การประเมินสถานภาพทรัพยากรป่าไม้โดยอาศัยดัชนีชี้วัดภูมิทัศน์ : กรณีศึกษา อุทยานแห่งชาติทับลาน

นายเอนก ศรีสุวรรณ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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ปีการศึกษา 2553

FOREST RESOURCES ASSESSMENT USING LANDSCAPE METRICS : CASE STUDY OF THAP LAN NATIONAL PARK

Anake Srisuwan

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geoinformatics

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FOREST RESOURCES ASSESSMENT USING LANDSCAPE METRICS : CASE STUDY OF THAP LAN NATIONAL PARK

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เอนก ศรีสุวรรณ : การประเมินสถานภาพทรัพยากรป่าไม้โดยอาศัยดัชนีชี้วัดภูมิทัศน์: กรณีศึกษาอุทยานแห่งชาติทับลาน (FOREST RESOURCES ASSESSMENT USING LANDSCAPE METRICS : CASE STUDY OF THAP LAN NATIONAL PARK) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.สุวิทย์ อ๋องสมหวัง, 139 หน้า.

วัตถุประสงค์หลักของการศึกษาในครั้งนี้ คือ (1) เพื่อจำแนกการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดิน ในปี พ.ศ. 2530 2548 และ 2550 (2) เพื่อประเมินสถานภาพและการเปลี่ยนแปลงของการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดิน (3) เพื่อประเมินสถานภาพปัจจุบันและการเปลี่ยนแปลงในระดับภูมิทัศน์และประเภทของภูมิทัศน์โดยใช้ดัชนีชี้วัดภูมิทัศน์ โดยนำข้อมูลภาพถ่ายดาวเทียม Landsat-TM ที่บันทึกข้อมูลในปี พ.ศ. 2530 2548 และ 2550 มาจำแนกประเภทการใช้ประโยชน์ที่ดินและสิ่งปกคลุม 14 ประเภท ด้วยวิธีการประมวลผลภาพเชิงเลขและการแปลตีความด้วยสายตา เพื่อใช้ในการประเมินสถานภาพและการเปลี่ยนแปลงของการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดิน จากนั้น นำข้อมูลการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินทั้ง 14 ประเภท มาจัดกลุ่มประเภทของภูมิทัศน์ 7 ประเภท ประกอบด้วย ป่า ป่าทดแทนตามธรรมชาติและสวนป่า เมืองและสิ่งปลูกสร้าง เกษตร ทุ่งหญ้า แหล่งน้ำ และพื้นที่เบ็ดเตล็ด เพื่อประเมินสถานภาพและการเปลี่ยนแปลงของภูมิทัศน์และประเภทภูมิทัศน์โดยอาศัยดัชนีชี้วัดภูมิทัศน์

โดยพบว่า การใช้ประโยชน์ที่ดินและสิ่งปกคลุมดิน ในปี พ.ศ. 2530 2548 และ 2550 มีรูปแบบการกระจายตัวคล้ายคลึงกัน ประเภทการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินที่สำคัญที่สุดในปี พ.ศ. 2530 2548 และ 2550 ได้แก่ ป่าธรรมชาติ ซึ่งครอบคลุมพื้นที่เท่ากับ 2,615.97 2,570.59 และ 2,514.08 ตร.กม. หรือคิดเป็นร้อยละ 68.41 67.22 และ 65.74 ของพื้นที่ศึกษา ตามลำดับ ในขณะเดียวกัน พบว่า พื้นที่เมืองและสิ่งปลูกสร้าง ทุ่งหญ้า อ่างเก็บน้ำ และพื้นที่เบ็ดเตล็ด มีขนาดพื้นที่เพิ่มขึ้นตลอดเวลา ในขณะที่นาข้าว ไม้ผลและไม้ยืนต้น ป่าเบญจพรรณ ป่าเต็งรัง ป่าทดแทนตามธรรมชาติและสวนป่า และแหล่งน้ำตามธรรมชาติ มีขนาดพื้นที่ลดลงอย่างต่อเนื่อง ในเวลาเดียวกัน ป่าดิบแล้ง ป่าไผ่ และไม้พุ่ม มีขนาดพื้นที่ค่อนข้างจะคงที่ ในขณะที่ พืชไร่มีการเปลี่ยนแปลงเพิ่มขึ้นลดลงอย่างไม่คงที่

ในการประเมินสถานภาพและการเปลี่ยนแปลงในระดับภูมิทัศน์ ค่าดัชนีชี้วัดภูมิทัศน์ทั้ง 3 ดัชนี (Dominance, Contagion and Fractal dimension) ลดลงอย่างต่อเนื่อง โดยพบว่า ค่าการเปลี่ยนแปลงของดัชนีชี้วัดภูมิทัศน์ในช่วงปี พ.ศ. 2530 - 2548 มีค่าเท่ากับ 0.044 และ มีค่าเท่ากับ 0.060 ในระหว่างปี พ.ศ. 2548 - 2550 จากผลที่ได้รับ แสดงให้เห็นว่า ภูมิทัศน์ของอุทยานแห่งชาติทับลานและพื้นที่โดยรอบถูกรบกวนตลอดเวลาในระยะเวลา 20 ปีที่ผ่านมา ในขณะเดียวกัน ในระดับประเภทของภูมิทัศน์ พบว่า ในระหว่างปี พ.ศ. 2530 - 2548 จำนวนของแปลงและความ

หนาแน่นของแปลงของประเภทของภูมิทัศน์ทุกประเภทมีค่าเพิ่มขึ้น ในขณะที่ พื้นที่เฉลี่ยของแปลงมีค่าลดลง ซึ่งหมายถึง มีการแตกตัวเกิดขึ้นในแต่ละประเภทของภูมิทัศน์ แต่อย่างไรก็ตาม ในระหว่างปี พ.ศ. 2548 - 2550 พบว่า จำนวนของแปลงและความหนาแน่นของแปลงของภูมิทัศน์ป่าและป่าทดแทนตามธรรมชาติและสวนป่ามีค่าลดลง ในขณะที่ พื้นที่เฉลี่ยของแปลงมีค่าเพิ่มขึ้น นั่นหมายความว่า ภูมิทัศน์ป่าและป่าทดแทนตามธรรมชาติและสวนป่ารวมเป็นกลุ่มก้อนมากขึ้น นอกจากนั้น พบว่า ในระหว่างปี พ.ศ. 2530 - 2548 ค่าระยะทางของแปลงใกล้สุดแบบยุคลิกเฉลี่ยของภูมิทัศน์ป่าและป่าทดแทนตามธรรมชาติและสวนป่ามีค่าลดลง แต่อย่างไรก็ตาม ค่าดัชนีชี้วัดภูมิทัศน์เหล่านี้มีค่าเพิ่มขึ้นในระหว่างปี พ.ศ. 2548 - 2550 นอกจากนี้ พบว่า ในระหว่างปี พ.ศ. 2530 - 2548 และปี พ.ศ. 2548 - 2550 ค่าดัชนี Interspersion and Juxtaposition มีค่าเพิ่มในเกือบทุกประเภทของภูมิทัศน์ ยกเว้นภูมิทัศน์เกษตรมีค่าลดลง ในระหว่างปี พ.ศ. 2548 - 2550 และภูมิทัศน์ทุ่งหญ้ามีค่าลดลงในระหว่างปี พ.ศ. 2530 - 2548 จากผลที่ได้รับเหล่านี้ แสดงให้เห็นว่า ภูมิทัศน์เกือบทุกประเภท มีแปลงใหม่เกิดขึ้นใหม่ในระหว่างปี พ.ศ. 2548 - 2550 ยกเว้นภูมิทัศน์ทุ่งหญ้าที่ไม่มีแปลงใหม่เกิดขึ้นใน ระหว่างปี พ.ศ. 2530 - 2548 และภูมิทัศน์ทางเกษตรที่ไม่มีแปลงเกิดขึ้นใหม่ใน ระหว่างปี พ.ศ. 2548 - 2550 ในทางลักษณะเดียวกัน พบว่า ในระหว่างปี พ.ศ. 2530 - 2550 ค่าขนาดการแตกตัวถ่วงน้ำหนักของภูมิทัศน์ป่าและป่าทดแทนตามธรรมชาติและสวนป่ามีค่าลดลงอย่างต่อเนื่อง ซึ่งหมายถึง ภูมิทัศน์ป่าและป่าทดแทนตามธรรมชาติและสวนป่ามีการเปลี่ยนแปลงเกิดขึ้นตลอดเวลา

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา ____________

ปีการศึกษา 2553 ลายมือชื่ออาจารย์ที่ปรึกษา ____________

ANAKE SRISUWAN : FOREST RESOURCES ASSESSMENT USING LANDSCAPE METRICS: CASE STUDY OF THAP LAN NATIONAL PARK. THESIS ADVISOR : ASST. PROF. SUWIT ONGSOMWANG, Dr. rer. Nat. 139 PP.

LANDSCAPE METRICS/ THAP LAN NATIONAL PARK, DONG PHRA YAYEN-KHAO YAI FOREST COMPLEX WORLD HERITAGE

The main objectives of the study are: (1) to classify land use and land cover in 1987, 2005 and 2007, (2) to assess land use and land cover and its change and (3) to assess status and change of landscape and landscape types using landscape metrics. In this study, Landsat - TM in 1987, 2005 and 2007 were firstly used to classify 14 land use and land cover types by digital image processing and visual interpretation to assess land use and land cover status and its change. The 14 classes of land use and land cover were then reclassified into seven landscape types: forest, natural forest succession and forest plantation, urban and built-up, agriculture, grassland, water bodies and miscellaneous landscape to assess status and its change of landscape and landscape types using landscape metrics.

It was found that pattern of land use and land cover distribution in 1987, 2005 and 2007 was similar. The most significant land use and land cover type in 1987, 2005 and 2007 was natural forest. These covered an area of 2,615.97, 2,570.59 and 2,514.08 sq.km or 68.41, 67.22 and 65.74%, respectively. At the same time, urban and built-up area, grassland, reservoir, and miscellaneous land had continued to increase, while paddy field, perennial and orchard, mixed deciduous forest, dry

dipterocarp forest, natural forest succession and forest plantation, and, natural water body had successively decreased. At the same time dry evergreen forest, bamboo forest and shrub land was rather stable while field crop was unstable.

For assessment of status and its change at landscape level, all three landscape metrics (Dominance, Contagion and Fractal dimension) had continued to decrease. Landscape change metric was 0.044 during 1987 - 2005 while it was 0.060 between 2005 and 2007. These results implied that Thap Lan National Park and its surrounding became more fragmented landscape in the past 20 years. In the meanwhile, at landscape types, number of patches and patch density for all landscape types were increased and mean patch areas were decreased during 1987 - 2005, it infers that fragmentation occurs in all landscape types in this period. However, number of patches and patch density for forest and natural forest succession and forest plantation were decreased and mean patch areas were increased during 2005 - 2007, it means that such landscape types are more compact. In addition, mean Euclidean nearest-neighbor distance for forest and natural forest succession and forest plantation were decreased during 1987 - 2005. However, these metrics were increased during 2005 and 2007. Furthermore, interspersion and juxtaposition index were increased in both periods for almost landscape types except agriculture land was decreased during 2005 - 2007 and grassland was decreased during 1987 - 2005. These results imply that new patches for almost landscape types occur during 1987 - 2007 except grassland between 1987 and 2005 and agriculture land between 2005 and 2007. Similarly, during 1987 - 2007 area-weighted fractal dimension for forest, natural forest succession and forest plantation landscape type were continuously decreased.

School of Remote Sensing　　　　Student's Signature A. Srisuwan

Academic Year 2010　　　　Advisor's Signature Suwit Ong.

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Anake Srisuwan

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LIST OF ABBREVIATIONS

ALT	=	Agriculture Landscape
AREA_MN	=	Mean Patch Area
A1	=	Paddy Field
A2	=	Field Crop
A3A4	=	Perennial and Orchard
BF	=	Bamboo Forest
C	=	Contagion
CA	=	Class Area
D	=	Dominance
DDF	=	Dry Dipterocarp Forest
DEF	=	Dry Evergreen Forest
DPKY - FCWH	=	Dong Phra Yayen - Khao Yai Forest Complex World Heritage
ENN_MN	=	Mean Euclidean Nearest-Neighbor Distance
F	=	Fractal Dimension
FRAC_AM	=	Area-weighted Fractal Dimension
FLT	=	Forest Landscape
FSFP	=	Natural Forest Succession and Forest Plantation
GL	=	Grassland
GLT	=	Grassland Landscape

LIST OF ABBREVIATIONS (Continued)

IJI	=	Interspersion and Juxtaposition Index
LDD	=	Land Development Department
LULC	=	Land Use and Land Cover
M	=	Miscellaneous Land
MDF	=	Mixed Deciduous Forest
MLT	=	Miscellaneous Landscape
NLT	=	Natural Forest Succession and Forest Plantation Landscape
NP	=	Number of Patches
PD	=	Patch Density
RFD	=	Royal Forest Department
SL	=	Shrub Land
U	=	Urban and Built-up Area
ULT	=	Urban and Built-up Landscape
WLT	=	Water Body Landscape
W1	=	Natural Water Body
W2	=	Reservoir

CHAPTER I

INTRODUCTION

1.1 Significance of the problem

Thap Lan National Park, where was the one of the Dong Phra Yayen - Khao Yai Forest Complex World Heritage (DPKY - FCWH), was inscribed in 2005. The justification for inscription of the Dong Phra Yayen - Khao Yai Forest Complex (DPKY - FC) contains more than 800 fauna species, including 112 species of mammals, 392 species of birds and 200 reptiles and amphibians. It is internationally important for the conservation of globally threatened and endangered mammal, bird and reptile species that are recognized as being of outstanding universal value. This includes 1 critically endangered, 4 endangered and 19 vulnerable species. The area contains the last substantial area of globally important tropical forest ecosystems of the Thailandian Monsoon Forest biogeographic province in northeast Thailand, which in turn can provide a viable area for long-term survival of endangered, globally important species, including tiger, elephant, leopard cat and banteng. The unique overlap of the range of two species of gibbon, including the vulnerable Pileated Gibbon, further adds to the global value of the complex. In addition to the resident species the complex plays an important role for the conservation of migratory species, including the endangered Spot-billed Pelican and critically endangered Greater Adjutant.

The Convention Concerning the Protection of the World Cultural and Natural Heritage was adopted by UNESCO in 1972. The main objective of the Convention was to protect and safeguard cultural heritage, considered valuable for the society. The Convention recognizes that the cultural heritage and the natural heritage are increasingly threatened with destruction by different causes. It also admits that protection at the national level often remains incomplete because of the scale of the resources which it requires. With this Convention, the State Parties promises to identify, protect, conserve, restore and transfer to future generations the cultural and natural heritage situated on their territories. Each State also promises to take the appropriate legal, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage. At international level, it requires the establishment of a system of international co-operation assistance designed to support States Parties to the Convention in their efforts to conserve and identify that heritage. In this context, the Intergovernmental Committee for the Protection of the Cultural and Natural Heritage and the Fund for the protection of the world cultural and natural heritage are hereby established within the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2010).

Forests are inherently dynamics in space and time. Their composition and distribution can change not only through continuous, subtle, and slow forest development and succession, but also through discontinuous, occasional, sudden natural disturbances (Botkin, 1990; Oliver and Larson, 1996; Spies, 1997). In addition to natural processes, human activities and disturbance are the source of much contemporary forest change. (Houghton, 1994; Meyer and Turner, 1994; Riitters et al., 2002). Such land cover change is widely considered the primary cause of biodiversity decline and species endangerment (Hansen et al., 2001). Monitoring natural and human caused land cover and forest change, disturbance processes and spatial pattern is relevant for the conservation of forest landscape and their inhabitants (Blamford, Green, and Jenkins, 2003).

Forest resources assessment by the integration of Geo-Informatics and landscape metrics was a method to study the status and its changes in the Thap Lan National Park. Result of the study can further learn the relationship between human activity and landscape dynamics and can be applied for protection, monitoring and rehabilitation of the changing on forest resources in DPYKY - FCWH.

1.2 Research objectives

1.2.1 To classify land use land cover in 1987, 2005 and 2007;

1.2.2 To assess land use and land cover (LULC) and its change;

1.2.3 To assess status and change of landscape and landscape types.

1.3 Scope and limitations of the study

Scope and limitations of the study can briefly explained as follows.

(1) Land use and land cover types in 1987, 2005 and 2007 will be classified by digital image processing and visual interpretation based on Landsat-TM data in 1987, 2005 and 2007. In this study, thirteen land use and land cover types will be here extracted include urban and built-up area, paddy field, field crop, perennial and orchard, dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, bamboo forest, natural forest succession and forest plantation, grassland, shrub, natural river,

reservoir, and miscellaneous land according to classification of Land Development Department (LDD) and the Royal Forest Department (RFD).

(2) Assessment of LULC and its change of Thap Lan National Park and 5 km buffer zone will be performed under GIS environment.

(3) Landscape metrics at landscape level include Dominance (D), Contagion (C) and Fractal Dimension (F) will be extracted using FRAGSTAT to explain the status and change of landscape.

(4) Landscape metrics at class level include Class area metrics (CA), Number of patches (NP), Patch density (PD), Mean patch area (AREA_MN), Area-weighted fractal dimension (FRAC_AM), Mean Euclidean nearest-neighbor distance (ENN_MN), Interspersion and juxtaposition index (IJI) will be calculated using FRAGSTAT to explain the status and change of landscape type.

(5) Landscape ecology will be here focused on structure characteristics of the landscape.

1.4 Benefit of the results

1.4.1 The results can be used to assess current status of the Thap Lan National Park and DPYKY - FCWH;

1.4.2 The results can be further applied for protection, monitoring and rehabilitation of forest resources in DPYKY - FCWH.

CHAPTER II

RELATED CONCEPT AND THEORIES AND LITERATURE REVIEW

2.1 Related concept and theories

The main related concepts and theories of this study are here summarized including landscape ecology and landscape metrics.

2.1.1 Landscape ecology

2.1.1.1 Concepts and definitions of landscape and ecology

Landscape: Landscapes are generally considered to be a heterogeneous area having a mosaic of landscape elements that are repeated across the area. Turner, Gradner and O'Neill (2001) defined it as "an area that is spatially heterogeneous in at least area of interest". The context of interest has a strong bearing on the definition of a landscape; a wildlife biologist may consider it to be a mosaic of habitat patches; a forest ecologist might call it a mosaic of forest type. To any organism, a landscape is relative based on what make up a mosaic with habitat patches meaningful to that particular organism. A landscape may not have a specific size, although humans often try to pin a size upon it (Kashin, 2004).

The disparity in definition is difficult to communicate clearly, and even more difficult to establish consistent management policies. Definitions of landscape invariably in clued an area of land containing a mosaic of patches or landscape elements. Forman and Godron (1986) defined landscape as “a heterogeneous land area composed of a cluster of interacting ecosystem that is repeated in similar form throughout”. The concept differs from the traditional ecosystem concept in focusing on groups of ecosystems and the interactions among them. There are many variants of the definition depending on the research or management context. For example, from a wildlife perspective, we might define landscape as an area of land containing a mosaic of habitat patches, often within which a particular “focal” or “target” habitat patch is embedded (Dunning, Danielson and Pulliam, 1992). Because habitat patches can only be defined relative to a particular organism’s perception of the environment (Wiens, 1976) (i.e. each organism defines habitat patches differently and at different scales), landscape size would differ among organism. However, landscapes generally occupy some spatial scale intermediate between an organism’s normal home range and its regional distribution. In other words, because each organism scales the environment differently (i.e. a salamander and hawk view their environment on different scales), there is no absolute size for a landscape; from an organism-centered perspective, the size of a landscape varies depending on what constitutes a mosaic of habitat or resource patches meaningful to that particular organism (Mcgarigal and Marks, 1994).

Ecology: Ecology is the interaction of organisms and their environment. Interactions between individuals of a species, or between two species and their environment, are a major part of ecology. With interactions in general, their strength varies with distance: this is true of planetary gravitation, it’s true with climate pattern, and it’s true of competition for resources between individual plants. This is because distance implies spatial location (Kashin, 2004).

Ecology was first defined in 1866 by Emst Haeckel, an enthusiastic and influential disciple of Charles Darwin. To him, ecology was “the comprehensive science of the relationship of the organism to the environment”. The spirit of this definition is very clear in an early discussion of biological sub disciplines by Burdon Sanderson (1983), in which ecology is “the science which concerns itself with the external relations of plants and animals to each other and to the past and present conditions of their existence”, to be contrasted with physiology (internal relations) and morphology (structure). For many, such definitions have stood the test of time. Ricklefs (1973) defined ecology as “the study of the natural environment, particularly the interrelationships between organisms and their surroundings.” This being so, it might be better still to define ecology as: “the scientific study of the distribution and abundance of organisms and the interactions that determine distribution and abundance” (Colin, Begon and Harper, 2003).

2.1.1.2 Concepts and definitions of landscape ecology

Landscape ecology offers new concepts, theory, and methods that are revealing the importance of spatial patterning on the dynamics of inter acting ecosystems. Landscape ecology has come to the forefront of ecology and land management and is still expanding very rapidly. The last decade has seen a dramatic growth in the number of studies and variety of topics that fall under the broad banner of landscape ecology. Interest in landscape studies has been fueled by many factors, the most important being the critical need to assess the impact of rapid, broad-scale change in our environment (Turner et al., 2001).

Landscape ecology emphasizes the interaction between spatial pattern and ecological process, that is, the cause and consequences of spatial heterogeneity across a range of scales. The term landscape ecology was introduce by German bio-geographer Carl Troll (1939), arising from the European tradition of regional geography and vegetation science and motivated particularly by the novel perspective offered by aerial photography. Landscape ecology combined the spatial approach of the geographer with the function approach of the ecologist (Naveh and Lieberman, 1984; Forman and Godron, 1986).

It has since become generally accepted that the structure of the landscape influences the ecological processes and function that are operating within it (Haines-Young and Chopping, 1996). The discipline of landscape of landscape ecology is now widely recognized as a distinct perspective in resource management and ecological science (Wulder and Frankling, 2006).

Most of us have an intuitive sense of the term landscape; we think of the expanse of land and water that we observe from the prominent point and distinguish between Agricultureand urban landscapes, lowland and mountainous landscape, natural and developed landscape. Any of us could list components of these landscapes, for example, farms, field, forest, wetlands, and the like. If we consider how organisms other than humans may see their landscape, our own sense of landscape may be broadened to encompass components relevant to a honey bee, beetle, vole, or bison. In all case, our intuitive sense includes a variety of different elements that comprise the landscape, change though time, and influence ecological dynamics (Turner et al., 2001).

The central goal of landscape ecology is the investigation of the reciprocal effects and interactions of landscape patterns and ecological processes (Turner, 1989) Fundamental to such investigation is the awareness that landscape observation is scale dependent, spatially and temporally with different landscape patterns and processes discernible from different points of view and time that are specific to the organism (e.g. trees vs. earthworms) or the abiotic process (e.g. carbon gas fluxes) under study (Perera and Euler, 2000).

Landscape can be observed from many points of view, and ecological processes in landscape can be studied at different spatial and temporal scales (Risser, 1987). “Landscape” commonly refers to the landforms of a region in the aggregate or to the land surface and its associated habitats at scales of hectares to many square kilometers area. Most simply, a landscape can be consider are structure, function and change (Forman and Godron, 1986) “Structure” refers to the spatial relationships between distinctive ecosystems, that is, shapes, numbers, kinds and configurations of components. “Function” refers to the interactions between the spatial elements, that is, the flow of energy, materials, and organisms among the component ecosystems. “Change” refers to alteration in the structure and function of the ecological mosaic through time (Turner, 1989).

Landscape structure must be identified and quantified in meaningful ways before the interactions between landscape pattern and ecological processes can be understood. The spatial patterns observed in landscapes result from complex interactions between physical, biological, and social forces. Most landscapes have been influenced by human land use, and the resulting landscape mosaic is a mixture of natural and human-managed patches that vary in size, shape, and arrangement (e.g. Bowen and Burgess, 1981; Burgess and Sharpe, 1996; Forman and Godron, 1981, 1986; Krummel et al., 1987; Turner and Ruscher, 1988). This spatial patterning is a unique phenomenon that emerges at landscape level (Klopatek, Krummel, Mankin and O'Neill, 1987).

Spatial pattern has important effect on a variety of physical and ecological processes including flows of energy and nutrients and movement of plants and animals (Turner, 1989; Risser, 1990; Wiens et al., 1993; Hunsaker et al., 1994; Wu and Levin, 1994, 1997; Wu, Gao and Tueller, 1997). To understand the interactions between pattern and processes it is necessary to quantitatively characterize spatial heterogeneity over a range of scales. Because today's spatial pattern results from yesterday's dynamic processes, pattern analysis may potentially reveal critical information on properties of underlying processes. Landscape ecology, focusing on the study on the reciprocal relationship between spatial pattern and ecological processes, provides a new conceptual framework for understanding how nature works (Pickett and Cadenasso, 1995; Wu and Loucks, 1995). In recent years, numerous studies have been carried out to quantify landscape pattern using various spatial analysis methods (O'Neill et al., 1988; Turner and Gardner, 1991; Cullinan and Thompson, 1992; Plotnic, Gardner and O'Neill, 1993; Wickham and Riitters, 1995; Riitters et al., 1995; Jelinski and Wu, 1996; Qi and Wu, 1996). In general, both promises and problems have been found regarding the plethora of techniques used in landscape pattern analysis (Wu et al., 1997).

Landscape ecology focuses on three useful characteristics of the landscape as followings.

(1) Structure: spatial relationships between distinctive ecosystems (or "elements") - or the distribution of energy/materials/species in relation to the size, shapes, number, types, and configurations of the ecosystems (Kashin, 2004).

(2) Function: the interactions among the spatial elements, that is, the flow of energy, materials, and species among the component ecosystems.

(3) Change: the alteration in the structure and function of the ecological mosaic overtime.

A landscape consists of three main components: a matrix, patches, and corridors (Figure 2.1). If we understand these components and their interrelationship, we can make better management decisions at landscape level (Barnes, 2010).

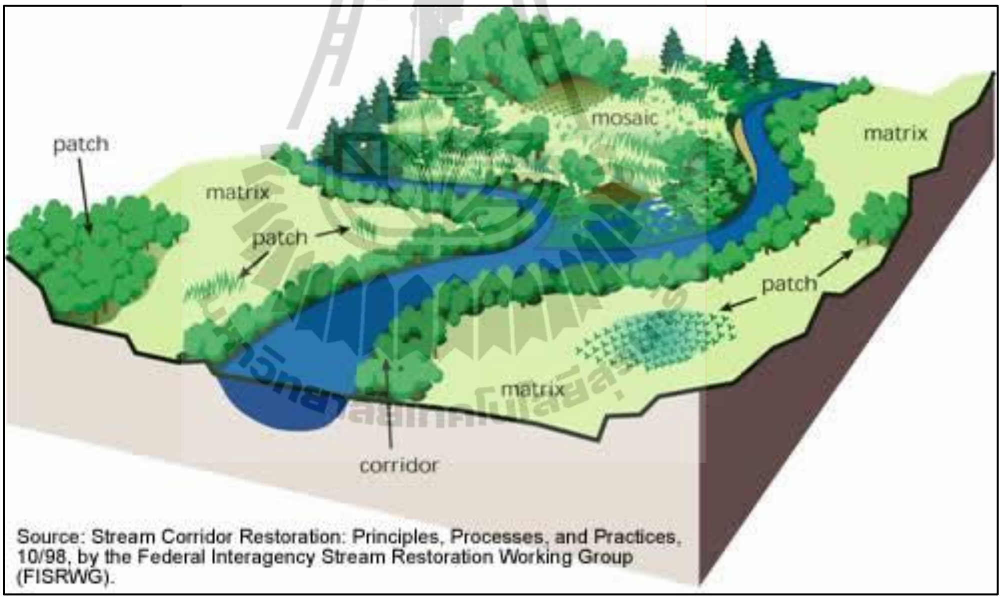


Figure 2.1 Three main components of landscape: matrix, patch and corridor.

Source: The University of Arizona (2011).

(1) **Matrix:** The matrix, the dominant component in the landscape, is the most extensive and connected landscape type, and it plays the dominant role in landscape functioning. If we try to manage a habitat without considering the matrix, we will likely fail to provide what wildlife need in that area. For instance, if your goal is to enhance the number of different species in a 40 acre forest patch surrounded by soybean fields, you will not create wildlife openings in the forest. That is, you will not

want to create more edge (the outer zone of a patch that differs from its interior) because in an agriculture matrix, any type of opening will create more and smaller forest patch in that area, further reducing the amount of interior habitat available to the wildlife that need it.

The characteristics of matrix structure are the density of the patch (porosity), boundary shape, network, and heterogeneity. If an area has been broken up but the patches are fairly close together, the patches are still dense enough to be useful for animal movement. However, if you open up a large forest area by creating small opening, the patches may not be dense enough to sustain certain kinds of animals, and you could have a problem with predation on other wildlife by raccoons, opossums, black rat snakes, or blue jays. A reduction in density might also increase nest parasitism by brown-headed cowbirds on neotropical migrant songbirds. We illustrate how lack of density can create problems Kentucky do not have a large matrix there is forest land. However, these birds pose a potential problem in other area of eastern Kentucky where the matrix has been highly fragmented by local mining, agriculture, and urban development.

Boundary shape also has implication for neotropical migrant birds and edge species of wildlife: the more uneven boundary, the more edge. Within matrix areas, networks connect habitats of different size and shape, creating what is called heterogeneity within the landscape. These different habitats patches usually are replicated throughout the matrix.

(2) **Patches:** Patches are nonlinear surface areas that differ in vegetation and landscape from their surroundings. They are units of land or habitats

there are heterogeneous when compared to the whole. They include four different types: disturbance, remnant, environmental resource and introduced.

- Disturbance patches are either natural or artificial. They result from various activities, including agriculture, forestry, urbanization and weather (i.e., tornados, hurricanes, ice storms, etc.). If left alone, a disturbance patch will eventually change until it combines with the matrix.

- Remnant patches result when human alter the landscape in an area and then leave parcels of the old habitats behind. Remnant patches are generally more ecologically stable and persist longer than disturbance patches.

- Environmental resource patches occur because of an environmental condition such as a wetland of cliff line.

- Introduced patches are ones in which people have brought in nonnative plants or animals or rearranged native species. Animals moving from one area to another can also bring in these nonnative elements.

(3) **Corridors:** The final landscape component is the corridor, the strip of land that differs from the matrix on either side. Corridors are areas that link patches together, serving as highways or conduits for organisms to transfer or move from patch. Corridors are a unique mixture of environmental and biotic attributes from the surrounding matrix and patches. They have origins and types similar to those of patches: there are disturbance, remnant, environmental resource and planted corridor. There are also stream corridors such as the patch followed by a river or streamside vegetation so important to migrating wildlife.

Different types of corridors forest different species. Corridors function in several ways to provide habitats for various species, especially the smaller ones like chipmunks. Line or narrow strip corridors are mainly dominated by edge species, whereas wider strip corridors, which may have mostly interior species, function for movement of animals. Corridors can serve as a conduit for movement or act as a barrier or filter (which may serve as a barrier to gene flow). For example, road can serve as an almost complete barrier to amphibian movement, ultimately isolating individual population.

Thus, landscape ecology involves the study of the landscape pattern, the interaction among patches within a landscape mosaic, and how these patterns and interactions change over time. In addition, landscape ecology involves the application of these principles in the formulation and solving of real-world problems. Landscape ecology considers the development and dynamics of spatial heterogeneity and its effects on ecological processes, and the management of spatial heterogeneity (Risser, Karr and Forman, 1984).

Among many reasons for a landscape perspective, three include:

(1) All ecological processes occur in spatial context;

(2) Hierarchy theory: ecological processes at one level of resolution are constrained by those higher and affected by those lower;

(3) The spatial scale of environmental problems has increased; thus the need for larger-scale environmental studies.

2.1.2 Landscape metric

2.1.2.1 Component of landscape metric

Landscape metrics or landscape indices broadly fall into one of two categories: non-spatial and spatial (Gustafson, 1998). Non-spatial indices describe landscape composition and include measurement of the number of patch classes or proportions of total area. Spatial indices describe patch attributes and contain information relevant to measuring fragmentation. The spatial indices can be further divided into those measuring fragmentation. The spatial indices can be further divided into those that describe patch composition, shape and configuration. In the strictest sense, only patch relates to fragmentation, but the traditional view of ecosystem fragmentation encompasses all three.

The following discussion compares/contrasts the three categories of landscape metrics relevant for fragmentation.

