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DECLARATION

The author hereby declares that the work presented in this thesis paper has been carried out and composed by himself as part of a program of two year studies at the Biology of Environment of the Nanjing Forestry University, China. All views and opinions expressed to remain there in the sole responsibility to the author, and it has not been presented in any previous application for a degree.

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Land Cover Change and Adaptation of Local Livelihood in Thapangthong District, Savannakhet Province, Lao PDR

ABSTRACT

The objectives of this research are: 1) To quantify the changes in land cover in between 2005 and 2016 in the case study area using remote sensing and GIS technologies and techniques. 2) To investigate the adaptation of local people to land cover changes focusing on selected villages.

Data were collected from the satellite images of the following methods Landsat-5 Thematic Mapper (TM) in 2005 and Landsat-8 Operational Land Imager (OLI) in 2016. There were five classes of land-cover as follows: 1) mixed deciduous forest, 2) dry Dipterocarp forest, 3) agriculture land, 4) built-up land and 5) water bodies. Questionnaires were conducted for household survey in the targeted villages. There were 129 households of the simple size used as respondents for the Houaymeun and Thongpang villages in the Thapangthong District of Savannakhet Province of Lao People's Democratic Republic (PDR). For the questionnaires, form contents were based on the impacts of human influence (by local villagers). For data analyses following descriptive statistic methods were used: frequency, percentage, mean, standard deviation, minimum and maximum values by using the IBM SPSS version 20 and Microsoft Excel version 2016.

The result showed that during last 11 years ago (2005-2016), dry Dipterocarp forest has decreased about 8.72% of the total area, whereas agriculture land increased approximately 7.13% of total area, followed by built-up land (0.12%), and water (0.62%). In addition, mixed deciduous forest has slightly increased by 0.85%, and especially the abandoned agricultural land expanded as a mixed deciduous forest. The overall classification accuracy of the map was 95.80% and Kapa Coefficient about 78.10%.

Due to land cover changes, there were many effects especially the agricultural activities, which were about 89.15% of the total effect. As agricultural production, the crop production was extremely impacted about 89.15% because of crop production is dependent on climate and land use condition. Besides, there were impacts of land cover change on 60.47% of households' environment by land cover changes followed by environment forest 50.39%, culture, 41.09% of economy, tradition 10.08% and society 6.20%. Otherwise, the key factors of land conversion impact occurred from agricultural production activities that households were hard to adapt the technique to do somehow with good practice into such production were land degradation, insect and disease outbreak, land limitation, feed insufficiencies, and water constrained; was not understandable how to learn and to apply new modern technology with existing local knowledge's farmers. There were many reasons of environmental issue from land conversion such as drought, natural fire storm, flooding, therefore the households could be adaptive to use the water through management practice of watershed, mass-media monitoring and find new areas. The factors of land change affected on forest were occurred from the decreasing of forests, difficulties in looking for woods, thus, mostly the households could be adaptive via looking for woods from the other areas to use, establishing the tree plantation and legislation of regulation with enactment. For non-timber forest products (NTFPs) has the difficulties in looking for such products used into households' activities, so the adaptation of households towards the effects of forest products were the non-timber forest products in the other far away area from the village. The particle scales of factors impacting the economy were from the decreasing of family incomes, high family expenditure and increase of production input cost. For the adaptation of households to the economy impacted were predominantly additional works, Increasing of production output, and reduction of expenditure.

Keywords: Land cover change, Remote Sensing, Geographic Information System, Adaptation of villagers

老挝沙湾拿吉省三邦区土地覆盖变化和区域生活适应

摘要

本文研究目的是：1）利用遥感和地理信息系统技术，量化老挝沙湾拿吉省三邦区 2005 年至 2016 年的土地覆盖变化规律。2）调查当地居民对村庄土地覆被变化的适应性。

数据来自 2005 年的 Landsat-5（TM）专题地图和 2016 年的 Landsat-8 操作陆地成像仪（OLI）的卫星图像。土地覆盖类型包括以下五种类型：（1）落叶混交林，（2）干性龙脑香林，（3）农业用地，（4）建设用地，（5）水体。在选定的研究村庄进行入户问卷调查，在老挝沙湾拿吉省三邦区厚朴村和通邦村共调查了 129 户，调查问卷题目、内容是基于居民（当地村民）的影响设计的。数据分析采用描述性统计方法，用 SPSS20 和 Microsoft Excel 2016 对频率、百分比、平均值、标准差、最小值和最大值进行统计分析。

结果表明，在过去 11 年（2005-2016 年），干龙脑香林森林总面积大约减少了约 8.72％，而农业用地增加了约 7.13％，其次是建设用地（0.12％）和水体（0.62％）。此外，落叶混交林略有增长 0.85％，特别的是弃耕的农业用地演替为落叶混交林。地图总体分类精度为 95.80％，卡帕系数为 78.10％。

土地覆盖变化产生了许多影响，尤其是农业活动，占总效应的 89.15%左右。由于作物生产取决于气候和土地利用状况，农业生产、作物生产受到极大的影响，约为 89.15％。此外，土地覆盖变化对家庭环境的影响为 60.47%，其次是森林环境 50.39%、文化为 41.09%、传统为 10.08%和社会为 6.20%。然而，土地转化影响的主要因素是农业生产活动，村民很难适应这种技术在土地退化，昆虫和疾病暴发，土地限制，饲料不足，水资源受限等不利条件下以良好的方式进行生产；当地有文化的村民难以理解如何学习和应用新的现代技术。土地变化造成干旱，自然火灾，洪水等环境问题原因很多，因此，农户可以通过流域管理实践、大众媒体监督和新领域的管理来适应水资源的利用。影响森林的土地变化的因素是森林的减少和寻找木材的困难。因此，大多数村民可以通过寻找其他地区森林、营造人工林和制定法律法规来适应。因为非木质林产品（NTFPs）用于家庭活动产品遇到困难，所以家庭对林业产品影响的适应性在远离村子另一个遥远地区的非木质林产品。影响经济增长的因素是家庭收入下降、家庭支出增加和生产投入成本增加。对家庭的影响经济的适应主要是额外的工作，产量的提高，减少支出。家庭适应经济的影响主要是增加附加产品、提高产量和减少开支。

关键词：土地覆盖变化，遥感，地理信息系统，村民适应性

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LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
GIS	Geographic Information System
GCPs	Ground Control Points
GPS	Geographic Positioning System
ERDAS	Earth Resources Data Analysis System
Ha	Hectare
FAO	World Food and Agriculture Organization
DEM	Digital Elevation Model
IUCN	International Union for Conservation of Nature
Lao PDR	Lao People's Democratic Republic
LUCC	Land Use and Land Cover Change
LULC	Land Use and Land Cover
MAF	Ministry of Agriculture and Forestry
MSS	Multispectral Scanner
NPA	National Protected Area
NTFPs	Non-timber forest products
NBCA	National Biodiversity Conservation Area
NPF	National Protection Forest
NOFIP	National Office of Forest Inventory and Planning
PFA	Production Forest Area
OLI	Operational Land Image
RS	Remote Sensing
SPOT	Satellite Pour l' Observation de la Terra
TM	Thematic Mapper
UTM	Universal Transverse Mercator
USGS	United States Geological Survey
UNDP	United Nations Development Program me
WGS	World Geodetic System
WWF	World Wide Fund for Nature
HANPP	Human Allocation of Net Primary Production

CHAPTER 1: INTRODUCTION

1.1. Background to the study

Lao People's Democratic Republic (Lao PDR) is a part of Indochina during the French colonial period. Lao PDR has about 236800 square kilometers of land area and with a population of ~6.5 million people (Lao Statistics Bureau, 2015). Lao PDR is situated in the tropical area and extremely rich in biodiversity and also has a large area of forest cover in contrast to other ASEAN member countries, which had forest cover of 70% of the total land area in 1940 and gradually reduced to only 41.5% by 2002. Therefore, Lao government established a sustainable forest management policy with three forest categories namely: 1) conservation forest covering 4.8 million ha (56.5%), 2) protection forest covering 0.5 million ha (6.0%) and 3) production forest (natural forest, natural regeneration and plantation forests) covering for about 3.2 million ha (37.5%) (Ministry of Agriculture and Forestry, 2005). During the last decades, the forest cover decreased due to land-use conversion for example shifting cultivation, commercial logging, commercial agriculture and tree plantation (Department of Land Planning and Development, 2006). According to the results of the forest cover survey in 2002, the total land area of Laos covered by natural forest (canopy density of higher than 20 % and height of above 5 meter) was 9.8 million ha or about 41.5 % of the total land area, while the dry lands (lowland dry Dipterocarp forest) covered roughly 1.3million ha or 13.9 % of the total land area. Almost all of this land area is located in the central and southern Laos.

Lao PDR is a developing country thereby often subjected to forest resource changes, changes in forest area are often related to environment problems associated with economic development and direct impacts of human livelihoods. Therefore, the change of forest area information is an important key used for resource planning and management in urgent developing countries. One way of assessing forest change is through looking at land-use and land cover changes. However, when investigating this problem, we need to consider budget, labor and time needed to explore a wide variety of information. Information regarding transformation of the forest status is often outdated and unclear (Chanthakhad, 2015).

The changes of land-use and land-cover are a factor that is important to support an area for agriculture and forestry and have a sustainable and conservation balance of the area's ecology. Moreover, particularly the average for forest cover has changed and is very important for the development of the economic-society (Ministry of Agriculture and Forestry, 2005).

Land use and land cover dynamics are widespread, accelerating, and significant processes driven by human actions that also produce changes that impact on humans (Agarwal *et al*., 2002). Land use is restrained by environmental factors such as soil characteristics, climate, topography, and vegetation. Whereas it also reflects the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchment and storage. Land cover indicates the physical and biotic features of the land surface and it is studied largely by natural scientists. The two are proximate sources of change, human activities that directly alter the physical environment. These activities reflect peoples' goals that are shaped by underlying social driving forces. Contemporary worldwide environmental change is clearly unique. The human reshaping of the world has reached a truly global scale, is unprecedented in its magnitude and rate and increasingly involves significant impacts on the biogeochemical systems that sustain the biosphere (Pandit, 2011).

Land and natural resources in Lao PDR are considered an invaluable heritage of the nation, including the richness and picturesque scenery of the forests, rivers, streams, mountains, historical signs, mineral, and bio-diversity, which is the source of the wealthy and fabulous capital needed for the sustainability of the country. Therefore, the land and natural resources have great importance to the country's development.

Savannakhet Province is located in the central part of Laos. It lies in the 16.54° North latitude and 104.78° East longitude with elevation ranging from 155 m to 529 m, and it cover an area of 21774 square kilometers. It includes 15 districts: Outhumphone, Champhone, Xaybouly, Khanthaboury, Xayphouthong, Songkhone, Thapangthong, Xonboury, Phalanxay, Atsaphangthong, Atsaphone, Vilaboury, Pin, Nong and Xepon districts. The province was established in 1895, shares borders with Vietnam to the East, Thailand to the West, Khammouane Province to the North and Saravan Province to the South. `

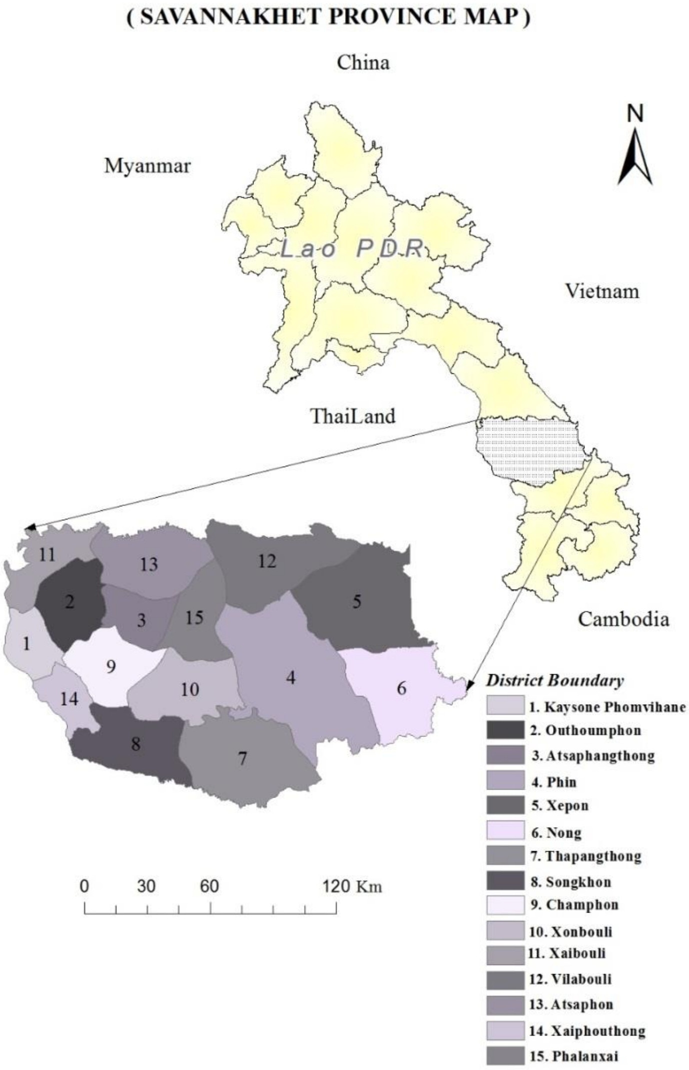

Fig. 1.1 Location map of Savannakhet province

Savannakhet is a province where enriches the forest resources. It was still about 70% forest covered in 2000 and included three national biodiversity conservation areas (NBCA): Phouxanghe (109,900 hectares), Dongphouvieng (197,000 hectares), and Xebangnouan (150,000 hectares). There are two state production forests in the province: Dongkapho (9,600 hectares) and Dongsithounh (212,000 hectares) (Ministry of Agriculture and Forestry, 2001). Savannakhet Province has a total population of 937,907 as of the June 2012 census and 1,013 villages and 147,175 households, the population density 43/km^2. The ethnic minority groups residing in the province include Lao Loum (Lowland Lao), Phu Tai and Bru (the only ones recognized by the provincial government). The Bru, however, is a diverse people with various dialects and cultures, in the 2000 census.

In comparing the land-use classes, it is seen that 55.5% of province is forest area, 23.8% is potential forest area (including shifting cultivation fields and fallow forests in early successional stages), 8.8 % is other wooded areas (mainly open woodlands), 9.1% is permanent agricultural land (mainly paddy fields), and 2.8% is other non-forest land such as urban areas, grassland, or wetland (NOFIP, 1992). A total of 80% of households are engaged in rice cultivation (UNDP, 1998).

Remote sensing technologies making use of satellite imagery and aerial photos are used widely, along with GIS, to support the allocation of land use, agriculture and forestry, environmental planning and other planning (Chobtham, 2008).

1.2. Justification

Thapangthong is one of the districts in Savannakhet province. In Thapangthong district, the forest cover fairly dens and consists of three typical forests:

1. National Biodiversity Conservation Area (NBCA) (Xebangnouane),
2. National Protection Forest area (Xetanoune) and
3. Production Forest Area (PFA) (Dong-Sithouane)

At present, the population and economies are both quickly increasing. These drive an increasing the demands of land used into building houses, the infrastructure, and especially for agriculture production. There were shifting cultivation, paddy fields, commercial timber for saw mills and commercial crops. Overall the production in the whole district has been increasing.

Forest cover changes are a key factor affecting the changes of the landscapes and environmental quality. Therefore, the change of forest shall have an important influence on the living habitat, livelihood or people, the area of agriculture, and the expansion of urbanization.

1.3. Research objective

The study aims to examine land cover change and local people's perception of land cover change in Thapangthong District. Specific objectives follow:

1. To quantify the change in land cover between the years 2005 and 2016 in the case study area using remote sensing and GIS technologies and techniques; and
2. To investigate the adaptation of local people to land cover change by focusing on selected villages.

The study results are to help to identify the people's participation in and relative condition or activities that relate to the land cover changes in Thapangthong district. This information is not currently known. This information is needed to study and the possibility sustainable forest management in the district.

CHAPTER 2: LITERATURE REVIEW

2.1. Land cover change: Definitions and Concepts

According to International Geosphere-Biosphere Program and the International Human Dimension Program (IGBP-IHDP, 1999), land cover refers to the physical and biophysical cover over the surface of earth, including distribution of vegetation, water, bare soil and artificial structures. Meyer & Turner (1994) point out that, and land cover (LUCC) is commonly grouped into two broad categories: conversion and modification. Conversion refers to a change from one cover or use category to another such as forest to grassland. On the other hand, modification represents a change within one land use or land cover category (for example, from rain fed cultivated area to irrigated cultivated area), which can lead to changes in its physical or functional attributes. These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate (Lambin *et al.*, 2003).

Land cover change is influenced by both the increase and decrease in given population (Lambin *et al.*, 2003). For instances, in developing countries like Ethiopia, population growth has been a dominant cause of land use and land cover change than other forces (Sage, 1994). Meyer & Turnner, (1994) also stated that there is a significant statistical correlation between population growth and land cover conversion in most of African, Asian, and Latin American countries. Lead to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grassland (Lambin *et al.*, 2003).

Normally, knowing the impact of land use and land cover change on natural resources like depends on an understanding of the past land use and land cover, as affected by population size and distribution, economic development, technology, and other factors. The land use and land cover change assessment is a very important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Hadgu, 2008).

2.2. Impact of land cover changes

The demands on land increase as population increases. Agriculture, which depends on the availability of seasonal rainfall, is often one of the main economies of a country. People need land for food production, habitation, and infrastructure, over the next century, the earth is facing challenges caused by land-use/land-cover change. Anthropogenic processes affect many parts of the earth's system (e.g., climate, hydrology), global biodiversity, and the fundamental sustainability of lands. Various estimates indicate that 50 percent of the ice-free land surface has been affected by or modified in some way by human activity (Vitousek *et al.*, 1997). Studies of land-use/land-cover change have made significant advances in furthering our understanding of socio-economic drivers of it, the impacts on natural and human systems, as well as the feedbacks between natural and human systems. Give the large number of case studies that have been completed, we now have the opportunity to look broadly at the results of these studies to assess if there are fundamental patterns of land-use and land-cover change that consistently appear regardless of global location, social organization, economic state, etc. Moreover, recently we are able to assess whether there are persistent impacts of land-use/land-cover that can be identified and related to an overall pattern.

