Another damage can occur in soil is soil degradation from adding too much ammonium sulfate fertilizer. The solution is putting limestone and organic fertilizer for adjusting soil balance (Department Of Agricultural Extension, 2013).

2.4.5 Cashew nut

The origin of cashew nut comes from South America. Cashew tree is a perennial plant which is durable to grow under dry condition. Moreover, it is also easy to make a plantation and rapidly grow. The shape of fruit is odd but its seed for consuming stick at the bottom. Cashew tree prefer warm climate as 25-27^{o}C. Annual rainfall of 1,000 mm is sufficient for production, but 1,500 -2,000 mm can be preferred as optimal rate. Although, this crop can be easily taken care but, proper soil quality is necessary for cashew tree growth (Tuncharoen & Kadcharoen, 2013).

Soil texture is clay loam, loam or sandy loam which can hold water content more than 28.2-30.5%. For chemical soil properties, appropriate soil pH is 5.4-6.4, organic matter should over 0.8%. The three major nutrients ought to be set more than 700 ppm of nitrogen, more than 40 ppm of phosphorus, and 144 ppm of potassium. Optimum CEC is over 12.4 meq/100g (Widiamaka et al., 2014).

The recommendations of cashew plantation are described. Before adding fertilizer, step firmly to make sure that soil is wet enough. Trimming is very important process to take care of cashew tree, as a result, cashew tree fruits have good quality of seed and a long-lasting life.

CHAPTER 3
Methodology

3.1 Research framework

The framework (Figure3.1) consist of selected study areas which are maize field, economics crop, hilly rice field, lowland rice paddy field, old-aged rice terrace, new- aged rice terrace, and abandoned field. Soil samples were collected to investigate soil properties both of chemical and physical properties. Furthermore the survey of agricultural activities used for describing as cause of soil problem. The final part is the study of proper land use management to practice in study areas.

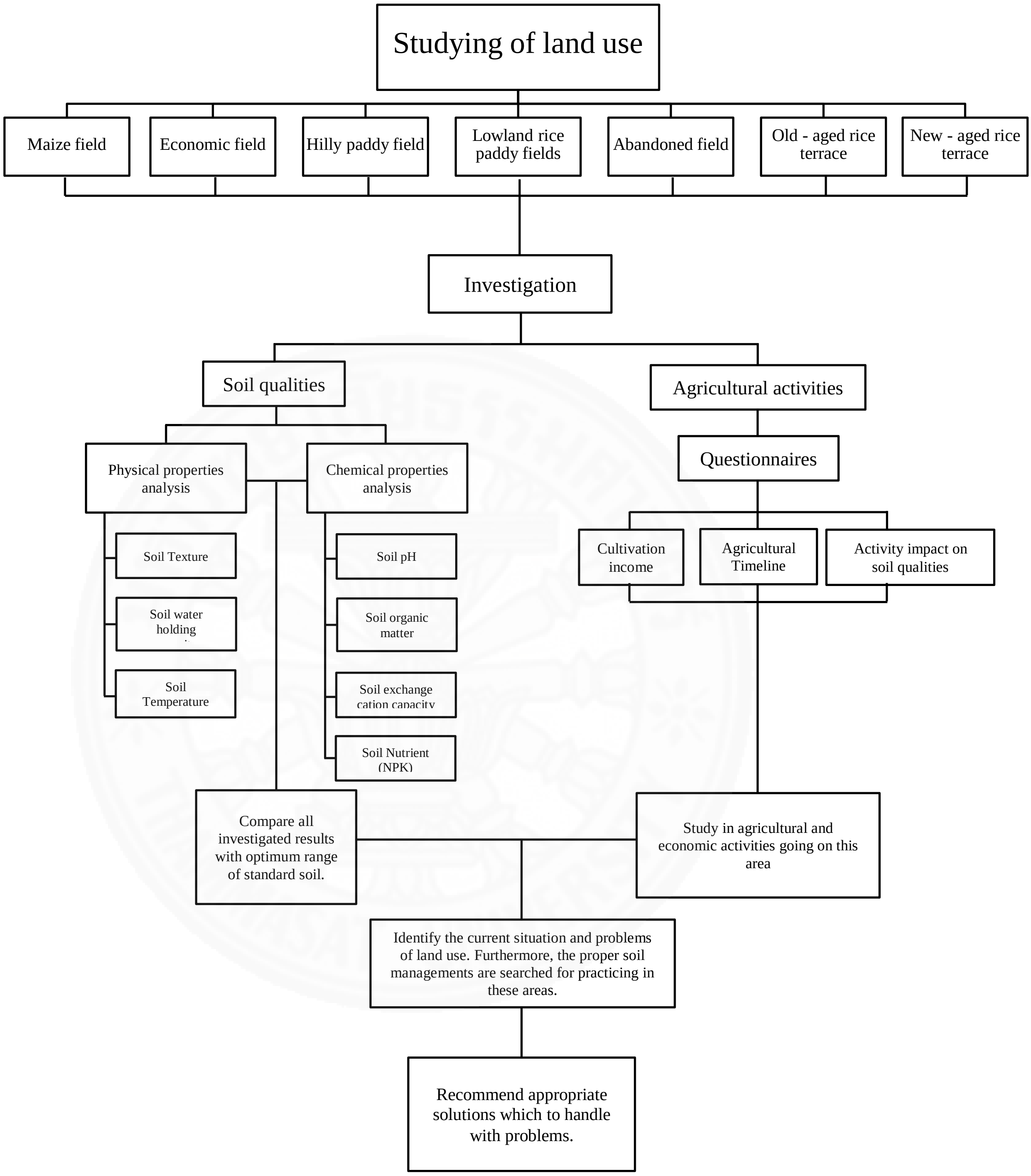


Figure3.1 Framework of the study.

3.2 Study site

Chaloem Phra Kiat is one of district which located on the upper part in Nan province. The total area of Chaloem Phra Kiat is 518.7 square kilometers (Figure3.2). All area was divided to 3 parts as 89% of mountainous area, 9% of valley flat, and 1% of water resource. The Nan River is the major water resource. The two sub-districts are Huai Kon and Khun Nan. Chaloem Phra Kiat district has a boundary connected to other counties. (Jeithongsri, 2012)

Northern: Laos

Eastern: Laos

Southern: Pua and Bo kluea district.

Western: Thung Chang district.

Climate in Chaloem Phra Kiat district is slightly cold. In summer, the average temperature is 33.0 ^{o}C, and the average temperature around 20.1 ^{o}C when winter (Cilmatological Center, 2017). The number of population is 9,853. Agriculture is typical perform as occupation in this area (Jeithongsri, 2012). Typical occupations that people in Chaloem Phra Kiat district are as follow;

Plantation: maize, corn, shiitake, and hilly rice

Husbandry: cattle, chicken, fish, and pig

Forest product: rattan, toddy palm, and fresh water seaweed.

Self employed

Out of planting season, famers do supplementary occupation such as weaving, making bloom stick, growing mushroom, and making basketry (Department Of Provincial Administration, 2012).

3.2.1 Sample areas

The seven agricultural areas are located in the same sub-district, Khun Nan. Those areas were selected in different village because each village has various agricultural patterns depend on its topography. All information of agricultural lands was given the detail (Table 3.1).