(1) Composition: Composition indices describe the basic characteristics of fragmentation. The two basic indices used to quantify fragmentation are number of patch and patch area, usually measured as mean patch area. However, they provide an incomplete picture because the fragmentation concept also encompasses the relative sizes of the prices that result. Also, mean patch size is sensitive to the addition or detection of small patches. As a result, the large patch of a given class as a percentage of the total landscape is used to indicate relative size (With and King, 2001; Saura and Matinez-Millan, 2001). The measures are affected by the resolution (Benson and MacKenzie, 1995) and extent of the study area. Patches density partly offsets this problem by indicating the number of patches within a given area (usually 100) and can, therefore, be used to compare different landscape (McCarigal and Marks, 1995; Saura and Matinez-Millan, 2001).

The indices discussed above are measures of patch attributes and do not necessarily have an ecological basis, although mean patch size and larges patch index can be relate to organism area requirement. A relatively new index related to patch size is average patch carrying capacity. Average patch carrying capacity scale patch size base on a species' area requirement (Vos et al., 2001). It may provide a more meaningful measure of patch size but will vary from one species to another. Also, the calculation for species with large home ranges that encompass patches of habitat (e.g. areas containing needed resources) and non-habitat (areas without such resources may prove difficult. In addition, Jaeger (2000) has introduced two new indices that relate to patch composition: splitting index and effective mesh size. Both are related to another index call the degree of division index, which is a measure of aggregation within a landscape. The splitting index relates to the number of patches and indicates how many equal-sized patches produce a particular value of the degree of division index. Effective mesh size relates to mean patch size and indicates what size of equal-sized patches will produce a particular degree of division index. Based on their mathematical properties, Jaeger claims that these new measures are better than their counterparts, but those claims have not yet been substantiated.

Two composition indices that are more ecologically based are core area and core area index (McCarigal and Marks, 1995; Schumaker, 1996). As previously discussed core area indicate interior area of a patch which retain similar abiotic and biotic conditions to pre-fragmented condition and do not experience strong influences from neighboring patches. These indices measure core area, as discussed earlier, and the process of interest. In effect, they straddle the boundary between both characteristics. Core area is a simple measurement of area, while core area index is a ratio of core area to patch area (and hence unitless).

(2) **Shape:** Shape indices attempt to quantify patch complexity, which can be important for different ecological processes. For example, circles or squares will have less edge and, potentially, more core area. Other shapes such as long narrow features like tree lines, or sinuous features like riparian areas may be less "visible" to species dispersing across the landscape, while convoluted or linear shapes may intercept the paths of more organisms or propagules (Forman, 1995).

Most measures of patch shape focus on some variation of perimeter-to-area ratio (Krummel et al., 1987). More complex shapes will have a larger perimeter or edge for a given area and therefore a higher perimeter: area ratio. The simple ratio of perimeter-to-area suffers from a negative relationship with size, given the same shape. For example, the perimeter-to-area ratio of a 4 x 4 square is 16 / 16 = 1, while the perimeter-to-area ratio for a 10 x 10 square is 40 / 100 = 0.4 (Frohn, 1998). Shape index overcomes size dependence by comparing the perimeter: area ratios to a standard shape such as a square or circle. This removes the relationship with size but imposes the restriction of choosing a reference shape (McCarigal and Marks, 1995; Patton, 1975).

Another index commonly use to characterize shape is fractal dimension (Krummel et al., 1987; O'Neill et al., 1988; Milne, 1991). Fractal dimension measures the degree of shape complexity. For image on a raster (gridded) map, fractral dimension varies from 1, which indicates relatively simple shapes such as squares, to 2, which indicates more complex and convoluted shapes. The methods for calculating fractal dimension vary depending upon the question or application. For landscape analysis, a common method involves regressing the patch perimeters versus patch areas on a log: log scale and relating the fractal dimension to the slope of the regression (McCarigal and Marks, 1995). Like shape index, fractal dimension measurements are not affected by patch scale per se, e.g. a square of any size will have the same fractal dimension. However fractal dimension will depend on the resolution of the study, as finer resolutions often reveal finer details and affect the perimeter: area ratios.

(3) Configuration: Patch configuration indices measure the degree of connectedness (Tischendorf and Fahrig, 2000) or, conversely, isolation (Moilanen and Hanski, 2001) between and among patches on a landscape. The notion of connectivity/isolation stems directly from the theory of Island Biogeography (MacArthur and Wilson, 1967), which relates species persistence on an island to a dynamic equilibrium between extinction (a function of island size) and colonization (a function of island distance from the mainland). There has been an extensive amount of work on developing these indices, probably because the concept relates well to the underlying ecology. Measures of patch configuration can generally be divided into two categories: indices based on distances between patches and indices that compare the overall spatial pattern, often called texture, of a landscape.

Distance-based configuration indices: Indices of patch configuration based on distance between patches vary in the degree to which they consider all other patches relative to a focal patch of interest. It has the advantage of being relative simple to compute and interpret but the disadvantage or not conveying more information on overall complexity. It is relate to the notion of dispersal and colonization, with increasing distance indicating a lower probability of successful dispersal and colonization.

Pattern-based configuration indices: Pattern-based indices of configuration attempt to provide a measure of the overall complexity of the landscape in question. Unlike distance measures, they do not have a patch focus and are calculated using the entire landscape.

2.1.2.1 Level of landscape metrics

Landscape can be characterized to three levels include (1) patch-level (2) class-level (3) landscape-level. The detail of each level is described as follows:

(1) Patch-level: Patch-level metrics are defined for individual patches, and characterize the spatial character and context of patch.

(2) Class-level: Class-level metrics are integrated over all the patches of a given type. These may be integrated by simple averaging, or though some sort of weighted-averaging scheme that biases estimate to reflect the greater contribution of large patches to the overall index. There are additional aggregate properties at the class level that result from the unique configuration of patches across the landscape.

(3) Landscape-level: Landscape-level metrics are integrated over all patch type or classes over the full extent of the data (i.e. the entire landscape). Like class metrics these may be integrated by a simple or weighted averaging, or may reflect aggregate properties of the patch mosaic (Mcgarigal, 2002).

2.2 Literature review

Trani and Giles (1999) used twenty-four pattern metrics and thirty-eight forest maps (scale: 1:24,000) to analysis for express aspects of spatial heterogeneity, fragmentation, edge characteristics, and connectivity. Landscape pattern metrics values were analyzed using SAS to produce descriptive statistics during each stage of the modeling process to detect progressive changes in landscape pattern. Results showed forest loss was also significantly reflected by mean patch size, number of patch, mean patch density, and interpatch distance. Metrics that contributed little to discrimination displayed unpredictable behavior or exhibited high variability about their mean values.

Li, Cheng and Xiao (2001) used nine landscape metrics at class level and thirteen landscape metrics at landscape level to analysis of landscape structure of the Heihe river basin. Result of landscape metrics of landscape pattern of the Heihe river basin was mainly controlled by the distribution of water resources. The landscape structure in the mountainous area showed a high continuity and complex patch shapes. The landscape structure of the oasis area showed the most complex landscape structure, the richest patch type, and the highest diversity. In the desert area a landscape metric with absolute dominance and very high contagion, while other landscape types in the zone were heterogeneous mosaics embedded in the matrix with very small percentage.

Griffith, Trettin and O'Neill (2002) used landscape pattern metrics to analyze dispersed versus condensed development scenarios and their effect on landscape pattern. They used five landscape metrics include 1) Dominance, 2) Contagion, 3) Spatial complex, 4) Edge and 5) Patch size. The result, landscape metrics, showed that a human disturbance had a greater simplifying effect on patch shape and also increased fragmentation than a natural disturbance.

Read and Lam (2002) used Landsat - TM from 1986, 1996 and 1997 to classify land-cover in four classes include 1) forest, 2) scrub, 3) pasture, 4) agriculture. They used three landscape metrics include 1) Shannon's diversity index, 2) Contagion index and 3) Fractal dimension from perimeter/area. In this study, they compared the spatial statistics and landscape metrics to characterize different land cover. The spatial statistics was includes 1) fractal dimension using the isarithm method, 2) fractal dimension using the modified TPSA method, 3) spatial autocorrelation. The result showed the landscape metrics use less information than the spatial statistics, which make use of both the value and spatial arrangement of the pixel.

Xia, Shengdong and Qifang (2002) used Landsat TM image from 1988, 1995 and 2001 to classify landscape in Heshan City of Guangdong province in China into seven types include 1) arable land, 2) forest, 3) shrubland, 4) grassland, 5) construction land, 6) water area and 7) other area. Several landscape indices were calculate from FRAGSTAT software, which included 1) number of patch, 2) percentage of landscape, 3) mean patch area, 4) patch density, 5) edge density, 6) perimeter-area fractal dimension, 7) indices of diversity and contagion. In this study they analyzed the landscape pattern on class level and landscape level. They found that the landscape of Heshan became more fragmented and less various, and every patch type had its own change characters.

Wang et al. (2003) used landscape metrics and driving factors to integrative measure of land use land cover changes. They used various landscape metrics included 1) diversity, 2) dominance, 3) homogeneity and 4) broken index. The landscape metrics calculated from the AML macro-program. The result showed the increasing of disturbances from human, the diversity index, the homogeneity index and the broken index are all increasing and the dominant index is decreasing. In contrast when natural landscape had been changed completely by human activities, as the increasing of disturbances from human, the diversity index the homogeneity index and the broken index are all decreasing and the dominant index is increasing.

Frohn and Hao (2006) used sixteen landscape metrics to evaluate with respect to the effects of spatial aggregation on six different years for deforested area in

Rondonia, Brazil. The landscape metrics were calculated by Patch Analyst 2.2 in ArcView software, that included 1) class area, 2) percent land, 3) patch density, 4) largest patch index, 5) mean patch size, 6) patch size standard deviation, 7) patch size coefficient of variation, 8) edge density, 9) mean nearest neighbor distance, 10) landscape shape index, 11) square pixel, 12) mean shape index, 13) area weighted mean shape index, 14) mean patch fractal dimension, 15) area weight mean patch fractal dimension, 16) double log fractal dimension landscape shape index (LSI) and square pixel (SqP) metrics showed the most predictable behavior of the shape complexity metrics having strong decrease with each increase in aggregation. The edge (ED) and patch density (PD) metrics showed the most predictable behavior among the edge and patch metrics, decreasing with increasing aggregation. The mean nearest neighbor (MNN) metric also behaved as expected but its result was less consistent than those of ED and PD. Many of the remaining metrics gave inconsistent and unpredictable results with respect to spatial aggregation.

Matsushita, Xu and Fukushima (2006) used landscape metrics to characterize landscape structure to investigate the change of landscape structure in the Lake Kusumigaura Basin, Japan. They used time-series land use land cover maps of three periods and 12 metrics for landscape level and 8 metrics for class level to analysis. The result showed human-modified landscape, such as artificial field and golf courses, increase rapidly during the study period, Increase patch number and decreased mean patch area indicated that most significant characteristic of land use land cover change in the study area in the fragmentation of the landscape. Both Shannon’s diversity and Shannon’s evenness indices increased considerably during the study period, also suggesting the landscape in the study area became more fragmented and heterogeneous. This fragmentation trend is most likely to continue due to the increasing population in the Lake Kusumigaura Basin in recent year.

Serra, Pons and Sauri (2008) used three different tools to differentiate land cover and land used change, driving forces and landscape dynamics. Three landscape metrics used to compare for each sub period and land-cover and land used included 1) number of patch, 2) mean patch size or average patch size and 3) largest patch index or percentage of land-cover and land used accounted for by largest patch. Results indicated the most relevant characteristics of landscape dynamics in the mountainous sub region, with a predominance of evergreen forest according to largest patch index (LPI), were the tendency to fragmentation of winter cereals, vineyards, olive trees and meadows and pastures due to their abandonment, especially in 1977 - 1993, according to mean patch size (MPS). On the other land, tendency to homogeneity appeared in the case of evergreen forest, shrub lands and urban surface in both periods and of deciduous forest in the first sub period. With a predominance of shrub lands according to LPI showed a tendency to fragmentation for permanence crops, meadows and pastures and evergreen forest.

Soverel et al. (2009) used five landscape metrics to described the forest fragmentation that included 1) number of forest patch, 2) mean forest patch size, 3) standard deviation of forest patch size, 4) mean forest patch perimeter-to-area-ratio, 5) edge density of forest patch. They used landscape metrics from 26 of Canada’s national parks to compare the greater park ecosystem (GPE). The result shown 58% had significantly fewer patches, 46% had significantly larger mean forest patch size (23% were not significantly different), and 46% had significantly smaller standard deviation of forest patch size (31% were not significantly different), relative to their GPEs.

CHAPTER III

THE STUDY AREA

3.1 General information

Thap Lan National Park was declared as Thailand's 40th national park in December 1981. It is the country's second largest national park, covering an area of 2,235.80 sq. km. The highest peak of the park is Khao Lamang, at a height of 992 m above sea level. Thap Lan National Park extends across two provinces: Nakhon Ratchasima and Pranchin Buri. Park headquarter is situated about 197 km from Bangkok. It comprised of continuous mountain ranges with naturally created valleys, chasms and waterfalls. Also, it is one of six related areas under the management of National Parks, Wildlife and Plant Conservation Department, which together constitute Queen Sirikit's Dong Phayayen-Khao Yai Forest Complex, in recognition of Her Majesty the Queen's 72nd birthday anniversary. The other five areas are Khao Yai national park, Pangsida national park; Ta Phraya national park; Phraphutthachai national park; and Dongyai wildlife sanctuary.

The fan palm (*Corypha lecomtei Becc*.) has a special place in Thai culture as its leaves were used as parchment, on which Buddhist texts were inscribed. During the 1960s and 1970s, communist guerillas sought refuge in the area we know today as Thap Lan National Park. These refugees cleared forest for rice cultivation, and the remnants of their encampments can still be seen today. More recently, influential officials exploited local villagers, forcing them to carry out illegal logging within the

Park's boundaries. Often, the loggers settled in the park to enable them to easily clear new land for agriculture. However, attitudes have begun to change in recent years, and now the villagers themselves are working with park authorities to help restore the Park's forests. For example, the Petroleum Authority of Thailand has sponsored one project involving tree planting at the edge of the park. The trees are provided by the Royal Forest Department and are planted by local villagers. Wildlife Fund Thailand provides expertise and training for the villagers, and has helped them to make an exhibition in the village to explain the project to the wider community. [Department of National Park, Wildlife and plant Conservation. (DNP), 2011].

3.2 Location and administration

Thap Lan National Park, where was the one of DPKY - FCWH is situated in Nakhon Ratchasima, Buri Ram and Prachin Buri Provinces (Figure 3.1). It locates between latitude 14°05´ to 14°33´ North and longitude 101°50´ to 102°40´ East. In this study, buffer zone about 5 km around the park is included into study area. It covers area of 3,824 sq. km. The study area has 25 sub-districts (Tambol) and consists of 246 villages. (DNP, 2550) (Figure 3.2 and Table 3.1).

3.3 Management

Park headquarter was located to follow closely the 304 road in Prachin Buri Province. Thap Lan National Park has 14 ranger stations which is distributed around the park namely, Klong Num Mun, Lam Ply Mas, Lam Plang, Khao Ma Ca, Hui Toei, Wang Ta Lu, Khao Mai Plong, Ta Ling Chun, Lam Ma Phai, Phu Lam Yai, Thai Sa

Mak Kee, Sub Sa Dao, Suan Hom, and Lam Phiak. The location and distribution of each station is shown in Figure 3.3.

3.4 Topography

The study area comprising of great range in the west (e.g. La-mong mountain, Phu-sam-ngam mountain, Phu-sung mountain). The Phu-sam-ngam was the higher mountain had approximately 992 m. above mean sea level (Figure 3.4). There is the origin of main rivers in Thailand (e.g. Mun and Bang-Pa-Kong rivers).

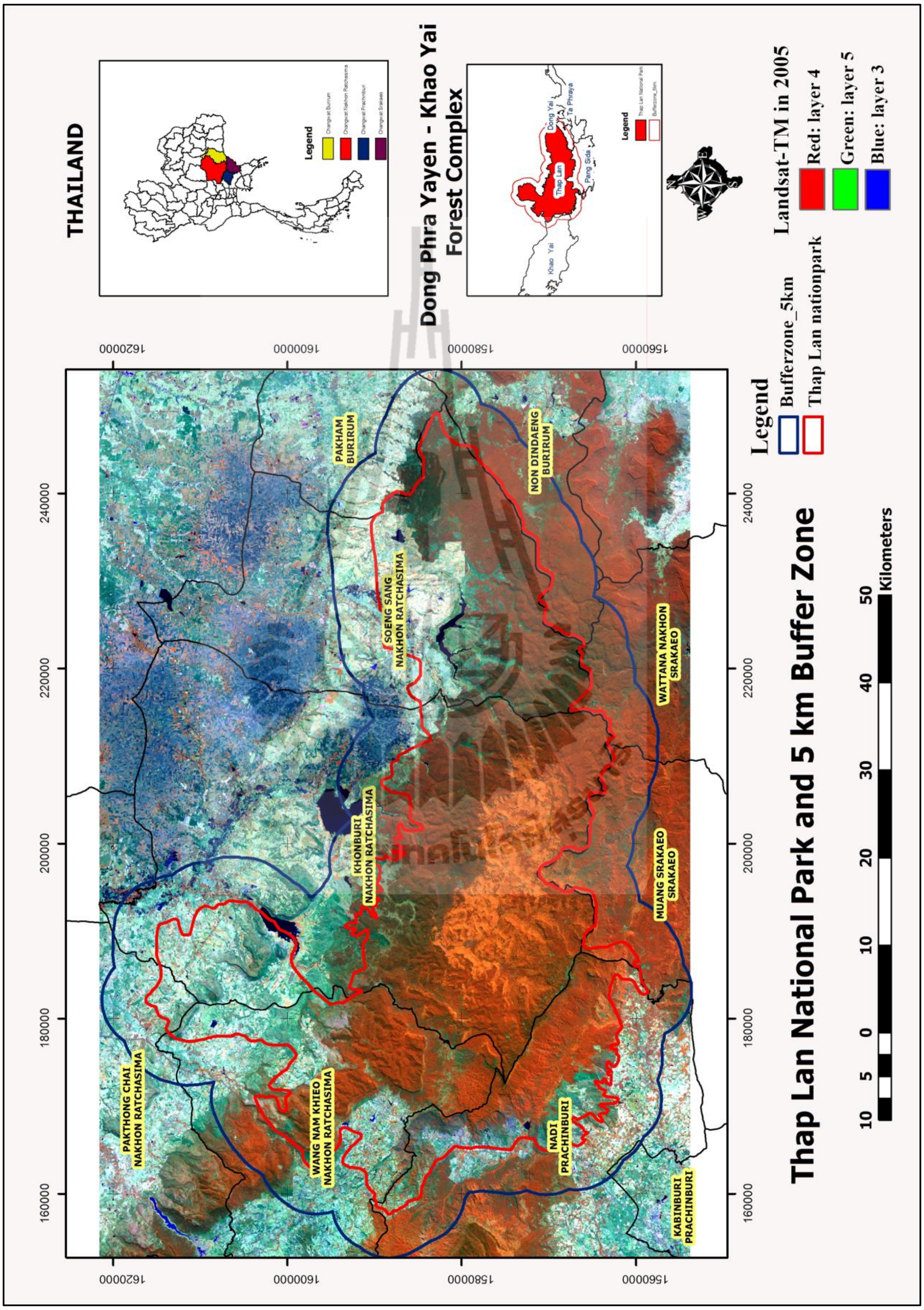


Figure 3.1 Location and administration.

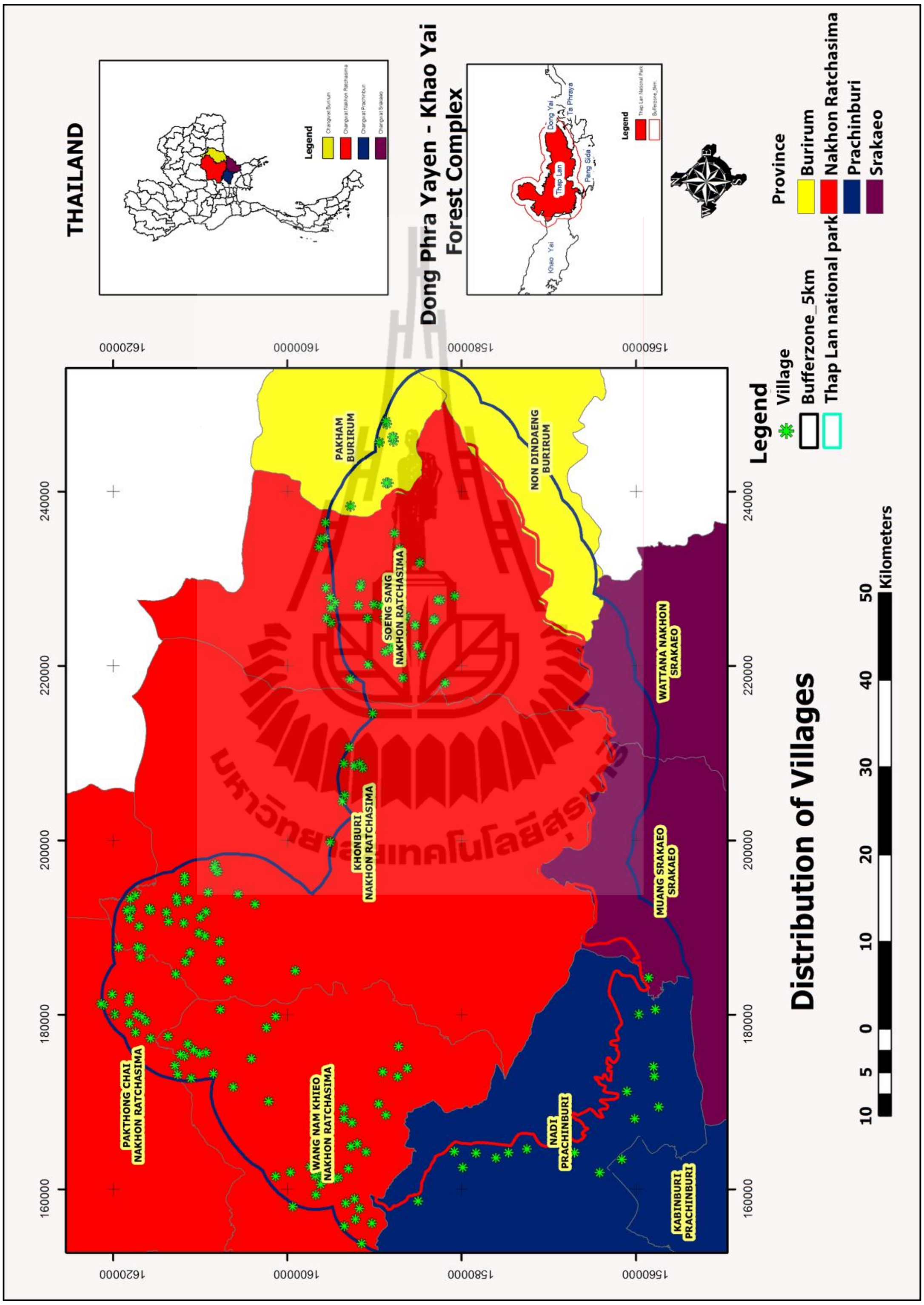


Figure 3.2 Villages within 5 km buffer zone of Thap Lan National Park.

Table 3.1 List of provinces, districts, sub-districts and number of villages.

Province	District	Sub-district	No. of villages
Nakhon Ratchasima	Khon Buri	1. Khon Buri	19
		2. Khon Buri Tai	4
		3. Chorakhe Hin	2
		4. Khok Krachai	7
		5. Lam Phiak	17
		6. Oraphim	11
		7. Khon Buri	19
		8. Khon Buri Tai	4
		9. Chorakhe Hin	2
		10. Khok Krachai	7
		11. Lam Phiak	17
		12. Oraphim	11
	Chok Chai	13. Thung Arun	4
	Pak Thong Chai	14. Ngio	3
		15. Don	1
		16. Phu Luang	6
		17. Samrong	2
		18. Sakae Rat	14
		19. Sa Takhian	8
		20. Non Sombun	9
		21. Wang Nam Khiao	22
		22. Udom Sap	31
Prachin Buri	Na Di	23. Bu Phram	7
		24. Kaeng Dinso	15
		25. Thung Pho	4
Total			**246**

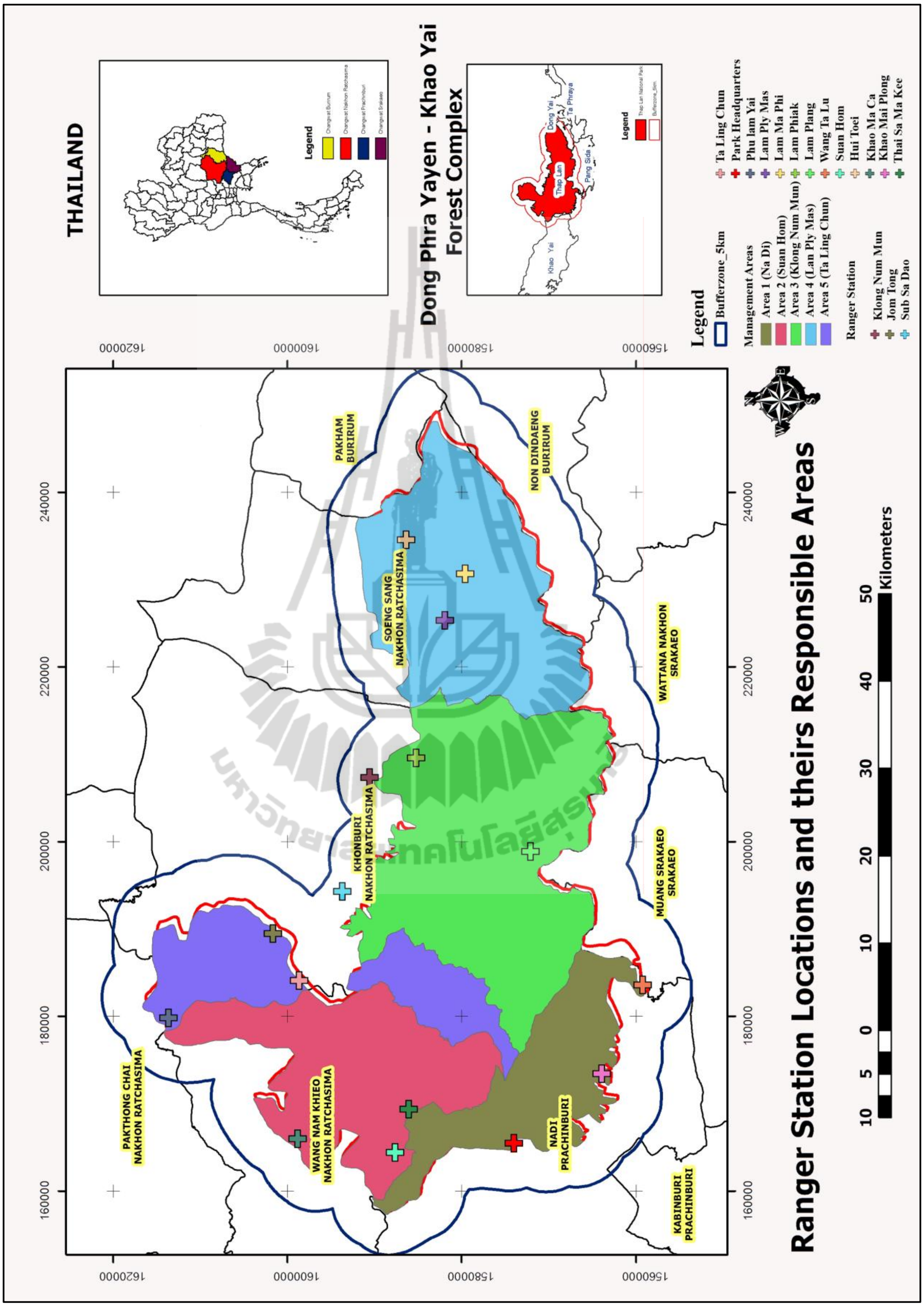


Figure 3.3 Ranger station and management areas of Thap Lan National Park.

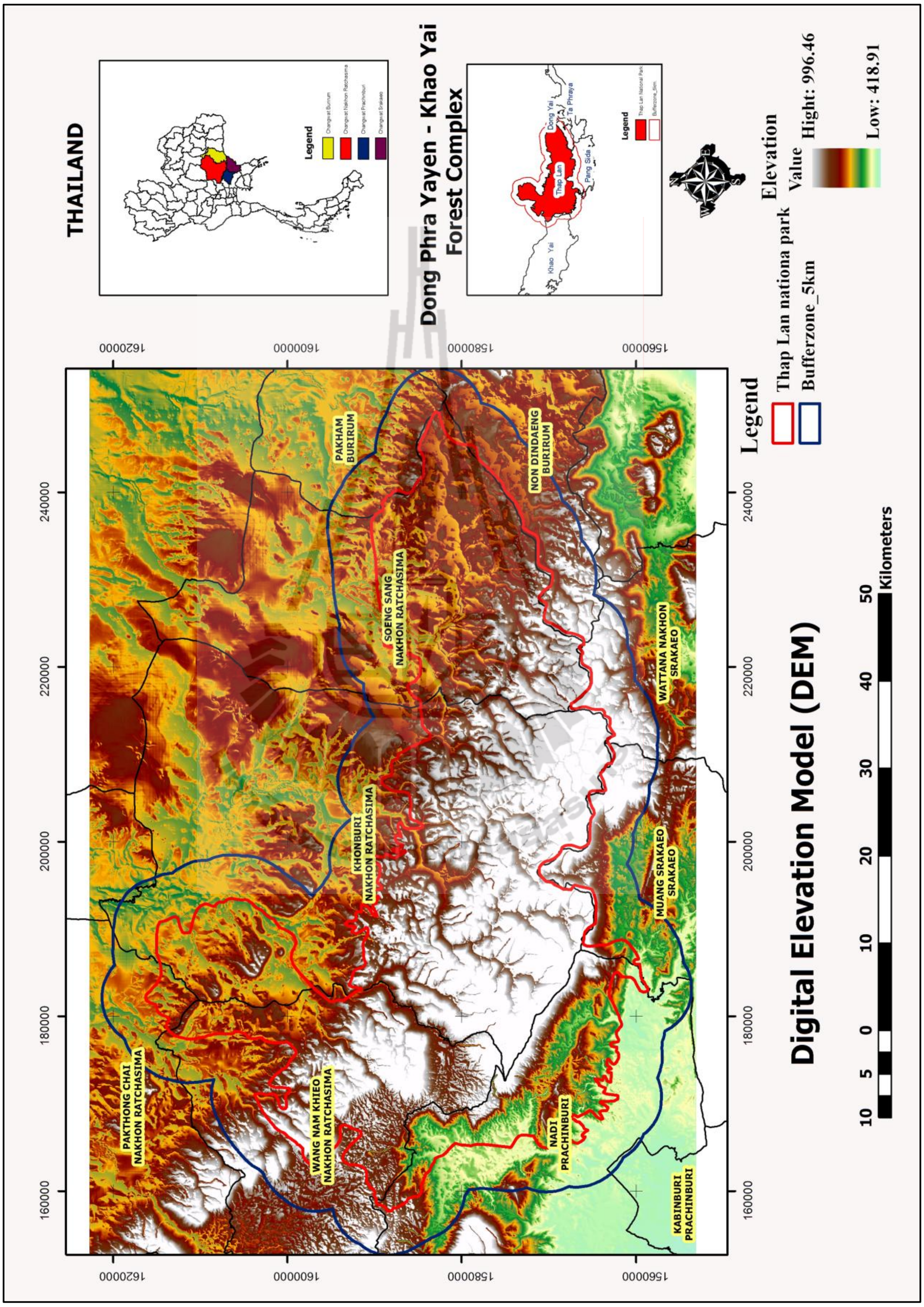


Figure 3.4 Topography of Thap Lan National Park.

3.5 Climate, temperature and rainfall

In general, there are three seasons in the region: hot season (mid February to mid May), rainy season (mid May to mid October) and cool dry season (mid October to mid February). Rainy season is under the influence of the southwest monsoons, while cool-dry season is influenced by the northeast monsoon carrying cold air from China.

The annual average temperature ranges from 27.0 to 27.7 °C. The highest temperature in April varies from 35.7 to 36.9 °C. The lower temperature in January varies from 16.9 to 19.4 °C.

