แบบจำลองทางภูมิศาสตร์เชิงพื้นที่สำหรับการคาดการณ์การใช้ที่ดิน และสิ่งปกคลุมดินและการวิเคราะห์ความเปราะบางของการบุกรุกทำลายป่า ในเกาะภูเก็ต ประเทศไทย

นายกฤตวัฏ บุญชู

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาภูมิสารสนเทศ
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2558

GEOSPATIAL MODELS FOR LAND USE AND LAND COVER PREDICTION AND DEFORESTATION VULNERABILITY ANALYSIS IN PHUKET ISLAND, THAILAND

Krittawat Boonchoo

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Geoinformatics

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GEOSPATIAL MODELS FOR LAND USE AND LAND COVER PREDICTION AND DEFORESTATION VULNERABILITY ANALYSIS IN PHUKET ISLAND, THAILAND

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

Thesis Examining Committee

____

(Asst. Prof. Dr. Songkot Dasananda)

Chairperson

____

(Assoc. Prof. Dr. Suwit Ongsomwang)

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การสร้างแบบจำลองภูมิศาสตร์เชิงพื้นที่มีบทบาทสำคัญในการคาดการณ์ข้อมูลการใช้ที่ดินและสิ่งปกคลุมดิน และผลที่ได้รับสามารถนำไปประยุกต์ใช้กับงานด้านต่าง ๆ เช่น การวางแผนและจัดการการใช้ที่ดิน การวิเคราะห์ความเปราะบางการบุกรุกทำลายป่าเพื่อการอนุรักษ์และคุ้มครองป่า วัตถุประสงค์ของการศึกษาคือ (1) เพื่อประเมินการเปลี่ยนแปลงการใช้ที่ดินและสิ่งปกคลุมดินในเกาะภูเก็ตและในพื้นที่ป่าคุ้มครอง (2) เพื่อค้นหาแบบจำลองทางภูมิศาสตร์เชิงพื้นที่ที่เหมาะสมสำหรับการคาดการณ์การใช้ที่ดินและสิ่งปกคลุมดิน (3) เพื่อตรวจสอบวิธีการทางภูมิศาสตร์เชิงพื้นที่ที่เหมาะสมสำหรับการวิเคราะห์ความเปราะบางการบุกรุกทำลายป่า และ (4) เพื่อกำหนดพื้นที่เฝ้าระวังการบุกรุกทำลายป่าและกำหนดตำแหน่งหน่วยพิทักษ์ป่าสำหรับพื้นที่ป่าคุ้มครอง องค์ประกอบหลักของวิธีการวิจัยประกอบด้วย การจำแนกการใช้ที่ดินและสิ่งปกคลุมดินและการประเมินการเปลี่ยนแปลงการใช้ที่ดินและสิ่งปกคลุมดิน การคาดการณ์การใช้ที่ดินและสิ่งปกคลุมดินด้วยแบบจำลองภูมิศาสตร์เชิงพื้นที่ที่เหมาะสม การวิเคราะห์ความเปราะบางของการบุกรุกทำลายป่าด้วยวิธีการทางภูมิศาสตร์เชิงพื้นที่ที่เหมาะสม และการกำหนดพื้นที่เฝ้าระวังการบุกรุกทำลายป่าและการกำหนดตำแหน่งหน่วยพิทักษ์ป่า

ผลการศึกษาพบว่า พื้นที่ป่าในปี พ.ศ. 2538 2545 และ 2557 ในพื้นที่ป่าคุ้มครอง 8 แห่ง ประกอบด้วย อุทยานแห่งชาติทางทะเลสิรินาถ ป่าสงวนแห่งชาติเขาบางขนุน เขากมลา เขานาคเกิด คลองท่ามะพร้าว คลองพารา คลองท่าจีน และคลองเกาะผี ลดลงอย่างต่อเนื่อง เนื่องจากการเพิ่มขึ้นของเมืองและสิ่งปลูกสร้าง ไม้ผลและไม้ยืนต้น และพื้นที่เพาะเลี้ยงสัตว์น้ำ ขณะเดียวกัน พื้นที่ป่าในปีเดียวกันในพื้นที่คุ้มครองอีก 7 แห่ง ประกอบด้วย สถานีพัฒนาและส่งเสริมการอนุรักษ์สัตว์ป่าเขาพระแทว ป่าสงวนแห่งชาติเขาไม้แก้ว เขาสามเหลี่ยม เขาโต๊ะแซะ คลองอู่ตะเภา คลองบางโรง และคลองท่าเรือ ค่อนข้างคงที่

ในการคาดการณ์การใช้ที่ดินและสิ่งปกคลุมดินในปี พ.ศ. 2569 ในพื้นที่ป่าคุ้มครอง 15 แห่ง ด้วยแบบจำลองภูมิศาสตร์เชิงพื้นที่ที่เหมาะสม (CLUE-S model และ CA-Markov model) พบว่า อัตราการบุกรุกทำลายป่ารายปีที่คาดการณ์สูงสุดและต่ำสุดจะเกิดขึ้นในป่าสงวนแห่งชาติเขากมลา และป่าสงวนแห่งชาติคลองท่าเรือ ตามลำดับ จากการวิเคราะห์ความเปราะบางการบุกรุกทำลายป่า

ด้วยวิธีการ Frequency Ratio พบว่า มีพื้นที่ป่าคุ้มครองที่มีความเสี่ยงของการบุกรุกทำลายป่าต่ำ จำนวน 7 แห่ง ขณะเดียวกัน มีพื้นที่ป่าคุ้มครองที่มีความเสี่ยงของการบุกรุกทำลายป่าสูง จำนวน 8 แห่ง นอกจากนั้น กรณีการกำหนดพื้นที่เฝ้าระวังการบุกรุกทำลายป่า พบว่า ไม่มีพื้นที่เฝ้าระวังการบุกรุกทำลายป่าในพื้นที่ป่าคุ้มครองจำนวน 3 แห่ง ได้แก่ ป่าสงวนแห่งชาติเขาสามเหลี่ยม เขาโต๊ะแซะ และคลองท่าเรือ ในทางตรงกันข้าม ในพื้นที่ป่าคุ้มครองอีก 12 แห่ง มีพื้นที่เฝ้าระวังการบุกรุกทำลายป่าจำนวนที่แตกต่างกัน โดยเฉพาะอย่างยิ่ง ป่าสงวนแห่งชาติเขากมลามีพื้นที่เฝ้าระวังการบุกรุกทำลายป่าจำนวนสูงสุด 229 แห่ง ในขณะเดียวกัน ในกรณีการกำหนดตำแหน่งหน่วยพิทักษ์ป่า พบว่า จำเป็นต้องมีการจัดตั้งหน่วยพิทักษ์ป่าให้กับพื้นที่ป่าคุ้มครอง 5 แห่ง ประกอบด้วย ป่าสงวนแห่งชาติเขานาคเกิด เขากมลา คลองท่าจีน คลองพาราและคลองอู่ตะเภา จำนวน 20 15 6 2 และ 1 หน่วย ตามลำดับ

จากผลการศึกษาที่ได้รับสามารถสรุปได้ว่า การบูรณาการระหว่างแบบจำลองภูมิศาสตร์เชิงพื้นที่เพื่อการคาดการณ์การใช้ที่ดินและสิ่งปกคลุมดินและวิธีการทางภูมิศาสตร์เชิงพื้นที่สำหรับการวิเคราะห์ความเปราะบางของการบุกรุกทำลายป่า สามารถนำมาใช้เป็นเครื่องมือการกำหนดพื้นที่เฝ้าระวังการบุกรุกทำลายป่าและการกำหนดตำแหน่งที่ตั้งหน่วยพิทักษ์ป่าได้อย่างมีประสิทธิภาพ

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา____________________________

ปีการศึกษา 2558 ลายมือชื่ออาจารย์ที่ปรึกษา_____________________

KRITTAWAT BOONCHOO : GEOSPATIAL MODELS FOR LAND USE AND LAND COVER PREDICTION AND DEFORESTATION VULNERABILITY ANALYSIS IN PHUKET ISLAND, THAILAND. THESIS ADVISOR : ASSOC. PROF. SUWIT ONGSOMWANG, Dr. rer. Nat. 319 PP.

LAND USE AND LAND COVER PREDICTION / DEFORESTATION VULNERABILITY ANALYSIS / GEOSPATIAL MODEL AND METHOD

Geospatial modelling plays important role to predict land use and land cover (LULC) data and their results can further applied in various aspects such as land use planning and management, deforestation vulnerability analysis for forest conservation and protection. Objectives of the study are (1) to assess LULC change in Phuket Island and its protected forest areas; (2) to identify an optimal geospatial model for LULC prediction; (3) to examine an optimize geospatial method for deforestation vulnerability analysis; and (4) to identify deforestation hotspot and allocate forest protection units for protected forest areas. Main components of research methodology consisted of LULC extraction and LULC change evaluation; LULC prediction with optimum geospatial model; deforestation vulnerability analysis with optimum geospatial method; and deforestation hotspot and forest protection unit allocation.