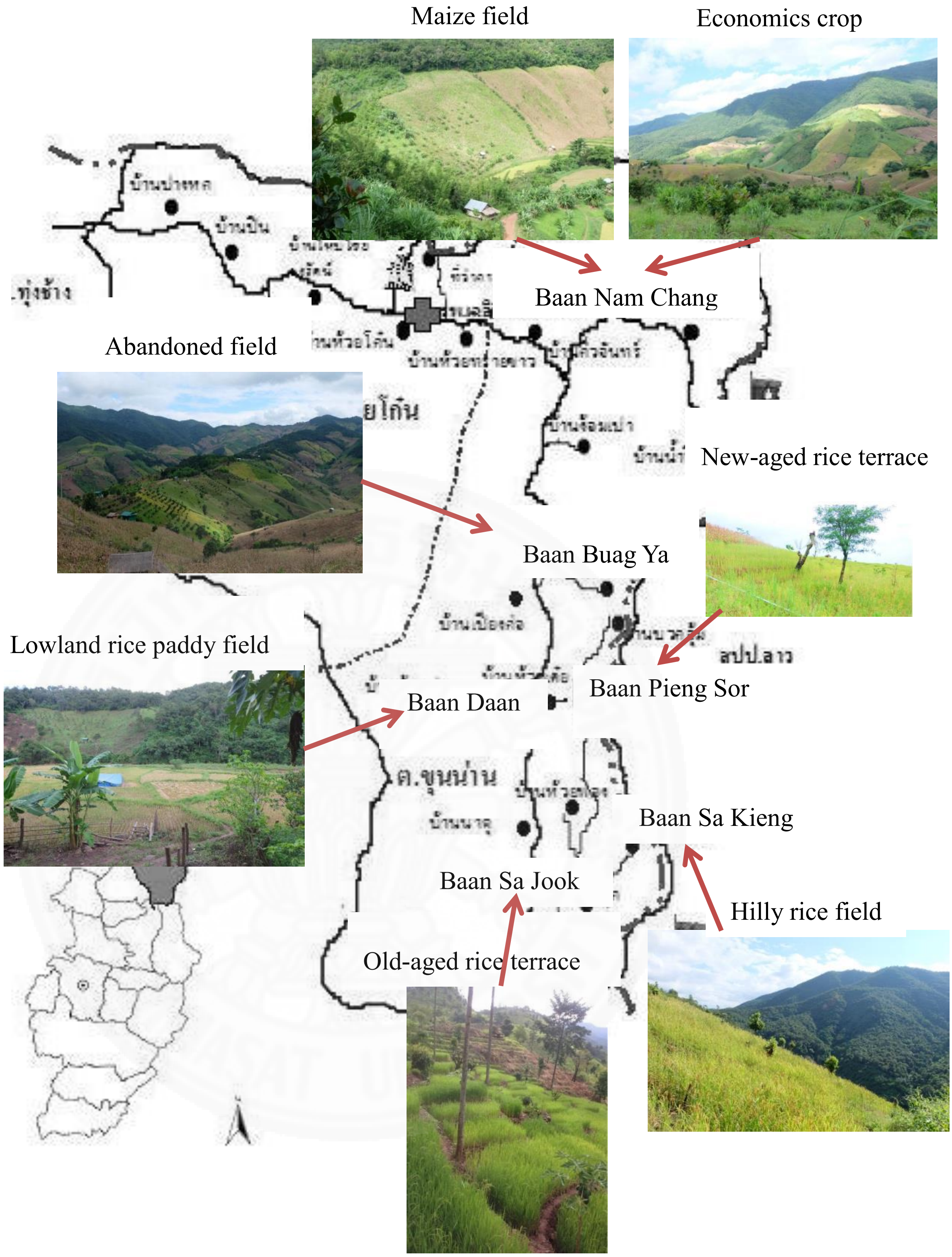


Figure3.2 Map shows overall view of Chaloem Phra Kiat district and agricultural type locations.

(Chalerm Pra Kiet Hospital, 2010)

Table 3.1 The description of study areas.

Villages	Planting categories	Crop categories	Avg. size of areas (Rai)	Avg. usage time (year)	Remark
Baan Nam Chang	Maize field	maize	44.5	19.5	-
	Economic field	banana, coffee and cashew nut	20.9	11.5	-
Baan Sa Kieng	Hilly paddy field	rice	8.3	19.5	-
Baan Pieng Sor	New- aged rice terrace	rice	4	3	-
Baan Daan	Lowland rice paddy field	rice	5	17	-
Baan Sa Jook	Old – aged rice terrace	rice	3.25	33	-
Baan Buag Ya	Abandoned field	none	5	>10	Abandoned for 3 years

3.3 Experiment preparation.

3.3.1 Soil sample collection

Soil samples were collected by random sampling method (Figure3.2) depends on land use topography (top, middle and low area). All steps follow the standard method from ASTM D4700. Five samples were collected from each area. Excavation of soil samples can be done by digging from the surface deep down to 6 to 8 inches. The shovel is inserted straight into the ground then soil is lifted out from the ground forming a V-shaped hole. (Figure3.4) The 1-inch slice of soil is taken out along with the vertical side of the hole. Both sides of soil are removed leaving only around 1 inch in the center with hand. The collected sample size will be 1 inch thick, 1 inch wide and 6 inches long. Soil strip is placed in the plastic bag and moved to the next spot. All soil samples from the same area are mixed together in one plastic bag (Figure3.5). After collecting soil, samples are air-dried, and sunlight needs to be avoided.

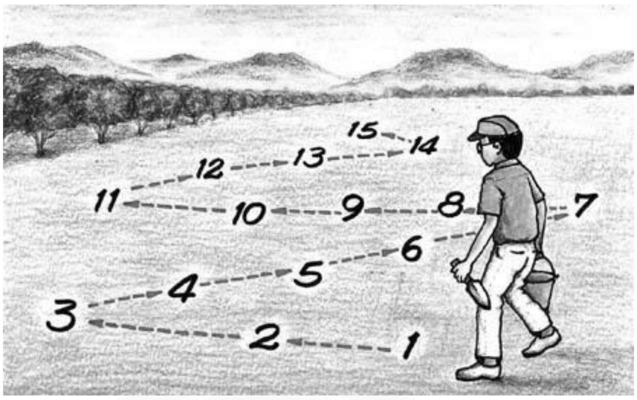


Figure3.3 Random sampling soil method.

(Department of soil development, 2010)

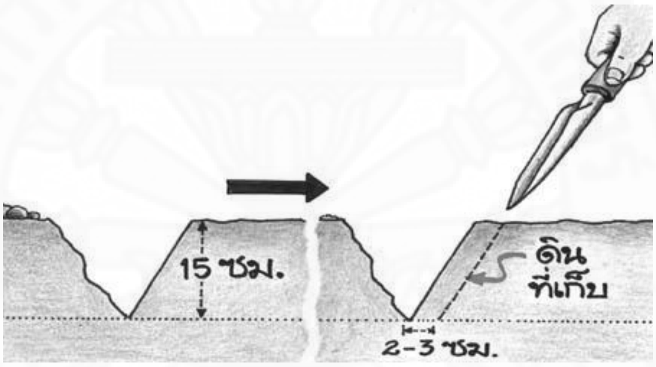


Figure3.4 The V shapes of soil hold.

(Department of soil development, 2010)

Figure3.5 All soil is contained in the same plastic bag.

(Department of soil development, 2010)

3.4 Soil sample analysis

3.4.1 Soil physical properties.

3.4.1.1 Soil texture

From the standard method of ASTM D2487-92, it describes soil classification by the separation of particle size (sand, silt, and clay) from both grain soil and settled soil mixed with water in a cylinder. The separation soil particles must follow many steps (Figure 3.6). In the last step, soil total weight sand, silt, and clay must end up with 100% weight that is calculated by textural triangle diagram (Figure 3.7).

Figure3.6 Soil texture separation step.

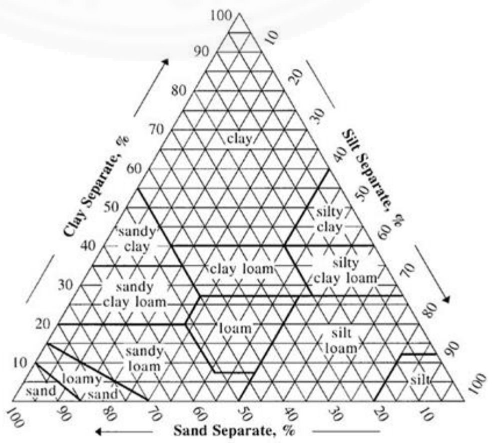


Figure3.7. Soil texture triangle (Lindbo).

3.4.1.2 Water holding capacity

Experiment of water holding capacity of soil follows the standard method is ASTM E1521-14(Abbott, 1985). This laboratory is conducted in pressure chamber by measurement of soil pores. The setting condition in pressure chamber is the major key of this method accordingly to pF pressure (table3.1) then the mass of dry soil is calculated by the equation.

Table3.2 Comparison of pressure and pF (Burt, 2014).

KPa	Bar	Atm	pF	Description
10	0.10	0.099	2.0	Field Capacity
20	0.20	0.197	2.31	
35	0.35	0.346	2.55	
60	0.60	0.592	2.79	
100	1.00	0.987	3.01	
200	2.00	1.974	3.31	
500	5.0	4.936	3.71	
1000	10.00	9.872	4.01	
1500	15.00	14.807	4.20	Permanent Wilting Point

The equation is

$$\mathrm{AWC}(\%) = \mathrm{FC} - \mathrm{PWP}$$

FC = Field capacity (%)
PWP = Permanent wilting point (%)

3.4.1 Soil chemical properties.

3.4.1.1 Soil pH

For the test follow the ASTM C4972-13 standard method by using distilled or de-ionized water to measure pH value. The pH meter is used for detecting active acidity of H+ then measured variable is calculated in the negative log from the equation(Steed & Reed, 2015).

$$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$$

3.4.1.2 Soil organic carbon

This method uses a chromic acid to measure the oxidizable organic carbon in soil. All steps of OM measurement follows the Walkley Black modified acid dichromate digestion (Figure 3.8) (Walkley & Black, 1934). Including, the calculation requires the equation below (Gelman et al., 2011).

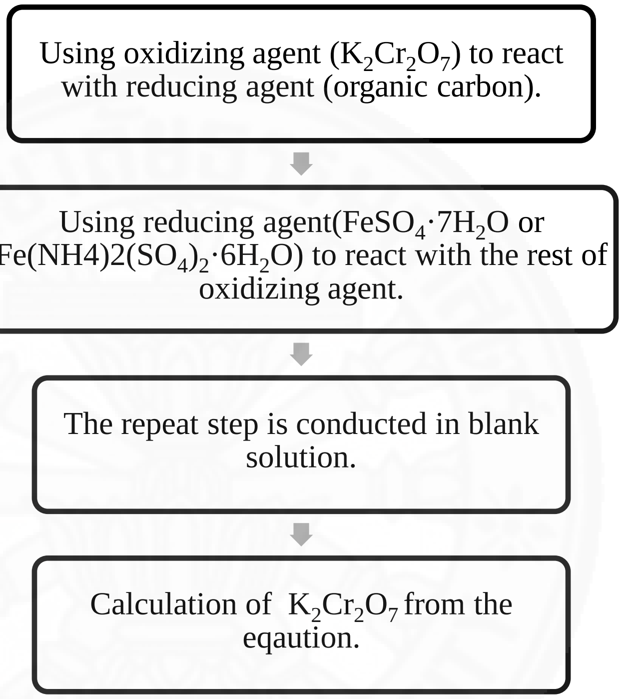


Figure3.8 Procedure of OM examination.