The annual average rainfall ranges from 1,096.6 to 1662.2 mm. The highest rainfall in September varies from 231.1 to 303.2 mm. The lower rainfall in December varies from 1.8 to 5.3 mm.

3.6 Land use and land cover

In 1999, Land Development Department (LDD) classified land use types in Thap Lan National Park into 6 categories including:

- Urban and built-up area 4.35 sq. km
- Forest land 1,646.07 sq. km
- Forest Plantation 43.38 sq. km
- Grassland and shrub 85.92 sq. km
- Water bodies 18.44 sq. km
- Miscellaneous land 390.00 sq. km

In 2000, Royal Forest Department (RFD) classified forest types of Thap Lan National Park into 4 categories including 1) Dry Evergreen Forest, 2) Mixed

Deciduous Forest, 3) Dry Dipterocarp Forest and 4) Bamboo Forest (Figure 3.5) (DNP, 2550).

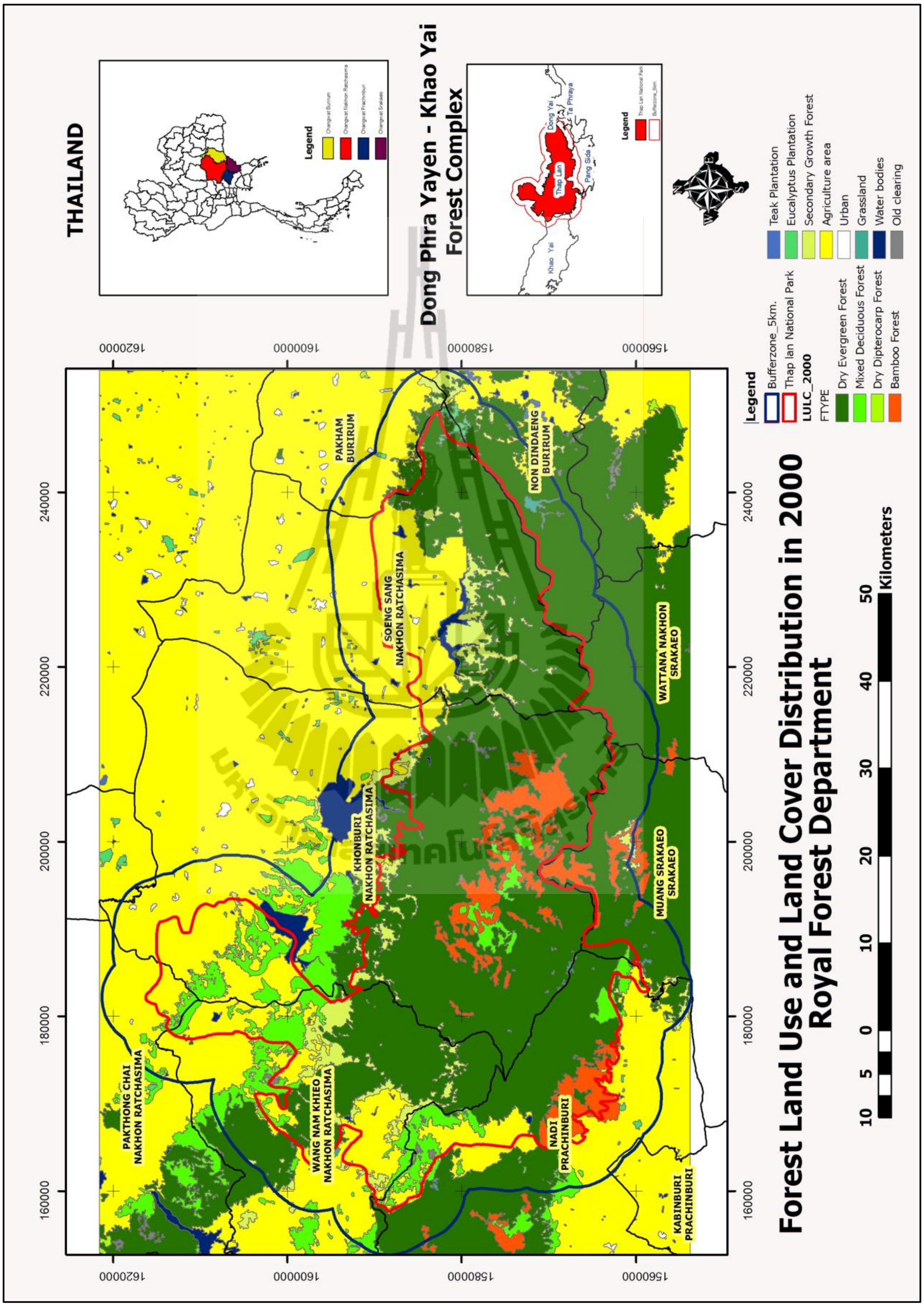


Figure 3.5 Forest land use and land cover in 2000 from Royal Forest Department of Thap Lan National Park.

CHAPTER IV

DATA, EQUIPMENT AND METHODOLOGY

4.1 Data and equipment

Data used for this research are spatial data (remotely sensed data, topographic data, secondary data and in situ data). For equipments, GPS and a notebook are used as hardware while GIS, remote sensing and spatial pattern analysis software are applied in this study (Table 4.1).

Table 4.1 Data and equipment.

Data and equipment	Date	Scale	Source/Remarks
1. RS/GIS Data Type			
1.1 Primary datasets			
- Topographic data**:** Sheet Number 5338 II, 5438 III, 5337 I, 5337 II 5537 III, and 5537 IV	2000	1:50,000	Royal Thai Survey Department
- Landsat - TM**:** Path 129, Row 50	18/12/1987 06/03/2005 08/02/2007	25 x 25 m	Geo-Informatics and Space Technology Development Agency (Public organization)

Table 4.1 Data and equipment (continued).

Data and Equipment	Date	Scale	Source/Remarks
1.2 Secondary datasets			
- Forest Cover data	2000	1:50,000	RFD
	2004		
- Land Use Data	2006	1:50,000	LDD
- National Park boundary	2000		RFD
- Forest inventory data	2009	40 x 40 m	In situ data collection
2. Equipments			
2.1 Hardware			
- GPS			Remote sensing Laboratory, SUT
- Notebook			
2.2 Software			
- ArcGIS 9			Remote sensing Laboratory, SUT
- Erdas Imagine 8.7			Remote sensing Laboratory, SUT
- FRAGSTATS 3.3			Forest Science Department, Oregon University

4.2 Methodology

In general, methodological framework of forest resources assessment using landscape metrics is schematically displayed in Figure 4.1. Herein three main research methodologies are developed to fulfill research objective including:

(1) to classify LULC in 1987, 2005 and 2007;

(2) to assess LULC and its change;

(3) to assess status and change of landscape and landscape type.

The detail of each research methodology is separately described in the following section.

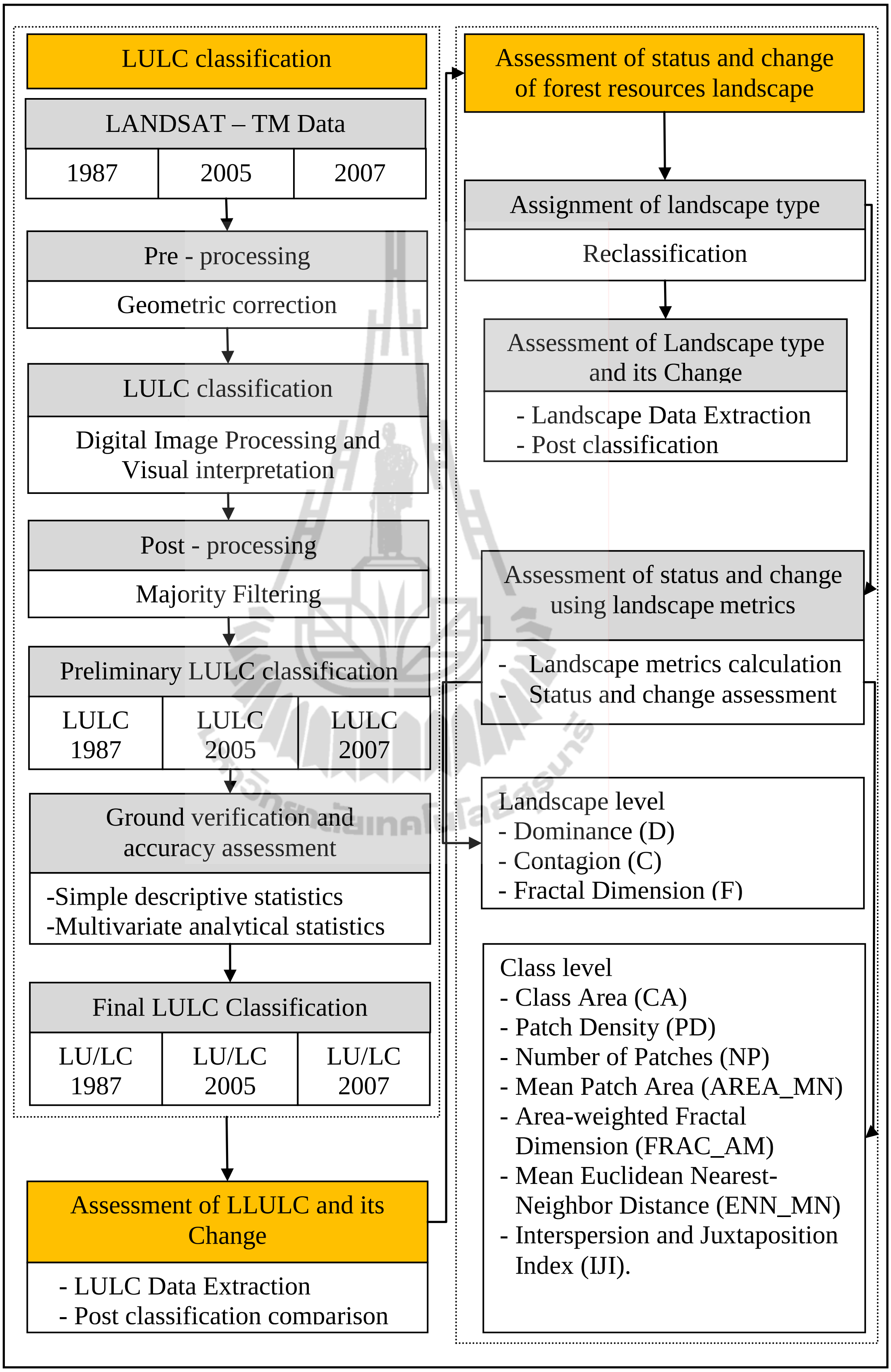


Figure 4.1 Methodology framework.

4.2.1 Classification of land use and land cover

Landsat - TM data (Path 129 Row 50) in 1987, 2005 and 2007 are major data sources for LULC classification in this study. In addition, land use data in 2006 of LDD, forest cover data in 2000 and 2004 of the RFD and field survey data in 2009 are compiled and used as ancillary data for LULC classification. Major steps in this study are 1) geometric correction of remotely sensed data, 2) LULC classification, 3) accuracy assessment. The detail of each step can be summarized as follows:

4.2.1.1 Geometric correction

Landsat - TM data in 1987, 2005 and 2007 were geometrically corrected with image to map rectification based on topographic map of the Royal Thai Survey Department. Herein, polynomial second order transformation for spatial interpolation and nearest neighbor resampling for intensity interpolation were conducted with RMS errors less than 0.5 pixel (12.5 m).

4.2.1.2 Land use and land cover classification

Band 3, 4 and 5 of Landsat - TM data in 1987, 2005 and 2007 were used to classify LULC types using supervised classification of Maximum Likelihood algorithm. In practice, training areas were identified from ground survey and land use land cover map from LDD and the RFD. In addition, visual interpretation for LULC types on the screen was also performed for correction of LULC classes. In this study, 14 LULC categories according to LDD and the RFD classifications were extracted from remotely sensed data including:

1) Urban and built-up area (U),
2) Paddy field (A1),
3) Field crop (A2),

4) Perennial and orchard (A3A4),

5) Dry evergreen forest (DEF),

6) Mixed deciduous forest (MDF),

7) Dry dipterocarp forest (DDF),

8) Bamboo forest (BF),

9) Natural forest succession and forest plantation (FSFP),

10) Grassland (GL),

11) Shrub land (SL),

12) Natural water body (W1),

13) Reservoir (W2),

14) Miscellaneous land (old clearing, uncultivated land, barren land/bare land) (M).

4.2.1.3 Accuracy assessment

In practice, number of sample size is firstly calculated based on statistics and sampling design was then selected for locating observing points for accuracy assessment. Then classified LULC was compared with ground information as matrix error for accuracy assessment.

(1) Calculate of number sample size

The actual number of ground reference test samples to be used to assess the accuracy of individual categories in a remote sensing classification map is a very important consideration (Jensen, 2005). In practice, number of sample size was firstly identified based on multinomial distribution with desired level of confidence of 90% and a precision of 10% as following Equation:

$$N = \frac{BII_i(1-II_i)}{b_i^2} \qquad \text{Eq. 4.1}$$

Where B is the upper (α/k) x 100^{th} percentile of the chi square $\left(\chi^2\right)$ distribution with one degree of freedom, II_i (i = 1, 12…k) is the proportion of the population in the i^{th} category, b is the absolute precision of the sample and k is the number of classes (Congalton and Green, 2009).

(2) Selection of sampling design

In this study, stratified random sampling technique was applied for locating observing points for accuracy assessment.

(3) Accuracy assessment

In practice, classified LULC in 2007 was compared with ground information in 2009 as matrix error for accuracy assessment with overall accuracy and kappa hat coefficient of agreement as following.

Overall accuracy is compute:

$$Overall\ accuracy = \frac{\sum_{i=1}^{k} X_{ii}}{N} \qquad \text{Eq. 4.2}$$

Where k is the number of rows in the matrix, X_{ii} is the number of observation in row i and column i and is N the total number of observations (Congalton and Green, 2009).

Kappa hat coefficient, $\hat{K}$, is computed:

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} \times x_{+1})}{N^2 - \sum_{i=1}^{k}(x_{i+} \times x_{+1})} \quad \text{Eq. 4.3}$$

Where k is the number of rows in the matrix, x_{ii} is the number of observation in row i and column i and x_{i+} and x_{+i} are the marginal totals for row i and column i respectively and *N* is the total number of observations (Congalton and Green, 2009).

4.2.2 Assessment of land use and land cover and its change

LULC data in 1987, 2005 and 2007 of Thap Lan National Park with 5km buffer area were assessed under GIS environment. Herein area and percentage of LULC categories will be calculated and compared between classes.

Furthermore, post-classification comparison change detection which is a heavily used quantitative change detection method (Jensen, 2005) were used to quantified change of LULC between 1987 and 2005 and 2005 and 2007 in term of from-to situation of LULC class information. This method is preferred because data from the two dates are separately classified, thereby minimizing any problems of normalizing for atmospheric and sensor differences between these dates. As a result, the credibility in results of the comparison is principally subject to the accuracy of the individual classification of the used images (Jensen, 2005).

4.2.3 Assessment of status and change of forest resources landscape

For assessment of current status and change of landscape in Thap Lan National Park and its surrounding, various landscape metrics were calculated using

FRAGSTATS which was the landscape structure analysis program and developed by the Forest Science Department, Oregon State University, U.S.A. It has been widely used for quantifying landscape structure in raster format (Mcgarigal and Marks, 1995). Landscape metrics, with provide abundant information about spatial pattern, can be divided into three level metrics including patch level metrics, class level metrics and landscape level metrics (Xia, Shengdong and Qifang, 2002). In this study, class level and landscape level metrics will be used to assess current status and change of forest resources and LULC. The detail of each step can be summarized as follows:

4.2.3.1 Assignment of landscape type

Fourteen LULC data from 1987, 2005 and 2007 of Thap Lan National Park and its buffer were firstly reclassified into 7 landscape types as following.

1) Forest landscape (FLT). This category composes of dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, bamboo forest.

2) Natural forest succession and forest plantation landscape (NLT).

3) Grassland landscape (GLT).

4) Agriculture landscape (ALT). This category composes of paddy field, field crop, perennial and orchard.

5) Urban and built-up landscape (ULT).

6) Water body landscape (WLT). This category composes of natural water body and reservoir.

7) Miscellaneous landscape (MLT). This category consists of shrub land and miscellaneous land (old clearing, uncultivated land, barren land/bare land).

4.2.3.2 Assessment of landscape type and its change

In this step, area and percentage of each assigned landscape type will be firstly calculated for describing current status of landscape. Then, post-classification comparison change detection will be here used to quantify change of landscape types between 1987 and 2005 and 2005 and 2007. This step will report form-to situation of landscape type information.

4.2.3.3 Assessment of status and change using landscape metrics

In this step, landscape and class levels metrics will be calculated for describing current status and change of forest resources and land use and land landscape.

(1) Status and change of landscape

At landscape level, landscape metrics include 1) Dominance (D), 2) Contagion (C) and 3) Fractal Dimension (F) will be computed for the landscape mosaic as a whole as follows:

1) Dominance (D). It is a measure of landscape diversity, or extent to which a few land cover type dominance the landscape. The index used here ranges from 0 to 1, (Griffith, Trettin and O'Neill, 2002). High values of D indicated a landscape that is dominance by one or a few landscape type, and low values indicate a landscape that the cover types are represented in approximately equal proportions. Dominance (D) metric is calculated by following equation:

$$\mathrm{D} = \frac{H_{max} + \sum_{k=1}^{n} ln(P_k)}{H_{max}} \qquad \text{Eq. 4.4}$$

Where, 0< P_k <1 is the proportion of land-cover type k, and n is the total number of land-cover types present in the landscape.

2) Contagion (C). It is a measure of the extent to landscape type are aggregated or clumped. High values reflect the clumping of large contiguous patches. Low values reflect a landscape that is dissected into small patches. The contagion index ranges from 0 to 1 (Griffith et al., 2002). Contagion (C) metric is calculated by following equation:

$$C = \left[1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]\times\left[ln(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2ln(m)}\right](100) \qquad \text{Eq. 4.5}$$

Where,

P_i is proportion of the landscape occupied by patch type (class) i.

g_{ik} is number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method.

m is number of patch types (classes) present in the landscape, including the landscape border if present.

3) Fractal Dimension (F). It is a measure of the complexity in landscape, fractal dimension calculated from perimeter/area had been use widely in landscape ecology to describe patch complexity. The Fractal Dimension range from 1 to 2, values closed to 1 indicate a landscape made up of shapes with simple perimeters, and values close to 2 represent landscape with very complex perimeters (Read and Lam, 2002). Fractal Dimension (F) metric is calculated by regressing the log of the patch perimeter against the log of the patch area for each patch on the landscape as following equation.

$$F = \frac{\ln(A)}{\ln(P)+\ln(0.25)} \quad \text{Eq. 4.6}$$

Where, P is the patch perimeter and A is patch area.

Under this level, the position in three-dimensional pattern space (Figure 4.2) will be defined to the current status of a landscape in each year. Simple geometry can be use to computed the distance between landscape in pattern space (Turner, Gardner and O'Neill, 2001).

In this study, change in the landscape will be analyzed by calculation of three-dimensional Euclidean distances that defines the distance between landscapes in pattern space as follows:

$$Change(\boldsymbol{Z}) = [(X_1 - X_2)^2 + (Y_1 - Y_2)^2 + (Z_1 - Z_2)^2]^{1/2} \quad \text{Eq. 4.7}$$

Where, X is Dominance, Y is Contagion, and Z is Fractal Dimension and at some magnitude (as yet unknown) this shift would represent a phase changes in the landscape (Frohn, 1998). The change metric has a potential range: 0<**Z**<1.73 (O'Neill et al., 1996).

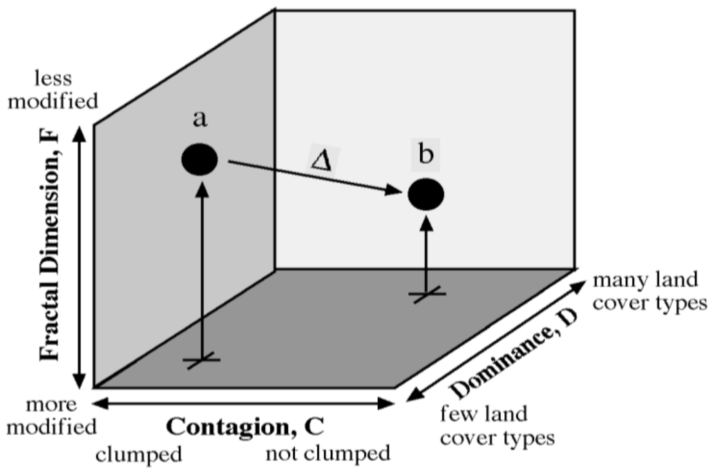


Figure 4.2 Landscape Metric Feature Space (Jensen, 2007).

(2) Status and change of landscape type

For class level, landscape metrics, which were computes each patch type (class) in the mosaic, were selected based on the review of previous work of Matsushita et al. (2006) include:

1) Class Area (CA). Class area equals the sum of area of all patches of the corresponding patch type.

$$\text{CA} = \sum_{j=1}^{a} a_{ij} \left[\frac{1}{10{,}000}\right] \qquad \text{Eq. 4.8}$$

Where, a_{ij} is area (m^2) of patch ij.

2) Number of Patches (NP). Number of patches equals the number of patch in the land cover type or landscape under investigation.

$$\text{NP} = n_i \qquad \text{Eq. 4.9}$$

Where, n_i is number of patches in the landscape of patch type (class) i.

3) Patch Density (PD). Patch Density equals the number of patches per unit area.

$$\text{PD} = \frac{\text{n}_\text{i}}{\text{A}}(10{,}000)(100) \qquad \text{Eq. 4.10}$$

Where, n_i is number of patches in the landscape of patch type (class) i and A is total landscape area (m^2).

4) Mean Patch Area (AREA_MN). Mean patch area equals the sum of the areas of all patches of the corresponding patch type (or all patches in the

landscape), divided by the number of patches of the same type (or total number of patches).

$$\text{AREA} = a_{ij}\left(\frac{1}{10,000}\right) \quad \text{Eq. 4.11}$$

Where, a_{ij} is area (m^2) of patch *ij*.

$$\text{MN} = \frac{\sum_{j=1}^{n} x_{ij}}{N}$$

MN (Mean) equals the sum, across all patches in the landscape, of the corresponding patch metric values, divided by the total number of patches. MN is given in the same units as the corresponding patch metric.

5) Area-weighted Fractal Dimension (FRAC_AM). Area-weighted Fractal Dimension equals the average patch fractal dimension of patches of the corresponding patch type, weight by patch area so that larger patches weight more than smaller patch.

$$\text{F} = \frac{\ln(A)}{\ln(P)+\ln(0.25)} \quad \text{Eq. 4.12}$$

Where, P is the patch perimeter and A is patch area.

$$\text{AM} = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[X_{ij}\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)\right]$$

AM (area-weighted mean) equals the sum, across all patches in the landscape, of the corresponding patch metric value multiplied by the proportional abundance of the patch

6) Mean Euclidean Nearest-Neighbor Distance (ENN_MN). Mean Euclidean Nearest-Neighbor Distance equals the sum of the distance to the nearest-

neighboring patch of the same type, base on shortest edge-to-edge distance, for each patch of the corresponding patch type, divided by the number of patches of the same type.

$$\mathrm{ENN} = h_{ij} \qquad \text{Eq. 4.13}$$

Where, h_{ij} is distance (m) from patch ij to nearest neighboring patch of the same type (class), based on patch edge-to-edge distance, computed from cell center to cell center.

$$\mathrm{MN} = \frac{\sum_{j=1}^{n} x_{ij}}{N}$$

MN (Mean) equals the sum, across all patches in the landscape, of the corresponding patch metric values, divided by the total number of patches. MN is given in the same units as the corresponding patch metric.

7) Interspersion and Juxtaposition Index (IJI). Interspersion and Juxtaposition Index equals minus the sum, of each unique edge type divided by the total landscape edge, multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch type times the number of patch type minus 1 divided by 2.

$$\mathrm{IJI} = \frac{-\sum_{k=1}^{m}\left[\left(\frac{e_{ik}}{\sum_{k=1}^{m} e_{ik}}\right)\ln\left(\frac{e_{ik}}{\sum_{k=1}^{m} e_{ik}}\right)\right]}{\ln(m-1)}(100) \qquad \text{Eq. 4.14}$$

Where, e_{ik} is total length (m) of edge in landscape between patch types (classes) i and k and m is number of patch types (classes) present in the landscape, including the landscape border, if present.

Under this level, landscape metrics will be used to described status and change in each landscape type.

CHAPTER V

ASSESSMENT OF LAND USE AND LAND COVER AND ITS CHANGE

The content of this chapter will present the results of the first and the second objectives focusing on assessment of LULC types in 1987, 2005 and 2007 and its change before and after declaration of DPKY - FCWH in 2005.

5.1 Assessment of land use and land cover

LULC types of Thap Lan National Park and its 5 km buffer zone in 1987, 2005 and 2007 were derived from Landsat - TM data based on digital image processing and visual interpretation. LULC classification which was modified from classification system of LDD and the RFD consisted of 1) Urban and built-up area, 2) Paddy field, 3) Field crop, 4) Perennial and orchard, 5) Dry evergreen forest, 6) Mixed deciduous forest, 7) Dry dipterocarp forest, 8) Bamboo forest, 9) Natural forest succession and forest plantation, 10) Grassland, 11) Shrub land, 12) Natural water body, 13) Reservoir, 14) Miscellaneous land (old clearing, uncultivated land, barren land/bare land). Characteristics of LULC in each year were extracted under GIS environment. Results were described in detail in the following sections.

5.1.1 Land use and land cover in 1987

The most significant LULC type of Thap Lan National Park and its 5 km buffer zone in 1987 was natural forest covering an area of 2,615.97 sq. km or 68.41% of the study area. These areas included dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, and bamboo forest distributed throughout the study area (Table 5.1 and Figure 5.1). The second dominant LULC type was agriculture land (paddy field, field crop and perennial and orchard) accounting for 678.24 sq. km or 17.74% of the area. These areas were found in the north and south-west of the study area. The third important LULC category was natural forest succession and forest plantation covering area of 374.25 sq. km or 9.79% of the area. This area was situated close to natural forest. Other LULC types included urban and built-up area, grassland, shrub land, natural water body, reservoir and miscellaneous land were distributed in 5 km buffer zone. These categories covered area of 155.76 sq. km or 4.07% of the area.

Table 5.1 Area and percentage of land use and land cover in 1987.

Land use and land cover type	**Area in sq. km**	**Percentage**
1. Urban and Built-up area	57.71	1.51%
2. Paddy Field	218.48	5.71%
3. Field Crop	289.25	7.56%
4. Perennial and Orchard	170.51	4.46%
5. Dry Evergreen Forest	1,761.66	46.07%
6. Mixed Deciduous Forest	294.47	7.70%
7. Dry Dipterocarp Forest	395.99	10.35%
8. Bamboo Forest	163.85	4.28%
9. Natural Forest Succession and Forest Plantation	374.25	9.79%
10. Grassland	21.34	0.56%
11. Shrub Land	15.58	0.41%
12. Natural Water Body	26.77	0.70%
13. Reservoir	6.12	0.16%
14. Miscellaneous Land	43.81	1.15%
Total	**3,824.22**	**100.00%**

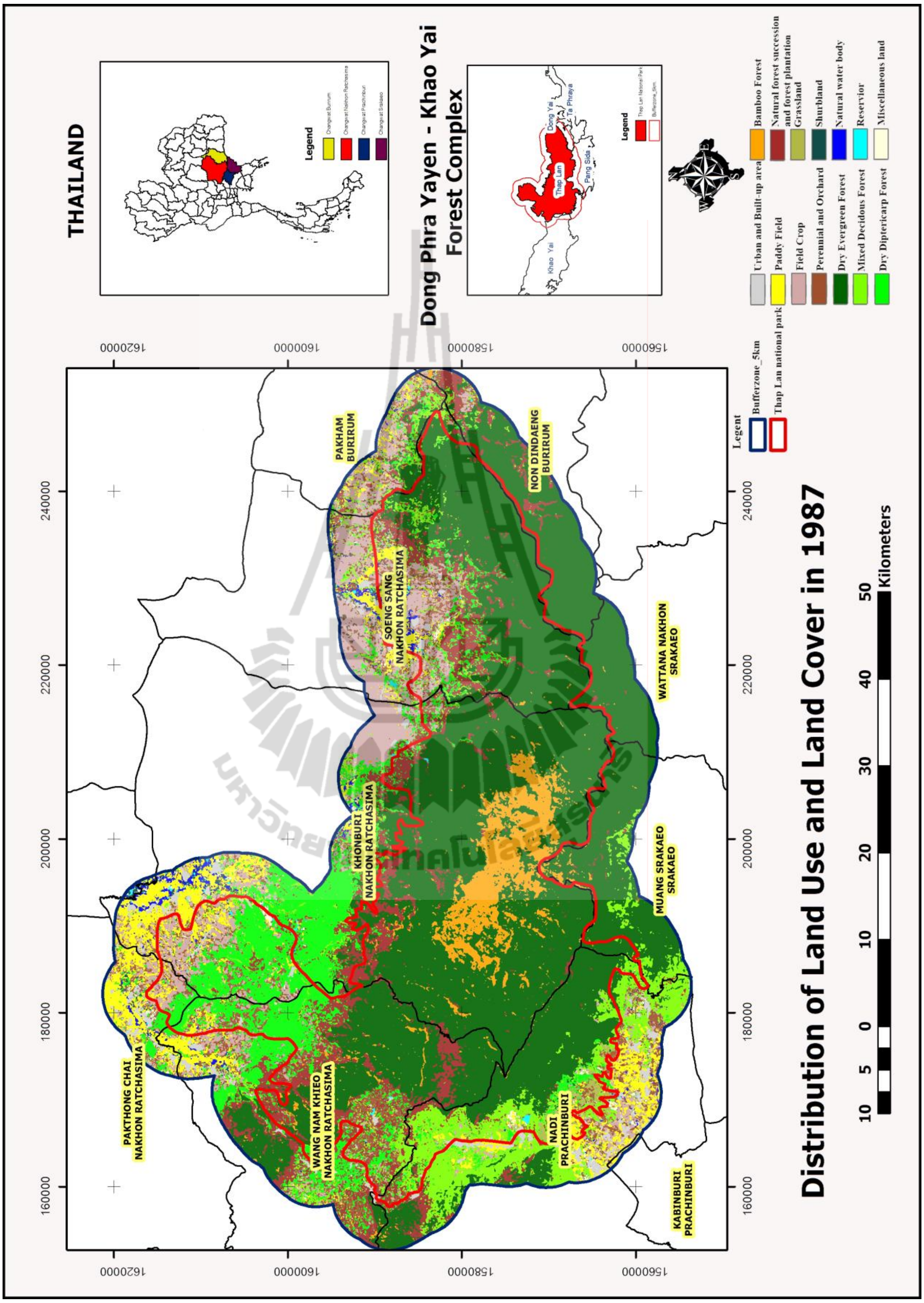


Figure 5.1 Distribution of land use and land cover in 1987.

5.1.2 Land use and land cover in 2005

In 2005 Thap Lan National Park was inscribed to the DPKY - FCWH. LULC in 2005 had the same pattern like those in 1987. The most significant LULC type was natural forest areas covering an area of 2,570.59 sq. km or 67.22% of the study area. These areas included dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, and bamboo forest distributed throughout the study area (Table 5.2 and Figure 5.2). The second dominant LULC type was agriculture land (paddy field, field crop and perennial and orchard) accounting for 668.75 sq. km or 17.49% of the area. The third important LULC category was natural forest succession and forest plantation covering area of 337.69 sq. km or 8.83% of the area. Other LULC types included urban and built-up area, grassland, shrub, natural water body, reservoir and miscellaneous land. These categories covered area of 247.19 sq. km or 6.46% of the area.

Table 5.2 Area and percentage of land use and land cover in 2005.

