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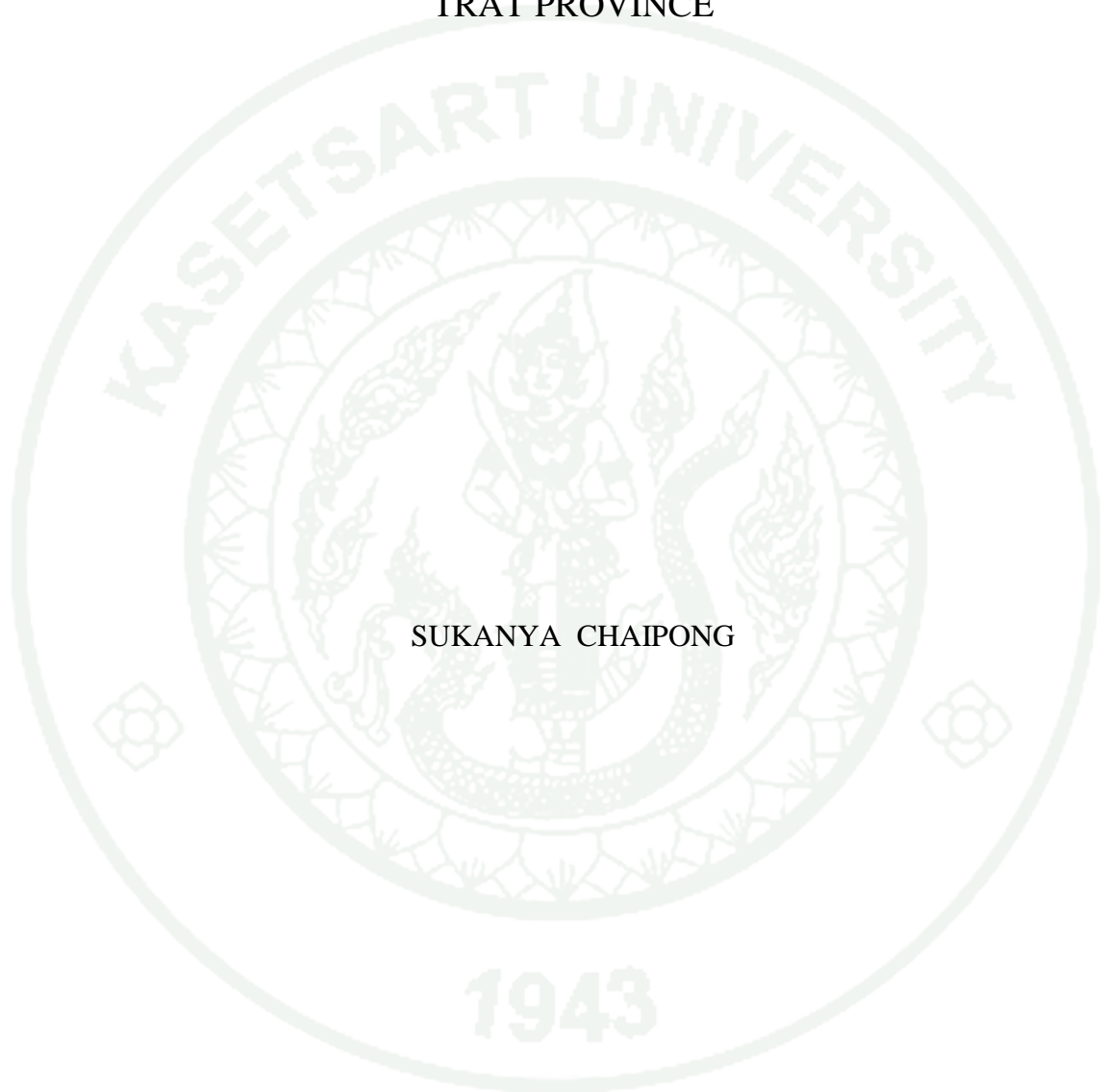
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THESIS

LANDSCAPE AGROFORESTRY MODELING FOR SUFFICIENCY
ECONOMY IN HUAI RAENG-KHLONG PHEED WATERSHED,
TRAT PROVINCE



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Sukanya Chaipong 2014: Landscape Agroforestry Modeling for Sufficiency Economy in Huai Raeng-Khlong Pheed Watershed, Trat Province. Doctor of Philosophy (Forestry), Major Field: Forestry, Faculty of Forestry.
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This research focused on land use modeling at the landscape scale based on the sufficiency economy philosophy. The main objectives were to determine key performance indicators of agroforestry under a sufficiency economy (SE), to develop landscape agroforestry modeling under an SE, and to apply the derived model to analyze the suitability of the existing land uses in the study area. The key performance indicators were: 1) the agroforestry indices (AFI)—organic matter, soil erosion, mixed species index, income distribution, net present value, using resource, land holding size, and acceptance of land use; and 2) the landscape agroforestry indices (LAFI)—soil type, slope, distance to water resources, capability of accessing to main road, watershed class, and conservation area.

The AFI and LAFI were weighted based on expert judgment and used in weighted linear combinations to develop the landscape agroforestry modeling based on an AFI equation and an LAFI equation. The site observation data were used in the AFI equation to obtain the land use types based on the SE level and the ranked secondary data were then used in the LAFI equation to determine the land suitability classification based on the land suitability (LS) level. Landscape agroforestry index classes (LAFIC) in the study area were identified at 4 levels. The LS levels from the highest to the lowest represented 256.01 (57.20%), 117.37 (26.22%), 42.92 (9.59%), 25.85 (5.78%) and 5.42 (1.21%) km², respectively. The final step of this study analyzed the suitability of the existing land use based on the LAFIC map. The LAFIC map showed that most land use types were categorized as being at the highest and high LS levels.

Student's signature

Thesis Advisor's signature

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Sukanya Chaipong

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TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	i
LIST OF TABLES	ii
LIST OF FIGURES	iv
LIST OF ABBREVIATIONS	v
INTRODUCTION	1
OBJECTIVES	4
LITERATURE REVIEW	5
MATERIALS AND METHODS	54
Materials	54
Methods	55
RESULTS AND DISCUSSION	79
CONCLUSION AND RECOMMENDATION	104
Conclusion	104
Recommendation	105
LITERATURE CITED	107
APPENDICES	135
Appendix A Information in RUSLE	136
Appendix B The expertises and quaitionaire	139
Appendix C Questionnaire for land user and results	154
Appendix D Results of NPV	162
CURRICULUM VITAE	271

LIST OF TABLES

Table		Page
1	Scale for pairwise comparisons.	32
2	Weight of indicators based on the philosophy of sufficiency economy.	35
3	Assessing LD/ SLM processes in croplands.	39
4	Factors, criteria and indicators of land use scale.	45
5	The indicators impact of landscape scale to sufficiency economy.	47
6	Factors, criteria and indicators of landscape scale.	50
7	Soil textural classification and ranking.	51
8	Watershed classes.	52
9	Land use types in 2010.	59
10	Selected land use types of Huai Raeng-Klong Peed watershed in 2010.	63
11	K factor of each land use types in study area.	68
12	CP factor of each land use types in study area.	69
13	Land suitability classes.	73
14	Soil textural classification and ranking.	74
15	Slope classification and ranking.	74
16	Distance to water resources and ranking.	75
17	Watershed classes and ranking.	75
18	Weighted value of agroforestry indices.	79
19	Weighted value of landscape agroforestry indices.	80
20	Agroforestry index classes.	82
21	Landscape agroforestry index classes.	82
22	Ranking score of AFI in study area in terms of environmental factor.	85
23	AFI in terms of environmental factors in study area.	85

LIST OF TABLES (Continued)

Table		Page
24	Ranking score of AFI in study area in terms of socio-economic factor.	88
25	AFI in terms of economic factors in study area.	88
26	AFI in terms of social factor in study area.	89
27	Sufficiency economy level in study area.	90
28	Ranking score of LAFI in study area.	92
29	Area of each ranking score of LAFI in terms of environmental factor in study area.	93
30	Area of each ranking score of LAFI in terms of governmental institutions and social factor in study area.	95
31	LAFIC and recommended land use.	101
32	Area of AFIC map under LAFIC map.	102
 Appendix Table		
A1	Predicted CP factor of land use types in each region in Thailand.	137
B1	The expertise list.	140
C1	Land user in each land use in study area.	158
C2	Basic and socio-economic information of land user in each land use in study area.	160

LIST OF FIGURES

Figure		Page
1	Classification of agroforestry system based on the type of components.	10
2	Agroforestry land use is linked to both agriculture and forestry.	15
3	Frame of multicriteria decision analysis.	25
4	Sufficiency economy philosophical framework.	34
5	Study area in Huai Raeng-Klong Peed sub sub-watershed, Eastern Thailand.	55
6	Land use types of Huai Raeng-Khlong Peed sub-watershed in 2010.	60
7	Site selection by soil series and slope class were sorted.	65
8	Research methodology frame work.	78
9	Sufficiency economy level of existing land use in the study area.	91
10	Ranked score of soil texture map in study area.	93
11	Ranked score of slope classes map in study area.	94
12	Ranked score of distance to water resources map in study area.	94
13	Ranked score of watershed classes map in study area.	96
14	Ranked score of conservation area map in study area.	96
15	Ranked score of capability of accessing to main road map in study area.	97
16	Landscape agroforestry index class map in study area.	98
17	LAFIC map interns of environmental aspect in study area.	100
18	AFIC map under LAFIC map.	103

Appendix Figure

A1	Malaysian soil erodibility nomograph for calculation of soil erodibility factor, K	137
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LIST OF ABBREVIATIONS

Al	=	Aluminum
ASTM	=	American Standard Testing Method
Ca	=	Calcium
ksc	=	Kilogram per square centimeter
Kg.	=	Kilogram
M	=	Molarity
MIP.	=	Mercury Intrusion Porosimetry
min	=	Minute
mm	=	Millimeter
NaOH	=	Sodium Hydroxide
Na ₂ SiO ₃	=	Sodium Silicate
SiO ₂	=	Silica
Std	=	Standard
XRD	=	X-ray Diffractometer
XRF	=	X-Ray Fluorescence
°C	=	Celsius degree temperature
w/b	=	Water to binder ratio
ThaiNAFE	=	Thai Network for Agroforestry Education
USDA	=	United States Department of Agriculture
WARPA	=	Wild Animals Reservation and Protection Act

LANDSCAPE AGROFORESTRY MODELING FOR SUFFICIENCY ECONOMY IN HUAI RAENG-KHLONG PHEED WATERSHED, TRAT PROVINCE

INTRODUCTION

Global deforestation has been severe especially in tropical forests that it mainly due to it is converted to agriculture (Food and Agriculture Organization of the United Nations [FAO] 2010). Agricultural expansion is widespread and large scale (Puri, 2006) resulting in the loss of multiple functions and the decrease in land productivity which is in consequence of soil erosion, flooding and drought so that some land has eventually been abandoned (Association for International Cooperation of Agriculture and Forestry [AICAF] 1999). In the past, Thailand was well known as rich in forest resources. In 1961, forest still occupied more than half of the country. However, by 2009, forest was only 33.56% of the land area (Rattanasuwan, 2011). Deforestation has had a severe impact on the environment and the economy; it has also seriously depleted forest genetic resources and other biological resources (Sumantakul, 2001). The main cause of deforestation in Thailand is agriculture which is widespread and large scale. The large scale issue is important to understand in terms of ecosystem management.

Deforestation can be reduced in several ways. One way is to simply establish new plantation on deforested areas. Agroforestry is a basic land use where woody perennials are deliberately cropped jointly with agricultural crops or animals on the same land management unit. It is a dynamic ecology based on a management system that sustains production for social, economic and environmental outcomes (The International Centre for Research in Agroforestry [ICRAF] 1993). Successful agroforestry operations have in fact increased crop production and farmers' income as well as improving the ecological conditions of these areas through reducing soil erosion, increasing tree coverage and maintaining soil fertility (Rao *et al.*, 1998; Nath *et al.*, 2005). The new alternative management of agroforestry is landscape ecology at

the landscape level which aims to improve the economic, environmental and social values of agroforestry (Pastur *et al.*, 2012). Landscape agroforestry is a set of ecological processes which can explain environmental phenomena; it is a mosaic of different land use types on a large-scale; it is the spatial interaction of several systems on a farm (Palma *et al.*, 2006). Therefore, landscape agroforestry is a tool that policy makers can use to manage natural resources.

Moreover, it offers an indirect solution to deforestation. The main policy in Thailand is the National Development Plan. It has adopted the sufficiency economy (SE) philosophy as the framework. The sufficiency economy is a philosophy of His Majesty the King, which strives to achieve the country's development through well-balanced and sustainable growth (Wibulswasdi *et al.*, 2010). The framework of the policy has been applied to land use planning through the development of regional plans and then by more specific plans. The land use plan under the sufficiency economy considers the farm scale which is also regarded as providing a new sustainable agricultural model to achieve self-reliance for rural households (Piboolsravut, 2004). It is well-known that Thailand still has extensive cropping in rural areas, which often occurs without any appropriate development direction. Although, rural land use planning is undertaken by several governmental institutions, the expansion of indirect cropping has continued unabated in rural areas. Thus, the great deal with that is the land use plan on the landscape scale from the requirements and constraints of the land under the main policy. The land use plan under the requirements and constraints is the land suitability. Thus, land use planning in rural areas under the main policy is required particularly at the landscape scale. One of several ways used to conduct land use planning is land suitability which develops a land use plan based on the requirements of the land user and the constraints of the land.

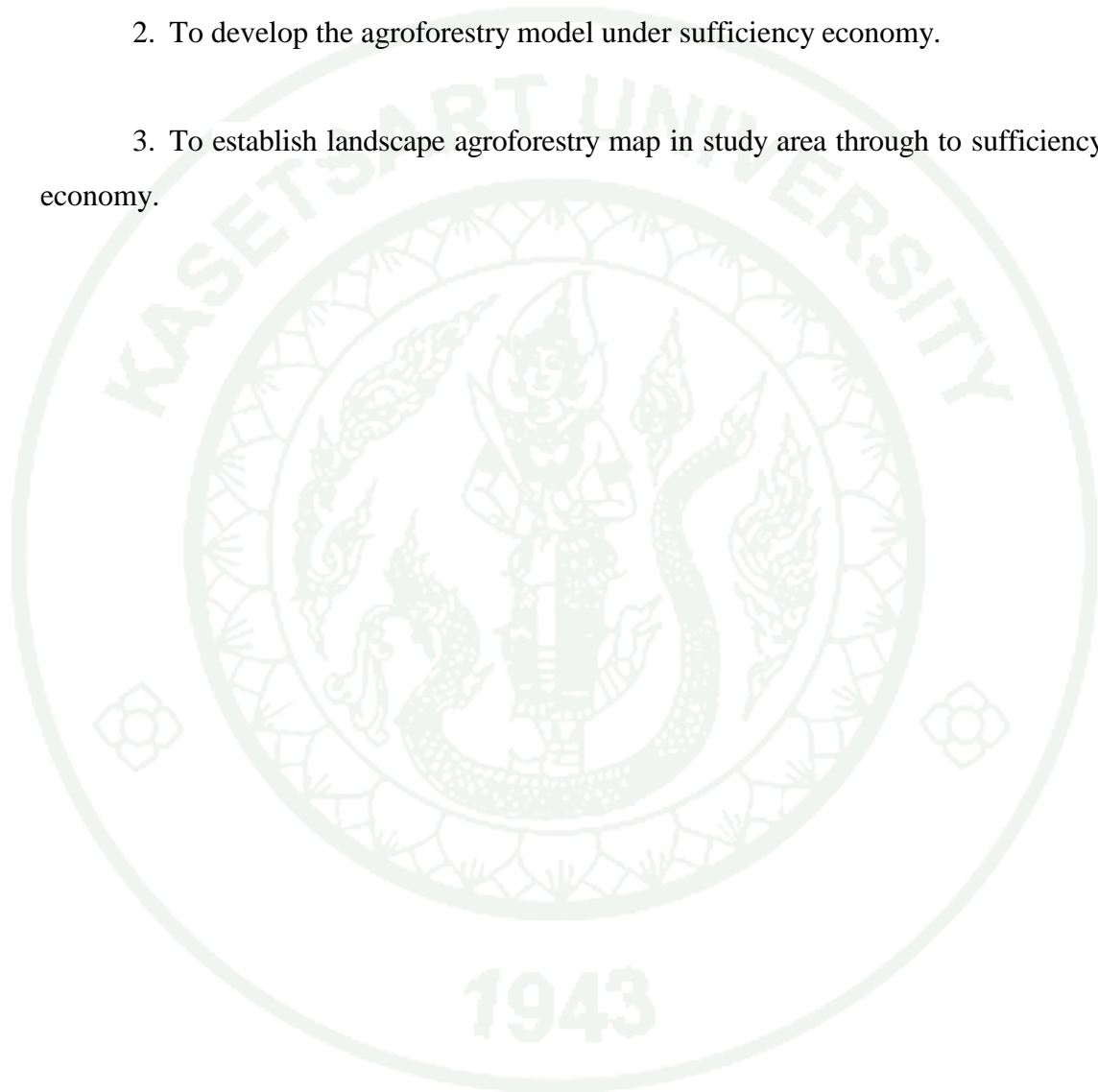
Land suitability is a system whereby the land use is well matched with the inherent characteristics of the land (FAO, 1976). The assessment of land suitability for a specific type of land use should be based on land use requirements and constraints (Baja *et al.*, 2001; Rabia *et al.*, 2013). Two of the most useful applications for planning and management are a geographic information system (GIS) integrated with

Multi-Criteria Decision Making (MCDM) methods which have considerably advanced the conventional map overlay approaches to land-use suitability analysis (Malczewski, 2004). GIS-based land-use suitability analysis has been applied in a wide variety of situations, particularly to determine the suitability of land for agricultural activities (Cambell *et al.*, 1992; Kalogirou, 2002; Baja *et al.*, 2007 Feizizadeh and Blaschke, 2013). The most popular evaluation technique for multi-criteria decision making to allocate resources and undertake environmental management is the Analytical Hierarchy Process (AHP) (Ramanathan and Ganesh, 1993; Kiker *et al.*, 2005). AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales (Saaty, 2008). As a result, land suitability is the main process underpinning the ability of a given type of land to support a defined use. The pairwise comparison method inherent in the AHP is a technique for the consideration of a variety of criteria. Land suitability mapping are to identify land use boundaries and to determine resource inventories through GIS application techniques.

The analysis of land suitability requires a consideration of a variety of criteria including not only the natural/physical capacity of a land unit but also the socio-economic and environmental impact implications (Duc, 2006). The basic concept of the SE can be judged using a criteria and indicator approach. Indicators have been based on the SE philosophy in order to evaluate the macro-performance of the Thai government starting from 2005 (National Economic and Social Advisory Council, 2007). In contrast, indicators to evaluate micro performance in land use policy are less distinct. Therefore, investigation of the key performance indicators for land use planning under the sufficiency economy is an important consideration in the land suitability process. This research aimed to develop a land suitability model on the landscape scale (landscape agroforestry) under the SE philosophy. The model is a tool which can examine the impact of land use that arises from uncontrolled land use planning and land use change. Therefore, this will be useful for land use planning and for rapid detecting in damaging problems that require urgent management.

OBJECTIVES

1. To study key performance for indicating the agroforestry under sufficiency economy.
2. To develop the agroforestry model under sufficiency economy.
3. To establish landscape agroforestry map in study area through to sufficiency economy.



LITERATURE REVIEW

This review will describe subjects related to study, including agroforestry systems, landscape agroforestry, land suitability, MCDM methods, AHP and SE theory. An overview of the proposed analytical framework for the study will be provided as well as an outline of the research objectives of this study.

1. Agroforestry systems

1.1 Agroforestry system and benefits

It is generally recognized that the terminology used for agroforestry is as diverse as who use it and as emphasize on issues, there were many people give the definitions of agroforestry as following;

ICRAF provides the following definition; agroforestry is a collective name for land-use systems and technologies (ICRAF, 1993), where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. In other words, it is a collective name for sustainable land-use system to get social, economical, and environmental benefits (Sanchez, 1995). In agroforestry systems, there are both ecological and economical interactions between the different components (ICRAF, 1993; Nair, 1993). The modification was done to incorporate the new sustainability framework in agroforestry, it should be reconsidered as a dynamic, ecologically based, natural resource management system that through the integration of trees on farms and in the agricultural landscape, diversities and sustains production for increased social, economic and environmental benefits (Leakey, 1996). In addition, the ecological integrity of an agroforestry system is a state of system development in which the habitat structure, natural functions and species composition of the system, which are interacting in ways that ensure its sustainability in the face of changing environmental conditions as well as both internal and external stresses (Wyant, 1996). Several definitions of agroforestry have been evolution from

agroforestry which is a land use system and technologies, where based on woody perennial on the same land management unit to get social, economical, and environmental benefits. Afterwards, ecosystem has been emerged in the agroforestry system as a dynamic of ecologically based in natural resource management system, which is ensured sustainability in changing environmental conditions.

The interaction among components within agroforestry system is indicated as illustration of significant benefits. Interaction is defined as the effect of one component in a system on the performance of another component and/or the overall system. The efficiency of agroforestry system is biophysical resources interactions as well as ecological interactions in the systems. Several researches were investigated in interaction between components in agroforestry system which have been found in ecosystem service and environmental benefits as follows; Deep roots woody trees are generally described as nutrient pumps capable of intercepting nutrients and water from soil layers which is very deep for agricultural crops (Noordwijk and Garrring, 1995). Moreover, the deep roots tree can access newly weathered soil nutrients is also a function of deep tap rooting systems (Jat and Poonia, 2006) and the root system can play an important role in reducing nutrient losses (Szott *et al.*, 1991) by increasing leaf litter inputs promoted the proliferation of fine roots into the litter layer is a response to nutrient availability in the litter rather than due to the lack of nutrients in the soil (Sayer *et al.*, 2006). This tree litter and pruning improve soil fertility (Batish *et al.*, 2008; Jose, 2009) and input of organic matter (Tripathi *et al.*, 2009). However, it depends on the quality and quantity of tree litter or prunings, soil type, and climatic conditions of the area (Noordwijk and Garrring, 1995; Batish, 2008). The agroforestry system has generally been shown to improve microclimate through modification of temperature that has conserved soil moisture and decreased soil temperature through foliage (Monteith *et al.*, 1991; Jat and Poonia, 2006; Batish, 2008). Furthermore, the agroforestry system can help to improve water quality by reducing levels of pollution and soil erosion (Batish, 2008; Jose, 2009). Additionally, the agroforestry practices such as windbreaks and shelterbelts are benefits that include effectively reducing wind velocity, wind erosion, noise pollution and also mitigating odor from concentrated livestock operations (Jose, 2009). The trees in agricultural lands are reduced weed

populations in the fallow phase (Rao *et al.*, 1998) and the shading tree effect, availability of less space of their growth, shifts in species composition, and altered environmental conditions may reduce weed population. Further, desirable allelopathic trees could be intercropped with crops to achieve weed management through rhizospheric allelochemicals-based signals (Batish, 2008).

Agroforestry system is important for biological pest control (Pandey, 2007). However, pest control can be efficient through management due to the modification of microclimate, water regime, moisture, air humidity, and surface temperature, the number of insects, pests, and pathogens increases, particularly near the tree line. Agroforestry practices can be the pest management through the windbreak or hedgerow that act as barrier to airborne pests and pathogens, repel them, and thus have a protective action. Whereas, the modification microclimate is near tree line may provide more habitats of enemies of insect pests (Batish, 2008). Agroforestry helps enhancing biodiversity and reducing biodiversity loss. In general, agroforestry plays five major roles in conserving biodiversity: (1) agroforestry provides habitat for species that can tolerate a certain level of disturbance; (2) agroforestry helps preserve germplasm of sensitive species; (3) agroforestry helps reduce the rates of conversion of natural habitat by providing natural habitats; (4) agroforestry provides connectivity by creating corridors between habitat and the conservation of area-sensitive floral and faunal species; and (5) agroforestry helps providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat (Jose, 2009). Moreover, agroforestry systems enhanced diversity both at the site level as well as at the landscape level, and they have more diversities both at above and belowground levels than the sole cropping system (Batish, 2008). Additionally, incorporation of trees or shrubs in agroforestry systems can increase the amount of carbon sequestered and CO² mitigation (Albrecht and Kandji, 2003) compared to a monoculture field of crop plants or pasture (Sharrow and Ismail 2004; Kirby and Potvin 2007). Montagnini and Nair (2004) stated that agroforestry can also has an indirect effect on carbon sequestration is through the use of agroforestry technologies for soil conservation, which could enhance carbon storage in trees and soils. Agroforestry systems with perennial crops may be important carbon sinks, while

intensively managed agroforestry systems with annual crops are more similar to conventional agriculture.

Moreover, land degradation, soil salinization, and global warming are causing food insufficiency. The challenged land use system has deliberated on the environment as the agroforestry, or woody perennial-based mixed species production systems, which was the potential land use to facilitate to food security (Kumar, 2006). Due to agroforestry systems support nutrition and the stability of production (FAO, 2013) through providing more species diversified system has a great capacity to deal with environmental variation (Anderson and Sinclair, 1993). Increasing average yields, the planting of trees as green fertilizers in southern Africa is able to stabilize crop production in drought years and during other extreme weather events, and improve crop rain use efficiency. This is important for food security in the context of climate change, which is increasing drought incidence in the region (FAO, 2013). In addition, the stability production can also supports farmer income. Batish (2008) stated that agroforestry helps in providing an opportunity to marginal and low-income farmers to improve their livelihood by marketing these products as household food, medicine, small timber, domestic wood supply, fiber, or fuel. However, much needs to be done in underutilized and medicinal tree species, which can offer economic returns to the farmers as well as providing other benefits of agroforestry systems. Furthermore, tree interactions in agroforestry as livestock were presented opportunities for increasing food production from farm animals which meet projected demand for foods of animal origin through management. The management type of interaction can be positive or negative, depending on the type of livestock and trees, and management systems. Goats are more selective in their feeding habits (Devendra, 1999).

Agroforestry system is the intentional use of woody perennial plants in combination with annual crops and/or animals on the same area. It is alternative land use choice to deliberate in environment and also sustains production for increased social and economy. However, agroforestry system needs to develop as a ecologically sustainable land use system that involves interplay positive and negative interactions leading to human development, conservation and natural resource management.

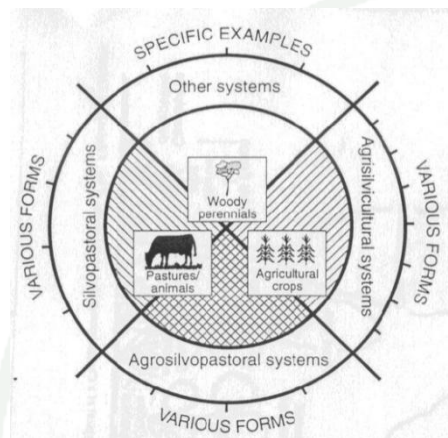
1.2 Agroforestry systems and practices

Several benefits of agroforestry system are raised from components which affect to structure, function, socioeconomic and ecology. To understand the characteristics of agroforestry systems that is divided according to the following (Nair, 1993):

- 1) Structure basis: refers to the component, including spatial arrangement of the woody components, vertical stratification of all the components, and temporal arrangement of the different components.
- 2) Functional basis: refers to the major function or role of the system, usually furnished by the woody components (these can be of a service or protective nature, e.g., windbreak, shelterbelt, soil conservation).
- 3) Socioeconomic basis: refers to the level of inputs of management (low input or high input) or intensity or scale of management and commercial goals (subsistence, commercial, intermediate).
- 4) Ecological basis: refers to the environmental condition and ecological suitability of systems, based on the assumption that certain types of systems can be more appropriate for certain ecological condition; i.e., there can be separate sets of agroforestry systems for arid and semiarid lands, tropical highlands, lowland humid tropics, etc.

These broad bases of classification of agroforestry are by no means independent or mutually exclusive. Indeed, it is obvious that they have to be interrelated. While the structural and functional bases often relate to the biological nature of the woody components in the systems, the socioeconomic and ecological stratification refers to the organization of the systems according to prevailing local conditions (socioeconomic or ecological) (Nair, 1993).

Moreover, agroforestry can classify based on structure basis of the type of components. There are agrisilviculture (crops and trees incl. shrub/trees and trees), silvopastoral (pasture/animals and trees) and agrosilvopastoral (crops, pasture/animals, and trees) (Nair, 1989). The example agroforestry system classification based on structure basis of the type of components as shown in Figure 1.



- Agrisilviculture; crops(including shrubs/vines) and trees
- Silvopastoral; pasture/animals and trees
- Agrosilvopastoral; crops,pasture/animals and trees.

Figure 1 Classification of agroforestry system based on the type of components.

Source: Nair (1993)

Classification schemes of agroforestry practices, where trees are intimately associated with agricultural components at a field scale, with the whole farm and forest systems of which they form a part. In fact, it is common for farming systems to involve the integration of several reasonably discrete agroforestry practices, on different types of land (Sinclair, 1999). Nair (1993) suggested that agroforestry practices on major group types in the tropics which related between the ecological characteristics of a region and the nature of the agroforestry systems. Humid lowlands; characterized by hot and humid climate are most of the year. The climatic conditions that favor rapid growth of a large number of plant species and various types of plant associations thus the common types should be shifting cultivation, taungya, plantation-crop combinations, multilayer tree gardens and intercropping systems. In semiarid lower lands are characteristics by one or two wet seasons and at least one long dry season. Drought is a hazard condition thus the agroforestry practices should

be silvopastoral systems, windbreaks and shelterbelts, multipurpose trees for fuel and fodder and multipurpose trees on farmlands. And highlands are approximately 20% of the tropical lands at elevations from 900-1,800 meter which is dry climate corresponds to be dry climate and procreate soil. The suitable agroforestry practices should be soil conservation hedges silvopastoral combinations and plantation-crop combinations.

Investigated traditional agroforestry practices in the Tropics were found the temporal or spatial arrangements of the plant components (Kang and Akinnifesib, 2000). Temporal or sequential systems include; bush fallow or improved fallow systems and taungya systems. Bush fallow or improved fallow systems, which were observed as traditional farming systems in the humid and sub-humid tropics, slash and burn was the method for land preparation and soil fertility management (Kaya and Nair, 2001) after the land had been exhausted the short cropping cycle, the land was usually allowed to return to forest or savanna vegetation to regenerate soil fertility through improved fallows or the rotation of fast growing nitrogen-fixing legume species with cereals have been shown to accumulate nitrogen and organic matter, recycle nutrients in the soil and improve soil physical and chemical properties, and increase crop yield (Sileshi and Mafongoya, 2003; David and Raussen, 2003). And taungya systems; the combination between field crops on forest lands, it enables farmers to enjoy free access to fertile forest land, which improved the survival, growth and nutrient uptake and reduced weed competition (Imo, 2009) and gets their trees planted at a cheaper cost through the utilization of available unemployed laborers and/or landless farmers. The sole purpose was to establishing forest plantation or to reforestation of abundance lands (Kang and Akinnifesib, 2000; Adekunle and Bakare, 2004).

Simultaneous systems consist of home gardens, agroforests, perennial tree-crop based systems, parkland or tiered agroforestry systems and alley cropping/fanning systems. Home gardens or compound farms was to produce subsistence items for domestic use and to generate additional income (Huai and Hamilton, 2009; Zaman *et al.*, 2010), which are low but stable yields (Kang and Akinnifesib, 2000) as

ecological systems were maintenance of soil fertility and soil structure and maintaining nutrient cycling (Gajaseni and Gajaseni, 1999; Huai and Hamilton, 2009). Agroforests, perennial tree-crop based systems and parkland (tiered agroforestry systems) have had similar components as follow; agroforests have planted the commercial species in the first year and after a few years have become a productive mixed tree/crop plantation with products for cash or for household consumption, perennial tree-crop based systems and parkland have included the tree crop as the main component, which have included perennial cash crops and/or fruit trees. Tree components have benefit under different species, which have been planted with variety of food crops and associated crop components rarely overlap. According to the perennial tree as a major component, that result as the close resemblance between the structure and function of the mature agroforest and that of a natural forest (Kang and Akinnifesib, 2000). Alley cropping/farming systems; it was an agroforestry technology in which food crops are grown in alleys formed by hedgerows of trees and shrubs. The hedgerows have managed preferably nitrogen-fixing species and periodically pruned to reduce competition between crops and tree (Henriksen *et al.*, 2002). The system was the alternative sustainable and more productive agricultural systems for managing the fragile uplands in the humid and sub-humid tropics (Kang, 1997; Kang and Akinnifesib, 2000).

Furthermore, the importance of agroforestry as a land-use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to climate change. The inclusion of trees in the agricultural landscapes often improves the productivity of systems while providing opportunities to create carbon sinks, particularly in agroforestry systems have a higher potential to sequester carbon than pastures, or field crops (Albrecht and Kandji, 2003; Nair *et al.*, 2009). According to a Payment for Environmental Services (PES) scheme, it has gained prominence as a tool for achieving ecosystem conservation and, at the same time, improving the livelihoods of farmers as environmental service providers. Pagiola (2007) developed an Environmental Services Index (ESI) and pays participants for net increases in ESI points. The highest point of ESI were found in a land use type close resemblance between the structure and function of a natural forest, but on the other

hand annual crop was the lowest ESI point such as natural pasture without trees, improved pasture without trees, semi-permanent crops, natural pasture with low tree density (<30 stems/ha) and monoculture fruit crops, respectively.

Agroforestry practices were promoted in Thailand by the Royal Forest Department (RFD) and Ministry of Agriculture and Cooperatives (MOA) in 1968. Due to forest land was markedly encroached for expansion of cultivated land, which caused a severely damage to the ecology and natural resources. Therefore, reforestation and agroforestry have been operated to sustain the rate of deforestation. Four main types of agroforestry operated in Thailand: agrisilviculture, silvopastoralculture, apsilviculture and Piscis-silviculture (Trongkongsin, 1987). Furthermore, the agroforestry carried out by the Forest Industrial Organization (FIO) can be grouped into three types as follow; forest trees and agriculture crops, forest trees and horticultural crops, and animals and trees (Phothitai, 1993). In addition, Thomas (2000a) summarized classification of agroforestry in field and landscape scale in the northern Thailand; field based (single field) and landscape based systems (many field in a broader landscape unit) are both divided into sequential and simultaneous types of systems, depending on their basic approach to dealing with plant competition. Most sequential systems are used as a transitional phase in the establishment of orchards or forest plantations and sequential annual-perennial crop rotations are possible. While most field-based simultaneous systems are among the most familiar forms of agroforestry, such as alley cropping, contour hedgerows, boundary plantings, silvo-pastoral systems, and home gardens, the category of complex agroforests is relatively new.

2. Landscape agroforestry

Land use change correspond ecological responses through patterns of land use changes in spatial-temporal level. Responding is produced by the interaction of biophysical (Turner, 1990; Lambin *et al.*, 2003) and socio-economic processes (Lambin *et al.*, 2003). Socioeconomic conditions and scales show at short-term scale, human activities, rather than natural forces, have become a major force in shaping the environment, while biophysical factors control the trends and processes of land use

change trader the macro environmental background (Jingan *et al.*, 2005). Obviously, agricultural intensification and forestry activities have been changed forested landscapes, which have produced large impacts on the biodiversity and ecosystem (Pastur *et al.*, 2012). Furthermore, the evidence responding of land use change that can modify the evapotranspiration and hence the total water yield of a catchment, but also the pathways that water will take on the volume, timing and quality of water in streams flowing to downstream areas (Thomas *et al.*, 2001) and hence the amount of soil particles, nutrients, agrochemicals and (in arid regions) salt that it will carry downstream. Evenness of river flow is influenced by the infiltration rates in the landscape when larger areas are considered, reducing the relative importance of land use (Noordwijk *et al.*, 2003). However, land use impacts on the watershed functions involves more than simply the sum of all the individual fields or plot in a watershed. This is especially true where a variety of different types of land use are practiced in individual fields or patches, resulting in mosaic patterns of land use in wider landscapes (Thomas, 2003).

Landscape mosaics are described by the landscape components of patches, corridors and the surrounding matrix (Turner *et al.*, 1995). There are directly influence the spatial patterning and flows in a landscape. Dynamics of landscape mosaics is the flux of energy, materials, nutrients and species among the component structures and the changes among them (Forman and Godron, 1981). Due to the impact of agroforestry was similar as compared to natural forest ecosystem, consequently the agroforestry was recommended as future land use for amelioration plans. Therefore, management of agroforestry on landscape as landscape ecology that can improve the economic, environmental and social values of agroforestry, and this knowledge should help to develop new management alternatives for agroforestry on landscape scale for the policy maker to natural resource management (Pastur *et al.*, 2012). The characteristic of landscape agroforestry (Figure 2), agroforestry appears to “encroach” on agricultural and forestry land. The overlap in the diagram illustrates that agroforestry links to agriculture and forestry, rather than being an independent land use system. The arrows indicate change, as land use shifts over time. The overlap between the two spheres may be either small or large, reflecting the proportion of land

used for agroforestry (Rudebjer *et al.*, 2005). Landscape agroforestry is important to study ecological systems. This scale is developed environmental modeling tools, where ecological processes are best understood. However, analysis at a higher scale can better explain environmental phenomena. This is particularly the case with agroforestry due to the spatial interaction as several systems of a farm which consists of a mosaic of different land-use types (Palma *et al.*, 2006).

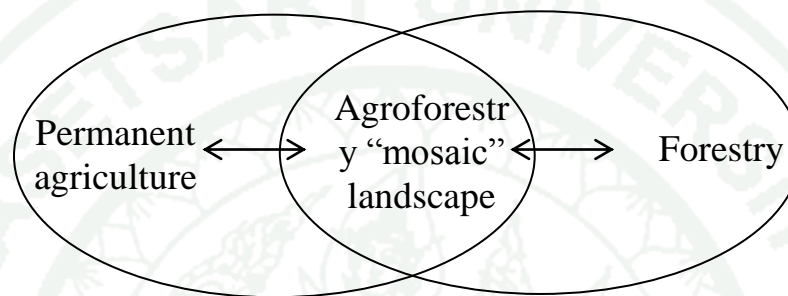


Figure 2 Agroforestry land use is linked to both agriculture and forestry.

Source: Rudebjer *et al.* (2005)

Spatial interaction of different land use patches has been increasingly recognized in landscape level issue. The science of landscape ecology aims to provide this understanding (Hobbs, 1997). Landscape ecology is defined as how landscape structure affects (the process that determine) the abundance and distribution of organisms (Fahrig, 2003). By considering landscape ecological concepts in landscape planning, the landscape design process, expressed in a plan through spatial concepts is embedded with the necessary ecological patterns and resulting functions. They have acknowledged the significance of the landscape ecological perspective for landscape planning, and a resulting need for reconsideration of planning theory and methods (Leitão and Ahern, 2002). Application of landscape ecology for landscape planning was found in several approaches, depending on the interpretation leads to the principle of landscape ecology. Such a metapopulation concept is used as a spatially explicit ecological theory, appropriate to describe the relation between biodiversity and the pattern of ecosystem patches in intensively used regions that ecological sustainability

is achieved if quality, area and configuration of the ecosystem network permit target species to persist (Termorshuizen *et al.*, 2007). Furthermore, the similar view which was adopted landscape ecological assessment by the focal species were tested as indicators of habitat quality, quantity and connectivity in the landscape (Mörtberg *et al.*, 2007). Moreover, numerous quantitative metric tools were adopted to address the spatial dimension of sustainability in a quantitatively rigorous and robust manner by integrating horizontal and vertical perspectives to approach ecological principles (Leitão and Ahern, 2002). Therefore, the indicator is important to evaluate landscape ecology as Uuemaa *et al.* (2009) concluded from peer-reviewed from 1994 to October 2008. Most of the landscape metrics and indices are used concerning biodiversity and habitat analysis, and also the evaluation of landscape pattern and its change and only a few articles on the relationships of landscape metrics/indices/indexes to social and landscape perception. There were analyzed seven main categories in the field of landscape as follow; (1) use/selection and misuse of metrics, (2) biodiversity and habitat analysis; (3) water quality; (4) evaluation of the landscape pattern and its change; (5) urban landscape pattern, road network; (6) aesthetics of landscape; (7) management, planning and monitoring.

According to landscape agroforestry is attended in the last decade. Many researchers and development workers had already begun to realize interactions of various configurations of trees on farms, communities and landscape. Due to land use change in mountain watershed regions in Thailand was damaged to the ecology and natural resources. In order to understanding this issue, and assessing tree roles in producing goods and services provide by agroforestry field and landscapes. Thomas (2000b) conducted agroforestry systems in landscape include sequential and simultaneous systems. Sequential systems include the classic long forest fallow rotational shifting cultivation systems which also include various types of protected areas in the landscape. In addition, pockets of irrigated paddy land carved into small upper valleys below their upland field and forests. Simultaneous systems appear the newest types and various forms the long fallow shifting cultivation components of the system are replaced by a mosaic of permanent agricultural and forest components. Individual land use components in the landscape may be based on segregation of

agricultural fields and community forests, or may involve various forms and degrees of simultaneous agroforestry integration. The effects of their systems are being conducted and the impact of other processes driving land use change have resulted in a wide range of spatially distributed land use practices that reflect various stages and pathways of transformation.

3. Land suitability

Different human activities require different land uses. It is unrealistic to restrict one type of land use in favor of the other everywhere. Therefore, land suitability need to allocation different land uses in a way that will support one type of land use while respecting other uses. Land suitability is a factor to be considered in the land use allocation (Wang and Hofe, 2007) which is the step of land use planning process for each promising land use type, establish the land requirements and match these with the properties of the land to establish physical land suitability. These techniques enable planners and local decision makers to analyze interactions in various ways (Steiner *et al.*, 2000).

There have been a lot of researches carried out land suitability by scientist around the world. Geography Information System (GIS) technique is one of the most useful application with planning and management in the land use suitability mapping and analysis. It has been applied in a wide variety of ecological approaches for defining land suitability (Riitters *et al.*, 1997; Magalhães *et al.*, 2011), geological favorability (Lane *et al.*, 1983; Delgado *et al.*, 2008), suitability of land for agricultural activities (Ahamed *et al.*, 2000; Sicat *et al.*, 2005; Hossain and Das, 2010), landscape evaluation and planning (Steiner *et al.*, 2000; Joss *et al.*, 2008), environmental impact assessment (Warner, 1996), selecting the best site for the public and private sector facilities (On Yen and Hong Chow, 1996), and regional planning (Marull *et al.*, 2007). Therefore, Malczewski (2004) stated that it has been applied in a wide variety of situations including urban/ regional/ environmental planning and management rather than agricultural/ ecological/ geological applications.