Many studies have attempted to assess whether there is a common pathway of land cover change relevant to common socio-economic driver (e.g., Turner *et al.*, 1990; Lambin *et al.*, 2001). A recent study of tropical deforestation sought to assess common drivers from an analysis of the result of 150 case studies (Geist & Lambin, 2001).

2.3. Local adaptation

Local adaptation relates to natural resource management, community forests, and other issues. For instance, Nepal is a pioneer country in adopting Community Forestry (CF) which has been a success story in the midland hill of the country. In recently years, CF is shifting priorities from supplying forest products to maximizing the economic benefits to local people though production of economically beneficial products. However, issues such as elite dominancy and exclusion of some are still prominent. These changes and issues necessitate examining forestry efforts from experts' and users' perspectives.

2.4. Application of Remote Sensing to LUCC.

Remote sensing is a technique to observe the earth surface or the atmosphere from a distance using satellites (space borne) or from the air using aircraft (airborne). Remote sensing uses a part or several parts of the electromagnetic spectrum. It records the electromagnetic energy reflected or emitted by the earth′s surface. The amount of radiation from an object (called radiance) is influenced by both the properties of the object and the radiation hitting the object (irradiance). The human eyes register the solar light reflected by these objects and our brains interpret the colors, the grey tones and intensity variations. In remote sensing, various kinds of tools and devices are used to make electromagnetic radiation outside this range from 400 to 700 nm visible to the human eye, especially the near infrared, middle-infrared, thermal-infrared and microwaves. Remote sensing imagery has many applications, including use in mapping land-use and cover, agriculture, soils, forestry, city planning, archaeological investigations, military observation, and geomorphologic surveying, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, Specifically regarding its use in land use and land cover changes analysis though its use on can: map and classify the land use and land cover, assess the spatial arrangement of land use and land cover, allow analysis of time-series images used to analyze landscape history, and report and analyze results of inventories. These can all be included as inputs to Geographic Information Systems (GIS), and provide a basis for model building. Land use and land cover is changing rapidly in most parts of the world, in this situation, accurate, meaningful, and available data is highly essential for planning and decision making.

Remote sensing is particularly attractive as a source for the land cover data. For instance, since 1970′s satellite remote sensing techniques have been used as a tool to detect and monitor land cover change at various scales with useful results (Stefanov *et al.*, 2001). William *et al.* (1991) pointed out that the information of land cover change which is extracted from remotely sensed data is vital for updating land cover maps and for the management of natural resources and monitoring phenomena on the surface. The importance of land cover mapping is to show the land cover changes many place included watershed area and to divide the land cover in different classes of land cover. Remotely sensed imagery plays a great role in obtaining information about both temporal trends and spatial distribution of watershed areas and change over the time dimension for projecting land cover changes but also to support impact assessment of the changes (Atasoy *et al.*, 2006). To monitor the rapid changes of land cover, classify the types of land cover, and obtain timely land cover information, multi-temporal remote sensed images are considered effective data sources.

2.5. Relationship between land cover change and livelihood

Due to human influence about 50% of the habitable surface of the Earth was changed and continuously changing (Vitousek *et al.,* 1997). The estimates confirmed that about half of the world’s land surface is still covered by forested areas (Mittermeier *et al.,* 2003). Furthermore, transformation of natural ecosystems for the cultivation of food, fiber and other products also contributes about 37 million hectares (34%) of the global land surface. Cultivated systems overlap with other biomes or ecosystems such as forests, dry-lands, and mountain in a non-travail manner (Cassman *et al.,* 2005). Net Primary Productivity (NPP) increased during the recent past decades by human beings and due to this massive growth, the ecosystems’ degradation through land-use/ land-cover change occurred. According to Vitousek *et al.* (1986, 1997), up to about 40% of terrestrial NPP are indirectly or directly used by humans. A recent study also showed that human consumption of NPP is around 11.5 PgC or 20.3% (Uncertainly range: 14.1-26.1%) of current terrestrial NPP (Imhoff *et al.*, 2004). However, this study did not include NPP foregone due to land-use/ land-cover change. Spatially explicit studies on a national scale have shown that the Human Allocation of Net Primary Productivity (HANPP) is considerably higher in densely populated, intensively used industrialized countries such as Austria. While above ground HANPP for Austria as a whole was around 50% in the 1990s, HANPP reached over 90% in intensively used regions (Haberl *et al.*, 2001). However, an uncertainty in detailed estimates or a wide range in estimates remains (Rojsczer *et al.*, 2001). Most of the fruitful lands of the world are already under agriculture (e.g., cultivation, garden, paddy filed) with relatively little scope for further expansion if not into humid forest ecosystems or into dry lands (Döös, 2002). It is likely that on the populated surface of the Earth, there are some places where practically we cannot practice our cultivation, livestock, and fisheries (Cassman *et al.*, 2005). Nowadays virtually no land surface remains untouched by humans (Turner, 2002). The world Conservation Service, including urban-industrial uses and taking into account remote urban influences beyond the agriculture sector estimates that wider ‘human footprint’ covers 83% of the global land surface (Sanderson *et al.*, 2002). In fact, most impacts are associated with positive influences as continuing increases in food and fiber production, resources use efficiency wealth, livelihood security, welfare and human well-being (Lambin *et al.*, 2003). Indeed, land-use/ cover-change as a mega-trend or forcing function in global environmental change (Turner, 2006) conformed generally with the development of human societies and civilizations at least over the last 300 years. In addition, some contemporary influences on climate and ecosystem service and conditions can clearly by associated with undesirable or negative in fluencies. Altering ecosystem services, i.e., the benefits people obtain from ecosystems such as provision services [e.g., water, food], regulating services [e.g., spiritual and recreational control], and cultural services [e.g., nutrient cycling] that maintain the condition for life on hectares (Millennium Ecosystem Assessment, 2003) and affects the ability of biological systems to support human needs (Cassman *et al.*, 2005).

Understanding the types and impacts of land use and land cover change is essential indicator for resource base analysis and development of efficient and appropriate response strategies for sustainable management of natural resources in a country. Land-use and land-cover change are driven by human actions and also drives changes that limit the availability of products and services for human and livestock, and it can undermine environmental health as well. Land-use/land-cover dynamics are widespread, speed up, and significant processes driven by human actions but also producing changes that impact humans. These dynamics alter the availability of different biophysical resources including soil, vegetation, animal, feed, water, and others.

2.6. Land covers change trajectories

General land cover change trajectories can be expected given an initial undisturbed state. In general, they involve with four broad categories of land cover (e.g. undisturbed, frontier, agriculture/managed and urbanized/industrialized). First, undisturbed land-cover is when the landscape is dominated by “natural” cover types, where change is primarily by natural disturbance with little anthropogenic use. The second, frontier is when the landscape is experiencing transformation in “natural” cover, usually by extensive anthropogenic land uses (e.g., conversion to agriculture, forest re-growth through resources extraction). Third, agricultural/managed is when the landscapes is being managed and this matches or supersedes natural cover and functions, such as rangelands or cultivated lands sustained by intensive in-puts. Land-cover may be relatively stable, and change in it may be slow. Fourth, urbanized/industrialized land cover is completely anthropogenically managed, as all areas are ‘built up’.

2.7. The Characteristics of Satellite image

Landsat satellite image has primary sensors such as OLI (Operational Land Imager), TM (Thematic Mapper), MSS (Multi-spectral Scanner), ETM+ (Enhanced Thematic Mapper Plus), and Each sensor is composed of bands or many multi-spectral wavelengths and each band of that sensor has the specifically the spectral ranges. For example, landsat-5 (TM) consist of Seven multispectral bands landsat-8 or (OLI) consist of eleven multispectral bands which characteristic of each band is shown (Table 2.1 & 2.2)

2.7.1. Landsat 5 Thematic Mapper

The Landsat-5 Thematic Mapper (TM) was high-resolution which consist of 7 spectral bands (Table 2.1). The spatial resolution is 30 meters for band 1, 2, 3, 4, 5 and 7. Whereas band 6 Thermal infrareds was collected at 120 meters but was resampled to 30 meters. Likewise, the thematic mapper collected images in visible, near infrared and mid infrared.

Table 2.1 Landsat-5 Thematic Mapper (TM)

Number of bands	Wavelength (µm)	Spatial Resolution (meter)
Band 1 (Visible blue)	0.45 to 0.52	30
Band 2 (Visible green)	0.52 to 0.60	30
Band 3 (Visible red)	0.63 to 0.69	30
Band 4 (Near-infrared)	0.76 to 0.90	30
Band 5 (Short-wave infrared)	1.55 to 1.75	30
Band 6 (Thermal)	10.4 to 12.3	120 * (30)
Band 7 (Short-wave infrared)	2.08 to 2.35	30

Source from http://gisgeograp hy.com/landsat-program-satellite-imagery-bands/

2.7.2. Landsat 8 Operational Land Imager

There are two main sensors of Landsat8: the Operational Land Imager (OLI) and the Thermal-Infrared Sensor (TIRS). The Operational Land Imager (OLI) was consist of 9spectr-al bands from band 1 to band 9 and for TIRS comprise 2 thermal bands with a spatial resolution of 100 meters (Table 2.2). Moreover Landsat-8 shall collect images using 9 spectral bands indifferent wavelengths of visible, near-infrared, and shortwave light to observe a 185- km wide swath of the Earth in 15-30-meter resolution covering wide areas of the Earth's landscape while providing adequate resolution to discriminate features like forests, farms, urban centers, and other land uses.

Table 2.2 Landsat-8 Operational Land Imager & Thermal Infrared Sensor

Number of bands	Wavelength (μm)	Spatial Resolution (meter)
Band 1 (Coastal / Aerosol)	0.433 to 0.453	30
Band 2 (Visible blue)	0.450 to 0.515	30
Band 3 (Visible green)	0.525 to 0.600	30
Band 4 (Visible red)	0.630 to 0.680	30
Band 5 (Near-infrared)	0.845 to 0.885	30
Band 6 (Short wavelength infrared)	1.56 to 1.66	30
Band 7 (Short wavelength infrared)	2.10 to 2.30	60
Band 8 (Panchromatic)	0.50 to 0.68	15
Band 9 (Cirrus)	1.36 to 1.39	30
Band 10 (Long wavelength infrared)	10.3 to 11.3	100* (30)
Band 11 (Long wavelength infrared)	11.5 to 12.5	100* (30)

Source from http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/landsat-8/

2.8. Band combinations between Landsat 5 or Landsat 7 and Landsat 8

Table 2.3 Displayed below are some common band combinations in RGB comparisons for Landsat 7 or Landsat 5, and Landsat 8.

		Landsat 7 Landsat 5	**Landsat 8**
	**Color Infrared**	**4, 3, 2**	**5, 4, 3**
	**Natural Color**	**3, 2, 1**	**4, 3, 2**
	**False Color**	**5, 4, 3**	**6, 5, 4**
	**False Color**	**7, 5, 3**	**7, 6, 4**
	**False Color**	**7, 4, 2**	**7, 5, 3**

Source: *http://landsat.usgs.gov/L8_band_combos.php*

2.9. Basic Concept in Image Analysis

According to Ayele (2011), Remotely Sensed data includes a variety of data source that are defined from the range of spectrum of electromagnetic radiations. Aerial photography is used to capture reflective signal from the visible and near infrared portion of the spectrum. Most digital scanners operate in similar portion of the spectrum. Thermal and radar sensor systems are sensitive to the different portion of the energy spectrum.

Remotely sensed data provides an operational Geographic Information System (GIS) with timely and synoptic data. Image analysis techniques are commonly utilized to perform regional vegetation mapping and update existing vegetation maps (Ayele, 2011). The utility of a sensor system for the detection of surface phenomena must be assessed along four dimensions: radiometric resolution, temporal resolution, spectral resolution and spatial resolutions (area or size of feature that can be identified) (Jensen, 1995).

Satellite digital sensor and airborne collected data and store data values for the exterior of the earth with the discrete unit collection of large matrix of these cells. Each cell is referred to as a picture element or pixel and may correspond to a hectare, square meter or square kilometer base on the sensor. One side of the cell is frequently uttered as the length of one side of the cell which is the spatial resolution of the sensor. According to Kidwell (1988), complex very high decree radiometer has spatial decree of 1.10 km. Landsat (TM), 30 m; Landsat (MSS) resolution is 79 m; and Satellite Pour l' Observation de la Terra (SPOT) 20 m (Ayele, 2011).

2.10. Image Classification

In the application context, the important thing in image classification is the thematic characteristics of an area (pixel) rather than its reflectance value. Thematic characteristics such as LULC, type of soil can be used for further analysis. On the other hand, the classified image can also be considered as data reduction: a number of multispectral bands resulted in a single value raster file. Image classification is an operation to replace visual analysis of the image data with quantitative techniques for automating the identification of skin tone in a picture (Bakker *et al.*, 2000), this usually engages the study of multispectral picture facts and the application of statistically based decision rules for determining the land cover identity of each pixel in an image (Ayele, 2011).

As described by Diday (1994), image classification is the process of creating thematic maps from satellite imagery. A thematic map is an informational representation of the image that shows the spatial distribution of an exacting topic. Images are computerized analysis from remote sensors is known as a quantitative analysis due to its ability to identify pixels based on the numerical properties. For quantitative analysis, usually different procedures of classification are used. Classification is a method that assigns categories to different pixel groups according to with the spectral character. There are two main spectrally oriented classification procedures for land cover mapping: unsupervised and supervised classifications (Ayele, 2011).

Diday (1994) unsupervised classification is computer-automated and it enables the user to specify some parameters that the computer uses to uncover statistically patterns to facilitate the inherent ant in the data outline are plainly collect of pixels with alike spectral uniqueness. More importantly in several cases to identify group of pixels with similar spectral characteristics than it is to sort pixels into recognizable categories. Explained, in supervised classification on the image analyst supervises the pixel categorization processes by indicating, to the computer algorithm mathematical descriptor. Of the various lands cover types in attendance in a picture. To do these delegates illustration the site of recognized wrap type, named teaching areas are used to generate the parametric signatures of each class (Ayele, 2011).

According to Jensen (1996) and Land Grebe (2003), each pixel in the data set is then compared numerically to each category in the interpretation key and labeled with the name of the category. There are different algorithms under this classification type in which minimum distance, variance, and covariance of the classes are considered during classification. Of these algorithms, the best is maximum probability classifier. Both the differences were quantitatively evaluated and covariance of the category spectral response patterns when classifying a generalizing at the most will give first and second levels, accuracy in interpretation can be attained that will make the land use and land cover data comparable in quality to those obtained in other ways. For land use and land cover data needed for planning and supervision purposes, the correctness of explanation at the comprehensive first and second levels are satisfactory when the interpreter makes the correct interpretation 85 to 90 % of the time (Ayele, 2011).

Rechards (1999) showed that supervised classification is the procedure most used for quantifying of Remote Sensing (RS) data. It rests upon using suitable algorisms to label the pixels in an image as representing particular ground cover types or classes. An important assumption in supervised classification usually adopted in (RS) is that each spectral class can be described by probability distributions in multispectral space: this will be a multivariable distribution with as many variables as dimensions of the space. Such distribution describes the chance of finding a pixel belonging to that class as any given location in many multispectral places. This is not difficult as it would be ERDAS IMAGINE that most pixels in the distinct cluster or spectral class would lie towards the center and would decrease in density positions away from the class center, thereby resembling a probability allocation. The allocations establish to be mainly worth is the normal distribution. It gives rise to tractable mathematical descriptions of the supervised classification process and robust in the sense that classification accuracy is not overly sensitive to violations of the assumptions that the classes are normal (Ayele 2011).

2.11. Classification Accuracy Assessment

Classification accuracy assessment is substantially a measure of how many ground truth pixels were classified correctly. When looking at the land-cover map, it is too vital to bear in mind that no map is a perfect symbol of actuality. Depending on the 30-meter resolution of the Landsat data used bearing in mind it is valuable to produce a map to map will be most accurate for viewing geographic patterns over bigger areas. The product of the exactness consideration provides us with an overall accuracy of the map depend on an average of the accuracies for each class in the map (Ayele 2011).

$$Overall\ Accuracy = \frac{Number\ of\ Pixels\ correctlyclassificatio}{Total\ Number\ of\ Pixel}$$

As explained by Jensen (2003), Kappa is used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data as indicated by the major diagonals and the column and row which indicates the chance agreement totals. Producer's accuracy is the total number of correct pixels in a category divided by the total number of pixels of that category as derived from the reference data (column total). This statistic indicates the probability of a reference pixel being correctly classified and is a measure of omission error (Ayele 2011).

The kappa factor is given by the formula (Jensen, 2003)

$$Kappa\ (K) = \frac{Po - Pe}{1 - Pe}$$

Where: Po = is the proportion of correctly classified cases

Pe = is the proportion of correctly classified cases expected by chance

According to Jensen (2003), Producer' accuracy gives how well a certain area can be classified, User's accuracy is when the total number of correct pixels in a class divided by the total number of pixels that were really classified in that class (row total), the result is a measure of commission error. User's accuracy is the probability that a pixel classified on the map actually represent that class on the ground

CHAPTER 3: RESEARCH METHOD

This study was conducted by using Geo-Informatics in which consisted of Geographic Information System (GIS), Remote Sensing (RS) and the Global Positioning System (GPS) (Olokeoguna *et al.*, 2014). The filed survey was used by questionnaire form and ground truth, Moreover, the survey design was developed and used for data gathering until process of data analysis in the study region. The following steps are implemented:

3.1. Location of the study site

The study sites are located in Thapangthong District, Savannakhet Province where lie in the 16° 05’ 34.48’’ N latitude and 105° 51’ 03.81’’ E longitude with elevations 219 meters of Mean Sea Level. The district was established in 1984, and shares borders with Pin and Xonboury districts to the North, Lakhonepheng, district to the South, Toumlan and Vapi districts of Saravan province to the East, Songkhone district to the west. Total area is 211,388.26 (hectare) and surrounded by various types of land-use and land-cover, rice field, agricultural land and forest land included as part of the National Biodiversity Conservation Area (NBCA) (*Xebangnouane*), Productive forest (*Dongsithounh)*, National Protection Forest (*Xetanoune*) and Production Forest Area (PFA) (*Dong-Sithouane*) (Forest Inventory Planning Division (FIPD, 2010).