Land use and land cover type	Area in sq. km	Percentage
1. Urban and Built-up area	67.59	1.77%
2. Paddy Field	197.93	5.18%
3. Field Crop	309.19	8.08%
4. Perennial and Orchard	161.63	4.23%
5. Dry Evergreen Forest	1,761.44	46.06%
6. Mixed Deciduous Forest	294.60	7.70%
7. Dry Dipterocarp Forest	350.83	9.17%
8. Bamboo Forest	163.72	4.28%
9. Natural Forest Succession and Forest Plantation	337.69	8.83%
10. Grassland	29.52	0.77%
11. Shrub Land	15.42	0.40%
12. Natural Water Body	21.06	0.55%
13. Reservoir	42.39	1.11%
14. Miscellaneous Land	86.65	2.26%
Total	**3,824.22**	**100.00%**

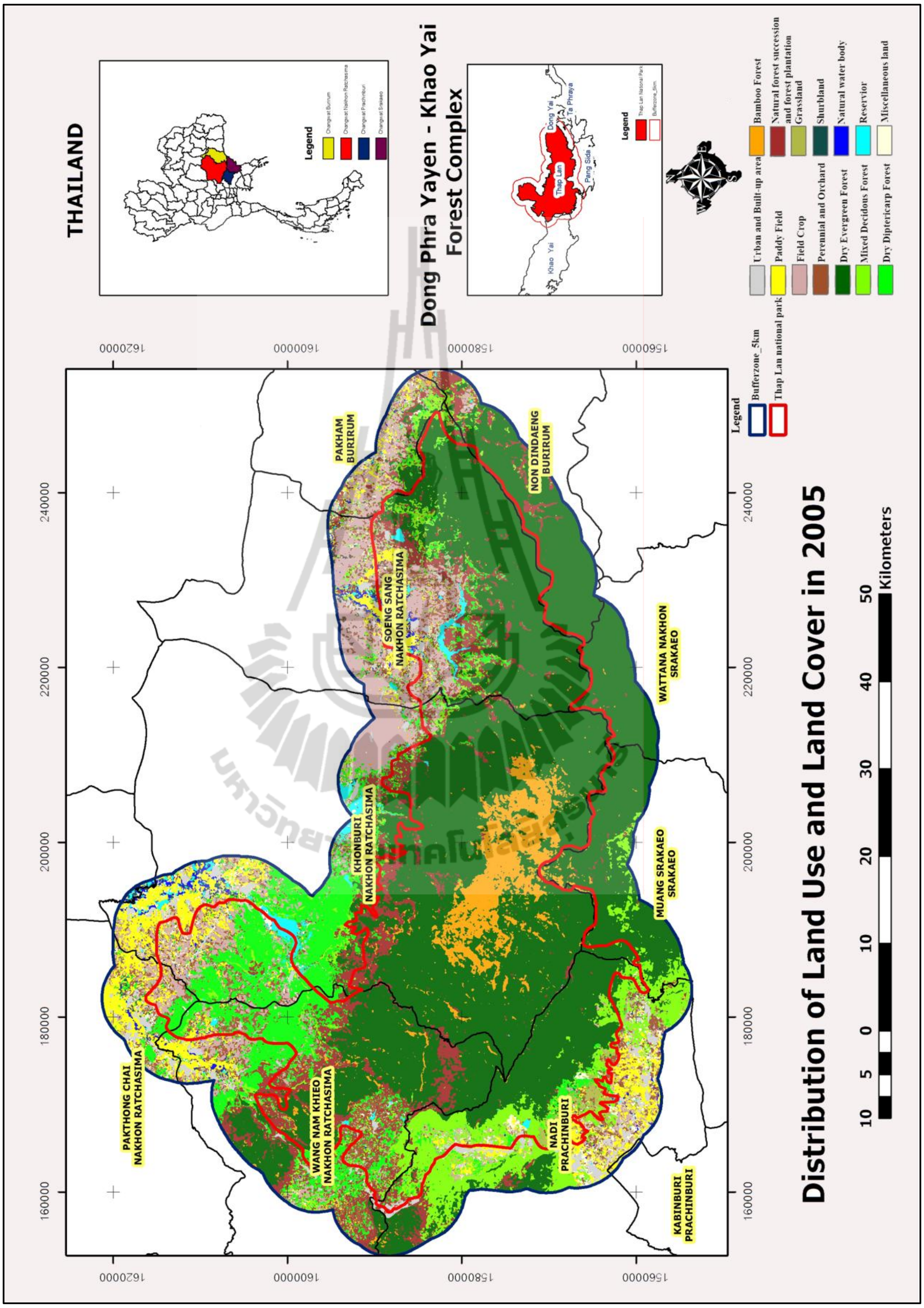


Figure 5.2 Distribution of land use and land cover in 2005.

5.1.3 Land use and land cover in 2007

In general, LULC in 2007 had the same pattern like those in 2005. The most significant LULC type was natural forest areas covering an area of 2,514.08 sq. km or 65.74% of the study area. These areas included dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, and bamboo forest distributed throughout the study area (Table 5.3 and Figure 5.3). The second dominant LULC type was agriculture land (paddy field, field crop and perennial and orchard) accounting for 532.33 sq. km or 13.92% of the area. The third important LULC category was natural forest succession and forest plantation covering area of 334.74 sq. km or 8.75% of the area. Other LULC types included urban and built-up area, grassland, shrub, natural river, reservoir and miscellaneous land. These categories covered area of 443.07 sq. km or 11.59% of the area.

Table 5.3 Area and percentage of land use and land cover in 2007.

Land use and land cover type	Area in sq. km	Percentage
1. Urban and Built-up area	68.12	1.78%
2. Paddy Field	167.90	4.39%
3. Field Crop	254.22	6.65%
4. Perennial and Orchard	110.21	2.88%
5. Dry Evergreen Forest	1,761.03	46.05%
6. Mixed Deciduous Forest	278.83	7.29%
7. Dry Dipterocarp Forest	311.16	8.14%
8. Bamboo Forest	163.06	4.26%
9. Natural Forest Succession and Forest Plantation	334.74	8.75%
10. Grassland	35.93	0.94%
11. Shrub Land	14.98	0.39%
12. Natural Water Body	20.46	0.54%
13. Reservoir	63.32	1.66%
14. Miscellaneous Land	240.26	6.28%
Total	**3,824.22**	**100.00%**

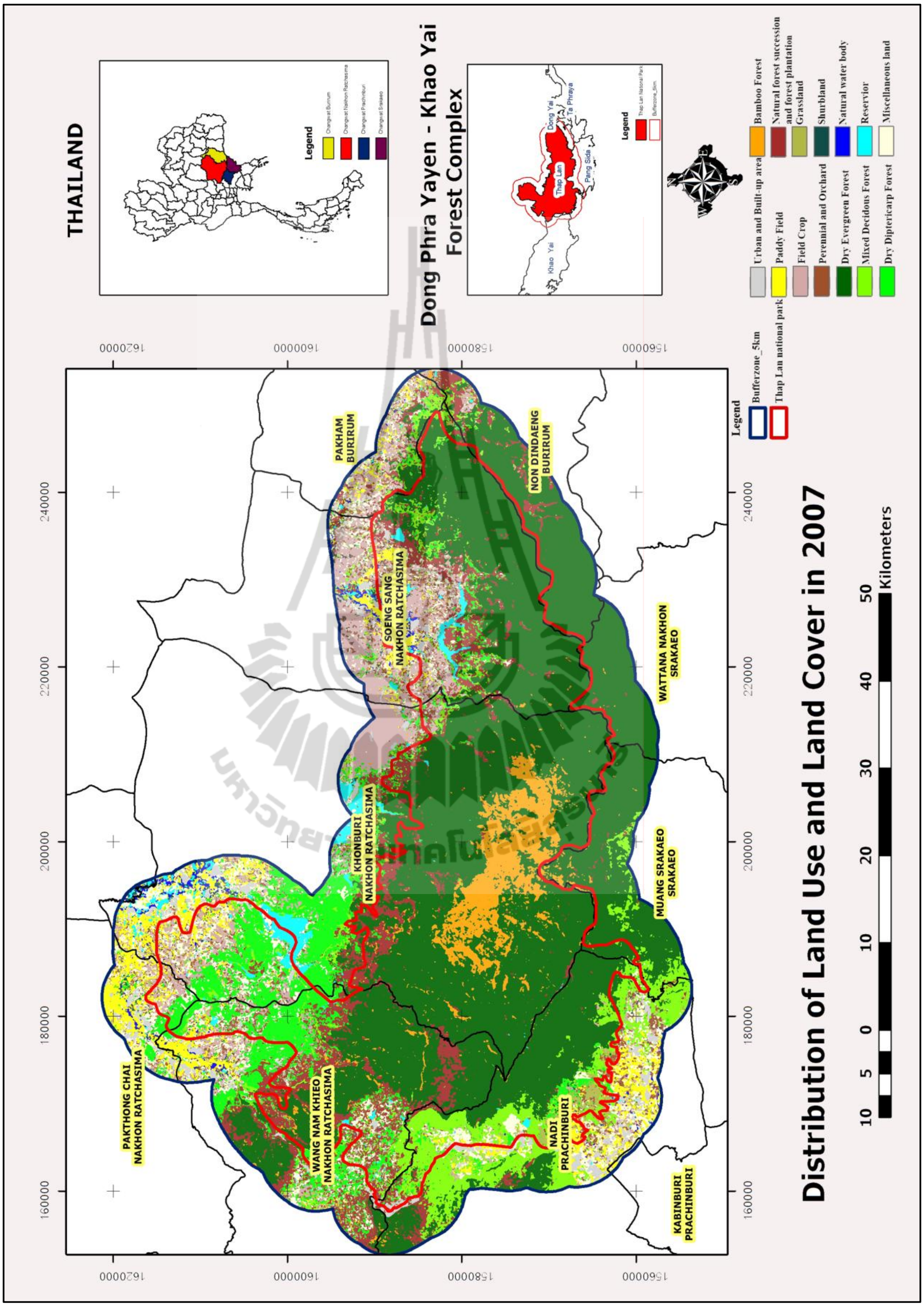


Figure 5.3 Distribution of land use and land cover in 2007.

In summary, LULC categories in 1987, 2005 and 2007 were presented to compare LULC change (Table 5.4 and Figure 5.4). It was found that the main disturbed natural forest in Thap Lan National Park and its 5 km buffer during 20 years (1987 - 2007) was dry dipterocarp and mixed deciduous forest. This result shows encroachment activity in national park and its 5 km buffer. At the same period, miscellaneous area (old clearing, uncultivated land, barren land/bare land) reservoir, grassland and urban and built-up area were continuously increased. This result shows effect of policy to deforestation, especially in case of increment of reservoir.

Table 5.4 Allocation for land use and land cover categories in 1987, 2005 and 2007.

LULC type	**1987**		**2005**		**2007**	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and Built-Up	57.71	1.51	67.59	1.77	68.12	1.78
Paddy Field	218.48	5.71	197.93	5.18	167.90	4.39
Field Crop	289.25	7.56	309.19	8.08	254.22	6.65
Perennial and Orchard	170.51	4.46	161.63	4.23	110.21	2.88
Dry Evergreen Forest	1,761.66	46.07	1,761.44	46.06	1,761.03	46.05
Mixed Deciduous Forest	294.47	7.70	294.60	7.70	278.83	7.29
Dry Dipterocarp Forest	395.99	10.35	350.83	9.17	311.16	8.14
Bamboo Forest	163.85	4.28	163.72	4.28	163.06	4.26
Natural Forest Succession and Forest Plantation	374.25	9.79	337.69	8.83	334.74	8.75
Grassland	21.34	0.56	29.52	0.77	35.93	0.94
Shrub Land	15.58	0.41	15.42	0.40	14.98	0.39
Natural Water Body	26.77	0.70	21.06	0.55	20.46	0.54
Reservoir	6.12	0.16	42.39	1.11	63.32	1.66
Miscellaneous Land	28.23	0.74	71.23	1.86	240.26	6.28
Total	**3,824.22**	**100.00**	**3,824.22**	**100.00**	**3,824.22**	**100.00**

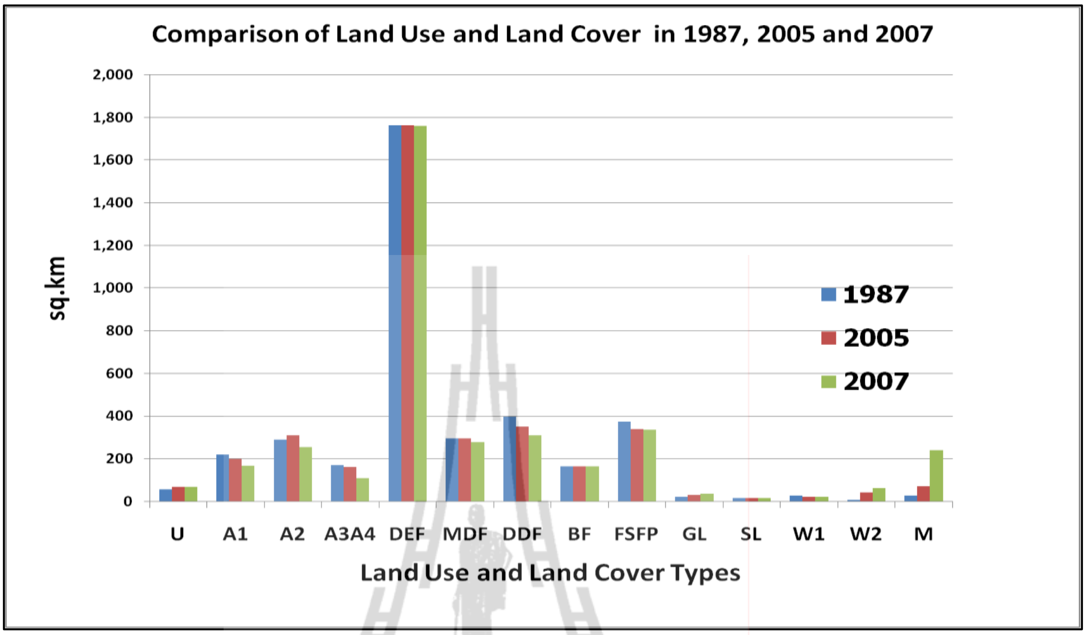


Figure 5.4 Comparison of land use and land cover type in 1987, 2005 and 2007.

5.1.4 Accuracy assessment

Classified LULC in 2007 was compared with ground information in 2009 for accuracy assessment using overall accuracy and kappa hat coefficient of agreement. In practice, error matrix between LULC type in 2007 and the reference LULC types from field survey in 2009 is firstly constructed and accuracy assessment is then evaluated using the above mentioned methods. In this study, 168 randomly stratified sampling points based on multinomial distribution theory with desired level of confident 90 percent and a precision of 10 percent were used for accuracy assessment (Figure 5.5). The error matrix between the classified LULC in 2007 and the reference LULC from field survey in 2009 was shown in Table 5.5. It was found that the overall accuracy was 87.50% and Kappa hat coefficient of agreement was 0.87.

5.1.5 Forest inventory data

During field survey in 2009, selected 40 x 40 m sample plots of natural forest included 8 plots of dry evergreen forest, 2 plots of mixed deciduous forest, 3 plots of dry dipterocarp forest, 2 plots of bamboo forest and 1 plots of natural forest succession and forest plantation were collected in situ data: location, local name, botanical name, total height and merchantable height and girth at breast height (GBH). Detail of forest inventory data was presented in Appendix.

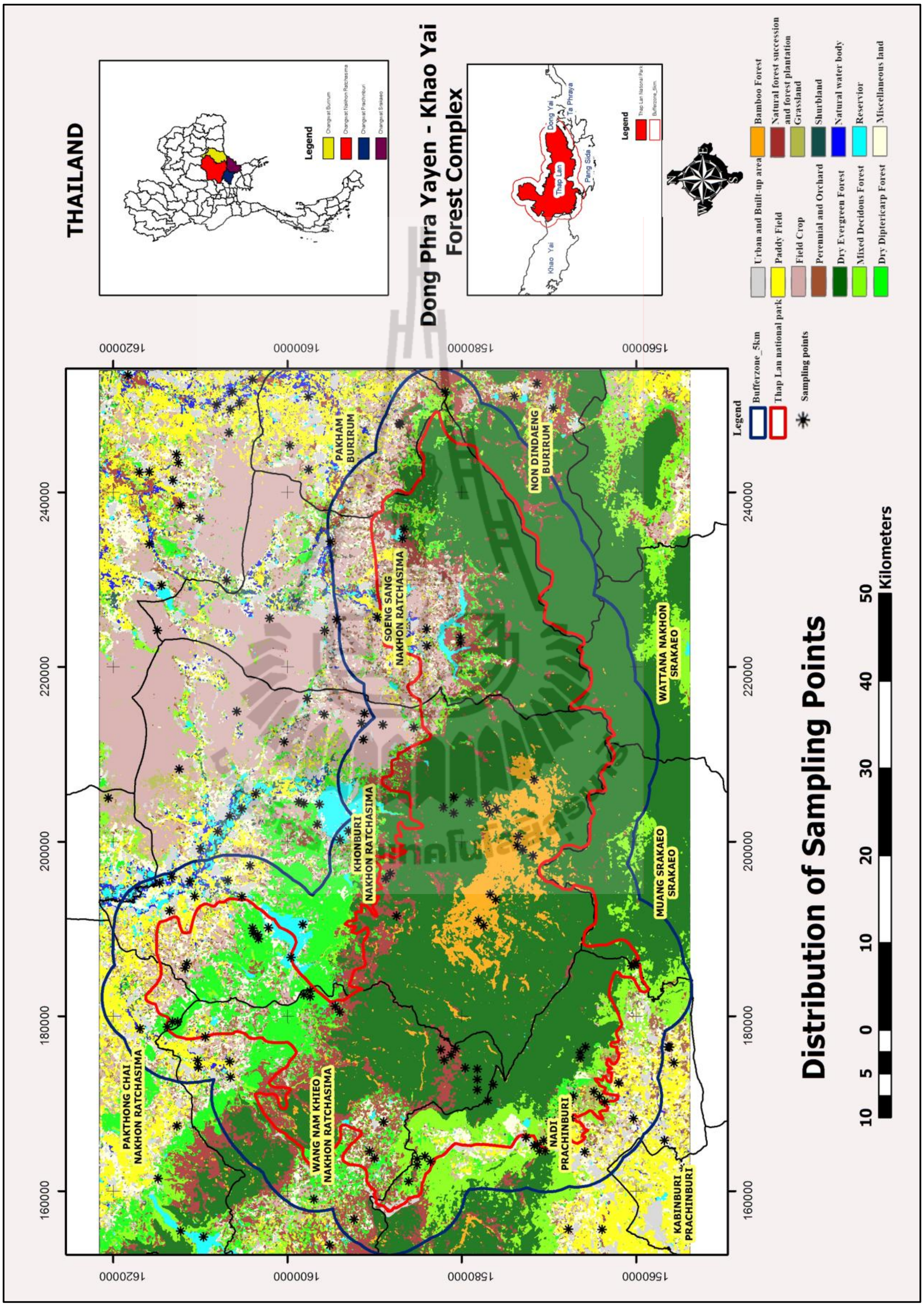


Figure 5.5 Distribution of sampling points.

Table 5.5 Error matrix between of land use and land cover in 2007 and ground reference data in 2009.

LULC in 2007	Reference Data in 2009													
	U	**A1**	**A2**	**A3A4**	**DEF**	**MDF**	**DDF**	**BF**	**FSFP**	**GL**	**SL**	**W1**	**W2**	**M**	**Total**
U	12	0	0	0	0	0	0	0	0	0	0	0	0	0	12
A1	0	6	0	0	0	0	0	0	0	0	1	1	0	0	8
A2	0	0	11	0	0	0	0	0	0	0	1	0	0	0	12
A3A4	0	0	0	9	0	0	0	0	0	0	0	0	1	0	10
DEF	0	0	0	0	12	0	0	0	0	0	0	0	0	0	12
MDF	0	0	0	1	0	12	0	0	0	1	0	0	0	0	14
DDF	0	0	0	0	0	0	12	0	0	0	0	0	0	0	12
BF	0	0	0	0	0	0	0	12	0	0	0	0	0	0	12
FSFP	0	2	0	0	0	0	0	0	12	1	2	0	0	0	17
GL	0	1	0	0	0	0	0	0	0	10	0	0	0	0	11
SL	0	0	0	0	0	0	0	0	0	0	7	0	0	0	7
W1	0	1	0	0	0	0	0	0	0	0	0	9	0	0	10
W2	0	2	0	0	0	0	0	0	0	0	1	1	11	0	15
M	0	0	1	2	0	0	0	0	0	0	0	1	0	12	16
Total	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**168**

5.2 Land use and land cover change

Post-classification comparison change detection algorithm was here applied for LULC change in two periods: 1987 - 2005 and 2005 - 2007. These results will be depicted LULC change before and after the declaration of DPKY - FCWH in 2005.

5.2.1 Land use and land cover change between 1987 and 2005

During this period, miscellaneous land (old clearing, uncultivated land, barren land/bare land) was the most increased with 42.99 sq. km or 1.12% of the study area. Most of those increased area came from paddy field, field crop, mixed deciduous forest, perennial and orchard, and dry dipterocarp forest. At the same time, reservoir, field crop, urban and built-up area, and grassland had also increased having area of 36.26, 19.93, 9.87 and 8.17 sq. km or 0.95, 0.52, 0.26 and 0.21% of the study area, respectively.

For decreased LULC class, dry dipterocarp forest was the most decreased with 45.17 sq. km or 1.18% of the study area. It was changed into field crop, reservoir, miscellaneous land and urban and built-up area. At the same time, natural forest succession and forest plantation, paddy field, perennial and orchard, and natural water body had also decreased having area of 36.57, 20.55, 8.88 and 5.71 sq. km or 0.96, 0.54, 0.23 and 0.15%, respectively. Detail of LULC change between 1987 and 2005 was presented in Table 5.6 and Figure 5.6.

In addition, LULC type in Thap Lan National Park was also extracted for explanation about LULC change (Table 5.7 and Figure 5.7). It was found that natural forest succession and forest plantation was decreased having area of 23.83 sq. km or 1.07% of the national park area. This area was mostly changed into natural forest included mixed deciduous forest (17.90 sq. km), dry dipterocarp forest (0.55 sq. km), and dry evergreen forest (0.18 sq. km). This finding shows successful activity of natural forest succession and forest plantation in the national park. At the same period, reservoir was increased having area of 14.00 sq. km or 0.63% of the national park area. This area came from national forest, national succession forest and plantation covered area of 4.81, 5.49 and 2.93 sq. km, respectively. This result implies about government policy on LULC change.

Table 5.6 Land use and land cover change matrix of Thap Lan National Park and its 5 km buffer in 1987 - 2005.

LULC in 1987	LULC in 2005 (Unit: sq. km)														
	U	**A1**	**A2**	**A3A4**	**DEF**	**MDF**	**DDF**	**BF**	**FSFP**	**GL**	**SL**	**W1**	**W2**	**M**	**Total**
U	55.86	0.27	0.27	0.38	0.00	0.08	0.06	0.00	0.04	0.01	0.02	0.03	0.03	0.69	57.71
A1	1.36	196.25	0.62	0.49	0.00	0.15	0.09	0.00	0.04	0.28	0.02	0.18	6.51	12.49	218.48
A2	3.03	0.63	266.95	0.45	0.00	0.18	0.34	0.00	0.13	5.26	0.03	0.05	1.27	10.92	289.25
A3A4	0.92	0.30	0.59	159.49	0.00	0.13	0.32	0.00	0.12	3.28	0.01	0.01	0.49	4.86	170.51
DEF	0.04	0.00	0.04	0.00	1,760.83	0.32	0.03	0.00	0.20	0.00	0.00	0.00	0.19	0.01	1,761.66
MDF	0.99	0.17	13.74	0.18	0.18	264.86	0.69	0.00	0.61	0.09	0.01	0.03	2.18	10.73	294.47
DDF	2.11	0.10	26.39	0.37	0.06	0.83	348.29	0.01	0.96	0.10	0.01	0.00	12.60	4.17	395.99
BF	0.06	0.00	0.01	0.00	0.00	0.00	0.00	163.69	0.02	0.00	0.00	0.00	0.04	0.03	163.85
FSFP	2.07	0.02	0.44	0.08	0.36	27.98	0.98	0.02	334.81	0.04	0.00	0.00	7.24	0.21	374.25
GL	0.01	0.03	0.01	0.04	0.00	0.04	0.01	0.00	0.72	20.41	0.05	0.00	0.01	0.01	21.34
SL	0.20	0.01	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.03	15.22	0.01	0.03	0.03	15.58
W1	0.18	0.11	0.03	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.02	20.72	5.58	0.10	26.77
W2	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	6.04	0.01	6.12
M	0.71	0.04	0.08	0.11	0.00	0.01	0.02	0.00	0.02	0.02	0.01	0.04	0.20	26.98	28.23
Total	**67.58**	**197.93**	**309.19**	**161.63**	**1,761.44**	**294.60**	**350.83**	**163.72**	**337.68**	**29.52**	**15.42**	**21.06**	**42.39**	**71.23**	**3,824.22**
Area of change (sq. km)	**9.87**	**-20.55**	**19.93**	**-8.88**	**-0.21**	**0.14**	**-45.16**	**-0.13**	**-36.57**	**8.17**	**-0.16**	**-5.71**	**36.26**	**42.99**	
Percentage of study area(%)	**0.26**	**-0.54**	**0.52**	**-0.23**	**-0.01**	**0.00**	**-1.18**	**0.00**	**-0.96**	**0.21**	**0.00**	**-0.15**	**0.95**	**1.12**	
Area per annum (sq. km)	**0.55**	**-1.14**	**1.11**	**-0.49**	**-0.01**	**0.01**	**-2.51**	**-0.01**	**-2.03**	**0.45**	**-0.01**	**-0.32**	**2.01**	**2.39**	

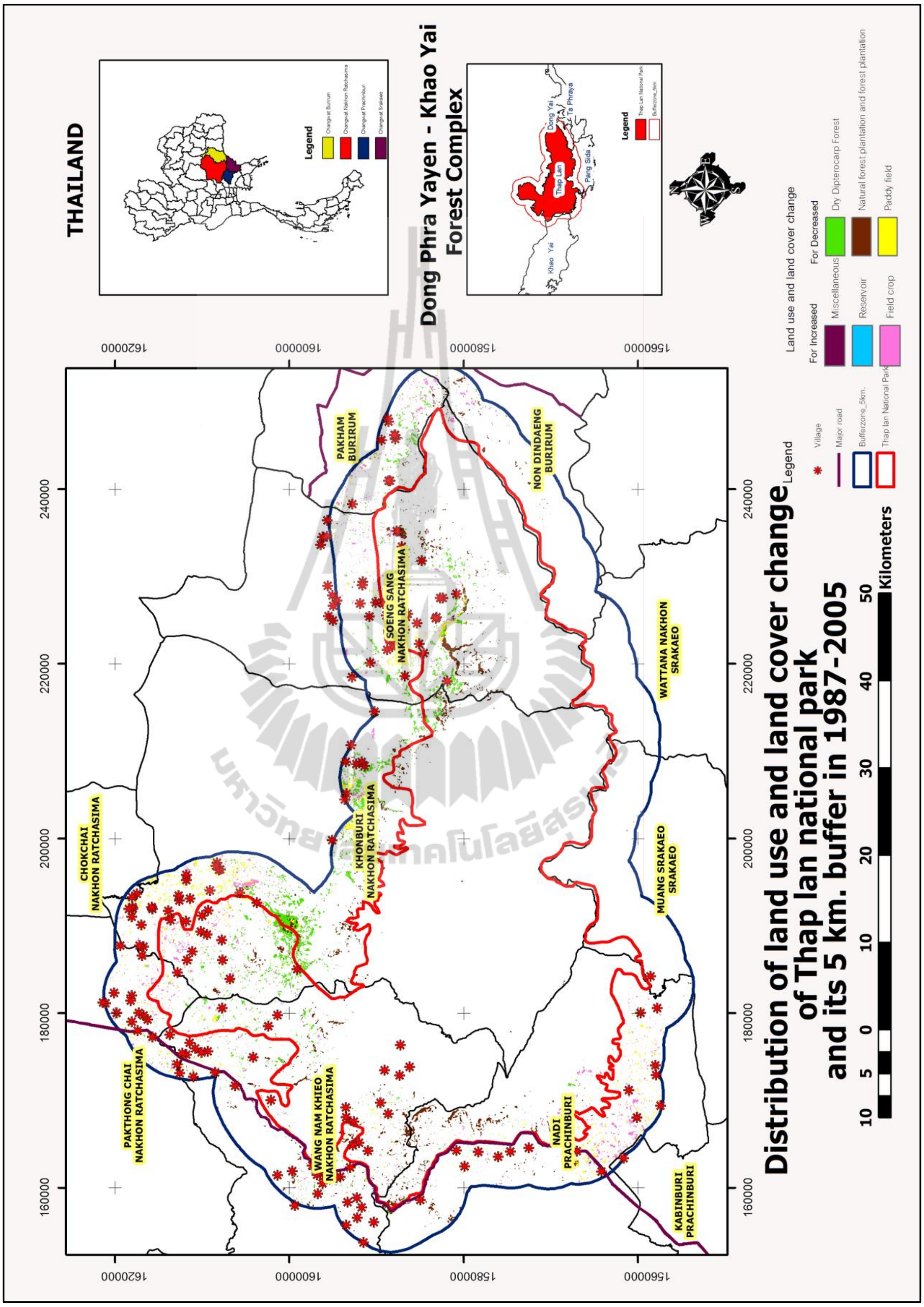


Figure 5.6 Distribution of land use and land cover change of of Thap Lan National Park and its 5 km buffer in 1987 - 2005.

Table 5.7 Land use and land cover change matrix of Thap Lan National Park in 1987 - 2005.

LULC in 1987	**LULC in 2005 (Unit: sq. km)**														
	U	**A1**	**A2**	**A3A4**	**DEF**	**MDF**	**DDF**	**BF**	**FSFP**	**GL**	**SL**	**W1**	**W2**	**M**	**Total**
U	10.82	0.01	0.02	0.06	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.12	11.08
A1	0.04	44.36	0.16	0.14	0.00	0.05	0.03	0.00	0.02	0.08	0.00	0.03	2.05	2.56	49.51
A2	0.46	0.17	87.81	0.17	0.00	0.04	0.15	0.00	0.07	1.65	0.01	0.02	0.69	3.65	94.88
A3A4	0.30	0.07	0.23	75.77	0.00	0.05	0.18	0.00	0.08	1.79	0.00	0.00	0.19	1.13	79.79
DEF	0.00	0.00	0.01	0.00	1,249.81	0.20	0.02	0.00	0.10	0.00	0.00	0.00	0.18	0.01	1,250.34
MDF	0.15	0.04	5.46	0.06	0.10	105.00	0.28	0.00	0.26	0.05	0.00	0.00	1.21	3.39	116.00
DDF	0.24	0.04	13.04	0.22	0.04	0.38	177.27	0.00	0.51	0.06	0.01	0.00	3.42	1.96	197.18
BF	0.04	0.00	0.00	0.00	0.00	0.00	0.00	155.42	0.01	0.00	0.00	0.00	0.00	0.02	155.51
FSFP	0.90	0.01	0.24	0.05	0.18	17.90	0.55	0.02	204.25	0.02	0.00	0.00	5.49	0.07	229.67
GL	0.00	0.01	0.00	0.02	0.00	0.03	0.01	0.00	0.54	14.15	0.02	0.00	0.00	0.00	14.79
SL	0.12	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	3.22	0.00	0.00	0.01	3.38
W1	0.10	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.86	0.69	0.02	5.71
W2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.15	0.00	2.16
M	0.11	0.01	0.03	0.05	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.08	9.24	9.54
Total	**13.26**	**44.74**	**107.03**	**76.53**	**1,250.13**	**123.66**	**178.52**	**155.45**	**205.85**	**17.82**	**3.27**	**4.93**	**16.16**	**22.19**	**2,219.54**
Area of change (sq. km)	**2.19**	**-4.78**	**12.15**	**-3.26**	**-0.20**	**7.66**	**-18.67**	**-0.05**	**-23.83**	**3.03**	**-0.11**	**-0.78**	**14.00**	**12.65**	
Percentage of study area(%)	**0.10**	**-0.22**	**0.55**	**-0.15**	**-0.01**	**0.34**	**-0.84**	**0.00**	**-1.07**	**0.14**	**0.00**	**-0.03**	**0.63**	**0.57**	
Area per annum (sq. km)	**0.12**	**-0.27**	**0.67**	**-0.18**	**-0.01**	**0.43**	**-1.04**	**0.00**	**-1.32**	**0.17**	**-0.01**	**-0.04**	**0.78**	**0.70**	

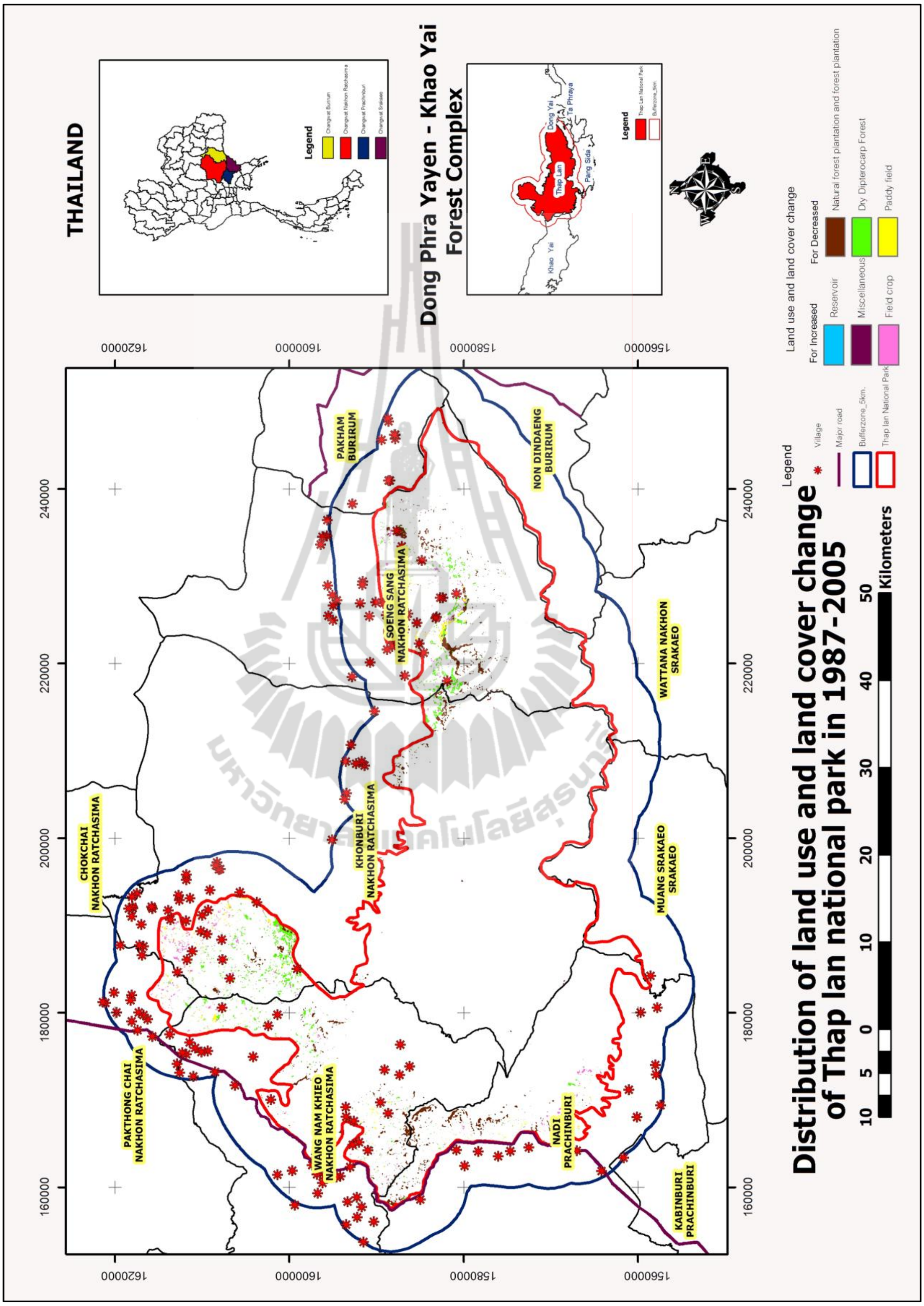


Figure 5.7 Distribution of land use and land cover change of of Thap Lan National Park in 1987 - 2005.