Land suitability analysis is a systematic procedure for examining combined effects of a related set of factors that an analyst assumes to be the important determinants of location suitability (Kaiser *et al.*, 1995). Specially, a land suitability analysis examines selected land characteristics to determine the level of suitability, and ranks available land accordingly. Those characteristics are represented with a set of factors. In general the process follows the following eight steps factors (Wang and Hofe, 2007)

Step 1. Select a land use type for analysis

A land suitability analysis focuses on one type of land development at a time. Normally, the development can be grouped as commercial, industrial, or residential use. When there is more than one land use type in the analysis, a suitability analysis of each land use type will be conducted. In the end, a preference order needs to be development in the areas which one suitable for multiple uses.

Step 2. Select factors to be considered and attribute values of each factor

The factors considered here are those that can help to decide on the priorities for land development. Some factors are related to the physical conditions that may determine the impact of the proposed land use to the area or to the development itself. Other factors reflect the demands posed by the proposed development. The factors could also be related to the costs and benefits of the proposed land use.

Step 3. Determine the score for each attribute of each factor

Once the factors are determined, their attributes need to determine. Attributes of a factor reflect its variation, which may be measured at any of the four levels of measurement-nominal, ordinal, interval, or ratio. The idea of a suitability analysis is to review relevant factors together, which requires a unified measurement of different factors. In order to link suitability to a factor, the relationships between the suitability measurement and the original factor attributes must be established.

Step 4. Weigh the factors

In this step, the relative importance of each factor is reflected in the weights assigned to each factor. The simplest weighing system assumes all factors are equally important; therefore, an equal weight will be assigned to each factor. When some factors are more important than others, those factors will be assigned a higher weight. Consequently, other factors will have a lower weight. When weights are expressed as percentages, the total of all weights must be 100%. This requirement ensures that the final composite score derived from the factors will have the same data range as each factor.

Step 5. Calculate a composite score from attribute value and weight for each factor

After assigning factor scores and weights, the composite suitability score we can calculate by using the following formula.

$$S = \sum w_i \cdot s_i \quad (1)$$

Where S is the sum of the product

w_i is the weight of each factors

s_i is the score of each factors

i is a factor.

Step 6. Rank the combined scores to establish suitability levels

Once composite scores are calculated for each piece of land, the land can be compared and ranked based on scores. The highest scores will be the most suitable land for the proposed use and the lowest scores will be the least suitable land. The suitability scores can be used as a guide for land use decision-making.

Step 7. Identify the available land based on existing land use

Unless development occurs in an area never touched by humans, it will require a conversion from an existing use, which has to meet certain people's needs, to the proposed use. As discussed before, land uses vary in intensity. It is rare that a land use with higher intensity is changed to another use with less intensity. In general, different land uses can be ranked based on human impact. Undeveloped land, such as forest area or barren land is the area where human impact is the least. Consequently, the new development would most likely occur on undeveloped land.

Step 8. Constraints with comprehensive plans, zoning or other land use controls to further remove unavailable land

Comprehensive plans, zonings, and/or other regulations specify the permitted uses in an area. Unless there is a zoning change of zoning, future residential development can only be considered in permitted areas. In addition, constraints may exist based on existing land uses or other physical conditions.

The land suitability analysis is a process of comprehensively considering multiple factors. It is used to eliminate areas where future development should not be considered. In addition, for areas where future development is permissible, and suitability analysis helps rank them in terms of future development preference. The benefit of land suitability analysis in planning is built upon these two outcomes. The unsuitable land will be excluded from consideration of future development. For areas that are suitable for new development, the more suitable land will be considered prior the less suitable land.

The land suitability was conducted with several methods. Malczewski (2004) concluded the advance method in GIS based on land suitability include computer-assisted overlay mapping, Multi-Criteria Decision Marking (MCDM) methods; there consist of Multi-Objective Decision Marking (MODM) methods and Multi-Attribute Decision Marking (MADM) methods, Artificial Intelligence (AI) methods; there

consist of fuzzy logic techniques, neural networks and evolutionary (genetic) algorithms, cellular automata. Over the last decade Multi-Objective Decision Analysis (MCDA) or also known as MCDM (Triantaphyllou and Baig, 2005) are applied in environmental sciences, particularly in natural resource management (Mendoza and Martins, 2006; Ananda and Herath, 2009). It has been successfully used tools for environmental applications (Huang *et al.*, 2011). Moreover, MCDM has been applied in energy policy analysis, farm management, food security, forest management, protection of natural areas, water management, ecosystem management, soil and water management, wetland management and national parks management (Ananda and Herath, 2009).

4. Multi-criteria decision making methods

Fundamentally, MCDM has inherent properties that make it appealing and practically useful; it seeks to take explicit account of multiple, conflicting criteria, it helps to structure the management problem, it provides a model that can serve as a focus for discussion, and it offers a process that leads to rational, justifiable, and explainable decisions. Moreover, MCDM also has some desirable features that make it an appropriate tool for analyzing complex problems such as those typically found in natural resource management (Mendoza and Martins, 2006).

MCDM is well known branch of decision making and is a branch of a general class of operations research models. MCDM can be divided into two broad classes of MADM and MODM (Hayashi, 2000; Chatterjee *et al.*, 2011). Both of these problems can be single-decision-maker problems or group decision problems (Massam, 1988). MCDM methods deal with the process of making decisions in the presence of multiple objectives. A decision-maker is required to choose among quantifiable or non-quantifiable and multiple criteria. The objectives are usually conflicting and therefore, the solution is highly dependent on the preferences of the decision-maker and must be a compromise (Pohekar and Ramachandran, 2003). Therefore, MCDM is characterized by method that supports planning and decision processes through

collecting, storing and processing different kinds of information to construct a viable of how to solve a multi-criteria problem.

MCDM process is suitable for a wide variety of decision situations. Furthermore, several weighting techniques have been developed to help decision makers in articulating their preferences. However, certain structural elements are common in the MCDM methods as following (Figure 3).

Step 1. Define the problem

This process involves defining the problems and goals, limiting assumptions to achieve the goals, system and organizational constraints, and stakeholder issues and involvement. The problem definition must be a concise and unambiguous and agreed upon by all decision makers and stakeholders. It is a crucial and necessary step before proceeding to the next step.

Step 2. Determine requirements

Requirements are conditions that any acceptable solution to the problem must meet. In mathematical form, these requirements are the constraints describing a set of feasible solutions. It is important that even if subject or judgmental evaluations may occur in the problem, the requirements must state in the exact quantitative form.

Step 3. Establish goals

Goals are broad statements of intent and desirable programmatic values. The goals may be conflicting but this is natural in practical decision-making situations.

Step 4. Identify alternatives

Alternatives offer different approaches for changing the initial condition into the desired condition. Alternatives must meet the requirements. If there are possible

alternatives, these should be screened one by one to check the requirements and to screen out infeasible alternatives from further consideration.

Step 5. Define criteria

Criteria are the controlling factors that represent the decision maker's or other stakeholder's point of view required to establish adequate comparisons of alternatives. A consistent set of criteria should avoid redundancy but must be exhaustive and covering issues by all parties. Decision criteria, which will be discriminated from alternatives, must be based on the goals (Baker *et al.*, 2001). It is usual to arrange the groups of criteria, sub-criteria, and sub-sub-criteria in a tree-structure (UK DTRL, 2001). Grouping criteria can help in the process checking; calculating weights in some method, and facilitating the emergence of higher level views of the issues (UK DTRL, 2001). Saaty (1980) suggested a hierarchical way of constructing the criteria structure. The bottom-up and top-down approaches can be used to identify the set of criteria (Lahdelma *et al.*, 2000). The bottom up approach is used to identify the set of criteria in decision aid studies. According to Baker *et al.* (2001) the criteria should be complete, meaningful, non-redundant, and manageable.

Step 6. Select a decision making

The selection of an appropriate tool is not an easy task and depends on the concrete decision problem, as well as on the objectives of the decision makers. According to the method that suits most of the following objectives should be considered;

1. It should be easy understood.
2. The approach should be capable to support the necessary number of decision makers.
3. It should be able to manage the number of alternatives.

4. The methodology should be able to handle inaccurate and uncertain information.

5. The methodology should cover the lowest need of preferences from the decision.

Step 7. Evaluate alternatives against criteria

To evaluate the alternatives against the criteria input data. Depending on the criteria, the assessment may be objective, or it can be subjective (judgmental), reflecting the alternatives or to choose a set of most promising alternatives.

Step 8. Validate solution based on problem statement

The selected alternatives always have to be validated against the requirements and goals of the decision problem. In complex problems the selected alternatives may also call the attention of the decision makers or stakeholder.

A general MCDM problem can be expressed in matrix form as:

$$\begin{array}{ccccccc}
 A_1 & A_2 & \dots & \dots & \dots & & A_m \\
 & & & & & & \\
 & & & & & & \\
 X_1 & C_{11} & C_{12} & \dots & \dots & & C_{1m} \\
 & & & & & & \vdots \\
 & & & & & & \vdots \\
 X_n & C_{n1} & C_{n2} & \dots & \dots & & C_{nm} \\
 W_j = [W_1, W_2, \dots & \dots & W_n]
 \end{array} \quad (2)$$

Where $A_i = 1, 2, \dots, m$ denote the alternatives

$X_j = 1, 2, \dots, m$ represent attributes or criteria

C_{ij} = Crisp or fuzzy values indicating the performance rating of each alternative A_i with respect to each criterion X_j .

$W_j = 1, 2, \dots, n$ are the weighting factors and represent relative importance of the criteria

The practical assessment of C_{ij} is critical due to unquantifiable, incomplete and no obtainable information and partial ignorance. The unquantifiable information leads to subjective rankings, for examples good, poor, high, low, etc. These subjective rankings lead to vagueness and uncertainty in the decision-making's judgment.

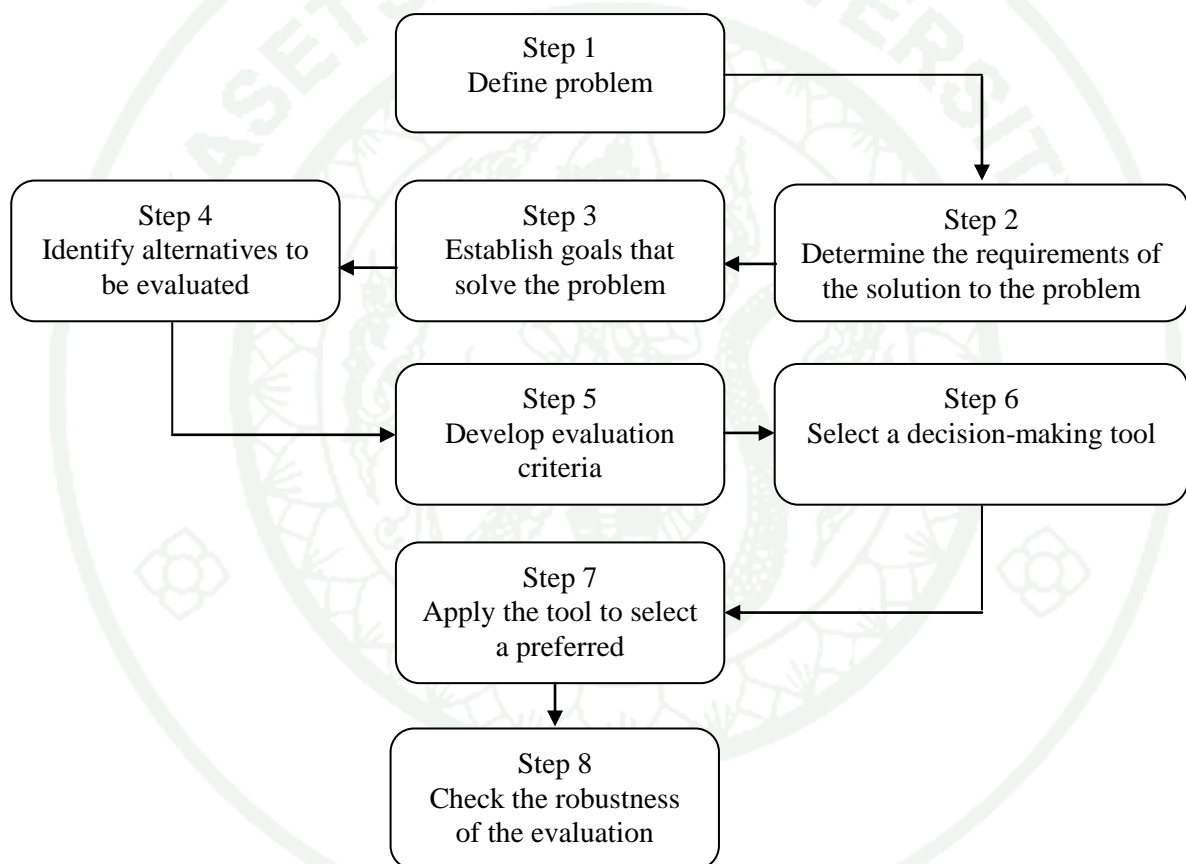


Figure 3 Frame of multicriteria decision analysis.

Source: Baker *et al.* (2001)

MCDM methods are classified into two major groupings based on the nature of the alternatives to be evaluated namely continuous and discrete methods. Continuous methods as the methods are designed in MODM, aim to identify an optimal quantity,

which can vary infinitely in a decision problem. Techniques such as linear programming, Goal Programming (GP) and aspiration-based models are considered continuous. Discrete methods as the methods are designed in MADM, it can be defined as decision support techniques that have a finite number of alternatives, a set of objectives and criteria by which the alternatives are to be judged and a method of ranking alternatives, based on how well they satisfy the objectives and criteria (Malczewski, 2004; Mendoza and Martins, 2006; Ananda and Herath, 2009). Further MCDA can classify into three broad categories; (1) value measurement methods; numerical scores are constructed in order to represent the degree to which one decision option may be preferred to another. Such scores are developed initially for each individual criterion, and are then synthesized in order to affect aggregation into higher level preference models such as Analytic Hierarchy Process (AHP), (2) goal, aspiration or reference level models; desirable or satisfactory levels of achievement are established for each criterion. The process then seeks to discover options which are closest to achieving these desirable goals or aspirations such as goal programming and compromise programming, and (3) outranking models; alternative courses of action are compared pairwise, initially in terms of each criterion in order to identify the extent to which a preference for one over the other can be asserted. In aggregating such preference information across all relevant criteria, the model seeks to establish the strength of evidence favoring selection of one alternative over another such as ELECTRE and PROMETHEE methods (Mendoza and Martins, 2006).

The basic model application of MADM methods includes the commonly utilized crisp are considered: AHP, SMART, TOPSIS, ELECTRE and PROMETHEE (Cicek and Celik, 2010). Brief representations of each method are given as follows: in a traditional application of AHP, a decision problem is structured in a hierarchical structure includes criteria and alternatives in respect to an overall goal. The pairwise judgments are then assigned based on the nine-point scale by Saaty (1980) to determine the relative importance of the decision elements. On the other hand, the SMART is simplified version and is developed by Edwards in 1977. It is not require much computational effort and usually shows good performance. SMART has been used mainly in business and social sciences. TOPSIS is one of the value based

methods which a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point (Olson, 2004). The TOPSIS chooses the best alternative, which has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The ELECTRE, the earliest outranking method, was initiated by Roy in (1991). It is one of the widely applied outranking methods to strict problems in MADM which requires setting of the indifference threshold, preference threshold, and standard deviation for a decision-making problem.

The wide variety of MCDM rule there is a question of which the method is the best one to be used in particular situation. This is a largely unsolved problem in decision analysis. Several studies demonstrate that the different multi-criteria evaluation rules generate considerably different land use suitability patterns (Malczewski, 2004). A question arises in terms of which method is preferred and is selected (Mendoza and Martins, 2006). There are several methods in each of categories. Priority based, out-ranking, distance based and mixed methods are also applied to various problems. Each method has its own characteristics and the methods can also be classified as deterministic, stochastic and fuzzy methods. There may be combinations of each method. Depending upon the number of decision makers, the methods can be classified as single or group decision making methods. Decision making under uncertainty and decision support systems are also prominent decision making techniques (Pohekar and Ramachandran, 2003).

Huang *et al.* (2011) stated that over the last two decades MCDM tools have been successfully used for environmental applications, even though the use of the specific methods and tools vary in different application areas. In terms of the total number of papers published, AHP/Analytic Network Process (ANP) dominates at 48%; MAUT and Outranking (combined ELECTRE and PROMETHEE) are at 16% and 13%, respectively. AHP has its highest penetration, at 80%, in spatial/GIS papers. Only in air quality/emission is PROMETHEE used more widely than AHP (dominating 60% of the category that includes 10 papers only) the percentage of AHP/ANP papers increased from about 15% in 2000 to over 40% in 2002 and has

dominated MCDA methods ever since. The wide use of AHP may be related to the availability of user-friendly and commercially supported software packages and enthusiastic and engaged user groups. The AHP is generally an easier technique to apply because eliciting the required information is less complex. Many decision-makers can respond to the comparisons involved when the number of attributes is small. For this reason, AHP and some of its variants are considered by some as their preferred method (Ananda and Herath, 2009). Therefore, AHP is one of category methods of MCDM which has successfully been applied in a range of fields, particularly in allocation resource and environmental management (Ramanathan and Ganesh, 1993; Gregory *et al.*, 2005).

5. Analytic hierarchy process (AHP)

AHP was developed in the early 1970s by Thomas L. Saaty (Saaty, 1980). It provides decision makers with a method to indicate decisions by weighing the evaluation criteria and making pair-wise judgments of a set or subset of alternatives (Hanne, 2001). AHP attempts to resolve conflict and analyze judgments through a process of determining the relative importance of a set of activities and criteria. AHP method is based on three principles; decomposition, comparative judgment, and synthesis of priorities. The AHP procedure involves three major steps as following (Malczewski, 1999).

Step 1. Develop the AHP hierarchy

The first step in the AHP procedure is to decompose the decision problem into a hierarchy that consists of the most important elements of the decision problem. In developing a hierarchy, the top level is the ultimate goal of the decision. The hierarchy then descends from the general to the more specific until a level of attributes is reached. This is the level against which the decision alternatives of the lowest level of the hierarchy are evaluated. Each level must be linked to the next-higher level. Typically, the hierarchical structure consists of four levels: goal, objectives, attributes, and alternatives.

Step 2. Compare the decision elements on a pairwise base

Pairwise comparisons are the basic measurement mode employed in the AHP procedure. The procedure greatly reduces the conceptual complexity of decision making since only two components are considered at any given time. It involves three steps: (a) development of a comparison matrix at each level of the hierarchy, beginning at the top and working down; (b) computation of the weights for each element of the hierarchy; and (c) estimation of the consistency ratio. It should be emphasized that this three-step process follows the procedure for estimating weight of importance for evaluation criteria.

Step 3. Construct an overall priority rating

The final step is to aggregate the relative weights of the levels obtained in the second step to produce composite weights. This is done by means of a sequence of multiplications of the metrics of relative weights at each level of the hierarchy.

A pairwise comparison matrix calculates the weight value for each criterion (w_i) by taking the eigenvector corresponding to the largest eigenvalue of the matrix, and then normalizing the sum of the components to a unity as:

$$\sum_{i=1}^n w_i = 1 \quad (3)$$

An importance scale is proposed for these comparisons (Table 1). The basic input is the pairwise comparison matrix A of n criteria constructed based on Saaty's scaling ratios, which is of the order as defined in equation (3):

$$A = [a_{ij}], i, j = 1, 2, 3, \dots, n \quad (4)$$

where A is a matrix with elements a_{ij} . It generally has the property of reciprocity, i.e. mathematically:

$$a_{ij} = \frac{1}{a_{ji}} \quad (5)$$

and after it has been generated, it is 30normalized as a matrix B:

$$B = [a_{ij}], i, j = 1, 2, 3, \dots, n \quad (6)$$

where B is the 30normalized matrix of A with elements b_{ij} :

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad i, j = 1, 2, 3, \dots, n \quad (7)$$

Each weight value w_i is computed as:

$$w_i = \frac{\sum_{j=1}^n b_{ij}}{[\sum_{i=1}^n \sum_{j=1}^n b_{ij}]} \quad i, j = 1, 2, 3, \dots, n \quad (8)$$

Equations (7) – (9) represent the relationships between the largest eigenvalue (λ_{max}) and corresponding eigenvector (W) of the matrix B:

$$BW = \lambda_{max} W \quad (9)$$

$$W = (w_1, w_2, \dots, w_n)^T \quad (10)$$

$$\lambda_{max} = \sum_{i=1}^n \frac{(BW)_i}{n w_i} \quad i, j = 1, 2, 3, \dots, n \quad (11)$$

where (BW) i is the i^{th} value of the vector BW. It is necessary to verify the consistency of the matrix B after obtaining the weight values. The consistency is judged on the basis of a consistency ratio, CR:

$$CR = \frac{\lambda_{max} - n}{(n - 1)RI} \quad (12)$$

where RI is a constant which corresponds to the mean random consistency index value according to n .

The determination of CR value is critical. In our case study, we adopted a standard CR threshold value of 0.10 which has been widely used as a measure of the consistency in a set of judgments of AHP applications in literature. If $CR < 0.10$, it deems that the pairwise comparison matrix has acceptable consistency and the weight values calculated in equation (6) are valid and can be utilized. Else if $CR = 0.10$, it means that the pairwise comparisons are lack of consistency, in other words, the matrix is better to be adjusted and the element values should be modified. However, although one might think that being consistent is of utmost importance, allowing for some inconsistency is reasonable. One of the strengths of AHP is that it does allow for inconsistent relationships, while, at the same time, providing CR as an indicator of the degree of consistency or inconsistency (Forman and Selly, 2001). Therefore, the AHP implementation in this study has incorporated an option to let the user define an acceptable CR threshold value. Significant approach should proceed if the user-defined CR requirement is met. But when CR is greater than 0.10, the user has to be careful to accept the resultant weights without changing input to the pairwise comparison matrix, as well as feel confident that the matrix really reflects the user's beliefs rather than contain an error (Bodin and Gass, 2003).

Table 1 Scale for pairwise comparisons.

Intensity of importance description	
score	description
1	Equal importance
3	Moderate importance
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values
Reciprocals	Values for inverse comparison

Source : Saaty and Vargas (1991)

The application of AHP has been carried out for the last 20 years. Even though it is widely recognized to have major limitations (Huang *et al.*, 2011). The integrated AHP; AHP has been combined with other models namely hybrid methods (Ananda and Herath, 2009) is applied rather than the stand-alone AHP. The five tools that commonly combined with the AHP include mathematical programming, Quality Function Deployment (QFD), meta-heuristics, SWOT analysis, and Data Envelopment Analysis (DEA), respectively. The major reason why the combined AHP–GP (Analytic Hierarchy Process–Goal Programming) approach was paid the most attention to is that the individual techniques possess unique advantages (Ho, 2008). Badri and Abdulla (2004) pointed out that good decisions are most often based on consistent judgments through the consistency verification operation of the AHP contributes. It acts as a feedback mechanism for the decision makers to review and revise their judgments. Consequently, the judgments made are guaranteed to be consistent, which is the basic ingredient for making good decisions. Nevertheless, the output of the AHP is the relative importance weightings of the criteria and the attributes merely. The GP can compensate for the AHP. It can definitely provide more and useful information for the decision makers. Based on the consistency, it is believed that it must be beneficial to the decision making process if both AHP and GP are integrated together (Ho,

2008). In addition, the AHP has been used to examine risk preferences of decision makers (Ananda and Herath, 2009) and integrated with GIS technique for site selection. AHP was combined with a GIS to examine several criteria. Each criterion was valuated with the aid of AHP and mapped by GIS (Sener *et al.*, 2010; Bunruamkeaw and Murayama, 2011).

6. Philosophy of sufficiency economy and application

The philosophy of sufficiency economy philosophy is a philosophy which is bestowed by His Majesty the King (Wibulswasdi *et al.*, 2010). The philosophy of SE lies at the heart of Thailand's development thinking, and indeed it can serve as guidance for the country's sustainable developments (United Nations Conference on Trade and Development [UNCTAD], 2000). The ninth to eleventh (2002–2016) of national development plans has applied SE as the framework for the country's development aimed to achieve well-balanced and sustainable growth at household, community, and nation levels (Sathirathai and Piboolsravut, 2004).

6.1 Sufficiency economy philosophy framework

The sufficiency economy philosophy framework (Figure 4) comprises three components and two underlying conditions. First, sufficiency entails three components. There are moderation, reasonableness, and requirement for a self immunity system, i.e. the ability to cope with shocks from internal and external changes. Second, two underlying conditions necessary to achieve sufficiency are knowledge and morality. SE requires breadth and thoroughness in planning, carefulness in applying knowledge, and the implementation of those plans. SE serves as a guide for the way of living/behaving for people of all levels, and is scalable with universal domain applicability (Piboolsravut, 2004).

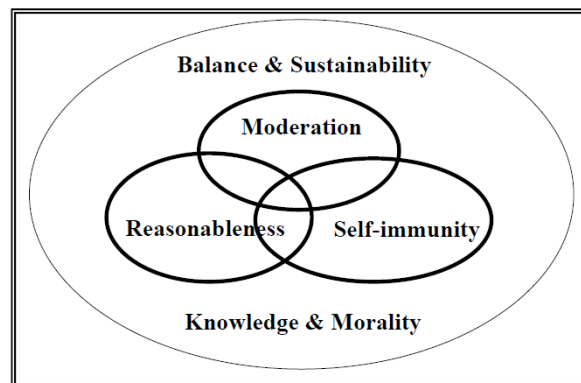


Figure 4 Sufficiency economy philosophical framework.

Source: Piboolsravut (2004)

6.2 Application of sufficiency economy philosophy and indicators

6.2.1 Nation level

SE at the national level starts with a national administrative and development plan that encourages and enables people to live their own lives and to cooperate with others in development based on SE, while prudently implementing the plan step by step. Application of SE at the national level should begin by laying foundations that enable the majority of people to have the basic necessities to live sufficiently and to support themselves adequately through the use of knowledge and morality in their lives. People should also be encouraged to expand their vision through the creation of learning networks among various socioeconomic backgrounds and professions, which eventually will lead to harmony and solidarity in society. In addition, the strategies to reform the structure of agricultural sector enable Thailand to have food security and safety and enhance the production of new types of agricultural products that manufactured by making use of biodiversity. The production system and service system are making use of technological advances appropriately to use energy and other natural resources less and in an environmentally friendly manner. The economic sector is a stable income base for agriculturists. Moreover, the agriculture is integrated farming and organic farming which is variety in the household and

expand cultivated lands for more sustainable agriculture (Office of the National Economic and Social Development, 2007).

Indicators based on SE in order to evaluate the macro-performance of the Thai government starting from 2005. The main purpose is to ensure that the government in the future will continue its policy in the direction to enhance SE further. In order to ensure such outcome, the indicators are developed from existing sets of quantitative data. Indicators are classified into seven dimensions including economic, ethical and culture, social, educational, public and private business management, science and technology and resource and environmental dimensions. In the process of identifying indicators for each dimension, the framework of SE explained in the form of a system analysis is used for the purpose as following (National Economic and Social Advisory Council, 2007) (Table 2),

Table 2 Weight of indicators based on the philosophy of sufficiency economy.

Dimensions	Weight
Economic	0.30
- Income distribution	
- Consumption expenditure/disposable income	
- Rate of openness	
- Value of factors import(Chemical fertilizer)/GDP in agricultural sector	
Ethic and Culture	0.10
- Crime to property	
- Death from accident and toxin	
- Average age of population	
- Divorce rate per 1,000 marriage	
- Children being abandoned per 100,000 children	
Social	0.10
- Access to services. Social Welfare.	
- Your assistance in helping society.	
- Peaceful conflict management.	
- Social responsibility	

Table 2 (Continued)

Dimensions	Weight
Educational	0.10
- The rate of continuation to secondary education	
- Marginalized children/population of children of the same are cohort	
Management of Public Sectors	0.15
- Transparency of the government	
Management of Private Business	0.05
- Immunization and performance management.	
- Social responsibility.	
Science and Technology	0.10
- The development for long-term self-reliance in technology	
Resource and Environment	0.10
- The quality of resource(fresh water quality)	
- The quality of resource(natural forest area)	
Total	1.00

Source: National Economic and Social Advisory Council (2007)

6.2.2 Community level

A “Sufficient Community” consists of individuals and families who have a degree of self-reliance that are based on their own knowledge and moral strength but they strive for sustainable progress. These members of a sufficient community are cooperated by sharing their efforts and exchanging their ideas, knowledge skills and experiences. They use community resources and develop community activities in ways that are appropriate to their geo-social circumstances in order to realize the utmost benefits and happiness of community members. Community activities are carried out and improved continuously, based on morality honesty, patience, perseverance, generosity and sympathy-which lead to social harmony and create a community that has immunity from the impacts arising from

changing. Eventually sufficient communities of sufficient individuals create a network with other communities (Office of the National Economic and Social Development, 2007).

6.3 S E application for land use and landscape scale

His Majesty introduced the unprecedented approach to manage farmland. Efficient water management was also developed to ensure year around farming. To adopt the new theory agriculture, farmers are advised to follow these three steps: Phase I is farmland division for optimum benefits. The land is divided into four parts with a ratio of 30:30:30:10. The first 30% is designated for a pond to store rainwater during the rainy season while during the dry season it serves to supply water to grow crops and raise aquatic animals and plants. The second 30% is set aside for rice cultivation during the rainy season for the family's daily consumption throughout the year to cut down on expenses and allow the farmers to be self-reliant. The third 30% is used for growing fruit and perennial trees, vegetables, field crops and herbs for daily consumption. If there is any surplus, it will be sold. The last 10% is set aside for accommodation, animal husbandry, roads and other structures (The Chaipattana Foundation, 2012). These documents are obvious in farm scale application and emphasized on agriculture land use type.

Therefore the application in landscape scale and land use scale was interpreted from the concept of the national level and the community level. In conclusion, the concept was to create a system of production and consumption for a sustainable and secure food production that manufactured by making use of biodiversity and technological advances appropriately to use energy and other natural resources less and in an environmentally friendly manner. Promote the new agriculture that integrated varieties of farming in the household and organic farm, which is appropriate for geo-social circumstances under the acceptance of the community and least effect to the resources and stable income base for agriculturists.

6.3.1 SE application in land use scale and key performances

a) SE application in land use scale

According to land use include different kinds of uses, one of the land use type is crop land which is expanded in the rural areas. These results affected to degradation of production. Thus the investigation is how the degradation occurs after production, which the production efficiency depends on several factors. This investigation was examined by FAO in the Land Degradation Assessment in Dry Land (LADA) project supported by the Global Environment Facility (GEF) and executed by FAO during the period 2006-2010 (FAO, 2011). The concept of the Land Degradation (LD) was related among Driving Forces-Pressures-State-Impacts-Responses (DPSIR). DPSIR framework is used to help analyze the relationships between the state (status and trends) of land resources; the direct pressures on land resources; the driving forces (the indirect drivers that act on the pressures); the impacts (of changes in the state) on ecosystem services and on people's livelihoods; and possible responses from land users, policy makers and other stakeholders designed to mitigate LD, adapt to its impacts or promote Sustainable Land Management (SLM).

LD is caused by a variety of complex interrelated degradation processes. These can be grouped into three major LD types, each of which can be subdivided according to a specific sub-set of degradation processes, namely: soil degradation; vegetation degradation; water resources degradation. The impacts of LD on the productivity of croplands, rangelands and forest/woodlands are of particular concern to land users as illustrated in production. Ultimately all these production systems are dependent on the growth and use of plants (planted or naturally growing) which in turn depends on the capacity of the soils to full fill a number of key functions and on the adequacy of rainfall (or irrigation) to satisfy plant water and nutrient requirements. Reduction in the capacity of land used for crop production (rained or irrigated) to sustain the yield of annual and/or perennial crops is due largely to soil degradation and is partly due to degradation of water resources. The main indicators of degradation/improvement in croplands are summarized in Table 3.

Table 3 Assessing LD/ SLM processes in croplands.

Effects of LD/SLM in croplands	Indicators
Change in soil properties - biological - chemical - physical - hydrological	<ul style="list-style-type: none"> - Change in soil organic matter (OM) content; plant nutrient availability, leading to change in fertility (i.e. yield/ha) and or change in required inputs (fertilizer/OM/ha) - Change in soil salinity and chemical toxicity (e.g. excess fertilizers, agro-chemicals, inadequate drainage in irrigated lands) leading to change in yields or crop suitability (tolerant species) - Change in soil physical structure resulting in change in germination rate, root development, infiltration / drainage (e.g. leading to runoff) - Water logging; change in soil moisture retention (acidification).
Soil erosion or reclamation	<ul style="list-style-type: none"> - Change in extent and severity of splash, sheet, rill and gully erosion (by water) and of topsoil removal by wind blow leading to change in productivity (yield/ha) and productive land area (gullies and their reclamation) - Change in extent and depth of windblown soil deposits and sand dune movement (wind erosion) leading to change in productivity and productive land area, and damage to property/infrastructure.
Change in water resources	<ul style="list-style-type: none"> - Change in the quantity and quality and flow regime of ground and surface water resources and change in water availability (human consumption, livestock, irrigation etc.)
Change in vegetation	<ul style="list-style-type: none"> - Change in conservation and use of wild tree and plant species in farming systems (borders, strips, multiple storeys etc) for fertilizer, mulch, shade, forage for livestock, and habitat for pollinators and beneficial predators.

Source: FAO (2011)

From above the indicators of soil degradation from the crop land and SE application in community level are merged as the criteria and indicators of land use scale, which was considered all of effect factor as in table 4. The consideration was under the available indicator for investigation in land use scale. Although, all of indicator can demonstrate the effect after production but it is taken long time and expensive cost. Therefore, the indicators were considerate including (1) sensitive to management-induced changes; (2) easily measured; (3) relevant across sites or over time; (4) inexpensive; (5) closely linked to measurement of desired values such as productivity or biodiversity; and (6) adaptable for specific ecosystems (Schoenholtz *et al.*, 2000). Three aspects were conducted in three aspects; physical aspect, economic aspect and social aspect as below,

b) Key performances

(1) Physical aspect

a. Change in soil properties

i. Change in soil organic matter (OM)

Changes in soil properties affect to indicate soil quality. The concept of “soil quality” has recognized soil organic matter as an important attributes that has a great deal of control on many of the key soil functions (Franzluebbers, 2002). Land cover/land use was important factors controlling the amount and composition of SOM fractions at the aggregate level (Yamashita *et al.*, 2006). Total soil organic matter (SOM) influences soil compatibility, friability, and soil water-holding capacity while aggregated SOM has major implications for the functioning of soil in regulating air and water infiltration, conserving nutrients, and influencing soil permeability and erodibility (Carter, 2002). Total organic C was the only indicator that consistently showed significant for assessing soil quality on a regional scale (Brejda *et al.*, 2000). Thus the OM has been effective indicator in terms of soil organic carbon.

ii. Change in soil moisture retention

Soil moisture is the major control for rainfall–runoff response, especially where saturation excess runoff processes dominate that are fundamental ecosystem resources providing the transpirable water for plants (Robinson *et al.*, 2008). Soil moisture plays a critical role in both crop growth and vegetation restoration in semiarid environments. The spatial and temporal variabilities were resulting from topography, soils, vegetation and land uses. Land uses can give rise to variations in soil physical and hydrological properties in relation to soil moisture, the creation of a mosaic pattern of land use may be advantageous in runoff and erosion control (Fua *et al.*, 2003).

iii. Change in soil physical structure

Although, soil texture and depth are sensitive indicator of several soil functions but they are soil properties that would change little through time for a given soil, and so they would not be very useful for assessing management effects. Besides, soil bulk density varies among soils of different textures, structures, and organic matter content, but within a given soil type, it can be used to monitor degree of soil compaction and puddling. Change in soil bulk density affect a host of other properties and processes that influence water and oxygen supply (Schoenholtz *et al.*, 2000). Consequently, soil bulk density was as effective indicator in terms of soil structure. Soil erosion can have a significant, negative impact on crop yields (Verity and Anderson, 1990), especially in years when weather conditions are unfavorable. According to, the soil structure stability is one of the most important characteristics that affect crop yield because it affects root penetration, water storage capacity, and the movement of air and water in the soil (Aparicio and Luis Costa, 2007) thus the soil structure stability has been proposed an indicator of soil sustainability as well as an indicator of environmental quality (Lal *et al.*, 1994).

iv. Change in soil salinity and chemical toxicity

The soil chemical properties were cited in recent literature pertaining to soil quality in agricultural, grassland and forest soils. They express to some extent, the dichotomy between the need for simplicity and practicability, which tends to favor static parameters that are easily and routinely measured, but are hierarchically several levels removed from soil function, and the desire to more accurately represent the dynamic processes that underlie site productivity, which tend to involve more laborious and/or costly assays (Schoenholtz *et. al*, 2000). Salinity and chemical toxicity are chemical aspect of soil properties were not chosen for indication.

b. Change in soil erosion or reclamation

As soil erosion continues, the soil is further degraded. Poor soil quality is reflected in decreases of organic matter, aggregate stability, phosphorus levels, and potential plant-available water as the net result of decreasing in soil productivity. Soil erosion by water is similar to soil degradation and productivity losses that can occur as a result of wind erosion (Natural Resources Conservation Service, 1998), thus soil erosion by water can represent as the soil erosion indicator. In the last few decades there have been several attempts to develop soil erosion rates at field, regional and global scales. Initial evaluations of field scale and catchment scale models were carried out at Global Change and Terrestrial Ecosystems (GCTE) meetings (Jetten *et al.*, 1999). One of tradition model to evaluation in the field scale is Universal Soil Loss Equation (USLE) by Wischmeier and Smith (1978). The general limitations of the USLE on spatial and temporal scales, and in climate and soil conditions, and new crop and management were contributed to eventual dissatisfaction (Renschler and Harbor, 2002). The Revised Universal Soil Loss Equation (RUSLE) was produced as alternative models based on USLE style applicability and usability by Renard *et al.* (1991).

c. Change in water resources

Additionally, water resources changes to water quality often occur over long period of time, making it difficult to determine the role of human activity as distinct from natural process (FAO, 2011). This situation can show the limitation to determine water quality in land use scale particularly in water quality after production of each land use types.

d. Change in vegetation

Change in vegetation is explained in change in conservation and use of wild tree and plant species in farming systems (borders, strips, multiple storeys etc) for fertilizer, mulch, shade, forage for livestock, and habitat for pollinators and beneficial predators. The most important indicators of change in vegetation to degradation are (FAO, 2011):

1. Reduced vegetation covers (plant and litter)
2. Changes in vegetation structure and plant community composition
3. Decline in species and habitat diversity
4. Changes in abundance of indicator species (e.g. of high or low pasture quality or poor soil quality and invasive species).
5. These are in turn linked to land productivity in terms of biomass and quality of products and in pasture/ rangelands also in terms of livestock productivity.

The measurement achieve to each indicator was comprehended; vegetation cover, vegetation structure and plant community composition can diagnose

by percentage of crown cover and number of crown layers. Percentage of crown cover is a major determinant of net primary production (Schomaker *et al.*, 2007) and also can illustrate community composition. Vegetation structure can conduct by canopy stratification which is one of the oldest concepts in tropical forest ecology. This technique provides an objective measure of canopy strata allowing for a valid comparison of stratification between the different profiles diagrams (Bakera and Wilsonb, 2000). Species richness is the simplest way to describe community and regional diversity, that maximizing species richness is often an explicit or implicit goal of conservation studies (Gotelli and Colwell, 2001). Thus, reduction in species and habitat diversity can measure by species diversity (species richness measurement). Land productivity in terms of biomass and quality of products can measure by plant biomass, which is defined as the above-ground dry organic materials produced per unit of area (e.g., gm^{-2}), and productivity is defined as the biomass production (primary production) per area and per time unit (Guo, 2007).

2) Economic aspect

Criteria of economic factor can directly adopt from SE national policy. It consists of income and consumption which were interpreted as land use activities. Thus income was interpreted as income from agricultural land use activities which consist of income distribution and Net Present Value (NPV). NPV was seen to be the most popular technique. The main reason is accuracy and takes into account the time value of money and adjusts for risk factors (Maroyi, 2011; Lutz, 2011). Income distribution in national plan was explicated as the promotion of fair competition and production of tools and mechanism of benefit distribution to allow the reform of the economic structure to solve the poverty problem and create better income distribution (Office of the National Economic and Social Development, 2007). It was addressed to encouragement to distribute income for alleviation poverty. Whereas, income distribution in terms of land use activities was comprehended as the effective of income distribution and considered main concept of SE which is for stability life. Thus this indicator is stable income which is similar as meaning of consumption expenditure/disposable income. Moreover, indicator of economy was explained in

value of factor import (Chemical fertilizer)/GDP in agricultural sector that can explicate as comparison between importing production factor and revenue. Consequently, if production factor reduce then the revenue will increasing. According to production factor reducing was adopted as resources using, which interpreted as using inner resources or less dependence of outer resources.

3) Social aspect

Criteria of social factor can directly adopt from the application of SE in terms of land use, thus the acceptance of land use as the criteria. According to SE in national policy has been promulgated that part of attentions address in sustainability under globalization and the impact of changing. Sustainability is one of issue to achievement, and the framework for evaluating sustainable land management (FESLM) (Smyth and Dumanski, 1993) attempts to connect all aspects of land use under investigation with the interacting conditions of the natural environment, the economy, and socio-cultural and political life (Lefroy *et al.*, 2000). One of factors to consider in evaluating sustainable land management was land resources in terms of farm size (FAO, 1993), that was adopted as land holding size. From above that can concluded the effective indicator under SE as in Table 4.

Table 4 Factors, criteria and indicators of land use scale.

Factors	Criteria	Indicators
Environment	Soil properties	- Organic matter (OM)
		- Bulk density
		- Soil moisture
	Soil erosion	- Soil erosion in each of land use
	Vegetation	- Percentage of crown cover
		- Number of crown layers
		- Biomass
		- Species diversity

Table 4 (Continued)

Factors	Criteria	Indicators
Economy	Income	- Income distribution - Net Present Value
	Using resources	- Using worth resources and Using independent outer resources
Social	Land holding	- Land holding side in each of land use
	Acceptation	- Acceptation of land use

6.1.1 SE application in landscape scale and key performances

a) SE application in landscape scale

According to SE in national policy and SE application of land use scale, they were application in landscape scale that mean; priority to zoning and area-based management with regard to the geographical conditions and bearing capability of the ecosystem. Build up the borderline of conserved areas by making an agreement with the community in order to prevent any illegal intrusion for land expansion in the future. Appropriate and various cultivating to environmentally friendly is promote to agriculturists, which under the capability of nature, culture, quantity and category of economic activities, infrastructure and public services. Therefore, environmental aspect focuses on the capability of physical conditions and socio-economic aspect addressed in the capability of infrastructure and public services to promote their land use activities. According to conserved areas regard to the geographical conditions and bearing capability of the ecosystem, the regulations of related institutions are considered as criteria.