Thapangthong district is far to the south the center point of Kaysonephomvihane City of a province by 147 km (Fig. 3.1). Based on the report of the district administration office, the total population of the district is estimated to be 40,708 people, and 20,199 females, the total households of 6.696, and there are 42 villages of total areas of the district. Whereas this study was selected 2 villages: *Houay Meun* and *Thong Pang* villages where have a total area of 7,214.55 hectares, have 477 households with a population of 2774 people and the study sites share boundaries with the neighboring villages and province as follow: Xonnabouly District of Savannakhet province to the north and Saravan Province to the south.

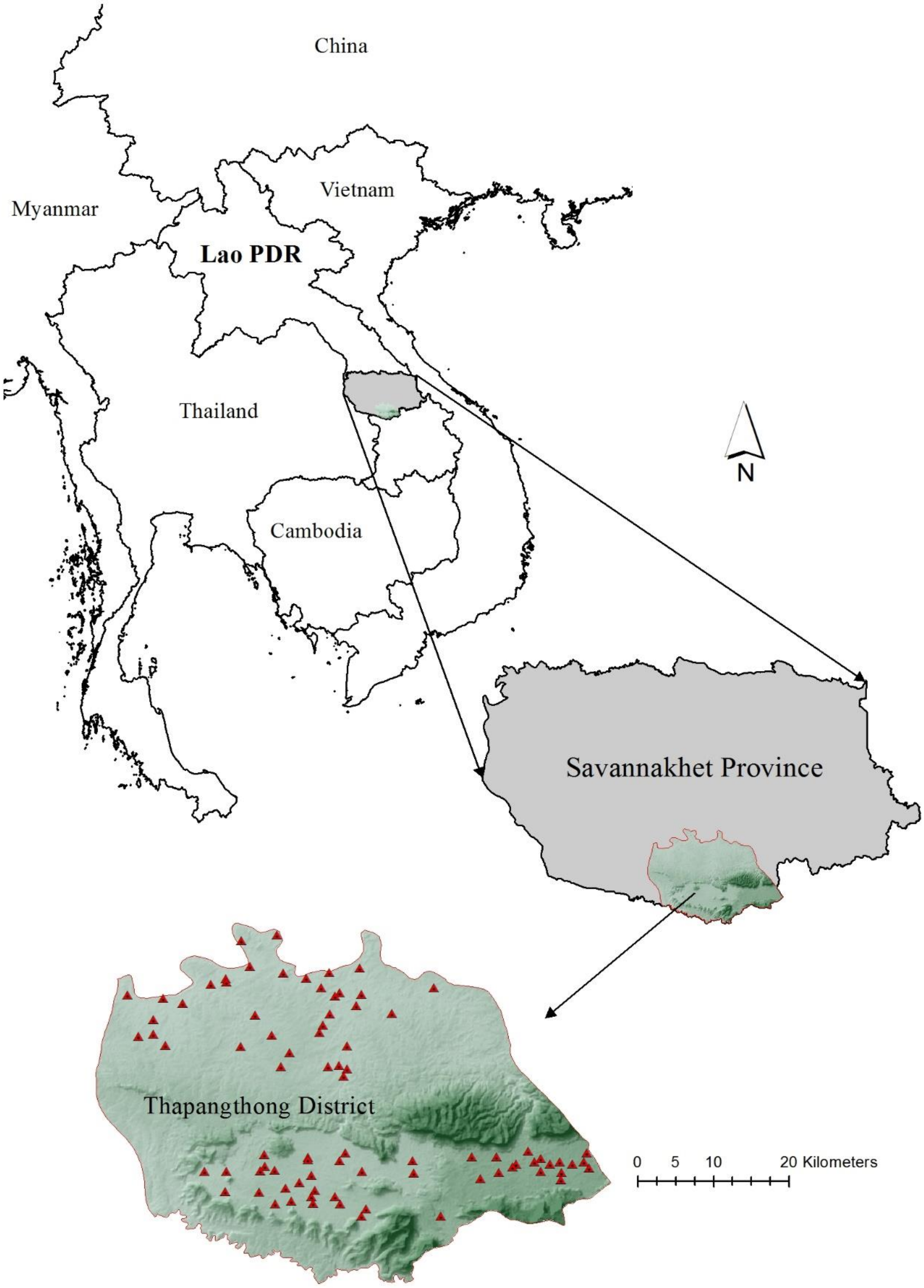

Fig. 3.1 Map showing location map of study area, at Thapangthong District, Savannakhet Province, Lao PDR

3.2. Climate

The study area has a monsoonal climate, the rainy season occurs from May to October and the dry season from November to April. The dry season is always cold and windy with the lowest humidity is 69 %, opposite with in rainy season is higher (87%). The average annual rainfall is 1461.30 mm receives during the rainy season and some area is flooded, the highest precipitation in July (423.40 mm). The temperature is highest just before and during the early part of the rainy season, thus April is the hottest month with an average temperature of 35 °C. January is the coldest month with an average temperature of 12 °C at low elevations.

Table 3.1 Climate data of Savannakhet province of 2014

Symbol	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
T_x	28.0	31.40	36.0	34.90	35.20	32.90	31.20	31.40	31.60	31.70	31.10	28.30	32.00
T_n	12.50	17.70	22.70	24.70	25.70	25.20	25.20	25.00	24.50	22.60	20.90	18.80	21.90
$(T_x+T_n)/2$	19.90	24.20	28.90	29.30	29.80	28.50	27.60	27.70	27.40	26.90	26.10	21.70	26.50
U_x	94.00	94.00	92.00	93.00	92.00	94.00	95.00	94.00	95.00	94.00	95.00	93.00	94.00
U_n	40.00	49.00	48.00	54.00	54.00	66.00	74.00	71.00	70.00	57.00	50.00	50.00	57.00
$(U_x+U_n)/2$	69.00	73.00	71.00	76.00	76.00	83.00	87.00	85.00	86.00	77.00	75.00	72.00	78.00
R	-	0.80	1.20	60.60	165.90	189.00	423.40	328.50	288.10	3.50	-	0.30	1,461.30
Sun	269.10	199.30	234.20	184.30	246.30	148.70	101.90	138.80	164.60	244.40	241.90	231.00	2,404.50

Source: Department of Meteorology and Hydrology, Ministry of Natural Resources and Environment. Remark: (Tx+Tn)/2= Mean temperature in c^o; T_x = Mean maximum temperature in c^o; T_n = Mean minimum temperature in c^o; $(U_x+U_n)/2$ = Mean humidity of air in %; U_x = Mean maximum humidity of air in %, U_n = Mean minimum humidity of air in %; R = Total rainfall in mm; Sun = Total sunshine duration in hours.

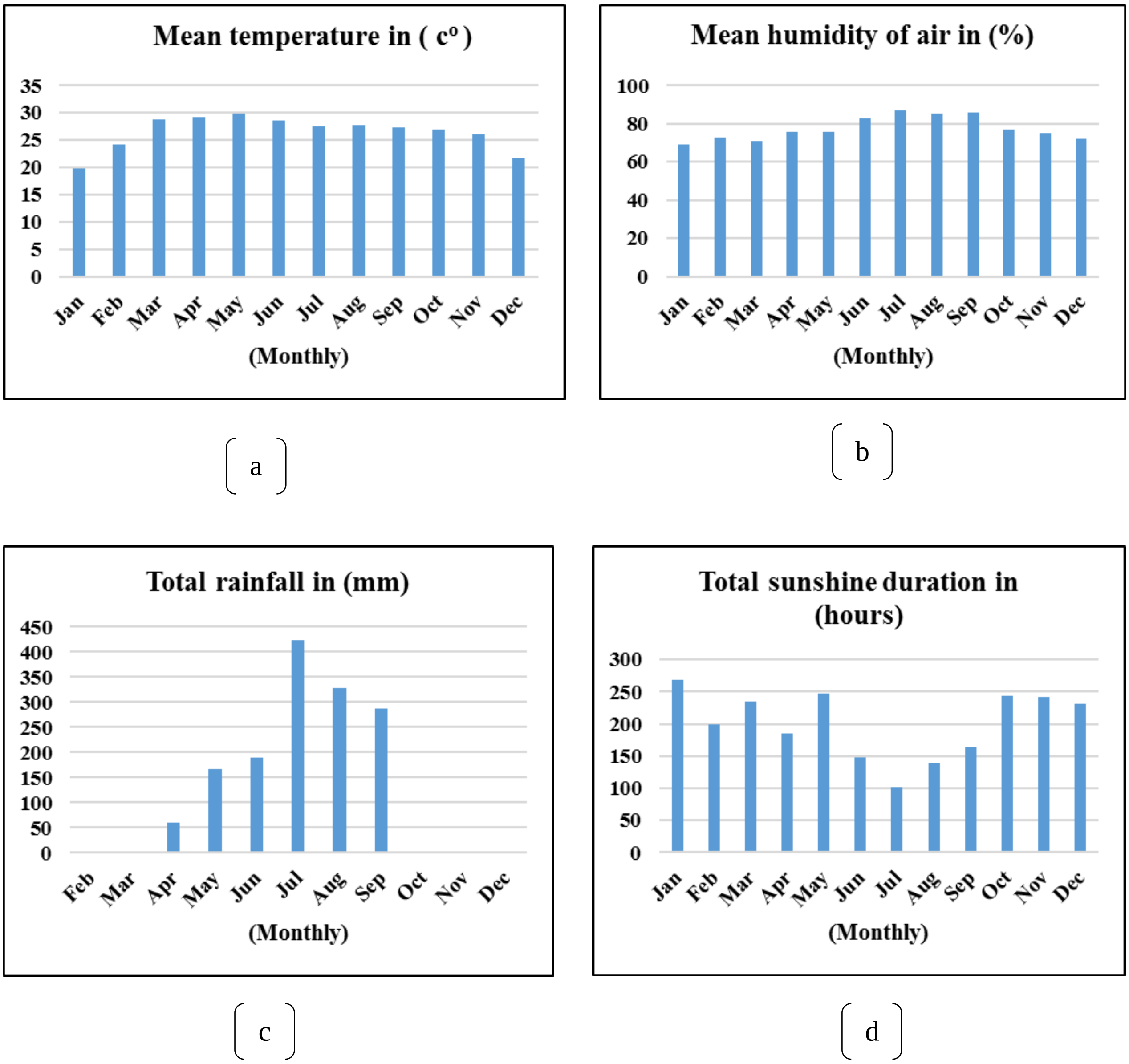

Fig. 3.2 Climate of Savannakhet province in 2014. (a) Temperature; (b) Humidity; (c) Rainfall; (d) Sunshine

3.3. Research Design

This study consists of both qualitative and quantitative aspects and has the types of data collection such as primary and secondary data to be collected. The methods of collection are below.

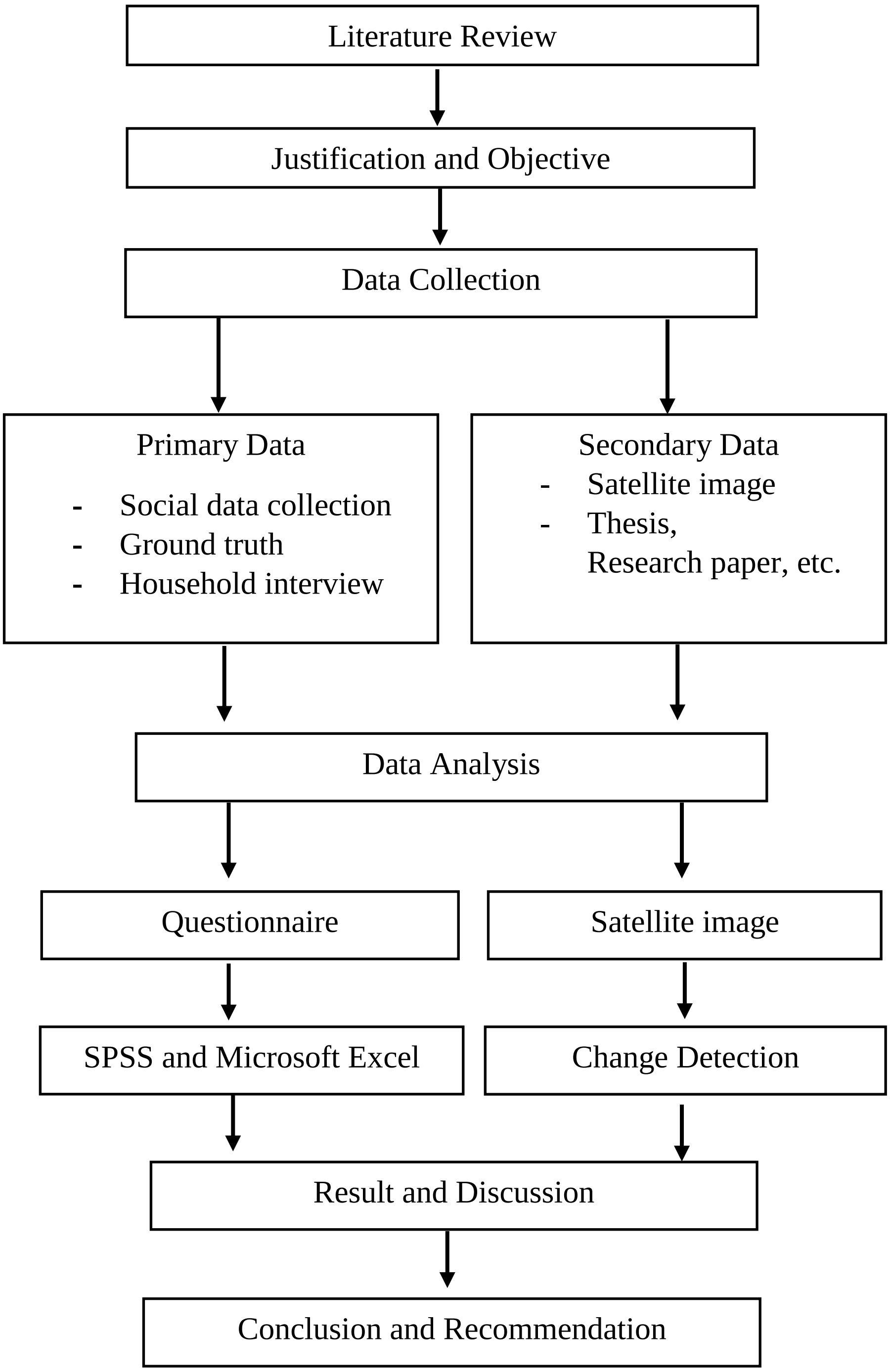

Fig. 3.3 The conceptual framework for this study

3.4. Data collection

The data collection in this study covered the two aspects: the first aspect was the Satellite Data and the second was household survey data.

3.4.1. Primary and Secondary data

Two types of data were gathered: primary data and secondary data. All data concerned to human activities in relation to land use and forest cover changes in between 2005 and 2016 were studied. The objective survey was conducted by interviewing people in two villages with total number of simple size about 129 households.

Primary data was obtained from local people by using questionnaires and focus group discussions with key informants such as oldest persons and heads of village at Houay Meun and Thong Pang villages in Thapangthong District of Savannakhet Province. The field surveys were provided the primary data on the changes in land use and forest practices within the last decades that focused on the causes of these changes and effects on the villagers' livelihoods.

Secondary data were particularly related to demographics socio-economics, agriculture production, household socio-economic statistics, and climate. The 'shapefiles' of boundaries, roads, rivers/streams were used from the National Geographic Department (NGD), Forest Inventory and Planning Division, Department of forestry, Ministry of Agriculture and Forestry, Provincial Agriculture and Forestry Office (PAFO), District Administrative Bureau (DAB), Ministry of Natural Resource and Environment, Land and Forest law, and conservation books.

3.4.2. Data collection process

1) Use of Satellite Data

The dataset on satellite images on the land-cover change were obtained by using Digital Image Processing Techniques. Fig. 3.4 shows the dataset information that can be obtained from images from 2005 and 2016. The following are the method used to classify these images.

The type of the satellite images used were: the Landsat-5 Thematic Mapper (TM) acquired on 2005-01-03 and Landsat-8 Operational Land Imager (OLI) acquired on 2016-03-22 date, Two Landsat images containing the study area were obtained from the US Geological Survey (USGS). The Satellite images were from eleven (11) years ago 2005 and 2016. The image for the year 2016 was used in addition to the household interviews in order to capture the history of different land use and forest change over time in Thapangthong District. GPS points of the surveyed households were also recorded. The time when buildings, farm fields, and agricultural land were established were discovered by interviewing the owners, local people and the village leaders. The GPS coordinates were used to draw the map to show the distribution of settlement.