As results, forest areas in 1995, 2002 and 2014 of 8 protected forest areas included Sirinath marine national park (MNP), Khao Bang Khanun, Khao Kamala Khao Nak Keod, Khlong Tha Maphrao, Khlong Para, Khlong Tajin and Khlong Khopee national reserved forest (NRF) areas had continuously decreased due to increasing of urban and built-up area, orchard and perennial trees and aquaculture areas. Meanwhile

the forest areas of 7 protected forest areas included Khao Phra Thaeo Wildlife Conservation Development and Extension Center (WCDEC), Khao Mai Kaew, Khao Sam Liam NRF, Khao Tosae, Khlong U-Tapao, Khlong Bangrong, Khlong Tarau NRFs were rather stable.

Based on LULC prediction in 2026 of 15 protected forest areas using an optimum geospatial model (CLUE-S model and CA-Markov model), annual highest and lowest predictive deforestation rate occurred in Khao Kamala NRF and Khong Tarau NRF, respectively. According to deforestation vulnerability analysis using Frequency Ratio method, there were 7 protected forest area with low risk of deforestation while there were 8 protected forest area with high risk of deforestation. Furthermore, in case of deforestation hotspot allocation, there were no deforestation hotspot presented in three protected forest areas included Khao Sam Liam, Khao Tosae and Khlong Tarau NRFs. On contrary, some number of deforestation hotspots presented in 12 protected forest areas. Particularly, Khao Kamala NRF had the highest deforestation hotspot of 229 points. Meanwhile, in case of forest protection unit allocation, there were five protected forest areas included Khao Nak Keod, Khao Kamala, Khlong Tajin, Khlong Para and Khlong U-Tapao NRFs required to establish forest protection area with number of 20, 15, 6, 2 and 1 units, respectively.

In conclusion, it appears that integration of geospatial model for LULC prediction and geospatial method for deforestation vulnerability analysis can be used as an efficiently tools for deforestation hotspot and forest protection units allocation.

School of Remote Sensing Student's Signature________________________

Academic Year 2014 Advisor's Signature________________________

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LIST OF ABBREVIATIONS

CA	=	Cellular Automata
CA-Markov	=	Cellular Automata and Markov Model
CDD	=	Community Development Department
CLUE-S	=	the Conversion of Land Use and its Effects at Small regional extent
DEM	=	Digital Elevation Model
DMCR	=	Department of Marine and Coastal Resources
DNP	=	Department of National Parks
DOPA	=	Department of Provincial Administration
DPT	=	Department of Public Work and Town & Country Planning
DVA	=	Deforestation Vulnerability Analysis
DVI	=	Deforestation Vulnerability Index
FR	=	Frequency Ratio
GDP	=	Gross Domestic Product
GIS	=	Geographic Information System
GISTDA	=	Geo-Informatics and Space Technology Development Agency (public organization)
LCM	=	Land Change Modeler
LDD	=	Land Development Department
LRA	=	Logistic Regression Analysis

LIST OF ABBREVIATIONS (Continued)

LULC	=	Land Use and Land Cover
MLP	=	Multi-Layer Perceptron
MNP	=	Marine National Park
MNRE	=	Ministry of Natural Resources and Environment
MOT	=	Ministry of Transport
NRF	=	National reserved forest
OAE	=	Office of Agricultural Economics
PSO	=	Permanent Secretary Office
RFD	=	Royal Forest Department
ROC	=	Relative operating characteristic
TFSMP	=	Thai Forestry Sector Master Plan
THEOS	=	Thailand Earth Observation Satellite
WCDEC	=	Wildlife Conservation Development and Extension Center

CHAPTER I

INTRODUCTION

1.1 Background problem and significance of the study

Changes in land use and land cover (LULC) are directly linked to the issues of the sustainability of social-economic system because they influence essential parts of human natural capitals, i.e., climate, soils, vegetation, water and biodiversity (Mather and Sdasyuk, 1991) mentioned by Khoi (2011). It is also considered as a central issue to sustainable development debate. The depletion of forests in developing countries, particularly tropical forests, has been of increasing concern to policy makers from the past until the present day. Thailand has developed rapidly, resulting in the expansion of services, tourism, transport, industry, commerce and agriculture. LULC change has been continuously transforming the essential functions of the Earth's terrestrial systems (Lambin, Rounsevell and Geist, 2000) and affecting to the structuring and functioning of ecosystems (Vitousek, Mooney, Lubchenco and Melillo, 1997). Furthermore, LULC change is one of the main driving forces of global environmental changes (Lambin, Rounsevell and Geist, 2000).

Forest resources are brought to exploitation to economic returns than the balance of the ecosystem. The cause results in the deforestation and degradation of forest resources, extinction of wildlife and various natural disasters, such as floods, droughts, landslides and so on (Siangwan, 2008). Deforestation is the conversion of forest to non-forest land. This process may be the result of the removal of forest cover for agricultural expansion or timber harvesting. It may lead to several environmental consequences that include changes in ecological, hydrological and climatic processes at both the local and global scales. It is occurring at an alarming rate in many parts of the world, especially in developing countries (Khoi, 2011).

From the statistics of the Royal Forest Department (RFD) in 2010, it was found that the existing forest cover of Thailand between 1973 and 2008 was continuously decreased (Table 1.1). In 1973 the existing forest area was about 43.21 per cent while it dropped to be 33.44 per cent in 2008.

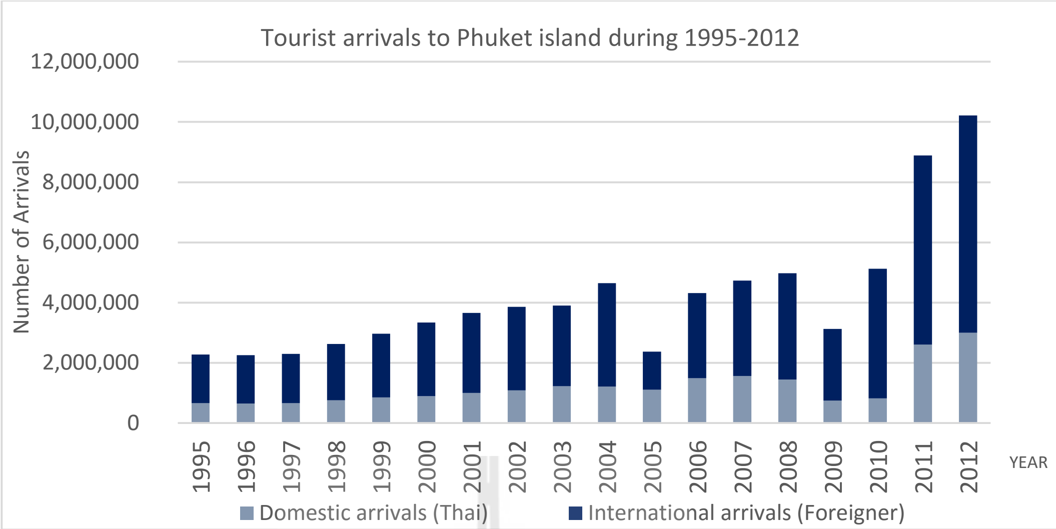
Table 1.1 Existing forest area in Thailand during 1973-2008.

Year	Forest area (sq. km)	Percentage	Map Scale
1973	221,707.00	43.21	1:250,000
1976	198,417.00	38.67	1:250,000
1978	175,224.00	34.15	1:250,000
1982	156,600.00	30.52	1:250,000
1985	150,866.00	29.40	1:250,000
1988	143,803.00	28.03	1:250,000
1989	143,417.00	27.95	1:250,000
1991	136,698.00	26.64	1:250,000
1993	133,554.00	26.03	1:250,000
1995	131,485.00	25.62	1:250,000
1998	129,722.00	25.28	1:250,000
2000	170,110.78	33.15	1:50,000
2004	167,590.98	32.66	1:50,000
2008	171,585.65	33.44	1:50,000

Source: The Royal Forest Department (2010).