Moreover, criteria and indicator was investigated by subject of land suitability and evaluation land allocation from the related research based on; 1)

landscape level, 2) land suitability for agricultural activities, and 3) without a specific agricultural activities. Their conclusion factors, criteria and indicators are classified as Table 5. From above, SE in national policy, SE application in landscape scales and relevant researches were merged. There are three factors, five criteria and six indicators as Table 6.

Table 5 The indicators impact of landscape scale to sufficiency economy.

Factors	Criteria	Indicators	Sources of data	
Environment	Soil	- Soil depth	(1)(4)(6)(7)(8)(9)	
		- Soil texture	(1)(4)(5)(6)(7)(9)	
		- Soil drainage	(1)(3)(5)(6)(7)(8)(9)	
		- Soil fertility	(6)	
	Topography	- Slope	(1)(2)(6)(7)(8)	
		- Erosion status	(1)(3)(4)(5)(7)(9)	
		- Aspect	(4)	
		- Elevation	(4)	
	Water resources	- Water resource variability(type)	- Water resource	(1)(9)
			- Water resource utilization	(1)
			- Water resource hazards	(1)(5)
		problems	- Water resource quality	(1)
			- Water resource productivity	(1)
			- Water resources socio-economics	(1)
	Vegetation and land	- Vegetation type	(1)(4)	
- Percentage land cover		(1)(4)		
Cover	- Drought tolerance	(1)		
	- Fire risk	(1)		

Table 5 (Continued).

Factors	Criteria	Indicators	Sources of data
Environment	Climate	- Rainfall amount	(1)(3)(4)
		- Rainfall variability	(1)(3)
		- Aridity	(1)
		- Drought incidence	(1)(3)
		- Length of the growing period	(1)(3)
		- Agro-climatic zone	(1)(8)
		- Temperature	(4)(8)(9)
		- Land use type (LUT)	(1)(2)(5)
	Land management and improvement	- Land use intensity (LUI)	(1)(3)
		- Land improvement	(1)
		- Reservation/protection area	(6)
		- Environmental hazards	(1)(6)(7)(9)
	Environmental hazards	- Floods	(1)(6)(7)(9)
		- Landslides	(1)
		- Winds	(1)
		- Frost	(1)
		- Temperature extremes	(1)
		- Rainfall extremes	(1)
		- Hailstorms	(1)
		- Human and livestock diseases	(1)
- Crop pests and diseases		(1) (3)	
- Air and water pollution,		(1)	
Fire risk			

Table 5 (Continued)

Factors	Criteria	Indicators	Sources of data
Social	Socio-cultural acceptability	- Land tenure status	(1)
		- Land holding size	(1)
		- Existence of title deed	(1)(4)(5)
		- Access to extension services	(1)
		- Training on conservation	(1)(6)
		- Access to social amenities (schools, health facilities)	(1)(4)(5)(6)
		- Road links to major roads	(1)(5)
		- House hold size and type	(1)
		- Socio-cultural limitations and concerns (gender, taboos, etc)	(1)
		Economy	Economic viability
- Net farm income	(1)(3)(6)(9)		
- Off-farm income	(1)(3)		
- Farm labor availability	(1)(3)(6)		
- Percentage farm produce sold	(1)(3)(6)		
- Difference between market and farm-gate prices	(1)(3)		

Sources: (1) Ochola and Kerkides (2004), (2) Bagheri and Azmin (2010), (3) Rod *et.al.* (2000), (4) Jafaril and Zaredar (2010), (5) Steiner *et. al.* (2000), (6) Chuong (2008), (7) Martin and Saha (2009), (8) Verdoodt and Ranst (2006), (9) Saroinsong *et. al.* (2007)

Table 6 Factors, criteria and indicators of landscape scale.

Factors	Criteria	Indicators
Environment	Soil properties	Soil texture
	Topography	Slope
	Water resources	Distance to water resources
Social	Infrastructure and public services	Access to agricultural input
Related institutions	Land use policy	Watershed class
		Conservation area

b) Key performances

(1) Environmental aspect

i. Soil types

Soil types are difference characteristics, which consists of surface characteristics, organic matter, bulk density, soil color, soil pH and so on. Soil texture is one important characteristic of soil types. Soil texture can determination the rate of water drain, and also influences available of water to the plant. In addition, well drained soils typically have good soil aeration meaning that the soil contains air that is similar to atmospheric air, which is conducive to healthy root growth, and thus a healthy crop. Differences in soil texture also impacts organic matter levels. The cation exchange capacity of the soil increases with percentage clay and organic matter and the pH buffering capacity of a soil, is also largely based on clay and organic matter content (Berry *et al.*, 2007). Plante *et al.* (2006) examine how soil texture differentially alters the distribution of organic carbon within physically and chemically defined pools of unprotected and protected soil organic matter. They found whole-soil organic carbon concentration was positively related to silt plus clay content at both sites. Therefore soil texture is selected as indicator. The United States

Department of Agriculture: USDA (1987) has divided soil type classes as five levels through soil texture and percentage clay as in Table 7.

Table 7 Soil textural classification and ranking.

Texture	%clay	Soil types
Very coarse Coarse	<10%	Sand, Loamy sand
Moderately coarse	10-20%	Sandy loam
Medium		Loam, Silt loam, Silt
Moderate fine	20-13%	Sandy clay loam, Sandy clay, Silt clay, Clay
Fine	>30%	Heavy clay >60% clay

Source: USDA (1987)

ii. Slope classes

The slope classes were investigated in slope classes for cultivation from the relevant literature. Koulouri and Giourga (2007) conducted in land abandonment and slope gradient as key factor of soil erosion which concluded the slope gradient was steep (25%), soil erosion was increasing significantly. In addition, FAO (1990) said, the slope $< 7^\circ$ was flat to gently sloping. It was a broad base terrace or simple conservation treatments. Therefore, slope 1-6% is suitability for cultivation but slope $> 25\%$ is unsuitability for cultivation. Moreover the relevant literatures in land suitability for cultivation are defined as the same in watershed classification in Thailand (Bunruamkaew *et al.*, 2011; Ochola *et al.*, 2004).

iii. Distance to water resources

The USDA investigated in the riparian forest buffer that concluded the streamside forest can function as a sink when nutrients are taken up by plants and sequestered in plant tissue. The streamside forest is assimilated in tree growth which may be stored for extended periods of time in woody tissue and

possibly removed as logs or other forest products. The land after 95 ft or 28.95 meter from a river is a carefully managed for sediment, fertilizer and pesticides (USDA, 1997). In addition, Koppen *et al.* (2009) conducted in how water is involved in domestic and productive activities. The results show; the distance <50 meter is suitability for vegetable, < 200 meter is suitable for fruit trees and 250 meter – 1 kilometer is not suitable for productive uses.

iv. Watershed classes

Watershed classes (WSC) is divided in to 5 zones with the first (WSC1) and the second (WSC2) are preserved as protection and commercial forests respectively and the rests (WSC3-WSC5) belong to agricultural and other purposes with appropriate conservation (Tangtham, 1996) as Table 8.

Table 8 Watershed classes.

Watershed classes(WSC)	Detail
WSC 1A,1B	Protected or Conservation forest and headwater source.
WSC 2	Commercial forest: These areas are designed for protection and/or commercial forests where mining and logging will be allowed within legal boundaries.
WSC 3	Fruit-tree plantation: These areas cover uplands with steep slopes and less erosive landforms. Areas may be used for commercial forests, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures.
WSC 4	Upland farming: This class describes those areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for few soil conservation measures.

Table 8 (Continued)

Watershed classes(WSC)	Detail
WSC 5	Lowland farming: WSC 5 are gentle slopes or flat areas needed for paddy fields or other agricultural uses with few restrictions.

Source: Tangtham (1996)

v. Conservation area

The legal authority for Thailand's protected areas is the Wild Animals Reservation and Protection Act (WARPA) of 1960 and the National Park Act of 1961 (Arbhabhira *et al.*, 1988; Dixon and Sherman, 1990; Gray *et al.*, 1994). There are four main types of protected areas in Thailand: national park, wildlife sanctuary, non hunting area, and forest park. Other kinds of protected areas include botanical gardens, which are reserved for collecting and planting native and exotic rare and economically valuable plant species (Arbhabhira *et al.*, 1988; Panusittikorn, 2001).

(2) Socio-economic aspect

Capability of accessing to main road was the one of socio-economic factor. FAO (1983) investigated in the accessing to main road for cultivation area in rain-fed agriculture. The distance > 10 kilometer is high convenience and the distance > 30 is low convenience. In addition, Lefroy *et al* (2000) conducted in indicators for sustainable land management based on farmer surveys Vietnam, Indonesia, and Thailand that concluded in the distance accessing to main road, the distance < 5 kilometers is high convenience and the distance > 10 kilometers is low convenience.

MATERIALS AND METHODS

Materials

1. Topography map scale 1: 50,000 of Royal Thai Survey Department sheet number 5433 I, 5433 II and 5433 III in 1997
2. Land use map scale 1:50,000 the Land Development Department in 2010
3. Soil series map scale 1:50,000 in study site of Land Development Department in 2002
4. A watershed class map at a scale of 1:50,000 of the Natural Resources and Environmental Management Division in 2001
5. A National Park map at a scale of 1:50,000 of the Royal Forestry Department in 2004
6. Program Arc GIS version 9.3 and Microsoft office 2007
7. Computer notebook
8. Sample collection of soil properties; spatula, or knife and small paper bags.
9. Questionnaire
10. Structure interviewer

Methods

1. Study Area

The Huai Raeng-Klong Peed watershed was located as a part of Trat province, Eastern Thailand (Figure 5). Trat province, located in eastern Thailand and 315 km far from Bangkok, covers an area of 2,862.6 km² between latitudes 11°90' and 12°85' N and longitudes 102°15' and 103°10' E (OEPP, 2001). It is surrounded by Khlung district, Chantaburi province on the north and west, by Cambodia on the east, and by the Gulf of Thailand on the south. The upland is mainly composed of the mountainous ranges whose average peak is 400 –1,300m. These ranges are called Khao Banthat (Mt. Banthat) in Thai separating the border between Cambodia and Thailand. The small hills whose peak range from 80 to 280 m scatters around the lowland of Trat province (Osoguchi, 2002).

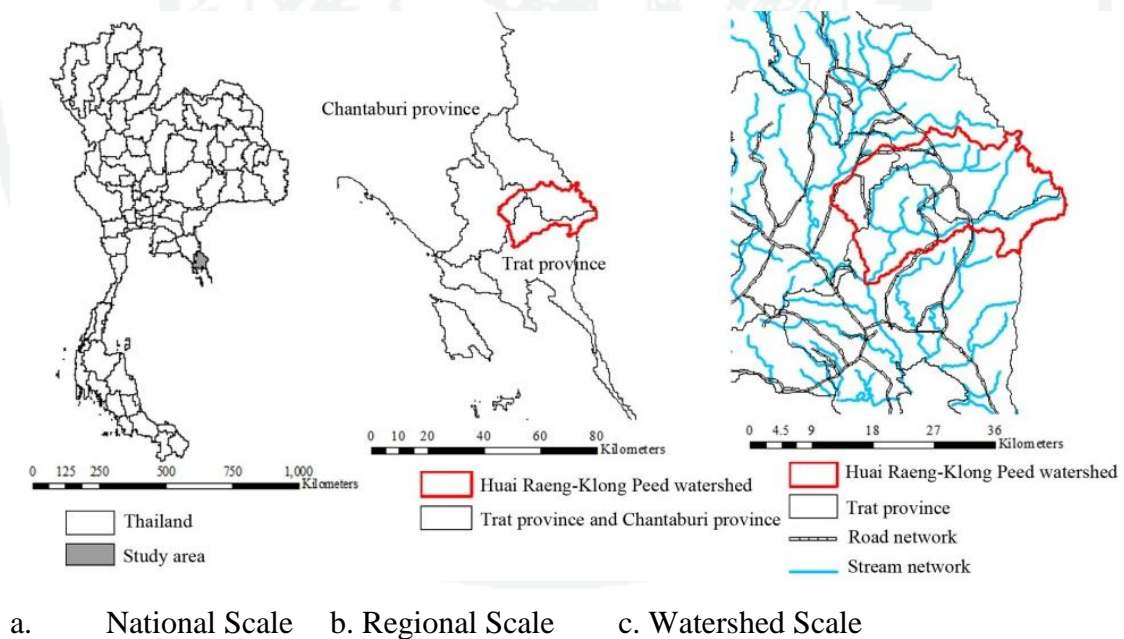


Figure 5 Study area in Huai Raeng-Klong Peed sub sub-watershed, Eastern Thailand.

1.1 Watershed boundary and Characteristics

Huai Raeng – Khlong Peed watershed is surrounded by north-eastern parts of Trat province, Eastern Thailand (Figure 5). The watershed area and perimeter is 447.5 km² and 119.9 km², respectively. The head of water is north-south longitudinal mountainous ranges called Mt. Banthat is separated the border of Cambodia and Thailand. The peak height of Mt. Banthat ranges from 620 to 1,250 m. The main streams in Huai Raeng – Khlong Peed watershed is Huai Raeng stream which flows in southwestward directions and Khlong Peed stream which flows in westward and southward directions. Two streams join at village, namely 7.8 km northeastward from the outlet. The outlet, 8m altitude at 102°30'E and 13°62'N, of Huai Raeng – Khlong Peed watershed joins the Khao Saming river and flows through the Trat river into the Gulf of Thailand. The stream pattern is dendric and the total stream length is 1,425.51 km (Osoguchi, 2000).

1.2 Topography

From the topographic data in Trat province (OEPP, 2001), the topography in the watershed was classified into three parts: longitudinal mountainous ranges scattered around the eastern part of watershed, lowland flat or gently sloping area scattered around the central and southern part of watershed and sloping area around 13 small hills whose peak height range from 130 to 250 m (Department of Land Development, 2000). The watershed area by slope class of 66% was flat slope (0-6%) as 295.4 km² followed by gentle slope (6-25%) 122.4 km² (27.35%) and steep to very steep slope (>25%), 29.7 km² (6.64%), respectively. The area by aspect class of the watershed area was equal each aspect. The most area was south-west aspect as 67.7 km² (15.13%) and the lowest was east aspect as 42.86 km² (9.59%). Other aspect were 61.86 km² (13.8%) for south-east and north-west, followed by 60.01 km² (13.41%) for west, 55.15 km² (12.32%) for south, 50.07 km² (11.19% for north and 47.95 km² (10.72%) for north-east, respectively (Department of Land Development, 2010).

1.3 Soil information

Soil in the watershed was mainly classified into Ultisol in terms of US soil taxonomy. The soil depth in the watershed was categorized into deep soil (100-150 cm) suitable for growing trees such as fruit trees and Para rubber (*Hevea brasiliensis*) plantation. In the watershed, 65.86% (294.76 km²) of the total area was mostly occupied well-drained area, whereas the area along the Khlong Peed stream and Mt. Tapon was poor drainage for 34.39 km² (7.68%) and the outlet of watershed was very poor drainage for 7.28 km² (1.62%) (Department of Land Development, 1999). The watershed area by soil group consist 2 groups; Upland soil group, 66.24% of the total area was well drained and fine-textured that occurs mostly on erosional surface uplands of udic soil moisture regime. It was suitable for orchard and tree plantation which was less water plants. Another kind of upland soil group was not for cultivation because it was on the steep; it was distributed 95.38 km² (21.31%). Another group was low land soil which distributed only 10.74% (48.04 km²), this group of soils was of poorly drained and flooding occasionally thus it was not for farm products orchard and tree plantation (Department of Land Development, 2002).

1.4 Climate information

The meteorological data in Huai Raeng – Khlong Peed watershed has only been recorded at Trat agroforestry research station since 1999, located in the southeastern border of the watershed. The recording data is maximum, minimum and average temperature, relative humidity (3 hour base) and rainfall amount (1 day base). The monthly average maximum, minimum temperature and relative humidity (1999-2012) ranged from 26.5 C^o in December to 29.2 C^o in April, and ranged from 86.4 % in January to 90.1 % in May, June and July, respectively. The annual average rainfall amount (1999-2012) varied 3,837 mm in 1999 to 3,153 mm in 2012.

1.5 Administration and Population

Huai Raeng – Khlong Peed watershed stretches over 3 sub-districts: Borai district composed of Danchumphon sub-district (tambon) (195.74 km² and 89.16 percentage in total sub-district area) and Nonthri sub-district (6.21 km² and 5.70 %), Muang Trat district composed of Takum sub-district (56.54 km² and 27.34 %) and Huai Raeng sub-district (136.26 km² and 90.15 %), and Noen Sai sub-district (3.75 km² and 6.25 %) and Khao Saming district composed of Wang Tha Khian sub-district (46.78 km² and 50.14 %) and Thung Nonthri sub-district (1.99 km² and 4.13 %) (Osoguchi, 2002). Sixteen villages are located inside the watershed area. The total estimated population and household in Huai Raeng – Khlong Peed watershed in 2013 was 25,539 people and 10,224 households (National Statistical Office, 2012).

1.6 Existing land use

Land use in 2010 in the study area was classified into 22 types. Natural forest/forest plantation was the major land use in the sub-watershed (35.16%). Rubber plantations were an important cultivated land area (26.05%). Grass/abandoned land, mixed fruit orchards, rubber and pine apple represented 9.45, 7.52 and 7.25 % respectively (Department of Land Development, 2010). Detail of land use types were shown in Table 9 and Figure 6. A comparison of the land use types in 1995, 1998, 2003 and 2007 using the spatial data showed that forest cover was the major land use on one-third of the watershed. However, the degradation of forest area decreased from 34.66% in 2003 to 31.18% in 2007. There has been a steady decline in fruit orchards and mixed fruit orchards since 1998. Rubber plantation have shown a distinct increase especially from 1995(14.35%) to 1998 (28.96%). Young rubber plantation which were mixed with pineapple were grown widely over a large area in 2007(7.92%) compared with previous years (Wachrinrat *et al.*, 2008).

Table 9 Land use types in 2010.

Rankin g	Types of land use	km²	ha	%
1	Natural forest/Reforestation	157.33	15,733.44	35.16
2	Rubber plantation	116.58	11,657.80	26.05
3	Grass/Abandoned land	42.30	4,229.58	9.45
4	Mixed fruit orchard	33.64	3,364.42	7.52
5	Rubber and pine apple	32.44	3,244.41	7.25
6	Reservoirs and water area	24.39	2,439.11	5.45
7	Fruit orchard	10.42	1,042.09	2.33
8	Oil palm	6.20	619.90	1.39
9	Animal husbandry	5.36	535.62	1.20
10	Rubber and fruit orchard	4.82	482.26	1.08
11	Residential, government office and factory	4.41	440.73	0.98
12	Paddy field	3.68	368.33	0.82
13	Pineapple	2.40	240.35	0.54
14	Residential and Mixed fruit	1.58	158.40	0.35
15	Tree plantation	0.51	51.37	0.11
16	Horticulture crop	0.38	38.35	0.09
17	Oil palm and orchard	0.28	27.64	0.06
18	Eagle Wood	0.27	27.20	0.06
19	Eagle Wood/Mixed orchard	0.21	20.67	0.05
20	Eagle Wood /Para rubber	0.15	14.98	0.03
21	Crop field	0.11	10.80	0.02
22	Rubber and crop field	0.03	2.74	0.01
	Total	447.50	44,750.19	100.00

Source: Department of Land Development (2010)

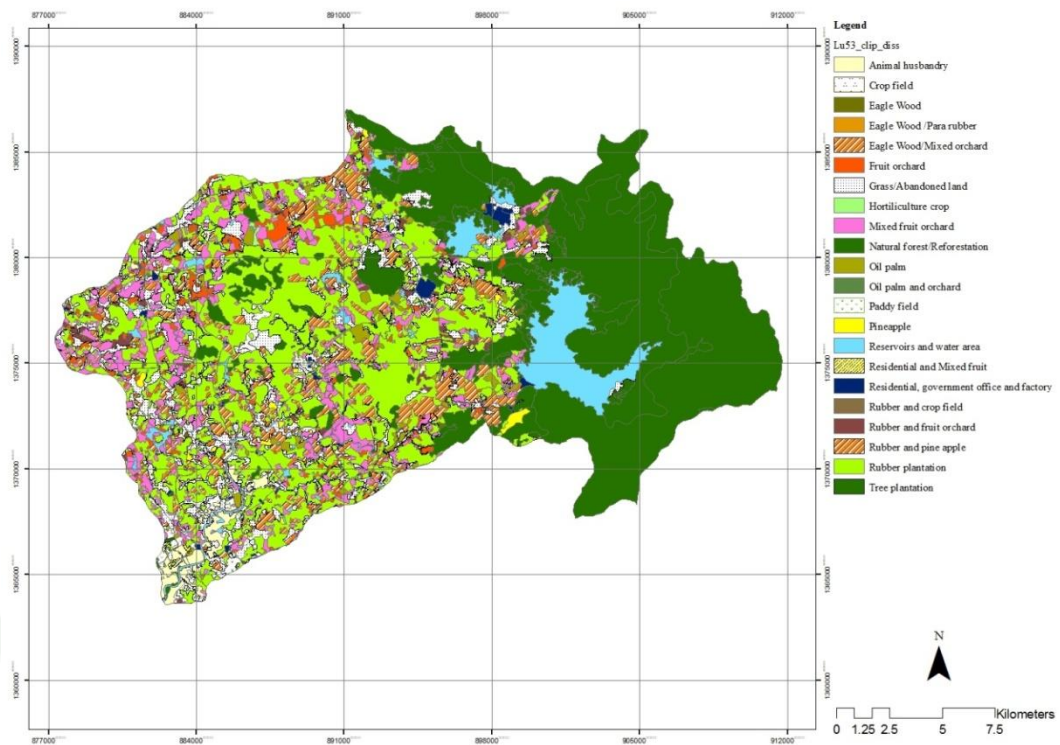


Figure 6 Land use types of Huai Raeng-Khlong Peed sub-watershed in 2010.

Source: Department of Land Development (2010)

2. Methodology

The goal in this research was to develop landscape agroforestry modeling under the SE. There were two parts to the investigation:

- 1) Development of agroforestry index classes through the classification of land use types under the sufficiency economy philosophy.

- 2) Development of landscape agroforestry index classes using the classification of landscape characteristics as a qualification for land use types under the sufficiency economy philosophy.

The land suitability methodology was the main process used in this research involving an AHP process as the content for MCDM methods. The pair-wise comparison method is a technique of the AHP and was chosen to determine the weighting criteria. A combination of the weighted values of factors and criteria, and the scores of indicators, were used to generate the land suitability maps by applying a GIS approach. The research methodology frame work is shown in Figure 8.

2.1 Defining a goal

Two components of the study involved defining the criteria and the indicators of key performance from a review of the literature and policy planning. The agroforestry indices (AFI) were defined by applying the sufficiency economy philosophy concept, the land quality concept and LADA indicator as in Table 4. In addition, the landscape agroforestry indices (LAFI) were defined by referring to relevant research in terms of the land suitability concept and land quality concept as in Table 6.

2.2 Decision and weighting factors, criteria and indicators

From indicator in Table 4 and 6 were established as quationair for the expertises (Appendices B). Estimation of each factor was based on a questionnaire to experts. The ratio method is a technique to estimate the weighting applied to each factor and a pair-wise comparison method was chosen to determine the weighting of each criterion. This method provides a matrix structure, where each criterion is compared with the other criteria that are relative to its importance, on a scale from 1 to 9. Then, a weighted matrix was calculated and used to derive a consistency ratio (CR) of the pair-wise comparison as in equation(12); if $CR > 0.10$, then some pair-wise values need to be reconsidered and the process is repeated until the desired value of $CR < 0.10$ is reached (Bodin and Gass, 2003).

The questionnaire (Appendix B) was used as a tool to estimate the weighting based on expertise. The expertise was detected from Council of the Dean of Agricultural Science, Thai Network for Agroforestry Education (ThaiNAFE), and related governmental institution in land use planning and sufficiency economy philosophy. Three categories of expertise were relevant to this research: agroforestry, agriculture and governmental institutions in terms of the land use planning policy aspect. Some questionnaires (62) were sent by mail, and 18 were delivered by hand with a breakdown of agriculture (22, 27.5%), the sufficiency economy aspect (38, 47.5%) and governmental institutions (20, 25%).

2.3 Model formulation

The model was generated from weighted linear combinations. The highest weighed value from the expertise was chosen. Their values were taken into weighted linear combinations to generate the model. The model consists of an agroforestry index equation and a landscape agroforestry index equation, with each equation weighted by values of AFI and LAFI, respectively. The equation is presented below:

$$S = \frac{\sum_{i=1}^n W_i R_i}{\sum_{i=1}^n W_i} \quad (13)$$

Where S = sum of overall cumulative suitability
 W_i = weighted value of each factor
 R_i = ranking score of each factor
 i = a factor number 1 to n.

2.4 Suitability classes

These processes were suitability classes which consist of classification of land use types under the sufficiency economy philosophy as called as agroforestry index classes (AFIC) and classification of landscape characteristics as a qualification

for land use types under the sufficiency economy philosophy as called as landscape agroforestry index classes (LAFIC).

AFIC was generated from the collected data in each indicator, then they were equally ranked using 5 levels; each level was taken as a representative value from the lowest (1) to the highest (5) as interval class value. Next, the collected data in each land use type were compared with the interval class value, and these collected data were used as representative values of each level. The complete process produced the AFIC of each land use types in study area under the SE.

And, the LAFIC was generated from secondary data map which consisted of six maps: soil type map, slope map, distance-to-water-resources map, watershed classes map, conservation area map and capability-of-access-to-main-road map. They were ranked using 5 levels; each level was taken as a representative value from the lowest (1) to the highest (5) as interval class value. The complete process produced the LAFIC of each indicator in study area under the SE. The data collection and calculation in each indicator was shown as following:

2.4.1 Agroforestry index classes (AFIC)

a) Data collection

Land use types were chosen based on a proportion of land use types in study area, and both of land use types based on woody perennial or agroforestry and nomocropping. The land use types chosen are listed in Table 10.

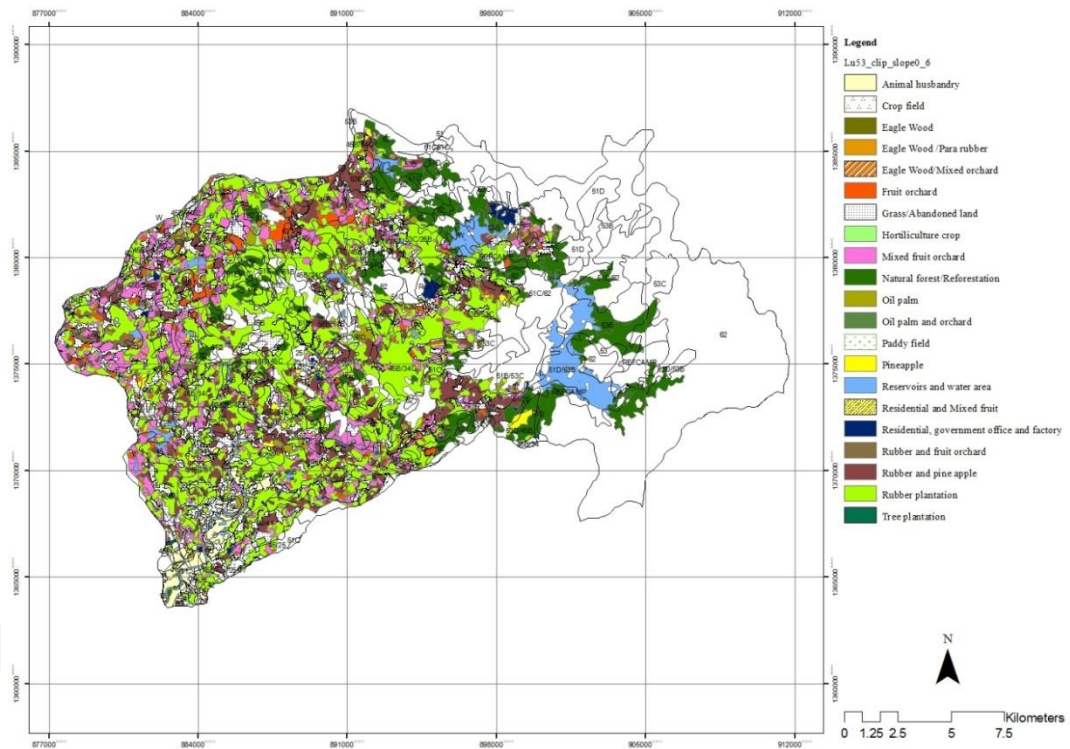
Table 10 Selected land use types of Huai Raeng-Klong Peed watershed in 2010.

No.	Land use type
1	Oil palm
2	Rubber plantation/fruit orchard
3	Rubber plantation

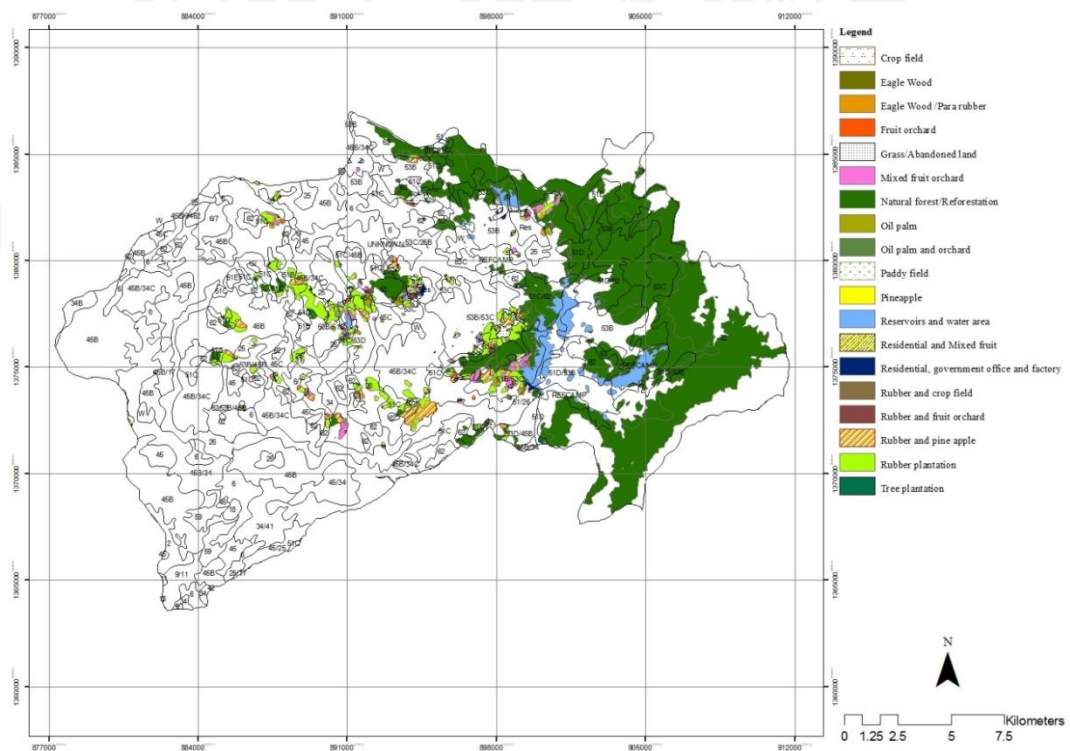
Table 10 (Continued)

No.	Land use type
4	Mixed fruit orchard
5	Eaglewood/para rubber
6	Home garden
7	Rambutan
8	Mangosteen
9	<i>Acacia mangium</i> plantation
10	Eaglewood

Next, selected land use types were sorted into two slope classes (0-6% and 6-25%) and into soil series by spatial matching analysis based on land use types map from 2010 as shown Figure 7. Land use types were analyzed using a completely randomized design. The land use type was considered as the treatment. Two sample plots of each land use type produced 20 sample plots, each sized 40 × 40 m. Each plot in study area was conducted in each indicator as following.



a. Land use types by soil types and slope class (0-6%)



b. Land use types by soil types and slope class (6-25%)

Figure 7 Site selection by soil series and slope class were sorted.

b) Data calculation

i. Soil properties

Organic matter (OM); soil samples were randomly collected from 3 points, with 2 samples at each point at soil depth 0-15 cm. and 15-30 cm. The collected data was conducted in laboratory of Department of silviculture, Faculty of Forestry, Kasetsart University.

ii. Soil erosion

The Revised Universal Soil Loss Equation (RUSLE) was produced as alternative models based on USLE style applicability and usability by Renard *et al.*, (1991). The soil loss in RUSLE is calculated, such that:

$$A = R.K.LS.CP \quad (14)$$

Where

- A = soil loss (ton/ha/yr)
- R = rainfall erosivity factor
- K = soil erodibility factor
- L = slope length factor
- S = slope-steepness
- C = crop management factor
- P = erosion control practice factor

R is rainfall erosivity factor, R factor in tropical rain forest climate, which consist of Chumporn uptil southes chantaburi and Trat (Srikajohn *et al.*, 1984) as shown in equation below,

$$R = 0.1 \quad (15)$$

Where R = rainfall erosivity factor
 X = mean amount rainfall in mm.

The rainfall data of meteorological stations of Thai Metrological Department in Trat province which was the rainfall data available ranging 30 years (1983-2013) were used to calculate the R-factor as 4,888.7 mm.

a. K factor

K factor is soil erodibility factor; the most widely used and frequently cited relationship is the soil erodibility nomograph (Wischmeier *et. al*, 1971). The nomograph Tew equation (Tew, 1999) for soil erodibility factor of peninsular Malaysia soil series (Appendix Figure 1) was applied from soil erodibility nomograph by Wischmeier (Table 11). The nomograph Tew equation was suitable for representing the soils % sand 0.10-2.00 mm. The nomograph comprises soil-profile parameters: percentage of clay, silt, very fine sand and sand passing (0.06-2 mm) sieve were extracted and the values of organic matter content (OM), class for soil structure (s) and soil permeability (p). A useful algebraic approximation as in equation of the nomograph is,

$$K = [1.0 \times 10^{-4} (12 - OM) M^{1.14} + 4.5(s - 3) + 8.0(p - 2)] / 100 \quad (16)$$

Where K = soil erodibility index in ton/ac (100 ft-tons in/ac.h).
 Division of the right side of this equation with 7.59 will yield K values expressed in SI units.
 OM = organic matter in percentage
 M = the product of the primary particle size fraction
 (% modified silt or the 0.002-0.1 mm size fraction)
 x (% silt + % sand)
 s = class for soil structure
 p = soil permeability

Table 11 K factor of each land use types in study area.

	Land use types	K factor
1	Oil palm	0.36
2	Rubber plantation/fruit orchard	0.39
3	Rubber plantation	0.38
4	Mixed fruits orchard	0.35
5	Eagle Wood /Para rubber	0.41
6	Home garden	0.30
7	Rambutan	0.27
8	Mangosteen	0.27
9	<i>Acacia mangium</i> plantation	0.34
10	Eagle Wood	0.36

Source: Modified from Tew (1999)

OM was investigated from collected data in each land use types. M was investigate from collected data in each land use types in the product of the primary particle size fraction (% modified silt or the 0.002-0.1 mm size fraction). Both OM and M was conducted in laboratory of Department of silviculture, Faculty of Forestry, Kasetsart University.

b. LS factor

LS factor is slope length and steepness factor, L is slope length factor, S is slope-steepness, which applied the equation defined by Wischmeier *et al.* (1978)

$$LS = (\lambda/22.13)^m(0.065 + 0.045s + 0.0065s^2) \quad (17)$$

Where LS= slope length and steepness factor

λ = slope length in meter

m = 0.2 for slope < 1%

0.3 for slope < 3%,

0.4 for slope < 5%,

0.5 for slope < 12%,

0.6 for slope >12%

s = slope steepness in percentage

Due to a sample plot sized 40 x 40 thus λ as 40 meters. The sample plot on two slope class consist 0-6% and 6-25% thus slope steepness in percentage(s) was average as 3 and 12.5%, respectively. The m value was representing as 0.5 due to the most slope steepness in percentage(s) <12%.

c. CP factor

C is crop management factor and P is erosion control practice factor. The CP factor can be replaced by vegetation management factor. Department of land development of Thailand have developed assessing to soil erosion prediction in CP factor (Appendices Table 1) and they were applied in each land use as shown in Table 10 (Thaikla and Thaikla, 2004).

Table 12 CP factor of each land use types in study area.

	Land use types	C	P	CP
1	Oil palm	0.60	0.80	0.48
2	Rubber plantation/fruit orchard	0.15	1.00	0.15
3	Rubber plantation	0.15	1.00	0.15
4	Mixed fruits orchard	0.23	1.00	0.23
5	Eagle Wood /Para rubber	0.15	1.00	0.15
6	Home garden	0.09	1.00	0.09

Table 12 (Continued)

	Land use types	C	P	CP
7	Rambutan	0.30	0.80	0.24
8	Mangosteen	0.30	0.80	0.24
9	<i>Acacia mangium</i> plantation	0.15	1.00	0.15
10	Eagle Wood	0.15	1.00	0.15

Source: Modified from Thaikla, P. and Thaikla, J. (2004)

iii. Vegetation

The vegetation criterion was investigated in mixed species index through species diversity; the most popular of the heterogeneity indices are those based on information theory. The expression for the information content per individual within an infinite population is given by the Shannon-Weaver formation (Peet, 2003). The Shannon index (H') was used as an index to measure the species abundance and richness as equation below,

$$H' = \sum_{i=1}^s p_i \ln p_i \quad (18)$$

Where s = Number of species

p_i = Relative cover of i^{th} species

iv. Income distribution, Resource using and Acceptance of land use

Questionnaire (Appendix C) was the tool for investigation in these indicator. The ordinal scale was represented as a value at one of five levels, from highest to lowest being 5 to 1, respectively.

v. Land holding size and Net Present Value

Structure interview was the tool for investigation in these indicator. The ratio scale was the representing value to investigate. Net present value (Appendix D) can investigate as equation,

$$(NPV) = \sum_{t=1}^n (B^t - C^t) / (1 + r)^t \quad (19)$$

Where B^t = Benefit in cost year t

C^t = Initial cost in year t

r = Discount rate

t = The year (1, 2, ..., n) and n is the number of periods.

Due to Bank of Thailand set bank rate of retail loads as 0.8 per year (Bank of Thailand, 2012) thus r was represented as 0.8 whilst t was represented as 25 years due to the most in period time of productivity.

c) Statistical Analysis

According to test the difference population medians among each indicator of land use types, the Kruskal-Wallis test was chosen to evaluate the population medians on a dependent variable which are the same distribution.

2.4.2 Landscape agroforestry index classes (LAFIC)

a) Data collection

Landscape agroforestry index consist soil types, slope, distance to water resources, conservation area and capability of accessing to main road. The landscape agroforestry map was conducted from secondary data from related institution. The LAFIC were developed from the secondary data map of governmental

institutions: a topography map at a scale of 1: 50,000 of the Royal Thai Survey Department, sheet numbers 5433 I, 5433 II and 5433 III in 1997; a soil type map at a scale of 1:50,000 of the Land Development Department in 2002; a watershed class map at a scale of 1:50,000 of the Natural Resources and Environmental Management Division in 2001; and a National Park map at a scale of 1:50,000 of the Royal Forestry Department in 2004.

b) Data calculation

The data in each indicator were equally ranked using 5 levels; each level was taken as a representative value from the lowest (1) to the highest (5). Each indicator was calculated as following,

To determine the suitable value classes were defined as the concept of land suitability of FAO. According to the FAO methodology (1976), this is strongly related to the land qualities. The suitability order defines and is expressed by:

(1) S (suitable), that characterizes a land where sustainable use giving good benefits is expected;

(2) N (not suitable) indicating a land which qualities do not allow the considered type of use, or are not enough for sustainable outcomes.

The classes (1, 2 and 3 for suitable order; 1 and 2 for unsuitable order) express the degrees of suitability or unsuitability. The representative value of LAFI was similar as AFI, which is ordinal scale from highest to lowest being 5 to 1, respectively. Thus, there are 5 classes and ranking score according to Table 13.

Table 13 Land suitability classes.

Order	Class	Description	Ranking
Suitable	S1 (Highly suitable)	Land having no, or insignificant limitations to the given type of use	5
	S2 (Moderately suitable)	Land having minor limitations to the given type of use	4
	S3 (Marginally suitable)	Land having moderate limitations to the given type of use	3
Not suitable	N1 (Currently not suitable)	Land having severe limitations that preclude the given type of use, but can be improved by specific management	2
	N2 (Permanently not suitable)	Land that have so severe limitations that are very difficult to be overcome	1

Source: Modified from FAO (1976)

i. Soil types

The United States Department of Agriculture: USDA (1987) has divided soil type classes as five levels through soil texture and percentage clay thus the ranking score was followed in Table 14.

Table 14 Soil textural classification and ranking.

Texture	%clay	Soil types	Ranking score
Very coarse Coarse	<10%	Sand, Loamy sand	1
Moderately coarse	10-20%	Sandy loam	3
Moderate		Loam, Silt loam, Silt	5
Moderately fine	20-13%	Sandy clay loam, Sandy clay, Silt clay, Clay	4
Fine	>30%	Heavy clay >60% clay	2

Source: Modified from USDA (1987)

i. Slope

From literature review and related research can conclude that slope 1-6% is suitability for cultivation but slope >25% is unsuitability for cultivation. In study area can and rank score into 5 levels as following in Table 15.

Table 15 Slope classification and ranking.

Slope classes	Characteristics	Ranking score
>60%	Unsuitability for cultivation	1
35-60%	Very steep	2
25-35%	Steep	3
6-25%	Gentle	4
<6%	Flat	5

Source: Modified from Bunruamkaew *et al.*(2011); Ochola *et al.*(2004)

ii. Distance to water resources

From literature review and related research can conclude that the distance <50 meter is suitability for vegetable, < 200 meter is suitable for fruit trees and 250 meter – 1 kilometer is not suitable for productive uses. In study area can divide and rank score into 5 levels as following in Table 16.

Table 16 Distance to water resources and ranking.

Distance to water resources	Description	Ranking score
<30 meter	Protected area for ecosystem	1
30-50 meter	Suitability area for vegetable	5
50-200 meter	Suitability area for fruit trees.	4
>200 meter	Unsuitability	2

iii. Watershed classes

In study area is divided watershed classes (WSC) into 5 zones and rank score into 5 levels as following in Table 17.

Table 17 Watershed classes and ranking.