The two Landsat images are dated 2005-01-03 and 2016-03-22 were used as primary data for the research. Details of the Landsat images are given in Table 3.2

Table 3.2 Satellite images used in land cover classification

No.	**Satellite images**	**Sensor**	**WRP: Path/Row**	**Number of bands**	**Spatial resolution**	**Acquire date**
1	Landsat 5	TM	126/049	7 (4-3-2)	30x30 m	2005-01-03
2	Landsat 8	OLI	126/049	11(5-4-3)	30x30 m	2016-03-22

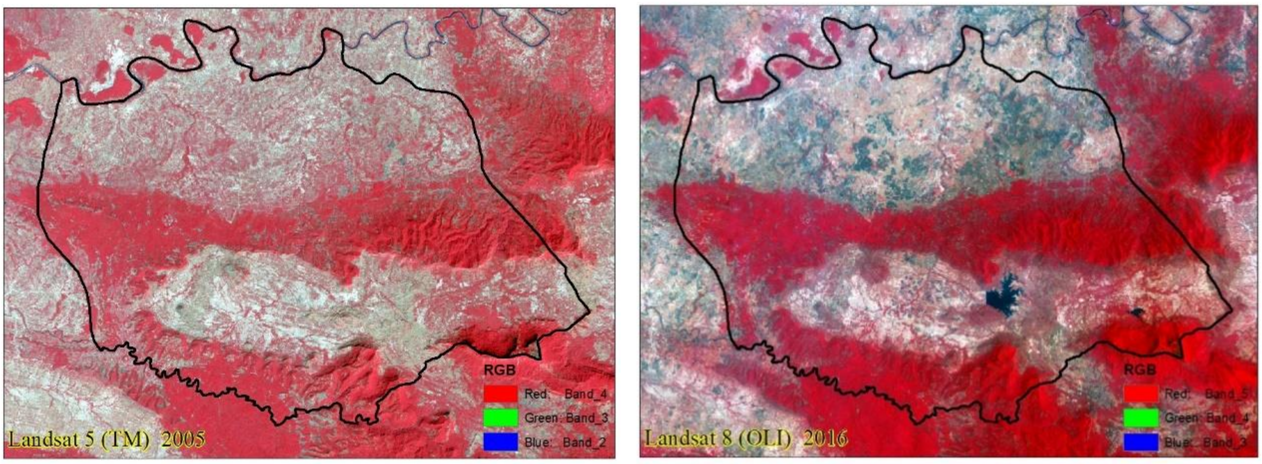

Fig. 3.4 Landsat satellite images used in the study area

2) Household survey data

a. Techniques of Sample size determination /Household questionnaire survey

The two villages had a population of 2774 persons, which included 1400 females and had 477 households in *Ban Houay Meun* about 281 households and about 196 households in *Ban Thong Pang*. Overall number of households was about 129 respondents for sample size. The latter was calculated by following the formula given by Krejcie & Morgan in 1970 and as well as formula of Taro Yamane in 1973 following below:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = the number of sample

N = total number of population based household number

e = error level at 10%

$$n = \frac{477}{1+477(0.1)^2} = 129$$

(*The number of sample is **129** households)*

After number of sample size determined in two villages was calculated by using below formula for dividing into each village:

$$n_i = \frac{nN_i}{N}$$

Where:

N_i = Number of sample size in each village (i=1, 2).

n = All number of sample size.

N = Total number of population based households number

N_i = Total number of population in each village (i=1, 2)

Table 3.3 determination of sample size in two villages

Village name	**No. of household (N_i)**	**Computation**	**Number of sample**
Ban Houay Meun	281	$\frac{129 \text{ x} 281}{477}$	76
Ban Thong Pang	196	$\frac{129 \text{ x} 196}{477}$	53
Total	**477**		**129**

b. Interview Method

The occurrence of interviewing was reliant on the stages of forms prepared for the interview a random sampling technique was used to interview the head of family, one person per household, according to the quantity of family unit sample. Rapid rural appraisal (RRA) was used to collect the data.

b.1. Questionnaire form

According to the objectives and methods used for data analysis, the questionnaire form was divided as two parts:

Part1. Questionnaire form on the general information: gender, status, education level, ethnic group, religion, occupation, age, and economic status of villager.

Part 2. Questionnaire form on assessment of the adaptation of local villagers to land cover changes of *Houay Meun* and *Thongpang* villages.

b.2. Data collection implementation using questionnaire form

The survey technique was used through interview, exploration, focus group discussion, and observation. The main content of study was focused on interview technique to draw the answers of each objective precisely.

b.2.1. Interview of respondents

Construction questionnaire form was applied to ask the respondents based on general information and adaptation of local villagers, and the random sampling technique was used into this study. Head of households or key person of households and authority staff were asked to obtain the accurate and precise answers as well. Source of variability was classified to minimize the heterogeneity within villages among household's groups. Interview had been spent the time at least 3 weeks.

b.2.2. Focus group discussion

Head of household or key persons about 8-12 people were requested to participate the each group discussion size. Two focus group discussions were used to conduct in each survey site. Discussing the way that people or participants perceive things with each other, the possibility to reveal their true feeling and understanding about the topic and objectives were increased. This was particularly important to have information people would otherwise like to conceal. In addition, this technique was invariably interested in the ways which individuals had discussed certain issues as a group, rather than simple as individuals. As mentioned above, the main objective of the focus groups discussion is to give a broader understanding on how the households to perceive the impact and adaptation on land cover change. Hence, the finding from these discussions were not represented in the analysis and discussion part. Finding used to triangle data collected from authority staff and households via questionnaire and establish the relevancy of such data.

b.2.3. Onsite inspection and observation

This technique was used to explore the facts which households were not willing to disclose and to have more detail information about issues and other facets. However, information by respondent was kept for secret during interview and FGD was reveal. Transect technique used into drawing the map of landscape system.

3.5. Data analysis

3.5.1. Satellite image of data analysis using ERDAS-ER Mapper Imagine and GIS software to processed

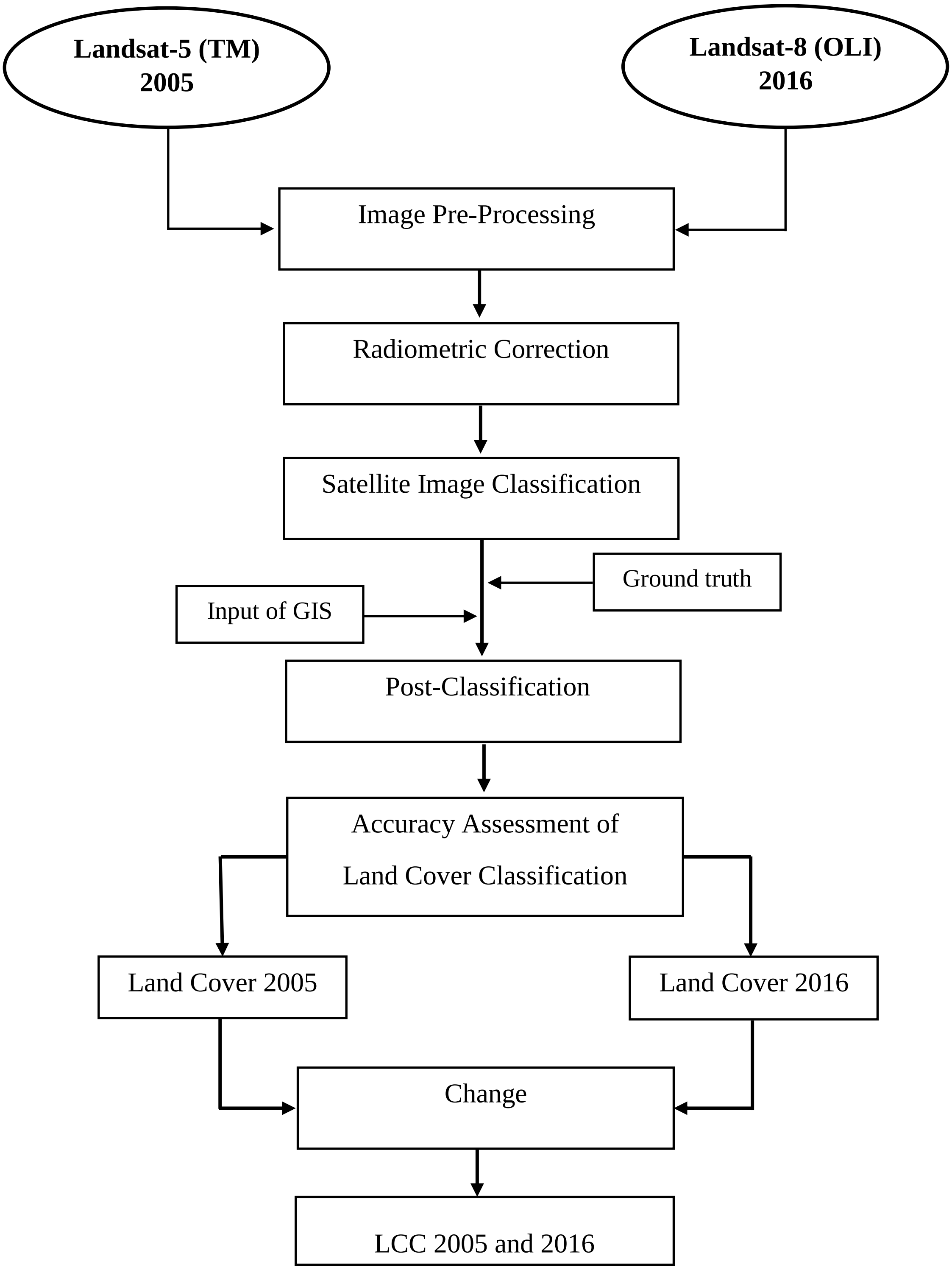

Fig. 3.5 Satellite image of data analyze framework

- **Steps in the analysis of satellite image data is given below**

1) Layer Stacking

According to Helen Cox (2009), stacking is the name of the process by which the different bands of information are overlaid in one file. This displays true and false color images by assigning Red, Green and Blue display colors to 3 different layers.

During layer stacking, the Universal Traverse Mercator (UTM) system with WGS84 as a datum was assigned as a preference as well as the projection. There are two Landsat images (Landsat-5TM 2005 and Landsat-8 OLI 2016) in this study area, all seven bands of Thematic Mapper (TM) and eleven bands of Observational Land Imager (OLI) were considered for Layers stacking in order to process the satellite imagery. The nature of these different bands had to be considered to make a decision as to which three-band combination would be most helpful for classification and visual interpretation. The color infrared composite of Landsat-5 (TM) bands used are band 4 reflective infrared wavelengths (0.76-0.90 µm), which is absorbed by water (appearing dark) and reflected by vegetation (appearing bright); bands 3 wavelengths (0.63-0.69 µm), which useful for identifying vegetation types, soils, and urban or built-up features and band 2 wavelengths (0.525-0.625 µm), which to helps find oil on the surface of water, and vegetation. In addition, this satellite image, band 4 is displayed in red, band 3 is displayed in green and band 2 is displayed in blue.

For Landsat-8 (OLI) images, the color infrared composite was used band 5 Near-Infrared Wavelength (0.845 - 0.885 µm), which useful for emphasizes biomass content and shorelines. Band 4 Red Wavelength (0.630 - 0.680 µm), use for discriminates vegetation slopes and band 3 Green Wavelength (0.525 - 0.600 µm), which useful for emphasizes peak vegetation, assessing plant vigor. After layer stacking, all the scenes were re-projected to UTM Zone 48 North using WGS 84 as a datum.

Table 3.4 The comparative bands between Landsat-5 (TM) and Landsat-8 (OLI)

Landsat 5 (TM)			Landsat 8 (OLI)		
Band Name	**Bandwidth (µm)**	**Resolution (m)**	**Band Name**	**Bandwidth (µm)**	**Resolution (m)**
			Band 1 Coastal	0.43 – 0.45	30
Band 1 Blue	0.45 – 0.52	30	Band 2 Blue	0.45 – 0.51	30
Band 2 Green	0.52 – 0.60	30	Band 3 Green	0.53 – 0.59	30
Band 3 Red	0.63 – 0.69	30	Band 4 Red	0.64 – 0.67	30
Band 4 Near Infrared (NIR)	0.76 – 0.90	30	Band 5 Near Infrared (NIR)	0.85 – 0.88	30
Band 5 Shortwave Infrared (SWIR) 1	1.55 – 1.75	30	Band 6 Shortwave Infrared (SWIR) 1	1.57 – 1.65	30
Band 6 Thermal	10.4-12.3	120* (30)	Band 7 Shortwave Infrared (SWIR) 2	2.11 – 2.29	30
Band 7 Shortwave Infrared (SWIR) 2	2.09 – 2.35	30	Band 8 Panchromatic	0.50 – 0.68	15
			Band 9 Cirrus	1.36 – 1.38	30
			Band 10 Thermal Infrared (TIRS) 1	10.6 – 11.19	100* (30)
			Band 11 Thermal Infrared (TIRS) 2	11.5 – 12.51	100* (30)

Source: https://landsat.usgs. gov/what-are-band-designations-landsat-satellites

2) Radiometric Correction

To improve visible interpretability an image by increasing apparent distinction between the features in the scene, digital enhancement such as level slicing, contrast stretching, spatial filtering, histogram equalization, edge enhancement, resolution merging, was carried out by the help visually the information in the images. These processes were done using image enhancement tools/options of ERDAS 2014.

3) Satellite image and Land cover classification

Landsat-5 Thematic Mapper (2005) and Landsat-8 Observational Land Imager (2016) images were earlier and very recent images available for study areas. Hence, it was possible to undertake field visit and collect GCPs. Supervised and Unsupervised classifications were preferred. The two Landsat images were also included to meet the preferred time horizon of the study. Meanwhile, it must be noted that efforts have been made to integrate historical information acquired from surveys to minimize complete reliance on spectral information and to solve the mystery of spectral similarity of different land cover classes in order to improve classification accuracy.

Therefore, supervised classification was selected to classify Landsat-5 and Landsat-8 images into different land cover classes, as supervised classification has higher accuracy than unsupervised classifications since the user can train the classes according to his wish thus, the base map and further two mentioned years maps for change detection was prepared by supervised classification. Maximum likelihood classifier is generally used for multi-spectral values 'n' bands, classified into classes 'k'. Data representing the different land cover classes obtained from the field study (GPS location) were used to train samples for supervised classification. Land cover was classified into the following five classes.

Table 3.5 Land cover type for classification in 2005 to 2016

No.	Land Cover types	Codes
1	Mixed Deciduous forest	MDF
2	Dry Dipterocarp Forest	DDF
3	Agriculture Land	AL
4	Built-up Land	BL
5	Water	W

Source: National Level Classification System for Lao PDR, Forest Inventory and Planning Division, Department of forestry, Ministry of Agriculture and Forestry

This type of classification was used to prepare the land cover maps. Training data collected from field study was used for the classification of 2005 and 2016 satellite images.

4) Definition of land covers classification system

Mixed Deciduous Forest:
In the mixed deciduous forest type, the deciduous tree species represent more than 50% of the stand. The forest stories are not as dense as those of evergreen type, and most of the seedlings and saplings are deciduous trees. Most often bamboo occurs in this type of forest. There are two sub-types of the mixed deciduous forest: Upper mixed deciduous forest located at an altitude of 200 m, in most areas there might be a lot of climbers, and it could be difficult to distinguish this forest type from the dry evergreen type. In dry regions, the deviation could be clearly seen. The type seems quite open with a significant amount of undergrowth and bamboo and lower mixed deciduous forest located at an altitude below 200m
Dry Dipterocarp Forest
It occurs in open stands. The tree diameter is comparably small and the height of the stand varies from 8 to 25 m. The crowns do not spread out widely. This type of forest is normally found in places with shallow soil, where the hard pan emerges above the ground, and on the polarized soil. On the poorest and shallow soils the trees are crooked and do not surpass 10 m in height: If the apex cover is less than 20% and the stand is undisturbed, the vegetation type should be classified as Savannah. Many species being characteristically for the Dry Dipterocarp forests are fire resistant and have a thick bark. Mai Sabeng (*Dipterocarps intricatus*), Mai Chick (*Shorea obtusa*), Mai Sat (*Dipterocarpus obtusifolius*), Mai Suak (*Terminalia tomentosa*) and Mai Hang (*Shorea siamensis*) are such species.
Agriculture Land
Agriculture land means the land aims for into agriculture activities such as grazing of cattle, rice field, cultivating like coffee, coconut, and cocoa.
Built-up Land
The built-up land areas are areas with small towns, institutions such as house, school, village offices, and others.
Water Area:
The water areas include rivers, water reservoirs (i.e. hydropower and dams for irrigation) and lakes. Lakes and Water reservoirs should have an area of 0.5 ha ^{2} and rivers should be at least 10 m wide to be classified as water. In other cases, it should be joined to adjoining land use class.

Source: National Level Classification System for Lao PDR, Forest Inventory and Planning Division, Department of forestry, Ministry of Agriculture and Forestry

5) Post-Classification

When finished combining the image data classes, the classified image was filtered before producing a final output, unclassified or false classification was removed.

6) Classification Accuracy Assessment

Classification accuracy assessment and Kappa coefficient error matrix were also determined based on image classification result. Eventually, the classified images were exported to ArcGIS Ver. 10.3 for map preparation and to describe the situation of the spatial land cover change of the study area (Hussien, 2009). Classification Accuracy assessment is a general term for comparing the classification to geographical data that are presented to be true, in order to define the accuracy of the classification process. Normally, the assumed-true data are received from field survey or data of ground truth. It is usually not practical to ground truth or otherwise test every pixel of image classification. Therefore, a set of reference pixels is usually used. Reference pixels are points on image classification for which actual data are (or will be) known. The reference pixels are randomly selected (Congalton, 1991).

7) Change Detection and Analysis

Following the image classification from the individual years, the multi-data post-classification comparison change detection algorithm was used to define the land cover changes (Fei Yuan, *et al.* 2005). Many methods of change detection have been used the various applications (Ayele, 2011). Example: post-classification comparison, image rationing, image differencing, image regression, principal component analysis. Therefore, this study was used by the convert from raster format in to vector (shapefile) format for classified images. The vector files were again converted to the raster grid by using spatial analysis extension of ArcMap ver. 10.3, Conversion of land cover was calculated by using raster calculator. The analysis and interpretation of different aspects of the numeric data of land use dynamics was done in Microsoft Excel. The results were presented in the easily understandable forms such as maps, charts, table, and graphs.