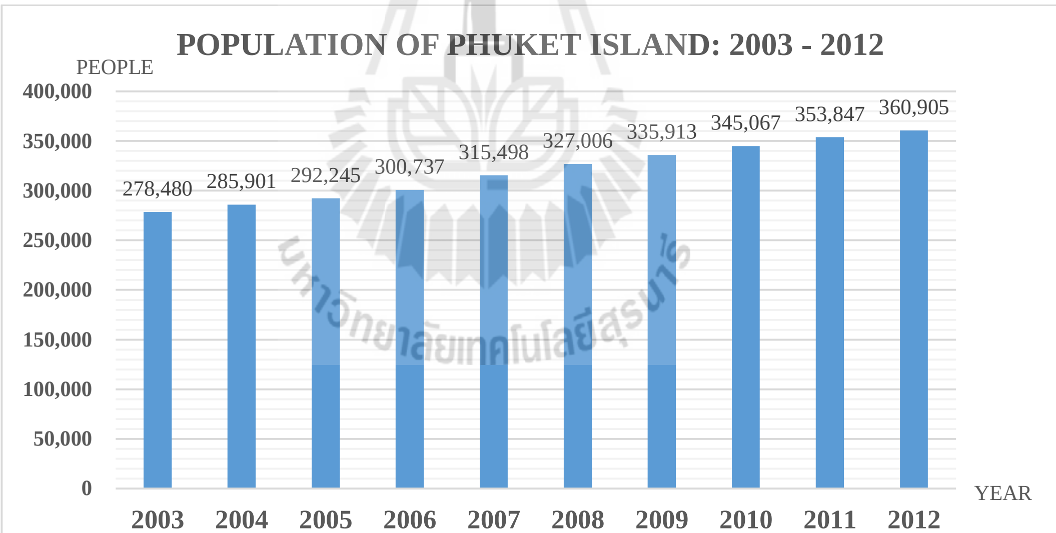
Meanwhile, the growth in tourism has often been supported by national or local government to expand its services to facilitate the expansion. Tourism development is one of the important economic activities used to promote economic growth in local communities (Kaosa-ard, 2007 cited in Untong, Kaosa-ard, Ramos, Sangkakorn and Rey-Maquieira, 2010). The development or promotion of local tourism also creates employment, income and tax revenue, as well as an opportunity to develop community infrastructure (Untong, 2006 cited in Untong et al., 2010). These benefits are often quoted as successful outcomes of local tourism development (Lawton, 2005; Lepp, 2007). In developing countries, the economic benefits of tourism development are often regarded as of primary importance (Ko and Stewart, 2002), while its social, cultural and environmental costs and impacts are of secondary importance (Bastias-Perez and Var, 1995). However, these tend to increase with increasing levels of local tourism development (Akis, Peristanis and Warner, 1996; Dyer, Gursoy, Sharma and Carter, 2007). Therefore, the primary goal of local tourism development is how to manage such development to achieve the highest level of benefits with least costs (Untong et al., 2010).

Phuket Island is one of Thailand's most popular and is home to an enormous community of the foreigner from all over the globe. Phuket has emerged as Thailand's strongest hotel market (LaSalle, 2013). Figure 1.1 presents the total number of domestic and international tourists between 1995 and 2012. Meanwhile, Phuket has a dramatically increased the number of population in the last decade (Figure 1.2). The island is a net importer of migrants, with a significant portion of the population coming over from the mainland.



Source: LaSalle (2013).

Figure 1.1 Tourist arrivals to Phuket Island during 1995-2012.



Source: Department of Provincial Administration, Ministry of Interior (2013).

Figure 1.2 Number of population of Phuket Island between 2003 and 2012.

As the largest source of income on the Phuket Island, tourism has great impact on the livelihood of the local community. The range of establishments necessary to successfully run the industry is astounding, including hotels, restaurants, entertainment, travel agencies, etc. There is also indirect employment through increased demand for transportation, communications, water supply, health care and others. On the other hand, the very activities that create these jobs, then negatively impact the resources that support non-tourism livelihoods. For example, the traditional fishermen on the island were previously able to move freely around the island as the best locations for fishing moved. With large beachfront resorts, they are restricted from certain areas and the fishing potential is limited. Another concern for the local community is that a traditional way of life is being eroded. The influx of tourists with foreign habits and new displays of wealth have been cited as factors in growing materialism among locals. These concerns are likely to continue, as the tourism industry is projected to continue growing, both in Phuket and Thailand as a whole. At the same time, domestic tourism increased, since many Thais can no longer afford to travel overseas as often as before (Raksakulthai, 2003).

In contrast, Sae-Tan (2013) mentioned that the growth of tourism has had positive impacts on both the local and national economy, the rapid expansion clearly does not come without risks or side effects. Changing and in some parts destroying the island's cultural and ecological heritage has come in leaps and bounds over only a few decades, but fixing past destruction may take generations.

Therefore, this study is to extract the series of LULC data and to apply geospatial models and techniques for LULC prediction and deforestation vulnerability analysis in protected forest areas (national parks and national reserved forest areas). Herewith, an optimum geospatial model and technique are here examined and applied to allocate forest protection units for national parks and national reserved forest areas due to LULC change in the future.

1.2 Research objectives

In this study, geospatial models (CA-Markov model, Land Change Modeler and CLUE-S model) and geospatial techniques (Frequency Ratio method and Logistic Regression Analysis) are applied for LULC prediction and deforestation vulnerability analysis, respectively. Specific objectives for the study are as follows:

(1) to assess LULC change in Phuket Island and its protected forest areas (national parks and national reserved forest areas) in three periods (1995-2002, 2002-2014 and 1995-2014);

(2) to identify an optimal geospatial model for LULC prediction of protected forest areas in Phuket Island;

(3) to examine an optimize geospatial technique for deforestation vulnerability analysis for protected forest areas; and

(4) to identify deforestation hotspot and allocate forest protection units for national parks and national reserved forest areas.

1.3 Definition, scope and limitations of the study

1.3.1 Definition of technical terms in the study

Relevant technical terms used in the study can be summarized as follows:

1) Protected forest area. Declared forest boundary by laws includes national park by National Parks Act B.E. 2504 (1961) and national reserved forest by National Reserved Forest Act, B.E. 2507 (1964) are defined as protected forest area.

2) National park is defined by National Parks Act B.E. 2504 (1961) as “land including mountain, rivulet, marsh, canal, swamp, waterway, lagoon, island and sea shore which is approved by the Minister for the purpose of protection and conservation of national park, making technical research, facilitating tourist or dwelling, or making security or delivering knowledge to people.”

3) National reserved forest area is defined by National Reserved Forest Act, B.E. 2507 (1964) as forest (“forest” means land including mountain, rivulet, marsh, canal, swamp, waterway, lagoon, island and sea shore in which nobody acquired by law) and determined to be national reserved forest under the law on forest protection and reservation.

4) Forest area is defined by DNP and RFD (2009) as any forest type such as evergreen forest, pine forest, mangrove forest, mixed deciduous forest, dry dipterocarp forest and beach forest which situate in national parks, wildlife sanctuary, national reserved forest and existing forest areas with area more than 0.5 hectare or 3.125 Rai and one tree at least 5 meters height and its crown cover more than 10 percent of the area.

5) Deforestation refers to land use change permanently from forest area to non-forest area. In this study, deforestation is extracted from evergreen and mangrove forest change using transitional LULC change matrix.

6) Deforestation vulnerability index. In general vulnerability is defined in the risk analysis and hazard assessment literature as the potential of loss (Dilley and Boudreau, 2001). Ii et al. (2003) defined vulnerability as "the degree to which a system, sub system, or system component is likely to experience harm due to exposure to hazard, either a perturbation or stress/stressor". In this study, deforestation

vulnerability index is the probability of vulnerable change from forest to be other LULC types by a human condition or process resulting from biophysical and socio-economic factors.

1.3.2 Scope of study

Scope of this study can be summarized as follows:

1) Three image datasets include black and white orthophotographs in 1995, color orthophotographs in 2002 and pan-sharpened THEOS image in 2014 are visually interpreted at the scale of 1:10,000 for LULC classification of protected forest areas (national parks and national reserved forest areas) in Phuket Island. Herewith, eleven LULC classes are extracted including (1) urban and built-up area (city and commercial, institutional land, industrial land, poultry farm house, airport and seaport), (2) paddy field, (3) field crop and horticulture (4) orchard and perennial trees, (5) aquaculture area, (6) idle land (7) evergreen forest, (8) mangrove forest, (9) scrub, (10) water body (natural and artificial) and (11) miscellaneous land (beach, soil pit, laterite pit and landfill). These results are used to assess and evaluate LULC change in Phuket Island and protected forest areas in specific periods. (1995-2002, 2002-2014 and 1995-2014) and to identify an optimum spatial model for LULC prediction in 2026 of protected forest areas and to develop an optimum geospatial technique for deforestation vulnerability analysis in protected forest areas.

2) An optimum geospatial model for LULC prediction from three selecting models (CA-Markov model, Land Change Modeler and CLUE-S model) is justified based on overall accuracy and Kappa coefficients comparison between predictive LULC data in 2014, which are derived from three models and the interpreted LULC in 2014 from THEOS data. The optimized geospatial model is then used to

predict LULC data in 2026. These results are used as a baseline information for deforestation hotspot identification and forest protection unit allocation of national parks and national reserved forest areas.

3) An optimum geospatial technique for deforestation vulnerability analysis from two selecting techniques (Frequency Ratios methods and Logistics Regression Analysis) is justified based on the relative operating characteristic (ROC) and Proportional Weighted Comparison between derived deforestation vulnerability index zonation based on deforested area between 1995 and 2002 and actual deforested areas between 2002 and 2014. The optimized geospatial technique is then used to construct deforestation vulnerability zonation based on deforested areas between 2002 and 2014. These results is also used as a baseline information for deforestation hotspot identification and forest protection unit allocation of national parks and national reserved forest areas.

Herewith, driving forces as biophysical and socio-economic factors for LULC change and deforestation based on literature reviews (Panayotou and Sungsawan, 1989; Tongpan, Panayotou, Jetanavanich and Mehi, 1990; TFSMP, 1993; Siangwan, 2008; Arekhi, 2011; and Khoi, 2011) are included elevation, slope, soil fertility, distance from road, distance from settlement, distance from water bodies, population density at sub-district and the average income of the population at sub-district. The classification system for each driving force are summarized in Table 1.2.