The equation of calculation is

$$\%\text{Organic carbon in soil(O.C.)} = \frac{10 \times (B - S) \times 100 \times N}{B \times 77 \times 1000 \times W}$$

$$\%\text{Organic Matter(O.M.)} = \frac{10 \times (B - S) \times 100 \times 100 \times 3 \times 100 \times N}{B \times 77 \times 58 \times 1000 \times W}$$

$$\text{or } \%OM = O.C. \times 1.724$$

B = Drops of FAS in Blank Titration (ml.)

S = Drops of FAS in Sample Titration (ml.)

W = Weight of soil sample

N = The concentration of $K_2Cr_2O_7$

3.4.1.3 Soil cation exchange capacity

The method is used for estimating the fertility of soil. Procedure emphasizing soil samples are saturated by 1 M of NH4OAc according to ASTM D7503 standard method and the inspection follows 4 major processes (Figure 3.9)(Land Development Department, 2010).

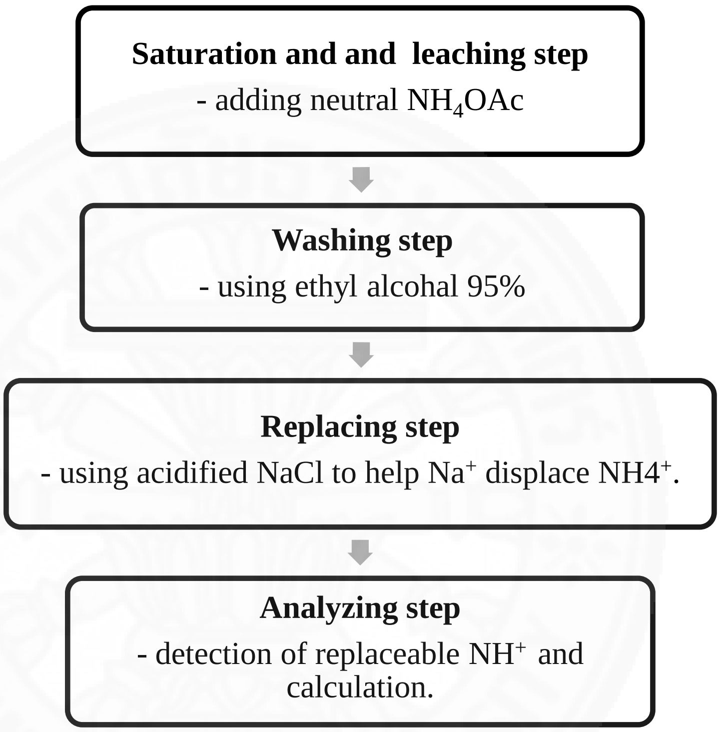


Figure3.9 Procudure of CEC inspection.

The equation of calculation is

$$Ca^{++} \text{ or } Mg^{++},\ cmol_c kg^{-1} = \frac{\text{Readable value}(mgL^{-1}) \times 2 \times \text{dilution factor}}{\text{equivalent weight of } Ca^{++} \text{ or } Mg^{++}}$$

3.4.1.4 Soil nutrients

- **Nitrogen**

Unelaborate nitrogen detection is used when nitrogen in soil is less than 5%. The investigation can be examined by inspecting the percentage of organic matter in soil and conducted with the equation as follows;

$$\%N = \%OM \times 0.05$$

%OM = percentage of organic matter in soil.

%N = Percentage of Nitrogen in soil

The elaborate methods of nitrogen inspection are Dumas method and Kjeldahl method accordingly to method 8075 standard method. The regular method is Kjeldahl method with 3 minor procedures (Figure3.10)(Hach Company, 2014).

Dissolving nitrogen step
-adding concentrated H_2SO_4 into soil.

↓

Humus digestion step
- using boric acid to soil

↓

Titration step
- adding HCl into sample.

↓

Analyzing step
- Calculation follows the equation.

Figure 3.10 Procedure of nitrogen inspection.

The equations of calculation are

$$N_1 = \frac{N_2 V_2}{V_1}$$

N_1= Concentration of HCl (M)
N_2= Concentration of Tris standard solution. (M)
V_1= Volume of Tris standard solution. (cm^3)
V_1= Average volume of HCl acid for titration.

$$\% \, total \, N = \frac{1.4 N_1 V}{W}$$

N_1 = Concentration of HCl (M)

V = Volume of HCl acid for titration.

W = weigh of soil sample.

- **Phosphorous**

This investigation follows bray II from ASTM STP1162 standard method. The essential solutions for these procedures are 0.1 HCl and 0.03 NH_4F. Principle of all processes is the replacement of F^- instead of P^+ on soil surface. The solution can be used to calculate phosphorus value.

The equation is

$$\text{Available Phosphorus} \left(\frac{\text{mg}}{\text{kg}}\right) = \frac{\text{B} \times \text{X} \left(\frac{\text{mg}}{\text{kg}}\right)}{\text{A} \times \text{DF(standard)}}$$

B = Phosphorus concentration from chart/equation (μg/2.5 mL)

A = Oven-dry sample weight (g)

X= Dilution factor

- **Potassium**

K value measurement detects exchangeable K^+ form in soil solution. The 1 M of NH4OAc is a solution for detecting potassium by flame spectrophotometer. The measured value is calculated by equation

$$\text{Available Phosphorus } (\text{mg/kg}^{-1}) = 10\text{K} \times \text{df}$$

K = constant of method (mg/kg^{-1})

df = dilution factor

3.5 Cultivation activities surveys.

The questionnaires focus on 5 topics of survey which are the questions were asked from farmers who own maize field, economic crops, hilly paddy field, lowland rice paddy field and rice terrace. (Examples of questionnaires are enclosed in appendices)

(1) Cost and benefit per planting season .

The topic emphasizes on cost of land use preparation before planting, transportation for purchasing product from the market, chemical treatment for soil, price of labors, etc. After the calculation of cost price and income, the total benefit of production will be deducted by total cost.

$$\text{Total benefit} = \text{Total income} - \text{Total cost}$$

(2) Schedule of activities

Farming timelines are arranged by farmer activities which are conducted in each month.

(3) Soil enhancers

Interrogation of this topic is related to types of chemical compound commonly used in each area and inspection of soil problems that probably happen in the future.

(4) Market for selling product

Place of selling crop yield and product transportation procedure.

(5) Problems of production.

The current problems usually occur during plantation and need the sustainable solution.

Chapter 4
Result and Discussion

4.1 The result of investigation of soil properties from sample areas.

A soil property is an indicator of soil quality. Planting crops in proper soil condition will encourage plant growth and influence plant to produce numerous yield. Soil sample collection for the investigation of soil properties is operated twice.

4.1.1 Soil investigation 1st round (September 2017)

In the first round, samples were collected in rainy season. The result shows varied physical and chemical properties of soil samples in all areas. (Table.4.1)

Results from soil texture classification showed that most soil samples were clay soil that can be majoring 3 sub-kinds. Clay soil which consists of 40% clay can be found at economic crops, hilly paddy field and abandoned field. Clay loam soil consists of 27-40% clay can be found at maize field and lowland rice paddy field. Sandy clay loam which consists of 20-27 % clay and more than 45% sand was found at new-aged rice terrace.

Soil texture results vary in line with soil water holding capacity. Thus, soils from economic crops, hilly paddy field and abandoned field performed best in absorption ability followed by maize field, lowland rice paddy field. Soil from old-aged rice terrace had lowest absorption ability.

Measurement of soil temperature presents invariable result. The average soil temperature is 25-30 ^{o}C. Although, some areas had high temperature because sample collection was proceeded during noon time, high soil temperature has slightly no effects on plant growth (Volz & DeMoss, 2002).

Chemical analysis shows that pH value is approximately 5-6. The old-aged rice terrace and new-aged rice terrace shows that soil pH is slightly acidic. Maize field, economics crops, hilly paddy field and lowland rice paddy field were estimated to have pH value as strong acid. Moreover, soil from abandoned area was very strongly acidic.

The approximate percent of organic matter value is 2-3. The areas having high OM value were maize field and new rice terrace. The reason of high OM percentage possibly was from the crop straw incorporation during soil preparation and the new-aged rice terrace can be caused by fresh area plantation (McCauley et al., 2017).

Nutrients in soil are nitrogen, phosphorus, and potassium. However, nitrogen cannot be detected because of some reasons. Therefore, numerically phosphorus was detected in both of old-aged rice terraces and new-aged rice terrace but less volume of phosphorus were found in the rest areas. There was high phosphorus value in rice terrace because rice terrace areas are wetland and the condition does not encourage soluble phosphorus. Thus, phosphorus can be greatly detected in soil surface (Mullins, 2009). In the other hand, a small amount of potassium was found in old-aged rice terrace and new-aged rice terrace because those areas are wetland and potassium is a good solute. Therefore, potassium value is low in soil (Daniel E Kaiser et al., 2016).

Cation exchange capacity represents good soil nutrients uptake ability. Investigation of abandoned field and economics crop showed low cation exchangeable capacity which is the consequence of lacking suitable soil maintenance (Department of Crop and Soil Sciences, 2007).

Table 4.1 The soil investigation result in September 2017.