Watershed classes(WSC)	Detail	Ranking score
WSC 1A,1B	Protected or Conservation forest and headwater source.	1
WSC 2	Commercial forest: These areas are designed for protection and/or commercial forests where mining and logging will be allowed within legal boundaries.	2

Table 17 (Continued)

Watershed classes(WSC)	Detail	Ranking score
WSC 3	Fruit-tree plantation: These areas cover uplands with steep slopes and less erosive landforms. Areas may be used for commercial forests, grazing, fruit trees, or certain agricultural crops with need for soil conservation measures.	3
WSC 4	Upland farming: This class describes those areas of gentle sloping lands suitable for row crops, fruit trees, and grazing with a moderate need for few soil conservation measures.	4
WSC 5	Lowland farming: WSC 5 are gentle slopes or flat areas needed for paddy fields or other agricultural uses with few restrictions.	5

Source: Modified from Tangtham (1996)

iv. Conservation area

The national park is one of conservation area as called as Khong-Keaw waterfall that has affected in the study area. Thus the area in national park has ranking score was 5 and the other area has ranking score was 1.

v. Capability of accessing to main road

Capability of accessing to main road emphasize in agricultural input and agricultural market. The minimal distance of a high convenience is <5 kilometer while in study area has highest distance 9.23 kilometers. Therefore the ranking score of the distance >5 kilometer was representative ranking score as 5. The

other distance was divided equal into 4 levels. There has ranking score 4, 3, 2 and 1, respectively.

2.5 Land suitability classes

The AFI in each land use were taken into the agroforestry index equation to produce AFIC in each land use. Next, the land use map of the Land Development Department in 2010 (Department of Land Development, 2010) was represented AFIC in each land use types to develop the AFIC map. The complete process produced the AFIC map of the land use types which indicated the level of land use type required to achieve SE.

The LAFI in each indicator were used in the landscape agroforestry index equation. The total of the equations was produced the LAFIC map. Map algebra application in ArcGIS 9.3 was used to develop the landscape agroforestry index classes map (LAFIC map) to produce land suitability classes which represented the classification of landscape characteristics for land use types under the SE.

2.6 Suitability of existing land use based on the LAFIC map

Suitability of existing land use based on the LAFIC map was established by spatial matching analysis application in ArcGIS 9.3 between the AFIC map and the LAFIC map. The zonal analysis method in ArcGIS 9.3 was used to determine the land use types under the land suitability or AFIC as appropriate for each LAFIC.

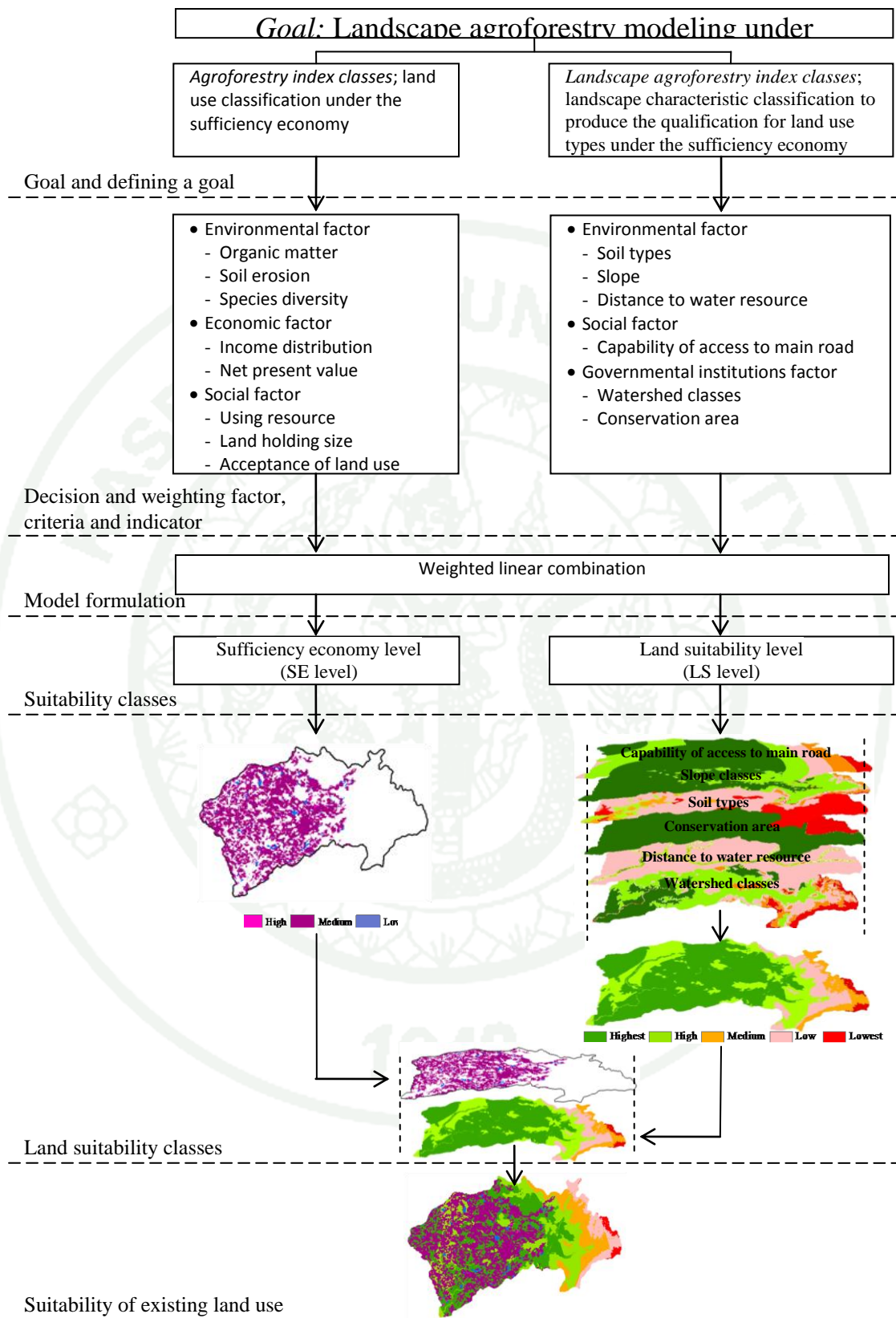


Figure 8 Research methodology frame work.

RESULTS AND DISCUSSION

The key performance indicators were weighted based on expert judgment (a period of time on 18, July to 31, August 2012) and used in the weighted linear combinations to develop the landscape agroforestry modeling based on an AFI equation and an LAFI equation. The site observation (a period of time on 1, October to 30, November 2012) data were used in the AFI equation to obtain the land use types based on the sufficiency economy level (SE level) and the ranked secondary data were then used in the LAFI equation to determine the land suitability level (LS level). The final step of this study analyzed the suitability of the existing land use based on the LAFIC map. The results showed as follows:

1. Key performances indicators of agroforestry under a sufficiency economy

Of the 80 questionnaires distributed, 58 (72.5%) were returned. The ratio method and pair-wise comparisons method were used to determine the AFI and LAFI as shown in Tables 18 and 19, respectively. The highest weighted value of the three soil properties and four vegetation classes, and the organic matter and species diversity were chosen as the indicators of their respective criteria. Weighted values of other criteria were used in the modeling. Thus, there were 8 and 6 key performance indicators of AFI and LAFI, respectively.

Table 18 Weighted value of agroforestry indices.

Weighted value of factors and criteria					
Environmental factor (CR = 0.066)		Economic factor (CR = 0.066)		Social factor (CR = 0)	
Weighted value of factor	10	Weighted value of factor	8	Weighted value of factor	10
Soil property	0.10	Income distribution	0.30	Land holding side	0.17
Soil erosion	0.69	Net farm income	0.09	Acceptance of land use	0.83
Vegetation	0.21	Resources using	0.61		

Table 18 (Continued)

Weighted value of indicator			
Indicators of vegetation (CR = 0.078)		Indicators of soil properties (CR = 0.066)	
Percentage of crown cover	0.06	Organic matter	0.69
Number of crown layers	0.15	Bulk density	0.10
Biomass	0.22	Soil moisture	0.21
Species diversity	0.57		

Table 19 Weighted value of landscape agroforestry indices.

Weighted value of factors and criteria					
Environmental factor (CR = 0.066)		Governmental institutions factor (CR = 0.066)		Social factor (CR = 0)	
Weighted value of factor	10	Weighted value of factor	7	Weighted value of factor	10
Soil properties	0.09	Watershed classes	0.83		
Topography	0.61	Conservation area	0.17		
Water resources	0.30				

2. Landscape agroforestry modeling for sufficiency economy

The weighed values of AFI (Table 18) and LAFI (Table 19) were determined using equation (13), to develop the AFI and LAFI equations in equations (20) and (21), respectively.

$$AFI = \frac{[10[(0.10R_{OM}) + (0.69R_{ERD}) + (0.21R_{MSI})] + [8[(0.30R_{ICD}) + (0.09R_{NPV}) + (0.61R_{RU})] + [10[(0.17R_{LHS}) + (0.83R_{ALL})]]}{28} \quad (20)$$

Where AFI = agroforestry indices
 R_{OM} = ranking of organic matter
 R_{ERO} = ranking of soil erosion
 R_{MSI} = ranking of mixed species index
 R_{ICD} = ranking of income distribution
 R_{NPV} = ranking of net present value
 R_{RU} = ranking of resource using
 R_{LHS} = ranking of land holding size
 R_{ALU} = ranking of acceptance of land use

$$LAFI = \frac{[[10[(0.09R_{SOT})+(0.61R_{SLP})+(0.30R_{DTW})]]]+[7[(0.83R_{WCL})+(0.17R_{CON})]]+[10R_{ACC}]}{27} \quad (21)$$

Where LAFI = landscape agroforestry indices
 R_{SOT} = ranking of soil types
 R_{SLP} = ranking of slope
 R_{DTW} = ranking of distance to water resources
 R_{WCL} = ranking of watershed classes
 R_{CON} = ranking of conservation area
 R_{ACC} = ranking of capability of accessing to main road

The agroforestry indices were divided into five classes using a class interval technique, to produce the agroforestry index classes and landscape agroforestry index classes shown in Tables 20 and 21, respectively. Each agroforestry index class contained a sufficiency economy level (SE level) and each landscape agroforestry index class contained a land suitability level (LS level) under based on the sufficiency economy approach.

Table 20 Agroforestry index classes.

Agroforestry index class (AFIC)	Agroforestry index (AFI)	Sufficiency economy (SE) level
1	4.2-5.0	Highest
2	3.4-4.2	High
3	2.6-3.4	Moderate
4	1.8-2.6	Low
5	1.0-1.8	Lowest

Table 21 Landscape agroforestry index classes.

Landscape Agroforestry index classes (LAFIC)	Landscape Agroforestry index (LAFI)	Land suitability (LS) level
1	4.2-5.0	Highest
2	3.4-4.2	High
3	2.6-3.4	Moderate
4	1.8-2.6	Low
5	1.0-1.8	Lowest

3. Agroforestry index classes of the study area

Key indicators which were used in the AFI were collected in the ten agroforestry land uses. The collected data were ranked and the representative values used as the ranking scores of AFI are shown in Table 22 and Table 23. In order to present the factors, the agroforestry indices were generated as three factors: environmental, socio-economic factor as shown in Tables 24, 25 and 26, respectively. The application of equation (20) produced the SE levels shown in Table 27 and in Figure 9.

3.1 Environmental factor

Although OM was not significant among the agroforestry land uses, this demonstration was able to explain the land use pattern related to OM, as land use change has a negative impact on the soil, especially the soil organic matter (Guimarães *et al.*, 2013; Neufeldt *et al.*, 2002), and OM is reduced by reduced physical protection or increased water erosion (Parras *et al.*, 2013; Fernandes *et al.*, 1997). The soil surface is the vital interface that receives much of the fertilizers and receives the intense impact of rainfall (Franzluebbers, 2002). Isicheia and Muoghalua (1992) stated that soils under tree canopies were found to have significantly higher levels of organic matter. This conclusion supports the results that the OM was slightly higher beneath the closed tree canopy than under the sparse tree canopy; the OM level was lower than 2% in mangosteen, rambutan, and oil palm. Several researchers have investigated the land use change effect on soil organic matter; OM quantity was analyzed by total organic C and N analysis (Glaser *et al.*, 2000) and compared with cultivated fields, with proportions of the soil organic carbon (SOC) of 50% and 30% were retained in the shrub cultivated field and tree cultivated field, respectively (Glaser *et al.*, 2000; Martens *et al.*, 2004). Murty *et al.* (2002) reviewed the literature to assess changes in soil C upon conversion of forests to agricultural and found that conversion led to an average loss of approximately 30% of soil C. Furthermore, the level of OM in different soil levels was investigated; on land converted into cultivated land, OM was significantly reduced in the surface soils (0–20 cm) by over 50% (Celik, 2005; Solomon *et al.*, 2002), whereas SOC stocks in the mineral soil (down to a depth of 60 cm) were lower in forest soil than in agricultural soils (John *et al.*, 2005). Consequently, the land conversion to cultivated land not only influenced the total SOC and N stocks in the soils and the SOM fractions, but also changed the chemistry of the SOM in the soil density fractions (John *et al.*, 2005; Helfrich *et al.*, 2006).

Soil erosion had no significant effect in the current study. Clearly, soil erosion is a complex process that depends on soil properties, ground slope, vegetation and the rainfall amount and intensity (Selby, 1993). A change in land use is widely

recognized as being capable of greatly accelerating soil erosion (Ursic *et al.*, 1965). Studies involving different environments agreed that the runoff and sediment yield decrease with an increase in soil cover by vegetation (Durán *et al.*, 2008; Francis *et al.*, 1990). These conclusions support the results that oil palm produced the highest soil erosion because it had the lowest crown cover. These results also confirmed the previous finding of Quinton *et al.* (2007) that the canopy cover showed a significant relationship with soil loss and runoff with the greatest reduction in soil loss taking place at canopy cover levels greater than 30%. Not only did the topographical effect dominate the overall regional erosion response but so also did land use conversion of forest to cultivated land. The conversion of forest to cultivated land with a soil loss $>100 \text{ Mg}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ was significant (Jose *et al.*, 2000). Often, this may be amplified by the conversion of arable land to forest on steeper slopes (Bakker *et al.*, 2008). However, soil erosion is likely to be more affected than runoff by changes in rainfall, though both are likely to be significantly impacted; the percentage of erosion and runoff will likely change more for each percentage of change in rainfall intensity; changes in ground cover have a much greater impact on both runoff and erosion than changes in canopy cover alone (Nearing *et al.*, 2005).

Only mixed species index (0.02, $P<0.05$) was significant. Clearly, the results showed that home gardens contained the highest mixed species index. These results confirmed a previous study (Niedrist *et al.*, 2009) that found the number of plant communities along with the number of species decreased constantly and significantly with increasing land use intensity and on abandoned land. Likewise, intensive commercial monocropping is likely to result in low species diversity (Tolera *et al.*, 2008) and reduced biodiversity (Rajendra *et al.*, 2010; Brookfield, 2001; Thrupp, 1998). Furthermore, species diversity influences soil microbial communities, as Mercirisa *et al.* (2006) and Gastinea *et al.* (2003) stated that the culturable soil microbial activity, substrates used and diversity declined with declining plant diversity and composition in grassland ecosystems.

Table 22 Ranking score of AFI in study area in terms of environmental factor.

Ranking score	Interval classes		
	Organic matter (%)	Soil erosion (ton.ha ⁻¹ .yr ⁻¹)	Mixed species index (H')
5	>4.34	<117.15	>1.232
4	3.70-4.34	117.15-179.10	0.924-1.232
3	3.06-3.70	179.10-241.04	0.616-0.924
2	2.43-3.06	241.04-302.99	0.309-0.616
1	<2.43	>302.99	<0.309

Table 23 AFI in terms of environmental factors in study area.

LU No.	Organic matter			Soil erosion			Mixed species index			Total value of environment
	(%) ^a	Ranking score ^b	Total value ^c	(ton.ha ⁻¹ .yr ⁻¹) ^a	Ranking score ^b	Total value ^c	Shannon index (H') ^a	Ranking score ^b	Total value ^c	
			(0.1)^d			(0.69)^d			(0.21)^d	(10)^d
1	1.78	1	0.1	364.94	1	0.69	0	1	0.21	10.0
2	2.31	1	0.1	121.47	4	2.76	0.655	3	0.63	34.9
3	2.41	1	0.1	119.52	4	2.76	0	1	0.21	30.7
4	2.74	2	0.2	164.82	4	2.76	0.693	3	0.63	35.9
5	3.32	3	0.3	128.97	4	2.76	0.691	3	0.63	36.9
6	2.05	1	0.1	55.21	5	3.45	1.505	5	1.05	46.0
7	1.97	1	0.1	133.70	4	2.76	0	1	0.21	30.7
8	1.85	1	0.1	133.26	4	2.76	0	1	0.21	30.7
9	4.98	5	0.5	105.87	5	3.45	0	1	0.21	41.6
10	2.81	2	0.2	113.80	5	3.45	0	1	0.21	38.6
Pvalue	0.42 ^{NS}			0.16 ^{NS}			0.02*			

^a = collected data, ^b = ranking score, ^c = weighed value multiplied by the ranking score, ^d = weighted value. Values within a column followed by the same letter are not significantly different ($P < 0.05$, Kruskal Wallis Test). * = significant at 0.05 level of probability, ^{NS} = not significant at 0.05 level of probability.

The home garden produced the lowest level of soil erosion but contained the highest mixed species index. Furthermore, the oil palm produced the highest soil erosion but had the lowest level of soil organic matter and contained the lowest species diversity. Consequently, home garden had the highest SE level while oil palm had the lowest SE level. Most of the tree-based cultivation systems produced high SE levels—namely, *Acacia mangium* plantation, eaglewood, eaglewood/para rubber, mixed fruit orchard and rubber plantation/fruit orchard. Land uses in the low SE level were not identified in the study area.

3.2 Socio-economic factor

Only one indicator in terms of socio-economic factor was income distribution (0.04, $P < 0.05$) as significant. Income distribution was examined with stable profitability of each land use during in 2007-2012; Oil palm, Englewood/Para rubber, Home garden and engle wood were higher level than others. These results conformed agricultural product trade in similar during time; oil palm price had slightly higher as oil crop price of the world, whilst Para rubber price had been decreased in 2012 because of European and American crises, tsunami in Japan on March and disaster in Thailand in 2012 had been impacted in automotive manufacturing and related manufacturing (Bank of Thailand, 2013). In the other hand, trade price of fruit product in 2007-2012 was fluctuated, and price decreasing in 2012 (Office of Agricultural economics, 2013). Although, home garden consists mixed fruit orchard but contained high income distribution because it is consumer goods and can sale in each season. Income distribution was shown consistency with acceptance of land use; when agricultural product trade price higher that acceptance of land use may be follow with the price of product trade. The results was shown mangosteen, rambutan and *Acacia mangium* plantation were lower than others that demonstrated fruit orchard, especially, mono-cropping trend to be lower acceptance of land use than mixed fruit orchard.

Comparison results of the same area study of Punapaipong (2004) research were found mixed fruit orchard and Para rubber as 91,834.86 and 8,916.99 baht/25 rai,

respectively, that results showed mixed fruit orchard had higher NPV than Para rubber, which was differenced in this research that NPV of mixed fruit orchard lower than Para rubber. These results were differenced with a previous study (Sofiyuddin *et al.*, 2012) that found all land-use systems showed positive profit-ability, with oil palm having the higher profitability. Important criterion was impact to NPV may be dominated by other capital budgeting criteria, like the internal rate of return and the profitability index (Berkovitch and Israel, 2004).

Only home garden had land holding size smaller than others and the size lower than 1 rai (1,600 m²). Mostly other land use has small farm size as below 10 rai. Although, large farm size is associated with greater wealth and increased availability of capital, which make investment in conservation more feasible (Norris and Batie, 1987), but small farms characterize agriculture in Asia play an important role for food security and poverty alleviation. The small farms present higher land productivity than large farms (Fan and Chan-Kang, 2005). In addition, small farmers have advantages in labor supervision because they rely mostly on family labor. This line of argument suggests that any type of land reform that reduces the inequality of landholdings will have a positive effect on productivity (Eswaran and Kotwal, 1986).

Resource using; it was self-reliance that was examined in degree of dependency from external inputs. Self-reliance is a part of the pillars for conducting the evaluation of sustainability (Smith and Dumanski, 1994). The high dependency on external inputs, such as inorganic fertilizers, pesticides, diesel, and irrigation water, increases farmers' vulnerability to reduced profit (Rasul and Thapa, 2003). The results in study area were found the degree of dependency from external inputs that Engle wood and Para rubber, *Acacia mangium* plantation and Eagle Wood had higher degree than others. In point of fact that each land use has difference system production and harvest. These results was shown the long term harvest of land use trend to dependency external inputs lower than short term harvest.

Table 24 Ranking score of AFI in study area in terms of socio-economic factor.

Ranking score	Interval classes				
	Income distribution	Net present value	Resource using	Land holding size	Acceptance of land use
	(score)	(baht.yr ⁻¹)	(score)	(ha ⁻¹)	(score)
5	4.2-5.0	>10,917	>20	>6.8	4.2-5.0
4	3.4-4.2	8,388-10,917	15-20	5.2-6.8	3.4-4.2
3	2.6-3.4	5,858-8,388	10-15	3.6-5.2	2.6-3.4
2	1.8-2.6	3,328-5,858	5-10	2.0-3.6	1.8-2.6
1	1.0-1.8	<3,328	<5	<2.0	1.0-1.8

Table 25 AFI in terms of economic factors in study area.

LU No.	Income distribution			Net present value			Resource using			Total value of economy
	Score ^a	Ranking score ^b	Total value ^c	Baht. yr ⁻¹ ^a	Ranking score ^b	Total value ^c	Score ^a	Ranking score ^b	Total value ^c	
			(0.3) ^d			(0.09) ^d			(0.61) ^d	
1	4	4	1.2	2,424.1	1	0.09	8.0	2	1.22	20.08
2	3	3	0.9	9,567.1	4	0.36	7.5	2	1.22	19.84
3	3	3	0.9	5,706.4	2	0.18	10.0	2	1.22	18.40
4	3	3	0.9	1,676.6	1	0.09	9.0	2	1.22	17.68
5	4	4	1.2	13,447.3	5	0.45	12.0	3	1.83	27.84
6	4	4	1.2	1,787.7	1	0.09	9.5	2	1.22	20.08
7	3	3	0.9	797.9	1	0.09	10.0	2	1.22	17.68
8	3	3	0.9	1,448.3	1	0.09	8.5	2	1.22	17.68
9	3	3	0.9	7,550.1	3	0.27	13.5	3	1.83	24.00
10	4	4	1.2	13,403.4	5	0.45	11.5	3	1.83	27.84
P-value	0.04*			0.60 ^{NS}			0.43 ^{NS}			

^a = collected data, ^b = ranking score, ^c = weighed value multiplied by the ranking score, ^d = weighted value. Values within a column followed by the same letter are not significantly different ($P < 0.05$, Kruskal Wallis Test). * = significant at 0.05 level of probability, ^{NS} = not significant at 0.05 level of probability.

Table 26 AFI in terms of social factor in study area.

LU No.	Land holding size		Acceptance of land use			Total value of (10) ^d	
	(ha ⁻¹) ^a	Ranking score ^b	Total value ^c (0.17) ^d	Score ^a	Ranking score ^b		Total value ^c (0.83) ^d
1	5.2	3	0.51	4	4	3.32	38.30
2	0.4	5	0.85	4	4	3.32	34.90
3	6.6	2	0.34	5	5	4.15	46.60
4	4.2	3	0.51	4	4	3.32	36.60
5	1.7	5	0.85	4	4	3.32	34.90
6	0.4	5	0.85	4.5	5	3.74	50.00
7	4.6	3	0.51	3.5	4	2.91	38.30
8	4.7	3	0.51	3.5	4	2.91	38.30
9	5.2	3	0.51	3	3	2.49	30.00
10	8.4	1	0.17	5	5	4.15	43.20
P	0.41 ^N			0.16 ^{NS}			

^a = collected data, ^b = ranking score, ^c = weighed value multiplied by the ranking score, ^d = weighted value. Values within a column followed by the same letter are not significantly different ($P < 0.05$, Kruskal Wallis Test). * = significant at 0.05 level of probability, ^{NS} = not significant at 0.05 level of probability.

3.3 Sufficiency economy level

The total values of each factor indicated that the home garden had the highest value in terms of environmental and social factors, because it produced the lowest soil erosion and the highest acceptance of land use. Englewood/para rubber and Englewood had the highest values of AFI in terms of the economic factors. Most of the fruit-based cultivation produced the lowest value in terms of economic factors such as mixed fruit orchard, rambutan and mangosteen. Due to, the trade price of fruit product in 2007-2012 was fluctuated and price decreasing in 2012 (Office of Agricultural economics, 2013). Moreover, the agricultural sector needs to increase production through increase the agricultural labor force and utilize farm resources more intensively (Jitsanguan, 2001) which were shown high using resources. Due to

oil palm was substantial biodiversity losses (Emily *et al.*, 2008) and oil palm has caused resulting in significant secondary external impacts such as soil erosion (Obidzinski *et al.*, 2012). That conclusion supports the results that oil palm obtained the lowest value in terms of environmental factors. The total weighed value of the environmental, economic and social factors produced the SE level; the high SE level land uses included home garden followed by eaglewood and eaglewood/para rubber, respectively. At the moderate SE level was para rubber/fruit orchard followed by *Acacia mangium* plantation, para rubber plantation, mixed fruit orchard, rambutan and mangosteen, respectively. Oil palm had a low SE level. Land uses in the highest and the lowest SE levels were not identified in the study area.

A total of 95.2% (160.03 km²) was graded at the moderate SE level followed by the low SE level (3.29%, 5.52 km²), the high SE level (1.51%, 2.54 km²), respectively. Most of the land use types were distributed on the gentle slopes in the middle and on the western side of the watershed as most characteristics of the study area were associated with a gentle slope and they did not relate to critical land for cultivation.

Table 27 Sufficiency economy level in study area.

Land use type	Total weight value	Agroforestry index (AFI)	Agroforestry index class (AFIC)	Sufficiency economy level (SE level)
Oil Palm	68.38	2.44	4	Low
Para rubber /fruit orchard	96.44	3.44	3	Moderate
Para rubber plantation	94.00	3.36	3	Moderate
Mixed fruit orchard	91.88	3.28	3	Moderate
Rambutan	86.68	3.10	3	Moderate
Mangosteen	86.68	3.10	3	Moderate
<i>A. mangium</i> plantation	95.60	3.41	3	Moderate
Eaglewood /Para rubber	106.44	3.80	2	High
Home garden	116.08	4.15	2	High
Eaglewood	109.64	3.92	2	High

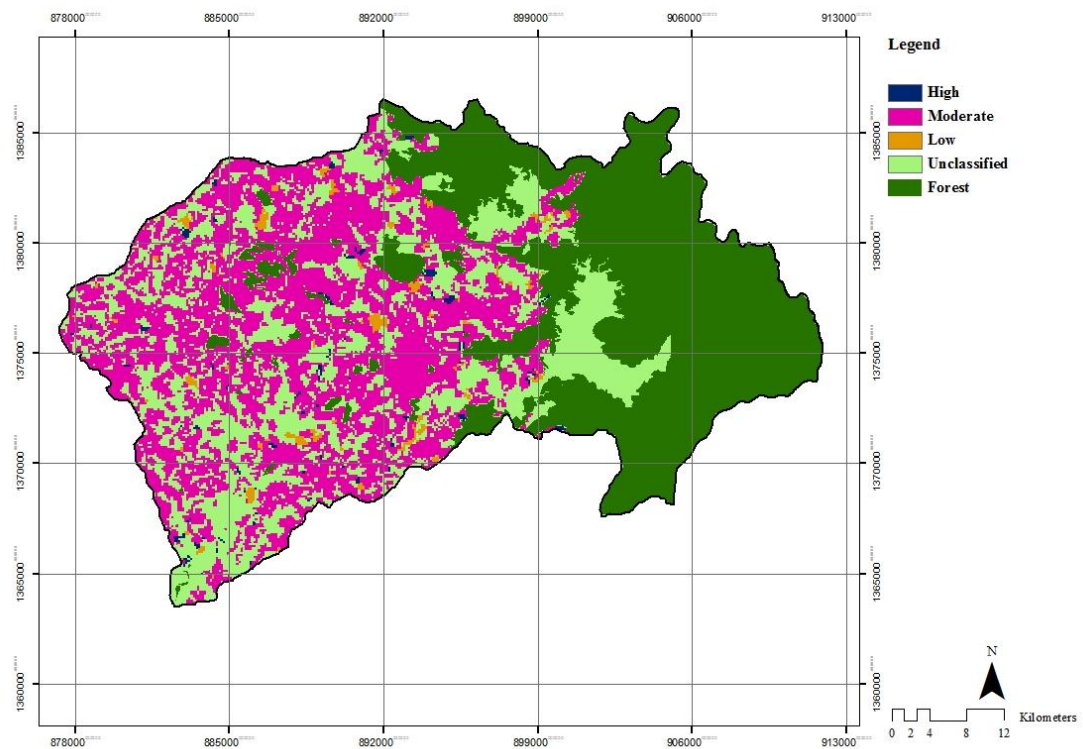


Figure 9 Sufficiency economy level of existing land use in the study area.

4. Landscape agroforestry index classes of the study area

Key indicators which were used in the LAFI were conducted in the five LAFI map; soil type map, slope map, distance-to-water-resource map, watershed class map, conservation area map and capability-of-accessing-to-main-road map as shown in Table 28. In order to present the factors, the landscape agroforestry indices were generated as three factors: environmental, governmental institutions and social factor as below.

Table 28 Ranking score of LAFI in study area.

Land suitability Class	S1 (Highly suitable)	S2 (Moderately suitable)	S3 (Marginally suitable)	N1 (Currently not suitable)	N2 (Permanently not suitable)
Ranking score	5	4	3	2	1
Soil properties:	Moderate	Moderately	Moderately	Fine	Very coarse and
Soil texture		fine	coarse		Coarse
Topography: slope classes (%)	<6	6-25	25-35	35-50	>60
Water resources: distance to water resources (m.)	30-50	50-200	-	>200	<30
Watershed classes (WSC)	5	4	3	2	1A,1B
Conservation area	Other land				National Park
Capability of accessing to main road (km)	<5	5-7.5	7.5-10	10-12.5	>12.5

Ranking score was modified as relevant from Arbhahirama *et al.* (1988); FAO (1983); Rod *et al.* (2000); Bunruamkaew *et al.* (2011); Ochola *et al.* (2004); USDA (1987); Koppen *et al.* (2009); Tangtham (1996)

4.1 Environmental factor

There consist of three maps in environmental factor as shown in Figure 10, 11, 12 and in Tables 29. LAFIC map in terms of environmental factor were shown in study area in each indicator; the most soil texture indicator was distributed in marginally suitable (284.96 km², 63.68%). The most slope classes indicator was distributed in highly suitable (295.40 km², 65.94%) whist, the most distance to water resources indicator was distributed in currently not suitable (385.08km², 32.02%). The most of all environmental factors was distributed in currently not suitable (32.02%) followed by highly suitable, marginally suitable, moderately suitable and permanently not suitable (22.51%, 22.46%, 14.03%, 8.98%), respectively.

Table 29 Area of each ranking score of LAFI in terms of environmental factor in study area.

LAFIC		Area (km ²)				
		(% of total area)				
		Ranking score				
		5	4	3	2	1
Soil texture	area(km ²)	2.01	15.05	284.96	32.11	113.38
	(%)	(0.45)	(3.36)	(63.68)	(7.18)	(25.34)
Slope classes	area(km ²)	295.40	122.40	16.60	12.60	0.50
	(%)	(65.94)	(27.32)	(3.71)	(2.81)	(0.11)
Distance to water resources	area(km ²)	4.80	50.90	-	385.08	6.72
	(%)	(1.07)	(11.37)	-	(86.05)	(1.50)
Total	area(km²)	302.21	188.35	301.56	429.79	120.6
	(%)	(22.51)	(14.03)	(22.46)	(32.02)	(8.98)

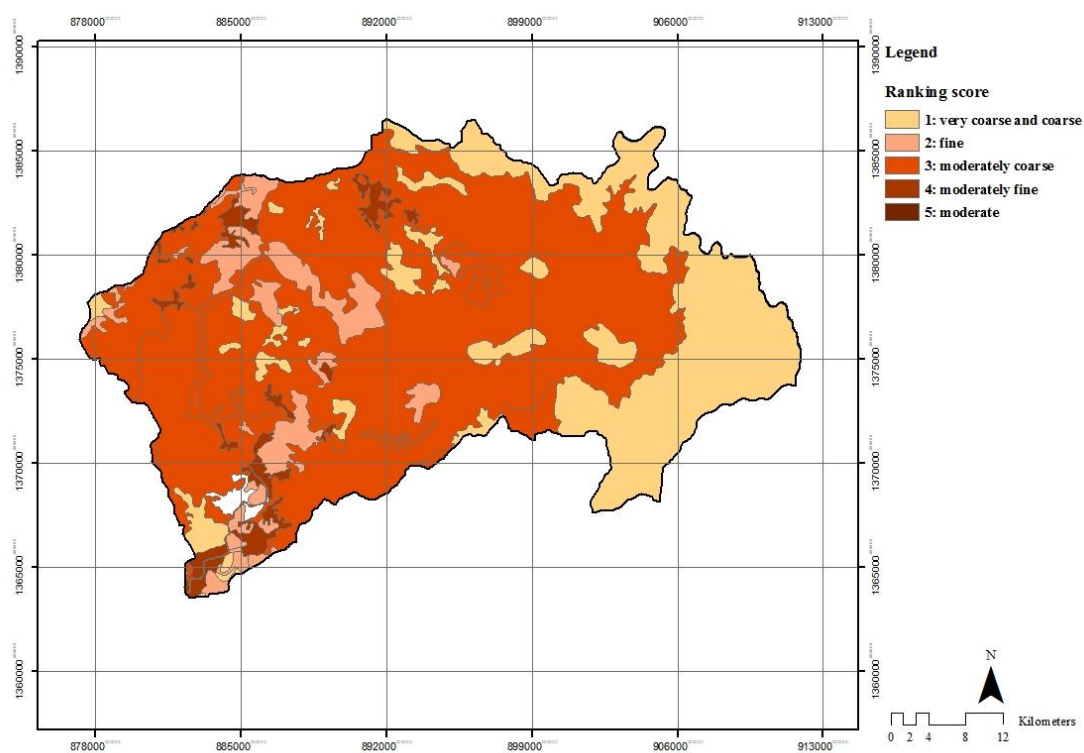


Figure 10 Ranked score of soil texture map in study area.

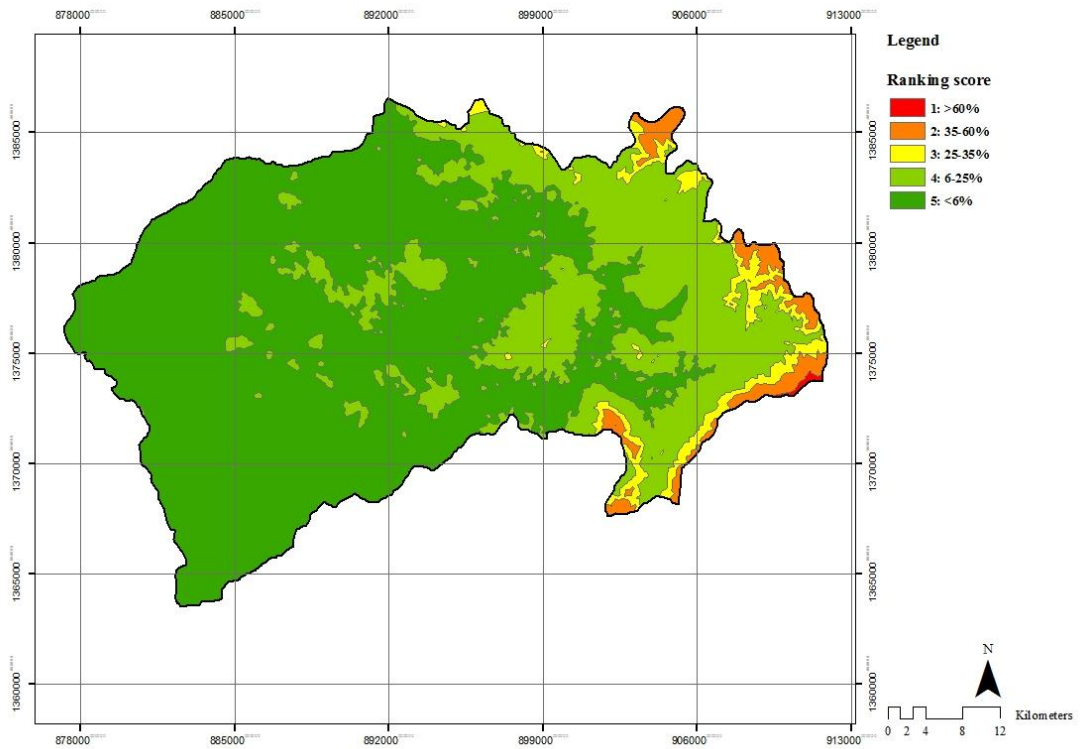


Figure 11 Ranked score of slope classes map in study area.

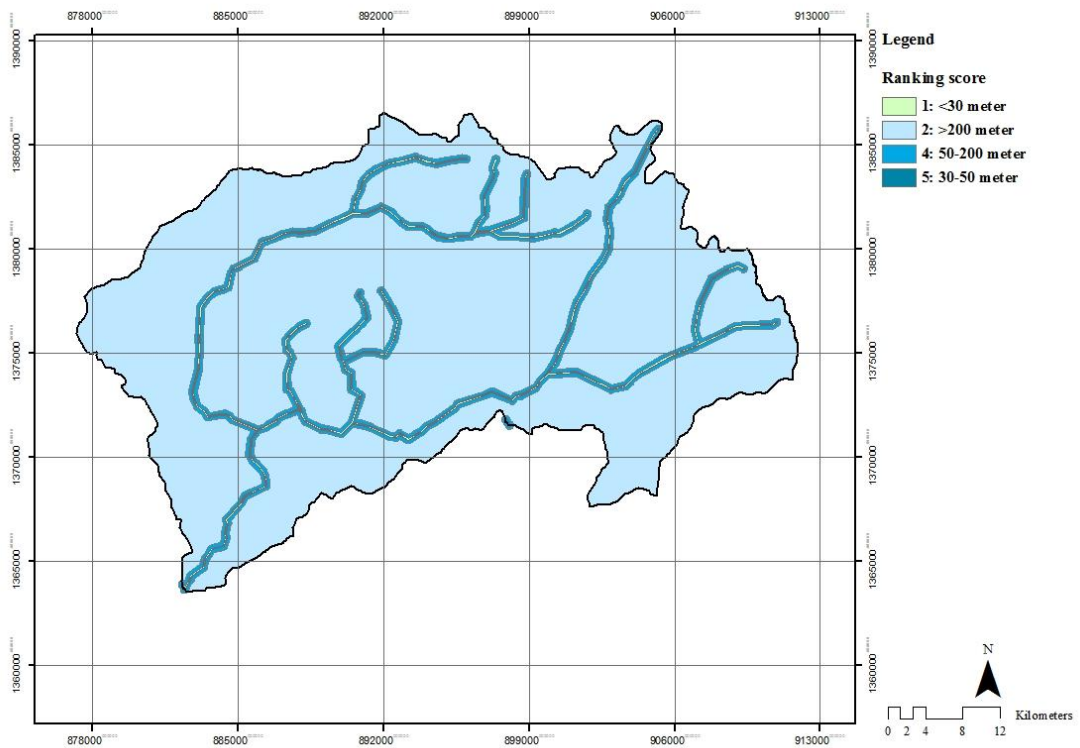


Figure 12 Ranked score of distance to water resources map in study area.

4.2 Governmental institutions and social factor

There consist of three maps in environmental factor as shown in Figure 13, 14, 15 and in Tables 30. LAFIC map in terms of governmental institutions and social factor were shown in study area in each indicator; the most watershed classes indicator was distributed in moderately suitable (209.80km², 46.88%). The most conservation area indicator was distributed in highly suitable (412.50km², 92.18%), which was the same as capability of accessing to main road indicator (261.91km², 58.53%). The most of all governmental institutions and social factor was distributed in highly suitable (59.15%) followed by moderately suitable, marginally suitable, permanently not suitable and currently not suitable (23.6%, 6.87%, 5.24%, 5.14%), respectively.

Table 30 Area of each ranking score of LAFI in terms of governmental institutions and social factor in study area.

LAFIC		Area (km ²)				
		(% of total area)				
		Ranking score				
		5	4	3	2	1
Watershed classes	area(km ²)	118.62	209.80	53.95	38.67	24.68
	(%)	(26.51)	(46.88)	(12.06)	(8.64)	(5.51)
Conservation area	area(km ²)	412.50	-	-	-	35.00
	(%)	(92.18)	-	-	-	(7.82)
Capability of accessing to main road	area(km ²)	261.91	106.60	38.10	30.23	10.67
	(%)	(58.53)	(23.82)	(8.51)	(6.76)	(2.38)
Total	area(km²)	793.03	316.4	92.05	68.9	70.35
	(%)	(59.15)	(23.6)	(6.87)	(5.14)	(5.24)

Remarks: Watershed classes was unclassified as water area (1.78 km², 0.40%)

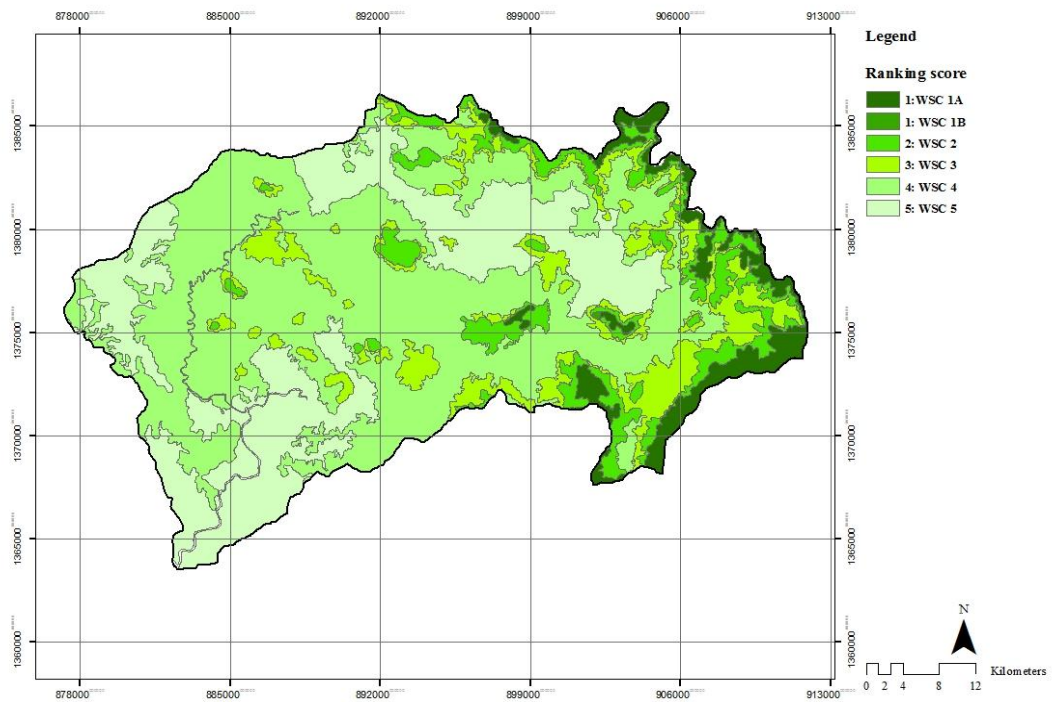


Figure 13 Ranked score of watershed classes map in study area.