8) Rate of change detection

The following formula was used to estimate the rate of changes of land cover pattern between 2005 and 2016.

$$\textbf{Rate of Change}\ (\%) = \left[\left(a^2/_{a^1}\right)^{\frac{1}{n}} - 1\right] \times 100$$

Where, a^1= base year data (2005 land use/land cover)

a^2= end time data (2016 land use/land cover)

n = number of years (i.e. 11 years)

9) Software used

This study has used the software of ArcMap version 10.3 and ERDAS IMAGINE version 2014 to data analysis, especially spatial data between raster and vector or vector to raster for land cover classification. On the other hand, used to the Microsoft Excel to mixed between vector file and excel and to help the calculation of land cover type

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3.5.2. Data process and Questionnaire data analysis

Data process was one of the key part of whole survey operation and included manual editing, encoding, data cleaning and consistency checking. After that data analysis was done by using the descriptive statistics such as frequency, percentage, mean, standard deviation, minimum and maximum values. For the questionnaire survey, data were analyzed by using the IBM SPSS version 20 and Microsoft Excel version 2016.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Land Cover Classification

The objective of the image classification was to determine the changes in land cover particularly, the attention to five classes distribution namely mixed deciduous forest, dry dipterocarp forest, agriculture land, and built-up land and water area. For the land cover classification Landsat-5 (TM) and Landsat-8 (OLI) images were used. Supervised classification and change detection analysis method were applied to land cover change between two time periods (in 2005 and 2016). The results of land cover classification revealed that the forest was the major type; mainly forest is dry dipterocarp forest, which is followed by mixed deciduous forest. Thus, the other land cover classes of different images data are given below:

4.1.1. Satellite Image Classification in 2005

For the satellite image classification of the year 2005, Landsat-5 (TM) was used for classification of satellite image. The land cover status is given detail in Table 4.1 and showed in Fig. 4.1. According to the results of land cover classification (Table 4.1) in 2005, dry dipterocarp forest covered 108,920 ha, mixed deciduous forest of 81,400.11 ha, water area of 1,280.54 ha, agriculture land of 19,336.80 ha, and built-up land of 399.98 ha which consist of 51.54%, 38.52%, 9.11%, 0.61% and 0.19% respectively.

Table 4.1 Land Cover Classification in 2005

Code	**Land Cover Types**	**In 2005**	
		Areas (ha)	**%**
MDF	Mixed Deciduous Forest	81,400.11	38.52
DDF	Dry Dipterocarp Forest	108,920.83	51.54
AL	Agriculture Land	19,336.80	9.15
BL	Built-up Land	399.98	0.19
W	Water	1,280.54	0.61
	Total	**211,338.26**	**100**

Source: From data analysis

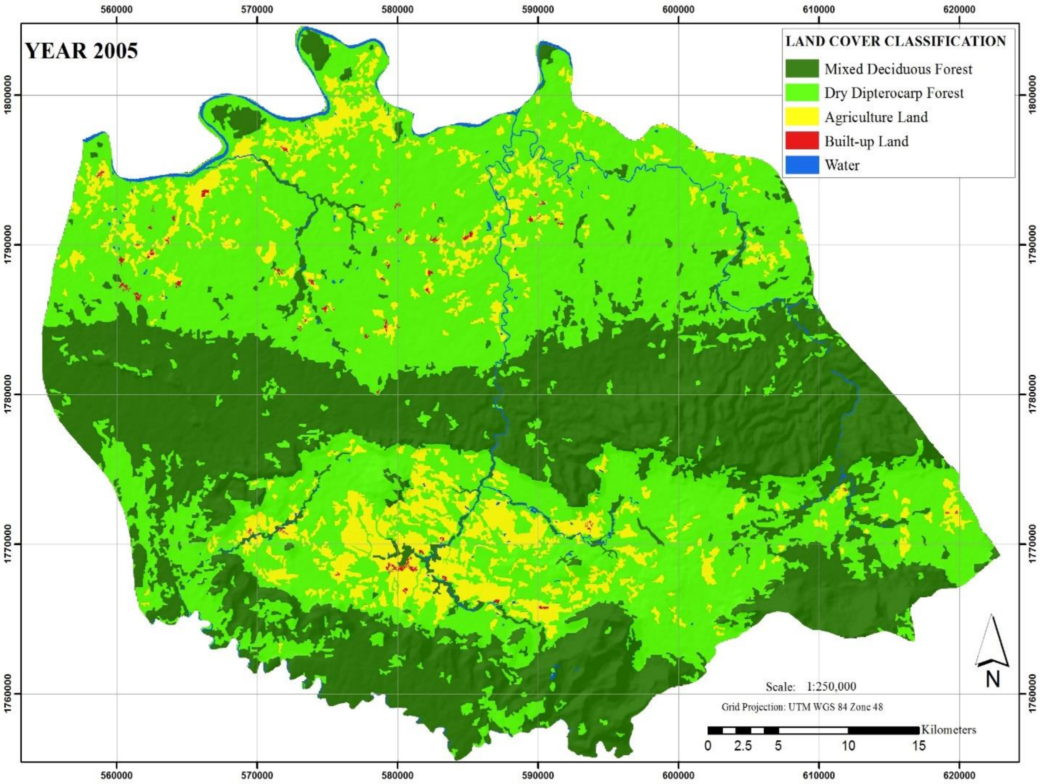


Fig. 4.1 Land Cover Classification in the year 2005

4.1.2. Satellite Image Classification in 2016

In 2016, Landsat-8 (OLI) was used for the satellite image classification. The land cover maps showed that the mixed deciduous forest has slightly increased to 83,200 ha (39.36%). The opposite agriculture land was increased fast 34,415.19 ha (16.38%), followed by water 2,579.64 ha (1.23%) and built-up land 651.68 ha (0.31%) respectively. Whereas dry dipterocarp forest decreased approximately 90,523 ha (42.81%) (Table 4.2 and Fig. 4.2).

Table 4.2 Land Cover Classification in 2016

Code	**Land Cover Types**	**In 2016**	
		Areas (ha)	**%**
MDF	Mixed Deciduous Forest	83,190.78	39.36
DDF	Dry Dipterocarp Forest	90,482.96	42.81
AL	Agriculture Land	34,415.19	16.28
BL	Built-up Land	651.68	0.31
W	Water	2,597.64	1.23
	Total	**211,338.26**	**100**

Source: From data analysis

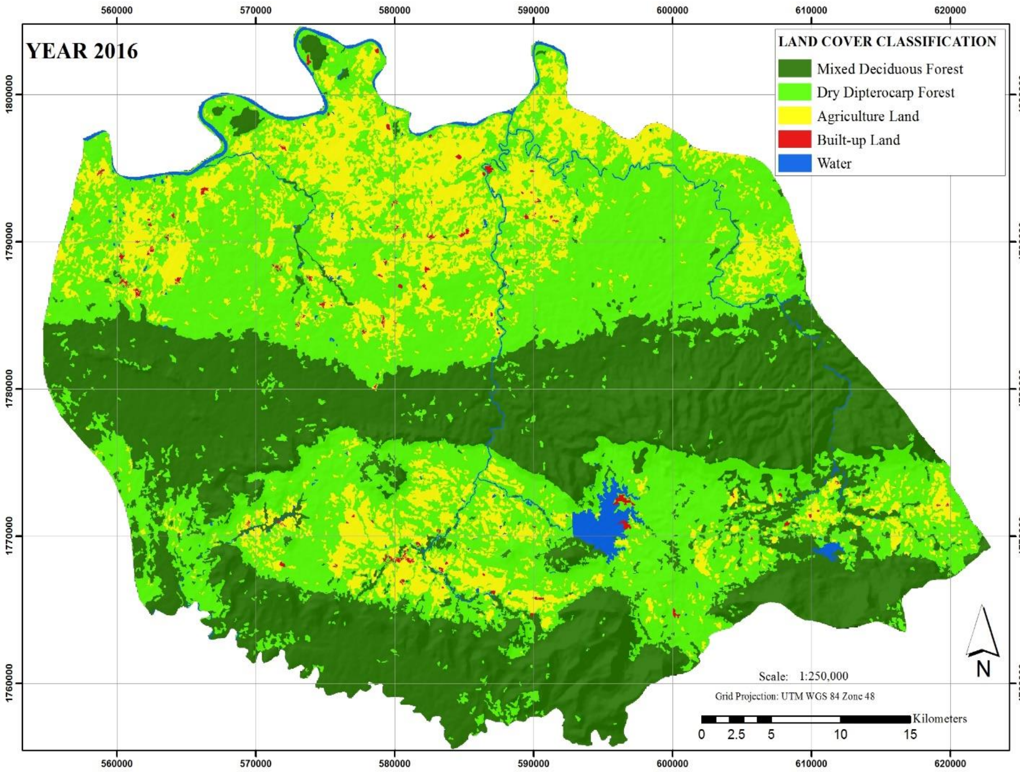
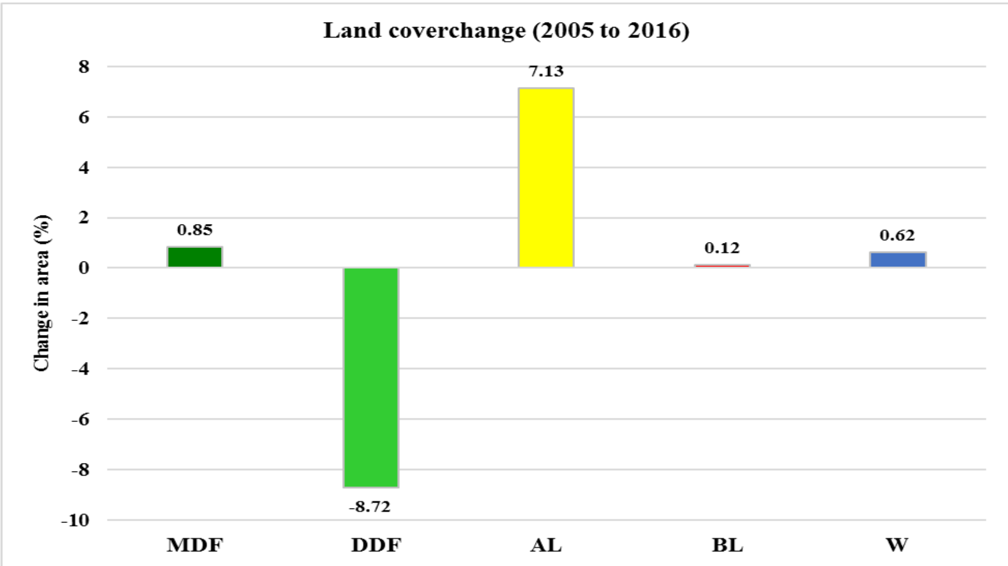


Fig. 4.2 Land Cover Classification in the year 2016

4.2. Land Cover Change

4.2.1. Rate of land cover change between 2005 to 2016

The comparison of land cover change of 2005 and 2016 showed that, data registered in Table 4.3 and Fig. 4.3 revealed that the positive and negative changes occurred in the land cover pattern of the Thapangthong district during the last decade.



MDF= Mixed Deciduous Forest; DDF= Dry Dipterocarp Forest; AL= Agriculture Land; BL= Built-up Land; W= Water

Fig. 4.3 Diagrammatic instance of land cover change in percent during between in 2005 &2016.

The dry dipterocarp forest of this study area has decreased from 108,920.83 ha in 2005 to 90,482.96 (ha) in 2016, which accounts for 8.72% of the total study area. The mixed deciduous forest of this area has slightly increased from 81,400.11 (ha) in 2005 to 83,190.78 (ha) in 2016 which is about 0.85% of the total study area. The agriculture land has increased from 19,336.80 (ha) in 2005 to 34,415.19 (ha) in 2016 which account for 7.13%. In addition to this, the built-up land from has declined from 399.98 (ha) in 2005 to 651.68 (ha) in 2016. The increased in built-up land account for 0.12%, and the water area of study has been increased from 1,280.54 (ha) in 2005 to 2,597.64 (ha) in 2016 which coved 0.62%.

Table 4.3 Change in land cover patterns between 2005 to 2016

Code	**Land Cover Types**	**Area of LCC (ha)**				**Area of change (ha)**	
		in 2005	**%**	**in 2016**	**%**	**2005-2016**	**%**
MDF	Mixed Deciduous Forest	81,400.11	38.52	83,190.78	39.36	1,790.68	0.85
DDF	Dry Dipterocarp Forest	108,920.83	51.54	90,482.96	42.81	-18,437.87	-8.72
AL	Agriculture Land	19,336.80	9.15	34,415.19	16.28	15,078.39	7.13
BL	Built-up Land	399.98	0.19	651.68	0.31	251.64	0.12
W	Water	1,280.54	0.61	2,597.64	1.23	1,317.10	0.62
	Total area	**211,338.26**	**100.00**	**211,338.26**	**100.00**		

Source: From data analysis

According to Table 4.3, that the dry dipterocarp forest area was decreased from approximately 51.54% in 2005 to 42.81% in 2016 due to human influence, forest to agriculture land (rice filed, garden, etc.). During the same period (2005-2016), the agriculture land has increased from 9.15% to 16.28% due the increase of human population in Thapangthong district (Table 4.5). On the other hand, mostly people were farmers, they cultivated rice. Secondly, the built-up lands increased from 0.19% to 0.31%. Water body was also increased from 0.61% to 1.23% because paddy need water: there are 2000 ha of total reservoir areas (SIS-PAFO, 2014) (Fig. 4.5). However, there are some types of land-use/land-cover was effected by reservoir such as forestland, agriculture land and human settlements. Finally, there is a class of mixed dry deciduous forest, which has increased from 38.52% to 39.36%. It is due to the new plantation industry for timber uses, they have planted trees like teak, rubber, etc., therefore, some rice field, garden, forestland was replaced by plantation (Department of Land Planning and Development, 2006).

As base on the result of spatial data analysis by using remote sensing (RS) and geographic information systems (GIS) in Thapangthong District was found that during 2005 to 2016, mostly the dry dipterocarp forest was decreased to convert the agriculture land (Table 4.3) and also slightly mixed deciduous forest was converted into agriculture land. On the other hand, there are some types of forest cover and land-use were converted to water body. However, some agricultural land turned to mixed deciduous forest as well (Miles Kenney-Lazar, 2010). The types of land-use/land-cover include production forest (can be converted to agricultural land), grazing land (raising livestock), and utilization forest (used for gathering forest products).

There are some reasons for the conversion of land cover in the past decades. Actually, the rate of land converted from forest cover to agriculture land due to the population was increased faster and economic expectation of the farmers change their future views from subsistence to economy perspective. Rely on Statistics district office (2017). The result found that the number of population within district from 27,115 people in year 1998 to 40,527 people in year 2015 (Table 4.4). Normally, the total of area 2,423.08 (ha) of production land in the district, thus agriculture lands was expanded by villager for paddy filed, there are 9228.11 (ha) in year 2015 to 9228.44 (ha) in year 2016, and also other agriculture land such as corn, bean… about 700 (ha) in year 2016 (Agriculture and Forestry District office, 2016; Savannakhet Irrigation Section [SIS-PAFO], 2014). A Chinese project (China Gezhouba Group Corporation (CGGC), Xesalalong Irrigation Project or CGGC was established in 2011. This project engulfed a total area of 2000 hectares. In addition, water intake structures, dam, water reservoir, flood spillway, canal and buildings along canal system also affected for the total forest area (SIS-PAFO, 2014). The project could be supported water for agricultural lands especially plantation and livestock in during dry season and rainy season. However, the land use and forest cover was changed by the reservoir especially built-up lands, paddy fields, gardens, etc. A village was flooded by water in 2014, hence, villagers had to relocate (Fig. 4.5; Natural Resource and Environment Office, 2014).

Many researchers were used the remote sensing (RS), geographic information system (GIS) technique for assess the land-use/ land-cover changes (Butt *et al.*, 2015, Prabhat Kumar Rai, 2013, Olokeogun *et al.*, 2014, Manonmani *et al.*, 2010, Selçuk Reis, 2008). Similarly, to using Landsat satellite imagery to be assessing the land use and land cover change of Phoukhaokhouay National Protected area, Lao PDR, to examine the rate of change of land use and land cover change between 1999 to 2014, the image classification was conducted by maximum likelihood classification (MLC) of supervised classification, the result found that forest cover has decreased by 1.11%, from evergreen forest and mixed deciduous forest to agriculture. Depending on the data of ground truth in field survey, thus the overall accuracy of remote sensing (RS) and geographical information system (GIS) estimated the value was 82% (Chanthakard, 2014). Impact of land use and land cover change on local livelihood in Pha-Oudom District of Borkoe Province of Lao PDR (Thongphanh *et al.*, 2007) to examined the land cover change though selected villages between the years 1988 to 2007. For the image interpretation was used the supervised of the maximum likelihood classification (MLC), thus, the result revealed the changes from 1988 to 2007 the landscape were foreseen largely for subsistence upland rice, whereas the data analysis of image interpretation shown a slow change of mature forest to secondary forest and agriculture.

Table 4.4 Number of population (1998-2015) in Thapangtphong District, Savannakhet Province.

Years	**Number of Population**	
	Total	**Female**
1998-1999	27,115	13,938
1999-2000	27,696	14,155
2000-2001	28,264	14,403
2001-2002	28,484	14,574
2002-2003	30,454	15,235
2003-2004	30,926	15,580
2004-2005	30,454	15,235
2005-2006	31,459	15,726
2006-2007	32,485	16,439
2007-2008	32,560	16,337
2008-2009	34,888	17,425
2009-2010	35,595	17,595
2010-2011	35,631	17,692
2011-2012	35,943	18,189
2012-2013	39,364	19,881
2013-2014	40,088	19,805
2014-2015	40,527	20,091
2015-2016		

Source: Statistics district office (2017)

Fig. 4.4 Characteristic of Xesalalong Irrigation Reservoir in Thapangthong District

Fig. 4.5 Cleared the dry Dipterocarp forest for agriculture land such as paddy filed, etc.