5.2.2 Land use and land cover change between 2005 and 2007

During this period, miscellaneous land (old clearing, uncultivated land, barren land/bare land) was the most increased with 169.03 sq. km or 4.42% of the study area. Most of those increased area came from field crop, perennial and orchard, dry dipterocarp forest, paddy field and mixed deciduous forest. At the same time, reservoir and grassland had also increased having area of 20.93 and 6.41 sq. km or 0.55% and 0.17% of the study area, respectively.

For decreased land use land cover class, field crop was the most decreased with 54.97 sq. km or 1.44% of the study area. It was changed into miscellaneous land, grassland and reservoir. At the same time, perennial and orchard, dry dipterocarp forest, paddy field, and mixed deciduous forest had also decreased having area of 51.42, 39.67, 30.03 and 15.77 sq. km or 1.34, 1.04, 0.79 and 0.41% of the study area, respectively. Detail of LULC change between 1987 and 2005 was presented in Table 5.8 and Figure 5.8.

Furthermore, LULC categories in Thap Lan National Park was also extracted for explanation about LULC change (Table 5.9 and Figure 5.9). It was found that perennial and orchard was decreased having area of 23.88 sq. km or 1.08% of the national park area. This area was mostly changed into miscellaneous land (old clearing, uncultivated land, barren land/bare land) covering area of 21.93 sq. km. This result do not show any affect to natural forest but it shows a temporary change between agricultural land and miscellaneous land (old clearing, uncultivated land, barren land/bare land) in this period (2 years). At the same period, miscellaneous land (old clearing, uncultivated land, barren land/bare land) was increased having area of 68.78 sq. km or 3.10% of the national park area. Most of this area came from agricultural land and natural forest covered area of 48.04 and 19.67 sq. km, respectively. This result implies two important facts. In case of agricultural land, it shows a temporary change between agricultural land and miscellaneous land in this period (2 years). While in case of natural forest, it shows about deforestation activity. In latter case, brightness value of dry dipterocarp forest and miscellaneous land (old clearing, uncultivated land, barren land/bare land) in dry season is, however, quite similar.

Table 5.8 Land use and land cover change matrix of Thap Lan National Park and its 5 km buffer in 2005 - 2007.

LULC in 2005	LULC in 2007 (Unit: sq. km)														
	U	**A1**	**A2**	**A3A4**	**DEF**	**MDF**	**DDF**	**BF**	**FSFP**	**GL**	**SL**	**W1**	**W2**	**M**	**Total**
U	65.27	0.30	0.05	0.08	0.00	0.12	0.14	0.00	0.07	0.01	0.02	0.03	0.04	1.46	67.59
A1	0.26	166.19	0.32	0.37	0.00	0.09	0.08	0.00	0.12	2.11	0.03	0.12	5.26	22.99	197.93
A2	0.35	0.46	245.14	0.86	0.02	0.29	0.53	0.00	0.40	2.90	0.05	0.03	1.62	56.54	309.19
A3A4	0.55	0.46	1.09	107.97	0.00	0.18	0.36	0.00	0.41	2.06	0.10	0.07	2.08	46.30	161.63
DEF	0.00	0.00	0.06	0.00	1,760.88	0.04	0.01	0.00	0.02	0.00	0.00	0.00	0.40	0.04	1,761.44
MDF	0.19	0.08	2.48	0.15	0.06	277.57	0.22	0.00	0.33	0.11	0.01	0.01	1.74	11.66	294.60
DDF	0.20	0.06	4.45	0.30	0.04	0.24	309.36	0.00	0.66	0.25	0.01	0.00	7.27	27.98	350.83
BF	0.00	0.00	0.01	0.00	0.01	0.00	0.00	163.05	0.04	0.00	0.00	0.00	0.04	0.57	163.72
FSFP	0.22	0.04	0.36	0.08	0.02	0.15	0.28	0.00	332.45	0.03	0.00	0.00	2.22	1.83	337.68
GL	0.16	0.05	0.10	0.23	0.00	0.03	0.07	0.00	0.03	28.37	0.01	0.00	0.01	0.45	29.52
SL	0.06	0.01	0.03	0.06	0.00	0.01	0.00	0.00	0.00	0.01	14.69	0.01	0.11	0.44	15.42
W1	0.06	0.06	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.01	0.01	20.13	0.16	0.59	21.06
W2	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.01	0.01	42.15	0.15	42.39
M	0.80	0.19	0.12	0.07	0.00	0.11	0.08	0.00	0.20	0.06	0.05	0.05	0.23	69.26	71.23
Total	**68.12**	**167.90**	**254.22**	**110.21**	**1,761.03**	**278.83**	**311.16**	**163.06**	**334.74**	**35.93**	**14.98**	**20.46**	**63.31**	**240.26**	**3,824.21**
Area of change (sq. km)	**0.54**	**-30.03**	**-54.97**	**-51.42**	**-0.41**	**-15.77**	**-39.67**	**-0.66**	**-2.94**	**6.41**	**-0.43**	**-0.60**	**20.93**	**169.03**	
Percentage of study area(%)	**0.01**	**-0.79**	**-1.44**	**-1.34**	**-0.01**	**-0.41**	**-1.04**	**-0.02**	**-0.08**	**0.17**	**-0.01**	**-0.02**	**0.55**	**4.42**	
Area per annum (sq. km)	**0.27**	**-15.02**	**-27.48**	**-25.71**	**-0.21**	**-7.88**	**-19.84**	**-0.33**	**-1.47**	**3.21**	**-0.22**	**-0.30**	**10.46**	**84.52**	

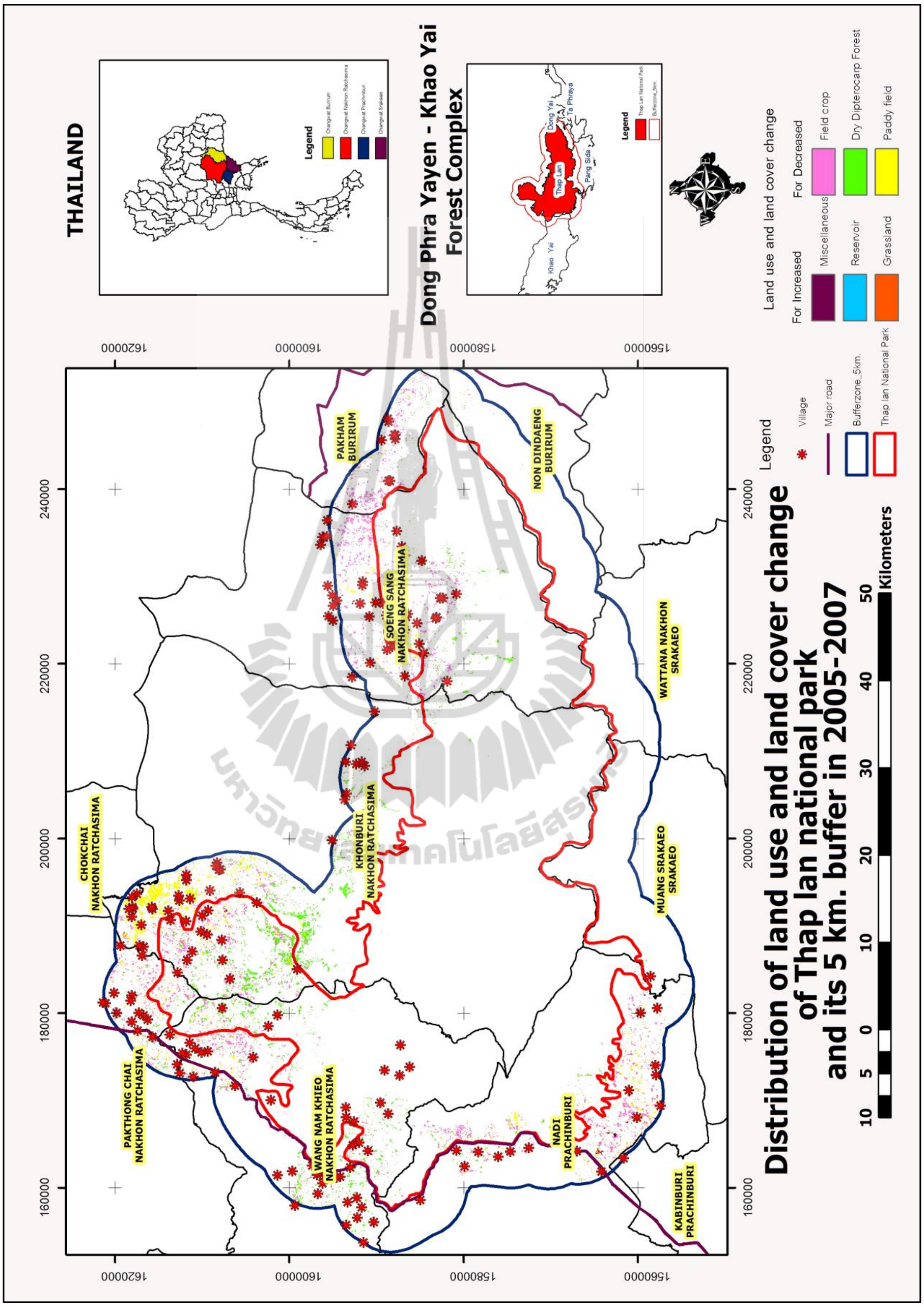


Figure 5.8 Distribution of land use and land cover change of of Thap Lan National Park and its 5 km buffer in 2005 - 2007.

Table 5.9 Land use and land cover change matrix of Thap Lan National Park in 2005 - 2007.

LULC in 2005	**LULC in 2007 (Unit: sq. km)**														
	U	**A1**	**A2**	**A3A4**	**DEF**	**MDF**	**DDF**	**BF**	**FSFP**	**GL**	**SL**	**W1**	**W2**	**M**	**Total**
U	12.84	0.00	0.02	0.04	0.00	0.01	0.06	0.00	0.03	0.00	0.00	0.00	0.00	0.26	13.26
A1	0.01	37.00	0.11	0.14	0.00	0.03	0.04	0.00	0.04	0.73	0.00	0.03	1.34	5.28	44.74
A2	0.09	0.11	82.83	0.39	0.01	0.10	0.26	0.00	0.20	1.51	0.02	0.01	0.66	20.83	107.03
A3A4	0.12	0.16	0.51	51.60	0.00	0.07	0.20	0.00	0.23	1.01	0.04	0.04	0.62	21.93	76.53
DEF	0.00	0.00	0.03	0.00	1,249.66	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.37	0.02	1,250.13
MDF	0.03	0.03	0.90	0.05	0.04	116.71	0.10	0.00	0.15	0.05	0.00	0.00	0.84	4.75	123.66
DDF	0.10	0.02	2.62	0.18	0.03	0.11	157.83	0.00	0.33	0.13	0.00	0.00	2.58	14.57	178.52
BF	0.00	0.00	0.00	0.00	0.01	0.00	0.00	155.07	0.02	0.00	0.00	0.00	0.02	0.33	155.45
FSFP	0.15	0.01	0.20	0.06	0.01	0.07	0.13	0.00	203.40	0.02	0.00	0.00	1.00	0.81	205.84
GL	0.00	0.01	0.03	0.13	0.00	0.01	0.05	0.00	0.01	17.41	0.00	0.00	0.00	0.15	17.82
SL	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.01	3.09	0.00	0.01	0.13	3.27
W1	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.71	0.03	0.15	4.93
W2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	16.08	0.05	16.16
M	0.12	0.03	0.04	0.02	0.00	0.03	0.04	0.00	0.08	0.02	0.01	0.01	0.07	21.73	22.19
Total	**13.46**	**37.39**	**87.32**	**52.65**	**1,249.76**	**117.19**	**158.71**	**155.08**	**204.52**	**20.89**	**3.18**	**4.80**	**23.63**	**90.98**	**2,219.54**
Area of change (sq. km)	**0.19**	**-7.35**	**-19.71**	**-23.88**	**-0.37**	**-6.47**	**-19.81**	**-0.38**	**-1.33**	**3.07**	**-0.10**	**-0.13**	**7.47**	**68.78**	
Percentage of study area(%)	**0.01**	**-0.33**	**-0.89**	**-1.08**	**-0.02**	**-0.29**	**-0.89**	**-0.02**	**-0.06**	**0.14**	**0.00**	**-0.01**	**0.34**	**3.10**	
Area per annum (sq. km)	**0.10**	**-3.67**	**-9.85**	**-11.94**	**-0.19**	**-3.24**	**-9.90**	**-0.19**	**-0.66**	**1.54**	**-0.05**	**-0.07**	**3.73**	**34.39**	

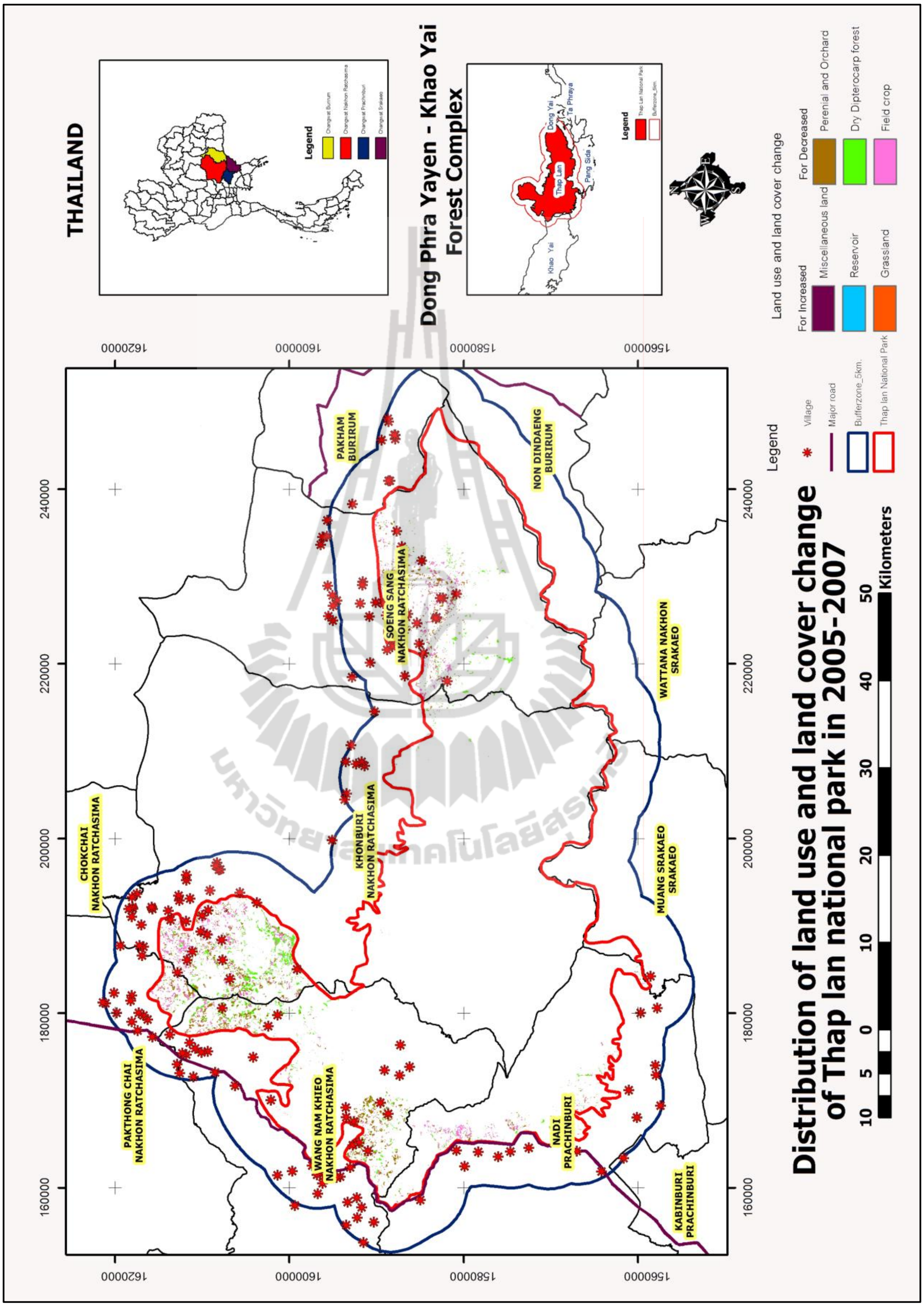


Figure 5.9 Distribution of land use and land cover change of of Thap Lan National Park in 2005 - 2007.

CHAPTER VI

CURRENT STATUS AND CHANGE ASSESSMENT OF FOREST RESOURCES AND LAND USE LANDSCAPE

The content of this chapter will present the results of the third objective focusing on assessment current status and changing of forest resources and LULC by landscape metrics in the study area.

6.1 Landscape composition

Fourteen LULC types in 1987, 2005 and 2007 were firstly reclassified into 7 landscape types included forest, natural forest succession and forest plantation, urban and built-up, agriculture, grassland, water body and miscellaneous landscape. Then, landscape composition and its change were extracted under GIS environment.

6.1.1 Landscape composition in 1987

In 1987, forest landscape was the most dominant in the study area, it covered an area of 2,615.97 sq. km or 68.41% of the study area (Table 6.1, Figure 6.1). Agriculture landscape was the next most abundant landscape type covering an area of 678.24 sq. km or 17.74% of the study area. Natural forest succession and forest plantation landscape was also abundant covering an area of 374.25 sq. km or 9.79% of the study area.

Table 6.1 Area and percentage of landscape types in 1987.

Landscape type in 1987	Area in sq. km	Percentage
Forest	2,615.97	68.41
Natural forest succession and forest plantation	374.25	9.79
Grassland	21.34	0.56
Agriculture	678.24	17.74
Urban and built-up	57.71	1.51
Water body	32.90	0.86
Miscellaneous	43.81	1.15
Total	**3,824.22**	**100.00**

6.1.2 Landscape composition in 2005

In 2005 forest landscape was still the most dominant in the study area and it covered an area of 2,570.59 sq. km or 67.22% of the study area (Table 6.2, Figure 6.2). Agriculture landscape was the next most abundant landscape type covering an area of 668.75 sq. km or 17.49% of the study area. Natural forest succession and forest plantation landscape was also abundant covering an area of 337.69 sq. km or 8.83% of the study area.

Table 6.2 Area and percentage of landscape type in 2005.

Landscape type in 2005	Area in sq. km	Percentage
Forest	2,570.59	67.22
Natural forest succession and forest plantation	337.69	8.83
Grassland	29.52	0.77
Agriculture	668.75	17.49
Urban and built-up	67.59	1.77
Water body	63.45	1.66
Miscellaneous	86.64	2.27
Total	**3,824.22**	**100.00**

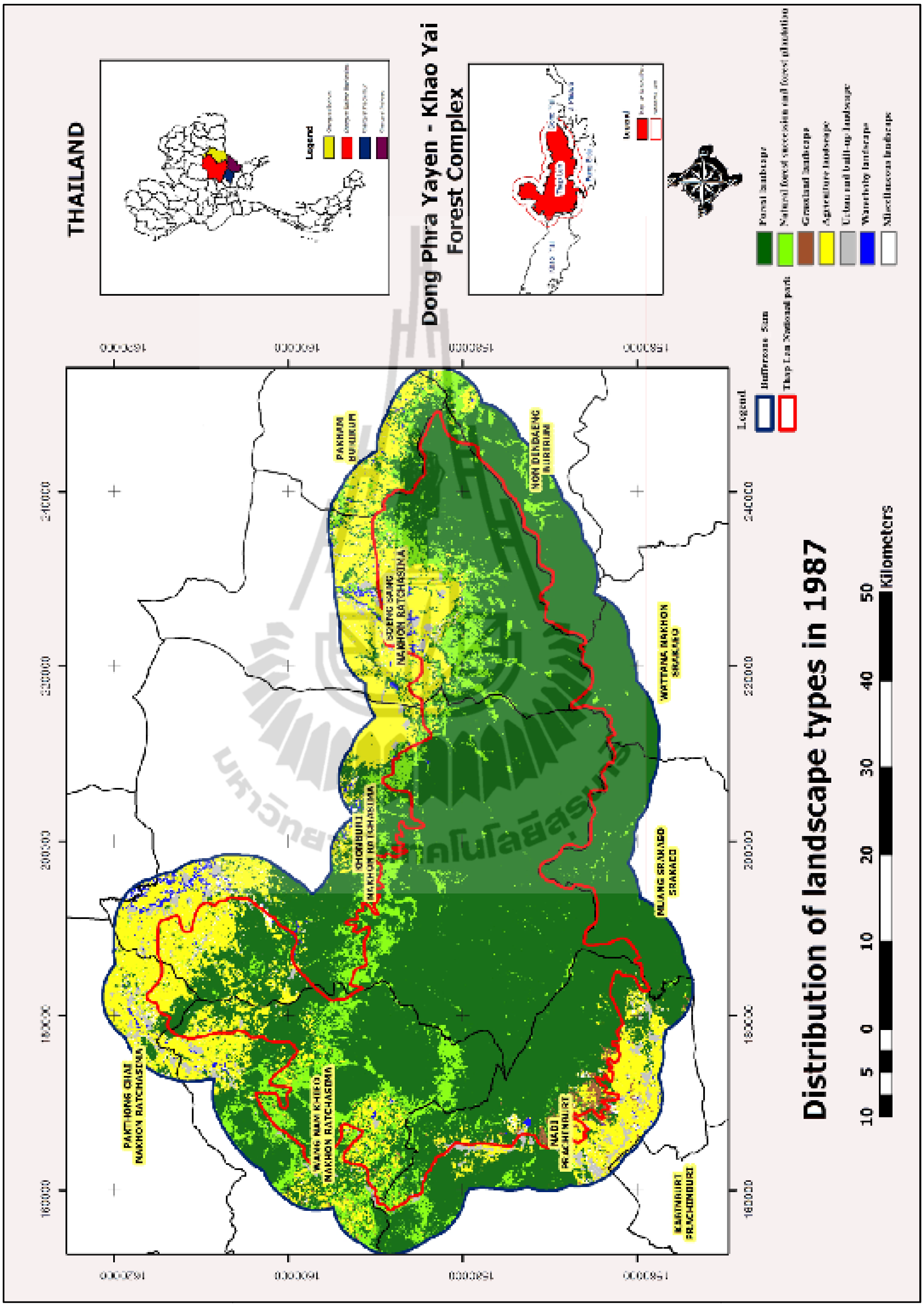


Figure 6.1 Distribution of landscape types in 1987.

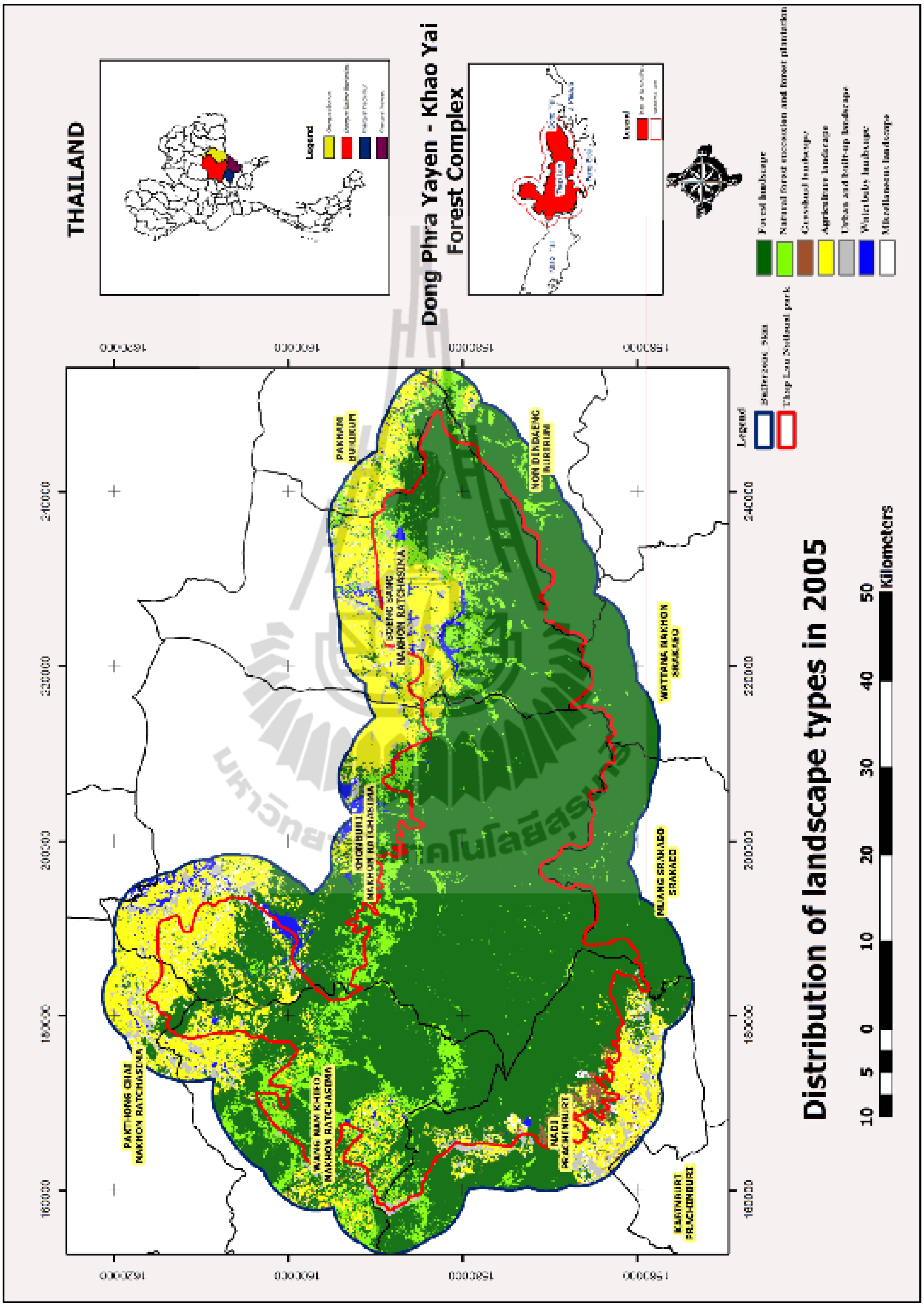


Figure 6.2 Distribution of landscape types in 2005.

6.1.3 Landscape composition in 2007

In 2007, forest landscape was still the most abundant in the study area and it covered an area of 2,514.08 sq. km or 65.74% of the study area (Table 6.3 and Figure 6.3). Agriculture landscape was the next most abundant landscape type covering an area of 532.33 sq. km or 13.92% of the study area. Natural forest succession and forest plantation landscape was also abundant covering an area of 334.74 sq. km or 8.75% of the study area.

Table 6.3 Area and percentage of landscape type in 2007.

Landscape type in 2007	**Area in sq. km**	**Percentage**
Forest	2,514.08	65.74
Natural forest succession and forest plantation	334.74	8.75
Grassland	35.93	0.94
Agriculture	532.33	13.92
Urban and built-up	68.12	1.78
Water body	83.78	2.19
Miscellaneous	255.24	6.67
Total	**3,824.22**	**100.00**

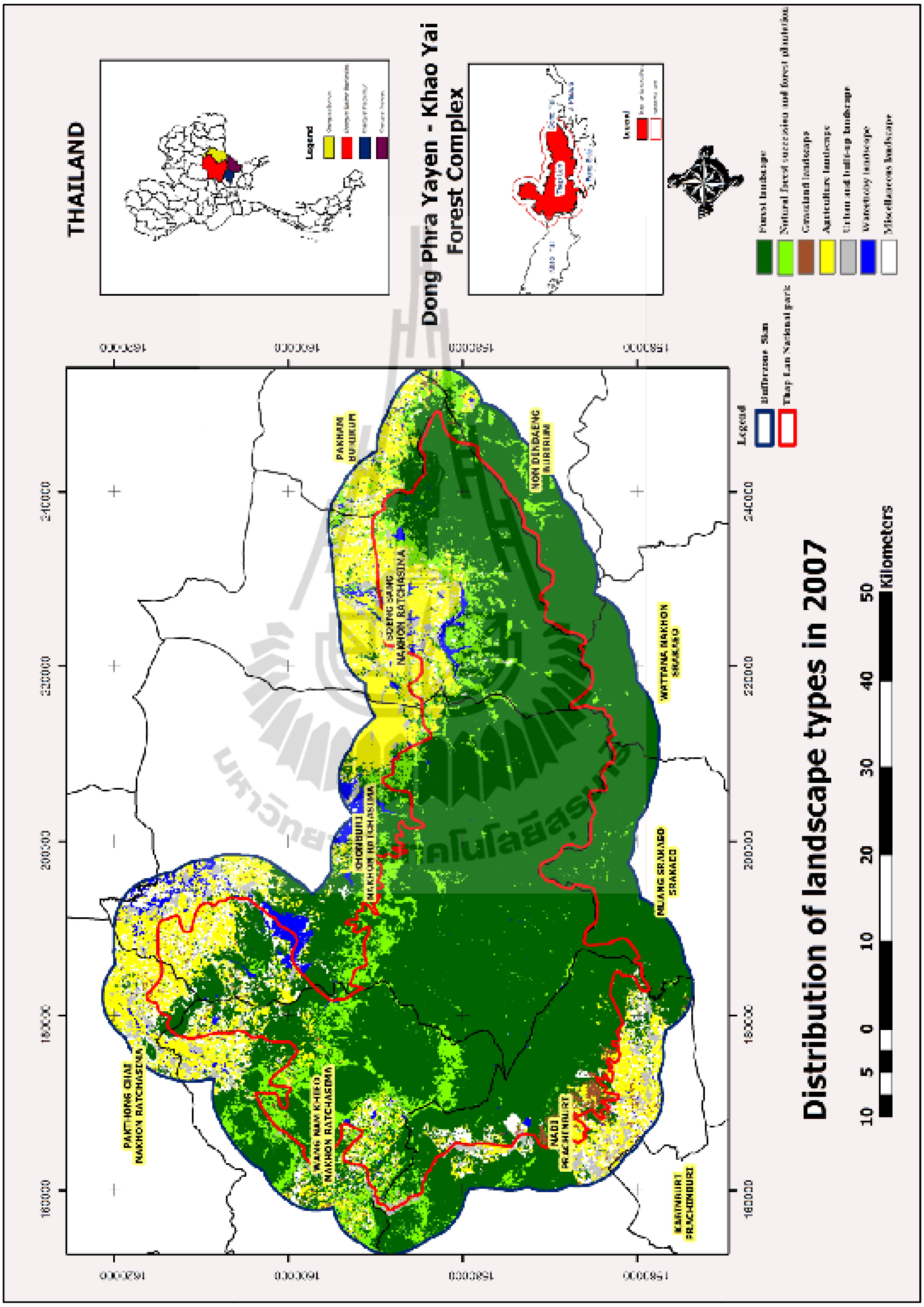


Figure 6.3 Distribution of landscape types in 2007.