1.3.3 Limiting of the study

Due to limitation of historical LULC record in 1995 and 2002, only accuracy assessment of LULC in 2014 is performed.

Table 1.2 Classification system of driving factors for LULC change and deforestation.

Biophysical factors		Reference
Elevation	0-100 m 100-200 m 200-300 m 300-400 m > 400 m	Panayotou and Sungsawan, 1989; Tongpan, Panayotou, Jetanavanich and Mehi, 1990; TFSMP, 1993; Siangwan, 2008; Arekhi, 2011; and Khoi, 2011.
Slope	0-8% 8-16% 16-35% 35-60% > 60 %	Panayotou and Sungsawan, 1989; Tongpan, Panayotou, Jetanavanich and Mehi, 1990; TFSMP, 1993; Siangwan, 2008; Arekhi, 2011; and Khoi, 2011.
Soil fertility	Attribute from soil types	Siangwan, 2008
Distance from road	0-500 m 500-1,000 m 1,000-1,500 m 1500-2,000 m > 2,000 m	Panayotou and Sungsawan, 1989; Tongpan, Panayotou, Jetanavanich and Mehi, 1990; TFSMP, 1993; Siangwan, 2008; Arekhi, 2011; and Khoi, 2011.
Distance from settlement	0-500 m 500-1,000 m 1,000-1,500 m 1,500-2,000 m >2,000 m	Panayotou and Sungsawan, 1989; Tongpan, Panayotou, Jetanavanich and Mehi, 1990; TFSMP, 1993; Siangwan, 2008; Arekhi, 2011; and Khoi, 2011.
Distance from water bodies	0-500 m 500-1,000 m 1,000-1,500 m 1,500-2,000 m >2,000 m	Khoi, 2011
Socio-economic factor		**Reference**
Population density at sub-districts level	Person/sq. km	Panayotou and Sungsawan, 1989 Arekhi, 2011 Khoi, 2011
Average income of the population at sub-districts level	Baht/head/sq. km	TFSMP, 1993

1.4 Study area

Phuket Island is Thailand’s largest island at 522 sq. km, that have its 15 protected forest areas inclusion by 2 national parks (Sirinath Marine National Park, Khao Phra Thaeo Wildlife Conservation Development and Extension Center) and 6 national reserved forest areas in tropical evergreen forest (Khao Mai Kaew, Khao Bang Khanun, Khao Sam Liam, Khao Kamala, Khao Nak Keod, Khao Tosae) and 7 national reserved forest areas in mangrove forest (Khlong U-Tapao, Khlong Tha Maphrao, Khlong Para, Khlong Bangrong, Khlong Tarau, Khlong Tajin, Khlong Khopee) (Figure 1.3). All protected forest areas are chosen as study site with 2.5 kilometers buffering outward from boundary line. This buffer area is used to represent the effect of human interaction to national parks and national reserved forest areas. The chronological establishment of national parks and national reserved forest areas in Phuket Island is summarized in Table 1.3.

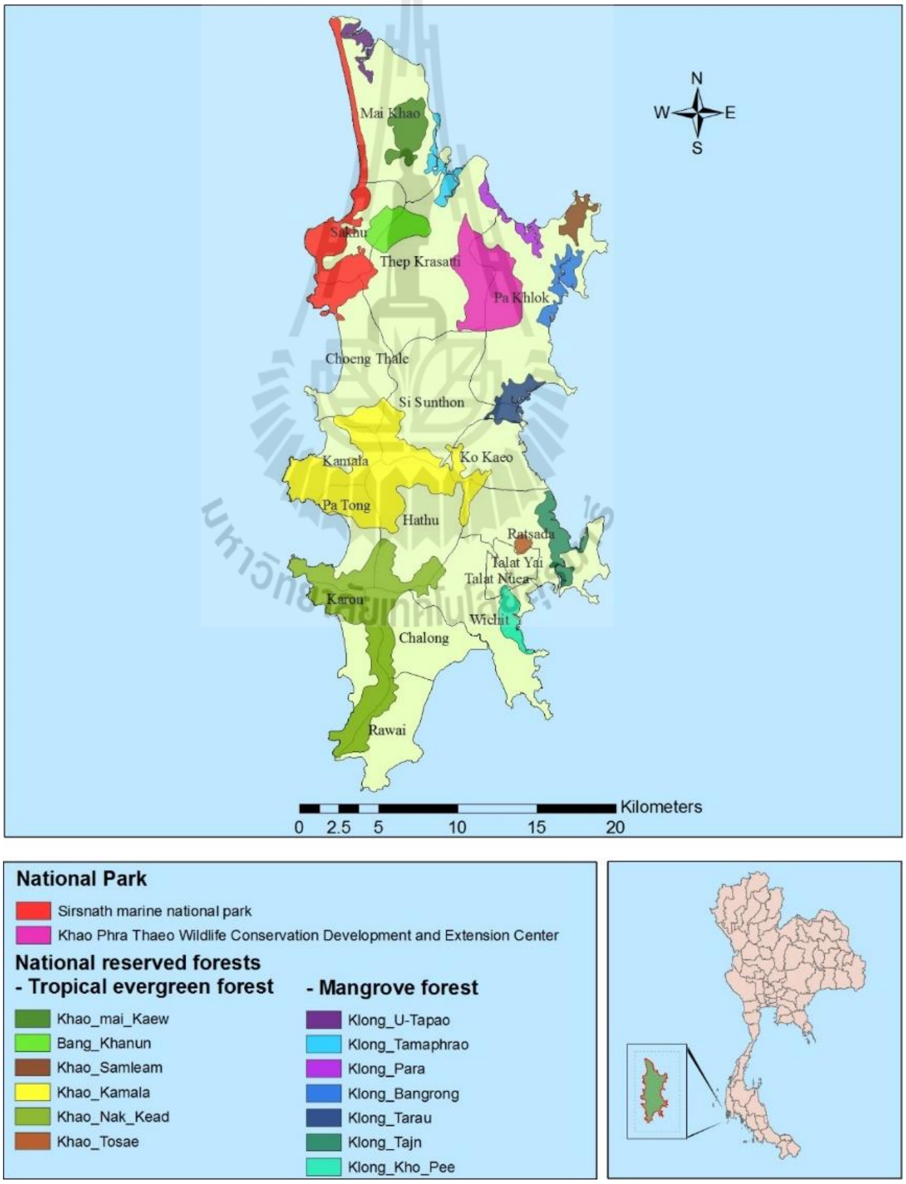


Figure 1.3 Study area in Phuket Island, Thailand.

Table 1.3 Development of the protected forest area in Phuket Island.

Protected forest area	Date of declaration	Area sq. km	Area Rai	Establishment by
Nai Yang MNP	13 July 1981	90.00	56,250	National Park Act 1961
Sirinath MNP	25 September 1990	94.48	59,050	National Park Act 1961
Khao Phra Thaeo Wildlife national park	September 1977	22.28	13,925	National Park Act1961
Khao Phra Thaeo WCDEC	8 Jul 1980	22.28	13,925	Wildlife Conservation and Protection Act 1992
Khao Mai Kaew NRF	27 February 1985	7.11	4,444	National Reserved Forest Act 1964
Khao Bang Khanun NRF	28 December 1945	8.00	5,000	Forest Act 1941
Khao Sam Liam NRF	6 June 1979	2.01	1,254	National Reserved Forest Act 1964
Khao Kamala NRF	22 January 1969	47.36	29,600	National Reserved Forest Act 1964
Khao Nak Keod NRF	26 November 1973	39.6	24,750	National Reserved Forest Act 1964
Khao Tosae NRF	25 October 1973	n. a	550	National Reserved Forest Act 1964
Khlong U-Tapao NRF	19 February 1964	2.49	1,556.25	National Reserved Forest Act 1964
Khlong Tha Maphrao NRF	26 September 1963	2.80	1,750	National Reserved Forest Act 1964
Khlong Para NRF	22 August 1963	3.75	2,343.75	National Reserved Forest Act 1964
Khlong Bangrong NRF	15 July 1968	6.22	3,887	National Reserved Forest Act 1964
Khlong Tarau NRF	5 November 1964	5.09	3,181	National Reserved Forest Act 1964
Khlong Tajin NRF	4 April 1958	6.30	3,937.50	National Reserved Forest Act 1964
Khlong Khopee NRF	26 November 1962	4.30	2,687.50	National Reserved Forest Act 1964

1.5 Benefits of the study

(1) The LULC status of Phuket Island and its protected forest areas and their changes;

(2) The optimum geospatial model for LULC prediction and LULC prediction of protected forest areas in 2026;

(3) The optimum geospatial technique for deforestation vulnerability analysis of protected forest areas and their deforestation vulnerability classification; and

(4) Deforestation hotspot and forest protection unit allocation of national parks and national reserved forest areas.

1.6 Outline of the thesis

The thesis is structured in two parts and follows a hierarchical organization (Figure 1.4). The first part includes Chapters I “Introduction”, Chapter II “Basic Concepts and Literature Reviews” and Chapter III “Equipment, Data and Methodology”. Meanwhile the second part includes Chapters IV “Land Use and Land Cover Assessment and Its Change and Deforestation”, Chapter V “Land Use and Land Cover Prediction”, Chapter VI “Deforestation Vulnerability Analysis”, Chapter VII “Deforestation Hotspot and Forest Protection Unit Allocation” and Chapter VIII “Conclusion and Recommendation”. Each chapter can be summarized as follows:

Chapter I contains background problem and significance of the study, research objectives, scope and limitations of the study, study area, benefits of the study and outline of the thesis.