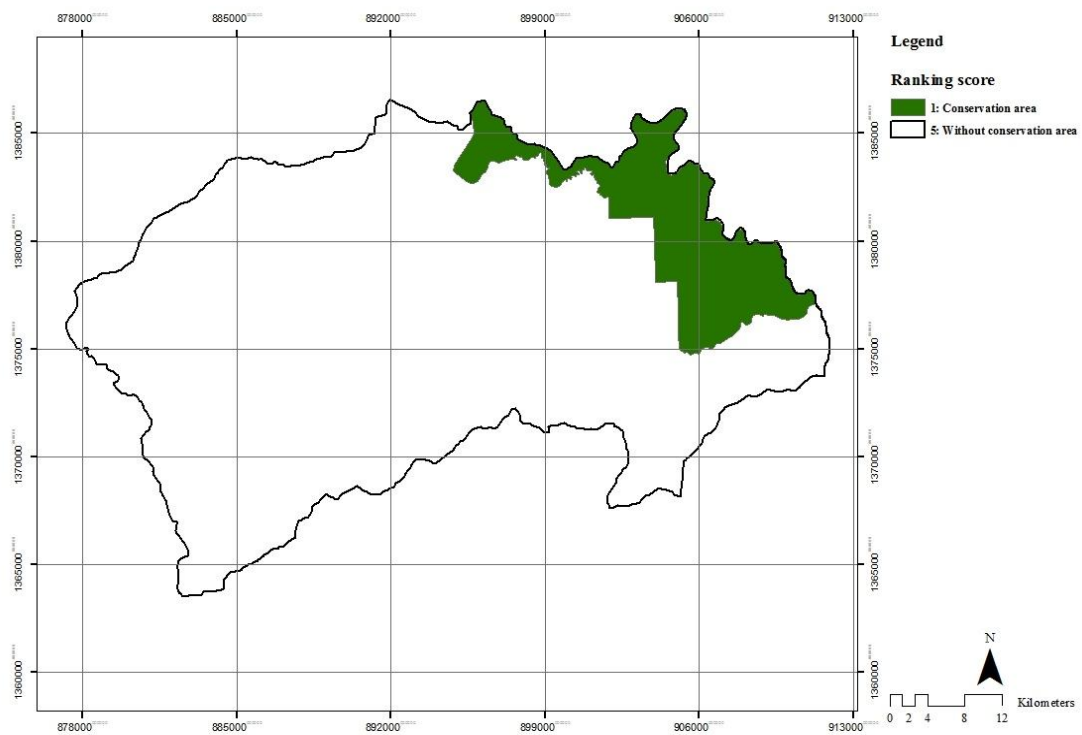


Figure 14 Ranked score of conservation area map in study area.

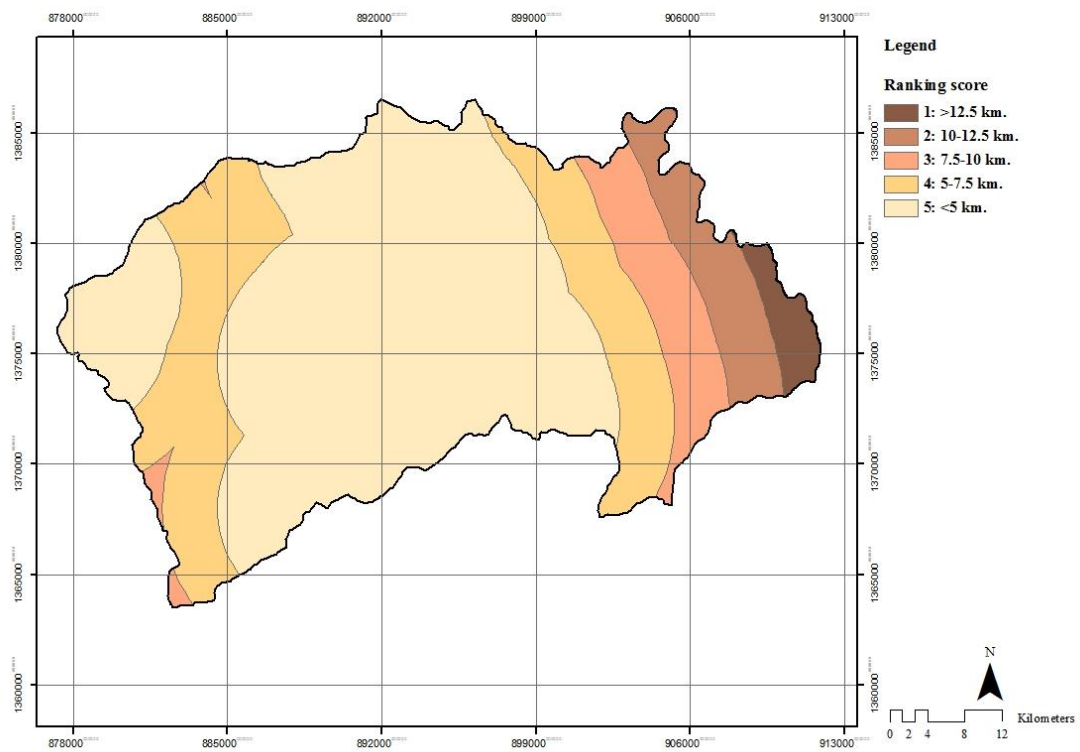
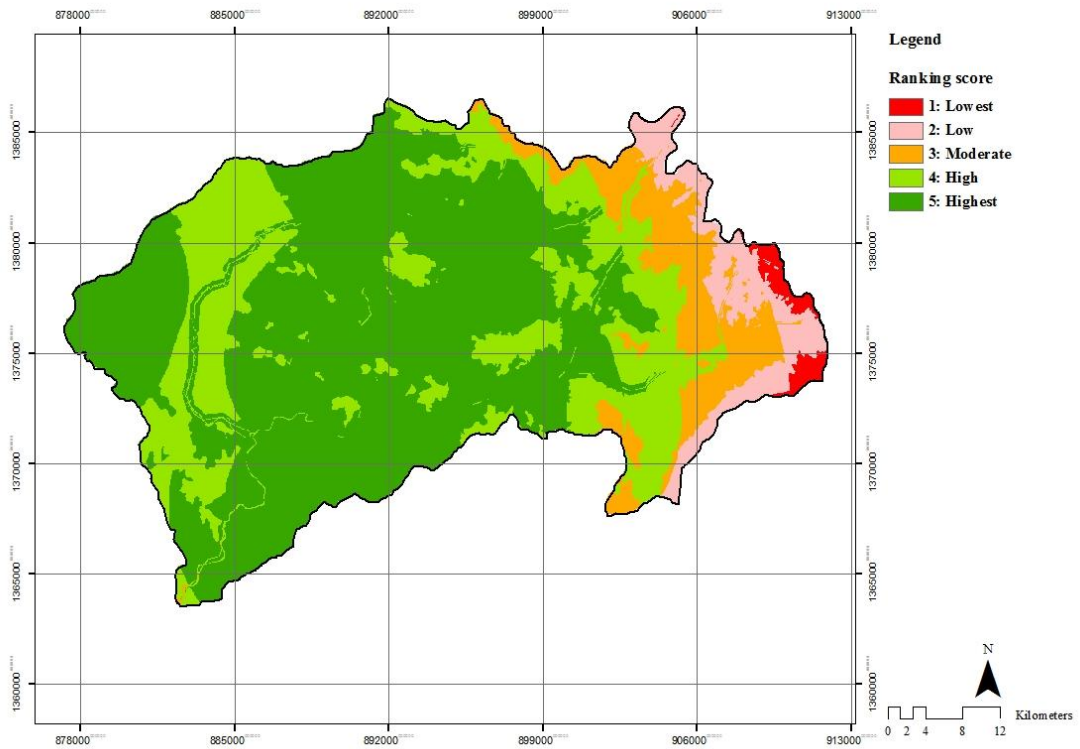


Figure 15 Ranked score of capability of accessing to main road map in study area.

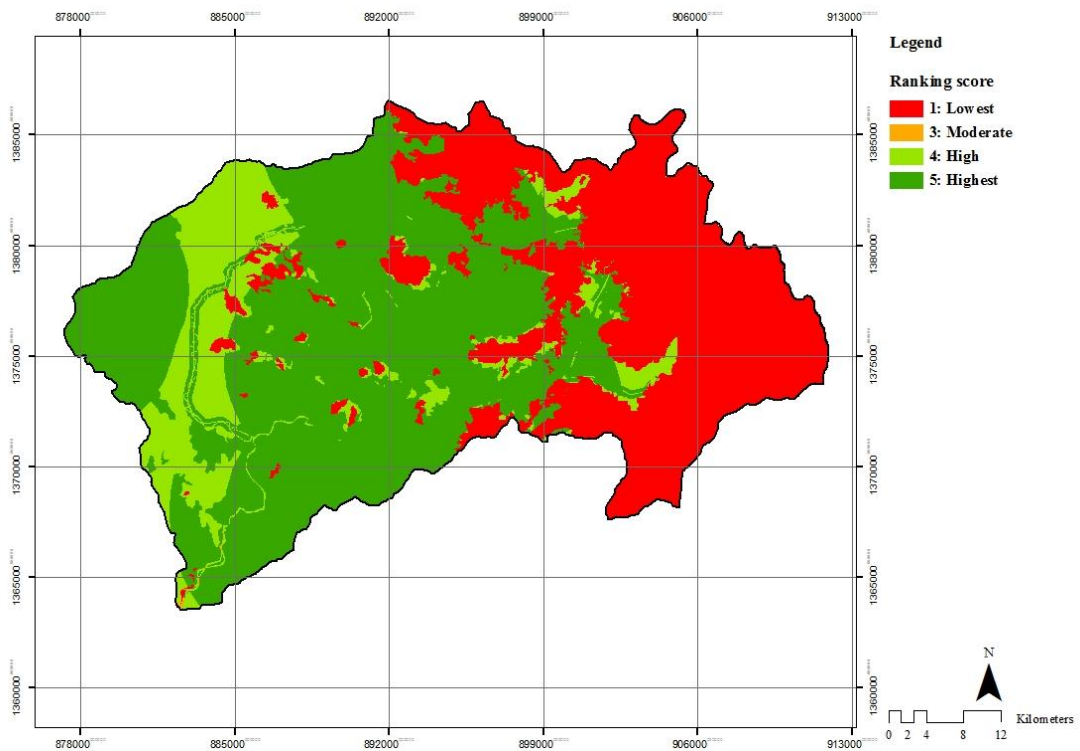
4.3 Sufficiency economy level

The application of equation (21) produced the LS levels. The LAFIC map was generated using two conditions: 1) using the model and 2) using the model which excludes conservation area and existing forest area, fixed as the LS level as shown in Figure 16a and Figure 16b, respectively.

The map which using the model indicated five LAFIC levels, with the highest to the lowest representing 256.01 (57.20%), 117.37 (26.22%), 42.92 (9.59%), 25.85 (5.78%) and 5.42 (1.21%) km², respectively. The map using the model which excludes conservation area and existing forest area produced four LAFIC levels excluding the moderate level. The highest LS level to the lowest LS level represented 229.76 (51.33%), 59.10 (13.20%), 0.30 (0.07%) and 158.41 (35.39%) km², respectively. Both results classified more than half of the total area at the highest LS level under both conditions.



a: LAFIC map based on the model



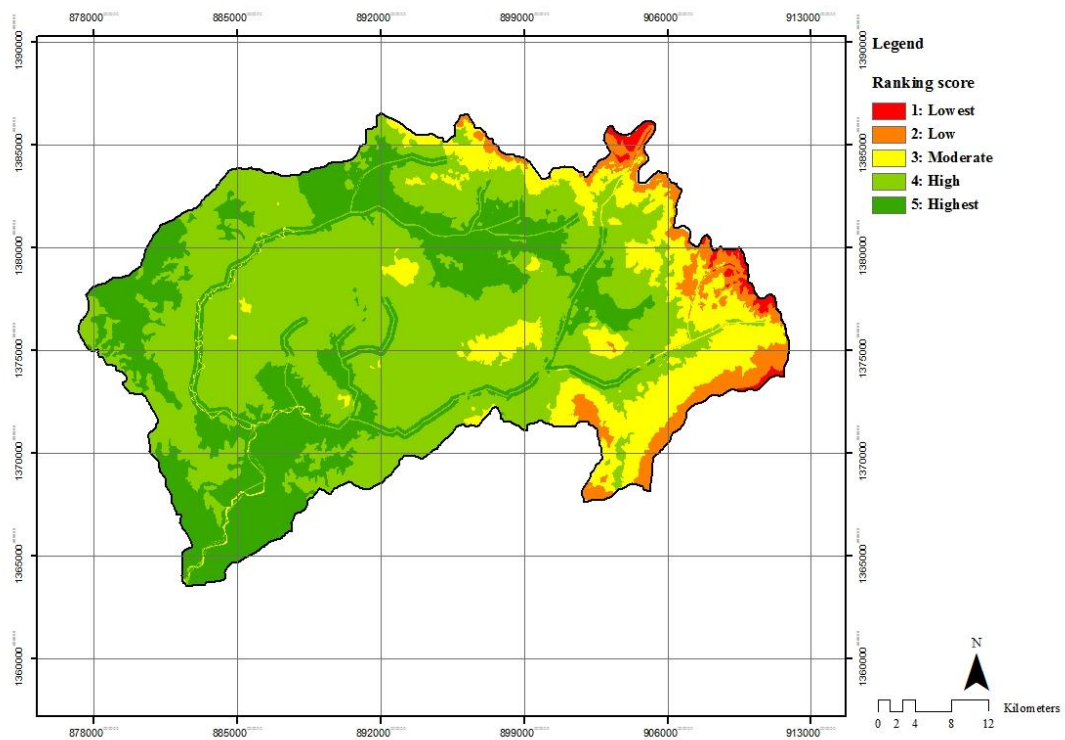
b: LAFIC map based on the model which excludes conservation area and existing forest area

Figure 16 Landscape agroforestry index class map in study area.

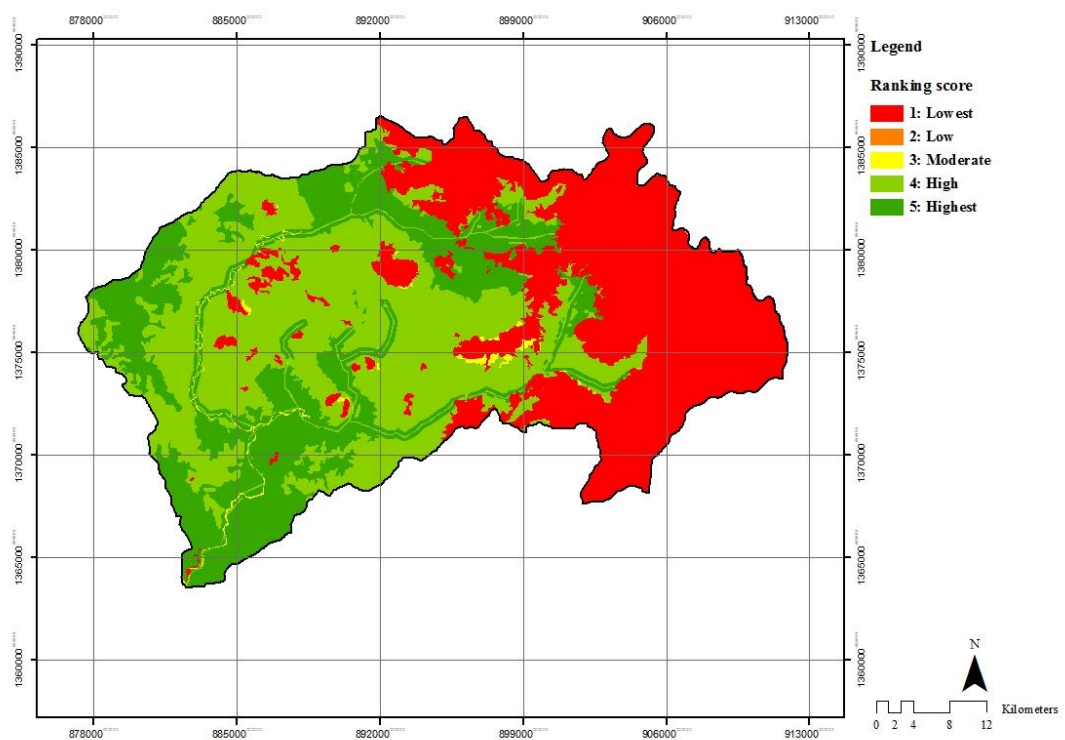
The most obvious difference between the highest and lowest LS levels was their location, with the highest LS level area distributed in the middle and on the western side of the watershed on gentle slopes. In contrast, the lowest LS level was distributed on the eastern side of the watershed in the forest area and on steep slopes.

Additionally, to demonstrate the LAFIC in terms of environmental aspect ($LAFIC_{ENV}$), the model was conducted which produced the $LAFIC_{ENV}$ map as Figure 17. The $LAFIC_{ENV}$ map which using the model indicated five LAFIC levels, with the highest to the lowest representing 125.52(28.04%), 233.99(52.28%), 61.01(13.68%), 23.30(5.21%) and 3.75(0.84%) km^2 , respectively. The $LAFIC_{ENV}$ map which using the model which excludes conservation area and existing forest area produced five LAFIC levels, with the highest to the lowest representing 113.62(25.39%), 172.51(38.54%), 3.20(0.71%), 0.06(0.01%) and 158.18(35.35%) km^2 , respectively. The results were shown; the most area distributed as the high level, the highest level was distributed on gentle slopes of the watershed, and some area distributed on the southern side of conservation area. The moderate, low and the lowest level were distributed on the eastern side on steep slopes of the watershed.

Although, LAFIC was emphasis on environment and socio-economic aspect but $LAFIC_{ENV}$ was only emphasis on environmental aspect. The results were compared among four scenarios; demonstrated that the high and the highest level were distributed on the gentle slopes, while the lowest, low and moderate level were distributed on the steep slopes on the eastern side of the watershed. These results were shown the highest weighed value of key performance (environmental factor; slope) in the model as influence to the result.



a: LAFIC_{ENV} map based on the model



b: LAFIC_{ENV} map based on the model which excludes conservation area and existing forest area

Figure 17 LAFIC map interms of environmental aspect in study area.

5. Suitability of existing land use based on the LAFIC map

The LAFIC map and the recommendations for land use provide a description of land use types under SE or AFIC which are appropriated for each LAFIC as shown in Table 30. The existing land use was represented as the AFIC to establish the AFIC map, which was then spatially matched with the LAFIC map as shown in Figure 18 and in Table 31. Both conditions had a similar distribution of the existing land use under the SE levels; more than 90 percentages was at the moderate SE level, which was distributed in the highest, high and moderate LS levels, respectively. Only less than 4 percentages was in the high and low SE levels, which were distributed in the highest and high LS levels, respectively. Comparing the existing land use and LAFIC identified that all agroforestry land uses in the study area were consistent with the suitability classes based on LAFIC.

Table 31 LAFIC and recommended land use.

LAFIC	AFIC	Agroforestry land use in study area
Highest	Lowest, low, moderate, high and the highest	Home garden, eaglewood, eaglewood /para rubber, para rubber /fruit orchard, <i>Acacia mangium</i> plantation, para rubber plantation, mixed fruit orchard, rambutan, mangosteen and oil palm
High	Low, moderate, high and the highest	Home garden, eaglewood, eaglewood /para rubber, para rubber /fruit orchard, <i>Acacia mangium</i> plantation, para rubber plantation, mixed fruit orchard, rambutan, mangosteen and oil palm
Moderate	Moderate, high and the highest	Home garden, eaglewood and eaglewood /para rubber, para rubber /fruit orchard, <i>Acacia mangium</i> plantation, para rubber plantation, mixed fruit orchard, rambutan and mangosteen

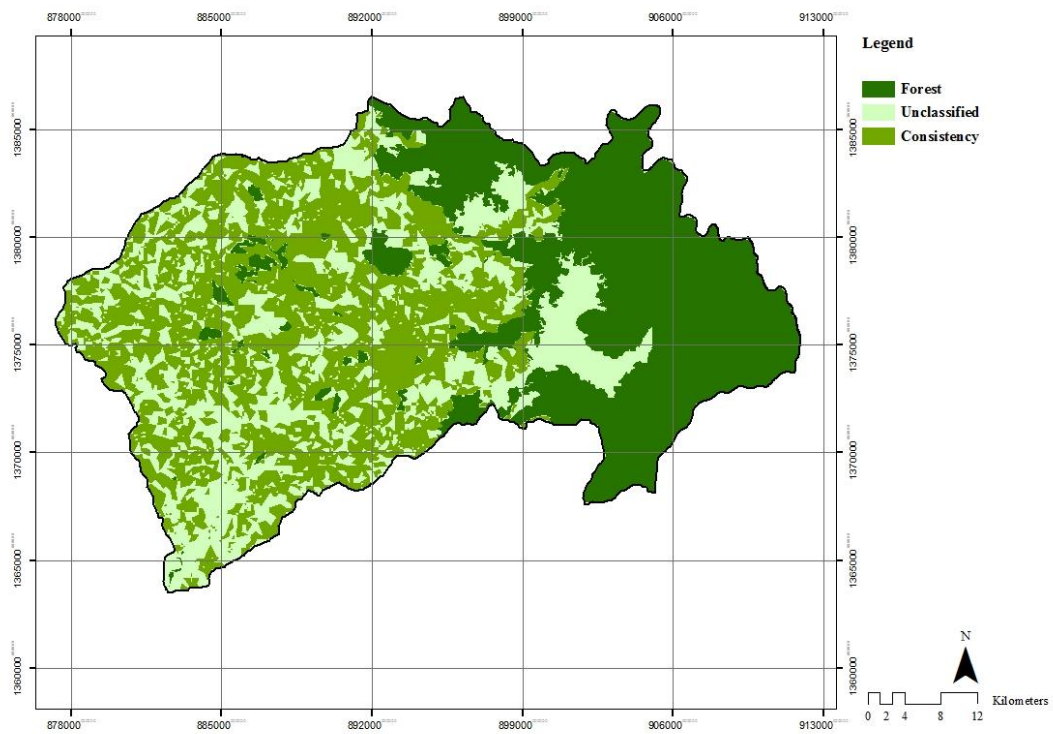
Table 31 (Continued)

LAFIC	AFIC	Agroforestry land use in study area
Low	High and the highest	home garden, eaglewood and eaglewood /para rubber
Lowest	-	-

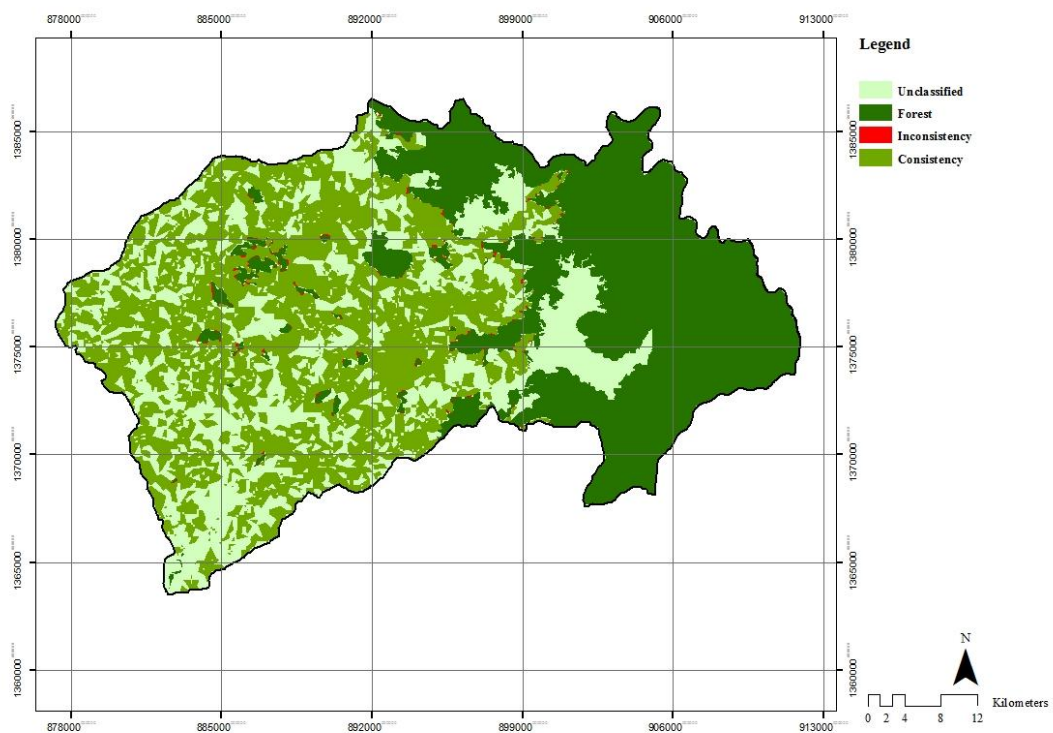
Table 32 Area of AFIC map under LAFIC map.

LS level	Moderate SE					
	High SE level(km ²)		level(km ²)		Low SE level(km ²)	
	(%)		(%)		(%)	
	a	b	a	b	a	b
Lowest	-	0.04	-	1.19	-	0.02
	-	(0.02)	-	(0.70)	-	(0.01)
Low	-	-	-	-	-	-
	-	-	-	-	-	-
Moderate	-	-	0.08	0.08	-	-
	-	-	(0.05)	(0.05)	-	-
High	0.32	0.30	34.74	34.36	1.11	1.10
	(0.19)	(0.18)	(20.52)	(20.30)	(0.66)	(0.65)
Highest	1.98	2.00	126.87	126.00	4.19	4.20
	(1.17)	(1.18)	(74.94)	(74.43)	(2.48)	(2.48)

a = area based on the model, b = area based on the model which excludes conservation area and existing forest area



a: LAFIC map based on the model



b: LAFIC map based on the model which excludes conservation area and existing forest area

Figure 18 AFIC map under LAFIC map.

CONCLUSION AND RECOMMENDATION

Conclusions

1. The key performance indicator

The key performance indicators were defined from a review of the literature and policy planning. The agroforestry indices (AFI) in terms of environmental factors consisted of three criteria: soil properties (organic matter), soil erosion and vegetation (mixed species index); in terms of economic factors, consisted of two criteria: income (income distribution and net present value) and resource using; and in terms of social factors, consisted of two criteria: land holding size and acceptance of land use. The landscape agroforestry indices (LAFI) in terms of environmental factors consisted of soil properties (soil types), topography (slope) and distance to water resources; in terms of social factors, consisted of capability of accessing to main road; and in terms of governmental institution factors, and consisted of watershed classes and conservation area.

2. The modeling for sufficiency economy

The expert advice estimated weighting based on the mailed questionnaire. The ratio method was used to adopt ranking factors. Criteria and indicators were computed by the pair-wise comparison method contained in the AHP technique. The weighed values of the factors were similar, particularly among the environmental and social factors which had the same weighted value. However, weighted values among criteria were obvious with some differences having the highest value representing more than half and these were: soil erosion, resource using, acceptance of land use, topography and watershed classes, which indicated that those criteria were efficient in the modeling. The weighted value was incorporated into the weighted linear combination in the landscape agroforestry modeling, with the modeling consisting of the AFI equation and the LAFI equation.

3. Landscape agroforestry map in study area

The analysis of SE levels in the study area found the high SE level consisted of home garden followed by eaglewood and eaglewood/para rubber, respectively. The moderate SE level consisted of para rubber /fruit orchard followed by *Acacia mangium* plantation, para rubber plantation, mixed fruit orchard, rambutan and mangosteen, respectively. Oil palm was reported at the low SE level. The highest and the lowest SE levels were not found in the study area. Therefore, the highest SE level should be identified as the best land use for all LS levels; it might be developed from the existing land use or established as a new land use.

More than half of the total area was classified in the highest LS level on the gentle slopes in the middle and on the western side of the watershed. In contrast, the lowest LS level was distributed on the eastern side of the watershed where there is forest and steep slopes. Not only are most characteristics of the study area associated with a gentle slope but also they do not relate to the critical land for cultivation. Consequently, the existing land use map matched the LAFIC map, with all agroforestry land use in the study area being consistent with the suitability classes based on LAFIC.

Recommendations

1. The characteristic of model was evident that the weighed values of the factors were similar, and the weighted values among criteria were obvious with some differences. They were indicated that those criteria were efficient in the modeling as following,

1.1 Importance AFI was indicated the land use types achieve to SE. There consist of acceptance of land use, soil erosion and resource using, respectively. Consequently, the land use should be high acceptance; the land use could be high acceptance of land use which should also be the high NPV and income distribution.

Furthermore, the land use should cultivate on the gentle slope and use lower dependency of outer resources.

1.2 Importance LAFI was indicated the characteristics of the land for each land use types achieve to SE. There consist of capability of accessing to main road, slope and watershed classes, respectively. Therefore, the characteristics of the land for cultivating should be nearby the main road lower than 5 km., on the gentle slope lower than 6%, and on 5th of the watershed class.

2. The three land use type in study area should develop to be the highest SE level; consist of Home garden, Englewood and Englewood/Para rubber. The indicator could develop; Home garden should increase organic matter by soil conservation and NPV, *A. mangium* plantation and Englewood should increase species diversity by simultaneous systems crop.

3. The modeling was applied from the weighted linear combination, which can modify the modeling through the weight value. The weight value might be modification to conform the policy, which might be changing in the future. Thus, the modeling can modify when the policy might be changing.

4. This study provided information to help identify priorities with regard to land use types and the land characteristics under SE. Thus, it is a tool for the management of resources under socio-economic factors. The application developed in this paper can be useful for the managers and planners in local and central governments and in other non-governmental organizations.

5. Inconsistency map after analysis of suitability of existing land use based on the LAFIC map should modify to be consistency map. The public participation on land use planning as a tool approaches to landscape analysis and improving planning and decision-making instruments. The stakeholder and policy maker need to collaborate more to obtain better insights in involved in land use change decisions and make their work more accessible to collaborative planning and management.

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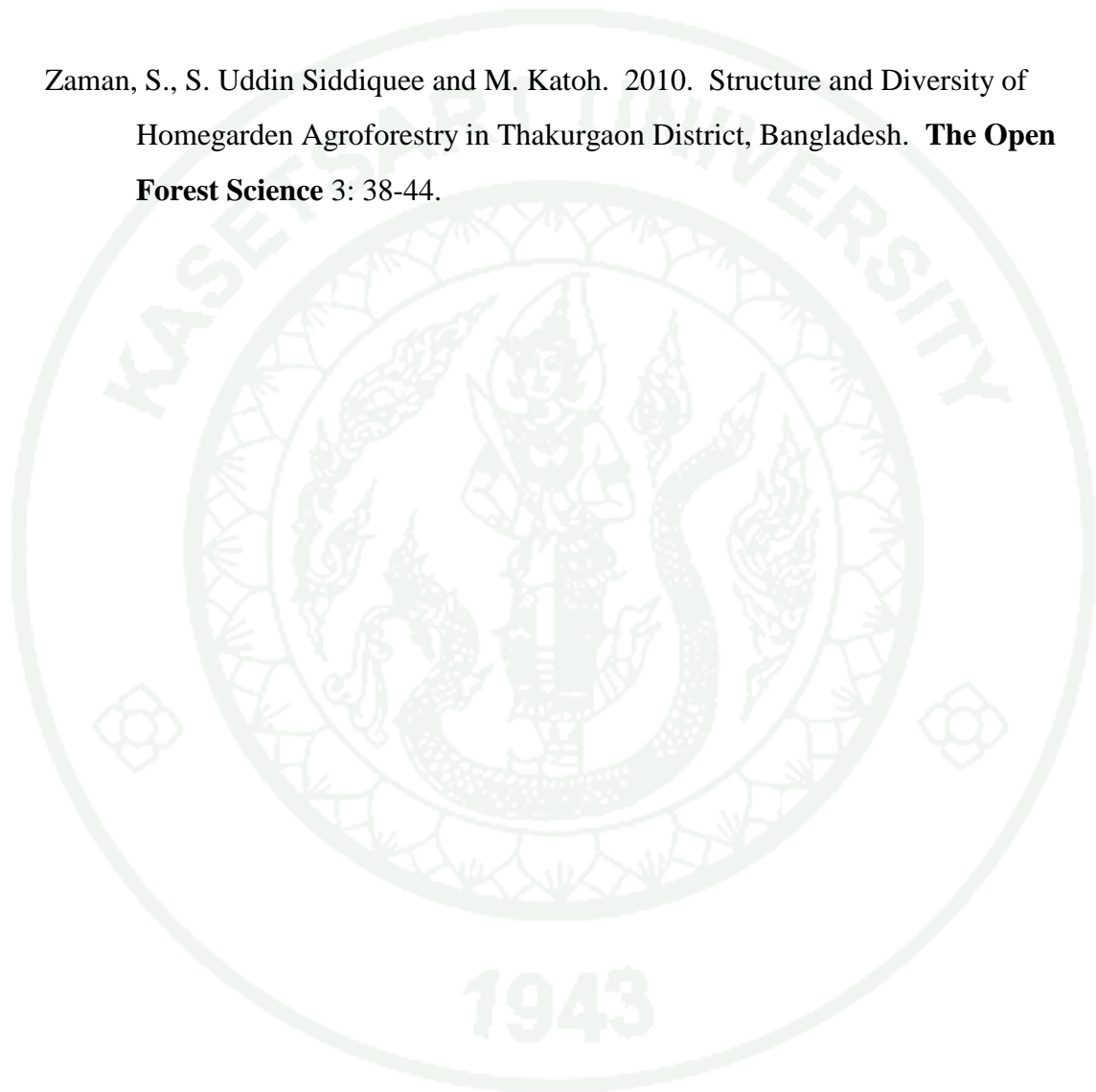
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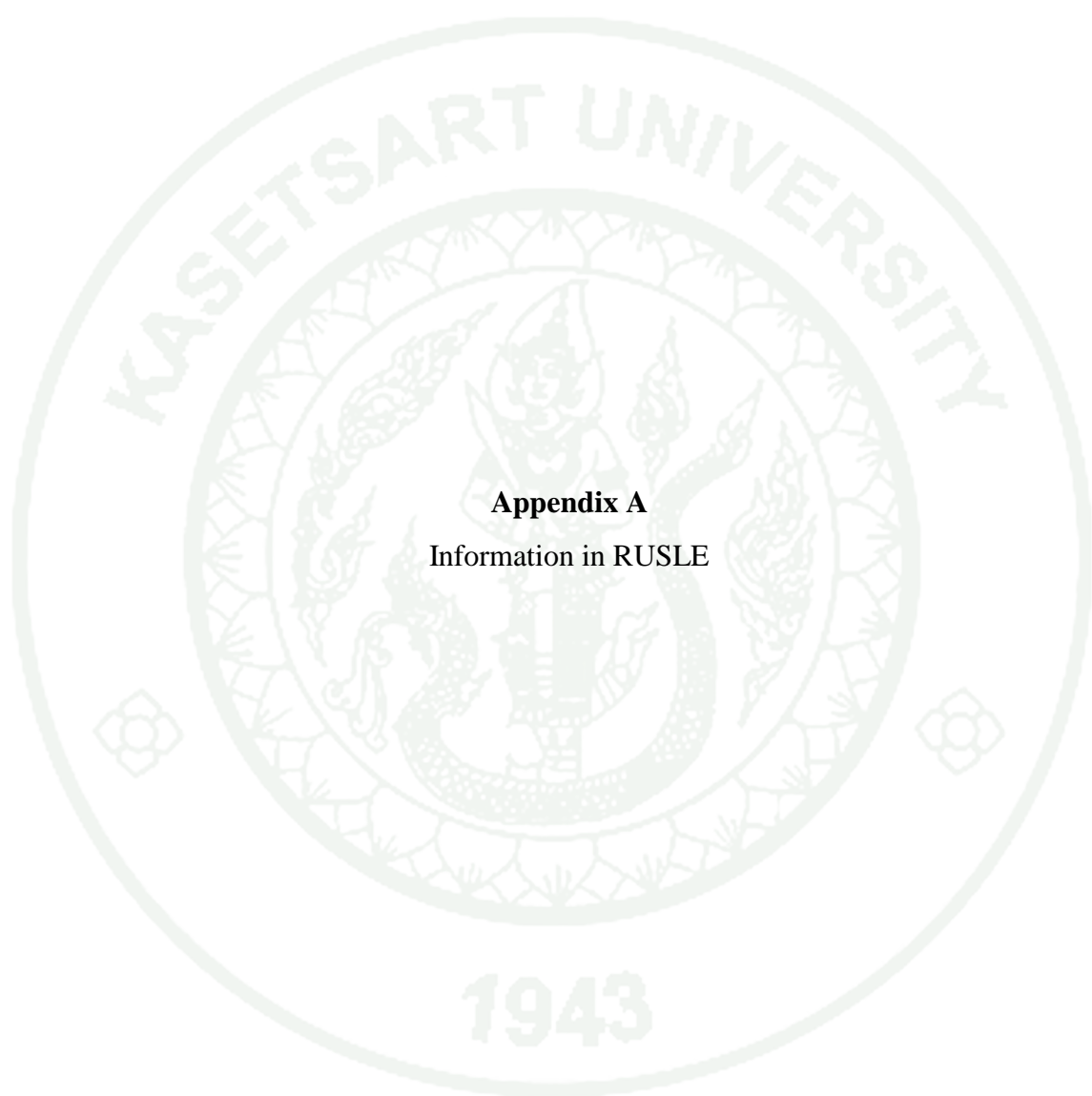
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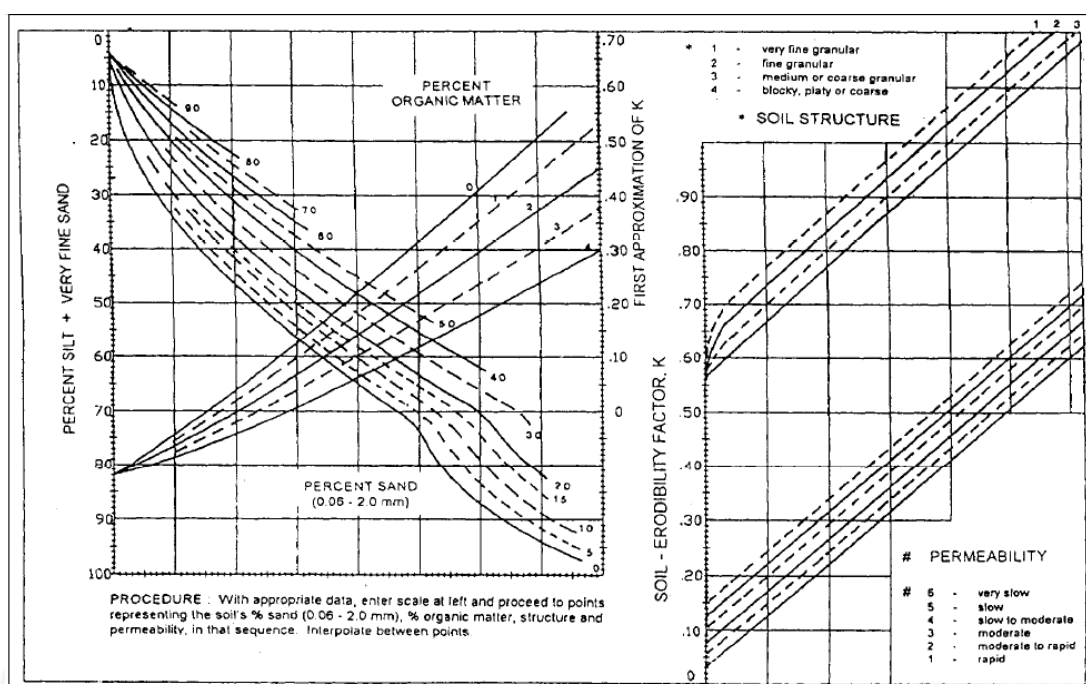




APPENDICES



Appendix A
Information in RUSLE



Appendix Figure A1 Malaysian soil erodibility nomograph for calculation of soil erodibility factor, K

Source: Tew (1999)

Appendix Table A1 Predicted CP factor of land use types in each region in Thailand.