6.2 Change of landscape composition

Basically, post-classification comparison change detection was here applied for landscape types change before and after the declaration of DPKY - FCWH in 2005.

6.2.1 Landscape types change between 1987 and 2005

Areas of man-made landscape types included miscellaneous (old clearing, uncultivated land, barren land/bare land), water body, urban and built-up area, and grassland landscape types were increased before the declaration of DPKY - FCWH in 2005 (1987 - 2005) (Table 6.4). The major change of landscape types were miscellaneous (old clearing, uncultivated land, barren land/bare land) and water body having area of 42.83 and 30.55 sq. km or 1.12 and 0.80% of the study area, respectively. Their annual increase areas were 2.38 and 0.80 sq. km, respectively. Most of the increased miscellaneous (old clearing, uncultivated land, barren land/bare land) area came from agriculture, forest landscapes while most of increased water body area came from agriculture, forest and natural forest succession and forest plantation landscape types.

In contrast, forest and natural forest succession and forest plantation landscape types had the most significant decrease in this period. Their annual decrease rates were 2.52 and 2.03 sq. km. At the same time, agriculture (paddy field, field crop and perennial and orchard) landscape types was decreased with an annual rate of 0.53 sq. km. Landscape type change in term of loss and gain between 1987 and 2005 was displayed in Figure 6.4.

Table 6.4 Change matrix of landscape types during 1987 - 2005.

Landscape type in 1987	Landscape types in 2005 (Unit: sq. km)							
	FLT	NLT	GLT	ALT	ULT	WLT	MLT	Total
FLT	2,539.79	1.80	0.19	40.99	3.20	15.04	14.96	2,615.96
NLT	29.34	334.81	0.04	0.54	2.07	7.25	0.21	374.25
GLT	0.06	0.72	20.41	0.08	0.01	0.01	0.06	21.34
ALT	1.23	0.29	8.82	625.77	5.31	8.49	28.34	678.24
ULT	0.13	0.04	0.01	0.92	55.86	0.05	0.70	57.71
WLT	0.01	0.01	0.00	0.17	0.22	32.34	0.14	32.90
MLT	0.04	0.02	0.05	0.28	0.91	0.28	42.23	43.81
Total	**2,570.59**	**337.68**	**29.52**	**668.75**	**67.58**	**63.45**	**86.64**	**3,824.22**
Area of change(sq. km)	**-45.37**	**-36.57**	**8.17**	**-9.49**	**9.87**	**30.55**	**42.83**	
Percentage of study area (%)	**-1.19**	**-0.96**	**0.21**	**-0.25**	**0.26**	**0.80**	**1.12**	
Area per annum (sq. km)	**-2.52**	**-2.03**	**0.45**	**-0.53**	**0.55**	**1.70**	**2.38**	

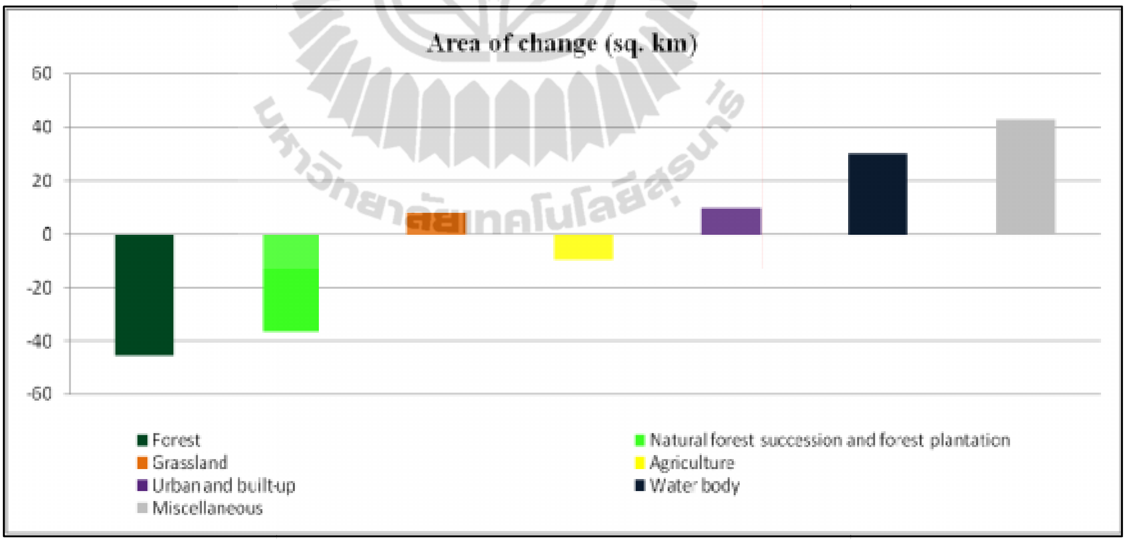


Figure 6.4 Distribution of forest and natural forest succession and plantation landscape types change between 1987 and 2005.

6.2.2 Landscape types change between 2005 and 2007

Landscape types change after the declaration of DPKY - FCWH in 2005 (2005 - 2007) had the same pattern as landscape types change between 1987 and 2005. Man-made landscape types including miscellaneous, water body, urban and built-up, and grassland landscape types were increased in this period (Table 6.5). The major change of landscape types was miscellaneous landscape type having an area of 168.60 sq. km or 4.41% of the study area. Its annual increase area was 84.30 sq. km. Most of the increased miscellaneous (old clearing, uncultivated land, barren land/bare land and shrub land) landscape type came from agriculture and forest landscape types.

In contrast, agriculture (paddy field, field crop and perennial and orchard) landscape type had the most significant decrease in this period. Its annual decrease rate was 68.21 sq. km. At the same time, forest landscape type was decreased with annual rate of 28.25 sq. km. Landscape type change in term of loss and gain between 2005 and 2007 was displayed in Figure 6.5.

Table 6.5 Change matrix of landscape types during 2005 - 2007.

Landscape type in 2005	Landscape type in 2007 (Unit: sq.km)							
	FLT	**NLT**	**GLT**	**ALT**	**ULT**	**WLT**	**MLT**	**Total**
FLT	2,511.48	1.04	0.36	7.59	0.39	9.46	40.27	2,570.59
NLT	0.45	332.45	0.03	0.48	0.22	2.22	1.83	337.68
GLT	0.10	0.03	8.37	0.38	0.16	0.01	0.46	29.52
ALT	1.56	0.93	7.07	522.84	1.16	9.18	126.01	668.75
ULT	0.26	0.07	0.01	0.43	65.27	0.07	1.47	67.59
WLT	0.03	0.03	0.01	0.12	0.06	62.45	0.76	63.45
MLT	0.20	0.20	0.07	0.49	0.86	0.39	84.44	86.64
Total	**2,514.08**	**334.74**	**35.93**	**532.33**	**68.12**	**83.78**	**255.24**	**3,824.21**
Area of change(sq. km)	**56.51**	**-2.94**	**6.41**	**-136.42**	**0.54**	**20.33**	**168.60**	
Percentage of study area (%)	**-1.48**	**-0.08**	**0.17**	**-3.57**	**0.01**	**0.53**	**4.41**	
Area per annum (sq. km)	**-28.25**	**-1.47**	**3.21**	**-68.21**	**0.27**	**10.16**	**84.30**	

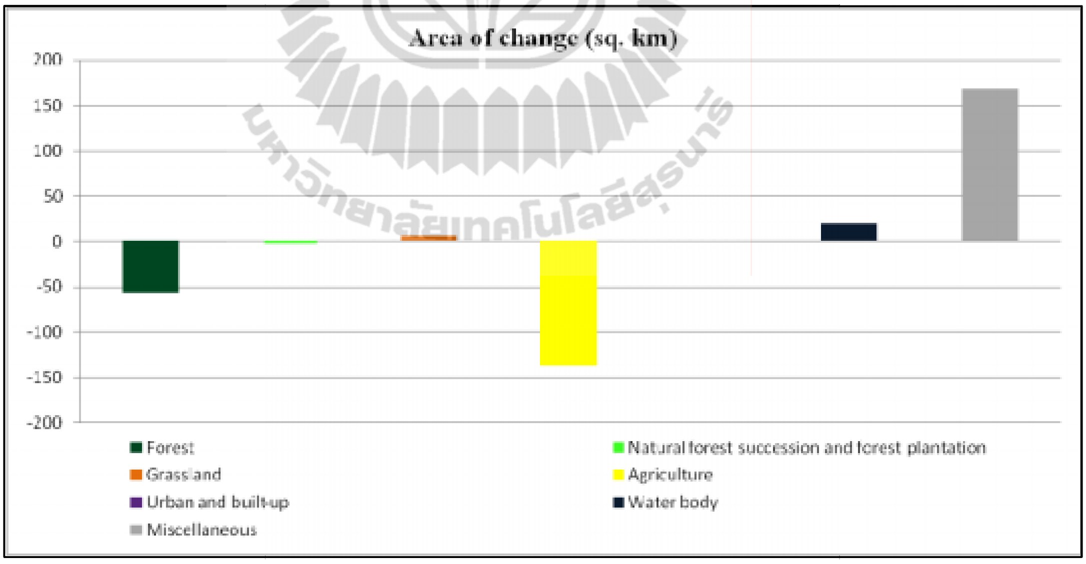


Figure 6.5 Distribution of forest and natural forest succession and plantation landscape types change between 2005 and 2007.

6.3 Assessment of forest resources landscape and its change

Under this section, status and change of forest resources and land use land landscape type at landscape and class levels are here described based on various landscape metrics measurement.

6.3.1 Landscape status in Thap Lan National Park and its 5 km buffer

At landscape level, dominance (D), contagion (C) and fractal dimension (F), in general, are calculated to describe the whole landscape status. In this study, dominance, contagion and fractal dimension were apparently changed during 1987 - 2007 (Table 6.6). The characteristic of each landscape metric or index can be here separately summarized as follows:

Dominance (D). Basically, dominance is used to measure diversity of landscape, or extent to which a few land cover type dominance in the landscape. The value of this index ranges from 0 to 1. In this study, dominance decreased from 0.497 in 1987 to 0.461 in 2005 and to 0.412 in 2007. Their changes reflect continuously declination of landscape diversity in Thap Lan National Park and its buffer due to many land use types.

Contagion (C). In general, contagion index is a measure of the extent to landscape type are aggregated or clumped. The contagion index ranges from 0 to 1. In this study, contagion decreased from 0.697 in 1987 to 0.673 in 2005 and to 0.645 in 2007. Their changes reflect that landscape has more dissected.

Fractal dimension (F). Basically, fractal dimension index is a measure of the complexity in landscape, fractal dimension calculated from perimeter/area had been use widely in landscape ecology to describe patch complexity. The Fractal Dimension has the range from 1 to 2. In this study, fractal dimension decreased from

1.279 in 1987 to 1.278 in 2005 and to 1.254 in 2007. Their changes imply that landscape came to simple patch.

Table 6.6 Landscape status in Thap Lan National Park and its 5 km buffer.

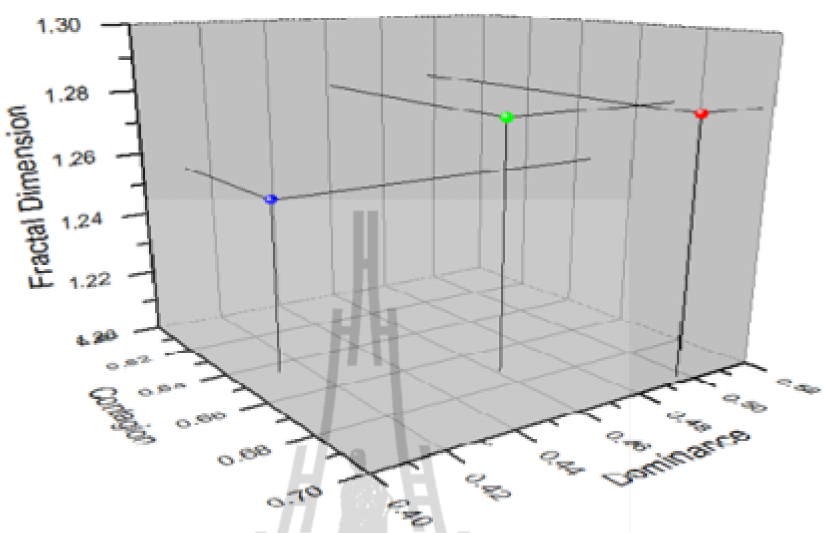
Year	Dominance (D)	Contagion (C)	Fractal dimension (F)
1987	0.497	0.697	1.279
2005	0.461	0.673	1.277
2007	0.412	0.645	1.254

6.3.2 Landscape changes in Thap Lan National Park and its 5 km buffer

Landscape change in Thap Lan National Park and its 5 km buffer before and after the declaration of DPKY - FCWH in 2005 is here described by calculation of three-dimensional Euclidean distances (Eq. 4.3) that defines the distance between landscapes in pattern space. It was found that landscape change was 0.044 during 1987 - 2005 while it was 0.060 during 2005 - 2007 (Table 6.7). These results imply that the change of landscape in Thap Lan National Park and its 5 km buffer after the declaration of DPKY - FCWH in 2005 increase. The relative position in three dimensional pattern space of landscape change in two periods with dominance, contagion and fractal dimension values was presented in Figure 6.6.

Table 6.7 Change of landscape in Thap Lan National Park and its 5 km buffer.

Period	Landscape metrics			Change
	Dominance	Contagion	Fractal dimension	
1987 - 2005	0.001316	0.000604	0.000003	0.044
2005 - 2007	0.002358	0.000749	0.000552	0.060
1987 - 2007	0.007199	0.002699	0.000635	0.103



Red dot represents landscape status in 1987.
Green dot represents landscape status in 2005.
Blue dot represents landscape status in 2007.

Figure 6.6 Three dimensional landscape metric feature space and their changes of the Thap Lan National Park and its 5 km buffer.

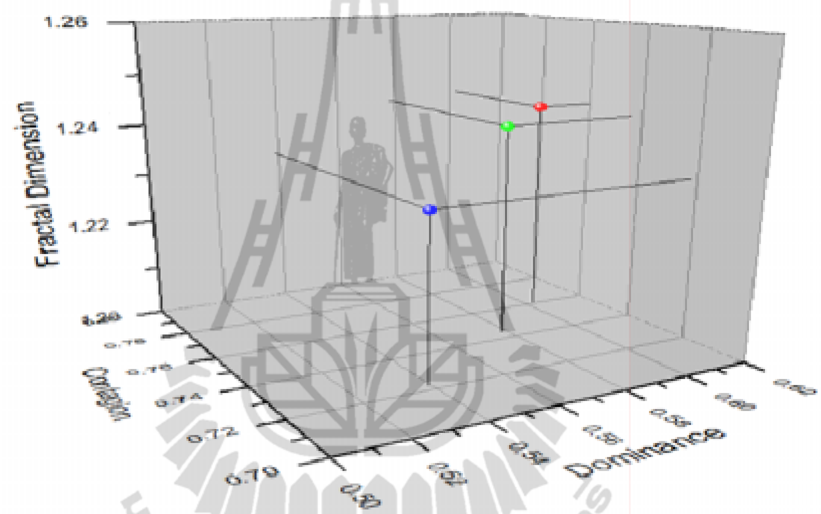
In addition, landscape status and its change in Thap Lan National Park was also extracted as shown in Table 6.8, Table 6.9 and Figure 6.7. It was found that pattern of landscape status and its change in Thap Lan National Park had the same pattern of Thap Lan National Park and its 5 km buffer.

Table 6.8 Landscape status in Thap Lan National Park.

Year	Dominance (D)	Contagion (C)	Fractal dimension (F)
1987	0.602	0.760	1.243
2005	0.578	0.744	1.242
2007	0.539	0.722	1.232

Table 6.9 Change of landscape in Thap Lan National Park.

Period	Landscape metrics			Change
	Dominance	Contagion	Fractal dimension	
1987 - 2005	0.000583	0.000263	0.000001	0.029
2005 - 2007	0.001521	0.000491	0.000094	0.046
1987 - 2007	0.003989	0.001472	0.000117	0.075



Red dot represents landscape status in 1987.
Green dot represents landscape status in 2005.
Blue dot represents landscape status in 2007.

Figure 6.7 Three dimensional landscape metric feature space and their changes of the Thap Lan National Park.

6.3.3 Status and change of landscape types in Thap Lan National Park and its 5 km buffer

At class level, landscape metrics included Class area metrics (CA), Number of patches metrics (NP), Patch Density (PD), Mean patch area (AREA_MN), Area-weighted fractal dimension (FRAC_AM), Mean Euclidean nearest-neighbor distance (ENN_MN), Interspersion and juxtaposition index (IJI) were calculated in each landscape type (class) in Thap Lan National Park and its 5 km buffer (Table 6.10). The characteristic of each index can be here separately described.

Class area (CA). By definition, class area equals the sum of area of all patches of the corresponding patch type. In this study, forest, natural forest succession and forest plantation and agriculture landscape types had been continuously decreased in two periods (1987 - 2005 and 2005 - 2007). At the same time, urban and built-up, grassland, water body and miscellaneous landscape types had been continuously increased (Figure 6.8). This result implies that interchange occurs among the landscape type in two periods.

Number of patches (NP). By definition, number of patches equals the number of patch in the land cover type or landscape under investigation. During 1987 - 2005 number of patches for all landscape types was increased. This infers that fragmentation occurs in all landscape types in this period. In contrast, number of patch for forest, natural forest succession and forest plantation, agriculture, water body and miscellaneous landscape types were decreased during 2005 - 2007. This infers that more aggregation occurs in these landscape types. At the same time, number of patch for urban and built-up and grassland landscape types were clearly increased. This infers that fragmentation occurs in these landscape types (Figure 6.9).

Patch Density (PD). By definition, patch density (PD) equals the number of patches per unit area. Pattern of status and change for landscape type based on patch density is the same with number of patch. During 1987 - 2005 patch density for all landscape types was increased. This infers that fragmentation occurs in all landscape types in this period. In contrast, patch density for forest, natural forest succession and forest plantation, water body and miscellaneous landscape types were decreased during 2005 - 2007. This infers that more aggregation occurs in these landscape types. At the same time, patch density for urban and built-up, agriculture and grassland landscape types were clearly increased. This infers that fragmentation occurs in these landscape types (Figure 6.10).

Mean patch area (AREA_MN). By definition, mean patch area equals the sum of the areas of all patches of the corresponding patch type (or all patches in the landscape), divided by the number of patches of the same type (or total number of patches). Pattern of status and change for landscape type based on mean patch area is similar with number of patch and patch density. During 1987 - 2005 mean patch area for forest, natural forest succession and forest plantation, agriculture and grassland landscape types was decreased. This infers that fragmentation occurs in these landscape types in this period. At the same time, mean patch area for urban and built-up, water body and miscellaneous landscape types was increased. This infers that less fragmentation occurs in these landscape types in this period. In contrary, during 2005 - 2007, mean patch area for forest, natural forest succession and forest plantation, water body and miscellaneous landscape types were increased. This infers that more aggregation occurs in these landscape types. At the same time, mean patch area for urban and built-up, agriculture and grassland landscape types were clearly decreased. This infers that fragmentation occurs in these landscape types (Figure 6.11).

Area-weighted fractal dimension (FRAC_AM). By definition, area-weighted fractal dimension equals the average patch fractal dimension of patches of the corresponding patch type, weight by patch area so that larger patches weight more than smaller patch. During 1987 - 2005 area-weighted fractal dimension for forest, natural forest succession and forest plantation, urban and built-up and grassland landscape types was decreased. This infers that fragmentation occurs in these landscape types in this period. At the same time, area-weighted fractal dimension for agriculture, water body and miscellaneous landscape types were increased. This infers that less modification occurs in these landscape types in this period. In contrary, during 2005 - 2007, area-weighted fractal dimension for forest, natural forest succession and forest plantation, agriculture and grassland landscape types were decreased. This infers that more modification occurs in these landscape types. At the same time, area-weighted fractal dimension for urban and built-up, water body and miscellaneous landscape types were clearly increased. This infers that less modification occurs in these landscape types (Figure 6.12).

Mean Euclidean nearest-neighbor distance (ENN_MN). By definition, mean Euclidean nearest-neighbor distance equals the sum of the distance to the nearest-neighboring patch of the same type, base on shortest edge-to-edge distance, for each patch of the corresponding patch type, divided by the number of patches of the same type. During 1987 - 2005 mean Euclidean nearest-neighbor distance for forest, urban and built-up, agriculture, grassland, water body and miscellaneous landscape types were decreased. This infers that more new patches occur in these landscape types in this period. At the same time, mean Euclidean nearest-neighbor distance for natural forest succession and forest plantation landscape type was increased. This infers that few patches occur in this landscape type. In contrast, during 2005 - 2007 mean Euclidean nearest-neighbor distance for forest, natural forest succession and forest plantation, urban and built-up, agriculture and water body landscape types were increased This infers that few patches occur in this landscape type in this period. At the same time, mean Euclidean nearest-neighbor distance for grassland and miscellaneous landscape types was decreased. This infers that more new patches occur in these landscape types. For natural forest succession and forest plantation, mean Euclidean nearest-neighbor distance in two periods was rather the same (Figure 6.13).

Interspersion and juxtaposition index (IJI). By definition, interspersion and Juxtaposition Index equals minus the sum, of each unique edge type divided by the total landscape edge, multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch type times the number of patch type minus 1 divided by 2. In two periods (1987 - 2005 and 2005 - 2007), interspersion and juxtaposition index (IJI) for forest, natural forest and forest plantation, urban and built-up, water body, and miscellaneous landscape types were continuously increased. This implies that new patches of these landscape types continuously occur in two periods. However, interspersion and juxtaposition index (IJI) for agriculture landscape type was increased during 1987 - 2005 while its value was decreased during 2005 - 2007. This means that new patches of agriculture landscape type occur during 1987 - 2005 while no new patches of agriculture landscape type occur during 2005 - 2007. In addition, interspersion and juxtaposition index (IJI) for grassland landscape type was decreased during 1987 - 2005 while its value was increased during 2005 - 2007. This means that no new patches of grassland landscape type occur during 1987 - 2005 while new patches of grassland landscape type occur during 2005 - 2007 (Figure 6.14).

Table 6.10 Landscape metric at class level of each date in Thap Lan National Park and its 5 km buffer.

Date	Landscape type	CA	NP	PD	AREA_MN	FRAC_AM	ENN_MN	IJI
	FLT	261,596.63	4,097.00	0.59	63.85	1.30	120.34	55.87
	NLT	37,425.25	6,570.00	0.95	5.70	1.21	155.88	35.84
	GLT	2,134.31	875.00	0.13	2.44	1.13	352.55	66.27
1987	**ALT**	67,824.00	2,574.00	0.37	26.35	1.29	133.93	83.16
	ULT	5,771.44	156.00	0.02	37.00	1.11	686.69	66.05
	WLT	3,289.69	1,544.00	0.22	2.13	1.12	250.62	63.33
	MLT	4,380.88	4,241.00	0.61	1.03	1.10	163.01	66.61
Date	**Landscape type**	**CA**	**NP**	**PD**	**AREA_MN**	**FRAC_AM**	**ENN_MN**	**IJI**
	FLT	257,059.31	5,473.00	0.79	46.97	1.30	106.48	66.07
	NLT	33,768.50	6,571.00	0.95	5.14	1.20	156.41	44.71
	GLT	2,951.50	1,639.00	0.24	1.80	1.12	250.22	65.64
2005	**ALT**	66,875.25	3,749.00	0.54	17.84	1.30	109.40	84.79
	ULT	6,758.50	180.00	0.03	37.55	1.11	583.91	74.42
	WLT	6,344.94	1,731.00	0.25	3.67	1.15	243.13	75.40
	MLT	8,664.19	6,593.00	0.95	1.31	1.12	134.13	67.64
Date	**Landscape type**	**CA**	**NP**	**PD**	**AREA_MN**	**FRAC_AM**	**ENN_MN**	**IJI**
	FLT	251,408.13	4,313.00	0.54	58.29	1.28	122.09	70.43
	NLT	33,474.25	6,270.00	0.03	5.34	1.20	160.62	51.73
	GLT	3,592.50	2,353.00	0.62	1.53	1.11	220.66	72.99
2007	**ALT**	53,232.81	3,721.00	0.91	14.31	1.26	120.92	80.04
	ULT	6,812.19	191.00	0.34	35.67	1.11	594.48	76.61
	WLT	8,378.25	1,558.00	0.23	5.38	1.15	307.82	77.15
	MLT	25,524.06	5,794.00	0.84	4.41	1.14	129.18	77.01

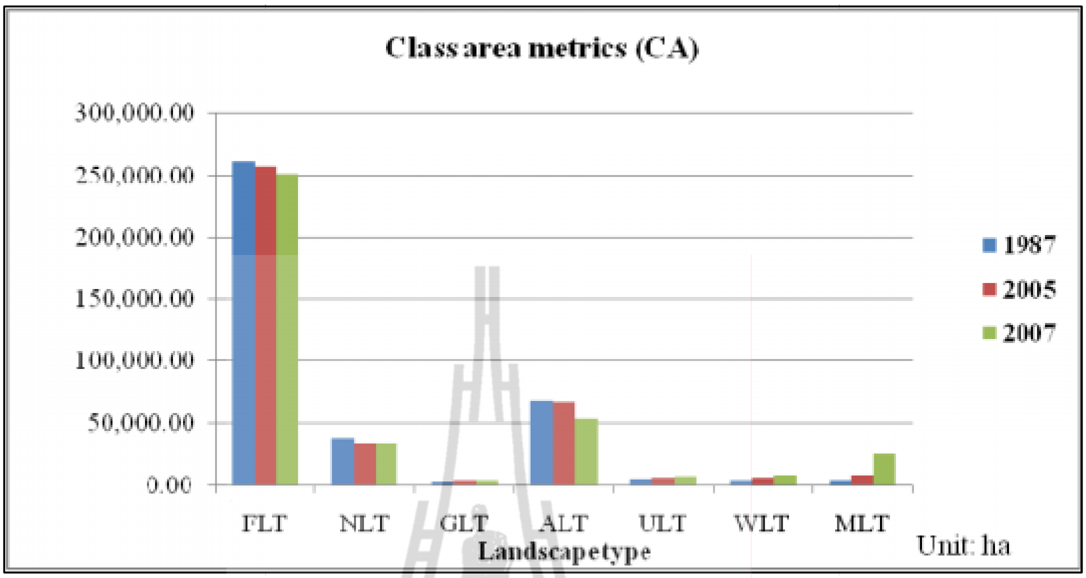


Figure 6.8 Comparison of class area among 1987, 2005 and 2007 in the study area.

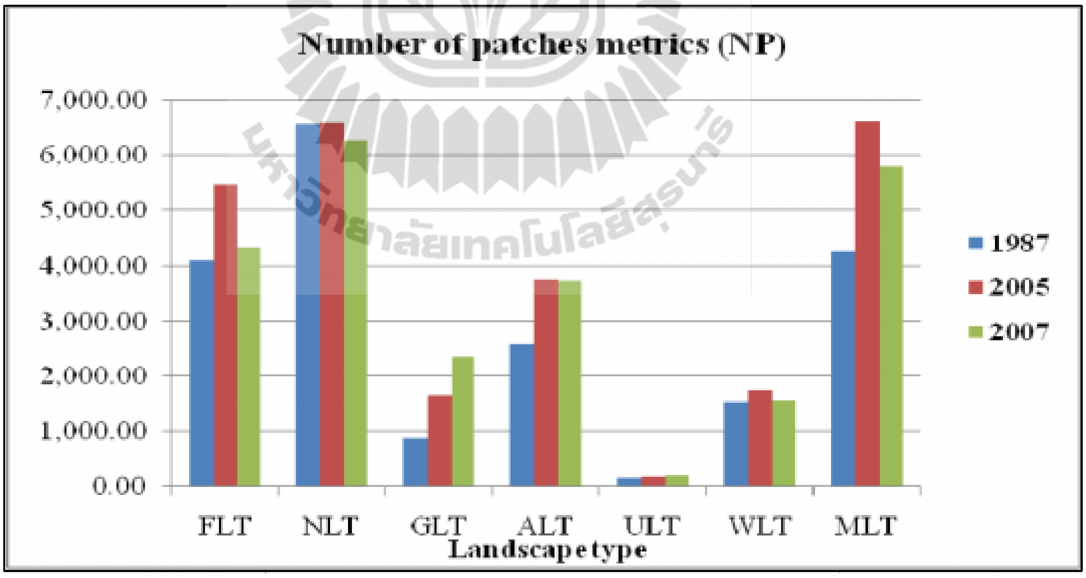


Figure 6.9 Comparison of number of patch among 1987, 2005 and 2007 in the study area.

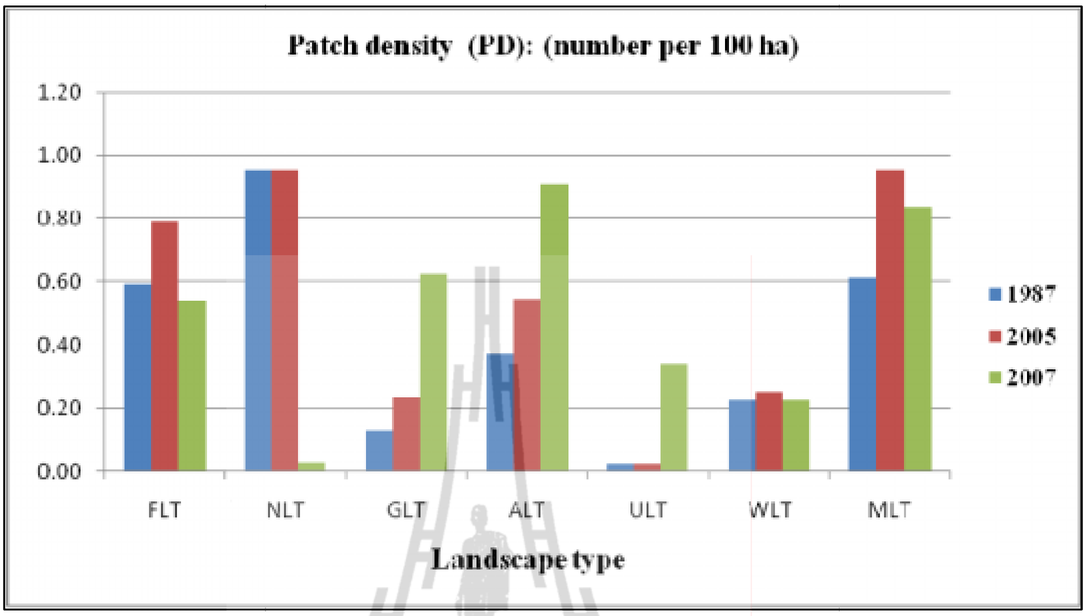


Figure 6.10 Comparison of patch density among 1987, 2005 and 2007 in the study area.