Chapter II consists of basic concepts and literature reviews include cause of deforestation and its driving force, geospatial model for LULC prediction, geospatial technique for deforestation vulnerability analysis and literature reviews.

Chapter III reports about equipment and data and explains details of methodology including Component 1: LULC extraction and LULC change evaluation; Component 2: LULC prediction; Component 3: Deforestation vulnerability analysis and Component 4: Deforestation hotspot and forest protection unit allocation.

Chapter IV contains historical and recent LULC assessment, LULC change assessment between 1995 and 2014 and deforestation in protected forest area.

Chapter V explains about optimum geospatial model for LULC prediction, LULC prediction in 2026 and deforestation prediction between 2014 and 2026.

Chapter VI consists of optimum geospatial method for deforestation vulnerability analysis, deforestation vulnerability analysis and zonation and forest area in 2014 and deforestation vulnerability zonation.

Chapter VII contains deforestation hotspot allocation and forest protection unit allocation.

Chapter VIII "Conclusion and Recommendation" contains conclusion of the study and recommendation.

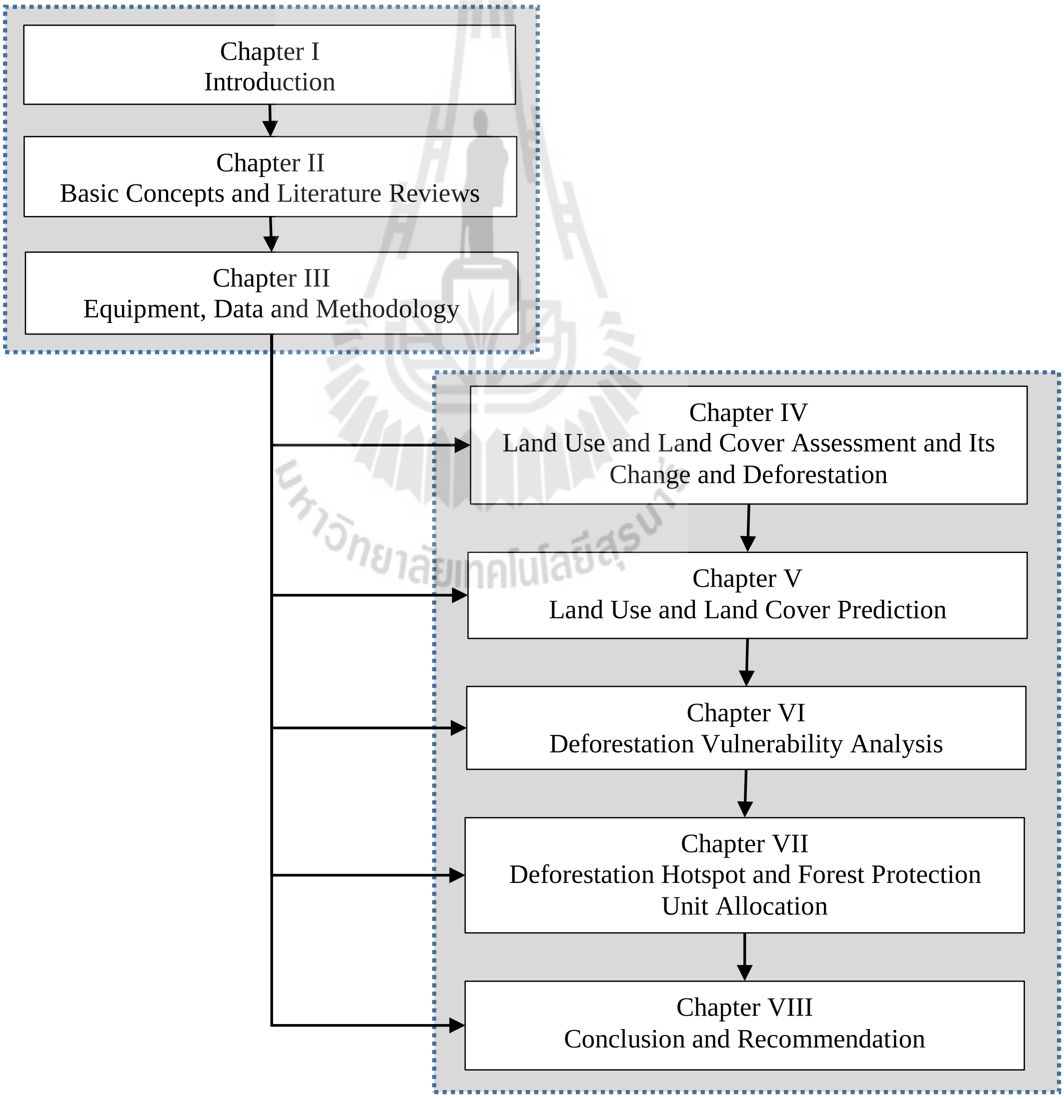


Figure 1.4 Structure of the thesis.

CHAPTER II

BASIC CONCEPTS AND LITERATURE REVIEWS

Basic concepts include (1) cause of deforestation and its factors, (2) geospatial model for LULC prediction (Cellular Automata Markov Model, Land Change Modeler and CLUE-S Model) and (3) geospatial technique for deforestation vulnerability analysis (Frequency Ratio Method and Logistic Regression Analysis) and literature reviews are here summarized.

2.1 Cause of deforestation and its driving force

Factors which contribute to deforestation is fairly extensive and complex, extending from population growth to expanding agricultural production for export. A study of deforestation in several Northeastern provinces cited population density, price of wood, poverty in term of real provincial Gross Domestic Product (GDP), road density, rice yield and distance from the market as central factors contributing to deforestation (Panayotou and Sungsawan, 1989 cited in Ongsomwang, 2002). A similar study in the same region cited poverty in term of real GDP per capita, population growth and the real price of cassava as the main causes (Tongpan, Panayotou, Jetanavanich and Mehi, 1990). Yet another study showed that the demand for agricultural land, which helps to explain the conversion of forest to agriculture, is positively related to the price of main crops and the numbers of the farm population and negatively related to agricultural productivity and degree of industrialization (Panayotou and Parasuk, 1990).

The two main underlying causes of deforestation in Thailand have been the increasing demand for land for agriculture to meet the needs of the growing population and commercial logging. Demand for land depends on land prices, agricultural productivity, prices of agricultural product and alternative sources of off-farm employment and income and population growth (TFSMP, 1993 cited in Ongsomwang, 2002). The intensity of logging, whether legal or illegal, is influenced by wood demand and prices, forest accessibility and population growth. The effects of these factors are probably as follows:

1) Land prices. There are no proper market or market prices for forest land since it belongs to the state, nevertheless land speculation is common close to growth centers. The implicit price of forest land is determined by the cost of clearing and transport, which the farmer would incur as long as the marginal cost is lower than the marginal benefits obtained from both the forest and the farm produce. Tourism has increased the price of forest and other land in prime tourist locations such as islands and near beaches.

2) Land productivity. As land productivity increases, the demand for land increases as forgers try to maximize profits. However, subsistence farmers need less land to meet basic food requirements. Conversely, if land productivity decreases, subsistence farmers need more land to support themselves, while profit-oriented farmers have less incentive to invest in new land. The aggregate of land productivity therefore dep(ends on the proportion of subsistence farmers to commercial or profit-oriented farmers.

3) Crop prices. Higher crop prices make it profitable to clear new land, some of which may have been economically inaccessible in the past. For commercial farmers, the effect of crop prices is similar to the effect of land productivity. Most of the agriculture expansion made possible by clearing forests has been aimed at increasing the production of upland cash crops.

4) Off-farm employment and income. Industrialization of the economy provides alternative income-earning opportunities and reduces the demand for land, in an open, diversified cash economy, food can always be purchased and exchanged for other good that are being produced.

5) Forest accessibility. The accessibility of the forest affects both logging and land cleaning through the profit maximizing behavior of the logger and the farmer. The most easily accessible forest is logged or cleared first and as time goes on, the remaining forest may simply become more and more economically inaccessible. This slows down deforestation, whereas the opening of new roads in connection with logging or infrastructure building increases the demand for new land.

6) Wood demand and prices. High demand for tropical hardwood for industrial or indigenous consumption and high wood prices are likely explain the high rate of deforestation, even if the logged-over areas had not been property regenerated. Logging probably had a greater effect on deforestation indirectly, by the construction of roads where made the forest easily accessible.

7) Population growth. Population acts as a demand shifter for new land or for more wood. In regions of high population density, one would expect the relative forest cover to be smaller, assuming the other factors to be equal.

Siangwan (2008) applied remote sensing and GIS for determining encroachment risk area of Khao Sanampriang Wildlife Sanctuary. The designation was also based on the fact that the targeted zones have been invaded. The study area was set up to determine the amount of physical factors that relies on the research papers and considering the condition of the area during the survey to collected data on land use in the field. Factors that contribute with outstanding changes in forest as following.