4.2.2. Change in land cover types 2005 to 2016

According to the result of land cover change from Geographic Information System (GIS), Table 7 showed overlaid analysis using land cover classification in between 2005 to 2016 showed that the dry dipterocarp forest has been converted to agriculture land approximately 21,028.21 ha (9.95%); followed by water body at 840.23 ha (0.40%); built-up land 80.76 ha (0.04%). From agricultural lands to built-up lands was about 179.18 ha (0.08%); water body 272.86 ha (0.13%); mixed deciduous forest at 112.88 ha (0.05%) receptively. In addition, the mixed deciduous forest converted to water 240.04 ha (0.12%); followed by agriculture land covered 130.75 ha (0.06%); built-up land 1.16 ha (0.00%). and from the built-up land to water body about 9.30 ha (0.00%) respectively.

Table 4.5 Change status of land cover types 2005 to 2016

Name change	**Types change**	**Area change (ha)**	**%**
Agriculture Land to Built-up Land	AL-BL	179.18	0.08
Agriculture Land to Mixed Deciduous Forest	AL-MDF	112.88	0.05
Agriculture Land to Water	AL-W	272.86	0.13
Built-up Land to Water	BL -W	9.30	0.00
Dry Dipterocarp Forest to Agriculture Land	DDF-AL	21,028.21	9.95
Dry Dipterocarp Forest to Built-up Land	DDF-BL	80.76	0.04
Dry Dipterocarp Forest to Water	DDF-W	840.23	0.40
Mixed Deciduous Forest to Agriculture Land	MDF-AL	130.75	0.06
Mixed Deciduous Forest to Built-up Land	MDF-BL	1.16	0.00
Mixed Deciduous Forest to Water	MDF-W	246.04	0.12

Source: Data analysis by using Geographic Information System (GIS)

4.3. Classification Accuracy Assessment

The overall classification accuracy, producers' accuracy and user accuracy were computed from Kappa Statistics and Confusion Matrix (KHAT) (Chust *et al*., 2004; Congalton, 1991). Overall classification accuracy was taken the probability of correctly mapped location with ground survey and user accuracy comparing the map with the data of ground survey. Producers' assessment compared between ground survey data and maps. In addition to this study, the ground survey data was collected by using Global Positioning Systems (GPS). Result of accuracy assessment indicated that the overall classification accuracy of the map was 95.80 % and Kapa Coefficient was about 78.10%.

Table 4.6 Accuracy assessment of land cover classification

Land Cover Types	Ground truth					Total	UA(%)
	MDF	DDF	AL	BL	W		
MDF	34	1	0	0	1	36	94.44
DDF	0	29	0	2	3	34	85.29
AL	0	0	37	0	0	37	100.00
BL	0	0	2	92	0	94	97.87
W	0	0	1	0	36	37	97.30
Total	34	30	40	94	40	**238**	
PA (%)	100.00	96.67	92.50	97.87	90.00		
Overall Classification Accuracy:						**95.80**	
Kapa Coefficient:						**78.10**	

Note: MDF= Mixed Deciduous Forest; DDF= Dry Dipterocarp Forest Producer Accuracy= PA
AL=Agriculture Land; BL= Built-up Land, W= Water User Accuracy = UA

4.4. The Characteristics of Sampling Household

4.4.1. Personal Information of Interviewed People

The general information provided from each respondent was gender, status, education, level, ethnic group, religion, occupation, age, as shown on following the tables:

Table 4.7 Proportion of respondents according to gender and status in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
1	**Gender**	**53**	**100**	**76**	**100**	**129**	**100**
-	Male	19	35.85	40	52.63	59	45.74
-	Female	34	64.15	36	47.37	70	54.26
2	**Status**	**53**	**100**	**76**	**100**	**129**	**100**
-	Single	3	5.66	3	3.95	6	4.65
-	Married	48	90.57	67	88.16	115	89.15
-	Divorced/widowed	2	3.77	6	7.89	8	6.20

Table 4.7 showed that the respondents were about 54.26 % of female and 45.74 % of male. For the dominant status was married approximately 89.15%, followed by divorced or widowed about 6.20 % and 4.65 % of single status.

Table 4.8 Proportion of respondents according to educational level, ethnic group and religion in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
1	**Education level**	**53**	**100**	**76**	**100**	**129**	**100**
-	Un-educated	15	28.30	22	28.95	37	28.68
-	Primary	20	37.74	36	47.37	56	43.41
-	Lower school	12	22.64	13	17.11	25	19.38
-	Upper school	6	11.32	3	3.95	9	6.98
-	College	0	-	2	2.63	2	1.55
2	**Ethnic group**	**53**	**100**	**76**	**100**	**129**	**100**
-	Lao	52	98	74	97	126	98
-	Lao Tung	1	2	2	3	3	2
3	**Religion**	**53**	**100**	**76**	**100**	**129**	**100**
-	Buddhism	53	100	74	97	127	98
-	Spiritualism	0	0	2	3	2	2

Table 4.8 Pointed out that respondents hold the education levels were predominant of primary school and un-education about 43.41% and 28.68% respectively and a minor study was college about 1.55%. The reasons that villagers have low educational level because of limited classes number located nearby the villages and their economic condition. For the religion that they are practicing was about 98 % of Buddhism and 2 % of spiritualism. Spiritualism is only practiced by Houaymeun villagers.

Table 4.9 Proportion of respondents according to occupation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
1	Official	6	11.32	6	7.89	12	9.30
2	Farmer	43	81.13	55	72.37	98	75.97
3	Worker	0	-	1	1.32	1	0.78
4	Civilian	3	5.66	14	18.42	17	13.18
5	Other	1	1.89	0	-	1	0.78
	Total	**53**	**100**	**76**	**100**	**129**	**100**

Besides, the respondents predominantly occupied as about 75.97 % of the farmer; and the rest of occupation was about 13.18 % of civilian, 9.30 % of official and 0.78 % of the worker (Table 4.9). There was only one family occupying as the worker and other. For the occupations held by respondent were mostly dependent on the natural resources to collect the food such as the mushroom, bamboo-shoot, wildlife, fish, and other edible plants. On the other hand, respondent uses the timber product as raw material for housing, animal housing, fencing, and others.

Table 4.10 Mean, Minimum and maximum of respondents according to age and family number

No	Parameter	Villages						Total		
		Thongpang			Houaymeun					
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1	Age (years)	47.35	21.00	75.00	50.07	18.00	76.00	48.96	18.00	76.00
2	Family number (person)	6.03	3.00	11.00	6.10	2.00	15.00	6.07	2.00	15.00

Table 4.10 showed the means of family size and age were 6.07 % per family and 50 years old. Besides, lowest were 18 years old and highest were on 76 years old, and family sizes were minimum about 2 persons and maximum about 15 persons. According to these result, the number of family size was quite big because the villagers engage the agricultural production,

particularly rice production that they need more labors used for such production season and reduction of labor wage.

4.4.2. Economic Status of Sampling Household

According to the questionnaire interview, consumption and income in Thongpang and Houaymeun villages as follows:

Table 4.11 Averages of respondents according to rice production in Thongpang and Houaymeun villages

No.	Description	Years	
		2005 (n=127)	2016 (n=126)
1	Average area of rice production (ha/ hh)	2.4	2.34
2	Productivity (ton/ ha)	1.82	1.8
3	average of rice product (ton/ hh)	4.36	2.34

(n=number of sampling household, ha=hectare & hh= household)

Table 4.11 showed that the respondents were about 2.40 (ha/ hh) in 2005 and 2.34 (ha/ hh) in 2016 of average area for rice production in each household. Actually, there were 1.82 (ton/ha) in 2005 and 1.80 (ton/ha) in 2016 of productivity. Therefore, for average of rice product were 4.36 (ton/hh) in 2005 and 2.34 (ton/hh) in 2016 respectively. Thus, the data revealed that the average of rice production within household was decreased during in 2005 to 2016.

Table 4.12 Average of respondents according to corn production in Thongpang and Houaymeun villages

No.	Description	Years	
		2005 (n=1)	2016 (n=2)
1	Average area of corn production (ha/hh)	0.1	0.17
2	Productivity (ton/ha)	1500	1208.57
3	Average of corn product (ton/hh)	150	211.5

(n=number of sampling household, ha=hectare & hh= household)

There were approximately 0.34 (ha/hh) and 0.17 (ha/hh) of average areas in corn production during in 2005 and in 2016 respectively (Table 4.11.). Productivity can be about 1500 (ton/ha) in 2005, and 1208.57 (ton/ha) in 2016. In addition, during 2005 to 2016, the average of corn production was decreased approximately 150 (ton/hh) in 2005 and 211.5 (ton/hh) in 2016.

Table 4.13. Average of respondents according to vegetable production in Thongpang and Houaymeun villages

No.	Description	Years	
		2005 (n=5)	2016 (n=3)
1	Average area of vegetable production (ha/hh)	0.34	0.23
2	Productivity (ton/ha)	204.71	181.43
3	average of vegetable product (ton/hh)	69.6	42.33

(n=number of sampling household, ha=hectare & hh= household)

Table 4.13 showed that the average area were 0.34 (ha/hh) in 2005 and 0.23 (ha/hh) in 2016 for vegetable production and the decrease of productivity, i.e., 204.71(ton/ha) in 2005 and 181.43 (ton/ha) in 2016. Hence, the average vegetable product were about 69.6 (ton/hh) in 2005 and 42.33 (ton/hh) in 2016, respectively.

Table 4.14 Average, Maximum and Minimum of respondents according to rice product consumption for households in Thongpang and Houaymeun villages

Rice product consumption for households	2005 (n=127)	2016 (n=126)
Average of rice consumption (kg/hh/year)	1,195	1,505.37
Minimum of rice consumption (kg/hh/year)	480	480
Maximum of rice consumption (kg/hh/year)	3,000	5,180
Average of rice consumption per person (kg/person/year)	250	248

(n=number of sampling household, hh= household)

Table 4.14 showed that from 2005 to 2016 the result of average in rice consumption for household were about 1,195 (kg/hh/year) in 2005 and the highest in 2016, 1,505.37 (kg/hh/year). Whereas, for average rice consumption per person was approximately 250 (kg/person/year) in 2005 and 248 (kg/person/year) in 2016. However, for maximum of rice consumption was 3000 (kg/hh/year) in 2005, and in 2016 was increased to 5180 (kg/hh/year). The minimum value for the latter consumption was similar about 480 (kg/hh/year) in the last decade. Based on the comparison of rice consumption between in 2005 and 2016 revealed that it was increased rapidly in each year. This may be due to almost all community were farmers and also the influence of recent increase of population.

Table 4.15 Average, Maximum and Minimum of respondents according to Rice production income in Thongpang and Houaymeun villages

Rice production income	2005 (n=123)	2016 (n=107)
Average income of rice production (kip/hh)	5,197,866.89	4,661,794.39
Average income of rice production per ha (kip/ha)	2,162,595	1,659,883
Minimum income of rice production per ha (kip/ha)	244,848	120,000
Maximum income of rice production per ha (kip/ha)	7,615,451	5,970,000

(n=number of sampling household, ha=hectare & hh= household)

According to table 4.14., mostly the villagers' income from the rice production. Thus, there were about 5,197,866.89 (kip/hh) in 2005 and 4,661,794.39 (kip/hh) in 2016 of average income from rice production per household. Moreover, for average income from rice production per hectare was 2,162,595 (kip/ha) in year 2005, and 1,659,883 (kip/hh) in year 2016. Therefore, the maximum income was decreased from 7,615,45 (kip/ha) in 2005 to 5,970,000 (kip/ha) in 2016. In addition, the minimum income of rice production per hectare was from 244,848 (kip/ha) in 2005 to 120,000 (kip/ha) in 2016. Thus, the income of rice production was decreased during in 2005 to 2016. This may be due to the recent changes in weather patterns. Moreover, in Thapangthong District of Savannakhet Province is situated in the lowland areas of Southern Laos and also Savannakhet Province has a lower central agricultural region, in which has the largest area of rainy season lowlands rice, surround 22% of the total area (103 400 ha in 1999). In the rainy season about 84% of the rice-growing areas found in southern Laos **(**Schiller *et al.,* 2001).

4.4.3. Adaptation of local villager on land change

Base on the result of data analysis in 2 villages: Thongpang and Houaymeun was obtained by questionnaire about adaptation of local villager on land change. Following the tables below:

Table 4.16 Proportion of respondents according to land change, adaptation and effect of land change in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change**						
	No	4	7.55	10	13.16	14	10.85
	Yes	49	92.45	66	86.84	115	89.15
II	**How to adapt on land change for livelihood**						
-	No	22	41.51	40	52.63	62	48.06
-	Yes	31	58.49	36	47.37	67	51.94
III.	**Effect of land change on livelihood**						
-	No	3	5.66	11	14.47	14	10.85
-	Yes	50	94.34	65	85.53	115	89.15

According to table 4.16 showed that there was 89.15 % of respondent answered as land change and there was only 51.94 % of respondents can adapt to land change for their livelihood and 89.15 % of respondent was affected by the land change. Hence, the land change with practicing the land use by specific ways should be considered to mitigate its effects because of the natural resources used within household for living conditions are dramatically reducing. Although, subtropical forests can provide 11 other land/environment services including regulating, supporting and cultural ecosystem services such as re-vegetation, land reclamation, soil improvement, soil conservation, erosion control and aesthetic value. Thus, at a worldwide scale, global change pressure (climate change, land-use practices and changes in atmospheric chemistry) are progressively affected the supply of good and services from forests (IUFRO, 2009). When land use practices such as agroforestry, farmer-managed natural regeneration, and the evergreen agriculture are replicated and cover large areas they transform the land in fundamental ways (UNCCD, 2014). Wu (2008) mentioned that land use change does come with costs and convention of farmland and forests to urban development reduces the number of lands available for food and timber production.

Table 4.17 Proportion of respondents according to land change impact on agriculture production in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
1	No	3	5.66	11	14.47	14	10.85
2	Yes	50	94.34	65	85.53	115	89.15
	Total	**53**	**100.00**	**76**	**100.00**	**129**	**100.00**

Table, 4.17 revealed that respondents encountered by the impact of land change on an agricultural production about 89.15 % and the village was more impacted as Thongpang village. Arunyawat & Shrestha (2016) stated that the impact of the change in land use with respect to ecosystem service plays the key role in order to execute a suitable land use in enhancing the ecosystem services. Overall, the chronic changes of land use in Laos have been summarized into four periods: 1) the civil war are (1963-1975) saw forest destruction due to bombing and reallocation; 2) the early socialist period (1975-1985) witnessed an expansion of paddy land and forest degradation; 3) the market transition period (1985-1995) experienced cash crop production resulting from trade and market liberalization; and 4) the post-socialist era (1990-present) has been experiencing an increase in commercial production and land reform as a consequence of development process (Fujita, 2006; Vixathep, *et al.*, 2013). The pace and intensity of land cover change have increased over the past three centuries and more particularly over the last three decades due to climate change and increasing human activities (Jianchu *et al.*, 2008).

Table 4.18 Proportion of respondents according to land change impact on crop production, its effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on crop production**						
1	No	3	5.66	11	14.47	14	10.85
2	Yes	50	94.34	65	85.53	115	89.15
II	**Factors of land change impact on crop production**						
1	No answer	3	5.66	11	14.47	14	10.85
2	Crop productivity decrease	17	32.08	19	25.00	36	27.91
3	Disease and insect outbreak	9	16.98	15	19.74	24	18.60
4	Drought	6	11.32	4	5.26	10	7.75
5	Land degradation	14	26.42	25	32.89	39	30.23
6	Infrastructure construction	3	5.66	2	2.63	5	3.88
7	Flooding	1	1.89	0	-	1	0.78
III	**Adaptation on land change impact for crop production**						
1	No answer	11	20.75	21	27.63	32	24.81
2	Chemical fertilizer application	28	52.83	32	42.11	60	46.51
3	Natural treatment	2	3.77	4	5.26	6	4.65
4	Land extension	1	1.89	2	2.63	3	2.33
5	Inorganic and organic products applied for crop production	1	1.89	2	2.63	3	2.33
6	Weeding	1	1.89	1	1.32	2	1.55
7	Producing the crop in 2 seasons	2	3.77	0	-	2	1.55
8	Reservoir construction or water storage	4	7.55	3	3.95	7	5.43
9	Soil quality improvement	3	5.66	11	14.47	14	10.85
IV	**Un-adaptation on land change impact for crop production**						
1	No answer	34	64.15	51	67.11	85	65.89
2	Don't know how to adapt	6	11.32	6	7.89	12	9.30
3	Animal manure application for improvement of soil quality	6	11.32	10	13.16	16	12.40
4	Don’t know how to solve the problem	0	-	2	2.63	2	1.55
5	Insufficiency and limitation of natural water sources	1	1.89	0	-	1	0.78
6	Same crop product produced	1	1.89	0	-	1	0.78
7	Land is far from river or water sources	0	-	2	2.63	2	1.55
8	Don’t have extra land allocation	2	3.77	0	-	2	1.55
9	Severe land degradation	3	5.66	5	6.58	8	6.20

There was 89.15 % of land change impact on crop production (Table 4.18). Thus, more than 18% of crop production was affected by land degradation; productivity decrease; and disease and insect outbreak. While natural disasters particularly drought and flooding have affected to crop production only 7.75% and 0.78% respectively. Due to the major factors affected on crop production, the adaptations used popularly for increasing the crop productivity were chemical fertilizer application and soil quality improvement. Nevertheless, the decrease of soil quality 12.40% and severe land degradation 6.25% were hard to adapt the technique to do somehow with good practice but how to adapt 9.30% into such production was not understandable to learn and apply new modern technology with existing local knowledge's farmers. In addition to that, available land and natural water were limited and deficient to use the one-year cycle of crop production intensification. Near urban areas, the area of farmland for rice production will be reduced with land use changes (Okamoto *et al.,* 2014). Agricultural production severely compromised in order to loss of land, shorter growing seasons, and more uncertainty about what and when to plant. Yield from rain-fed crop could be halved by 2020 in some countries coupled with net revenue from crop could fall by 90% by 2010. Thus, adaptation capacity has limited access to capital including market, infrastructure and technology, and concerned about ecosystem degradation and widespread of diseases (UNFCCC, 2007).