Sample areas	pH	OM (%)	P (mg/kg)	K (mg/kg)	Cation exchange Capacity (meq/ 100g)	WTC (%)	Sand (%)	Silt (%)	Clay (%)	Soil texture	Soil temperature (°C)		
											Ambient temperature	Average under 5 cm depth	Average under 10 cm depth
Maize field	5.3	2.95	4	101	9.75	47.17	44.2	28.2	27.6	Clay loam	29.0	26.7	25.7
Economics crops	5.1	2.40	4	94	7.65	48.56	36.2	23.2	40.6	Clay	28.0	25.8	26.2
Hilly paddy field	5.1	2.30	3	117	11.06	44.14	30.2	29.3	40.6	Clay	25.0	26.1	25.3
Abandoned field	4.9	2.23	3	134	8.37	45.41	32.2	27.2	40.6	Clay	28.5	27.3	26.4
Lowland rice paddy field	5.1	1.94	5	141	10.42	44.32	30.2	41.2	28.6	Clay loam	28.0	29.2	27.9
Old-aged rice terrace	6.3	2.14	21	48	11.85	39.99	46.2	26.2	27.6	Sandy clay loam	26.5	25.9	25.3
New-aged rice terrace	6.4	2.79	43	58	11.47	42.39	32.2	36.2	31.6	Clay loam	27.5	27.4	26.6

4.1.2 Soil investigation 2nd round (January 2018)

The second round of collecting soil sample was operated in dry season during land clearance period. Inspection soil properties show both of physical and chemical soil properties (Table.4.2).

Soil texture from all study areas was classified as clay loam soil. The proportion of sand, silt, and clay were separated approximately 30:30:40.

Soil texture results influenced on soil water holding capacity. Thus, percentage of soil water holding capacity was 40-50%, exceptional low-land rice paddy field is 29.8%. Humus level in soil is one of the factors to control soil absorption ability (McCauley et al., 2017).

Measurement of soil temperature presents invariable result. The average soil temperature is 24-30 ^{o}C. The result of soil temperature was not concerned because it had less impacts on soil microbial activities (Volz & DeMoss, 2002).

Chemical analysis showed that pH value is approximately 5-6. The lowland rice paddy field and maize field show soil pH slightly acidity. Old-aged rice terrace was estimated to have pH value as moderate acidity. Soil pH of economics crops, hilly paddy field and new-aged rice terrace are strongly acidic and abandoned area is very strong acid.

The reason of high OM percentage is possibly from the burning process during land clearing activity. Humus is one of organic matter components. As the result of low OM value in lowland rice paddy field affect with low level of water holding capacity (WHC). Although, old-aged rice terrace had lowest OM because clay is the main particle to hold water in soil, thus, WHC in lowland rice paddy was lower than old-aged rice terrace (Bray & T, 1945).

For essential nutrients in the soil, nitrogen is numerically detected more than 2000 ppm in most study areas, exceptional economic crops which is lower than 1000 ppm. Highest phosphorus volume was detected in lowland rice paddy field and the lowest volume in abandoned field which is no addition of fertilizer. High phosphorus value in lowland rice paddy field is from incorporation of rice straw and it becomes organic phosphorus in soil(Grant et al., 2005). In the other hand, high amount of potassium was found with approximately 100 ppm in most study sites. Economic crop is different because potassium is a necessary nutrient for plant uptake which encourages fruiting activity and earns higher yield crops (Daniel E Kaiser et al., 2016).

Exchange cation capacity in abandoned field and economics crops has low cation exchangeable capacity which influences low pH value.

Table 4.2 The soil investigation result in January 2018.

Sample areas	pH	OM (%)	N (mg/ kg)	P (mg/ kg)	K (mg/ kg)	Cation exchange capacity	WTC (%)	Sand (%)	Silt (%)	Clay (%)	Soil texture	Soil temperature (°C)		
												Ambient temperature	Average under 5 cm depth	Average under 10 cm depth
Maize field	6.0	3.87	2,067	20	106	12.99	51.08	32.6	32.0	35.4	Clay loam	30.0	28.0	26.7
Economics crops	5.2	2.82	950	5	69	8.25	47.65	37.6	27.0	35.4	Clay loam	30.5	25.8	26.2
Hilly paddy field	5.2	3.04	2,883	5	190	11.04	46.39	24.8	35.8	39.4	Clay loam	30.0	26.1	25.3
Abandoned field	4.9	1.94	2,267	3	108	7.37	31.6	31.6	29.0	39.4	Clay loam	29.5	27.3	27.9
Lowland rice paddy field	6.1	1.57	2,179	40	107	10.72	29.8	29.8	41.0	29.2	Clay loam	30.0	28.6	28.0
Old-aged rice terrace	5.9	1.55	2,141	20	113	10.23	43.50	36.8	30.0	33.2	Clay loam	27.5	25.0	24.7
New-aged rice terrace	5.0	3.01	3,021	7	173	11.06	48.85	24.8	35.8	39.4	Clay loam	27.0	24.6	24.1

4.2 The comparison between the optimum condition for plant and soil sample examined properties.

This section presents the comparison of soil standard which indicates the optimum ranges of soil for planting crops with properties of investigated soil including describing appropriation of soil and cultivation.

4.2.1 Maize field (Table 4.3)

The comparison shows that clay loam is in the optimum range of soil texture for growing maize. Crop residue decomposition can encourage pH value because organic matter and clay particles capture H^+ ion in soil and also displace H^- that promotes pH value to neutral. Organic matter sets with optimal range and the second result elevates from the first result because of crops residue decomposition process by the microorganism in soil (Department of soil science faculty agriculture, 2005).

The surveys studying in maize field showed that farmers were adding fertilizer during plantation. The major components in fertilizer are 16% nitrogen, P_2O_5 20%, and K_2O 0%.

Soil nutrients are within the standard. However, it is focused on phosphorus due to the obvious volume increase from the effect of decomposition of microbial activity (Charles A. Shapio et al., 2008).

Table4.3 The comparison examined result of soil from maize field with the optimal range conditions.

Maize	Optimum conditions	Round 1 collection	Round 2 collection	Total percent change (%)
Soil texture (proportion of Sand:Silt:Clay	Clay loam	Clay loam (44:28:27)	Clay loam (33:32:35)	-
pH	5.5-6.4	5.3	6.0	11.7
OM (%)	1.8-3.0	2.95	3.87	23.8
N (mg/kg)	>50	-	2,067	-
P (mg/kg)	10-20	4	20	80
K (mg/kg)	40-60	101	106	4.7
CEC (meq/ 100g)	10-25	9.75	12.99	24.9
Water holding capacity (%)	>30.5	47.17	51.08	-
Sources	(Charles A. Shapio et al., 2008; Field and renewable energy crops research institute, 2005)	-	-	-

4.2.2 Hilly rice paddy field. (Table.4.4)

Clay loam is suitable soil to grow rice in this area. Soil water holding capacity, pH, and Cation exchange capacity are good after results were compared with the standard condition. Organic matter rose up for 38.4% by crop residue decomposition(McCauley et al., 2017). Moreover, this area grew rice without the addition of fertilizer but the amount of three major soil nutrients stowed in soil is suitable for the standard value. Cation exchange capacity is lower than the standard because pH value is strongly acidic which does not promote any available cation to transfer into plant root (Department of Crop and Soil Sciences, 2007).

Table 4.4 The comparison examined result of soil from Hilly rice paddy field with the optimal range conditions.

Hilly rice paddy field	**Optimum conditions**	**Round 1 collection**	**Round 2 collection**	**Total percent change (%)**
Soil texture (proportion of Sand:Silt:Clay	Clay loam	Clay (30:29:41)	Clay loam (25:36:39)	-
pH	5.0-8.0	5.1	5.2	1.9
OM (%)	1.7-3.4	2.30	3.04	24.3
N (mg/kg)	1000-2000	-	2,883	-
P (mg/kg)	5-10	3	5	40
K (mg/kg)	>78	117	190	38.4
CEC (meq/ 100g)	14.4	11.06	11.04	0.2
Water holding capacity (%)	30.5	40.6	46.39	-
Sources	(Auttanun, 2007; Haifa Chemicals group, 2014; Keulen, 1977)			

4.2.3 Lowland rice paddy field. (Table.4.5)

The difference of double soil sample collecting shows many change. After compares the soil optimal criterion of rice cultivation, a changes of pH value from 5.1 becomes 6.1 because crops residue decomposition process. The remaining crop is basic and has potential to control H+ balance so it can adjust soil pH to close to neutral (Klodpeng 1985). The changes of pH influence on the elevation of phosphorus because 5.8 of pH is the proper condition of potassium and calcium combination ($Ca_3(PO_4)_2$) and that cannot dissolve in water. In the other hand, the increase of pH can reduce P and Ca reaction and also accumulate available phosphorus in soil(Lajtha et al., 1999). The reduction of potassium quantity cause plant uptake during the rice grain production or nutrient runoff by leaching water after draining.(Grant et al., 2005). Furthermore, the water holding capacity decreases accordingly to the decrease of OM. Organic matter reduction leads to lower CEC than the optimal rate.

Table 4.5 The comparison examined result of soil from lowland rice paddy field with the optimal range conditions.