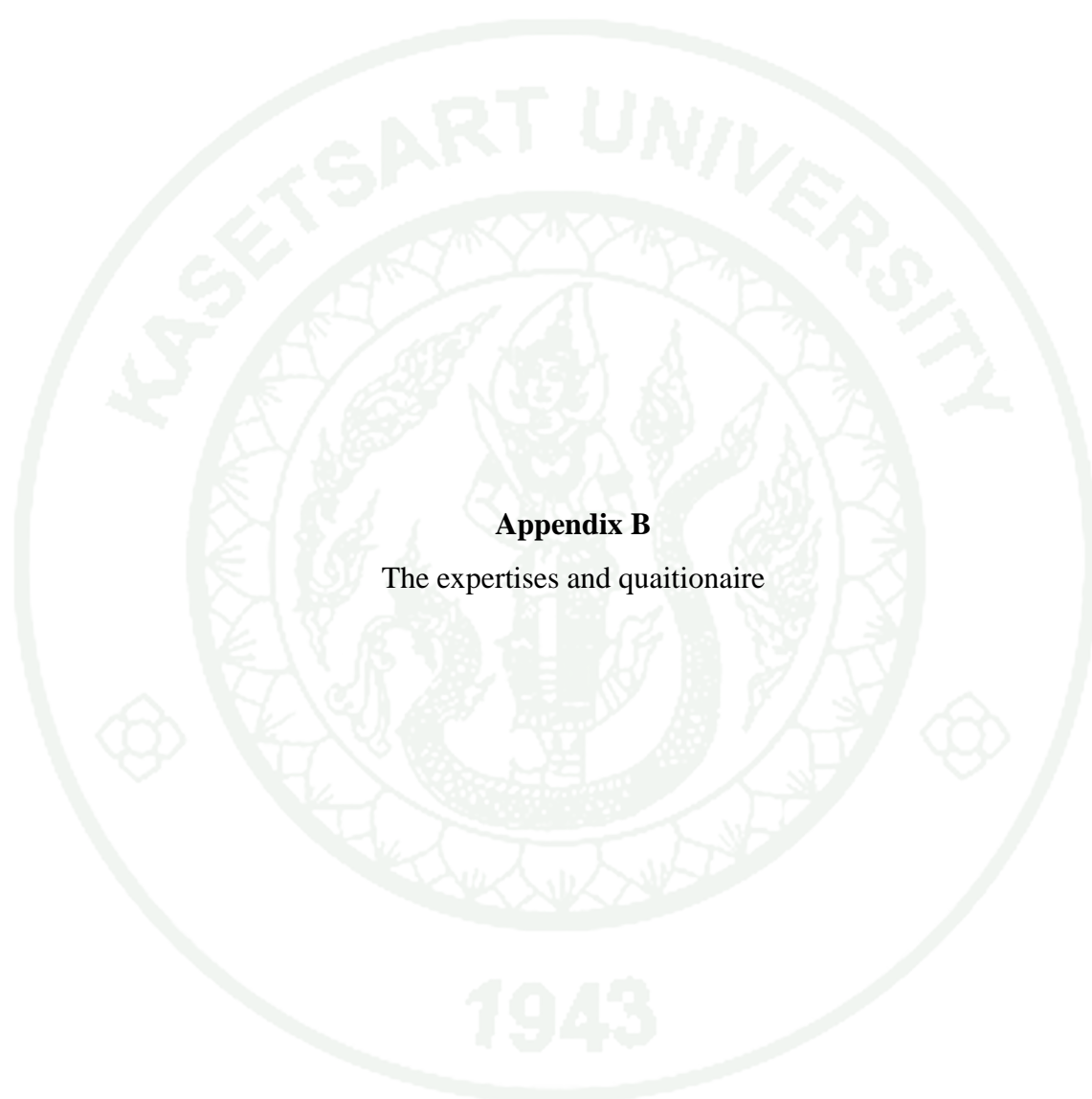
Land use types	Central and western		Northern		North-eastern		Eastern		Southern	
	C	P	C	P	C	P	C	P	C	P
Paddy filed	0.28	0.1	0.28	0.1	0.28	0.1	0.28	0.1	0.28	0.1
Crop filed	0.485	1.0	0.474	1.0	0.525	1.0	0.485	1.0	0.322	1.0
Tree	0.15	1.0	0.15	1.0	0.15	1.0	0.15	1.0	0.16	1.0
Fruit orchard	0.30	1.0	0.3	1.0	0.3	1.0	0.3	1.0	0.3	1.0
Orchard	0.60	1.0	0.6	1.0	0.6	1.0	0.6	1.0	0.6	1.0
Shifting cultivation	0.25	1.0	0.25	1.0	0.25	1.0	0.25	1.0	0.25	1.0
Pasture	0.10	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0

Appendix Table A1 (Continued).

Land use types	Central and western		Northern		North-eastern		Eastern		Southern	
	C	P	C	P	C	P	C	P	C	P
Integrated farming	0.225	1.0	0.225	1.0	0.225	1.0	0.225	1.0	0.225	1.0
Deciduous forest	0.003	1.0	0.003	1.0	0.003	1.0	0.001	1.0	0.001	1.0
Mixes deciduous forest	0.048	1.0	0.048	1.0	0.048	1.0	0.048	1.0	0.048	1.0
Tree plantation	0.088	1.0	0.088	1.0	0.088	1.0	0.088	1.0	0.088	1.0
Agroforestry	0.088	1.0	0.008	1.0	0.088	1.0	0.088	1.0	0.088	1.0
Natural pasture	0.015	1.0	0.015	1.0	0.015	1.0	0.015	1.0	0.015	1.0

Remark: Other land use types is unpredicted CP factor

Source: Thaikla and Thaikla (2004)



Appendix B

The expertises and quaitonaire

Appendix Table B1 The expertise list.

ThaiNAFE network		
No.	Name	Address
1	Mr. Jongrak Watcharinrat, Ph.D. (ดร. จงรักวัชรินทร์รัตน์)	Department of Sivilculture, Faculty of Forestry, Kasetsart University
2	Assist. Prof. Sawaeng Ruaysoongnern, Ph.D.(ผศ.ดร. แสงฉายสูงเนิน)	Faculty of Agriculture, Khon Kaen University
3	Assoc. Prof. Boonserm Cheva-issarakul, Ph.D.(รศ.ดร. บุญเสริมชีวะอิสระกุล)	Faculty of Agriculture, Chaing Mai University
4	Assist. Prof. Theerapong Soawaphak (ผศ. วีระพงษ์เสาวภาคย์)	Faculty of Agriculture, Chaing Mai University
5	Assist. Prof. Thanongsak Juntirapong, Ph.D.(ผศ.ดร. ว่าที่รท. ทรงศักดิ์จันทิระพงษ์)	Faculty of Agriculture, Rajamangala University of Technology Tawan-ok
6	Assoc.Prof. Kriangsak Sringermyuang, Ph.D.(รศ.ดร. เกียรติศักดิ์ศรีเงินขวาง)	Faculty of Architecture and Environmental Design, Maejo University
7	Mr. Prajate Umnat, Ph.D. (ดร. ประเจตอำนาจ)	Maejo University Phare Campus
8	Mr.Thanakorn Lattirasuvan, Ph.D. (ดร. ธนากรลัทธีระสุวรรณ)	Maejo University Phare Campus
9	Assoc.Prof. Dusit Wechakit, Ph.D. (รศ.ดร. ดุสิตเวชกิจ)	School of Agriculture and Cooperatives, Sukhothai Thammathirat University
10	Assoc.Prof. Pramod Keawwongsri, Ph.D. (รศ.ดร. ปราโมทย์แก้ววงศ์ศรี)	Faculty of Natural resources, Price of Songkla University
11	Assist. Prof. Surajit Phuphak (ผศ. สุรจิต ภูภักดิ์)	Faculty of Agriculture, Ubon Ratchathani University

Appendix Table B1 (Continued).

Lecturer : spacialist in agroforestry		
No.	Name	Address
12	Assoc.Prof. Suwat Terapongtanakorn, Ph.D.(รศ.ดร. สุวัฒน์ธีระพงษ์ธนากร)	Faculty of Agriculture, Ubon Ratchathani University
13	Assoc.Prof. Monton Jamroenprucksa, Ph.D.(รศ.ดร.มณฑลจำเริญพฤกษ์)	Department of Sivilculture, Faculty of Forestry, Kasetsart University
14	Assoc.Prof. Thanpisit Phuangchik (รศ. ธัญพิสิษฐ์ฟวงจิก)	Faculty of Science and Technology, Thammasat University
15	Assoc.Prof. Vipak Jintana, Ph.D. (รศ.ดร. วิพัทธ์จินตนา)	Department of Forest Management, Faculty of Forestry, Kasetsart University
16	Assoc.Prof. Pongwatchara Sirijuntawong (รศ. พงศ์วัชรสิริจันทรวงศ์)	Faculty of Agriculture, Rajamangala University of Technology Isan Surin Campus
Lecturer: specialist in agriculture and land cropping and / or sufficiency economy		
No.	Name	Address
17	Assist.Prof. Chatchai Tantasirin (ผศ. ชัชชัยตันตสิรินทร์)	Department of Conservation, Faculty of Forestry, Kasetsart University
18	Assist.Prof.Dr. Somnimirt Pukngam, Ph.D.(ผศ.ดร. สมนิมิตรพุกงาม)	Department of Conservation, Faculty of Forestry, Kasetsart University
19	Ms. Supattra Thueksathit, Ph.D. (ดร. สุภัทราธิกสถิตย์)	Department of Conservation, Faculty of Forestry, Kasetsart University

Appendix Table B1 (Continued).

No.	Name	Address
20	Mr. Piyapong Tongdeenok, Ph.D. (ดร. ปิยพงษ์ทองดินอก)	Department of Conservation, Faculty of Forestry, Kasetsart University
21	Assist.Prof. Sakhan Teejuntuk, Ph.D. (ผศ.ดร.ศการ ทีจันท์ก)	Department of Sivilculture, Faculty of Forestry, Kasetsart University
22	Assist.Prof. Roongreang Poolsiri, Ph.D. (ผศ.ดร.รุ่งเรืองพูลศิริ)	Department of Sivilculture, Faculty of Forestry, Kasetsart University
23	Prof. Wuthipol Hoamuangkaew, Ph.D. (ศ.ดร.วุฒิพลหัวเมืองแก้ว)	Department of Forest Management, Faculty of Forestry, Kasetsart University
24	Assoc.Prof. Apichart Pattaratuma, Ph.D. (รศ.ดร.อภิชาติภัทรธรรม)	Department of Forest Management, Faculty of Forestry, Kasetsart University
25	Assist.Prof. Natchapol Samard (ผศ.ณัชพลสามารถ)	Faculty of Agriculture, Ubon Ratchathani University
26	Assist.Prof. Boontium Lersupavithnapa (ผศ. บุญเทียมเลิศสุภวิษัณภา)	Faculty of Agriculture, Ubon Ratchathani University
27	Assist. Prof. Chanchai Sangchyoswat, Ph.D. (ผศ.ดร. ชานชัยแสงชโยสวัสดิ์)	Faculty of Agriculture, Chaing Mai University
28	Assist. Prof. Thaworn Onpraphai, Ph.D. (ผศ.ดร.ถาวรอ่อนประไพ)	Faculty of Agriculture, Chaing Mai University

Appendix Table B1 (Continued).

No.	Name	Address
29	Assist.Prof. Jaruntorn Boonyanuphap, Ph.D.(ผศ.ดร. จรรย์ธรบุญญาอนุภาพ)	Faculty of Agriculture, Naresuan University
30	Assoc.Prof. Patma Vityakon, Ph.D. (รศ.ดร. ปัทมาวิทยากรแรมโบ)	Faculty of Agriculture, Khon Kaen University
31	Mr. Surachart Pechkeo, Ph.D. (ดร.สุรชาติเพชรแก้ว)	Faculty of Natural resources, Price of Songkla University
32	Assist.Prof. Supatida Aumtong, Ph.D. (ผศ.ดร. สุภธิดาอำทอง)	Faculty of Agricultural Production, Maejo University
33	Assist.Prof. Pathipan Sutigoolabud,Ph.D. (ผศ.ดร. ปฎิภาณสุทธิกุลบุตร)	Faculty of Agricultural Production, Maejo University
34	Assist.Prof. Wallop Promthong, Ph.D. (ผศ.ดร. วัลลภพรหมทอง)	Faculty of Agricultural Technology, Rajamangala University of Technology Thanyaburi
35	Assist.Prof. Niyom Buaban (ผศ. นิยมบัวบาน)	Faculty of Agricultural Technology, Rajamangala University of Technology Thanyaburi
36	Prof. Nipon Tangtham, Ph.D. (ศ.ดร.นิพนธ์ตั้งธรรม)	Forestry Research Center, Kasetsart University
37	Assist.Prof. Boonwong Thaiusa, Ph.D. (ผศ.ดร. บุญวงศ์ไทยอุตสวรรค์)	Department of Sivilculture, Faculty of Forestry, Kasetsart University
38	Mrs. Wathinee Krisanapant, Ph.D. (ดร.วาทินีกฤษณะพันธ์)	Department of Sivilculture, Faculty of Forestry, Kasetsart University

Appendix Table B1 (Continued).

No.	Name	Address
Lecturer : spacialist in sufficiency economy		
39	Assist.Prof. Thanwa Jitsanguan, Ph.D. (ผศ.ดร. ชันวาทิตต์สงวน)	Faculty of Economics, Kasetsart University
40	Prof. Tawadchai Suppadit, Ph.D. (ศ.ดร. ทวีชัยศุกษิษฐ์)	School of Social and Environment Development, National Instituite of Development Administration
41	Dean of Faculty of Agricultural Technology of King Mongkut's Institute of Technology Ladkrabang	
42	Dean of Faculty of Sciences and Agricultural Technology of Rajamangala University of Technology Lanna	
Department of Forest Resource Management, Royal Forest Department		
43	Director of Department of Community Forest Management, Royal Forest Department	
44	Director of Division of Promotion of Community Forest Management, Royal Forest Department	
45	Director of Division of Development of Agroforestry, Royal Forest Department	
Department of Forest Resource Management Office 9 (Chonburi)		
46	Director of Department of Community Forest Management Office 9, Royal Forest Department	
47	Chief of Forest Land Management of of Community Forest Management Office 9, Royal Forest Department	
48	Chief of Community Forest Management of of Community Forest Management Office 9, Royal Forest Department	
49	Chief of Coordination Center Forest of Trat	

Appendix Table B1 (Continued).

 Department of Land Development

50 Director of Policy and Land use Division

51 Director of Land Development Regional Office 2

Land Development Station of Trat Province, Department of Land Development

52 Director of Land Development Station of Trat Province

53 Head of Land Development Regional Office 3

54 Head of Land Development Regional Office 4

Department of Public Works and Town & Country Planning

55 Director of Division of Regional and Country Planning

56 Chief of Country Planning

Trat Office of Public Works and Town & Country Planning

57 Director of Trat Office of Public Works and Town & Country Planning

58 Chief of Operation Subdivision of Trat Office of Public Works and Town
& Country Planning

Questionnaire for the expertise

Explanation

1. This research is the part of doctoral dissertation, watershed and environmental management field, department of conservation, faculty of forestry, Kasetsart University. The research is The Landscape Agroforestry Modeling for Sufficiency Economy in Huai Raeng-Klong Peed Watershed, Trat Province, Thailand.

2. The objectives of the questionnaire

2.1 To select the indicator for indication to achieve to the sufficiency economy.

2.2 To weight value of each indicator for indication to achieve to the sufficiency economy. Two parts of questionnaire consist of,

Part 1 Weighting for agroforestry indices.

Part 2 Weighting for landscape agroforestry indices.

Researcher

Miss Sukanya Chaipong

Doctoral student

Part 1 Weighting for agroforestry index classes.

Agroforestry indices means the land use which appropriate for topography circumstances in order to realize the utmost benefits resources, and the land use is accepted by land user.

1) Weight value of factor

As agroforestry meaning please take (✓) in the weight value which are represented 1 – 10 as the lowest to the highest value.

Weight value level	1 ————— 10 Lowest ————— moderate ————— highest									
	1	2	3	4	5	6	7	8	9	10
Environment										
Economy										
Social										

2) Weight value of criteria and indicators

2.1) Environment

- **Criteria**

Comparing both criteria and please take (✓) at the end of criterion for the more important than another, and please take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.

Criteria		Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
			1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(1) Between <u>Soil properties and Soil erosion</u> , which one more important than another.	Soil properties						
	Soil erosion						
(2) Between <u>Soil properties and Vegetation</u> , which one more important than another.	Soil properties						
	Vegetation						
(3) Between <u>Soil erosion and Vegetation</u> , which one more important than another.	Soil erosion						
	Vegetation						

2.1) Environmental Factor

- indicator

Remarks : In this section for the expertise in ecology, if you are not the expertise in this field please across to 2.2 in page 4th

Comparing both criteria and please take (✓) at the end of criterion for the more important than another, and please take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.

Criteria	Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
		1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(1) Between <u>Organic matter and Bulk density</u> , which one more important than another.	Organic matter					
	Bulk density					
(2) Between <u>Organic matter and Soil moisture</u> which one more important than another.	Organic matter					
	Soil moisture					
(3) Between <u>Bulk density and Soil moisture</u> which one more important than another.	Bulk density					
	Soil moisture					
(4) Between <u>Percentage of crowns cover and Number of crown layers</u> which one more important than another.	Percentage of crowns cover					
	Number of crown layers					

Criteria		Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
			1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(5) Between <u>Percentage of crowns cover</u> and <u>Biomass</u> which one more important than another.	Percentage of crowns cover						
	Biomass						
(6) Between <u>Number of crown layers</u> and <u>Species diversity</u> which one more important than another.	Number of crown layers						
	Species diversity						
(7) Between <u>Number of crown layers</u> and <u>Biomass</u> which one more important than another.	Number of crown layers						
	Biomass						
(8) Between <u>Number of crown layers</u> and <u>Species diversity</u> which one more important than another.	Number of crown layers						
	Species diversity						
(9) Between <u>Biomass</u> and <u>Species diversity</u> which one more important than another.	Biomass						
	Species diversity						

2.2) Economic Factor

- **Indicator**

Comparing both criteria and please take (✓) at the end of criterion for the more important than another, and please take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.

Criteria	Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
		1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(1) Between <u>Income distribution and Net present value</u> , which one more important than another.	Income distribution					
	Net present value					
(2) Between <u>Income distribution and Resource using</u> , which one more important than another.	Income distribution					
	Resource using					
(3) Between <u>Net present value and Resource using</u> , which one more important than another.	Net present value					
	Resource using					

2.3) Social Factor

- **Indicator**

Comparing both criteria and please take (✓) at the end of criterion for the more important than another, and please take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.


Criteria		Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
			1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(1) Between <u>Land holding size and Acceptance of land use</u> , which one more important than another.	Land holding size						
	Acceptance of land use						

Part 2 Weighting for agroforestry index classes.

□ Landscape agroforestry indices mean the characteristics of the land which appropriate for land use under the sufficiency economy; the land has potential on providing for land use under the utmost benefits resources.

1) Weight value of factor

As landscape agroforestry meaning please take (✓) in the weight value which are represented 1–10 as the lowest to the highest value.

Weight value level	 1 10 Lowest-----moderate-----highest									
	Factor	1	2	3	4	5	6	7	8	9
Environment										
Economy; Distance to main road										
Social(Institutions Related; watershed classification)										

2) Weight value of criteria and indicators

2.1) Environment

- **Criteria**

Comparing both criteria and please take (✓) at the end of criterion for the more important than another, and please take (✓) for weight which are represented 1–9 as the lowest to the highest value.

Criteria	Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
		1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(1) Between <u>Soil properties and Slope class</u> , which one more important than another.	Soil properties					
	Slope classes					

(2) Between <u>Soil properties and Distance to water resources</u> , which one more important than another.	Soil properties					
	Distance to water resources					

(3) Between <u>Slope classes and Distance to water resources</u> , which one more important than another.	Slope classes					
	Distance to water resources					

2) Weight value of criteria and indicators

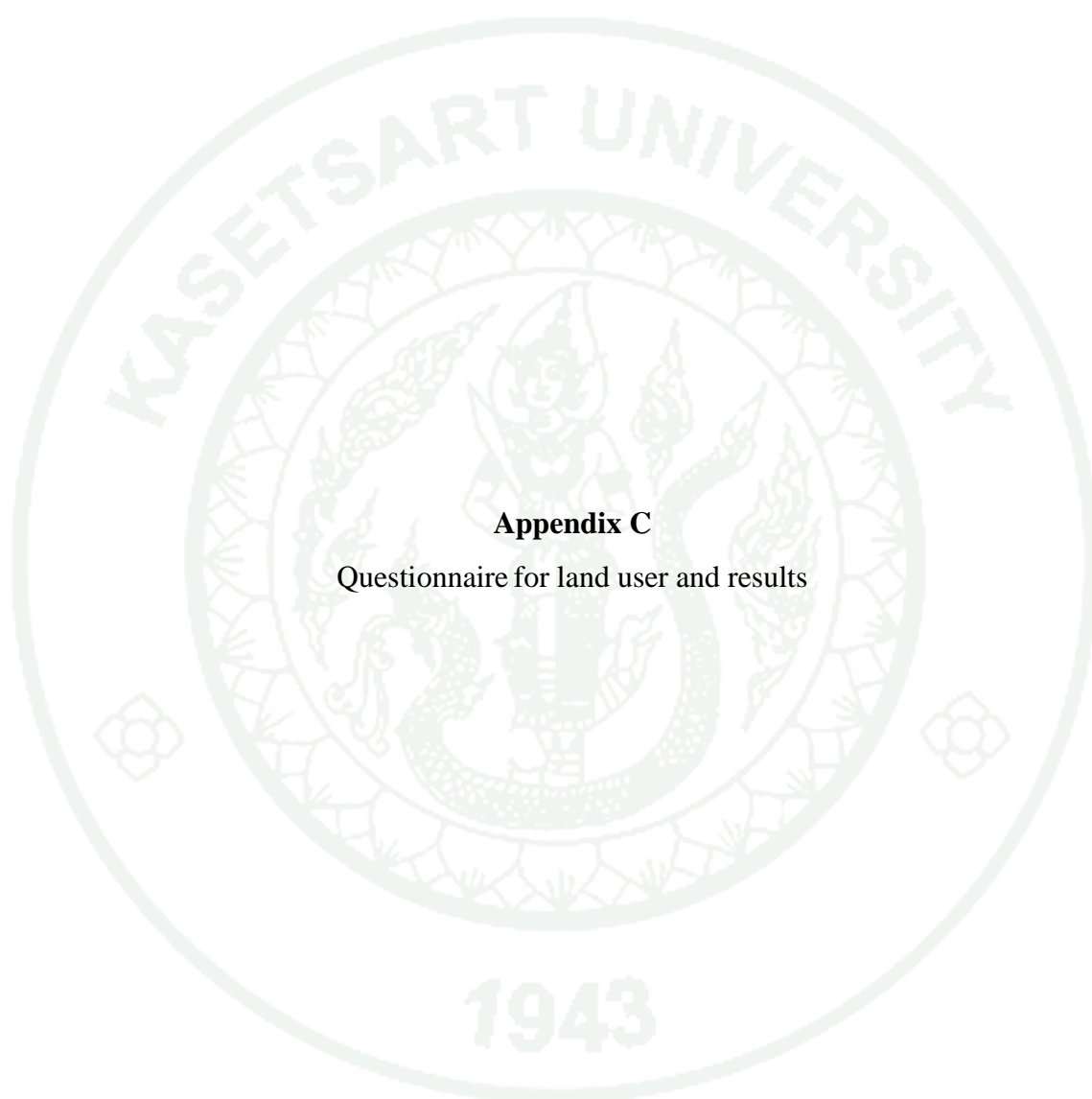
2.2) Institutions Related

- **Criteria**

Comparing both criteria and please take (✓) at the end of criterion for the more important than another, and please take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.

Criteria	Take (✓) the more important than another	Take (✓) for weight which are represented 1 – 9 as the lowest to the highest value.				
		1 Lowest	3 Low	5 Moderate	7 High	9 Highest
(1) Between <u>Watershed classification and Conservation area</u> , which one more important than another.	Watershed classification					
	Conservation area					

.....Thank you very much.....



Appendix C
Questionnaire for land user and results

Questionnaire for land user

Name..... Land use types.....
 Adress..... District.....
 Province.....Geographic coordinate.....

Explanation

1. This research is the part of doctoral dissertation, watershed and environmental management field, department of conservation, faculty of forestry, Kasetsart University. The research is The Landscape Agroforestry Modeling for Sufficiency Economy in Huai Raeng-Klong Peed Watershed, Trat Province, Thailand.
2. The objectives of the questionnaire
 - 2.1 To study in economic indicator of study area.
 - 2.2 To study in social indicator. Two parts of questionnaire consist of,
 - Part 1 Basic information of farmer.
 - Part 2 Socio-economic information from harvesting.
3. Please take (✓) and fill out in form their questionnaire.
4. These information is not related in your tax but it is used for information in this research.

Researcher

Miss Sukanya Chaipong

Doctoral student

Part 1 Basic information of farmer.

1.1) Sex

- 1: Female 2: Male

1.2) Ageyears

1.3) Education

- 1: Non education 3: High school 5: Bachelor's degree and higher
 2: Primary school 4: Diploma

1.4) Period of settlement (over 6 months as 1 year).

- 1: 0-1 year 3: 3-5 year
 2: 1-3 year 4: >5 year

Part 2 Socio-economic information from harvesting.

2.1) Do you have your household income?

- 1: Adequate, saving, non loan
 2: Adequate, non saving, loan
 3: Inadequate, non saving, non loan

2.2) Total debts =baht/year

2.3) Total land holding = rai (1 rai = 1,600 m²) it can be separated as following,

2.3.1) By land tenure

- Amount own land =.....rai
 - Amount non own land =.....rai

2.3.2) By land using

- Non- agricultural sector =rai
 - Agricultural sector =rai, it can be separated as following,
 - Paddy field =rai - Farm =rai
 - Orchard =rai- Other =rai

2.3.3) How long have you had your experience farming? =rai

2.4) Cropping types, harvesting income

1) Cropping systems

1.1) Crop	Crop type =
	Period of cultivation =year
1.2) Crop rotation	Rotation crop type =
	Period of cultivation =year

2) Land holding size =rai

3) Land tenure own land land others own of some land

4) Do you have stable income harvesting since 2008 - 2013? (Income distribution)	<input type="checkbox"/> 5: Yes	<input type="checkbox"/> 1: No
5) How do you accept your cultivation? (Acceptance of land use)	<input type="checkbox"/> 5: highest <input type="checkbox"/> 4:high <input type="checkbox"/> 3: moderate <input type="checkbox"/> 2: low <input type="checkbox"/> 1: lowest	

2.5) Self-reliance resources or dependency on external inputs (Resources using).

2.5.1) What source of seed?

- 1: Purchased from markets
- 2: Contribution
- 3: Collected from surrounding area
- 4: Previous plantation
- 5: Breeding by yourself

2.5.2) How does the water for cultivation be adequate?

- 1: Be inadequate
- 2: Be adequate in rainy season
- 5: Be adequate all season

2.5.3) What source of fertilization and herbicides?

- 1: Purchased from markets
- 2: Contribution
- 3: Unused
- 4: Marking by yourself and purchase
- 5: Marking by yourself

2.5.4) Do you have labor cost?

- 1: Yes, for all of the system
- 3: Yes, for some of the system
- 5: No

2.5.5) How to sell the products? (You can answer more than one choice)

- 1: Products are taken to the market for sale.
- 2: Products are sold to farmer organization.
- 5: Dealer comes to buy the products in the site cultivation.

Appendix Table C1 Land user in each land use in study area.

No.	Land use types	Name
1	Oil palm	Mr. Audum Maliwan (นายอุดม มะลิวัลย์)
		Mr. Nimit Arphiban (นายนิมิตร อภิบาล)
2	Para rubber/fruit orchard	Ms. Pawara Sakunwong (นางปวรา สกุลวงศ์)
		Ms. Siripa Wongduan (นางศิริภา วงศ์เดือน)
3	Para rubber plantation	Mr. Somchaiy Aimsamour (นายสมชาย อิ่มเสมอ)
		Ms. Boppa Noimalee (นางนุปลา น้อยมาลี)
4	Mixed fruit orchard	Ms. Boppa Noimalee (นางนุปลา น้อยมาลี)
		Mr. Boonmee Shisai (นายบุญมี สีใส)
5	Engle wood/Para rubber	Mr. Nu Komkeaw (นายหนู กำแก้ว)
		Ms. Laeas Sukuntharud (นางละเอียด สุกนทรศ)

Appendix Table C1 (Continued)

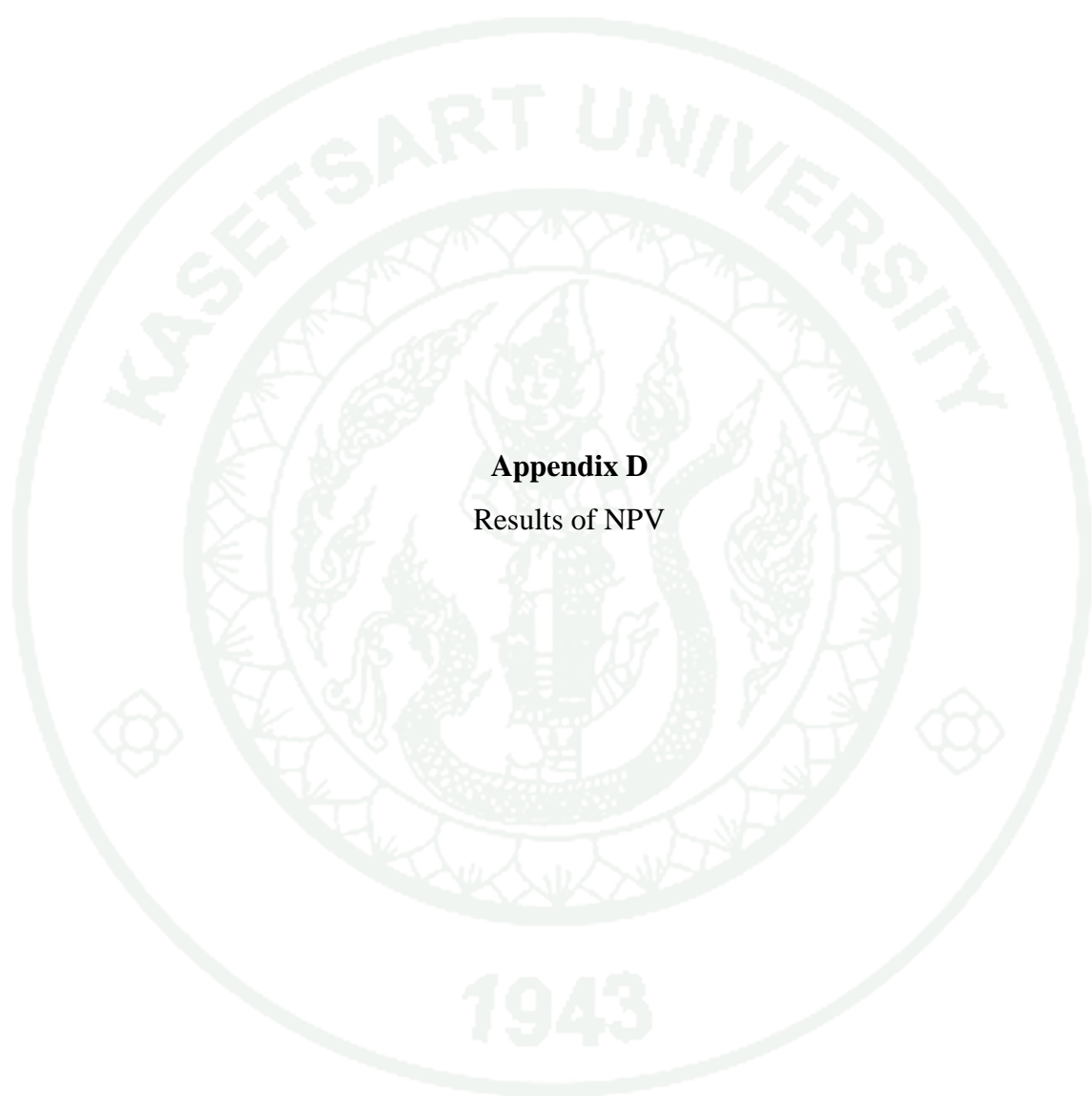
No.	Land use types	Name
6	Home garden	Ms. Pontip Aonsang (นางพรทิพย์ อ่อนแสง)
		Ms. Praneed Deecom (นางปราณีต ดีคำ)
7	Lambutan	Mr. Thad Padnuson (นายทัต แพทย์นุเคราะห์)
		Ms. Nongnut Thongboonma (นางนงนุช ทองบุญมา)
8	Mangosteen	Ms. Nongnut Thongboonma (นางนงนุช ทองบุญมา)
		Mr. Boonmee Pootisan (นายบุญมี โพธิสาร)
9	<i>Acacia mangium</i> plantation	Forest Industrial Organization, Trad province. องค์การอุตสาหกรรมป่าไม้จังหวัดตราด
		Mr. Wichai Tucomee (นายวิชัย ทุกามี)
10	Engle wood	Mr. Chumpon Maneewong (นายชุมพร มณีพงศ์)
		Mr. Sompon Chounuson (นายสมพร เชื้อนุสรณ์)

Appendix Table C2 Basic and socio-economic information of land user in each land use in study area.

Land use types	Basic information					Deposit	Land holding size(rai)	Income distribution	Acceptance of land use	Resources using				
	Sex	Age	Education	Settlement	Income					Seed	Water	Fertility and Herbicide	Labor cost	Sale products
Oil palm	2	42	2	4	1	0	35	4	4	1	2	1	5	1
	2	38	2	4	1	0	30	4	4	1	2	1	1	1
Para rubber/fruit orchard	1	42	2	4	1	0	1	3	4	4	1	1	3	1
	2	25	3	3	1	0	4	3	4	1	1	1	1	1
Para rubber plantation	2	60	3	4	1	0	67	3	5	2	5	1	1	1
	1	45	3	4	1	0	15	3	5	2	5	1	1	1
Mixed fruit orchard	1	45	2	4	1	0	3	3	4	1	5	1	1	1
	1	53	2	4	1	0	50	3	4	1	1	1	5	1
Engle wood/Para rubber	2	40	3	4	4	100,000	20	4	5	4	1	1	3	1
	2	50	2	4	1	0	1	4	3	4	5	1	3	1
Home garden	2	59	2	4	4	100,000	2.5	4	4	1	1	1	5	1
	2	60	2	4	1	0	3	4	5	4	1	1	3	1

Appendix Table C2 (Continued)

Land use types	Basic information					Deposit	Land holding size(rai)	Income distribution	Acceptance of land use	Resources using				
	Sex	Age	Education	Settlement	Income					Seed	Water	Fertility and Herbicide	Labor cost	Sale products
Lambutan	2	64	2	4	1	0	13	4	4	1	5	1	1	1
	1	43	3	4	4	142,000	44	3	3	1	5	1	3	1
Mangosteen	1	43	3	4	4	142,000	44	3	3	1	5	1	3	1
	2	58	2	4	2	200,000	15	3	4	1	2	1	1	1
<i>Acacia mangium</i> plantation	2	36	5	4	1	0	58	3	3	5	1	1	3	1
	2	39	2	4	1	0	7	3	3	4	5	1	5	1
Engle wood	2	52	4	4	1	0	90	4	5	1	1	1	3	1
	2	67	2	4	1	0	15	4	5	4	5	1	5	1



Appendix D
Results of NPV

Net present value of *Acacia mangium* plantation in study area.

(Unit: Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	600					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	300					
- Hoe	300					300
- Big knife	240					240
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	140					
- Pineapple planting cost	600					
- Apply fertilizer cost	420	420	420			
- Weed cost	140	140	140			
- Injecting pesticides cost	140	140	140			
Material cost						
- Breeding cost of <i>Acacia mangium</i> plantation	2,800					
- Breeding cost of pineapple	900					
- Fertilizer	600	600	600			
- Herbicide	120	120	120			
- petrol cost for spraying and injection pumps	60	60	60			
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	9,564.5	1,684.5	1,684.5	204.5	204.5	744.5
2. Income						
- Timber product						
- Pineapple product	24,000	19,200	14,400			
3. Net income	24,000	19,200	14,400			
4. NPV	13,366.2	16,218.1	11,773.6	-189.4	-189.4	-689.4

Net present value of *Acacia mangium* plantation in study area. (Continued)

(Unit: Baht/rai)

Year	7 th	8 th	9 th	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Hoe					300	
- Big knife					240	
1.4 Arrangement cost						
Labor cost	300	300	300	300	300	300
- Planting orientation cost	4.5	4.5	4.5	4.5	4.5	4.5
- Pineapple planting cost	304.5	304.5	304.5	304.5	844.5	304.5
- Apply fertilizer cost						140,000
- Weed cost						
- Injecting pesticides cost						140,000
Material cost	-281.9	-281.9	-281.9	-281.9	-781.9	129,347.7
- Breeding cost of <i>Acacia mangium</i> plantation						
- Breeding cost of pineapple						
- Fertilizer	300	300	300	300	300	300
- Herbicide	4.5	4.5	4.5	4.5	4.5	4.5
- petrol cost for spraying and injection pumps	304.5	304.5	304.5	304.5	844.5	304.5
1.5 Maintenances cost						
- Repairing cost of instrument	300.0	300.0	300.0	300.0	300.0	300.0
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	304.5	304.5	304.5	304.5	844.5	304.5
2. Income						
- Timber product						140,000
- Pineapple product						
3. Net income						140,000
4. NPV	-281.9	-281.9	-281.9	-281.9	-781.9	129,347.7

Net present value of *Acacia mangium* plantation in study area. (Continued)

(Unit: Baht/rai)

Year	13 rd	14 th	15 th	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				300		
- Hoe				240		
- Big knife				240		
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	140					
- Pineapple planting cost	600					
- Apply fertilizer cost	420	420	420			
- Weed cost	420	420	420			
- Injecting pesticides cost	140	140	140			
Material cost						
- Breeding cost of <i>Acacia mangium</i> plantation	2,800					
- Breeding cost of pineapple	900					
- Fertilizer	600	600	600			
- Herbicide	120	120	120			
- petrol cost for spraying and injection pumps	60	60	60			
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	500	500	500
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	6,504.5	2,064.5	2,064.5	1,344.5	504.5	504.5
2. Income						
- Timber product						
- Pineapple product	24,000	19,200	14,400			
3. Net income	24,000	19,200	14,400			
4. NPV	16,199.5	15,866.2	11,421.8	-1,244.9	- 467.1	- 467.1

Net present value of *Acacia mangium* plantation in study area. (Continued)

(Unit: Baht/rai)

Year	19 th	20 th	21 st	22 nd	23 rd	24 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Hoe			300			
- Big knife			240			
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pineapple planting cost						
- Apply fertilizer cost						
- Weed cost						
- Injecting pesticides cost						
Material cost						
- Breeding cost of <i>Acacia mangium</i> plantation						
- Breeding cost of pineapple						
- Fertilizer						
- Herbicide						
- petrol cost for spraying and injection pumps						
1.5 Maintenances cost						
- Repairing cost of instrument	500	500	500	500	500	500
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	504.5	504.5	1,044.5	504.5	504.5	504.5
2. Income						
- Timber product						
- Pineapple product						
3. Net income						
4. NPV	-467.1	-467.1	-967.1	-467.1	-467.1	-467.1

Net present value of *Acacia mangium* plantation in study area. (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				
				1 person/ 150 baht/day (finished in 2 days)
1.2 Cost of land				
				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		180		Average from sample as 300 baht/year (useful life 15 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Big knife		60		Each of 120 baht and 2 hoes/rai (useful life 2 years)
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Planting orientation = 2x6 m. = 140 plant/rai (labor cost =140 baht/rai)
- Pineapple planting cost				120 baht/day (finished in 5 persons/rai)
- Apply fertilizer cost				3 times/year (labor cost =150 baht/day)
- Weed cost				1 times/year (labor cost =140 baht/day)
- Injecting pesticides cost				1 times/year (labor cost =140 baht/day)
Material cost				
- Breeding cost of <i>Acacia mangium</i> plantation				1 plant = 20 baht(140 plant/rai)
- Breeding cost of pineapple				3 times/year (fertilizer cost =200 baht/rai)
- Fertilizer				1 times/year (substances cost =120 baht/rai)
- Herbicide for weeding				60 baht/rai/year
- petrol cost for spraying and injection pumps				

Net present value of *Acacia mangium* plantation in study area. (Continued)

(Unit: Baht/rai)

Year	25 th	Remain der cost	NPV	Remarks
1.5 Maintenances cost				Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th = 300 baht, 16 th - 26 th = 500 baht
- Repairing cost of instrument	500			
1.6 Land tax	4.5			Source: Punapaipong (2004)
Total cost of investment	504.5			
2. Income	140,000			
- Timber product				6,000 products/rai and 1 product = 4 baht (product of 1 th year = 100%, 2 th = 20%, 3 th = 40%)
- Pineapple product				
3. Net income	140,000	340		
4. NPV	129,162.5	188.9	335,084.7	8 %

Net present value of Engle wood in study area.