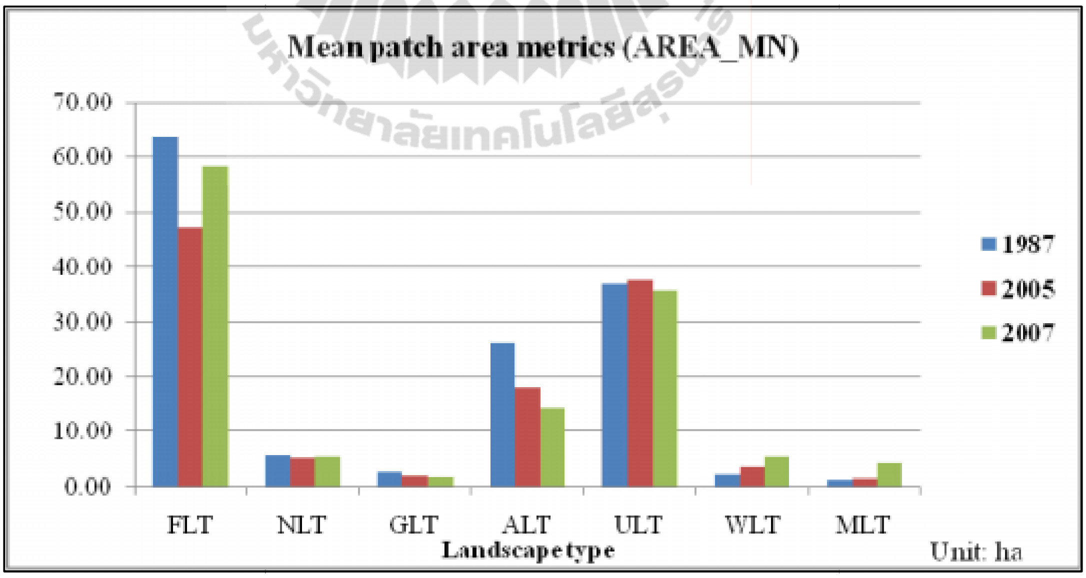


Figure 6.11 Comparison of mean patch area among 1987, 2005 and 2007 in the study area.

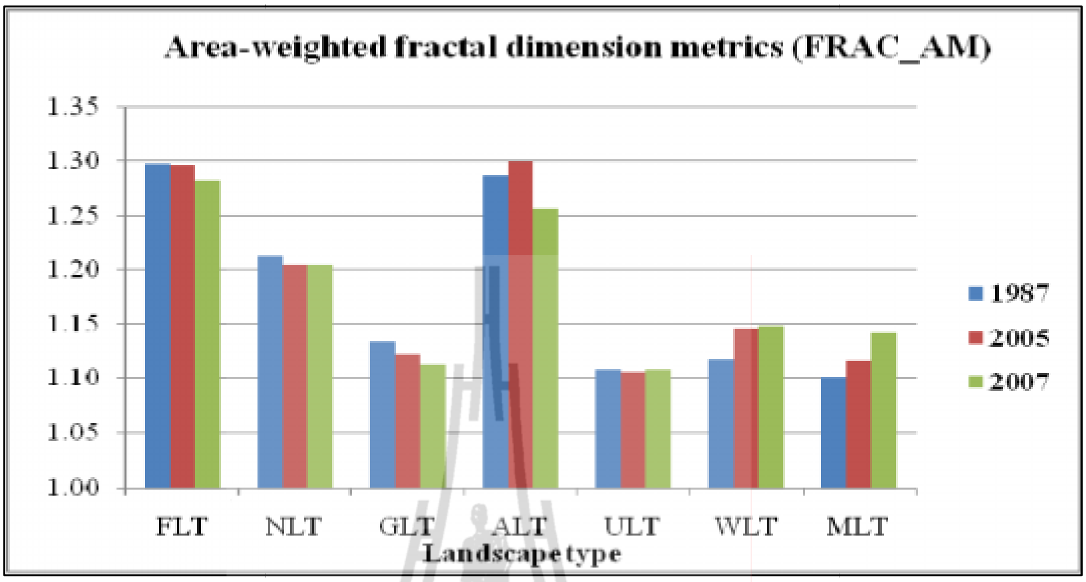


Figure 6.12 Comparison of Area-weighted fractal dimension among 1987, 2005 and 2007 in the study area.

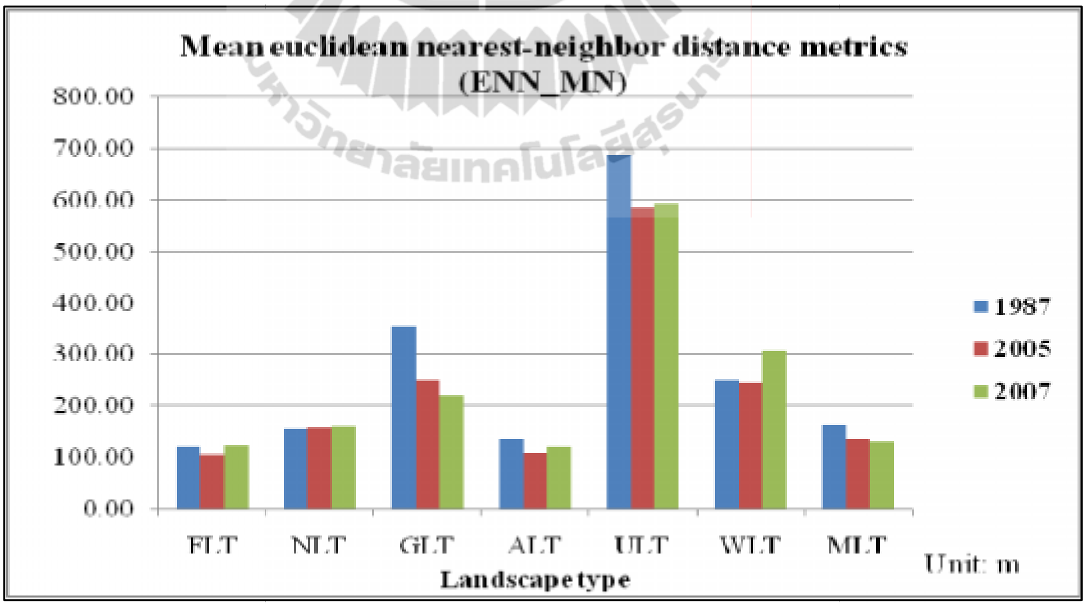


Figure 6.13 Comparison of Mean Euclidean nearest-neighbor distance among 1987, 2005 and 2007 in the study area.

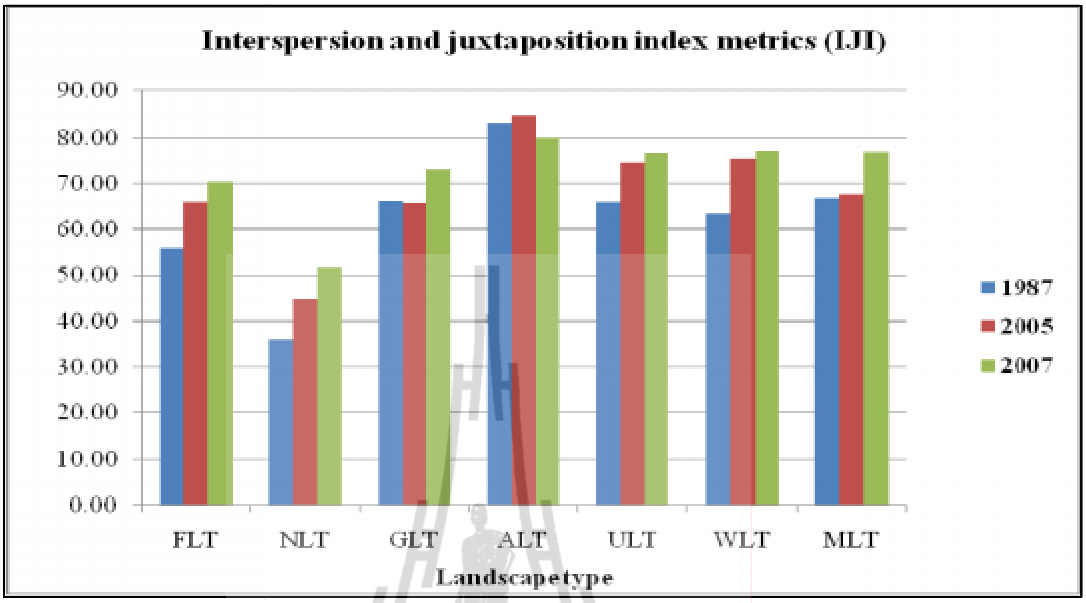


Figure 6.14 Comparison of Interspersion and juxtaposition index among 1987, 2005 and 2007 in the study area.

Furthermore, status and change of landscape types only in Thap Lan National Park was also extracted and summarized as shown in Table 6.11. Comparison of 7 relevant landscape metrics of each landscape type in different dates were displayed in Figure 6.15 to Figure 6.21. It was found that pattern of landscape metric change of most landscape types in Thap Lan National Park is similar with Thap Lan National Park and its 5 km buffer except miscellaneous landscape type (MLT).

Table 6.11 Landscape metric at class level of each date in Thap Lan National Park.

Date	Landscape type	CA	NP	PD	AREA_MN	FRAC_AM	ENN_MN	IJI
	FLT	171902.9	2012	0.2912	85.4388	1.252	112.0254	50.0864
	NLT	22967.25	3245	0.4696	7.0777	1.2081	165.2428	31.5013
	GLT	22418.38	1130	0.1635	19.8393	1.2379	142.4766	77.5611
1987	**ALT**	1107.813	56	0.0081	19.7824	1.0745	1300.4652	73.0314
	ULT	1478.938	419	0.0606	3.5297	1.1438	348.7623	62.324
	WLT	786.75	455	0.0658	1.7291	1.1076	282.2438	60.4359
	MLT	1292.375	1487	0.2152	0.8691	1.1004	184.1023	64.0654
Date	**Landscape type**	**CA**	**NP**	**PD**	**AREA_MN**	**FRAC_AM**	**ENN_MN**	**IJI**
	FLT	170775.8	2564	0.371	66.6052	1.2505	102.5582	60.2005
	NLT	20584.63	3240	0.4689	6.3533	1.1989	165.3772	40.4737
	GLT	22829.81	1598	0.2312	14.2865	1.2577	123.3117	79.9182
2005	**ALT**	1326.375	56	0.0081	23.6853	1.0823	1274.6494	79.8871
	ULT	1781.813	681	0.0985	2.6165	1.137	254.8565	62.4631
	WLT	2546.625	2394	0.3464	1.0638	1.1115	158.7685	65.4692
	MLT	2109.188	553	0.08	3.8141	1.1347	272.3976	77.5777
Date	**Landscape type**	**CA**	**NP**	**PD**	**AREA_MN**	**FRAC_AM**	**ENN_MN**	**IJI**
	FLT	168073.1	2071	0.2997	81.1555	1.2457	118.0119	65.3483
	NLT	20451.75	3161	0.4574	6.47	1.1973	167.8857	48.0609
	GLT	17736.31	1677	0.2427	10.5762	1.2356	131.0854	79.7574
2007	**ALT**	1345.813	60	0.0087	22.4302	1.0818	1323.2182	83.1545
	ULT	2088.813	1007	0.1457	2.0743	1.1279	220.5562	68.8849
	WLT	2843.25	525	0.076	5.4157	1.1368	383.5861	81.8808
	MLT	9415.25	2278	0.3296	4.1331	1.1352	145.6843	74.5591

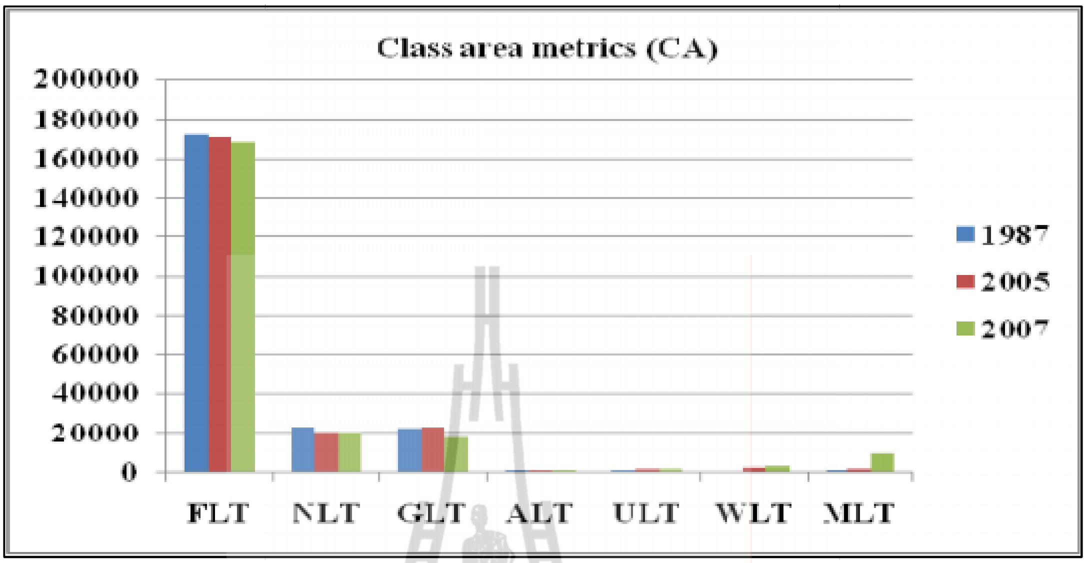


Figure 6.15 Comparison of class area among 1987, 2005 and 2007 in Thap Lan National Park.

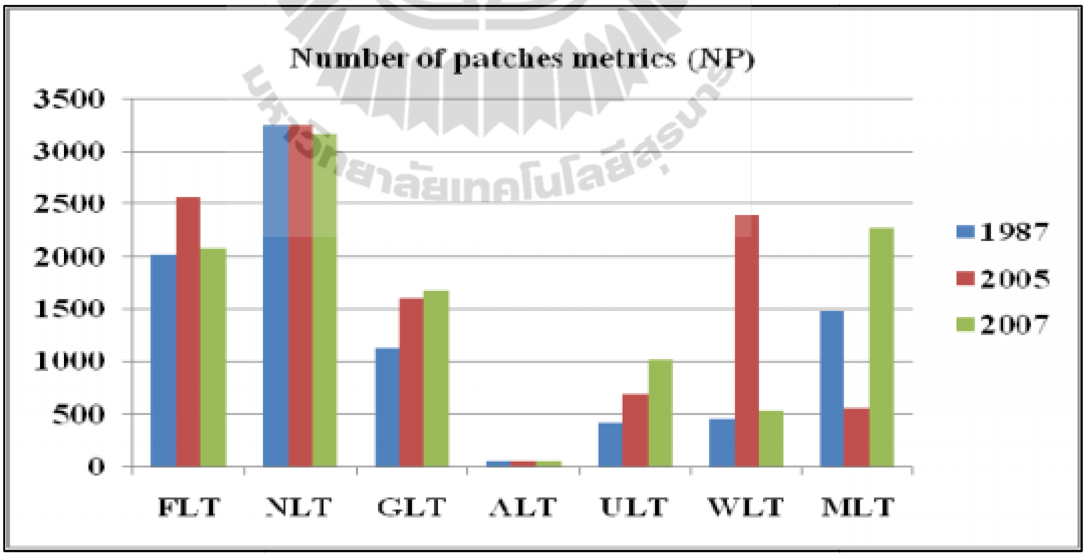


Figure 6.16 Comparison of number of patch among 1987, 2005 and 2007 in Thap Lan National Park.

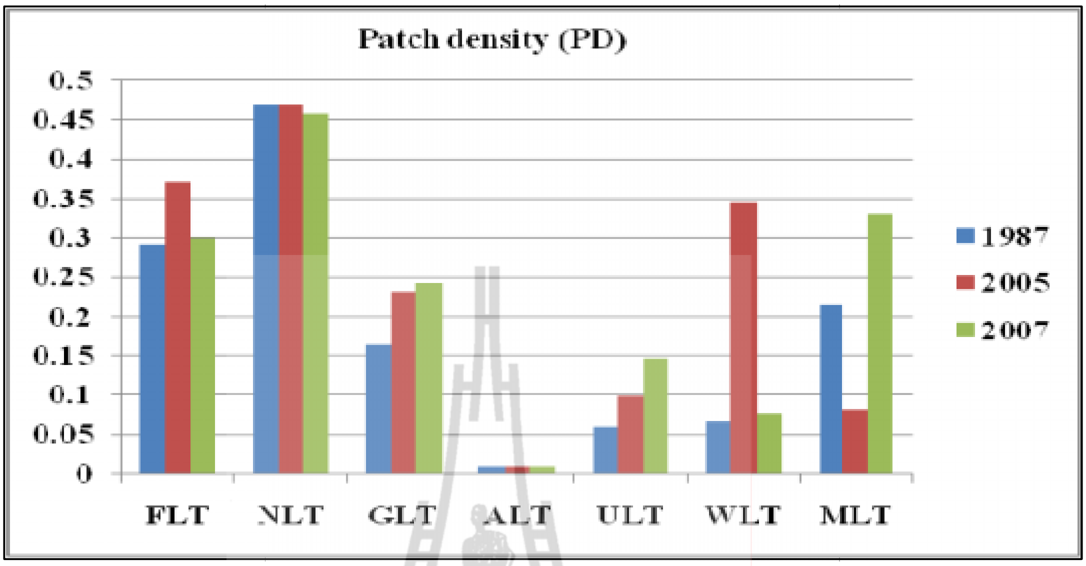


Figure 6.17 Comparison of patch density among 1987, 2005 and 2007 in Thap Lan National Park.

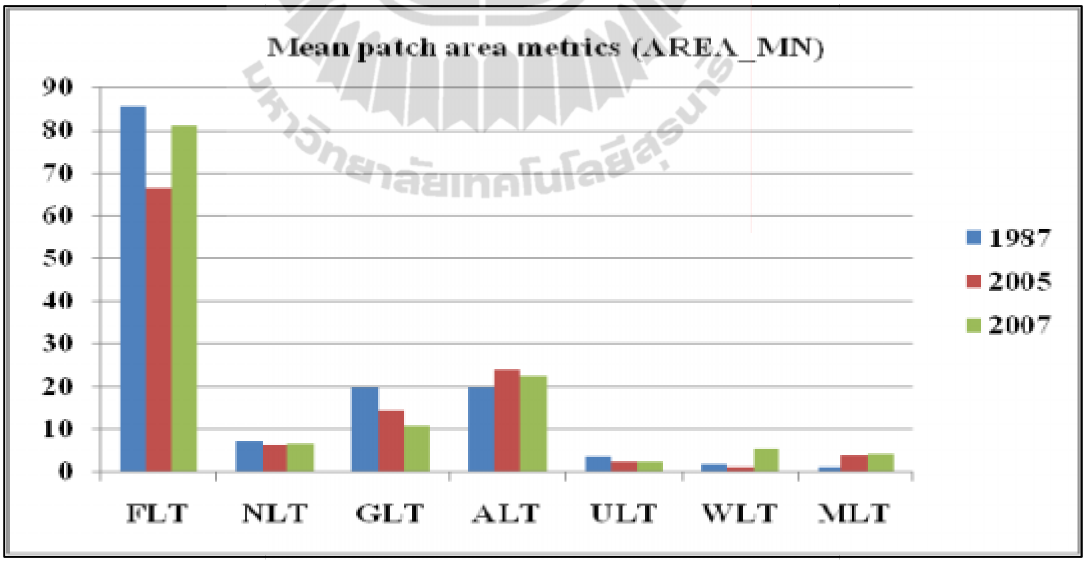


Figure 6.18 Comparison of mean patch area among 1987, 2005 and 2007 in Thap Lan National Park.

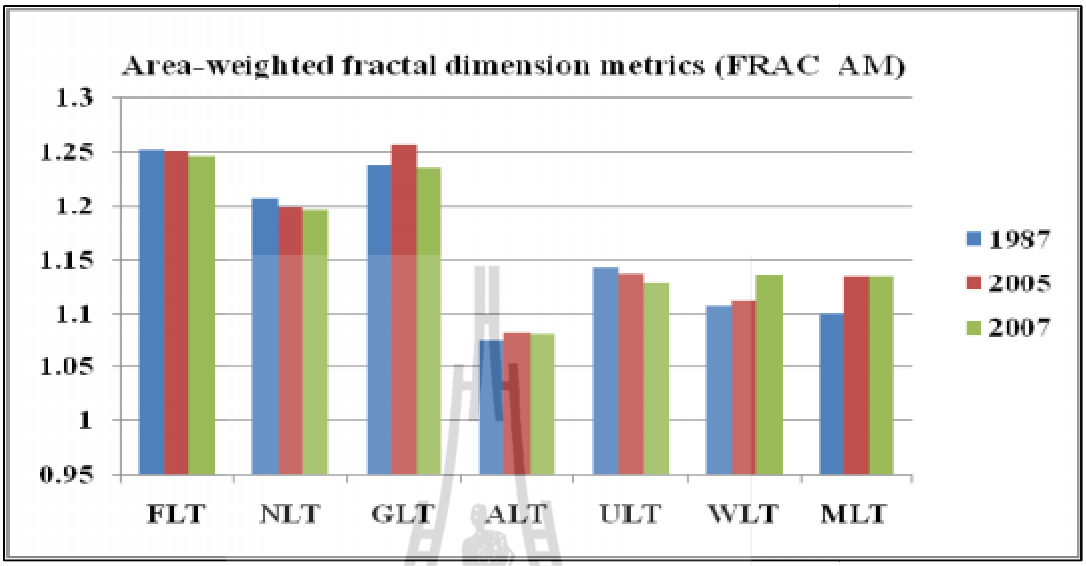


Figure 6.19 Comparison of Area-weighted fractal dimension among 1987, 2005 and 2007 in Thap Lan National Park.

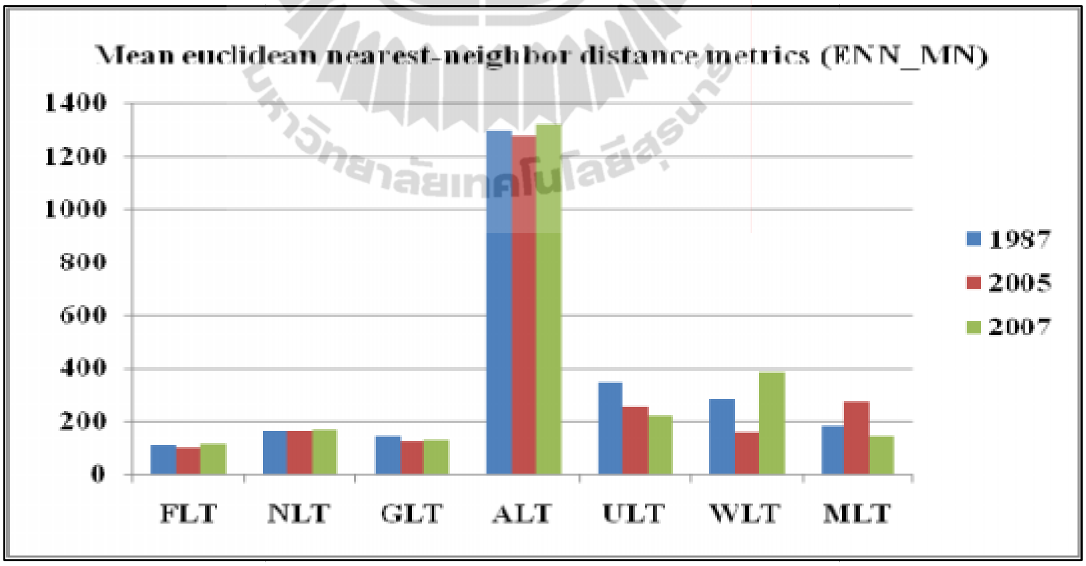


Figure 6.20 Comparison of Mean Euclidean nearest-neighbor distance among 1987, 2005 and 2007 in Thap Lan National Park.

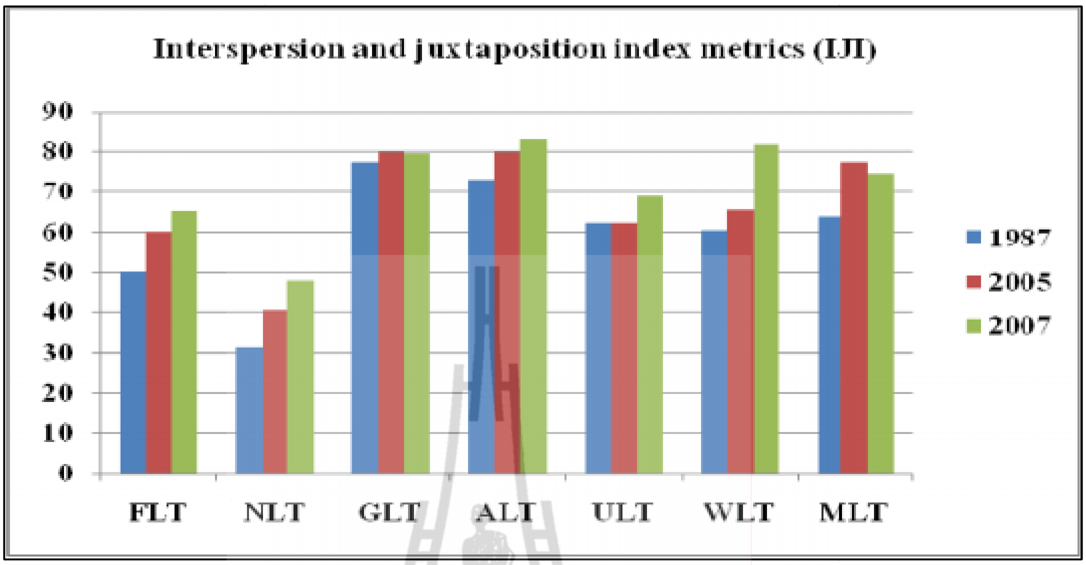


Figure 6.21 Comparison of Interspersion and juxtaposition index among 1987, 2005 and 2007 in the Thap Lan National Park.

CHAPTER VII

CONCLUSION, DISCUSSION AND RECOMMENDATION

There are two main results which are reported in this study including (1) assessment of land use and land cover and its change (Chapter V), (2) assessment of status and change of forest resources landscape (Chapter VI). For this chapter, main results from the last two chapters including assessment of land use and land cover and its change, landscape composition, change of landscape composition, and assessment of forest resources landscape and its change are here separately concluded and discussed with some recommendations.

7.1 Conclusion and discussion

7.1.1 Land use and land cover in 1987, 2005 and 2007

LULC types in Thap Lan national park with 5 km buffer zone were extracted from band 3, 4 and 5 of Landsat-TM data in 1987, 2005 and 2007 included (1) Urban and built-up area, (2) Paddy field, (3) Field crop, (4) Perennial and orchard, (5) Dry evergreen forest, (6) Mixed deciduous forest, (7) Dry dipterocarp forest, (8) Bamboo forest, (9) Natural forest succession and forest plantation, (10) Grassland, (11) Shrub land, (12) Natural water body, (13) Reservoir, (14) Miscellaneous land (old clearing, uncultivated land, barren land/bare land). It was found that patterns of

LULC distributions in 1987, 2005 and 2007 are similar. The most significant LULC type of Thap Lan national park and its 5 km buffer zone in 1987, 2005 and 2007 was natural forest covering an area of 2,615.97, 2,570.59 and 2,514.08 sq. km or 68.41, 67.22 and 65.74% of the study area. These areas included dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, and bamboo forest. While, the second dominant LULC type was agriculture land (paddy field, field crop and perennial and orchard) accounting for 678.24, 668.75 and 532.33 sq. km or 17.74, 17.49 and 13.92% of the study area. The third important LULC category was natural forest succession and forest plantation covering area of 374.25, 337.69 and 334.74 sq. km or 9.79, 8.83 and 8.75% of the study area. Other LULC types included urban and built-up area, grassland, shrub land, natural water body, reservoir and miscellaneous land were distributed in 5 km buffer zone. These categories covered area of 155.76, 247.19 and 443.07 sq. km or 4.07, 6.46 and 11.59% of the study area.

The development of LULC in 1987, 2005 and 2007 shown that urban and built-up area, grassland, reservoir, and miscellaneous land had continued to increase, while paddy field, perennial and orchard, mixed deciduous forest, dry dipterocarp forest, natural forest succession and forest plantation and, natural water body had successively decreased. At the same time dry evergreen forest, bamboo forest and shrub land was rather stable while field crop was unstable. These results imply that forest land encroachment activity in Thap Lan national park and its 5 km buffer zone in 20 years (1987 - 2007) are mostly take place in dry dipterocarp and mixed deciduous forests. Also, these results show effect of policy to deforestation, especially increment of reservoir.

7.1.2 Land use and land cover change between 1987 and 2005

Before the declaration of DPKY - FCWH in 2005 (1987 - 2005), it was found that urban and built-up area, field crop, grassland, reservoir, and miscellaneous land had increased 9.88, 19.94, 8.18, 36.27 and 43.00 sq. km or with increasing rates of 17.12, 6.89, 38.33, 592.65 and 152.32% of their areas in 1987, respectively. Concerning annual increment areas, urban and built-up area, field crop, grassland, reservoir, and miscellaneous land had gained the areas of 0.26, 0.52, 0.21, 0.95 and 1.12, respectively. On the contrary, during the same period, paddy field, perennial and orchard, dry dipterocarp forest, natural forest succession and forest plantation, and, natural water body had lost the areas of 20.55, 8.88, 45.16, 36.56 and 5.71 sq. km or with decreasing rates of 9.41, 5.21, 11.40, 9.77 and 21.33% of the their areas in 1987, respectively. Annual declining areas of paddy field, perennial and orchard, dry dipterocarp forest, natural forest succession and forest plantation, and natural water body were 0.54, 0.23, 1.18, 0.96 and 0.15 sq. km, respectively.

7.1.3 Land use and land cover change between 2005 and 2007

After the declaration of DPKY - FCWH in 2005 (2005 - 2007), it was found that grassland, reservoir and miscellaneous land had increased 6.41, 20.93 and 169.03 sq. km or with increasing rates of 21.71, 49.37 and 237.30% of their areas in 2005, respectively. Concerning annual increment areas, grassland, reservoir, and miscellaneous land had gained the areas of 3.21, 10.46 and 84.52, respectively. In contrary, during the same period, paddy field, field crop, perennial and orchard, mixed deciduous forest, and dry dipterocarp forest, natural forest succession and forest plantation and, natural water body had lost the areas of 30.03, 54.97, 51.42, 15.77, 39.67, 2.95 and 0.60 sq. km or with decreasing rates of 15.17, 17.78, 31.81, 5.35, 11.31, 0.87 and 2.85% of the their areas in 2005, respectively. Annual declining areas of paddy field, field crop, perennial and orchard, mixed deciduous forest, and dry dipterocarp forest, natural forest succession and forest plantation and, natural water body were 15.02, 27.48, 25.71, 7.88, 19.84, 1.47 and 0.30 sq. km, respectively.

7.1.4 Landscape composition in 1987, 2005 and 2007.

Basically, fourteen LULC types in 1987, 2005 and 2007 were firstly reclassified into seven landscape types: forest, natural forest succession and forest plantation, urban and built-up, agriculture, grassland, water bodies and miscellaneous landscape. Then assessment of landscape type and its change was conducted under GIS environment.

In 1987, 2005 and 2007 forest landscape type was the most dominant in the study area. It covered area of 2,615.97, 2,570.59 and 2,514.08 sq. km or 68.41, 67.22 and 65.74% of the study area. At the same time, agriculture landscape type was the second abundant landscape type covering an area of 678.24, 668.75 and 532.33 sq. km or 17.74, 17.49 and 13.92% of the study area. Also, natural forest succession and forest plantation landscape type was the third abundant covering an area of 374.25, 337.69 and 334.74 sq. km or 9.79, 8.83 and 8.75% of the study area. While other landscape types included urban and built-up, grassland, water body, and miscellaneous landscape types covered area of 155.76, 247.20 and 443.07 sq. km or 4.07, 6.46 and 11.59%.

The evolution of landscape type in 1987, 2005 and 2007 shown that urban and built-up area, grassland, water body and miscellaneous landscape types had continued to increase, while forest, natural forest succession and forest plantation and agriculture landscape types had successively decreased.

7.1.5 Landscape types change between 1987 and 2005

Before the declaration of Dong Phra Yayen - Khao Yai Forest Complex World Heritage in 2005 (1987 - 2005), it was found that urban and built-up, grassland, water body and miscellaneous landscape types had increased 9.88, 8.18, 30.55 and 42.83 sq. km or with increasing rates of 17.12, 38.33, 92.86 and 97.76% of their areas in 1987, respectively. Concerning annual increment areas, urban and built-up, grassland, water body and miscellaneous landscape types had gained the areas of 0.55, 0.45, 1.70 and 2.38, respectively. In contrary, during the same period, forest, natural forest succession and forest plantation and agriculture landscape types had lost the areas of 45.38, 36.56 and 9.49 sq. km or with decreasing rates of 1.73, 9.77 and 1.40% of the their areas in 1987, respectively. Annual declining areas of forest, natural forest succession and forest plantation and agriculture landscape types were 2.52, 2.03 and 0.53 sq. km, respectively.