Lowland rice paddy field	Optimum conditions	Round 1 collection	Round 2 collection	Total percent change (%)
Soil texture (proportion of Sand:Silt:Clay	Clay loam	Clay loam (30:41:28)	Clay loam (30:41:29)	-
pH	5.0-8.0	5.1	6.1	16.4
OM (%)	1.7-3.4	1.94	1.57	19.1
N (mg/kg)	1000-2000	-	2,179	-
P (mg/kg)	5-10	5	40	87.5
K (mg/kg)	>78	141	107	24.1
CEC (meq/ 100g)	14.4	10.42	10.72	2.8
Water holding capacity (%)	30.5	45.41	29.8	-
Sources	(Auttanun, 2007; Haifa Chemicals group, 2014; Keulen, 1977)	-	-	-

4.2.4 Old-aged rice terrace. (Table.4.6)

The soil result from old-aged rice terrace focused on organic matter which approximately decreased by 27.6 %. This change has an effect on soil acidity and CEC value due to uncontrollable hydrogen balance (Department of soil science faculty agriculture, 2005). This study site produces rice without adding more enhancement compound. However, potassium is one of the major nutrients elevated by 57.5% from microbial decomposition or possibility from collection process. The first sample collection was conducted during planting period so this place is flooded with water. Well known potentiality of exchangeable potassium is good solubility. Most exchangeable K accumulated in water instead of soil surface. The detection K value is lower than reality. Whereas, next sample collection was operated in dry season, thus, water was drained and exchangeable potassium is stored with soil surface. As a result, the detection of potassium was higher than the first sample collection (Daniel E Kaiser et al., 2016)

Table 4.6 The comparison examined result of soil from old-aged rice terrace with the optimal range conditions.

Old-aged rice terrace	Optimum conditions	Round 1 collection	Round 2 collection	Total percent change (%)
Soil texture (proportion of Sand:Silt:Clay	Clay loam	Sandy Clay loam (46:26:28)	Clay loam (36:30:33)	-
pH	5.0-8.0	6.3	5.9	6.3
OM (%)	1.7-3.4	2.14	1.55	27.6
N (mg/kg)	1000-2000	-	2,141	-
P (mg/kg)	5-10	21	20	4.8
K (mg/kg)	>78	48	113	57.5
CEC (meq/ 100g)	14.4	11.85	10.23	13.7
Water holding capacity (%)	30.5	39.99	43.50	-
Sources	(Auttanun, 2007; Haifa Chemicals group, 2014; Keulen, 1977)	-	-	-

4.2.5 New-aged rice terrace. (Table.4.7)

From soil investigation result in new-aged rice terrace, it was found that most of soil properties are suitable for conducting rice terrace production. The exception is CEC which is lower than the optimum range (Department of Crop and Soil Sciences, 2007). The changes of soil nutrient emphasize the reduction of phosphorus. Accordingly, soil pH becomes strongly acidic and disturbs the balance of H^+ because soil microorganism reduces phosphorus production. (Mullins, 2009) Whereas, soil potassium volume rose up by 66.5 %. The cause from some parts of the study areas were burned during land clearing step. Ash contains potassium carbonate (K_2CO_3), sodium carbonate (Na_2CO_3), and potassium sulfate (K_2SO_4). That leads to increasing K volume in soil. (Daniel E Kaiser et al., 2016)

Table 4.7 The comparison examined result of soil from new-aged rice terrace with the optimal range conditions.

New-aged rice terrace	Optimum conditions	Round 1 collection	Round 2 collection	Total percent change (%)
Soil texture (proportion of Sand:Silt:Clay	Clay loam	Clay loam (32:36:31)	Clay loam (25:36:39)	-
pH	5.0-8.0	6.4	5.0	21.9
OM (%)	1.7-3.4	2.79	3.01	7.3
N (mg/kg)	1000-2000	-	3,021	-
P (mg/kg)	5-10	43	7	83.7
K (mg/kg)	>78	58	173	66.5
CEC (meq/ 100g)	14.4	11.47	11.06	3.6
Water holding capacity (%)	30.5	48.85	42.39	-
Sources	(Auttanun, 2007; Haifa Chemicals group, 2014; Keulen, 1977)	-	-	-

4.2.6 Economics crop. (Table.4.8)

Variety of annual plants and perennial plants are planted in this area. However, the scope of study focuses only few major plants which are cashew nut, coffee bean, and banana. From the examined result of soil properties, it reveals that this area is intensely used. Adding both chemical fertilizer (NPK 15-15-15 fertilizer and urea fertilizer) and chemical pesticide (Gramoxone and Glyphosate) are operated with soil.

Soil texture, soil temperature, and soil WHC value are in optimum level. However, soil pH is strong acid (Lake 2000). It makes soil CEC lower than the standard and it also influences on soil potentiality to transfer exchangeable ion (Department of Crop and Soil Sciences, 2007). Moreover, all microbial activity and nutrient production process are bogged down and the quantity of phosphorus and potassium is less than the soil standard (Daniel E Kaiser et al., 2016; Mullins, 2009). Due to the high nutrient requirement of plants during fructification process, especially phosphorus and potassium which are very important for helping plant fruitage, they are absorbed by plant root numerously (Klodpeng, 1985).

Table 4.8 The comparison examined result of soil from economics crop with the optimal range conditions.

Economics crop	Optimum conditions for cashew nut	Optimum conditions for Banana	Optimum conditions for coffee	Round 1 collection	Round 2 collection	Total percent change (%)
Soil texture (proportion of Sand:Silt:Clay	Clay loam-Sandy clay loam	Clay loam-Soil loam	Clay loam - loam	Clay (36:23:41)	Clay loam (38:27:35)	-
pH	5.4-6.4	4.5-7.0	5.5-6.0	5.1	5.2	1.9
OM (%)	>0.8	1.8	1.0-3.0	2.4	2.82	15.5
N (mg/kg)	>700	2500	>20	-	950	-
P (mg/kg)	>40	80	60-80	4	7	20
K (mg/kg)	144	133-312	100-130	94	69	26.6
CEC (meq/ 100g)	>12.4	10-20	>0.75	7.65	8.25	7.3
Water holding capacity (%)	28.2-30.5	30.5	30.5	48.46	47.65	-
Source	(Widiamaka et al., 2014)	(Pattison et al., 2008)	(Ministry of Agriculture and Cooperatives 2014, Abayneh Melke and Ittana 2015			

4.3 The current situation of agricultural land use in Chaloem Phra Kiat district, Nan province

This study shows the results about highland cultivation in Chalerm Phra Kiat district, Nan province. In the past, approximately 70,000 Rai is forest area and the rest area of 50,000 Rai is residential and cultivation area. Agricultural production mostly performs in plain area. However, plain area is a limited space in Chalerm Phra Kiat district. It approximates 5% of agricultural area.

Chalerm Phra Kiat district applies land use management modeling to practice land use separation. Land use is divided accordingly to the purposes; 20% economics crop (cashew nut, banana, coffee, mullet, and so on), 10% of reserved forest, 10% of community forestry, and 2% of community resident. Plants commonly grown in this area are rice, maize, cashew nut, coffee, banana and so on (Jeithongsri, 2012). Nowadays, coffee is very trendy since the private sectors make an offer to farmers by raising the price of coffee beans and the demand of overseas purchasing. This reason encourages farmers to begin coffee plantation for few years ago.

In the past, farmers generally used fire-dependent agricultural pattern because burning is an easy way to deal with the remaining crops during land clearing step. However, burning without permission from local officials is not allowed. Since 2013, this legislation has reduced agricultural burning by 96% (Wang pimool et al., 2013). Furthermore, the regular agricultural problem in upland is soil surface loss. Terracing method is practiced to solve this problem. In Chalerm Phra Kiat district, this method has been adopted for 8 years. They gradually started the adjustment by transforming the hilly paddy field to become terrace field. This method is very suitable to solve soil loss problem, but farmers have to pay high cost for conducting terracing method. Normally, this method is appropriate with crops that need irrigation system such as rice.

Most agriculture in this area is a household agriculture and farmers do not only plant crops, but they also make livestock farm to earn an extra income. Pigs and cattle are normal livestock. Previously, those animals were treated without cage; therefore, some crops are destroyed by them. Thus, the cage is necessary for locking them up.

4.3.1 The survey data of agricultural activities in Chaloem Phra Kiat district.

This sector reveals the detail of agricultural activities from the questionnaire about usual management which are practiced in cultivation areas during planting season (Table 4.9).

Agricultural area, such as maize field and economics crop, were added chemical fertilizer to enhance soil properties. The NPK is common fertilizer. The pesticide as Paraquat and Gyphosate were put into soil of maize field, hilly rice field and economic crops to eliminate pest. Insecticide, such as Abamectin, was used with old-aged rice terrace. The disposal crop residue was practiced by burning maize field. However, in most areas, tillage and burying method are used to get rid of agricultural waste. Drought and pest are general problems found in study areas. Watering process requires water supply from rainfall and natural resources such as stream water, canal or pond.

Table 4.9 The survey data of agricultural activities.

Activities / Areas	Adding fertilizer	Adding pesticide	Disposal of plant residue	Agricultural problem	Watering (resource)
Maize field (4 owners)	NPK 46-0-0	- Gyphosate - Paraquat	- Burning - Plowing and burying	Pest	- Rainfed - Natural water resource
Hilly rice paddy field (4 owners)	None	- Gyphosate - Paraquat	Tillage and burying	Pest	- Rainfed - Natural water resource
Lowland rice paddy field (2 owners)	None	None	Tillage and burying	Drought	- Rainfed - Natural water resource
Old-aged and new-aged rice terrace (2 owners)	None	Abamectin	Tillage and burying	Pest	- Rainfed - Natural water resource
Economics crop (5 owners)	- NPK 46-0-0 NPK 15-15-15	- Gyphosate - Paraquat	- Tillage and burying - Separation for sale - Fermentation	None	- Rainfed - Natural water resource - Water tap

The agricultural activity period during planting season can be described using the schedule (Table 4.10). Most crops begin planting period between April to May. Rainy season, during May and July, is very suitable for adding fertilizer. The elimination of unwanted plants is conducted afterwards. Farmers have to firmly know that some chemical compounds will not negatively affect the crops. Subsequently, the crop harvesting is operated during Septembers to January. Some temporary plants, such as rice and maize, are eliminated in land clearing step. Waste disposal can be practiced in many alternatives. Burning and incorporation are usual procedure to eliminate remaining crops. However, some kind of plants can fruit many times in next year, for example, cashew nut and coffee.