1) Slope. This factor is directly effects on the occupation of forested areas for agricultural land by invaders.

2) Elevation. The elevation above the mean se level of forested area related to deforestation.

3) Distance to road. This indicator implies the ease access to the forested area.

4) Distance from village. Forest area near the village as a place of residence can be easily deforested more than far away from the village.

5) Geological information. The geological units are related with LULC.

6) Soil type. Soil types will limit the use of land for agriculture.

2.2 Geospatial model for LULC prediction

In this study three predictive models include Cellular Automata Markov Model, Land Change Modeler and CLUE-S Model are here used to evaluate and to predict LULC in national parks. The summary of each model is described as following.

2.2.1 Cellular Automata Markov Model (CA- Markov Model)

The Markov chain analysis is a widely used technique for predictive LULC change modeling in landscape studies. Markov analysis is a statistical tool using transition probability matrix based on neighborhood effects in a spatial influence algorithm (Ilkwon, GwanYong, SooJin and John, 2011). One inherent problem with Markov is that it provides no sense of geography. The transition probabilities may be accurate on per category basis, but there is no knowledge of the spatial distribution of occurrences within each land use category (Ye and Bai, 2008 cited in Ilkwon et al., 2011). To solve this problem, CA (Cellular Automata)-Markov chain was developed to add a spatial dimension to the model using cellular automata. A cellular automaton is an agent or object that has the ability to change its state based upon the application of a rule that relates the new state to its previous state and its neighbor (Eastman, 2009).

Markov model

Markov model is a theory based on the process of the formation of Markov random process systems for the prediction and optimal control theory method (Jiang, Zhang and Kong, 2009 cited in Sang, Zhang, Yang, Zhu and Yun, 2011). The Markov model not only explains the quantification of conversion states between the land use types, but can also reveal the transfer rate among different land use types. It is commonly used in the prediction of geographical characteristics with no aftereffect event which has now become an important predicting method in geographic research. Based on the conditional probability formula Bayes, the prediction of LULC change is calculated by the following equation (Hou, Chang and Yu, 2004; Jiang, Zhang and Kong, 2009 cited in Sang et al., 2011):

$$S(t+1) = P_{ij} \times S(t), \tag{2.1}$$

where $S(t)$, $S(t+1)$ are the system status at the time of t or $(t+1)$; P_{ij} is the transition probability matrix in a state which is calculated as follows (Hou, Chang and Yu, 2004 cited in Sang et al., 2011):

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \dots & P_{1n} \\ P_{21} & P_{22} & \dots & P_{2n} \\ \dots & \dots & \dots & \dots \\ P_{n1} & P_{n2} & \dots & P_{nn} \end{bmatrix}, \tag{2.2}$$

$$\left(0 \leq P_{ij} < 1 \; and \; \sum_{j=1}^{N} P_{ij} = 1, (i, j = 1, 2, \dots, n)\right).$$

CA model

The behavior of CA models is affected by uncertainties arising from the interaction between model elements, structures and the quality of data sources used as the model input (Batty, Xie and Sun, (1999), Peterson, Bergen, Brown, Vashchuk and Blam, 2009). It focuses mainly on the local interactions of cells with distinct temporal and spatial coupling features and the powerful computing capability of space, which is especially suitable for dynamic simulation and display with self-organizing feature systems. The use of geographic cellular automata for LULC change simulations not only takes into account comprehensive consideration soil conditions, climatic conditions, topography and other natural factors, but also considers a comprehensive policy, economy, technology and other human factors and takes into account the historical trends of land use with strong applicability. The CA model can be expressed as follows (Hou, Chang and Yu, 2004 cited in Sang et al., 2011):

$$S(t, t+1) = f(S(t), (N)), \tag{2.3}$$

where S is the cellular finite discrete state set, t and $t+1$ are the mean different moments and f is the cellular transformation rule in local space.

CA-Markov model

CA–Markov is a combined Cellular Automata/Markov Chain/Multi-Criteria/Multi-Objective Land Allocation (MOLA) for land cover prediction method that adds an element of spatial contiguity as well as knowledge of the likely spatial distribution of transitions to Markov chain analysis (Sang et al., 2011).

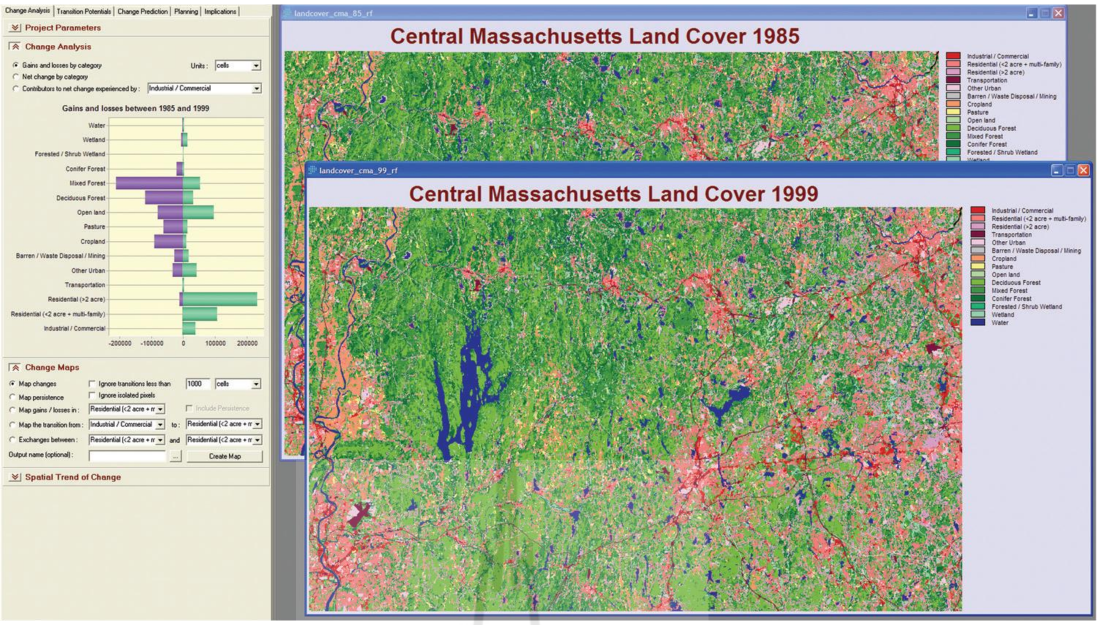
The Markov model focuses on the quantity in predictions for LULC change. For this model, the spatial parameters are weak and do not know the various types of LULC change in the spatial extents (Wickramasuriya, Bregt, van Delden and Hagen-Zanker, 2009). The CA model has a strong space conception, which is a strong capability of space time dynamic evolution with complex space systems. The CA-Markov model, which incorporates the theories of Markov and CA, is about the time series and space for the advantages of forecasting. It can achieve better simulation for temporal and spatial patterns of LULC change in quantity and space (Wang and Bao, 1999 cited in Sang et al., 2011). The CA-Markov module in IDRISI32 integrates the functions of cellular automaton filter and Markov processes, using conversion tables and conditional probability of the conversion map to predict the states of LULC change and it may be better to carry out LULC change simulations (Sang et al., 2011).

2.2.2 Land Change Modeler (LCM)

The LCM for Ecological Sustainability is an integrated software environment for analyzing land cover change, projecting its course into the future and assessing its implications for habitat and biodiversity change (Eastman, 2009). The LCM (available in IDRISI or as an Arc-GIS extension) is a suite of tools with which the LULC change analysis and modeling can be combined with biodiversity assessments. The change modeling module is based on Markov chain matrices and transition susceptibility maps obtained by logistic regression or by training learning machines (Eastman, 2009; Johnson, 2009). The LCM was applied to identify trends in LULC change (Václavík and Rogan, 2009), tropical deforestation (Khoi and Murayama, 2010), urban growth (Aguejdad and Houet, 2008), erosion under different conservation scenarios and habitat modeling (Gontier, Mortberg and Balfors, 2009).

Land Change Modeler is conducted under three modules of Land Change Modeler include: (1) change analysis, (2) transition potential, and (3) change prediction required for LULC prediction.

(1) Change analysis module. Two LULC dataset are used to calculate transitional LULC change matrix for loss and gain evaluation and change map generation (Figure 2.1).