(Unit: Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	600					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	333.3					
- Pump	725.0					
- Pruning shear	46					46
- Hoe	300					300
- Big knife	240					240
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	1,300					
- Planting cost	1,300					
- Pruning	300	300	300			
- Apply fertilizer cost	300	300	300	300	300	
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost	250	250	250			
- Activating cost					2,760	3,680
Material cost						
- Breeding cost of Engle wood	18,200					
- Herbicide	150	150	150			
- Herbicide for weeding	360	360	360	120	120	120
- Inorganic fertilizer	2,600	5,200	5,200	10,400	10,400	
- Organic fertilizer	1,625	3,250	3,250	6,500	6,500	
- Electrical for water supply	550	550	550	550	550	
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	31,751.8	10,932.5	10,932.5	18,442.5	21,202.5	4,958.5
2. Income						
- Production						2,523
- Timber product						
3. Net income						2,523
4. NPV	-29,399.8	-10,122.7	-10,122.7	-17,076.4	-19,631.9	-2,255.1

Net present value of Engle wood in study area (Continued)

(Unit: Baht/rai)

Year	7 th	8 th	9 th	10 th	11 st	12 ^{sd}
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Pruning shear					46	
- Hoe					300	
- Big knife					240	
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Planting cost						
- Pruning						
- Apply fertilizer cost						
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost						
- Activating cost	3,680					
Material cost						
- Breeding cost of Engle wood						
- Herbicide						
- Herbicide for weeding	120	120	120	120	120	120
- Inorganic fertilizer						
- Organic fertilizer						
- Electrical for water supply						
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	4,472.5	792.5	792.5	792.5	1,378.5	792.5
2. Income						
- Production	10,052	10,052	10,052	10,052	10,052	10,052
- Timber product						
3. Net income						
4. NPV	5,166.2	8,573.6	8,573.6	8,573.6	8,031.0	8,573.6

Net present value of Engle wood in study area (Continued)

(Unit: Baht/rai)

Year	13rd	14th	15th	16th	17th	18th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				333.3		
- Pump				725		
- Pruning shear				46		
- Hoe				300		
- Big knife				240		
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Planting cost						
- Pruning						
- Apply fertilizer cost						
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost						
- Activating cost			600			
Material cost						
- Breeding cost of Engle wood				18,200		
- Herbicide						
- Herbicide for weeding	120	120	120	120	120	120
- Inorganic fertilizer						
- Organic fertilizer						
- Electrical for water supply						
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment						
2. Income						
- Production	10,052	10,052	7,569			
- Timber product			110,833.4			
3. Net income	10,052	10,052	118,402.4			
4. NPV	8,573.6	8,573.6	108,342.5	-19,293.3	-919	-919

Net present value of Engle wood in study area (Continued)

(Unit: Baht/rai)

Year	19th	20th	21st	22nd	23rd	24th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Pruning shear			46			
- Hoe			300			
- Big knife			240			
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Planting cost						
- Pruning						
- Apply fertilizer cost						
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost						
- Activating cost		2,760	3,680	3,680		
Material cost						
- Breeding cost of Engle wood						
- Herbicide						
- Herbicide for weeding						
- Inorganic fertilizer						
- Organic fertilizer						
- Electrical for water supply						
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	992.5	3,752.5	5,258.5	4,672.5	992.5	992.5
2. Income						
- Production			2,523	10,052	10,052	10,052
- Timber product						
3. Net income			2,523	10,052	10,052	10,052
4. NPV	-919.0	-3,474.5	-2,532.9	4,981	8,388.4	8,388.4

Net present value of Engle wood in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1. Investment cost				
				1 person/ 150 baht/day
1.1 Site preparation cost				(finished in 2 days)
1.2 Cost of land				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		180		Average from sample as 333.3 baht/year (useful life 15 years)
- Pump		250		Average from sample as 725 baht/year (useful life 15 years)
- Pruning shear		15		46 baht/shear/rai (useful life 5 years)
- Hoe		100		Each of 150 baht and 2
-				hoes/rai (useful life 5 years)
- Big knife		60		Each of 120 baht and 2 knives/rai (useful life 2 years)
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Labor cost of planting orientation = 5 baht/point
- Planting cost				Para rubber = 70 plants/rai, Engle wood = 50 plants/rai
- Pruning				Year 1 th – 3 rd = 1 time/year(150 baht/day) (finished in 2 persons/rai)
- Apply fertilizer cost				Year 1 th - 5 th = 2 time/year(150 baht/day) (finished in 1 persons/rai)

Net present value of Engle wood in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Weed cost	120			1 time/year (labor cost =200 baht/day) (finished in 3 days/10 rai/2 persons) and year 25 th labor cost = 350 baht
- Injecting pesticides cost				Year 1 th – 3 rd = 1 time/year(150 baht/day (finished in 1 persons/rai)
- Activating cost				Source: Chantaratanawong (2004)
Material cost				
- Breeding cost of Engle wood				70 baht/plant(1 rai/260 plants)
- Herbicide				Year 1 th – 3 rd = 1 time/year
- Herbicide for weeding				Year 1 th – 3 rd = 3 times/year, year 4 th -25 th = 1 time/year (250 baht/day /rai)
- Inorganic fertilizer				Year 1 st = 0.5 kg./plant, year 2 nd -3 rd = 1 kg./plant, year 4 th – 5 th = 2 kg./plant(1 kg. = 20 baht)
- Organic fertilizer				Year 1 st = 0.5 kg./plant, year 2 nd -3 rd = 1 kg./plant, year 4 th – 5 th = 2 kg./plant(1 kg. = 12.5 baht)
- Electrical for water supply				
- Petrol cost for spraying and injection pumps	248			
1.5 Maintenances cost	500			
- Repairing cost of instrument	4.5			Year 1 st – 6 th = 200 baht, year 7 th – 15 th = 300 baht, year 16 th – 25 th = 500 baht

Net present value of Engle wood in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1.6 Land tax	1,082.5			Source: Punapaipong (2004)
Total cost of investment	248			
2. Income				
- Production	10,052.0			Source: Chantaratanawong (2004)
- Timber product	110,833.4			”
3. Net income	120,885.4			
4. NPV	110,928.6		189,001.6	Rate 8 %

Net present value of Rambutan in study area

(Unit: Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	560					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	487.5					
- Pump	1,481.3					
- Wheelbarrow	580					
- Hoe	300					
- Pruning shear(small branches)	113			113		
- Pruning shear(big branches)	46			46		
- plastic rope				50	50	50
- Bow saws				180		
- Fruit picker basket				200		
- Basket				400		
- Staircase Aluminum				400	400	400
- Soft sharpening stone						
- Hard sharpening stone						
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	100					100
- Pruning				280	280	
- Apply fertilizer cost				420	420	
- Weed cost	150	150	150	150	150	150
- Injecting pesticides cost		140	140	140	140	
- Injecting weedkiller cost		140	140	140	140	
- Harvesting						
- Braced branch				100	100	
- Digging pond	1,388.3					1,388.3
Material cost						
- Breeding cost of Rambutan	800					800
- Accelerate flowering fertilizer						
- Accelerate fertilizers						
- Post harvest fertilizer						
- Herbicide for weeding	338	338	338	338	338	338

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
- Wood for braced branch				3,000	3,000	
- Plastic rope				50	50	
- Herbicide	160	160	160	240	240	160
- Electrical for water supply	650	650	650	650	650	650
- Petrol cost for transportation						
- Plumbing pipe	1,750					1,750
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
- Repairing cost of plumbing pipe		100		100		
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,108.1	1,882	1,782	7,201	6,162	11,108.1
2. Income						
- Product						
- Timber product						
3. Net income						
4. NPV	-10,285.3	-1,742.6	-1,650	-6,667.6	-5,705.6	-10,285.3

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	7 th	8 th	9 th	10 th	11 st	12 nd
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow						
- Hoe					300	
- Pruning shear(small branches)			113			
- Pruning shear(big branches)			46			
- plastic rope	50	50	50	50	50	50
- Bow saws			180			
- Fruit picker basket			200			
- Basket		400				
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting pesticides cost	140	140	140	140	140	140
- Injecting weedkiller cost	140	140	140	140	140	140
- Harvesting	3,600	3,600	3,600	3,600	3,240	3,240
- Braced branch	100	100	100	100	100	100
- Digging pond	280	280	280	280	280	280
Material cost						
- Breeding cost of Rambutan						
- Accelerate flowering fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	7th	8th	9th	10th	11st	12nd
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	320	320	320	320	400	400
- Electrical for water supply	650	650	650	650	650	650
- Petrol cost for transportation	135	135	135	135	135	135
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,397	13,897	13,936	13,497	13,417	13,217
2. Income						
- Product	18,000	18,000	18,000	18,000	16,200	16,200
- Timber product						
3. Net income	18,000	18,000	18,000	18,000	16,200	16,200
4. NPV	4,262	3,799.1	3,763	4,169.4	2,576.9	2,762

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	13 rd	14 th	15 th	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				487.5		
- Pump				1,481.3		
- Wheelbarrow						
- Hoe				300		
- Pruning shear(small branches)		113				
- Pruning shear(big branches)		46				
- plastic rope	50	50	50	50	50	50
- Bow saws		180				
- Fruit picker basket		200				
- Basket	400					400
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting pesticides cost	140	140	140	140	140	140
- Injecting weedkiller cost	140	140	140	140	140	140
- Harvesting	3,240	3,240	3,240	2,880	2,880	2,880
- Braced branch	100	100	100	100	100	100
- Digging pond						
Material cost						
- Breeding cost of Rambutan						
- Accelerate flowering fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	13rd	14th	15th	16th	17th	18th
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	400	400	400	400	400	400
- Electrical for water supply	650	650	650	650	650	650
- Petrol cost for transportation	135	135	135	135	135	135
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	500	500	500
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,517	13,756	13,117	15,326	12,957	13,457
2. Income						
- Product	16,200	16,200	16,200	14,400	14,400	16,200
- Timber product						
3. Net income	16,200	16,200	16,200	14,400	14,400	16,200
4. NPV						

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	19 th	20 th	21 th	22 th	23 rd	24 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow		580				
- Hoe			300			
- Pruning shear(small branches)	113					
- Pruning shear(big branches)	46					
- plastic rope	50	50	50	50	50	50
- Bow saws	180					
- Fruit picker basket	200					
- Basket				400		
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting pesticides cost	140	140	140	140	140	140
- Injecting weedkiller cost	140	140	140	140	140	140
- Harvesting	2,880	2,880	2,880	2,880	2,880	2,880
- Braced branch	100	100	100	100	100	100
- Digging pond						
Material cost						
- Breeding cost of Rambutan						
- Accelerate flowering fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	19th	20th	21th	22th	23rd	24th
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	400	400	480	480	480	480
- Electrical for water supply	650	650	650	650	650	650
- Petrol cost for transportation	135	135	135	135	135	135
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	500	500	500	500	500	500
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,496	13,637	13,337	13,537	13,037	13,137
2. Income						
- Product	14,400	14,400	14,400	14,400	14,400	14,400
- Timber product						
3. Net income	14,400	14,400	14,400	14,400	14,400	14,400
4. NPV	837.0	706.5	984.3	799.1	1,262.0	1,169.4

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1. Investment cost				
				1 person/ 140 baht/day (finished in 2 days)
1.1 Site preparation cost				
1.2 Cost of land				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		250		Average from sample as 487.5 baht/year (useful life 15 years)
- Pump		500		Average from sample as 1,562.5 baht/year (useful life 15 years)
- Wheelbarrow		350		Average from sample as 580 baht/year (useful life 20 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Pruning shear (small branches)		30		Each of 113 baht and 1 shear/rai (useful life 5 years)
- Pruning shear(big branches)		15		Each of 46 baht and 1 shear/rai (useful life 5 years)
- plastic rope	50			Each of 50 baht and 1 plastic rope/rai
- Bow saws		60		Each of 180 baht and 1 bow saws /rai (useful life 5 years)
- Fruit picker basket		80		Each of 200 baht and 1 fruit picker basket /rai (useful life 5 year)
- Basket		160		Each of 100 baht and 4 basket /rai (useful life 5 year)
- Staircase Aluminum	400	180		Each of 1,200 baht and 1 staircase/3 rai (useful life 5 year)
- Soft sharpening stone	100	40		Each of 100 baht and 1 sharpening stone/rai

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Hard sharpening stone	100	40		Each of 100 baht and 1 sharpening stone/rai
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Labor cost of planting orientation = 5 baht/point(20 plant2/rai)
- Pruning	280			1 time/rai/year (140 baht/day) (finished in 2 persons/rai)
- Apply fertilizer cost	420			3 times/year (labor cost =140 baht/day) (finished in 1 days/rai/1 person)
- Weed cost	150			1 time/year (labor cost =150 baht/day)
- Injecting pesticides cost	140			1 time/year (labor cost =140 baht/day)
- Injecting weedkiller cost	140			1 time/year (labor cost =140 baht/day)
- Harvesting	2,880			1 kg. = 2 baht of labor cost
- Braced branch	100			5 baht/plant
- Digging pond				
Material cost				
- Breeding cost of Rambutan				800 baht/rai
- Accelerate flowering fertilizer	1,200			1 time/year/2 kg./plant (1 kg. = 20 baht)
- Accelerate fertilizers	1,200			1 time/year/2 kg./plant (1 kg. = 20 baht)
- Post harvest fertilizer	720			1 time/year/2 kg./plant (1 kg. = 12 baht)
- Herbicide for weeding	337.5			3 times/year (112.5 baht/time)
- Wood for braced branch	3,000			1 time/year

Net present value of Rambutan in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Plastic rope	50			1 plastic rope = 50 baht/1 rai
- Herbicide	480			1 times/year(1 liter = 160 baht) Year 1 st – 3 rd = 1 liter, year 4 th – 6 th = 1.5 liter, year 7 th – 10 th = 2.5 liter and year 21 st – 25 th = 3 liter
- Electrical for water supply	650			Average from sample
- Petrol cost for transportation	135			Average from sample
- Plumbing pipe				Average from sample
1.5 Maintenances cost				
- Repairing cost of instrument	500			Year 1st – 6th = 200 baht, 7th – 15th = 300 baht and year 16th – 25th = 500 baht
- Repairing cost of plumbing pipe				2 years/100 baht
1.6 Land tax	4.5			Source: Punapaipong (2004)
Total cost of investment	13,037			
2. Income				
- Product	14,400			1 rai = 2,000 kg., 1 kg. = 10 baht (100% production in year 6th – 10th, 10% reduce in year 11st – 15th and 20% reduce in year 16th – 25th)
- Timber product	3,000			150 baht/ plant(20 plants/rai)
3. Net income	19,205			
4. NPV	5,711.1		19,948.2	Rate 8%

Net present value of Oil palm in study area

(Unit: Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	800					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	247.6					
- Pump	514.3					
- Hoe	300					300
- Knife	240					240
- Scuffle hoe				200		
- Sickle						
- Basket				400		
- Staircase Aluminum						
- Soft sharpening stone						
- Hard sharpening stone						
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	220					
- Oil Palm planting cost	1,000	1,000	1,000	1,000	1,000	1,000
- Apply fertilizer cost				480	480	480
- Weed cost	110	110	110	110	110	110
- Injecting pesticides cost		133.3	133.3	133.3	133.3	133.3
- Injecting weedkiller cost		133.3	133.3	133.3	133.3	133.3
- Digging pond				2,400	2,400	2,400
- Harvesting	3,000					
Material cost						
- Breeding cost of oil palm	1,430					
- Herbicide					68.4	68.4
- Fertilizer	660	1,320	2,640	2,640	2,640	2,640
- Gloves				50	50	50
- Petrol cost for transportation			1,500	1,500	1,500	1,500
- Plumb	533.3					
- Plumbing pipe	3,333.3					

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	14,592.9	3,001.1	4,221.1	9,351.1	8,719.5	9,359.5
2. Income						
- Product						
- Timber product				12,312	12,312	12,312
3. Net income				12,312	12,312	12,312
4. NPV	-13,512	2,778.8	3,908.4	2,741.6	3,326.4	2,733.8

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	7 th	8 th	9 th	10 th	11 st	12 nd
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Hoe					300	
- Knife					240	
- Scuffle hoe			200			
- Sickle	100			100		
- Basket		400				
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Oil Palm planting cost						
- Apply fertilizer cost	480	480	480	480	480	480
- Weed cost	110	110	110	110	110	110
- Injecting pesticides cost	133.3	133.3	133.3	133.3	133.3	133.3
- Injecting weedkiller cost	133.3	133.3	133.3	133.3	133.3	133.3
- Digging pond						
- Harvesting	2,400	2,400	2,400	2,400	2,400	2,400
Material cost						
- Breeding cost of oil palm						
- Herbicide	68.4	68.4	68.4	68.4	68.4	68.4
- Fertilizer	2,640	2,640	2,640	2,640	2,640	2,640
- Gloves	50	50	50	50	50	50
- Petrol cost for transportation	1,500	1,500	1,500	1,500	1,500	1,500
- Plumb					533.3	
- Plumbing pipe						

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	7 th	8 th	9 th	10 th	11 st	12 nd
1.5 Maintenances cost						
- Repairing cost of instrument	300.0	300.0	300.0	300.0	300.0	300.0
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	8,119.5	8,519.5	8,219.5	8,219.5	9,092.8	8,119.5
2. Income						
- Product	12,312	12,312	12,312	12,312	12,312	12,312
- Timber product						
3. Net income	12,312	12,312	12,312	12,312	12,312	12,312
4. NPV	3,881.9	3,511.6	3,789.4	3,789.4	2,980.7	3,881.9

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	13 rd	14 th	15 th	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				247.6		
- Pump				514.3		
- Hoe				300		
- Knife				240		
- Scuffle hoe		200				
- Sickle	100			100		
- Basket	400					400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Oil Palm planting cost						
- Apply fertilizer cost	480	480	480	480	480	480
- Weed cost	110	110	110	110	110	110
- Injecting pesticides cost	133.3	133.3	133.3	133.3	133.3	133.3
- Injecting weedkiller cost	133.3	133.3	133.3	133.3	133.3	133.3
- Digging pond						
- Harvesting	2,400	2,400	2,400	2,400	2,400	2,400
Material cost						
- Breeding cost of oil palm						
- Herbicide	68.4	68.4	68.4	68.4	68.4	68.4
- Fertilizer	2,640	2,640	2,640	2,640	2,640	2,640
- Gloves	50	50	50	50	50	50
- Petrol cost for transportation	1,500	1,500	1,500	1,500	1,500	1,500
- Plumb					533.3	
- Plumbing pipe						

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	13 rd	14 th	15 th	16 th	17 th	18 th
1.5 Maintenances cost						
- Repairing cost of instrument	300.0	300.0	300.0	300.0	300.0	300.0
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	8,119.5	8,519.5	8,219.5	8,219.5	9,092.8	8,119.5
2. Income						
- Product	12,312	12,312	12,312	12,312	12,312	12,312
- Timber product						
3. Net income	12,312	12,312	12,312	12,312	12,312	12,312
4. NPV	3,881.9	3,511.6	3,789.4	3,789.4	2,980.7	3,881.9

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	19 th	20 th	21 st	22 nd	23 rd	24 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Hoe			300			
- Knife			240			
- Scuffle hoe	200					
- Sickle	100			100		
- Basket				400		
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Oil Palm planting cost						
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Oil Palm planting cost						
- Apply fertilizer cost	480	480	480	480	480	480
- Weed cost	110	110	110	110	110	110
- Injecting pesticides cost	133.3	133.3	133.3	133.3	133.3	133.3
- Injecting weedkiller cost	133.3	133.3	133.3	133.3	133.3	133.3
- Digging pond						
- Harvesting	2,400	2,400	2,400	2,400	2,400	2,400
- Plumb			533.3			
- Plumbing pipe						

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	19 th	20 th	21 st	22 nd	23 rd	24 th
1.5 Maintenances cost						
- Repairing cost of instrument	500	500	500	500	500	500
- Repairing cost of plumbing pipe		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	8,519.5	8,519.5	8,519.5	8,519.5	8,519.5	8,519.5
2. Income						
- Product	12,312	12,312	12,312	12,312	12,312	12,312
- Timber product						
3. Net income	12,312	12,312	12,312	12,312	12,312	12,312
4. NPV	3,511.6	3,696.8	2,795.6	3,233.8	3,789.4	3,696.8

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				1person/150baht/day(finished in 2 days)
1.2 Cost of land				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		250		Average from sample as 247.6 baht/year(useful life15 years)
- Pump		180		Average from sample as 514.3 baht/year(useful life15 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Knife		60		Each of 120 baht and 2 knives/rai (useful life 2 years)
- Scuffle hoe		80		Each of 120 baht and 2 scuffle hoes/rai (useful life 2 years)
- Sickle		60		Each of 100 baht and 1 sickle/rai (useful life 3 years)
- Basket	100	140		Each of 100 baht and 4 baskets/rai (useful life 5 years)
- Soft sharpening stone		40		Each of 100 baht and 1 stone/rai (useful life 1 years)
- Hard sharpening stone				Each of 200 baht and 2 stone/rai (useful life 4 years)
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Planting orientation = 22 plant2/rai (labor cost = 220 baht/rai)
- Oil Palm planting cost				1 times/year (labor cost =200 baht/day) (5 labors/rai)

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Apply fertilizer cost	480			3 times/year (labor cost =200 baht/day) (4 labors/35 rais) (finished in 7 days)
- Weed cost	110			1 times/year (labor cost =5 baht/plant/day)
- Injecting pesticides cost	133.3			1 times/year (labor cost =140 baht/day) (4 labors/30 rai and finished in 5 days)
- njecting weedkiller cost	133.3			1 times/year (labor cost =140 baht/day) (4 labors/30 rai and finished in 5 days)
- Digging pond				Average from sample = 3000 baht/rai
- Harvesting	2,400			24 times/year (labor cost =200 baht/rai)
Material cost				
- Breeding cost of oil palm				Be contributed
- Herbicide	68.4			
- Fertilizer	2,640			3 times/year(1 kg. = 20 baht) Year 1 st = 0.5 kg./plant, year 2 nd = 1 kg./plant, year 3 rd = 2 kg./plant)
- Gloves	50			Each of 50 baht/rai (useful life 1 years)
- Petrol cost for transportation	1,500			
- Plumb				Two Plumbs = 8,000 baht/30 rai (Useful life = 10 years)
- Plumbing pipe				
1.5 Maintenances cost				
- Repairing cost of instrument	500			Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht, 16 th -26 th =500 baht

Net present value of Oil palm in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Repairing cost of plumbing pipe				Repairing cost = 100 baht/year/rai (2 years/times)
1.6 Land tax	4.5			Source:Punapaipong (2004)
Total cost of investment				
2. Income	8,219.5			
- Product	12,312			Product 1 rai = 144 kg. (1 kg. = 4.5 baht)
- Timber product	4,400			Timber product = 200 baht/plant
3. Net income	17,662			
4. NPV	8,743.1		60,601.7	Rate 8%

Net present value of Mangosteen plantation in study area

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	560					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	373.8					
- Pump	1,181.3					
- Wheelbarrow	530					
- Hoe	300					300
- Pruning shear(small branches)	113			113		
- Pruning shear(big branches)	46			46		
- plastic rope				50	50	50
- Bow saws				180		
- Fruit picker basket				200		
- Basket				400		
- Staircase Aluminum				400	400	400
- Soft sharpening stone						
- Hard sharpening stone						
1.4 Arrangement cost						
Labor cost						
-Planting orientation cost	100					
-Pruning				280	280	280
-Apply fertilizer cost				420	420	420
-Weed cost	150	150	150	150	150	150
-Injecting Weed cost		140	140	140	140	140
-Injecting pesticides cost		140	140	140	140	140
-Harvesting						
-Braced branch				100	100	100
-Digging pond	1,055					
Material cost						
-Breeding cost of Mangos teen plantation	550					

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
- Accelerate flowering fertilizer						1,200
- Accelerate fertilizers						1,200
- Post harvest fertilizer						
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5
- Wood for braced branch				3,000	3,000	3,000
- Plastic rope				50	50	50
- Herbicide	160	160	160	240	240	240
- Electrical for water supply	500	500	500	500	500	500
- petrol cost for transportation						120
- Plumbing pipe	1,600					
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	9,761	1,732	1,632	7,051	6,012	12,352
2. Income						
- Product						
- Timber product						18,000
3. Net income						18,000
4. NPV	-9,038	-1,603.7	-1,511.1	6,528.7	5,566.7	5,229.6

1943

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow						
- Hoe					300	
- Pruning shear (small branches)			113			
- Pruning shear (big branches)			46			
- plastic rope	50	50	50	50	50	50
- Bow saws				180		
- Fruit picker basket				200		
- Basket			400			
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	2,700	2,700	2,700	2,700	2,430	2,430
- Braced branch	100	100	100	100	100	100
- Digging pond						
Material cost						
- Breeding cost of Mangos teen plantation	550					

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	7st	8nd	9rd	10th	11th	12th
- Accelerate flowering fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	320	320	320	320	400	400
- Electrical for water supply	500	500	500	500	500	500
- petrol cost for transportation	120	120	120	120	120	120
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	12,332	12,832	12,871	12,432	12,442	12,242
2. Income						
- Product						
- Timber product	18,000	18,000	18,000	16,200	16,200	16,200
3. Net income	18,000	18,000	18,000	16,200	16,200	16,200
4. NPV	-9,038	-1,603.7	-1,511.1	6,528.7	5,566.7	5,229.6

1943

Net present value of Mangosteen plantation in study area (Continued)

(Unit: Baht/rai)

Year	7 th	8 th	9 th	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow						
- Hoe					300	
- Pruning shear (small branches)			113			
- Pruning shear(big branches)			46			
- plastic rope	50	50	50	50	50	50
- Bow saws			180			
- Fruit picker basket			200			
- Basket		400				
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	2,700	2,700	2,700	2,700	2,430	2,430
- Braced branch	100	100	100	100	100	100
- Digging pond						
Material cost						
- Breeding cost of Mangos teen plantation						

Net present value of Mangosteen plantation in study area (Continued)

(Unit: Baht/rai)

Year	7th	8th	9th	10th	11th	12th
- Accelerate flowering						
fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	338	338	338	338	338	338
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	320	320	320	320	400	400
- Electrical for water supply	500	500	500	500	500	500
- petrol cost for transportation	120	120	120	120	120	120
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing	1,200	1,200	1,200	1,200	1,200	1,200
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment						
2. Income	12,332	12,832	12,871	12,432	12,442	12,242
- Product	18,000	18,000	18,000	16,200	16,200	16,200
- Timber product						
3. Net income	18,000	18,000	18,000	16,200	16,200	16,200
4. NPV	5,248.1	4,785.2	4,749.1	3,488.9	3,479.6	3,664.8

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	13 st	14 nd	15 rd	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				373.8		
- Pump				1,181.3		
- Wheelbarrow						
- Hoe				300		
- Pruning shear (small branches)		113				
- Pruning shear(big branches)		46				
- plastic rope	50	50	50	50	50	50
- Bow saws		180				
- Fruit picker basket		200				
- Basket	400					400
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	2,430	2,430	2,430	2,160	2,160	2,160
- Braced branch	100	100	100	100	100	100
- Digging pond						
Material cost						
- Breeding cost of Mangos teen plantation						

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
- Accelerate flowering fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	400	400	400	480	480	480
- Electrical for water supply	500	500	500	500	500	500
- petrol cost for transportation	120	120	120	120	120	120
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	500	500	500
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	12,542	12,781	12,142	14,027	12,027	12,572
2. Income						
- Timber product						
- Mangos teen product	16,200	14,400	14,400	14,400	14,400	14,400
3. Net income	16,200	14,400	14,400	14,400	14,400	14,400
4. NPV	3,387	1,499.1	2,090.7	345.4	2,155.6	1,692.6

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	19 st	20 nd	21 rd	22 th	23 th	24 ^h
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow		530				
- Hoe			300			
- Pruning shear (small branches)	113					
- Pruning shear (big branches)	46					
- plastic rope	50	50	50	50	50	50
- Bow saws	180					
- Fruit picker basket	200					
- Basket				400		
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	2,160	2,160	2,160	2,160	2,160	2,160
- Braced branch	100	100	100	100	100	100
- Digging pond						
Material cost						
- Breeding cost of Mangos teen plantation						

Net present value of Mangosteen plantation in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
- Accelerate flowering fertilizer	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer	720	720	720	720	720	720
- Herbicide for weeding	337.5	337.5	337.5	337.5	337.5	337.5
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	400	400	400	480	480	480
- Electrical for water supply	500	500	500	500	500	500
- petrol cost for transportation	120	120	120	120	120	120
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	500	500	500	500	500	500
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	12,611	12,702	12,452	14,652	12,152	12,252
2. Income						
- Timber product						
- Mangos teen product	14,400	14,400	14,400	14,400	14,400	14,400
3. Net income	14,400	14,400	14,400	14,400	14,400	14,400
4. NPV	1,656.5	1,572.2	1,803.7	1,618.5	2,081.5	1,988.9

Net present value of Mangosteen plantation in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remain der cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				
				1 person/140baht/day (finished in 2 days)
1.2 Cost of land				
				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		250		Average from sample as373.8baht/year(useful life15 years)
- Pump		500		Average from sample as846.4baht/year(useful life15 years)
- Wheelbarrow		350		Average from sample as1,481.3baht/year(useful life20years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Pruning shear(small branches)		30		Each of 113 baht and 1piece/rai (useful life 5 years)
- Pruning shear(big branches)		15		Each of 46 baht and 1piece/rai (useful life 5 years)
- plastic rope	50			Each of 50 baht and 1role/rai
- Bow saws		60		Each of 180 baht and 1piece/rai (useful life 5 years)
- Fruit picker basket		80		Each of 200 baht and 1piece/rai (useful life 5 years)
- Basket		160		Each of 100 baht and 4pieces/rai (useful life 5 years)
- Staircase Aluminum	400	180		Each of 1,200 baht/3 raies and 1piece/rai (useful life 5 years)
- Soft sharpening stone	100	40		Each of 100 baht and 1piece/rai (Every year)

Net present value of Mangosteen plantation in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remain der cost	NPV	Remarks
- Hard sharpening stone	100	40		Each of 100 baht and 1piece/rai (Every year)
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Planting orientation = 20x5 m. = 100 plant/rai
- Pruning	280			140 baht/time(Twice a year)
- Apply fertilizer cost	420			3 times/year (labor cost =140 baht/day)
- Weed cost	150			1 times/year & total 30 trees (labor cost = 5 baht/a tree)
- Injecting Weed cost	140			1 times/year (labor cost =140 baht/day)
- Injecting pesticides cost	133.3			1 times/year (labor cost =140 baht/day)
- Harvesting	2,160			3 baht/ 1 kg.
- Braced branch	100			5 baht/ a tree
- Digging pond				
Material cost				
- Breeding cost of Mangos teen plantation				(800 baht/rai)
- Accelerate flowering fertilizer	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate fertilizers	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Post harvest fertilizer	720			1 bag = 900 baht (1 bag = 50 kg.) (2 kg./plant)
- Herbicide for weeding	337.5			3times/10 raies (Lite =112.5 baht/rai)
- Wood for braced branch	3,000			1 time/year (5 pieces/ 1 plant) (1 piece = 20 baht)
- Plastic rope	50			50 baht/ role / rai

Net present value of Mangosteen plantation in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remain der cost	NPV	Remarks
- Herbicide	480			(4 times/year, year 1 st – 4 th = 1 lite, year 5 th – 6 th = 11.5 lites, year 7 th -10 th = 2 lites, year 11 st – 20 th = 2.5 lites and year 21 st – 25 th = 3 lites. (1 lite = 160 baht)
- Electrical for water supply	500			650 baht / rai
- petrol cost for transportation	120			135 baht / rai
- Plumbing pipe				1,600 baht / rai
1.5 Maintenances cost				
- Repairing costof instrument	500			Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht,16 th - 26 th =500 baht
- Pipe Repairing				100 baht (time / 2 years)
1.6 Land tax	4.5			Source:Punapaipong (2004)
Total cost of investment	12,152			
2. Income				
- Timber product	4,500			150 baht / a tree
- Mangos teen product	14,400			650 kg./rai and 1 kg. = 20 kg.(product of 6-10 th year = 100%, 11-15 th = decrease 10%, 16-25 th =decrease 40%)
3. Net income	20,705			
4. NPV	7,919.4		36,208.3	Rate 8%

Net present value of Mixed fruit orchard in study area

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	560					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	466.7					
- Pump	2,666.7					
- Wheelbarrow	775					
- Hoe	300					300
- Pruning shear (small branches)	113			113		
- Pruning shear(big branches)	46			46		
- plastic rope				50	50	50
- Bow saws				180		
- Fruit picker basket				200		
- Basket				400		
- Staircase Aluminum				400	400	400
- Soft sharpening stone						
- Hard sharpening stone						
1.4 Arrangement cost						
Labor cost	140					
- Planting orientation cost				280	280	280
- Pruning				420	420	420
- Apply fertilizer cost	150	150	150	150	150	150
- Weed cost		140	140	140	140	140
- Injecting Weed cost		140	140	140	140	140
- Injecting pesticides cost				3,250	3,250	3,250
- Harvesting				150	150	150
- Braced branch	1,388.3					
- Digging pond				280	280	280
Material cost						
- Breeding cost of Long-Kong	275					
- Breeding cost of Mangosteen	275					

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
- Accelerate flowering fertilizer Mangosteen						1,200
- Accelerate fertilizers Mangosteen						1,200
- Post harvest fertilizer Mangosteen						1,080
- Accelerate flowering fertilizer Long-Kong				1,200	1,200	1,200
- Accelerate fertilizers Long-Kong				1,200	1,200	1,200
- Post harvest fertilizer Long-Kong						1,080
- Herbicide for weeding	142.8	142.8	142.8	142.8	142.8	142.8
- Wood for braced branch				3,000	3,000	3,000
- Plastic rope				50	50	50
- Herbicide	160	160	160	240	240	240
- Electrical for water supply	400	400	400	400	400	400
- petrol cost for transportation				169.7	169.7	169.7
- Plumbing pipe	1,100					
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,162.9	1,437.3	1,337.3	12,626.0	11,587	16,547
2. Income						
- Product Mangosteen						13,000
- Product Long-Kong				10,000	10,000	10,000
- Timber product						
3. Net income				10,000	10,000	23,000
4. NPV	-10,336	-1,330.8	-1,238.2	-2,431.5	-1,469.4	5,975

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow						
- Hoe					300	
- Pruning shear(small branches)			113			
- Pruning shear(big branches)			46			
- plastic rope	50	50	50	50	50	50
- Bow saws			180			
- Fruit picker basket			200			
- Basket		400				
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	3,250	3,250	3,250	3,250	3,250	3,250
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of Long-Kong						
- Breeding cost of Mangosteen						

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	7st	8nd	9rd	10th	11th	12th
- Accelerate flowering fertilizer Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Mangosteen	1,080	1,080	1,080	1,080	1,080	1,080
- Accelerate flowering fertilizer Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Long- Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Long- Kong	1,080	1,080	1,080	1,080	1,080	1,080
- Herbicide for weeding	142.8	142.8	142.8	142.8	142.8	142.8
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	320	320	320	320	400	400
- Electrical for water supply	400	400	400	400	400	400
- petrol cost for transportation	169.7	169.7	169.7	169.7	169.7	169.7
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	16,527	17,027	17,066	16,627	16,907	16,707
2. Income						
- Product Mangosteen	13,000	13,000	13,000	11,700	11,700	11,700
- Product Long-Kong	10,000	10,000	10,000	9,000	9,000	9,000
- Timber product						
3. Net income	23,000	23,000	23,000	20,700	20,700	20,700
4. NPV	5,993.5	5,530.6	5,494.5	3,771.3	3,512.0	3,697.2

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	13 st	14 nd	15 rd	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				466.7		
- Pump				2,666.7		
- Wheelbarrow						
- Hoe				300		
- Pruning shear (small branches)		113				
- Pruning shear(big branches)		46				
- plastic rope	50	50	50	50	50	50
- Bow saws		180				
- Fruit picker basket		200				
- Basket	400					400
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	3,250	3,250	3,250	3,250	3,250	3,250
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of Long-Kong						
- Breeding cost of Mangosteen						

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
- Accelerate flowering fertilizer Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Mangosteen	1,080	1,080	1,080	1,080	1,080	1,080
- Accelerate flowering fertilizer Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Long- Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Long- Kong	1,080	1,080	1,080	1,080	1,080	1,080
- Herbicide for weeding	142.8	142.8	142.8	142.8	142.8	142.8
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	400	400	400	400	400	400
- Electrical for water supply	400	400	400	400	400	400
- petrol cost for transportation	169.7	169.7	169.7	169.7	169.7	169.7
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	500	500	500
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	17,007	17,246	16,607	20,340	16,807	17,307
2. Income						
- Product Mangosteen	11,700	11,700	11,700	10,400	10,400	10,400
- Product Long-Kong	9,000	9,000	9,000	8,000	8,000	8,000
- Timber product						
3. Net income	20,700	20,700	20,700	18,400	18,400	18,400
4. NPV	3,419.5	3,198.2	3,789.8	-1,796.6	1,475	1,012

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow		775				
- Hoe			300			
- Pruning shear (small branches)	113					
- Pruning shear(big branches)	46					
- plastic rope	50	50	50	50	50	50
- Bow saws	180					
- Fruit picker basket	200					
- Basket				400		
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	140	140	140	140	140	140
- Injecting pesticides cost	140	140	140	140	140	140
- Harvesting	3,250	3,250	3,250	3,250	3,250	3,250
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of Long-Kong						

Net present value of Mixed fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
- Breeding cost of Mangosteen						
- Accelerate flowering fertilizer Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Mangosteen	1,080	1,080	1,080	1,080	1,080	1,080
- Accelerate flowering fertilizer Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Long- Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Long- Kong	1,080	1,080	1,080	1,080	1,080	1,080
- Herbicide for weeding	142.8	142.8	142.8	142.8	142.8	142.8
- Wood for braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- Plastic rope	50	50	50	50	50	50
- Herbicide	400	400	480	480	480	480
- Electrical for water supply	400	400	400	400	400	400
- petrol cost for transportation	169.7	169.7	169.7	169.7	169.7	169.7
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	500	500	500	500	500	500
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	17,346	17,682	17,187	17,387	16,887	16,987
2. Income						
- Product Mangosteen	10,400	10,400	10,400	10,400	10,400	10,400
- Product Long-Kong	8,000	8,000	8,000	8,000	8,000	8,000
- Timber product						
3. Net income	18,400	18,400	18,400	18,400	18,400	18,400
4. NPV	975.9	664.8	1,123.2	938	1,400.9	1,308.3

Net present value of Mixed fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remaind er cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				
				1 person/140baht/day (finished in 2 days)
1.2 Cost of land				
				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		250		Average from sample as466.7baht/year(useful life 15 years)
- Pump		500		Average from sample as2666.7baht/year(useful life 15 years)
- Wheelbarrow		350		Average from sample as755baht/year(useful life 15 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Pruning shear (small branches)		30		Each of 113 baht and 1piece/rai (useful life 5 years)
- Pruning shear(big branches)		15		Each of 46 baht and 1piece/rai (useful life 5 years)
- plastic rope	50			Each of 50 baht and 1role/rai
- Bow saws		60		Each of 180 baht and 1piece/rai (useful life 5 years)
- Fruit picker basket		80		Each of 200 baht and 1piece/rai (useful life 5 years)
- Basket		160		Each of 100 baht and 4pieces/rai (useful life 5 years)
- Staircase Aluminum	400	180		Each of 1,200 baht/3 raies and 1piece/rai (useful life 5 years)
- Soft sharpening stone	100	40		Each of 100 baht and 1piece/rai (Every year)

Net present value of Mixed fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remaind er cost	NPV	Remarks
- Hard sharpening stone	100	40		Each of 100 baht and 1piece/rai (Every year)
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				1 labor/1 rai(1 labor cost = 140 baht)
- Pruning	280			140 baht/time(Twice a year)
- Apply fertilizer cost	420			3 times/year (labor cost =140 baht/day)
- Weed cost	150			1 times/year & total 30 trees (labor cost = 5 baht/a tree)
- Injecting Weed cost	140			1 times/year (labor cost =140 baht/day)
- Injecting pesticides cost	140			1 times/year (labor cost =140 baht/day)
- Harvesting	3,250			5 baht/ 1 kg. (product = 650 kg./rai)
- Braced branch	150			5 baht/ a tree
- Digging pond				
Material cost				
- Breeding cost of Long-Kong				
- Breeding cost of Mangosteen				
- Accelerate flowering fertilizer Mangosteen	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate fertilizers Mangosteen	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Post harvest fertilizer Mangosteen	1,080			1 bag = 900 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate flowering fertilizer Long-Kong	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate fertilizers Long- Kong	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)

Net present value of Mixed fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remaind er cost	NPV	Remarks
- Post harvest fertilizer Long-Kong	1,080			1 bag = 900 baht (1 bag = 50 kg.) (2 kg./plant)
- Herbicide for weeding	143			2 times/7 raies (Lite =100 baht/rai)
- Wood for braced branch	3,000			1 time/year (5 pieces/ 1 plant) (1 piece = 20 baht)
- Plastic rope	50			50 baht/ role / rai
- Herbicide	480			(4 times/year, year 1 st – 4 th = 1 lite, year 5 th – 6 th = 11.5 lites, year 7 th -10 th = 2 lites, year 11 st – 20 th = 2.5 lites and year 21 st – 25 th = 3 lites. (1 lite = 160 baht)
- Electrical for water supply	400			
- petrol cost for transportation	169.7			
- Plumbing pipe				1,100 baht / rai
1.5 Maintenances cost				
- Repairing cost of instrument	500			Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht, 16 th - 26 th =500 baht
- Pipe Repairing				100 baht (time / 2 years)
1.6 Land tax	4.5			Source:Punapaipong (2004)
Total cost of investment	16,887			
2. Income				
- Product Mangosteen	10,400			650 kg./rai and 1 kg. = 20 kg.(product of 6-10 th year = 100%, 11-15 th = decrease 10%, 16-25 th =decrease 40%)
- Product Long-Kong	8,000			650 kg./rai and 1 kg. = 10 kg.(product of 6-10 th year = 100%, 11-15 th = decrease 10%, 16-25 th =decrease 40%)
- Timber product	4,500			
3. Net income	24,705			
4. NPV	7,238.9		41,916.1	Rate 8%

Net present value of Para rubber plantaion in study area.

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	480					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	700					
- Wheelbarrow	450					
- Hoe	300					300
- Big knife	240					240
- Rubber tapping knife						
- Cup for rubber latex						
- Wire						
- Tube for latex						
- Besom for latex						
- Soft sharpening stone						
- Hard sharpening stone						
- Acetylene lamp						
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	300					
- Planting of Para rubber	650					
- Planting of Pine apple	600					
- Pruning		480	480	480	480	480
- Apply fertilizer cost	360	360	360	240	240	240
- Weed cost	70	70	70	70	70	70
- Injecting pesticides cost		480	480	480	480	480
- Harvesting						7,840
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Pine Apple	890					
- Herbicide					120	120
- Fertilizer					1,400	1,400
- Acid						30
- Chemical						30

Net present value of Para rubber plantaion in study area.

(Unit:Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	7,244.5	1,594.5	1,594.5	1,474.5	2,994.5	3,534.5
2. Income						
- Product						
- Pine Apple product	24,000	19,200	14,400			
- Timber product						
3. Net income	24,000	19,200	14,400			
4. NPV	15,514.4	16,301.4	11,856.9	-1,365.3	-2,772.7	-3,272.7

Net present value of Para rubber plantaion in study area.