Table 4.10 The timeline of agricultural activities in planting season.

Crops	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Maize											
Rice											
Cashew nut											
Coffee											
Banana											

Note: 1. Colors represented cultivation activities as following;

- Planting
- Fertilizer adding
- Unwanted plant elimination
- Crop Harvesting
- Crop Harvesting in later year.
- Clearance of agriculture wastes

4.3.2 Cost, income and profit of cultivation.

Each cultivation area needs the fund to conduct. The information of cost and income from Chalerm Phra Kiat district is shown the table (Table4.11) which contains of crop yield, cost, and income. The analyzed data were compared with average total crop yield of Nan province (Table 2.3) showing worthiness of the cultivation investment (Table 4.11).

The survey data was analyzed and revealed the highest earning income from conducting lowland rice paddy field. Total benefit of lowland rice paddy field is 47,897.8 baht per Rai in one planting season and the number of crop yield is 4,000 kilogram per Rai. The number of yield crop per Rai higher than the average data of Nan province by 3,493 kilogram or approximate profit is 41,813 baht per Rai. Nevertheless, growing rice in plain-area of Chalerm Phra Kiat district is limited by lacking of space. The second amount of yield from rice terrace is 1,166.5 kilogram per Rai and estimated earning profit is 13,175 baht per Rai. Hilly rice field is the final sequence of rice production which earns the lowest profit and it is lowers than the average total rice yield in Nan which is approximately 900 baht per Rai.

The highest income of economic crop is banana production. Farmers harvested banana fruit for 2,367.8 kilogram per Rai higher than the average for 2,052 baht. The gained profit is 9,511.65 baht per Rai and farmers can harvest banana for the whole year.

Two crops which obtained the lowest income are cashew nut and coffee. The sequent amount of yield are 14.8 and 21.8 kilograms per Rai and those number are lower than the average of Nan province because the number of cashew trees and coffee is less than those crops planted in recent few years. Furthermore, Pid Thong Royal Initiative Discovery Foundation makes an offer with local farmers to raise the price higher than the general market. However, farmers can harvest those plants many times. Thus, both of cashew nut and coffee plantation will earn more profit in long term.

Table 4.11 The table shows the cost and benefit of cultivation in Khun Nan sub-district, Chalerm Phra Kiat district, Nan province.

Agricultural areas	Avg. Cost/Rai (Baht)	Avg. Income/Rai (Baht)	Avg. Total profit/Rai (Baht)	Avg. Yield/Rai (kg.)	Remark
Maize field (4 owners)	88.43	4,205.25	4,116.82	695.05	
Hilly rice paddy field (4 owners)	24.23	5,210	5183.77	434.15	Estimated profit. Rice not for sale but, for household consumption.
Lowland rice paddy field (2 owners)	102.2	48,000	47,897.8	4,000	
Rice terrace (2 owners)	825	14,000	13,175	1,166.5	
Cashew nut (5 owners)	60.82	1,921.83	1861.01	14.84	
Coffee (5owners)	116.07	1,133.33	1,017.26	21.83	
Banana (5 owners)	349.6	9,861.25	9,511.65	2,367.8	Estimated converter unit from hand unit.

Table 4.12 The comparison between average yield crop and gaining yield.

Agricultural areas	Avg. crop yield /Rai (kg.) (Ministry of Agriculture and Cooperatives, 2015, 2017)	Avg. yield gaining/Rai (kg.)	Average total profit/Rai (baht) (Ministry of Agriculture and Cooperatives, 2015, 2017)	Avg. Total profit gaining/Rai (Baht)	Remark
Low land paddy field	507	4,000	6,084	47,897.8	Estimated profit, Rice not for sale but, for household consumption
Rice terrace		1,166.5		13,175	
Hilly rice paddy field		434.15		5,183.77	
Banana	315	2,367.5	1,899	9,511.65	Estimated unit
Maize field	593	695.05	3,690	4,116.82	
Cashew nut	43	14.84	1,017	1,861.01	
Coffee	116.07	21.83	872	1,017.26	

4.4 The agricultural activities affect soil quality and recommendations for management.

This part describes improper agricultural land use management conducted by farmers in the study areas which can lead to soil deterioration problems. In addition, proper recommendations were given to solve soil problems in each study area.

4.4.1 Maize

Problem statement

The concerned issues are adding chemical fertilizer and chemical pesticide. The only one type of chemical fertilizer added is NPK 46-0-0 (urea) which contains only 46% of nitrogen. This activity can lead to unvaried nutrient problem and microbial activity in soil is interrupted by too high nitrogen concentration.

For pest elimination step, Glyphosate and Paraquat were added for twice. Chemical pesticide directly affects soil. It destroys soil structure, and soil surface will be eroded by water runoff (Teimkao, 2014). Furthermore, the research of soil pesticide revealed that 99.9 % of chemical pesticide persists in soil particles, and the rest of them, only 0.1%, is directly absorbed by the unwanted plants (Pimentel, 1995).

The remaining crops were disposed by burning. It is the easiest way to dispose of crop waste. Whereas, burning crop residue does not only burn waste but also burns soil organic component or soil microorganism. As a result, it directly disturbs soil nutrients and soil moisture balance (STAN et al., 2014).

Recommendation for maize production

Due to investigated soil result, the suggestion of maize production is as follows. Soil fertilizer should be added twice. The first round, only NPK 16-16-18 should be added for 20 kg/Rai. The second time, famer should put the mixture of organic fertilizer with NPK fertilizer. (Table4.12)

Table 4.13 Suggestion of adding soil fertilizer according to soil properties from maize field (Charles A. Shapio et al., 2008; Plessis, 2003).

Fertilizer formula	**Suggestion quantity for adding (Kg/Rai)**
Urea 46-0-0	18
Diammonium phosphate or DAP 16-46-0	10.9
Potassium chloride 0-0-60	8.3
Dried organic fertilizer (manure or compost crops)	1,000-2,000

However, chemical pesticides have some disadvantages. This is the easiest and cheapest way to get rid of unwanted plants. Whereas, adding chemical pesticide has some limitations. Farmers should spray chemicals when soil is moist enough. Nevertheless, farmer should use the integrated control, for example, adding chemical components along with an alternative. Insecticide can be replaced by dissolved sodium bicarbonate (baking soda) (Danka Stefanovic et al., 2006). Tillage can help control weed. Growing Fabaceae plant as a rotary plant does not only earn more money from crop yield but Fabaceae plant also competitively grows with other unwanted plants (Hoffmann & Moran, 1991).

Elimination of remaining crop is conducted by plowing and burying. Microorganism will turn the crop residue to become useful crop nutrients. However, the hilly field is not easy for tillage land. Therefore, farmers should use maize straw for covering soil surface or compost for fertilizing other plants.

4.4.2 Hilly rice paddy field

Problem statement

This area has no adding of soil enhancer but some chemical pesticide is added. As a result, this activity can lead to soil degradation or negative impacts to organisms living in soil. It leads to the reduction of microorganism activity and soil loses natural fertility (Teimkao, 2014).

Moreover, the earning profit from conducting hilly rice field is lower than general rate according to Nan economic data (Table 2.3) because of low quantity of rice production.

Recommendation for hilly rice field production.

Accordingly examined soil results show that famer should add fertilizer mixed with organic compounds (Table 4.13).

In addition, the result from the study on cost and income is shown inTable 2.3 and Table 4.11. Adopting terrace method can encourage more rice production and it is beneficial for soil quality retention (Arnáez et al., 2015; Balbo & Puy, 2017; Lennartz et al., 2009).

Table 4.14 Suggestion of adding soil fertilizer according to soil properties from hilly rice paddy field (Haifa Chemicals group, 2014; Keulen, 1977).

Fertilizer formula	Suggestion quantity for adding (Kg/Rai)
Urea 46-0-0	7
Diammonium phosphate or DAP 16-46-0	6
Dried organic fertilizer (manure or compost crops)	600 (manure) or 250 (compost crops)

4.4.3 Lowland rice paddy field

Problem statement

The major problem of operating lowland rice paddy field is insufficient water supply. Only rainfed quantity is not enough to grow rice for whole season, because average rainfall demanded of general rice is 1,400-2000 mm. per planting season. Planting crops under drought condition can be caused of many soil problems such as imbalance nitrogen value in soil or the reduction rice uptake nutrient potentiality through the root (Mahdi M. Al-Kaisi et al., 2013). Finally, rice will produces low-grade grain.

Recommendation for lowland rice paddy field production.

After investigated soil sample from lowland rice paddy field, the result shows percentage of OM less than the optimal range (Table 4.5). The suggestion is adding organic fertilizer from crop residue with others supplementary nutrient (Table 4.14).

Nevertheless, the fertilizing rather is divided as 2 times. First round is adding only manure or compost crops before sowing rice grain for 1 day. After rice seeding for 15 days is an appropriate time to put chemical fertilizer accordingly rice nutrients requirement.

Table 4.15 Suggestion of adding soil fertilizer according to soil properties from lowland rice paddy field (Haifa Chemicals group, 2014; Keulen, 1977).