Table 4.19 Proportion of respondents according to land change impact on livestock production, its effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	**Parameter**	**Villages**				**Total**	
		Thongpang		**Houaymeun**			
		Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
I	**Land change impact on livestock production**						
1	No	19	35.85	23	30.26	42	32.56
2	Yes	34	64.15	53		87	67.44
II	**Factors of land change impact on livestock production**						
1	No answer	18	33.96	24	31.58	42	32.56
2	Disease outbreak	27	50.94	42	55.26	69	53.49
3	Animal product decrease	1	1.89	0	-	1	0.78
4	Limitation and decrease of feed resources	7	13.21	9	11.84	16	12.40
5	Animal population increase	0	-	1	1.32	1	0.78
III	**Adaptation on land change impact for livestock production**						
1	No answer	21	39.62	28	36.84	49	37.98
2	Vaccination	14	26.42	24	31.58	38	29.46
3	Treatment and medicine	8	15.09	15	19.74	23	17.83
4	Loosing the natural recovery way	2	3.77	3	3.95	5	3.88
5	Animal transference	2	3.77	1	1.32	3	2.33

6	Land extension	4	7.55	3	3.95	7	5.43
7	Stop of production	1	1.89	0	-	1	0.78
8	Seeking the animal feed sources	1	1.89	2	2.63	3	2.33
IV	**Un-adaptation on land change impact for livestock production**						
1	No answer	44	83.02	61	80.26	105	81.40
2	Lack of grass land	0	-	1	1.32	1	0.78
3	Severe disease outbreak	6	11.32	12	15.79	18	13.95
4	Inadequate fertility of new land	2	3.77	0	-	2	1.55
5	Feed insufficiencies	0	-	1	1.32	1	0.78
6	New land is far from ex-land	1	1.89	0	-	1	0.78
7	Land limitation	0	-	1	1.32	1	0.78

Table 4.19 showed that there was 67.44 % of livestock production impacted by a land change. Disease outbreak 53.49% and limitation and decrease of feed resources 12.40% were vulnerable on livestock. Paralleled with these vulnerabilities, livestock producers could adjust their practice only vaccination 29.46%, treatment and medicine 17.83%, and land extension 5.43% until to stop the production 0.78%. Due to severe disease outbreak, there was 13.93% of livestock producer could not adapt to this condition for protecting and maintaining their animal herd or flock existed. Feed insufficiencies coupled with the land limitation that played the key challenges to the adaption of livestock producers because there were many changes in the one-year cycle of production in order to increase the product volume, particularly the price of feed gradually increasing from time to time but also limit of available lands. Testing the context of agriculture is largely accepted that improved management of land, water, and agro-input would likely constitute a fundamental part of adaptation practices. The practice of fattening small and large ruminants is also used to adapt to increase such productivity coupled with using the by-product from crop production to reduce the cost of feed concerned currently through learning-by-doing. Besides, lack of knowledge about potential options for adapting the production system was encountered with limited assets and risk-taking capacity to access and use the technologies and financial services (FAO, 2014). Nevertheless, livestock producers have traditionally adapted to various environmental and climate changes by building on their in-depth knowledge of the environment in which they live. However, the expanding human population, urbanization, environmental degradation and increased consumption of animal source foods has rendered some of those coping mechanism ineffective (Sidahned, 2008; IFAD, 2012). Animal diseases emerging and re-emerging paralleled with low and declining soil fertility and/or land degradation were still encountered and cannot be adapted (Ayantunde *et al.*, 2015).

Table 4.20 Proportion of respondents according to land change impact on Fishery and Aquaculture, their effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on Fishery and aquaculture**						
1	No	45	84.91	57	75.00	102	79.07
2	Yes	8	15.09	19	25.00	27	20.93
II	**Factors of land change impact on Fishery and aquaculture**						
1	No answer	45	84.91	57	75.00	102	79.07
2	Fish number decrease and not abundant	2	3.77	11	14.47	13	10.08
3	Fishery difficulty and the low number of fish	6	11.32	6	7.89	12	9.30
4	Severe method for fishing	0	-	1	1.32	1	0.78
5	Flooding	0	-	1	1.32	1	0.78
II	**Adaptation on land change impact for Fishery and aquaculture**						
1	No answer	46	86.79	59	77.63	105	81.40
2	Seeking of new fishing area	4	7.55	12	15.79	16	12.40
3	Fish culture	0	-	1	1.32	1	0.78
4	Allocation of fishing area and conservation area	3	5.66	3	3.95	6	4.65
5	Weir construction	0	-	1	1.32	1	0.78
IV	**Un-adaptation on land change impact for Fishery and aquaculture**						
1	No answer	49	92.45	70	92.11	119	92.25
2	Overloading of fishing	3	5.66	5	6.58	8	6.20
3	Un-perdition of climate	0	-	1	1.32	1	0.78
4	Insufficiencies of fish number	1	1.89	0	-	1	0.78

Table 4.20 showed that there was about 20.93% of fishery and aquaculture affected from land changes. Due to the major factors influencing the fishing and aquaculture were fish number decrease and not abundant about 10.08%, and fishery difficulty and a low number of fish 9.30%. However, villagers can be adaptive by using some approaches such as s finding new places for fishing (12.40%) and allocation of fishing area and conservation area (4.65%). In contrast with these approaches, there were about 6.20% of villagers cannot change the behavior with overloading of fishing and about 0.78% of villagers cannot adapt to un-perdition of climate and insufficiencies of fish number.

Table 4.21 Proportion of respondents according to land change impact on economy, its effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on economy**						
1	No	30	56.60	46	60.53	76	58.91
2	Yes	23	43.40	30	39.47	53	41.09
II	**Factors of land change impact on economy**						
1	No answer	30	56.60	45	59.21	75	58.14
2	Family income decrease from NTFPs collection	1	1.89	0	-	1	0.78
3	Family income decrease	18	33.96	25	32.89	43	33.33
4	Agricultural income decrease	1	1.89	0	-	1	0.78
5	High family expenditure	1	1.89	3	3.95	4	3.10
6	Minimum of trading	0	-	1	1.32	1	0.78
7	Difficulty of job seeking	0	-	1	1.32	1	0.78
8	Increase of production	2	3.77	1	1.32	3	2.33
III	**Adaptation on land change impact for economy**						
1	No answer	40	75.47	48	63.16	88	68.22
2	Extra-work employed	4	7.55	12	15.79	16	12.40
3	Unknown	1	1.89	1	1.32	2	1.55
4	Saving of expenditure	2	3.77	8	10.53	10	7.75
5	Increasing of production	6	11.32	5	6.58	11	8.53
6	Relative rental	0	-	1	1.32	1	0.78
7	Natural livelihood	0	-	1	1.32	1	0.78
IV	**Un-adaptation on land change impact for economy**						
1	No answer	41	77.36	64	84.21	105	81.40
2	Un-adaptation	5	9.43	0	-	5	3.88
3	Unavailable area and addition production	3	5.66	7	9.21	10	7.75
4	Hard in living	0	-	1	1.32	1	0.78
5	Low production	2	3.77	3	3.95	5	3.88
6	Land degradation	2	3.77	1	1.32	3	2.33

Table 4.21 revealed that the impact of land change can cause the villagers' economy about 41.9%. The particle scales of factors impacting the economy were from the decreasing of incomes of families (33.33%), high family expenditure (3.10%) and an increase of production input cost (2.33%). For the adaptation of villagers to the economy impacted by land, changes were predominantly additional works (12.40%), increasing of production output (8.53%), and reduction of expenditure (7.75%). However, there were unavailable area and addition production, low production and Land degradation that were the challenge affecting to how to

adapt. According to Wu (2008), there are three major factors, the especially land is one of production in classical economics (along with capital and labor) and a crucial input for food production and housing. So, land use is the spine of agricultural economies and it provides social benefits and substantial economic. Land use change is essential for economic development and social progress.

Table 4.22 Proportion of respondents according to land change impact on culture and tradition, their effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on culture and tradition**						
1	No	51	96.23	65	85.53	116	89.92
2	Yes	2	3.77	11	14.47	13	10.08
II	**Factors of land change impact on culture and tradition**						
1	No answer	51	96.23	65	85.53	116	89.92
2	Types of dressing	2	3.77	9	11.84	11	8.53
3	A lot of events and festivals in every year	0	-	1	1.32	1	0.78
4	Diversities in cultures	0	-	1	1.32	1	0.78
III	**Adaptation on land change impact for culture and tradition**						
1	No answer	51	96.23	65	85.53	116	89.92
2	Selves adaptation to separate	0	-	1	1.32	1	0.78
3	Inherit the old cultures to be sustainable	0	-	2	2.63	2	1.55
4	Training the generations	2	3.77	8	10.53	10	7.75
IV	**Un-adaptation on land change impact for culture and tradition**						
1	No answer	51	96.23	71	93.42	122	94.57
2	Online societies	0	-	3	3.95	3	2.33
3	Other cultures interfere in	2	3.77	2	2.63	4	3.10

Base on table 4.22 showed that there was 10.08% of affect from the land change in culture and tradition. Thus, the factor of land change affected were types of dressing approximately 8.53% and a lot of events and festivals in every year 0.78%. In this cause, the villagers could be adaptive to the land changes in the cultures through training the generations that covered 7.75%, whereas some villagers could not adapt approximately 3.10%, due to accessing the online societies and the other cultures integration about 2.33%.

Table 4.23 Proportion of respondents according to land change impact on society, its effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	**Parameter**	**Villages**				**Total**	
		Thongpang		**Houaymeun**			
		Freq.	%	**Freq.**	%	**Freq.**	%
I	**Land change impact on society**						
1	No	51	96.23	70	92.11	121	93.80
2	Yes	2	3.77	6	7.89	8	6.20
II	**Factors of land change impact on society**						
1	No answer	51	96.23	71	93.42	122	94.57
2	No peacefulness	1	1.89	1	1.32	2	1.55
3	Many migrants	0	-	1	1.32	1	0.78
4	Confusion and conflict	1	1.89	2	2.63	3	2.33
5	Thieves	0	-	1	1.32	1	0.78
III	**Adaptation on land change impact for society**						
1	No answer	52	98.11	72	94.74	124	96.12
2	To build the societies that have regulations	0	-	1	1.32	1	0.78
3	Tradition conservation	0	-	1	1.32	1	0.78
4	Be penal tied according to law	0	-	1	1.32	1	0.78
5	Management planning	1	1.89	0	-	1	0.78
6	Trainings	0	-	1	1.32	1	0.78
IV	**Un-adaptation on land change impact for society**						
1	No answer	53	100	76	100	129	100
2	Strict regulations	1	1.89	0	-	1	0.78
3	Many ideas	0	-	1	1.32	1	0.78

Table 4.23 showed that there was 6.20% of society affected by land change. The causes affected to the societies found that families have provided the ideas for the societies met confusion and conflict approximately 2.33% and were not in peace (1.55%). Base on the result from villagers found that 0.78% of the societies for adaptation such as make a regulation, training and tradition conservation. Similarly, there was 0.78% of villagers could not adapt.

Table 4.24 Proportion of respondents according to land change impact on environment, its effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on environment**						
1	No	22	41.51	29	38.16	51	39.53
2	Yes	31	58.49	47	61.84	78	60.47
II	**Factors of land change impact on environment**						
1	No answer	21	39.62	30	39.47	51	39.53
2	Flooding	2	3.77	1	1.32	3	2.33
3	Drought	21	39.62	32	42.11	53	41.09
4	Storm	5	9.43	4	5.26	9	6.98
5	Drought and natural fire	4	7.55	7	9.21	11	8.53
6	Flooding, drought and natural fire	0	-	1	1.32	1	0.78
7	Flooding, drought and storm	0	-	1	1.32	1	0.78
III	**Adaptation on land change impact for environment**						
1	No answer	21	39.62	30	39.47	51	39.53
2	Don't know how to adapt	21	39.62	26	34.21	47	36.43
3	Water saving	5	9.43	9	11.84	14	10.85
4	Mass-media monitoring	1	1.89	3	3.95	4	3.10
5	Stop destroying forests	0	-	2	2.63	2	1.55
6	Don't know how to adapt and water saving	2	3.77	5	6.58	7	5.43
7	Find new areas	3	5.66	1	1.32	4	3.10
IV	**Un-adaptation on land change impact for environment**						
1	No answer	21	39.62	31	40.79	52	40.31
2	Unknown	15	28.30	21	27.63	36	27.91
3	Lack of compensatory water source	1	1.89	3	3.95	4	3.10
4	Limitation of area	5	9.43	8	10.53	13	10.08
5	Loss the properties	1	1.89	0	-	1	0.78
6	Not know in advance	1	1.89	4	5.26	5	3.88
7	No raining	1	1.89	0	-	1	0.78
8	Do not know how to adapt oneself	8	15.09	9	11.84	17	13.18

According to the table (4.24), the result revealed that 60.47% of the environment was affected by land changes. There were many reasons for the environmental issue from land conversion which by 41.09% of drought, followed by natural fire 8.53%, storm 6.98%, flooding 2.33% and other 0.78%. Therefore, the villagers could be adapt by used the water and conserve it, mass-media monitoring and find new areas which account for 10.85%, 3.10%, and 3.10% respectively. Whereas, limitation of areas 10.08%, lack of water source 3.88% were could not adapt the land conversion. However, there was 41.98% of some villagers does not know about adaptive approach impacted by environmental issues. In addition, land management practices have a significant effect on natural resources, including water, nutrients, soil, plants, air, and animals. Constructing the irrigation system for agriculture has changed the water cycle and caused groundwater levels being declined in many parts of the world. Deforestation can generate the greenhouse effect, habitats destruction, and loss of biodiversity. Deforestation also affects the systematically hydrological cycle and soil erosion increased flooding, runoff, and landslides (Wu, 2008).

Table 4.25 Proportion of respondents according to land change impact on forest, its effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on forest**						
1	No	26	49.06	38	50.00	64	49.61
2	Yes	27	50.94	38	50.00	65	50.39
II	**Factors of land change impact on forest**						
1	No answer	26	49.06	41	53.95	67	51.94
2	Reducing of forests	25	47.17	26	34.21	51	39.53
3	Reducing of specie of wood seedlings	0	-	1	1.32	1	0.78
4	Difficult to find woods	2	3.77	8	10.53	10	7.75
III	**Adaptation on land change impact for forest**						
1	No answer	26	49.06	41	53.95	67	51.94
2	Unknown	14	26.42	13	17.11	27	20.93
3	Far from the village	3	5.66	1	1.32	4	3.10
4	Stop cutting wood	0	-	1	1.32	1	0.78
5	Use soft wood instead	2	3.77	1	1.32	3	2.33
6	Find in the other areas	5	9.43	14	18.42	19	14.73
7	Identify the conservation areas and making up the tree plantation	1	1.89	4	5.26	5	3.88
8	Legislation of regulation	1	1.89	1	1.32	2	1.55
9	Find additional occupation	1	1.89	0	-	1	0.78
IV	**Un-adaptation on land change impact for forest**						
1	No answer	26	49.06	41	53.95	67	51.94
2	Don't know how to adapt oneself	21	39.62	25	32.89	46	35.66
3	New land might not have fertilized	0	-	1	1.32	1	0.78
4	Tree seedling finished in the areas	1	1.89	0	-	1	0.78
5	Tree areas are not the same	1	1.89	1	1.32	2	1.55
6	Population increase	4	7.55	8	10.53	12	9.30

Table 4.25, showed that there was 50.39 % of forest impacted by the land change. The key factors of land conversion impact on forest occurred from the decreasing of forests that covered 39.53% and the other causes were from difficulties in looking for woods covered 7.75%. Thus, mostly the villagers could be influenced by use of woods from the other areas (14.73%). Identify the conservation areas and initiate the tree plantation 3.88% and legislation of regulation 1.55%. However, some villagers could not adapt to land change on forest because of the high population density (Population increase), 9.30%, some species of trees are not same (about 1.55%). Moreover, there were some villagers did not know how to adapt oneself that covered by 35.66%. In addition to that Monica *et al.* (2003) described that among the types of forest communities, e.g., cove hardwood and oak-pine were affected by the land-cover change. Relative to its potential, cove hardwoods engaged about 30-40% of its potential area in two study landscape in the 1950s and oak-pine engaged only ~50% of its area cove hardwood remained decreased in scope and number of patches in the 1990s (Monica *et al.*, 2003).