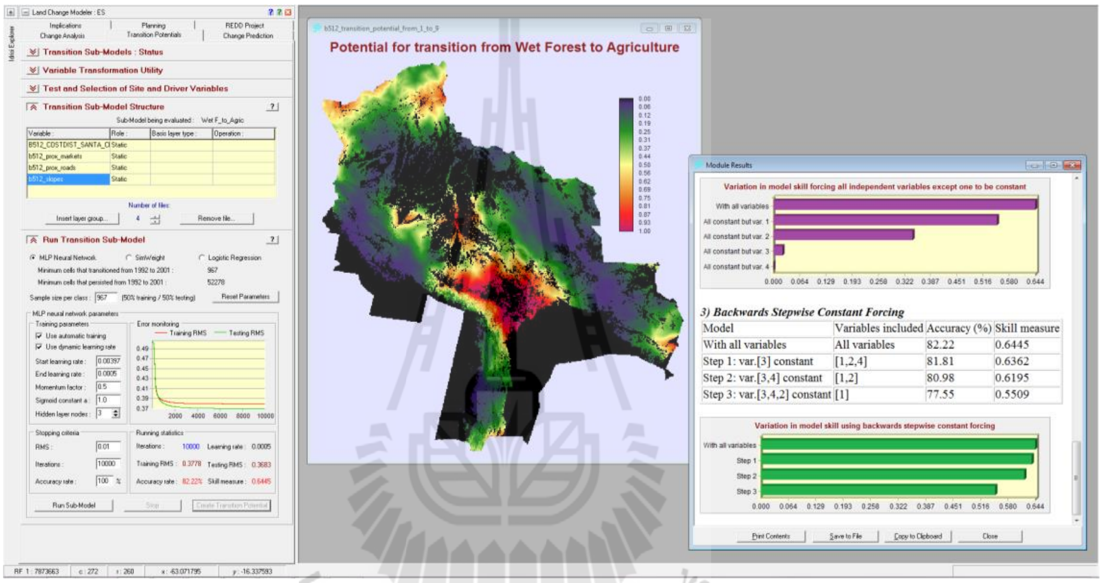


Source: Clark Labs., 2013

Figure 2.1 Change analysis module.

(2) Transition potential module. Potential for transitional change between LULC type are firstly identify to generate variable transformation with specific transformation type (e.g. evidence likelihood). Once such variables have been identified, the user selects the type of modeling procedure to extract the relationships between the land cover transitions and driver variables. Herein, a transition potential map as from-to change detection in specific time will be generated (Figure 2.2).

Currently three types of modeling procedure are available include Logistic Regression, Multi-Layer Perceptron (MLP) neural network and a similarity weighted instance-based learning algorithm called SimWeight. Logistic regression is a type of generalized linear model that uses a logit function to relate the presence and absence of change to a set of driver variables. MLP is a non-parametric algorithm that attempts to simulate how the human brain works and is capable of fitting complex nonlinear functions to find the relationship between change and explanatory variables. The SimWeight procedure is an instance-based machine learning algorithm, which generates transition potential based on the logic of a K-nearest neighbor algorithm. Although its performance is similar to that of MLP, it doesn't require extensive user-specified parameters (Clark Labs, 2013).

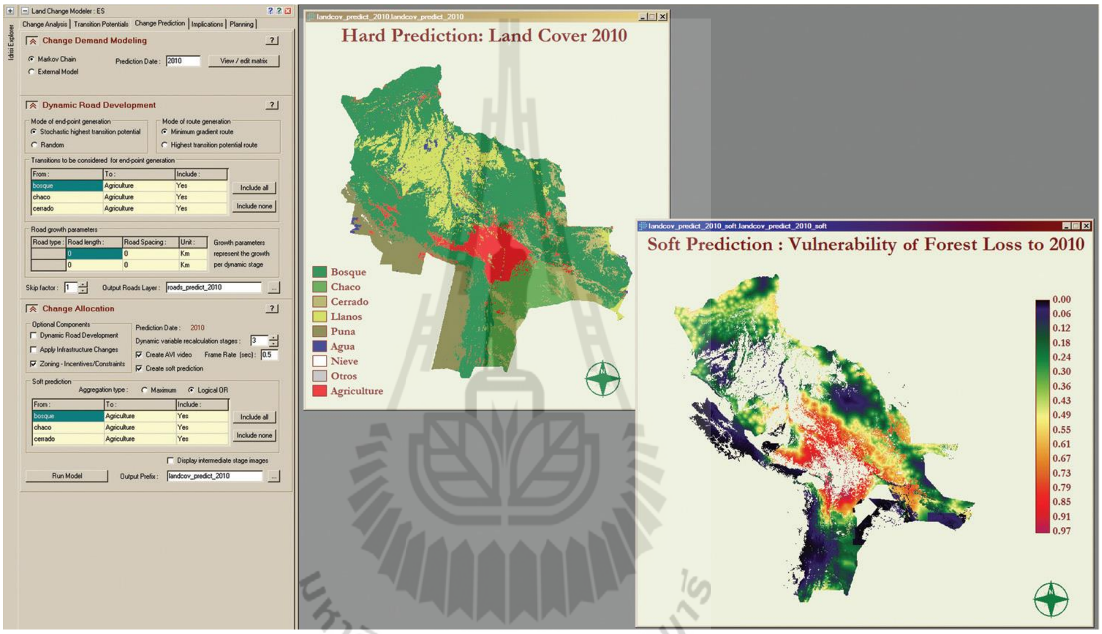


Source: Clark Labs., 2013

Figure 2.2 The transition potential modeling is one of the major components of land cover change prediction.

(3) Change prediction module. Under this module, LULC are predicted for specific period using change demand modeling (Markov chain) and change allocation conditions. After determining the drivers and quantities of change, it will be determined which locations would be more susceptible to experience these change. For the actual prediction output, LCM have the option of creating one scenario of change (hard prediction map) and one scenario of vulnerability to change (soft

prediction map) (Figure 2.3). The hard prediction map is based on a multi-objective land competition model that produces only one possible scenario. The soft prediction map is a continuous map of vulnerability to change for the selected set of transitions. The soft prediction model is generally preferred for habitat and biodiversity assessment since it provides a comprehensive assessment of change potential (Clark Labs, 2013).



Source: Clark Labs., 2013

Figure 2.3 Two output of LCM: a hard prediction map or a soft prediction map.

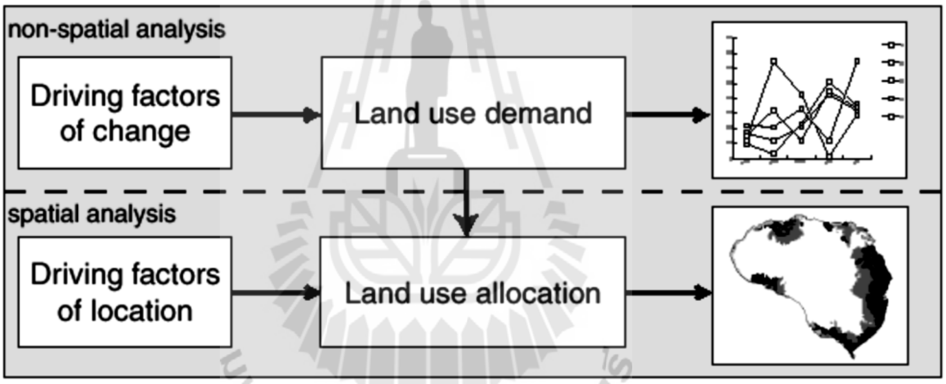
2.2.3 CLUE-S Model

The Conversion of Land Use and its Effects modelling framework (CLUE) was developed to simulate LULC change using empirically quantified relations between land use and its driving factors in combination with dynamic modelling of competition between land use types. The model was developed for the national and continental level and applications for Central America, Ecuador, China and Java, Indonesia are available. For study areas with such a large extent the spatial resolution for analysis was coarse and, as a result, each land use is represented by assigning the relative cover of each land use type to the pixels. Land use data for study areas with a relatively small spatial extent is often based on land use maps or remote sensing images that denote land use types respectively by homogeneous polygons or classified pixels. This results in only one dominant land use type occupying one unit of analysis. Because of the differences in data representation and other features that are typical for regional applications, the CLUE model cannot directly be applied at the regional scale. Therefore the modelling approach has been modified and is now called CLUE-S (the Conversion of Land Use and its Effects at Small regional extent). CLUE-S is specifically developed for the spatially explicit simulation of LULC change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems (Verburg, 2010).

The following basic characteristics of CLUE-S model include model structure, spatial policies and restrictions, land use type specific conversion settings, land use requirements (demand) and location characteristics are here summarized based on Verberg (2010).

Model structure

The model is sub-divided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure (Figure 2.4). The non-spatial module calculates the area change for all land use types at the aggregate level. Within the second part of the model these demands are translated into LULC change at different locations within the study region using a raster-based system. The user-interface of the CLUE-S model only supports the spatial allocation of LULC change. For the land use demand module different model specifications are possible ranging from simple trend extrapolations to complex economic models. The choice for a specific model is very much dependent on the nature of the most important land use conversions taking place within the study area and the scenarios that need to be considered. The results from the demand module need to specify, on a yearly basis, the area covered by the different land use types, which is a direct input for the allocation module.