Fertilizer formula	Suggestion quantity for adding (Kg/Rai)
Urea 46-0-0	13
Dried organic fertilizer (manure or compost crops)	600 (manure) or 250 (compost crops)

During the gap of planting season, crop rotation is suggested to proceed in this cultivation area. The rotational plants are Sesbania, Mung bean, Pummelo and so on (Hoffmann & Moran, 1991). After planting season, plowing and burying are the suitable solution to handle leftover rice straws. It also helps soil OM accumulation. The increase of organic content in soil encourages accruing cation exchange capacity and soil ability to hold water content (WHC) (McCauley et al., 2017) Moreover, this recommendation can solve water issue in drought by creating water storage.

4.4.4 Old-aged rice terrace

Problem statement

Some pesticides were applied in this cultivation area. Abamectin is well known as insecticide or anthelmintic, Abamectin is well soluble in water and it can attach soil particles. Moreover, under sunlight, this chemical can self-decay within 8-12 hours and its half-life is 4-6 hours. It barely has an effect on soil properties.

Recommendation for old- aged rice terrace production.

For the result of soil sample investigation (Table 4.6), rice production needs nutrient enhancement which follows the recommendation. (Table 4.15) Farmers should apply Fabaceae plant as rotational crop to help soil increase nutrients and organic components.

Although, Abamectin has less impact on soil properties, farmers should avoid using chemical pesticide. The additional suggestion is to replace pesticide by using sodium bicarbonate (Danka Stefanovic et al., 2006) or using pungent herbs solution for spraying onto plants (Shaji et al., 2017).

Table 4.16 Suggestion of adding soil fertilizer according to soil properties from old-aged rice terrace (Haifa Chemicals group, 2014; Keulen, 1977).

Fertilizer formula	Suggestion quantity for adding (Kg/Rai)
Urea 46-0-0	13
Dried organic fertilizer (manure or compost crops)	600 (manure) or 250 (compost crops)

4.4.5 New-aged rice terrace

Problem statement

The current problem is burning crop residue. Rice straws are eliminated by burning during land clearing period. Due to the burning on soil surface, some microbial and soil humus were burnt concurrently. While microorganism activities are decreasing, soil is losing the fertility. Moreover, soil is supposed to directly obtain nutrient from crop residue decomposition process but all nutrients lose by burning soil surface (Rahkonen et al., 1999). Moreover, if soil loss its humidity, the soil surface can be eroded by water runoff.

Recommendation for new- aged rice terrace production.

Soil condition in study area is set in optimal rate which means no need to add any fertilizer (Table 4.7). The suggestion is that farmers should stop burning crop residue and do tillage or bury rice straws instead of burning. Consequently, soil is abundant of fertility and has longer duration of usage time (STAN et al., 2014).

4.4.6 Economic crops

Problem statement

Various plants were grown in this cultivation area. Many chemical enhancers were used for increasing soil quality. Major fertilizers added are urea and NPK without mixing with organic fertilizer. Using chemical fertilizer intensely cause plenty effects on soil acidity and soil microorganism (Koohatammakun & Saengsuwan, 2017). Furthermore, adding uncombined NPK 15-15-15 fertilizer can lead to dried and tough soil problems (Savci, 2012).

One major issue which has been focused on is using chemical pesticide. In this case, the farmer used Glyphosate and Paraquat. Both of them have an effect on organism living in soil. Moreover, it bogged down microorganism activity producing nutrients. As a result, soil will lose fertility (Hussain et al., 2009).

Another problem is low yield from cultivation. Both cashew nut and coffee yield production are lower than the average data (Table 2.3) because farmers planted those crops for few years. However, Pid Thong Royal Initiative Discovery Foundation help local famers by setting price of coffee and cashew nut higher than general market price. Thus, farmers still earn profit more than average data.

Recommendation for economic crops production

First of all pH soil should be adjusted by adding 350 kg/Rai twice per year (Klodpeng, 1985). The guidance is separated into 3 parts to adapt with 3 crops as follow:

Banana: Banana well grows under wet condition. The rainfed requires for banana plantation is approximately 1,200- 2,500 mm per year (Pattison et al., 2008). This crop can fruit all year. Trimming is a necessary step to take care of bananas. The banana leaf can be used to cover soil under banana tree to avoid sunray and encourage soil water retention. It also avoids unwanted plant growth under the banana tree.

The additional nutrients should be added to banana plantation accordingly to soil examined result (Table.4.16).

Table 4.17 Suggestion of adding soil fertilizer into banana plantation according to soil properties from economic crops (Posomboon, 2001).

Sequence of adding	Fertilizer formula	Suggestion quantity for adding (Kg/tree)
1	$NaNO_3$	0.06
2	K_2O	1.3-1.4
2	Dried organic fertilizer (manure or compost crops)	0.5-1

Coffee: The suitable condition for coffee plantation is low temperature climate, especially temperature between 15-21 ^{o}C, and coffee dislikes intense sunray (Department Of Agricultural Extension, 2013). The average temperature in Nan province is higher than optimal condition for coffee plantation. However, farmers can solve this problem by growing other shade trees. For getting more yields, coffee needs usual trimming on its branch.

In high quality coffee production, the important thing is nutrient adding guidance shown in the table (Table 4.17).

Table 4.18 Suggestion of adding soil fertilizer into coffee plantation according to soil properties from economic crops (Posomboon, 2001).

Sequence of adding	Fertilizer formula	Suggestion quantity for adding (Kg/tree)
1	NPK (15-15-15)	0.4-0.7
2	0-0-60	0.2
2	Dried organic fertilizer (manure or compost crops)	1-2

Cashew nut: Cashew tree is a perennial plant well grown under every condition. Improper maintenance can lead to many problems, for example, plant deterioration, getting less yield and shorter lifespan. Preservation of cashew tree should start with putting appropriate nutrients into soil. (Table 4.18) Moreover, trimming branch is a very important step for promoting cashew tree production giving good quality nut.

Table 4.19 Suggestion of adding soil fertilizer into cashew nut plantation according to soil properties from economic crops (Posomboon, 2001).

Plant age (Year)	Fertilizer formula	Suggestion quantity for adding (Kg/tree)
1-3	High phosphorus fertilizer (12-24-12)	0.3-1
4-6	NPK (15-15-15)	1.5-5
>7	NPK (13-13-21)	2-3
all ages	Dried organic fertilizer (manure or compost crops)	3-5

The next issue is pesticide. The economic crop is the area which is not easy to deal with insects and weed plant without using chemicals. The best way is to try to reduce the frequency of pesticide usage. Other solutions are rotational planting and plant selection which are shading plants in order to avoid unwanted plant growth under economics tree. The suggested crops (Table 4.20) were recommended because they are well-grown under drought conditions and easy to maintain. Furthermore, legume was suggested to plant for dealing soil nutrients problem. Legume can help soil to stow soil nutrients and encourage soil health (Shaji et al., 2017; United States Department of Agriculture, 1998).

Table 4.20 Alternative crops recommendation (D. Ray Langham et al., 2008; Tripathi et al., 2014; Yebes, 2015).

Crops	**Soil texture**	**Rainfed requirement (mm)**	**Soil pH**	**Climate temperature (^{o}C)**	**Price sale/kg. (baht)**
Sesame	Loam-clayloam	625-1,100	5 - 8	27	111.25
Papaya	Sandy loam - loam	1,200-2,00	5.6 - 6	21-32	32
Dragon fruit	Sandy loam	500-1500	6-7	18-26	Red:30 White: 28.6

Chapter 5
Conclusions and Recommendations

5.1 Conclusion

The study of agricultural land use in Chaloem Phra Kiat district, Nan province is under the assistance of Pid Thong royal initiative discovery foundation.

Previously, cultivation has proceeded only in plain area. Since the extension of economic competition from many directions, agriculture needs more space for crop yield production. For the reason that plain area is limited, an alternative is planting on hilly landscape.

Planting on hilly field without proper management can lead to many problems. The significant problem focused on in this study is soil quality degradation from agricultural activities. Some farming activities affect soil decadent, for example, soil degradation, soil lacking of nutrients, and soil damage from chemicals enhancers.

Seven agricultural areas are maize field, hilly rice paddy field, lowland rice paddy field, old-aged rice terrace, new-aged rice terrace, economic crops, and abandoned field. They were selected for studying in 2 main parts. The first part is investigation soil properties and the second part is questionnaires survey

The examined results show that soil properties were still suitable for planting when compared the result with the optimum standard except the abandoned field. In the survey part, many factors influencing on the cultivation in all area were found. However, the agricultural problems still exist in many areas and they are in need proper management.

The problems found in maize field are burning crop residue activity, using chemical fertilizer and pesticide, and no support from government. The solutions are to stop burning, to follow fertilization recommendation, to plant legume crops as rotary plant and to make organic farming.

In all rice production, lowland rice paddy field is the best agricultural type with high profit from the investment. However, this area is located in plain area which is limited space in this district. Farmers should reschedule the planting period that can rise up water supply from rainfed and create more water storage. Terracing agriculture is the second highest earned profit. Adoption of terracing method does not only obtain high income but also help soil to retain fertility. Conducting hilly rice paddy field gains the lowest profit from rice production. Besides, soil deterioration possibly happened from adding chemical pesticide. Pesticide is well known as a cause of negative impacts not only in the environment but also directly to human health. Pest elimination using this method should be avoided.