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Wheelbarrow						
- Hoe					300	
- Big knife					240	
- Rubber tapping knife	520		520		520	
- Cup for rubber latex	315					
- Wire	122.5					
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp	400				400	
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Planting of Para rubber						
- Planting of Pine apple						
- Pruning						
- Apply fertilizer cost	120	120	120	120	120	120
- Weed cost	70	70	70	70	70	70
- Injecting pesticides cost	480	480	480	480	480	480
- Harvesting	7,840	7,840	7,840	7,840	7,056	7,056
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Pine Apple						

Net present value of Para rubber plantaion in study area (Continued)

(Unit:Baht/rai)

Year	7st	8nd	9rd	10th	11th	12th
- Herbicide	120	120	120	120	120	120
- Fertilizer	2,800	2,800	2,800	2,800	2,800	2,800
- Acid	30	30	30	30	27	27
- Chemical	30	30	30	30	27	27
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,557	12,024.5	12,719.5	12,024.5	12,869.5	11,234.5
2. Income	19,600	19,600	19,600	19,600	17,640	17,640
- Product						
- Pine Apple product						
- Timber product						
3. Net income	19,600	19,600	19,600	19,600	17,640	17,640
4. NPV	5,595.4	7,014.4	6,370.8	7,014.4	4,417.1	5,931

Net present value of Para rubber plantaion in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				700		
- Wheelbarrow						
- Hoe				300		
- Big knife				240		
- Rubber tapping knife	520		520		520	
- Cup for rubber latex			315			
- Wire						
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp			400			
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Planting of Para rubber						
- Planting of Pine apple						
- Pruning						
- Apply fertilizer cost	120	120	120	120	120	120
- Weed cost	70	70	70	70	70	70
- Injecting pesticides cost	480	480	480	480	480	480
- Harvesting	7,056	7,056	7,056	6,350.4	6,350.4	6,350.4
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Pine Apple						
- Herbicide	120	120	120	120	120	120
- Fertilizer	2,800	2,800	2,800	2,800	2,800	2,800
- Acid	27	27	27	24.3	24.3	24.3
- Chemical	27	27	27	24.3	24.3	24.3

Net present value of Para rubber plantaion in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	500	500	500
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,929.5	11,234.5	12,644.5	11,963.5	11,418.5	10,723.5
2. Income						
- Product	17,640	17,640	17,640	15,876	15,876	15,876
- Pine Apple product						
- Timber product						
3. Net income	17,640	17,640	17,640	15,876	15,876	15,876
4. NPV	5,287.5	5,931.0	4,625.5	3,622.7	4,127.3	4,770.8

Net present value of Para rubber plantaion in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Wheelbarrow		135				
- Hoe			300			
- Big knife			240			
- Rubber tapping knife	520		520		520	
- Cup for rubber latex					315	
- Wire		123				
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp	400				400	
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Planting of Para rubber						
- Planting of Pine apple						
- Pruning						
- Apply fertilizer cost	120	120	120	120	120	120
- Weed cost	70	70	70	70	70	70
- Injecting pesticides cost	480	480	480	480	480	480
- Harvesting	6,350.4	6,350.4	6,350.4	6,350.4	6,350.4	6,350.4
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Pine Apple						
- Herbicide	120	120	120	120	120	120
- Fertilizer	2,800	2,800	2,800	2,800	2,800	2,800
- Acid	24.3	24.3	24.3	24.3	24.3	24.3
- Chemical	24.3	24.3	24.3	24.3	24.3	24.3

Net present value of Para rubber plantaion in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
1.5 Maintenances cost						
Repairing cost of instrument	500	500	500	500	500	500
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,818.5	10,981.0	11,958.5	10,723.5	12,133.5	10,723.5
2. Income						
- Product	15,876	15,876	15,876	15,876	15,876	15,876
- Pine Apple product						
- Timber product						
3. Net income	15,876	15,876	15,876	15,876	15,876	15,876
4. NPV	3,756.9	4,532.4	3,627.3	4,770.8	3,465.3	4,770.8

Net present value of Para rubber plantaion in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				1 person/140baht/day (finished in 2 days)
1.2 Cost of land				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		250		Average from sample as 700 baht/year(useful life15 years)
- Wheelbarrow		100		(useful life 20 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Big knife		60		Each of 120 baht and 2 knife/rai (useful life 2 years)
- Rubber tapping knife	520	100		Each of 130 baht and 4 knife/rai (useful life 2 years)
- Cup for rubber latex		84		Each of 4.5 baht and 70 piece/rai (useful life 8 years)
- Wire		14		Each of 1.75 baht and 70 wire/rai (useful life 13 years)
- Tube for latex	175	70		Each of 2.5 baht and 70 piece/rai (useful life 2 years)
- Besom for latex	30	12		Each of 5 baht and 6 pieces/rai (every year use)
- Soft sharpening stone	100	40		Each of 100 baht and 1 piece/rai (every year use)
- Hard sharpening stone	100	40		Each of 200 baht and 2 pieces/rai (useful life 4 years)
- Acetylene lamp		180		
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Be contributed
- Planting of Para rubber				120 baht/time/5 labors
- Planting of Pine apple				120 baht/time/5 labors

Net present value of Para rubber plantaion in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Pruning				2 times/year/2 labors (only in year 1 st – 6 th) 3 times/year in year 1 st – 3 rd , 2 times/year in year 4 th – 6 th , 1 time/year in after year 7 th (1 labor/rai, 1 labor = 120 baht)
- Apply fertilizer cost	120			1 times/year (1 baht/ a tree)
- Weed cost	70			2 times/year in year 2 nd -10 th , 1 time/year in year 11 st – 25 th (1 labor = 120 baht)
- Injecting pesticides cost	480			Productive labor as 60:40(product : labor)
- Harvesting	6,350.4			
Material cost				
- Breeding cost of Para rubber				Be contributed
- Breeding cost of Pine Apple				890 baht/rai
- Herbicide	120			Be contributed
- Fertilizer	2,800			In year 1 st – 4 th is contributed, year 5 th – 6 th (1 time/year, 1 plant/1 kg.), year 7 th -25 th (2 times/year, 1 plant/1 kg.) (1 kg. = 20 baht)
- Acid	24.3			3 bottoms/rai/year(1 bottom = 10 baht), in year 7 th – 10 th can produce 100%, in year 11 st – 15 th product were decreased 10%, in year 16 th – 25 th product were decreased 20%,

Net present value of Para rubber plantaion in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Chemical	24.3			1.5 kg./rai/year (1 kg. = 20 baht), in year 7 th – 10 th can produce 100%, in year 11 st – 15 th product were decreased 10%, in year 16 th – 25 th product were decreased 20%,
1.5 Maintenances cost				
- Repairing cost of instrument	500			Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht, 16 th - 26 th =500 baht
Total cost of investment	11,418.5			
2. Income				
- Product	15,876.0			1 rai can produce 560 kg./year 6,000 pine apple/rai(1 pine apple = 4 baht). In year 1 st can produce 100%, in year 2 nd product were decreased 20%, in year 3 rd product were decreased 40%
- Pine Apple product				
- Timber product	12,600			
3. Net income	29,526			
			142,659.	
4. NPV	16,766.2		7	Rate 8%

Net present value of Engle wood/Para rubber in study area

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	480					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	700					
- Plumb	975					
- Wheelbarrow	360					
- Hoe	300					
- Big knife	240					
- Rubber tapping knife						
- Cup for rubber latex						
- Wire						
- Tube for latex						
- Besom for latex						
- Soft sharpening stone						
- Hard sharpening stone						
- Acetylene lamp						
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	600					
- Pruning	240	240	240	240	240	240
- Apply fertilizer cost	600	600	600	240	240	240
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost	310	540	540	480	480	480
- Harvesting						
- Activating cost					2,760	3,680
Material cost						
- Breeding cost of Para rubber	1,050					
- Breeding cost of Engle wood	2,500					
- Herbicide	120	120	120	120	120	120
- Fertilizer (Para rubber)					1,400	1,400
- Fertilizer (Engle wood)	2,600	5,200	5,200	10,400	10,400	
- Inorganic fertilizer	1,625	3,250	3,250	6,500	6,500	

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
- Acid						
- Chemical						
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
- Electrical for water supply	1,800	1,800	1,000	1,000	1,000	1,000
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	17,072.5	12,322.5	11,522.5	19,552.5	23,712.5	8,152.5
2. Income						
- Product Para rubber						
- Product of Engle wood						
- Timber product of Engle wood						2,523
- Timber product Para rubber						
3. Net income						2,523
4. NPV	-15,807.9	-11,409.7	-10,669.0	-18,104.2	-21,956.0	-5,212.5

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Plumb						
- Wheelbarrow						
- Hoe					300	
- Big knife					240	
- Rubber tapping knife	520		520		520	
- Cup for rubber latex	315					
- Wire	123					
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp	400				400	
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning						
- Apply fertilizer cost	120	120	120	120	120	120
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost	480	480	480	480	480	480
- Harvesting	7,840	7,840	7,840	7,840	7,056	7,056
- Activating cost	3,680					
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Engle wood	2,500					
- Herbicide	120	120	120	120	120	120
- Fertilizer (Para rubber)	2,800	2,800	2,800	2,800	2,800	2,800
- Fertilizer (Engle wood)						
- Inorganic fertilizer						

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	7st	8nd	9rd	10th	11th	12th
- Acid	30	30	30	30	27	27
- Chemical	30	30	30	30	27	27
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
- Electrical for water supply	1,000	1,000	1,000	1,000	1,000	1,000
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	21,035.0	13,322.5	14,017.5	13,322.5	14,167.5	12,532.5
2. Income						
- Product Para rubber	19,600	19,600	19,600	19,600	17,640	17,640
- Product of Engle wood	10,052	10,052	10,052	10,052	10,052	10,052
- Timber product of Engle wood						
- Timber product Para rubber						
3. Net income	29,652	29,652	29,652	29,652	27,692	27,692
4. NPV	7,978.7	15,119.9	14,476.4	15,119.9	12,522.7	14,036.6

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				700		
- Plumb				430		
- Wheelbarrow						
- Hoe				300		
- Big knife				240		
- Rubber tapping knife	520		520		520	
- Cup for rubber latex			315			
- Wire						
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp			400			
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning						
- Apply fertilizer cost	120	120	120	120	120	120
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost	480	480	480	480	480	480
- Harvesting	7,840	7,840	7,840	7,840	7,056	7,056
- Activating cost			600			
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Engle wood		2,500				
- Herbicide	120	120	120	120	120	120
- Fertilizer (Para rubber)	2,800	2,800	2,800	2,800	2,800	2,800

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
- Fertilizer (Engle wood)						
- Inorganic fertilizer						
- Acid	27	27	27	24.3	24.3	24.3
- Chemical	27	27	27	24.3	24.3	24.3
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
- Electrical for water supply	1,000	1,000	1,000	1,000	1,000	1,000
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,227.5	15,032.5	14,542.5	13,691.5	12,716.5	12,021.5
2. Income						
- Product Para rubber	17,640	17,640	17,640	15,876	15,876	15,876
- Product of Engle wood	10,052	10,052	7,569			
- Timber product of Engle wood						
- Timber product Para rubber						
3. Net income	27,692	27,692	136,042.4	15,876	15,876	15,876
4. NPV	13,393.1	11,721.8	112,499.9	2,022.7	2,925.5	3,569

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Plumb						
- Wheelbarrow		360				
- Hoe			300			
- Big knife			240			
- Rubber tapping knife	520		520		520	
- Cup for rubber latex					315	
- Wire		122.5				
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp	400				400	
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning						
- Apply fertilizer cost	120	120	120	120	120	120
- Weed cost	120	120	120	120	120	120
- Injecting pesticides cost	480	480	480	480	480	480
- Harvesting	6,350.4	6,350.4	6,350.4	6,350.4	6,350.4	6,350.4
- Activating cost		2,760	3,680	3,680		
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of Engle wood		2,500				
- Herbicide	120	120	120	120	120	120
- Fertilizer (Para rubber)	2,800	2,800	2,800	2,800	2,800	2,800
- Fertilizer (Engle wood)						
- Inorganic fertilizer						

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
- Acid	24.3	24.3	24.3	24.3	24.3	24.3
- Chemical	24.3	24.3	24.3	24.3	24.3	24.3
- petrol cost for spraying and injection pumps	248	248	248	248	248	248
- Electrical for water supply	1,000	1,000	1,000	1,000	1,000	1,000
1.5 Maintenances cost						
- Repairing cost of instrument	500	500	500	500	500	500
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,116.5	15,264	16,936.5	15,701.5	13,431.5	12,021.5
2. Income						
- Product Para rubber	15,876	15,876	15,876	15,876	15,876	15,876
- Product of Engle wood			2,523	10,052	10,052	10,052
- Timber product of Engle wood						
- Timber product Para rubber						
3. Net income	15,876	15,876	18,399	25,928	25,928	25,928
4. NPV	2,555.1	566.7	1,354.2	9,469.0	11,570.8	12,876.4

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainder cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				
				1 person/120baht/day (finished in 2 days)
1.2 Cost of land				
				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		250		Average from sample as 700 baht/year(useful life 15 years)
- Plumb		350		Average from sample as 975 baht/year(useful life 15 years)
- Wheelbarrow		120		Average from sample as 360 baht/year(useful life 15 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Big knife		60		Each of 120 baht and 2 knife/rai (useful life 2 years)
- Rubber tapping knife	520	100		Each of 130 baht and 4 knife/rai (useful life 2 years)
- Cup for rubber latex		84		Each of 4.5 baht and 70 piece/rai (useful life 8 years)
- Wire		14		Each of 1.75 baht and 70 wire/rai (useful life 13 years)
- Tube for latex	175	70		Each of 2.5 baht and 70 piece/rai (useful life 2 years)
- Besom for latex	30	12		Each of 5 baht and 6 pieces/rai (every year use)
- Soft sharpening stone	100	40		Each of 100 baht and 1 piece/rai (every year use)
	100	40		Each of 200 baht and 2 pieces/rai (useful life 4 years)
- Hard sharpening stone				
- Acetylene lamp		180		
1.4 Arrangement cost				
Labor cost				

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainder	NPV	Remarks
				1 plant = 5 baht(Engle wood = 50 plants/rai, Para rubber = 70 plant/rai)
- Planting orientation cost				2 times/year/2 labors (only in year 1 st – 6 th)
- Pruning				3 times/year in year 1 st – 3 rd , 2 times/year in year 4 th – 6 th , 1 time/year in after year 7 th (1 labor/rai, 1labor = 120 baht)
- Apply fertilizer cost	120			1 times/year (1 baht/ a tree)
- Weed cost	120			2 times/year in year 2 nd -10 th , 1 time/year in year 11 st – 25 th (1 labor = 120 baht)
- Injecting pesticides cost	480			Productive labor as 60:40(product : labor)
- Harvesting	6,350.4			Source: (Chantaratanawong, 2004)
- Activating cost				
Material cost				
- Breeding cost of Para rubber				70 plants/rai(1 plant = 15 baht)
- Breeding cost of Engle wood				50 plants/rai(1 plant = 50 baht)
- Herbicide	120			Engle wood use 1 lite/rai(1 lite = 120 baht)
- Fertilizer (Para rubber)	2,800			In year 1 st – 4 th is contributed, year 5 th – 6 th (1 time/year, 1 plant/1 kg.), year 7 th -25 th (2 times/year, 1 plant/1 kg.) (1 kg. = 20 baht) (punctuate between inorganic and organic fertilizer)

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainder	NPV	Remarks
		cost		
- Fertilizer (Engle wood)				In year 1 st use 0.5 kg./rai, year 2 nd – 3 rd use 1 kg./rai, year 4 th – 5 th use 2 kg./rai (1 bag(50kg.) = 1,000 baht) (punctuate between inorganic and organic fertilizer)
- Inorganic fertilizer				In year 1 st use 0.5 kg./rai, year 2 nd – 3 rd use 1 kg./rai, year 4 th – 5 th use 2 kg./rai (1 bag(50kg.) = 1,000 baht) (punctuate between inorganic and organic fertilizer)
- Acid	24.3			3 bottoms/rai/year(1 bottom = 10 baht), in year 7 th – 10 th can produce 100%, in year 11 st – 15 th product were decreased 10%, in year 16 th – 25 th product were decreased 20%,
- Chemical	24.3			1.5 kg./rai/year (1 kg. = 20 baht), in year 7 th – 10 th can produce 100%, in year 11 st – 15 th product were decreased 10%, in year 16 th – 25 th product were decreased 20%,
- petrol cost for spraying and injection pumps	248			Average from sample as 248 baht/year
- Electrical for water supply	1,000			In year 1 st – 2 nd give too much water more than other.
1.5 Maintenances cost				
- Repairing cost of instrument	500			Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht,16 th - 26 th =500 baht

Net present value of Engle wood/Para rubber in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainder	NPV	Remarks
		cost		
1.6 Land tax	4.5			Source:Punapaipong (2004)
Total cost of investment	13,691.5			
2. Income	15,876			1 rai can produce 560 kg./year Source: (Chantaratanawong, 2004)
- Product Para rubber	10,052			Source: (Chantaratanawong, 2004)
- Product of Engle wood	110,833.4			2004)
- Timber product of Engle wood	12,600			1 timber = 180 baht(70 plant/rai)
- Timber product Para rubber	150,781.4			
3. Net income	126,935.1		307,554	
4. NPV	13,691.5			Rate 8%

Net present value of Para rubber/fruit orchard in study area

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	480					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	900					
- Pump	833.3					
- Wheelbarrow	400					
- Pruning shear (small branches)	113			113		
- Pruning shear(big branches)	46			46		
- Bow saws				180		
- Fruit picker basket				200		
- Basket				400		
- Staircase Aluminum				400	400	400
- Hoe	300					300
- Knife	240					240
- Braced branch				3,000	3,000	3,000
- plastic rope				50	50	50
- Rubber tapping knife						
- Cup for rubber latex						
- Wire						
- Tube for latex						
- Besom for latex						
- Soft sharpening stone						
- Hard sharpening stone						
- Acetylene lamp						
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	500					
- Pruning		480	480	480	480	480
- Apply fertilizer cost	450	450	450	750	750	750
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost		120	120	120	120	120

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
- Injecting pesticides cost		360	360	360	360	360
- Harvesting of Para rubber						
- Harvesting of fruit orchard				3,250	3,250	3,250
- Braced branch				150	150	150
- Digging pond	1,388.3					
Material cost						
- Breeding cost of Para rubber	1,050					
- Breeding cost of fruit orchard	825					
- Accelerate flowering fertilizer Mangosteen						1,200
- Accelerate fertilizers Mangosteen						1,200
- Post harvest fertilizer Mangosteen						1,080
- Accelerate flowering fertilizer Long-Kong				1,200	1,200	1,200
- Accelerate fertilizers Long-Kong				1,200	1,200	1,200
- Post harvest fertilizer Long-Kong						1,080
- Electrical for water supply	1,500					
- Plumbing pipe	1,750					
- Acid						
- Chemical						
- Petrol cost for spraying and injection pumps	300	300	300	300	300	300
- Petrol cost for transportation				3,000	3,000	3,000
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
- Pipe Repairing		100		100		100

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	1st	2nd	3rd	4th	5th	6th
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	13,430.1	2,164.5	2,064.5	15,653.5	14,614.5	19,814.5
2. Income						
- Product Para rubber						
- Timber product of Para rubber						
- Product Mangosteen						13,000.0
- Product Long-kong				10,000	10,000	10,000
- Timber product						
3. Net income				10,000	10,000	23,000
4. NPV	-12,435.3	-2,004.2	-1,911.6	-5,234.7	-4,272.7	2,949.5

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow						
- Pruning shear(small branches)			113			
- Pruning shear(big branches)			46			
- Bow saws			180			
- Fruit picker basket			200			
- Basket		400				
- Staircase Aluminum	400	400	400	400	400	400
- Hoe					300	
- Knife					240	
- Braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- plastic rope	50	50	50	50	50	50
- Rubber tapping knife	520		520		520	
- Cup for rubber latex	315					
- Wire	122.5					
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp	400				400	
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning						
- Apply fertilizer cost	600	600	600	600	600	600
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	120	120	120	120	120	120

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
- Injecting pesticides cost	360	360	360	360	360	360
- Harvesting of Para rubber	7,840	7,840	7,840	7,840	7,056	7,056
- Harvesting of fruit orchard	3,250	3,250	3,250	3,250	3,250	3,250
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of fruit orchard						
- Accelerate flowering fertilizer Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Mangosteen	1,080	1,080	1,080	1,080	1,080	1,080
- Accelerate flowering fertilizer Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Long-Kong	1,080	1,080	1,080	1,080	1,080	1,080
- Electrical for water supply					533.3	
- Plumbing pipe						
- Acid	30	30	30	30	27	27
- Chemical	30	30	30	30	27	27
- Petrol cost for spraying and injection pumps	300	300	300	300	300	300
- Petrol cost for transportation	3,000	3,000	3,000	3,000	3,000	3,000
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	7st	8nd	9rd	10th	11th	12th
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	28,307	27,274.5	28,008.5	26,874.5	28,152.8	26,084.5
2. Income						
- Product Para rubber	19,600	19,600	19,600	19,600	17,640	17,640
- Timber product of Para rubber						
- Product Mangosteen	13,000	13,000	13,000	11,700	11,700	11,700
- Product Long-kong	10,000	10,000	10,000	9,000	9,000	9,000
- Timber product						
3. Net income	42,600	42,600	42,600	40,300	38,340	38,340.0
4. NPV	13,234.3	14,190.3	13,510.6	12,431.0	9,432.6	11,347.7

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	13 st	14 nd	15 rd	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer			900			
- Pump			833.3			
- Wheelbarrow						
- Pruning shear(small branches)		113				
- Pruning shear(big branches)		46				
- Bow saws		180				
- Fruit picker basket		200				
- Basket	400					400
- Staircase Aluminum	400	400	400	400	400	400
- Hoe				300		
- Knife				240		
- Braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- plastic rope	50	50	50	50	50	50
- Rubber tapping knife	520		520		520	
- Cup for rubber latex			315			
- Wire						
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp			400			
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning						
- Apply fertilizer cost	600	600	600	600	600	600
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	120	120	120	120	120	120

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	13 st	14 nd	15 rd	16 th	17 th	18 th
- Injecting pesticides cost	360	360	360	360	360	360
- Harvesting of Para rubber	7,840	7,840	7,840	7,840	7,056	7,056
- Harvesting of fruit orchard	3,250	3,250	3,250	3,250	3,250	3,250
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of fruit orchard						
- Accelerate flowering fertilizer Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Mangosteen	1,080	1,080	1,080	1,080	1,080	1,080
- Accelerate flowering fertilizer Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Long-Kong	1,080	1,080	1,080	1,080	1,080	1,080
- Electrical for water supply					533.3	
- Plumbing pipe						
- Acid	27	27	27	27	27	27
- Chemical	27	27	27	27	27	27
- Petrol cost for spraying and injection pumps	300	300	300	300	300	300
- Petrol cost for transportation	3,000	3,000	3,000	3,000	3,000	3,000
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	27,079.5	26,623.5	27,394.5	27,846.8	26,168.5	25,973.5
2. Income						
- Product Para rubber	17,640	17,640	17,640	15,876	15,876	15,876
- Timber product of Para rubber						
- Product Mangosteen	11,700	11,700	11,700	10,400	10,400	10,400
- Product Long-kong	9,000	9,000	9,000	8,000	8,000	8,000
- Timber product						
3. Net income	38,340	38,340	38,340	34,276	34,276	34,276
4. NPV	10,426.4	10,848.6	10,134.7	5,953.0	7,506.9	7,687.5

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	19 st	20 nd	21 rd	22 th	23 th	24 ^h
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow		400				
- Pruning shear (small branches)	113					
- Pruning shear (big branches)	46					
- Bow saws	180					
- Fruit picker basket	200					
- Basket				400		
- Staircase Aluminum	400	400	400	400	400	400
- Hoe			300			
- Knife			240			
- Braced branch	3,000	3,000	3,000	3,000	3,000	3,000
- plastic rope	50	50	50	50	50	50
- Rubber tapping knife	520		520		520	
- Cup for rubber latex					315	
- Wire		122.5				
- Tube for latex	175		175		175	
- Besom for latex	30	30	30	30	30	30
- Soft sharpening stone	100	100	100	100		100
- Hard sharpening stone	100	100	100	100	100	100
- Acetylene lamp			400			
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning						
- Apply fertilizer cost	600	600	600	600	600	600
- Weed cost	150	150	150	150	150	150
- Injecting Weed cost	120	120	120	120	120	120

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
- Injecting pesticides cost	360	360	360	360	360	360
- Harvesting of Para rubber	7,840	7,840	7,840	7,840	7,056	7,056
- Harvesting of fruit orchard	3,250	3,250	3,250	3,250	3,250	3,250
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of Para rubber						
- Breeding cost of fruit orchard						
- Accelerate flowering fertilizer Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Mangosteen	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Mangosteen	1,080	1,080	1,080	1,080	1,080	1,080
- Accelerate flowering fertilizer Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Accelerate fertilizers Long-Kong	1,200	1,200	1,200	1,200	1,200	1,200
- Post harvest fertilizer Long-Kong	1,080	1,080	1,080	1,080	1,080	1,080
- Electrical for water supply			533.3			
- Plumbing pipe						
- Acid	24.3	24.3	24.3	24.3	24.3	24.3
- Chemical	24.3	24.3	24.3	24.3	24.3	24.3
- Petrol cost for spraying and injection pumps	300	300	300	300	300	300
- Petrol cost for transportation	3,000	3,000	3,000	3,000	3,000	3,000
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	27,107.5	26,096.0	27,241.8	25,973.5	26,883.5	25,573.5
2. Income						
- Product Para rubber	15,876	15,876	15,876	15,876	15,876	15,876
- Timber product of Para rubber						
- Product Mangosteen	10,400	10,400	10,400	10,400	10,400	10,400
- Product Long-kong	8,000	8,000	8,000	8,000	8,000	8,000
- Timber product						
3. Net income	34,276	34,276	34,276	34,276	34,276	34,276
4. NPV	6,637.5	7,574.1	6,513.1	7,687.5	6,844.9	8,057.9

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				1 person/120baht/day (finished in 2 days)
1.2 Cost of land				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		300		Average from sample as 900 baht/year(useful life15 years)
- Pump		300		Average from sample as 833.3 baht/year(useful life15 years)
- Wheelbarrow		100		Average from sample as 400 baht/year(useful life15 years)
- Pruning shear(small branches)		30		Each of 113 baht and 1 shear/rai (useful life 5 years)
- Pruning shear(big branches)		15		Each of 46 baht and 1 shear/rai (useful life 5 years)
- Bow saws		60		Each of 180 baht and 1 bow saws/rai (useful life 5 years)
- Fruit picker basket		80		Each of 200 baht and 1 basket/rai (useful life 5 years)
- Basket		160		Each of 100 baht and 4 baskets/rai (useful life 5 years)
- Staircase Aluminum	400	180		Each of 400 baht and 1piece/rai (useful life 5 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Knife		60		Each of 120 baht and 2 knife/rai (useful life 2 years)
- Braced branch	3,000	300		1 time/year (5 pieces/ 1 plant) (1 piece = 20 baht)
- plastic rope	50	-		50 baht/ role / rai
- Rubber tapping knife	520	100		Each of 130 baht and 4 knife/rai (useful life 2 years)

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Cup for rubber latex		84		Each of 4.5 baht and 70 piece/rai (useful life 8 years)
- Wire		14		Each of 1.75 baht and 70 wire/rai (useful life 13 years)
- Tube for latex	175	70		Each of 2.5 baht and 70 piece/rai (useful life 2 years)
- Besom for latex	30	12		Each of 5 baht and 6 pieces/rai (every year use)
- Soft sharpening stone	100	40		Each of 100 baht and 1piece/rai (Every year)
- Hard sharpening stone	100	40		Each of 100 baht and 1piece/rai (Every year)
- Acetylene lamp		180		
1.4 Arrangement cost				
Labor cost				
- Planting orientation cost				Be done by themselves
- Pruning				2 times/year/2 labors (only in year 1 st – 6 th)
- Apply fertilizer cost	600			3 times/year in year 1 st – 3 rd , 2 times/year in year 4 th – 6 th , 1 time/year in after year 7 th (1 labor/rai, 1labor = 120 baht)
- Weed cost	150			1 time/year/1 labor(150 baht/day)
- Injecting Weed cost	120			1 time/year/1 labor(120 baht/day)
- Injecting pesticides cost	360			3 times/year(120 baht/day) Productive labor as
- Harvesting of Para rubber	6,350.4			60:40(product : labor)
- Harvesting of fruit orchard	3,250			1 kg. = 5 baht of labor cost (product = 650 kg./year)

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Braced branch	150			5 baht/plant
- Digging pond				
Material cost				
- Breeding cost of Para rubber				Be contributed
- Breeding cost of fruit orchard				890 baht/rai
- Accelerate flowering fertilizer Mangosteen	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate fertilizers Mangosteen	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Post harvest fertilizer Mangosteen	1,080			1 bag = 900 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate flowering fertilizer Long-Kong	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Accelerate fertilizers Long-Kong	1,200			1 bag = 1,000 baht (1 bag = 50 kg.) (2 kg./plant)
- Post harvest fertilizer Long-Kong	1,080			1 bag = 900 baht (1 bag = 50 kg.) (2 kg./plant)
- Electrical for water supply				
- Plumbing pipe				
- Acid	24.3			3 bottoms/rai/year(1 bottom = 10 baht), in year 7 th – 10 th can produce 100%, in year 11 st – 15 th product were decreased 10%, in year 16 th – 25 th product were decreased 20%,
- Chemical	24.3			1.5 kg./rai/year (1 kg. = 20 baht), in year 7 th – 10 th can produce 100%, in year 11 st – 15 th product were decreased 10%, in year 16 th – 25 th product were decreased 20%,

Net present value of Para rubber/fruit orchard in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainde r cost	NPV	Remarks
- Petrol cost for spraying and injection pumps	300			
- Petrol cost for transportation	3,000			
1.5 Maintenances cost				
- Repairing cost of instrument	500			Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht, 16 th - 26 th =500 baht
- Pipe Repairing				2 times/year(1 time = 100 baht)
1.6 Land tax	4.5			
Total cost of investment	26,168.5			
2. Income				
- Product Para rubber	15,876			1 rai can droduce 140 kg. (560 kg./year, 1 kg. = 35 baht)
- Timber product of Para rubber	12,600			1 timber = 180 baht 650 kg./rai and 1 kg. = 20 kg.(product of 6-10 th year = 100%, 11-15 th = decrease 10%, 16-25 th =decrease 40%)
- Product Mangosteen	10,400			650 kg./rai and 1 kg. = 10 kg.(product of 6-10 th year = 100%, 11-15 th = decrease 10%, 16-25 th =decrease 40%)
- Product Long-kong	8,000			1 timber = 100 baht
- Timber product	3,000			
3. Net income	52,101			
4. NPV	24,011.6		171,121.3	Rate 8%

Net present value of Home garden in study area

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
1. Investment cost						
1.1 Site preparation cost	600					
1.2 Cost of land	2,000					
1.3 Instrument cost						
- Sprayer	200					
- Pump	600					
- Wheelbarrow	750					
- Hoe	300					
- Pruning shear(small branches)	113			113		
- Pruning shear(big branches)	46			46		
- Plastic rope				50	50	50
- Bow saws				180		
- Fruit picker basket				200		
- Basket				400		
- Staircase Aluminum				400	400	400
- Soft sharpening stone						
- Hard sharpening stone						
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost	140					
- Pruning				280	280	280
- Apply fertilizer cost				420	420	420
- Injecting Weed cost		140	140	140	140	140
- Harvesting				3,000	3,000	3,000
- Braced branch				150	150	150
- Digging pond	2,000					
Material cost						
- Breeding cost of coconut	150					
- Breeding cost of rose apple	160					
- Breeding cost of breadfruit	20					
- Breeding cost of durian	240					
- Breeding cost of jack fruit	40					
- Breeding cost of long-kong	480					

Net present value of Home garden in study area

(Unit:Baht/rai)

Year	1 st	2 nd	3 rd	4 th	5 th	6 th
- Breeding cost of mangsteen	80					
- Breeding cost of maprang	80					
- Bio-fertilizer		603		1,005		1,005
- Inorganic fertilizer	251.3		502.5		502.5	
- Herbicide weeding	24	24	24	24	24	24
- Braced branch				5,600	5,600	5,600
- Electricity	200	200	200	200	200	200
- Petrol cost for spraying and injection pumps	400					
- Plumbing pipe	2,000					
1.5 Maintenances cost						
- Repairing cost of instrument	200	200	200	200	200	200
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,078.8	1,271.5	1,071	12,512.5	10,971	11,078.8
2. Income						
- Product of coconut					8,000	8,000
- Product of rose apple				2,000	2,000	2,000
- Product of breadfruit			2,000	2,000	2,000	2,000
- Product of durian						4,000
- Product of jack fruit					1,200	1,200
- Product of long-kong				20,000	20,000	20,000
- Product of mangsteen						200
- Product of maprang						
Total product			800	9,600	13,280	14,960
- Timber product						
3. Net income			800	9,600	13,280	14,960
4. NPV	-10,258.1	-1,177.3	-250.9	-2,696.8	2,138	2,857.9

Net present value of Home garden in study area (Continued).

(Unit:Baht/rai)

Year	7 st	8 nd	9 rd	10 th	11 th	12 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow						
- Hoe					300	
- Pruning shear (small branches)			113			
- Pruning shear(big branches)			46			
- Plastic rope	50	50	50	50	50	50
- Bow saws			180			
- Fruit picker basket			200			
- Basket		400				
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Injecting Weed cost	140	140	140	140	140	140
- Harvesting	3,000	3,000	3,000	3,000	3,000	3,000
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of coconut						
- Breeding cost of rose apple						
- Breeding cost of breadfruit						
- Breeding cost of durian						
- Breeding cost of jack fruit						

Net present value of Home garden in study area (Continued).

(Unit:Baht/rai)

Year	7st	8nd	9rd	10th	11th	12th
- Breeding cost of long-kong						
- Breeding cost of mangsteen						
- Breeding cost of maprang						
- Bio-fertilizer		1,005		1,005		1,005
- Inorganic fertilizer	502.5		502.5		502.5	
- Herbicide weeding	24	24	24	24	24	24
- Braced branch	5,600	5,600	5,600	5,600	5,600	5,600
- Electricity	200	200	200	200	200	200
- Petrol cost for spraying and injection pumps					400	
- Plumbing pipe					2,000	
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,271	12,273.5	11,810	11,873.5	13,971	11,873.5
2. Income						
- Product of coconut	8,000	8,000	8,000	8,000	8,000	8,000
- Product of rose apple	2,000	2,000	2,000	2,000	2,000	2,000
- Product of breadfruit	2,000	2,000	2,000	2,000	2,000	2,000
- Product of durian	4,000	4,000	4,000	4,000	4,000	4,000
- Product of jack fruit	1,200	1,200	1,200	1,200	1,200	1,200
- Product of long-kong	20,000	20,000	20,000	20,000	20,000	20,000
- Product of mangsteen	200	200	200	200	200	200
- Product of maprang	525	525	525	525	525	525
Total product	15,170	15,170	15,170	15,170	15,170	15,170
- Timber product						
3. Net income	15,170	15,170	15,170	15,170	15,170	15,170
4. NPV	3,610.2	2,681.9	3,111.1	3,052.3	1,110.2	3,052.3

Net present value of Home garden in study area (Continued).

(Unit:Baht/rai)

Year	13 st	14 nd	15 rd	16 th	17 th	18 th
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer				200		
- Pump				600		
- Wheelbarrow						
- Hoe				300		
- Pruning shear(small branches)			113			
- Pruning shear(big branches)			46			
- Plastic rope	50	50	50	50	50	50
- Bow saws			180			
- Fruit picker basket			200			
- Basket	400					400
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Injecting Weed cost	140	140	140	140	140	140
- Harvesting	3,000	3,000	3,000	3,000	3,000	3,000
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of coconut						
- Breeding cost of rose apple						
- Breeding cost of breadfruit						
- Breeding cost of durian						
- Breeding cost of jack fruit						

Net present value of Home garden in study area (Continued)

(Unit:Baht/rai)

Year	13st	14nd	15rd	16th	17th	18th
- Breeding cost of long-kong						
- Breeding cost of mangsteen						
- Breeding cost of maprang						
- Bio-fertilizer		1,005		1,005		1,005
- Inorganic fertilizer	502.5		502.5		502.5	
- Herbicide weeding	24	24	24	24	24	24
- Braced branch	5,600	5,600	5,600	5,600	5,600	5,600
- Electricity	200	200	200	200	200	200
- Petrol cost for spraying and injection pumps						
- Plumbing pipe						
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	11,671	12,412.5	11,271	13,173.5	11,471	12,473.5
2. Income						
- Product of coconut	8,000	8,000	8,000	8,000	8,000	8,000
- Product of rose apple	2,000	2,000	2,000	2,000	2,000	2,000
- Product of breadfruit	2,000	2,000	2,000	2,000	2,000	2,000
- Product of durian	4,000	4,000	4,000	4,000	4,000	4,000
- Product of jack fruit	1,200	1,200	1,200	1,200	1,200	1,200
- Product of long-kong	20,000	20,000	20,000	20,000	20,000	20,000
- Product of mangsteen	200	200	200	200	200	200
- Product of maprang	525	525	525	525	525	525
Total product	15,170	15,170	15,170	15,170	15,170	15,170
- Timber product						
3. Net income	15,170	15,170	15,170	15,170	15,170	15,170
4. NPV	3,239.8	2,553.2	3,610.2	1,848.6	3,425	2,496.8

Net present value of Home garden in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
1. Investment cost						
1.1 Site preparation cost						
1.2 Cost of land						
1.3 Instrument cost						
- Sprayer						
- Pump						
- Wheelbarrow		135				
- Hoe			300			
- Pruning shear(small branches)	113					
- Pruning shear(big branches)	46					
- Plastic rope	50	50		50	50	50
- Bow saws	180					
- Fruit picker basket	200					
- Basket				400		
- Staircase Aluminum	400	400	400	400	400	400
- Soft sharpening stone	100	100	100	100	100	100
- Hard sharpening stone	100	100	100	100	100	100
1.4 Arrangement cost						
Labor cost						
- Planting orientation cost						
- Pruning	280	280	280	280	280	280
- Apply fertilizer cost	420	420	420	420	420	420
- Injecting Weed cost	140	140	140	140	140	140
- Harvesting	3,000	3,000	3,000	3,000	3,000	3,000
- Braced branch	150	150	150	150	150	150
- Digging pond						
Material cost						
- Breeding cost of coconut						
- Breeding cost of rose apple						
- Breeding cost of breadfruit						
- Breeding cost of durian						
- Breeding cost of jack fruit						
- Breeding cost of long-kong						

Net present value of Home garden in study area (Continued)

(Unit:Baht/rai)

Year	19st	20nd	21rd	22th	23th	24^h
- Breeding cost of mangsteen						
- Breeding cost of maprang						
- Bio-fertilizer		1,005		1,005		1,005
- Inorganic fertilizer	502.5		502.5		502.5	
- Herbicide weeding	24	24	24	24	24	24
- Braced branch	5,600	5,600	5,600	5,600	5,600	5,600
- Electricity	200	200	200	200	200	200
- Petrol cost for spraying and injection pumps			400			
- Plumbing pipe			2,000			
1.5 Maintenances cost						
- Repairing cost of instrument	300	300	300	300	300	300
- Pipe Repairing		100		100		100
1.6 Land tax	4.5	4.5	4.5	4.5	4.5	4.5
Total cost of investment	12,010	12,208.5	14,171	12,473.5	11,471	12,073.5
2. Income						
- Product of coconut	8,000	8,000	8,000	8,000	8,000	8,000
- Product of rose apple	2,000	2,000	2,000	2,000	2,000	2,000
- Product of breadfruit	2,000	2,000	2,000	2,000	2,000	2,000
- Product of durian	4,000	4,000	4,000	4,000	4,000	4,000
- Product of jack fruit	1,200	1,200	1,200	1,200	1,200	1,200
- Product of long-kong	20,000	20,000	20,000	20,000	20,000	20,000
- Product of mangsteen	200	200	200	200	200	200
- Product of maprang	525	525	525	525	525	525
Total product	15,170	15,170	15,170	15,170	15,170	15,170
- Timber product						
3. Net income	15,170	15,170	15,170	15,170	15,170	15,170
4. NPV	2,925.9	2,742.1	925	2,496.8	3,425	2,867.1

Net present value of Home garden in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remaind er cost	NPV	Remarks
1. Investment cost				
1.1 Site preparation cost				
				1 person/140baht/day (finished in 2 days)
1.2 Cost of land				
				Rent for 2,000 baht/rai/year
1.3 Instrument cost				
- Sprayer		100		Average from sample as 200 baht/year(useful life 15 years)
- Pump		500		Average from sample as 600 baht/year(useful life 15 years)
- Wheelbarrow		100		Average from sample as 200 baht/year(useful life 20 years)
- Hoe		100		Each of 150 baht and 2 hoes/rai (useful life 5 years)
- Pruning shear (small branches)		30		Each of 113 baht and 1 piece/rai (useful life 5 years)
- Pruning shear (big branches)		15		Each of 46 baht and 1 piece/rai (useful life 5 years)
- Plastic rope	50			Each of 50 baht and 1 role/rai
- Bow saws		60		Each of 180 baht and 1 piece/rai (useful life 5 years)
- Fruit picker basket		80		Each of 200 baht and 1 piece/rai (useful life 5 years)
- Basket		160		Each of 100 baht and 4 pieces/rai (useful life 5 years)
- Staircase Aluminum	400	180		Each of 1,200 baht/3 raies and 1 piece/rai (useful life 5 years)
- Soft sharpening stone	100	40		Each of 100 baht and 1 piece/rai (Every year)
- Hard sharpening stone	100	40		Each of 100 baht and 1 piece/rai (Every year)

Net present value of Home garden in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remainder cost	NPV	Remarks
1.4 Arrangement cost				
Labor cost				
				1 labor/1 rai(1 labor cost = 140 baht)
- Planting orientation cost				140 baht/time(Twice a year)
- Pruning	280			140 baht/time(Twice a year)
- Apply fertilizer cost	420			3 times/year (labor cost =140 baht/day)
- Injecting Weed cost	140			1 times/year (labor cost =140 baht/day)
- Harvesting	3,000			3,000 baht/year
- Braced branch	150			5 baht/ a tree
- Digging pond				Average from sample as 2,000 baht/year
Material cost				
- Breeding cost of coconut				1 coconut = 15 baht
- Breeding cost of rose apple				1 rose apple = 20 baht
- Breeding cost of breadfruit				1 breadfruit = 20 baht
- Breeding cost of durian				1 durian = 20 baht
- Breeding cost of jack fruit				1 jack fruit = 10 baht
- Breeding cost of long-kong				1 long-kong = 20 baht
- Breeding cost of mangsteen				1 mangosteen = 20 baht
- Breeding cost of maprang				1 maprang = 20 baht
- Bio-fertilizer				3 times/year in year 1 st – 2 nd use 1 plant/0.15 kg., in year 3 rd – 25 th use 1 plant/ 0.25 kg. (punctual between inorganic fertilizer and bio-fertilizer)
- Inorganic fertilizer	502.5			”
- Herbicide weeding	142.8			2 times/7 raies (Lite =100 baht/rai)
- Braced branch	5,600			100 baht/ a tree
- Electricity	200			Average from sample

Net present value of Home garden in study area (Continued)

(Unit: Baht/rai)

Year	25 th	Remaind er cost	NPV	Remarks
- Petrol cost for spraying and injection pumps				Average from sample
- Plumbing pipe				Average from sample as 2,000 baht/year
-				
1.5 Maintenances cost				
- Repairing cost of instrument				Repairing cost in 1 st -6 th = 200 baht, 7 th -15 th =300 baht, 16 th - 26 th =500 baht
- Pipe Repairing				100 baht (time / 2 years)
1.6 Land tax	4.5			Source:Punapaipong (2004)
Total cost of investment	11,589.8			
2. Income				
- Product of coconut	8,000			400 coconut/year (20 baht/coconut)
- Product of rose apple	2,000			100 kg./year
- Product of breadfruit	2,000			100 kg./year (1 kg. = 200)
- Product of durian	4,000			80 durian/year(1 durian = 50 baht)
- Product of jack fruit	1,200			60 jack fruit/year(1 jack fruit = 20 baht) 60
- Product of long-kong	20,000			1,000 kg. product/year(1 kg. = 20 baht)
- Product of mangsteen	200			10 kg. product/year (1 kg. = 20 baht)
- Product of maprang	525			15 kg. product /year (1 kg. = 35 baht)
Total product	15,170			
- Timber product	2,010			150 baht/ a tree
3. Net income	17,180			
4. NPV	5,176.1		44,962.5	Rate 8%

CURRICULUM VITAE

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