Table 4.26 Proportion of respondents according to land change impact on NTFPs, their effect, adaptation and un-adaptation in Thongpang and Houaymeun villages

No.	Parameter	Villages				Total	
		Thongpang		Houaymeun			
		Freq.	%	Freq.	%	Freq.	%
I	**Land change impact on NTFPs**						
1	No	24	45.28	35	46.05	59	45.74
2	Yes	29	54.72	41	53.95	70	54.26
II	**Factors of land change impact on NTFPs**						
1	No answer	24	45.28	35	46.05	59	45.74
2	Lessing down	24	45.28	28	36.84	52	40.31
3	Difficult to find the wild animal and forest products	4	7.55	13	17.11	17	13.18
4	Making up the tree Plantation	1	1.89	0	-	1	0.78
III	**Adaptation on land change impact for NTFPs**						
1	No answer	24	45.28	35	46.05	59	45.74
2	Don't know how to adapt	11	20.75	20	26.32	31	24.03
3	Making up the trees plantation	1	1.89	0	-	1	0.78
4	Find new areas and far away	9	16.98	13	17.11	22	17.05
5	Buy additional food and planting for consumption	3	5.66	1	1.32	4	3.10
6	Not to sell but only sufficient for eating	0	-	2	2.63	2	1.55
7	Conservation	2	3.77	3	3.95	5	3.88
8	Leaving as natural	3	5.66	1	1.32	4	3.10
9	Finding in the seasonal	0	-	1	1.32	1	0.78

IV	**Un-adaptation on land change impact for NTFPs**						
1	No answer	24	45.28	34	44.74	58	44.96
2	Unknown	24	45.28	33	43.42	57	44.19
3	Lessing down the seedling and seedling were destroyed	2	3.77	1	1.32	3	2.33
4	Need more	3	5.66	7	9.21	10	7.75
5	Far away	0	-	1	1.32	1	0.78

Table 4.26 showed that mostly there was 54.26% of non-timber forest products (NTFPs) affected by the land change. The causes of affecting the forest products were from decreasing of the non-timber forest product that covered 40.31%. The other causes from difficulties in looking for forest products of the villagers were covered 13.18%. Thus, for the adaptation of villagers towards the effects in forest products by the families did not know how to adapt oneself (24.03%), and some villagers provided the ideas that they had to look for the non-timber forest products in the other far away area from the village, which was covered by 17.05%, and 3.88% should be conservation area of the forest. Whereas, some villagers could not adapt to non-timber forest product were approximately 44.19%. Despite, as we known, NTFPs have been harvested by human demand for subsistence use and trade in many years ago. On the other hand, non-timber forest product obtained from plant resource (e.g. fruits, seeds, leaves, flowers, roots, bark, resins, latex, and other non-wood plant parts). The growing commercial trade of forest products, especially crafts and plant medicines, has resulted in the harvest of increasing volumes from wild plant populations (Ticktin, 2004). Mostly, non-timber forest products have been included of the forest (production forest or utilization forest, etc.). Zipperer (1993) described five identifiable patterns of deforestation (i.e., indentation, internal, fragmentation, and removal) in the Eastern United States. Hence, each has detached effect on habitat quality of forest patches. By overlaying land use maps between 1973 and 1981 of three areas in the Maryland State (i.e., Anne Arundel, Prince Georges, & Wicomico), Zipperer (1993) measured the conversion in the central core area edge length of individual patches, which showed forest central decreased by 16.3 km^2 in Prince Georges, 23.8 km^2 in Anne Arundel, and 8.4 km^2 in Wicomico.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusions

This research has used an integrated approach of remote sensing (RS), Geographic Information System (GIS) for the land cover change detection. This study revealed that the forest cover has decreased especially dry Dipterocarp forest approximately 42.81% in Thapangthong District of Savannakhet Province of Laos. Conversely, the agricultural land was increased rapidly (16.28%), followed by water bodies (1.23%) and built-up land (0.31%). Furthermore, the mixed deciduous forest has slightly increased approximately 39.36%, where the dominant species were Teak, bamboo, fallow field.

The comparison of the land cover change between 2005 and 2016 showed that mostly dry Dipterocarp forest of this study area has decreased from 108,920.83 ha in 2005 to 90,482.96 ha in 2016 with covering about 8.72% of the total study area, whereas, the agricultural lands have increased from 19,336.80 ha in 2005 to 34,415.19 ha in 2016, which accounts for about 7.13%. Following them the built-up land from 399.98 ha in 2005 to 651.68 ha in 2016 (about 0.12% of increase of area). In addition, water body areas of the study area have increased from 1,280.54 ha in 2005 to 2,597.64 ha in 2016 which coved 0.62%, and the mixed deciduous forest of this area has slightly increased from 81,400.11 (ha) in 2005 to 83,190.78 (ha) in 2016 which is about (0.85%). The overall classification accuracy of the map was 95.80% and the Kapa Coefficient was 78.10%.

In addition, approximately 89.15% of households was affected by land change and there was only 51.94 % of respondents can adapt to land change by their livelihood. These results found that the land change effected on the agricultural production (89.15 %) followed by environment (60.47%), non-timber forest products (54.26 %), forest (50.39%), economy (41.09%), culture and tradition (10.08%) and the society (6.20%). Moreover, the key factors of land conversion impact on agricultural production were land degradation, productivity decrease, insect and disease outbreak, and land limitation. The reasons for that household was not able to adapt to such factors were lack of land, severe insects and disease outbreak, and disability of household for understanding how to learn and to apply the new approaches and techniques into agricultural production system with new technologies. There were many reasons for the environmental issue from land conversion such as drought, natural fire, storm, flooding. The households can be influenced by giving knowledge how to use water sustainably by water management with using the reservoirs or earth ponds, mass-media monitoring and new area seeking. The factors of land change affected on forest have occurred by the decreasing of forests that covered 39.53% and the other causes were from difficulties in looking for woods. Thus, about 14.73% of the households used to woods from other areas for adaptation, some were able to influence by establishing the tree plantation (3.88%), legislation and enactment of regulation (1.55%) and introducing non-timber forest products (NTFPs) was about 40.31% of the decreasing of the non-timber forest product, and have a difficulty in looking for forest products of the villagers about 13.18%. Thus, for the adaptation of villagers towards the effects on forest products, the families did not know how to adapt themselves (24.03%) and the idea that to look for the non-timber forest products in the other far away area from the village was about 17.05%, and the conservation of the forest area was 3.88%. The factors impacting on the economy were from the decreasing of incomes of families (33.33%), high family expenditure (3.10%) and an increase of production input cost (2.33%). For the adaptation of villagers to the economy impacted by land changes were predominantly by additional works (12.40%), increasing of production output (8.53%), and reduction of expenditure (7.75%).

5.2. Recommendations

1. According to the result of this study, which reveals that the conversion and situations of the area, the local government should determine and design of regulations and law to control certain the type of land cover, e.g. expand the agriculture land such as paddy filed, garden. Thus, this area should be protected and conserved especially in dry Dipterocarp and Mixed deciduous forests
2. The national level or provincial, District Administrative Bureau (DAB), should have clear and cooperative policies and directives towards legalization already existing informal settlements and put in place possible and efficient controlling mechanism to minimize further informal land transaction
3. Further study is wanted the satellite data with high spatial resolution used to follow conversion analyze of land use/land cover such as satellite SPOT, IKONOS, Quick Bird.
4. Finally, I must have mentioned that this study based on six-month period, hence, to achieve much more accurate and reliable results we need more data. This study was conducted based on the available funds and resource personnel in the Lao PDR.

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APPENDIX 01: Household level questionnaire

This questionnaire was made for collecting data with the purpose of supporting of this on the topic: Land Cover Change and Adaptation of local livelihood at Thongpang and Houaymeun Villages, Thapangthong District, Savannakhet Province, Lao PDR.

Remark: *This questionnaire isn't effect to those who give the information.*

I. General information

Village……………………..; Thapangthong Distric, Savannakhet Province

Interviewer: ……………………………..

Number of house: ………………………

Date of interview: ……/……/……………

1. Number of interviewer: ……………./Phone Number:+85620……………………

   ☐ Head of the family ☐ Member of family

2. Age:……………..years
3. Gender: ☐ Male ☐ Female
4. Status: ☐ Single ☐ Married ☐ Divorce / Widow
5. Family Member:……………..people
6. Level of Education: ☐ Primary ☐ Secondary ☐ Highschool
7. Family migrate from: ☐ Original ☐ Migrate from other

   Village:………………………………….,District:……………………………

   Province:…………………………,year:……………………………………….
8. Reason of migrate:…………………………………………………………..
9. Ethnic ☐ Lao ☐ Laothung ☐ laosung ☐ phouthai
10. Religion: ☐ Buddhist ☐ Christian ☐ Other
11. Occupation: ☐ Civil of official ☐ Agriculturalist ☐ Labor ☐ People
12. Core labor:……..people; Reserve…………………….people

II. Economic Families

2.1. Land use, Land tenure, Irrigation and problem area in 2005

No	Land use characteristics	Approximate area (Hectares)	Style of takeover	Problem area	Irrigation	Far from home (kilometers)
1						
2						
3						
4						
5						

1.3. Land use, Land tenure, Irrigation and problem area in 2016

No	Land use characteristics	Approximate area (Hectares)	Style of takeover	Problem area	Irrigation	Far from home (kilometers)
1						
2						
3						
4						
5						

2.4. Household occupational characteristics

2.4.1. Income from plant in each year

No	Types of crop	2005			2016			Monthly
		Approximate area (Hectares)	yield	Value (kip)	Approximate area (Hectares)	yield	Value (kip)	
1	Paddy rice							
2	Maize							
3	Soy bean							
4	Crop							
5	Sesame							
6	Other, specify							
Total								

2.4.2. Income from Animals in each year

No	Types of Animals	2005			2016			Monthly
		Approximate area (Hectares)	yield	Value (kip)	Approximate area (Hectares)	yield	Value (kip)	
1	Poultry							
2	Fish(kg)							
3	Cow							
4	Buffalo							
5	Goat							
6	Swine							
7	Other, specify							
	Total							

2.4.3. Income from household activities

No	Items	2005 (kip/year)	2016 (kip/year)
1	Salary		
2	Trade		
3	Processing		
4	Non-timber forest product		
5	Services		
6	Contractor		
7			
8			
9	Other, specify		
Total			

III. Adaptation for land change

2.1. Did you know your land use change?

Yes ☐ No ☐

A. What did you do for that change?

Yes ☐ No ☐

If yes specify what did you do

1……………………………………………………..

2………………………………………………………

3………………………………………………………

4………………………………………………………

B. Land change effect on your life

Yes ☐ No ☐

Effect	Adaptation or reduce
1. Agricultural Yes ☐ No ☐	
1.1 Cultivate Yes ☐ No ☐	
If yes (specify)	
1………………………………………………..	…………………………………………………………
2………………………………………………..	…………………………………………………………..
3…………………………………………… …	…………………………………………………………
4………………………………………………	…………………………………………………………
	…………………………………………………………
1.2 Animals Yes ☐ No ☐	…………………………………………………………..
	…………………………………………………………
If yes (specify)	…………………………………………………………
1………………………………………………..	…………………………………………………………
2………………………………………………..	…………………………………………………………
3………………………………………………	…………………………………………………………
4………………………………………………	…………………………………………………………
1.3 Fishing fish Yes ☐ No ☐	…………………………………………………………
	…………………………………………………………
If yes (specify)	………………………………………………………….
1………………………………………………..	…………………………………………………………
2………………………………………………..	
3…………………………………………………	
4…………………………………………………..	
2. Economic Yes ☐ No ☐	
If yes (specify)	
1………………………………………………..	
2………………………………………………..	
3…………………………………………………	
4…………………………………………………..	

3. Cultural Yes ☐ No ☐ If yes (specify) 1…………………………………………… 2…………………………………………… 3…………………………………………… 4……………………………………………………	 ………………………………………………… ………………………………………………… ………………………………………………… ………………………………………………………
4. Society Yes ☐ No ☐ If yes (specify) 1…………………………………………… 2…………………………………………… 3…………………………………………… 4……………………………………………………	 ………………………………………………… ………………………………………………… ………………………………………………… ……………………………………………………
5. Environmental Yes ☐ No ☐ If yes (specify) 1. Drought 2. Flood 3. Storm 4. Forest fire	 ………………………………………………… ………………………………………………… ………………………………………………… ………………………………………………………
6. Forest Yes ☐ No ☐ If yes (specify) 1…………………………………………… 2…………………………………………… 3…………………………………………… 4……………………………………………………	 ………………………………………………… ………………………………………………… ………………………………………………… ………………………………………………………
7. Non-timber forest products Yes ☐ No ☐ If yes (specify) 1…………………………………………… 2…………………………………………… 3…………………………………………… 4……………………………………………………	 ………………………………………………… ………………………………………………… ………………………………………………… ………………………………………………………

2.2. Are there anything can't adaptation if land changes

Effect	Can't Adaptation or reduce
1. Agricultural Yes ☐ No ☐	
1.1 Cultivate Yes ☐ No ☐	
If yes (specify)	
1………………………………………………	
2………………………………………………	………………………………………………………
3………………………………………………	………………………………………………………
4………………………………………………	………………………………………………………
1.2 Animals Yes ☐ No ☐	……………………………………………………………
If yes (specify)	
1………………………………………………	………………………………………………………
2………………………………………………	………………………………………………………
3………………………………………………	………………………………………………………
4………………………………………………	………………………………………………………
1.3 Fishing fish Yes ☐ No ☐	
If yes (specify)	
1………………………………………………	………………………………………………………
2………………………………………………	………………………………………………………
3………………………………………………	………………………………………………………
4……………………………………………………	………………………………………………………
2. Economic Yes ☐ No ☐	
If yes (specify)	
1………………………………………………	………………………………………………………
2………………………………………………	………………………………………………………
3………………………………………………	………………………………………………………
4……………………………………………………	………………………………………………………
3. Cultural Yes ☐ No ☐	
If yes (specify)	
1………………………………………………	………………………………………………………
2………………………………………………	………………………………………………………
3………………………………………………	………………………………………………………
4. Society Yes ☐ No ☐	
If yes (specify)	
1………………………………………………	………………………………………………………
2………………………………………………	………………………………………………………
3………………………………………………	………………………………………………………
4………………………………………………	………………………………………………………

5. Environmental Yes ☐ No ☐ If yes (specify) 1. Drought 2. flood 3. Storm 4. Forest fire	 ……………………………………………… ……………………………………………… ……………………………………………… ………………………………………………
6. Forest Yes ☐ No ☐ If yes (specify) 1…………………………………………… 2…………………………………………… 3…………………………………………… 4……………………………………………	 ……………………………………………… ……………………………………………… ……………………………………………… ………………………………………………
7. Non-timber forest products Yes ☐ No ☐ If yes (specify) 1…………………………………………… 2…………………………………………… 3…………………………………………… 4……………………………………………	 ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………………

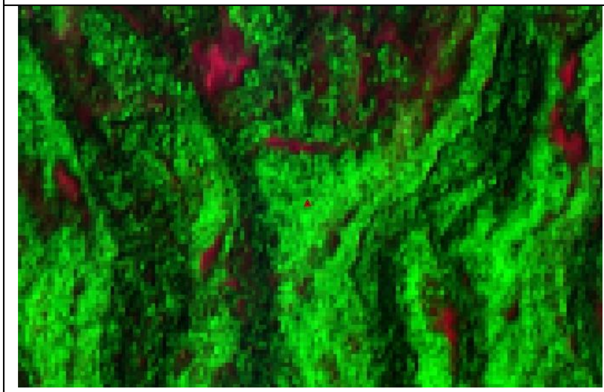
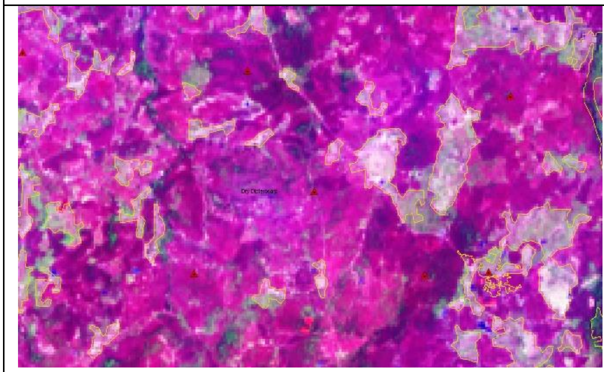
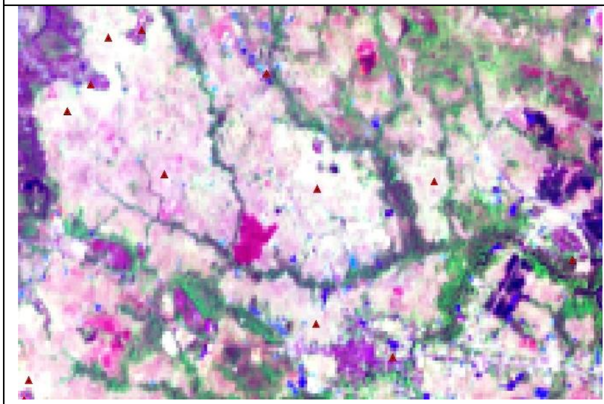
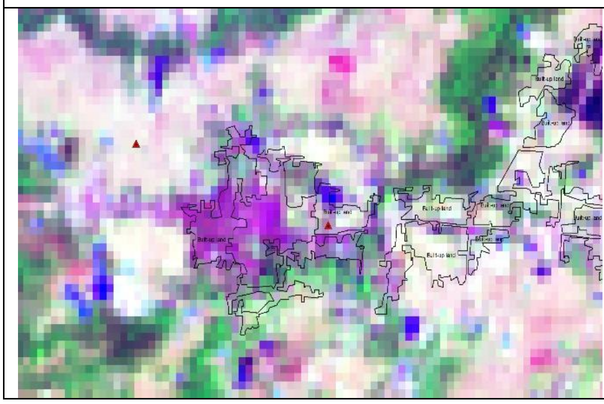
APPENDIX 02: Photo for Household survey and Ground truth in Thapangthong District.

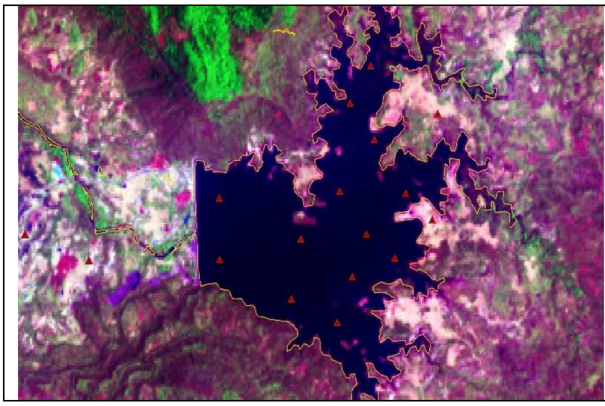
Interview with head of village

Interview with villagers

Ground truth using the GPS

APPENDIX 03: Type of land cover classes in Thapangthong district, Savannakhet Province.

Landsat satellites	Photo (Field)	Name of Class
		Mixed Deciduous Forest (MDF)
		Dry Dipterocarp Forest (DDF)
		Agriculture Land (AL)
		Built-up Land (BL)

		Water (W)

Source: 2016 Ground truth survey for accuracy assessment

APPENDIX 04: Some activities of human in Thapangthong district, Savannakhet Province.