Economics crop is the cultivated area which is intensely used. Farmers add both of chemical fertilizer and pesticide to enhance soil properties. The solution suggested that farmers should follow fertilization recommendation, reduce frequency of pesticide usage and plant the rotary crop. Alternative crops were suggested such as legume, dragon fruit, papaya, and sesame. The problem of earning low profit from cashew nut and coffee plantation can be explained. Coffee and cashew nut plantation is encouraged instead of growing maize. Pid Thong Royal Initiative Discovery Foundation wants to persuade local farmers to plant those crops, so they set cost price of coffee and cashew nut higher than general market price. Although, the yield is less than the average total yield of Nan province, but farmers still gain profit from cultivation and probably gain more crop yields in long-term plantation.

The result was firmly interpreted as farmers can continue conducting the cultivation in those areas but they should concern about three improper farming activities which impact on soil quality; adding chemical fertilizer, adding chemical enhancer and planting in drought condition. In addition, soil proper management should be practiced to maintain soil properties and encourage longer lifespan for the usage of agricultural land.

5.2 Recommendation

The recommendations to manage problems are to control fertilizer addition following crop requirement, apply alternative crops, adopt terrace method, create more water storage, replace burning crop residue activity by tillage, and burying.

Further study should focus on terracing method in the application of plantations including plan to create new pattern of water storage which is cheaper and requires less space for the installation.

5.3 Limitation of study

Samples were collected only 2 times in rainy season and dry season. More replication of sample testing needs to be done in order to provide additional information.

There was a difficulty in accessibility to the study area. During sample collection, some of the land owners were not available for the question survey. Therefore, the information acquired might be incomprehensive.

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Appendix

Appendix A
Questionnaire

- **The questionnaire, Thai version**
- **The questionnaire, English version**

แบบสำรวจการใช้พื้นที่เพาะปลูกในอำเภอเฉลิมพระเกียรติ จังหวัดน่าน

ชนิดของพื้นที่เกษตรกรรม..ชื่อเจ้าของพื้นที่...

อาชีพ ☐ เกษตรกร ☐ เกษตรกรและเลี้ยงสัตว์ ☐ อาชีพอื่นร่วมกับการทำการเกษตรกรรม ☐ อื่นๆ

พื้นที่เกษตรกรรมมีเอกสารสิทธิ์หรือไม่ ☐ ไม่มี ☐ มี ประเภท ....

จำนวนพื้นที่ถือครอง(สามารถตอบได้มากกว่า 1 ข้อ)

☐ เป็นเจ้าของ......ไร่ ☐ เช่า...............ไร่ ราคาเช่า......บาท/ไร่ ☐ อื่นๆ ระบุ................................

ภาวะหนี้สิน ☐ไม่มี ☐ มี จำนวน................................บาท

ถ้ามีท่านกู้ยืมจากแหล่งใด ☐ ธนาคารเพื่อการเกษตรและสหกรณ์ ☐ สหกรณ์การเกษตร

☐ ธนาคารพาณิชย์ ☐ ญาติ

☐ พ่อค้า ☐ เพื่อนบ้าน

☐ แหล่งเงินกู้นอกระบบอื่นๆ ☐ อื่นๆ ระบุ....................

ชนิดพืชที่ปลูก*

ที่	ชนิดพืช	ผลผลิต	ราคาต้นทุน (บาท/ตัน)	ราคาขาย (บาท/ตัน)	พื้นที่ใช้เพาะปลูก(ไร่)	เดือนที่เริ่มเพาะปลูก	เดือนที่สิ้นสุดการเพาะปลูก
1							
2							
3							
4							
5							
6							
7							

ระยะเวลาในการทำการเกษตรในพื้นที่นี้....................ปี

แหล่งน้ำในการทำการเกษตร ☐ เพียงพอ ☐ ไม่เพียงพอ

☐ น้ำฝน ☐ คลองชลประทาน ☐ แหล่งน้ำธรรมชาติ(ลำคลอง ห้วย) ☐ อื่นๆ ระบุ......

เครื่องจักรในการทำการเกษตร

ที่	รายชื่อเครื่องจักรในการทำการเกษตร	จำนวน(หน่วย)	ค่าใช้จ่ายของเชื้อเพลิงต่อการใช้งาน 1 ครั้ง (บาท)
1.	รถแทรกเตอร์		
2.	รถไถเดินตาม		
3.	รถบรรทุกขนาดใหญ่		
4.	รถกระบะ		
5.	เครื่องนวดข้าว		
6.	ระหัดวิดน้ำ		
7.	เครื่องพ่นสารเคมี กำจัดศัตรูพืช		
8.	อื่นๆ		

แรงงานในการทำเกษตรต่อฤดูกาล......คน ค่าจ้าง...........บาท/คน

การเตรียมพื้นที่เพื่อการเพาะปลูก

ชนิดพืช	วิธีการเตรียมดิน			จำนวนครั้งที่ใส่ปุ๋ยต่อฤดูกาล (ครั้ง)		
	ชนิดปุ๋ย	ราคาปุ๋ย (บาท/หน่วย)	เดือนที่ใส่ปุ๋ย	ใส่ก่อนการปลูกพืช	ใส่ระหว่างการปลูกพืช	ใส่ภายหลังการเก็บเกี่ยว

การกำจัดศัตรูพืช

มีการกำจัดศัตรูพืชหรือไม่ ☐ ไม่มี ☐ มี (กรุณาเติมข้อมูลด้านล่าง)

ชนิดพืช	วิธีการกำจัด			จำนวนครั้งที่กำจัดศัตรูพืช		
	วิธีการกำจัด (หากใช้สารเคมีกรุณาระบุชนิด)	ค่าใช้จ่าย (บาท/หน่วย)	เดือนที่ทำการกำจัดวัชพืช	ก่อนทำการปลูกพืช	ระหว่างการปลูกพืช	ภายหลังการเก็บเกี่ยว

การเก็บเกี่ยวผลผลิตและการจำหน่ายผลผลิต

ชนิดพืช	การเก็บเกี่ยวผลผลิต			การจำหน่ายผลผลิต			
	วิธีการเก็บเกี่ยวผลผลิต	ค่าใช้จ่าย (บาท/หน่วย)	เดือนที่ทำการเก็บเกี่ยวผลผลิต	ตลาดที่ส่งขาย	วิธีการขนส่ง (ขนส่งเอง-พ่อค้ามารับซื้อ)	ค่าใช้จ่ายในการขนส่ง	เดือนที่ทำการจำหน่ายผลผลิต

การกำจัดขยะเกษตรกรรมหลังการเพาะปลูก

☐ เผา ☐ ไถกลบ – ฝังกลบ ☐ นำไปทำปุ๋ยชีวภาพ ☐ รวมรวมให้เทศบาล

กำจัด ☐ คัดแยกเพื่อขาย ☐ อื่นๆ ระบุ..................

พืชชนิดอื่นที่สนใจปลูกเพิ่มเติม/ทดแทน (ถ้ามี)

1.).................. 2.).................. 3.)..................

ปัญหาที่พบในการทำเกษตรกรรมอื่นๆที่พบในพื้นที่นี้..

....

The survey of land use for cultivation in Chaloem Phra kiat district, Nan Province

Category of cultivation:.................................... Owner's name....................................

Career ☐ Agriculturist ☐ Agriculturist with Husbandry ☐ Agriculturist with other jobs

Ownership certification ☐ No ☐ yes, type of certifications ....

How many areas you own?

☐ Own..............rai ☐ Rent........ rai Rental fee ....Bath/rai ☐ others ....

Are you in debt? ☐ No ☐ yes, ...Bath

Which organization you lend money from?

☐ Bank for Agriculture and Agricultural Cooperatives. ☐ Commercial bank.
☐ Agricultural marketing co-operation ☐ Relative
☐ Middle man ☐ Neighbors
☐ Non-formal loan ☐ Others ....

Plant categories

No.	Categories	Yield (Kg.)	Cost (Bath/Kg.)	Sale price (Bath/Kg.)	Planting Area (Rai)	Beginning month of cultivation.	Last month of cultivation.
1							
2							
3							
4							
5							
6							

Duration that this area has been used .... Years

Is water resource for agriculture sufficient? ☐ Yes ☐ No

☐ Rain fed ☐ Irrigation ☐ Natural water resource (Canel, Steam or River) ☐ Others......

Agricultural machines

No.	Machines	Unit	Cost of fuel per time (Bath)
1.	Tracker		
2.	Hand tractor		
3.	Truck		
4.	Pickup-truck		
5.	Threshing machine		
6.	Water-wheels		
7.	Sprayer		
8.	Others		

Number of labors ....persons. Hiring cost........Bath/person

Land use preparation

Plant Categories	Principals			Rounds (time)		
	Type of fertilizers	Cost of Fertilizers (Bath/Unit)	Month for adding fertilizer	Tillage part	During planting time	After harvesting

Pest and unwanted plant control

Do you have a pest or weed control? ☐ No ☐ Yes (Please fill information in the table.)

Plant Categories	Principals			Rounds (time)		
	Methods (If using chemicals please identify)	Cost (Bath/Unit)	Month for adding	Tillage part	During planting time	After harvesting

Harvesting and Merchandising crop yields

Plant Categories	Harvesting			Merchandising			
	Methods	Cost of Harvesting (Bath/Unit)	Month of harvesting.	Markets	Transportation of products (On your own – pick up by middle man)	Cost of logistic.	Month of selling.

Disposal of residual plants

☐ Burning ☐ Plowing – burying ☐ Fermentation ☐ Gathered by Municipal division.

☐ Separation for sale. ☐ Others..............................

Do you have an interest in alternative crop besides what you have planted?

1.).................... 2.).................... 3.)....................

Do you have any problem from using this agricultural area?..............................

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