7.1.6 Landscape types change between 2005 and 2007

After the declaration of DPKY - FCWH in 2005 (2005 - 2007), it was found that urban and built-up, grassland, water body and miscellaneous landscape types had increased 0.53, 6.41, 20.33 and 168.60 sq. km or with increasing rates of 0.78, 21.71, 32.04 and 194.60% of their areas in 2005, respectively. Concerning annual increment areas, urban and built-up, grassland, water body and miscellaneous landscape types had gained the areas of 0.27, 3.21, 10.16 and 84.60, respectively. In contrary, during the same period, forest, natural forest succession and forest plantation and agriculture landscape types had lost the areas of 56.51, 2.95 and 136.42 sq. km or with decreasing rates of 2.20, 0.87 and 20.40% of the their areas in 2005, respectively.

Annual declining areas of forest, natural forest succession and forest plantation and agriculture landscape types were 28.25, 1.47 and 68.21 sq. km, respectively.

7.1.7 Status and change of landscape at landscape level

At landscape level, it was found that all three landscape metrics (Dominance, Contagion and Fractal dimension) of Thap Lan national park and its 5 km buffer zone in 1987, 2005 and 2007 had continued to decrease. In fact, dominance decreased from 0.497in 1987 to 0.461 in 2005 and to 0.412in 2007. While, contagion decreased from 0.697 in 1987 to 0.673 in 2005 and to 0.645 in 2007. At the same time, fractal dimension decreased from 1.279 in 1987 to 1.277 in 2005 and to 1.254 in 2007, reflecting landscape came to simple patch. These results imply that Thap Lan national park and its surrounding became more fragmented landscape in the past 20 years.

In addition, it was found that landscape change metric was 0.044 during 1987 - 2005 while it was 0.060 between 2005 and 2007. This result implies that the change of landscape in Thap Lan national park and its 5 km buffer zone after the declaration of DPKY - FCWH in 2005 is increasing.

O'Neill et al. (1996) suggested that landscape change should be compared between ideal state and degraded state. For ideal state, we could ask how far the present landscape deviate from cover (D = 0.9), in large (C = 0.9) and complex (F = 1.9) patches. Also, we might ask how far the landscape deviate from a totally degraded state with many LULC types (D = 0.1), in dissected (C = 0.1) and simple patch (F = 1.1). In the study, when we compared landscape status from 1987, 2005 and 2007 with ideal state and degraded state it was discovered that landscape of Thap Lan national park and its 5 km buffer zone tend to be degrade.

7.1.8 Status and change of landscape types at class level

At class level, landscape metrics included Class area metrics (CA), Number of patches metrics (NP), Patch Density (PD), Mean patch area (AREA_MN), Area-weighted fractal dimension (FRAC_AM), Mean Euclidean nearest-neighbor distance (ENN_MN), Interspersion and juxtaposition index (IJI) were calculated and described in each landscape type (class) in Thap Lan national park and its 5 km buffer zone.

Class area (CA). Forest, natural forest succession and forest plantation and agricultural landscape types had been continuously decreased in two periods (1987 - 2005 and 2005 - 2007). At the same time, urban and built-up, grassland, water bodies and miscellaneous landscape types had been continuously increased. This result reflects that interchange occurs among the landscape type.

Number of patches (NP). During 1987 - 2005 number of patches for all landscape types was increased. In contrast, number of patch for forest, natural forest succession and forest plantation, agricultural, water bodies and miscellaneous landscape types were decreased during 2005 - 2007. At the same time, number of patch for urban and built-up and grassland landscape types were clearly increased. This result implies that fragmentation occurred in all landscape types between 1987 and 2005, meanwhile during 2005 and 2007 forest, natural forest succession and forest plantation, agriculture and miscellaneous landscape types is more aggregated.

Patch Density (PD). During 1987 - 2005 patch density for all landscape types was increased. In contrast, patch density for forest, natural forest succession and forest plantation, water bodies and miscellaneous landscape types were decreased during 2005 - 2007. At the same time, patch density for urban and built-up, agricultural and grassland landscape types were clearly increased. This result reflects that fragmentation occurred in all landscape types between 1987 and 2005, meanwhile during 2005 and 2007 forest, natural forest succession and forest plantation, water body and miscellaneous landscape types is more aggregated.

Mean patch area (AREA_MN). Pattern of status and change for landscape type based on mean patch area is similar with number of patch and patch density. During 1987 - 2005 mean patch area for forest, natural forest succession and forest plantation, agricultural and grassland landscape types was decreased. At the same time, mean patch area for urban and built-up, water body and miscellaneous landscape types was increased. In contrary, during 2005 - 2007, mean patch area for forest, natural forest succession and forest plantation, water bodies and miscellaneous landscape types were increased. At the same time, mean patch area for urban and built-up, agricultural and grassland landscape types were clearly decreased. This result implies that fragmentation occurred in some landscape types except urban and built-up, water body and miscellaneous between 1987 and 2005, meanwhile during 2005 and 2007 forest, natural forest succession and forest plantation, water body and miscellaneous landscape types is more aggregated.

Area-weighted fractal dimension (FRAC_AM). During 1987 - 2005 area-weighted fractal dimension for forest, natural forest succession and forest plantation, urban and built-up and grassland landscape types was decreased. At the same time, area-weighted fractal dimension for agricultural, water bodies and miscellaneous landscape types were increased. In contrary, during 2005 - 2007, area-weighted fractal dimension for forest, natural forest succession and forest plantation, agricultural and grassland landscape types were decreased. At the same time, area-weighted fractal dimension for urban and built-up, water bodies and miscellaneous landscape types were clearly increased. This result implies that fragmentation occurred in some landscape types except agriculture, water body and miscellaneous between 1987 and 2005, meanwhile during 2005 and 2007 forest, natural forest succession and forest plantation, agriculture and grassland landscape types is more fragmented.

Mean Euclidean nearest-neighbor distance (ENN_MN). During 1987 - 2005 mean Euclidean nearest-neighbor distance for forest, urban and built-up, agricultural, grassland and water body landscape types were decreased. At the same time, mean Euclidean nearest-neighbor distance for natural forest succession and forest plantation landscape type was increased. In contrast, during 2005 - 2007 mean Euclidean nearest-neighbor distance for forest, natural forest succession and forest plantation, urban and built-up, agriculture and water body landscape types were increased. At the same time, mean Euclidean nearest-neighbor distance for grassland and miscellaneous landscape types was decreased. This result implies that more new patches occurred in almost landscape types except natural forest succession and forest plantation between 1987 and 2005, meanwhile during 2005 and 2007 less new patches occurred in forest, natural forest succession and forest plantation, urban and built-up, agriculture and water body landscape types.

Interspersion and juxtaposition index (IJI). In two periods (1987 - 2005 and 2005 - 2007), interspersion and juxtaposition index (IJI) for forest, natural forest and forest plantation, urban and built-up, water bodies, and miscellaneous landscape types were continuously increased. However, interspersion and juxtaposition index (IJI) for agricultural landscape type was increased during 1987 -

2005 while its value was decreased during 2005 - 2007. In addition, interspersion and juxtaposition index (IJI) for grassland landscape type was decreased during 1987 - 2005 while its value was increased during 2005 - 2007. This result implies that new patches occurred in almost landscape types except grassland between 1987 and 2005, meanwhile during 2005 and 2007 new patches occurred in almost landscape types except agriculture.

In summary, when number of patch (NP) and patch density (PD) increase and mean patch area (AREA_MN) decrease in any landscape type, it means that fragmentation gradually occurs in such landscape type. In addition, when the mean Euclidean nearest-neighbor distance (ENN_MN) decrease and interspersion and juxtaposition index (IJI) changes in any landscape type, it reflects that many new small size patches develops in such landscape type. Furthermore, when area-weighted fractal dimension (FRAC_AM) of any landscape type decreases, it means that such landscape is more modified.

In conclusion, geoinformatics and landscape metrics can be used to assess and monitor forest resources and LULC that frequently change over time.

7.2 Recommendation

The possibly recommendations could be made for further studies as follows:

1. Methodology from this study should be tested and implemented in another protected areas of DPKY - FCWH.

2. Results from this study can be used as a baseline for further study such as ecological process, wildlife habitat suitability, landscape sustainability.

3. For current status and change assessment, period of time should be the same. This will be useful for another predictive model such as CA - Markov.

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APPENDIX

APPENDIX A

FOREST SAMPLING PLOT

Table A.1 Forest type: Dry evergreen forest.

Site location: Heaw nok kok, WGS 1984, ZONE48, X1575643, Y171183

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
1	กรวยป่า	*Horsfieldia macrocoma* Warb. Var. *canarioides*	32	12	6
2	กรวยป่า	*Horsfieldia macrocoma* Warb. Var. *canarioides*	34	12	6
3	ผักหวานป่า	*Melientha suavis* Pierre	44	8	3.5
4	ลำใยป่า	*Paranephelium xestophyllum* Miq.	36	10	10
5	กระดูก	*Suregada multiflorum* (A.Juss.) Baill.	32	12	5
6	สีเสียดแดง (สีเสียดเปลือก)	*Pentace burmanica* Kurz	110	20	16
7	ยางเหียง	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	41	18	15
8	หว้าแดง(หว้าหิน)	*Syzygium claviflorum* (Roxb.) A.M.Cowan & Cowan	61	20	15
9	แดงดง(หน้าบุต)	*Aglaia rufinervis* (Blume) Bentv.	31	5	3
10	ลำใยป่า	*Paranephelium xestophyllum* Miq.	68	22	18
11	ปอโพธิ์ศรี	*Hibiscus tiliaceus* L.	32	18	15
12	ปอโพธิ์ศรี	*Hibiscus tiliaceus* L.	76	28	25
13	กรวยป่า	*Horsfieldia macrocoma* Warb. Var. *canarioides*	68	28	20
14	ยางเหียง	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	118	30	22
15	เปล้าน้ำเงิน	*Croton cascarilloides* Raeusch.	45	8	3
16	คางคก	*Nyssa javanica* (Blume) Wangerin	78	20	17
17	ละมั่ง (บงมัง เฉียงพร้านางแอ)	*Carallia brachiata* (Lour.) Merr.	84	22	20
18	เปล้าน้ำเงิน	*Croton cascarilloides* Raeusch.	39	10	6
19	เลือดม้า	*Knema globularia* (Lam.) Warb.	40	10	6
20	เปล้าน้ำเงิน	*Croton cascarilloides* Raeusch.	46	18	4
21	ตาทิบทอง (ตาทิบหิน)	*Neolitsea siamensis* Kosterm	83	28	24
22	เสม็ดแดง	*Syzygium cinnereum* (Kurz) P. Chantaranothai. & J. Parn.	113	31	28
23	กรวยป่า	*Horsfieldia macrocoma* Warb. Var. *canarioides*	43	23	10
24	เสม็ดแดง	*Syzygium cinnereum* (Kurz) P. Chantaranothai. & J. Parn.	113	31	28
25	หว้า	*Syzygium cumini* (L.) Skeels	64	15	8
26	หว้า	*Syzygium cumini* (L.) Skeels	78	18	8
27	หว้า	*Syzygium cumini* (L.) Skeels	77	19	10
28	เปล้าน้ำเงิน	*Croton cascarilloides* Raeusch.	38	6	2.5
29	เปล้าน้ำเงิน	*Croton cascarilloides* Raeusch.	34	5	2
30	ละมั่ง (บงมัง เฉียงพร้านางแอ)	*Carallia brachiata* (Lour.) Merr.	85	18	16
31	แสนประสาน	*Terminalia triptera* Stapt	62	18	15
32	กะเบา	*Hydnocarpus anthelminthicus* Pierre ex Laness.	38	18	13
33	ตะเคียนหิน	*Hopea ferrea* Laness.	38	13	9

Figure A.1 Ground photograph: Dry evergreen forest.

Table A.2 Forest type: Mixed deciduous forest.

Site location: Wang Ta Lu, WGS 1984, ZONE48, X 1560038, Y 185951

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
1	เมื่อดแอ	*Memecylon scutellatum* Naudin	45	8	3
2	กำจัด	*Zamia limonella* (Dennst.) Alston	39	8	6
3	ตะแบกนา	*Lagerstroemia floribunda* Jack	226	1	5
4	ก้านจ้อง (ก้านทอง)	*Swintonia schwenckii (Teijsm. & Binn.) Teijsm. & Binn.*	52	8	5
5	ตะแบกนา	*Lagerstroemia floribunda Jack*	95	20	13
6	ก้านจ้อง (ก้านทอง)	*Swintonia schwenckii (Teijsm. & Binn.) Teijsm. & Binn.*	39	10	2.5
7	ตะแบกนา	*Lagerstroemia floribunda* Jack	71	18	13
8	เมื่อดแอ	*Memecylon scutellatum* Naudin	126	6	5
9	ตะแบกนา	*Lagerstroemia floribunda* Jack	94	20	13
10	ก้านจ้อง (ก้านทอง)	*Swintonia schwenckii* (Teijsm. & Binn.) Teijsm. & Binn.	42	8	6
11	เมื่อดแอ	*Memecylon scutellatum* Naudin	30	5	4
12	เมื่อดแอ	*Memecylon scutellatum* Naudin	62	4	3
13	ตะแบกนา	*Lagerstroemia floribunda* Jack	75	16	11
14	เมื่อดแอ	*Memecylon scutellatum* Naudin	60	8	3.5
15	ข่อยหนาม	*Streblus ilicifolius* (Vidal) Corner	31	4	1.5
16	เมื่อดแอ	*Memecylon scutellatum* Naudin	40	6	4
17	พะยูง	*Dalbergia cochinchinensis* Pierre	41	7	4
18	ตอใส (ต่อใส้)	*Elaeis griffithii* (Wight) A.Gray	85	10	8
19	พะยูง	*Dalbergia cochinchinensis* Pierre	49	8	4
20	ตอใส (ต่อใส้)	*Elaeis griffithii* (Wight) A.Gray	138	20	12
21	เมื่อดแอ	*Memecylon scutellatum* Naudin	56	9	5

Table A.2 Forest type: Mixed deciduous forest (continued).

Site location: Wang Ta Lu, WGS 1984, ZONE48, X 1560038, Y 185951

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
22	ตะแบกนา	*Lagerstroemia floribunda* Jack	102	11	8
23	พะยูง	*Dalbergia cochinchinensis* Pierre	38	7	5.5
24	ตะแบกนา	*Lagerstroemia floribunda* Jack	92	6	5
25	ก้านจ้อง (ก้านทอง)	*Swintonia schwenckii* (Teijsm. & Binn.) Teijsm. & Binn.	70	8	6.5
26	ตะแบกนา	*Lagerstroemia floribunda* Jack	120	20	7
27	พะยูง	*Dalbergia cochinchinensis* Pierre	32	6	3.5
28	อีแปะ	*Vitex quinata* (Lour.) F.N.Williams	30	6	1.7
29	เมือดแอ	*Memecylon scutellatum* Naudin	54	7	5
30	แต้วเปรี้ยว	*Cratoxylum maingayi* Dyer	62	12	11
31	ตะแบกนา	*Lagerstroemia floribunda* Jack	123	20	7
32	เมือดแอ	*Memecylon scutellatum* Naudin	51	6	1.7
33	ตะแบกนา	*Lagerstroemia floribunda* Jack	90	20	13
34	พะยูง	*Dalbergia cochinchinensis* Pierre	32	7	3
35	พะยูง	*Dalbergia cochinchinensis* Pierre	30	1	4
36	เมือดแอ	*Memecylon scutellatum* Naudin	40	10	5
37	เมือดแอ	*Memecylon scutellatum* Naudin	30	5	2
38	ตะแบกนา	*Lagerstroemia floribunda* Jack	126	20	8
39	ปอแดง	*Sterculia guttata* Roxb.	94	19	10
40	ตะแบกนา	*Lagerstroemia floribunda* Jack	103	20	11
41	เมือดแอ	*Memecylon scutellatum* Naudin	50	7	3
42	เข็มดอกข้าวสาร	*Ixora cibdela* Craib	38	6	1.8
43	เข็มดอกข้าวสาร	*Ixora cibdela* Craib	104	18	9
44	เข็มดอกข้าวสาร	*Ixora cibdela* Craib	33	6	2.5
45	ตะแบกนา	*Lagerstroemia floribunda* Jack	34	6	6
46	ตะแบกนา	*Lagerstroemia floribunda* Jack	117	20	8

Figure A.2 Ground photograph**:** Mixed decidous forest.

Table A.3 Forest type: Dry dipterocarp forest.

Site Location: Had jom tong, WGS1984, ZONE48, X190737, 1603870

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
1	กระบก 53 46	*Irvingia malayana* Oliv. ex A.W.Benn.	38	8	2
2	เต็ง	*Shorea obtusa* Wall. ex Blume	38	10	4.5
3	เต็ง	*Shorea obtusa* Wall. ex Blume	32	7	5
4	เต็ง	*Shorea obtusa* Wall. ex Blume	31	7	2.5
5	พันชาด (ชาด)	*Erythrophleum succirubrum* Gagnep.	44	8	4.5
6	รัง	*shorea siamensis* Miq.	58	12	4.5
7	เต็ง	*Shorea obtusa* Wall. ex Blume	37	12	6
8	มะม่วง	*Mangifera indica* L.	33	7	2.5
9	เต็ง	*Shorea obtusa* Wall. ex Blume	28	9	4
10	เต็ง	*Shorea obtusa* Wall. ex Blume	45	8	2
11	หวงไทร (หัสคุณ)	*Micromelum minutum* (G.Forst.) Wight & Arn.	42	8	2.5
12	หวงไทร (หัสคุณ)	*Micromelum minutum* (G.Forst.) Wight & Arn.	45	6	1.5
13	แสมดง (แสมสาร)	*Senna garrettiana* (Craib) H.S.Irwin & Barneby	63,58	12	5
14	เต็ง	*Shorea obtusa* Wall. ex Blume	33	6	2
15	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	34	7	2.5
16	มะขามป้อม	*Phyllanthus emblica* L.	51	7	2
17	ชิงชัน	*Dalbergia oliveri Gamble*	32	8	4
18	มะม่วงหัวแมลงวัน	*Buchanania lanzan* Spreng.	66	10	4
19	แสมสาร	*Senecio garrettiana* (Craib) H.S. Irwin & Barneby	85	6	1.8
20	เต็ง	*Shorea obtusa* Wall. ex Blume	31	4	
21	เต็ง	*Shorea obtusa* Wall. ex Blume	43	10	6
22	ชิงชัน	*Dalbergia oliveri Gamble*	78	15	6
23	รัง	*shorea siamensis* Miq.	37	10	2.5

Table A.3 Forest type: Dry dipterocarp forest (continued).

Site Location: Had jom tong, WGS1984, ZONE48, X190737, 1603870

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
24	แสมสาร	*Senecio garrettiana* (Craib) H.S. Irwin & Barneby	35	6	2
25	รัง	*shorea siamensis* Miq.	52	12	25
26	ยอป่า (ยอเถื่อน)	*Morinda coreia* Ham.	30	6	4
27	เต็ง	*Shorea obtusa* Wall. ex Blume	43	8	3.5
28	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	71	8	1.3
29	มะม่วงหัวแมลงวัน	*Buchanania lanzan* Spreng.	35	6	4
30	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	40	8	1.7
31	เต็ง	*Shorea obtusa* Wall. ex Blume	34	8	3
32	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	27	8	2.5
33	เต็ง	*Shorea obtusa* Wall. ex Blume	39	6	2.5
34	เต็ง	*Shorea obtusa* Wall. ex Blume	30	6	1.8
35	ตอใส (ต่อใส้)	*Elaeis griffithii* (Wight) A.Gray	48	8	3.5
36	รัง	*shorea siamensis* Miq.	35	8	4
37	พันซาด (ซาด)	*Erythrophleum succirubrum* Gagnep.	39	8	3.5
38	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	40, 42	10	3.5
39	รัง	*shorea siamensis* Miq.	30	8	1
40	พันซาด (ซาด)	*Erythrophleum succirubrum* Gagnep.	48	12	2.5
41	มะม่วงหัวแมลงวัน	*Buchanania lanzan* Spreng.	31	6	3
42	พันซาด (ซาด)	*Erythrophleum succirubrum* Gagnep.	41	8	5
43	กำลังเสือโคร่ง	*Beta alnoides* Buch.-Ham. Ex G.Don	35, 20	9	2
44	แสมสาร	*Senecio garrettiana* (Craib) H.S. Irwin & Barneby	40	6	2.5
45	ประดู่	*Pterocarpus macrocarpus* Kurz	92	15	6
46	รัง	*shorea siamensis* Miq.	43	10	2
47	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	38	8	2.5
48	มะม่วงหัวแมลงวัน	*Buchanania lanzan* Spreng.	31	6	3.5
49	รัง	*shorea siamensis* Miq.	30	8	4
50	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	55	8	1.8
51	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	30	8	3
52	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	30	8	2
53	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	35, 32	11	2.5
54	พันซาด (ซาด)	*Erythrophleum succirubrum* Gagnep.	36	8	2
55	พันซาด (ซาด)	*Erythrophleum succirubrum* Gagnep.	37,47	10	3
56	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	41	9	2
57	พันซาด (ซาด)	*Erythrophleum succirubrum* Gagnep.	54	7	2
58	แสมสาร	*Senecio garrettiana* (Craib) H.S. Irwin & Barneby	33	6	2
59	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	30	8	2.5
60	เต็ง	*Shorea obtusa* Wall. ex Blume	35	5	2.5
61	ตะคร้อ	*Schleichera oleosa* (Lour.) Oken	30	6	2
62	เต็ง	*Shorea obtusa* Wall. ex Blume	30	4	1.5
63	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	41	6	3.5

Table A.3 Forest type: Dry dipterocarp forest (continued).

Site Location: Had jom tong, WGS1984, ZONE48, X190737, 1603870

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
64	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	32	7	1.7
65	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	61	11	2.5
66	เต็ง	*Shorea obtusa* Wall. ex Blume	45	10	2.5
67	เต็ง	*Shorea obtusa* Wall. ex Blume	32	6	1.5
68	รัง	*shorea siamensis* Miq.	40	9	2
69	บัวบก	*Stephania pierrei* Diels	55, 32	10	1
70	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	45	8	2
71	ตะคร้อ	*Schleichera oleosa* (Lour.) Oken	41	8	2
72	รัง	*shorea siamensis* Miq.	49	10	2
73	ตะคร้อ	*Schleichera oleosa* (Lour.) Oken	44	5	1.7
74	ตะคร้อ	*Schleichera oleosa* (Lour.) Oken	41	5	2
75	เต็ง	*Shorea obtusa* Wall. ex Blume	30	5	1.6
76	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	71	9	3
77	เต็ง	*Shorea obtusa* Wall. ex Blume	31	5	2
78	แสมสาร	*Senecio garrettiana* (Craib) H.S. Irwin & Barneby	49	12	3.5
79	เต็ง	*Shorea obtusa* Wall. ex Blume	44	11	4
80	เต็ง	*Shorea obtusa* Wall. ex Blume	45	27	2.5
81	มะม่วง	*Mangifera indica* L.	40	7	2.5
82	เต็ง	*Shorea obtusa* Wall. ex Blume	39	8	2
83	พันชาด (ชาด)	*Erythrophleum succirubrum* Gagnep.	41	8	2.5
84	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	48	9	4
85	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	60	11	4
86	แดง	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen	47	8	3

Figure A.3 Ground photograph: Dry dipterocarp forest.

Table A.4 Forest type: Bamboo forest.

Site Location: Lum pang, WGS 1984, Zone48, X 198969, Y 1572232

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
1	ไผ่ปล้องนวล	*Bambusa* sp.	64	10	8
2	ยางแดง	*Dipterocarpus turbinatus* C.F.Gaertn.	39	8	7
3	เปล้าใบเลื่อย (เปล้าใหญ่)	*Croton roxburghii* N.T. Balakr.	51	8	7
4	ไผ่ปล้องนวล	*Bambusa* sp.	37	8	7
5	ปอพาน (ปอพราน)	*Colona auriculata* (Desv.) Craib	37	12	6
6	กระท้อน	*Sandoricum koetjape (Burm.f.) Merr.*	210	22	15
7	เชื่อมคะนอง (เคี่ยมคะนอง เคียนทราย)	*Shorea henryana Pierre*	200	45	25
8	ละมั่ง (บงมัง เฉียงพร้านางแอ)	*Carallia brachiata (Lour.) Merr.*	175	40	15
9	พะยอม	*Shorea roxburghii G.Don*	165	45	30
10	พะยอม	*Shorea roxburghii G.Don*	210	22	28
11	เชื่อมคะนอง (เคี่ยมคะนอง เคียนทราย)	*Shorea henryana Pierre*	355	50	30
12	สีเสียดแดง (สีเสียดเปลือก)	*Pentace burmanica* Kurz	63	10	6
13	กระเบียน	*Ceriscoides turgida* (Roxt) Tirveng	41	6	3.5
14	กระเบียน	*Ceriscoides turgida* (Roxt) Tirveng	32	6	4
15	หมีเหม็น	*Litsea glutinosa* (Lour.) C.B.Rob.	61	12	9
16	ยางแดง	*Dipterocarpus turbinatus* C.F. Gaertn.	127	30	22
17	ยางแดง	*Dipterocarpus turbinatus* C.F. Gaertn.	243	48	27
18	กระท้อน	*Sandoricum koetjape* (Burm.f.) Merr.	51	12	8
19	มันปู	*Glochidion littorale* Blume, *Glochidion wallichianum* Müll. Aeg.	35	6	4
20	สีเสียดแดง	*Pentace burmanica* Kurz	73	10	8
21	ยางแดง	*Dipterocarpus turbinatus* C.F. Gaertn.	31	7	-
22	กระท้อนป่า	*Sandoricum koetjape* (Burm.f.) Merr.	187	50	30

Figure A.4 Ground photograph: Bamboo forest.

Table A.5 Forest type: Natural succession forest and forest plantation.

Site Location: Phu heep, WGS 1984, ZONE48, X 1579373, Y 168117

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
1	ลาน	*Corypha lecomtei* Becc.	90	4	4
2	ลาน	*Corypha lecomtei* Becc.	102	0.5	-
3	ลาน	*Corypha lecomtei* Becc.	90	6	-
4	มะเดื่อปล้อง	*Ficus hispida* L.f.	31	8	6
5	ลาน	*Corypha lecomtei* Becc.	100	2	-
6	ลาน	*Corypha lecomtei* Becc.	100	4.5	-
7	ปอหูช้าง	*Pterocymbium acerifolium (L.) Willd.*	35	7	5
8	ลาน	*Corypha lecomtei Becc.*	120	5	-
9	ลาน	*Corypha lecomtei Becc.*	80	2	-
10	ลาน	*Corypha lecomtei Becc.*	40	0.6	-
11	ลาน	*Corypha lecomtei Becc.*	150	2.5	-
12	กะฮาด	*Amesiodendron chinense (Merr.)*	50	10	8
13	กะฮาด	*Amesiodendron chinense (Merr.)*	30	0.7	2.5
14	น้ำจ้อย (มะเกลือกา)	*Diospyros gracilis Fletcher*	50	1	4
15	น้ำจ้อย (มะเกลือกา)	*Diospyros gracilis Fletcher*	40	0.5	2.5
16	มะเดื่อปล้อง	*Ficus hispida L.f.*	33	5	3.5
17	สักขี	*Vatica harmandiana Pierre*	113/114	14	7
18	ลาน	*Corypha lecomtei Becc.*	40	1	-
19	สักขี	*Vatica harmandiana Pierre*	50	1	-
20	สักขี	*Vatica harmandiana Pierre*	30	50	-
21	เขว้า	*Haldina cordifolia* (Roxb.) Ridsdale	40/26	5.5	3
22	เขว้า	*Haldina cordifolia* (Roxb.) Ridsdale	30	50	-
23	เขว้า	*Haldina cordifolia* (Roxb.) Ridsdale	150	2	-
24	เขว้า	*Haldina cordifolia* (Roxb.) Ridsdale	30	0.7	-
25	โมกมัน	*Wrightia arborea* (Dennst.) Mabb.	30	0.5	-
26	โมกมัน	*Wrightia arborea* (Dennst.) Mabb.	70	1.2	-
27	โมกมัน	*Wrightia arborea (Dennst.) Mabb.*	40	0.5	-
28	ปอแดง	*Sterculia guttata* Roxb.	50	9	7
29	ปอแดง	*Sterculia guttata* Roxb.	100	4.5	-
30	ปอแดง	*Sterculia guttata* Roxb.	70	0.9	-
31	ปอแดง	*Sterculia guttata* Roxb.	130	2.5	-
32	ปอแดง	*Sterculia guttata* Roxb.	40	0.6	-
33	ปอแดง	*Sterculia guttata* Roxb.	150	3	-
34	ปอแดง	*Sterculia guttata* Roxb.	30	0.5	-
35	ปอแดง	*Sterculia guttata* Roxb.	100	5.5	-
36	อะราง	*Peltophorum dasyrachis* (Miq.) Kurz.	56	12	5

ฃ**Table A.5** Forest type: Natural succession forest and forest plantation (continued).

Site Location: Phu heep, WGS 1984, ZONE48, X 1579373, Y 168117

No.	Local Name	Botanical name	GBH	Height (m.)	
			(cm.)	Total	First
37	ปอหูช้าง	*Pterocymbium acerifolium* (L.) Willd.	120	4	
38	น้ำจ้อย (มะเกลือกา)	*Diospyros gracilis* Fletcher	130	2.2	-
39	น้ำจ้อย (มะเกลือกา)	*Diospyros gracilis* Fletcher	40	0.8	-
40	น้ำจ้อย (มะเกลือกา)	*Diospyros gracilis* Fletcher	80	0.8	-
41	น้ำจ้อย (มะเกลือกา)	*Diospyros gracilis* Fletcher	40	0.7	-
42	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	46	5	2
43	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	150	2	-
44	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	150	2	-
45	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	80	4.5	-
46	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	40	1	-
47	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	30	0.9	-
48	ปะดู่คั่ง	*Pterocarpus macrocarpus* Kurz	50	0.7	
49	มะเดื่อปล้อง	*Ficus hispida* L.f.	48	8	3
50	มะเดื่อปล้อง	*Ficus hispida* L.f.	80	1	-
51	มะเดื่อปล้อง	*Ficus hispida* L.f.	90	0.8	-
52	มะเดื่อปล้อง	*Ficus hispida* L.f.	70	0.9	-
53	มะเดื่อปล้อง	*Ficus hispida* L.f.	70	0.7	-
54	ปะดู่คั่ง(ป่า)	*Pterocarpus macrocarpus* Kurz	39	13	5
55	ปะดู่คั่ง(ป่า)	*Pterocarpus macrocarpus* Kurz	108	10	-
56	ปะดู่คั่ง(ป่า)	*Pterocarpus macrocarpus* Kurz	40	2	-
57	ปะดู่คั่ง(ปลูก)	*Pterocarpus macrocarpus* Kurz	78	11	4
58	ปะดู่คั่ง(ปลูก)	*Pterocarpus macrocarpus* Kurz	180	4	-
59	ปะดู่คั่ง(ปลูก)	*Pterocarpus macrocarpus* Kurz	32	6	2.5
60	ปอแดง	*Sterculia guttata* Roxb.	53	8	4
61	ตอใส (ต่อใส้)	*Elaeis griffithii* (Wight) A.Gray	40/46	12	2
62	ประดู่	*Pterocarpus macrocarpus* Kurz	33	6	3
63	ประดู่	*Pterocarpus macrocarpus* Kurz	120	1.3	
64	ประดู่	*Pterocarpus macrocarpus* Kurz	39	6	2
65	ประดู่	*Pterocarpus macrocarpus* Kurz	40	0.8	
66	สัมกบ	*Hymenodictyon orixense* (Roxb.) Mabb.	59	11	7
67	ประดู่	*Pterocarpus macrocarpus* Kurz	31	4	3
68	โมกมัน	*Wrightia arborea* (Dennst.) Mabb.	38	8	7
69	อะราง	*Peltophorum dasyrachis* (Miq.) Kurz.	43	8.5	4
70	อะราง	*Peltophorum dasyrachis* (Miq.) Kurz.	178	13	2.5

Figure A.5 Ground photograph: Natural succession forest and forest plantation.

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Publications

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