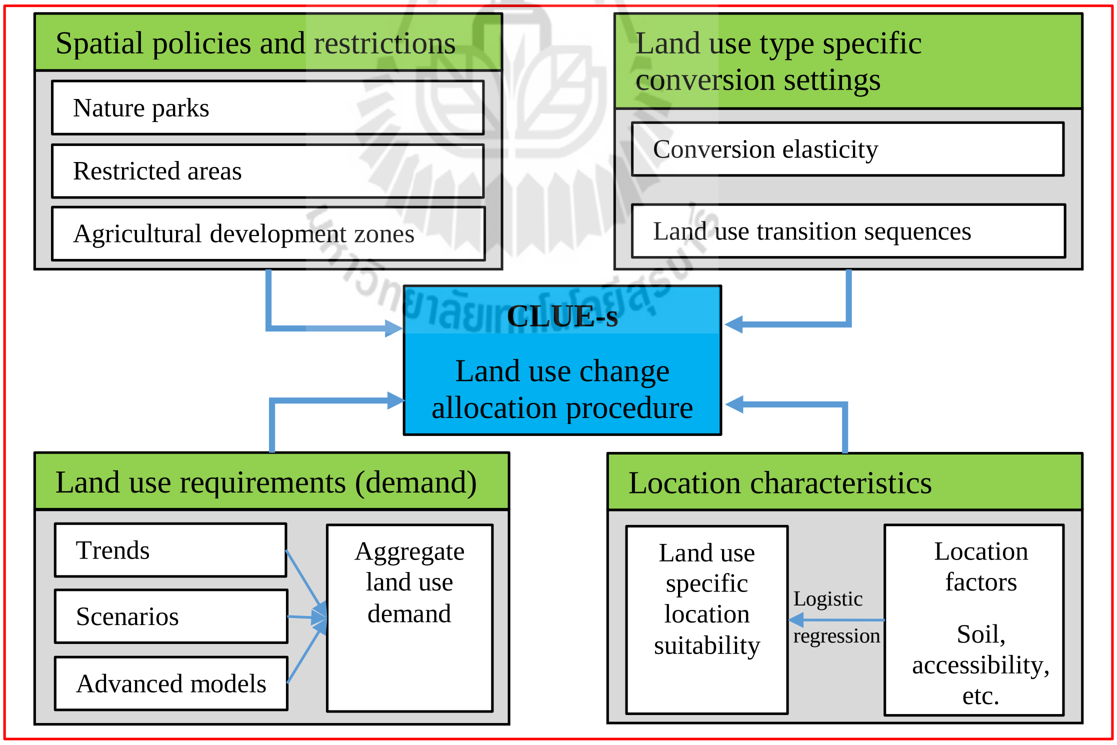
Source: Verburg, 2010

Figure 2.4 Overview of the CLUE-S modelling procedure.

The allocation is based upon a combination of empirical, spatial analysis and dynamic modelling (Verburg, 2010). Figure 2.5 gives an overview of the information needed to run the CLUE-S model. This information is subdivided into four categories: (1) spatial policies and restrictions, (2) land use type specific conversion settings, (3) land use requirement (demand) and (4) location characteristics that together create a set of conditions and possibilities for which the model calculates the best solution in an iterative procedure.

Spatial policies and restrictions

Spatial policies and land tenure can influence the pattern of LULC change. Spatial policies and restrictions mostly indicate areas where LULC change are restricted through policies or tenure status. For the simulation maps that indicate the areas for which the spatial policy is implemented must be supplied. Some spatial policies restrict all LULC change in a certain area, e.g., a log-ban within a forest reserve. Other land use policies restrict a set of specific land use conversions, e.g., residential construction in designated agricultural areas or permanent agriculture in the buffer zone of a nature reserve. The conversions that are restricted by a certain spatial policy can be indicated in a land use conversion matrix.



Source: Verburg, 2010

Figure 2.5 Overview of the information flow in the CLUE-S model.

Land use type specific conversion settings

Land use type specific conversion settings determine the temporal dynamics of the simulations. Two sets of parameters are needed to characterize the individual land use types: conversion elasticity and land use transition sequences. The first parameter set, the conversion elasticity, is related to the reversibility of LULC change. Land use types with high capital investment will not easily be converted in other uses as long as there is sufficient demand. Examples are residential locations but also plantations with permanent crops (e.g., fruit trees). Other land use types easily shift location when the location becomes more suitable for other land use types. Therefore, for each land use type a value needs to be specified that represents the relative elasticity to change, ranging from 0 (easy conversion) to 1 (irreversible change). The user should decide on this factor based on expert knowledge or observed behavior in the recent past.

The second set of land use type characteristics that needs to be specified are the land use type specific conversion settings and their temporal characteristics. These settings are specified in a conversion matrix. This matrix defines:

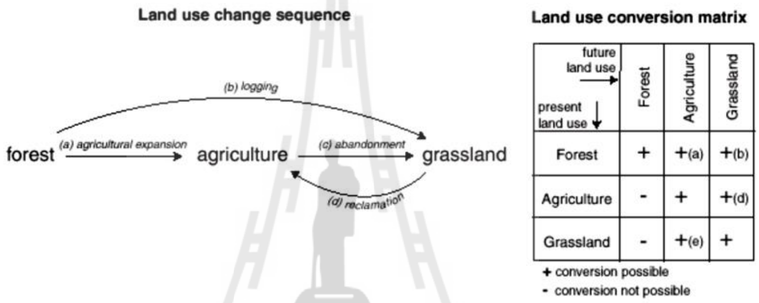
(1) To what other land use types the present land use type can be converted or not (Figure 2.6).

(2) In which regions a specific conversion is allowed to occur and in which regions it is not allowed.

(3) How many years (or time steps) the land use type at a location should remain the same before it can change into another land use type.

(4) The maximum number of years that a land use type can remain the same.

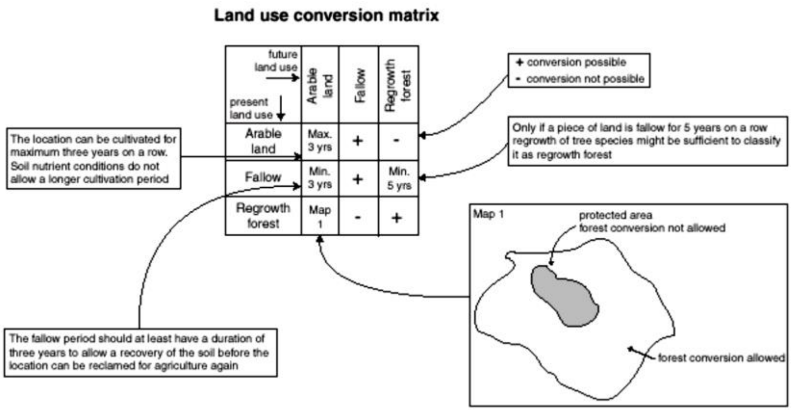
It is important to note that only the minimum and maximum number of years before a conversion can or should happen is indicated in the conversion table. The exact number of years depends on the land use pressure and location specific conditions. The simulation of these interactions combined with the constraints set in the conversion matrix will determine the length of the period before a conversion occurs. Figure 2.7 provides an example of the use of a conversion matrix for a simplified situation with only three land use types.



present land use / future land use	Forest	Agriculture	Grassland
Forest	+	+(a)	+(b)
Agriculture	-	+	+(d)
Grassland	-	+(e)	+

Source: Verburg, 2010

Figure 2.6 Illustration of the translation of a hypothetical LULC change sequence into a land use conversion matrix.



present land use / future land use	Arable land	Fallow	Regrowth forest
Arable land	Max. 3 yrs	+	-
Fallow	Min. 3 yrs	+	Min. 5 yrs
Regrowth forest	Map 1	-	+

Source: Verburg, 2010

Figure 2.7 Example of a land use conversion matrix with the different options implemented in the model.

Land use requirements (demand)

Land use requirements (demand) are calculated at the aggregate level (the level of the case-study as a whole) as part of a specific scenario. The land use requirements constrain the simulation by defining the totally required change in land use. All changes in individual pixels should add up to these requirements. In the approach, land use requirements are calculated independently from the CLUE-S model itself. The calculation of these land use requirements is based on a range of methods, depending on the case study and the scenario. The extrapolation of trends in LULC change of the recent past into the near future is a common technique to calculate land use requirements. When necessary, these trends can be corrected for changes in population growth and/or diminishing land resources. For policy analysis it is also possible to base land use requirements on advanced models of macro-economic changes, which can serve to provide scenario conditions that relate policy targets to LULC change requirements.

Location characteristics

Land use conversions are expected to take place at locations with the highest 'preference' for the specific type of land use at that moment in time. Preference represents the outcome of the interaction between the different actors and decision making processes that have resulted in a spatial land use configuration. The preference of a location is empirically estimated from a set of factors that are based on the different, disciplinary, understandings of the determinants of land use change. The preference is calculated as following:

$$R_{ki} = a_k X_{1i} + b_k X_{2i} + b_k X_{3i} + \cdots, \tag{2.4}$$

where R is the preference to devote location i to land use type $k, X_1, X_2, \ldots$ are biophysical or socio-economical characteristics of location i and a_k and b_k the relative impact of these characteristics on the preference for land use type k.

Although, the preference R_{ki} cannot be observed or measured directly and has therefore to be calculated has a probability (Verburg, 2010). The function, that relates these probabilities with the biophysical and socio-economic location characteristics, is defined in a statistical model can be developed as a binomial logit model of two choices: convert location *i* into land use type k or not. The preference R_{ki} is assumed to be the underlying response of this choice following:

$$log\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_{1i} + b_k X_{2i} + b_k X_{3i} + \cdots + \beta_n X_n. \qquad (2.5)$$

The regression coefficients (β's) are direct outputs of the regression calculations, P is probability for the occurrence of the considered land use type and X are the driving factors.

2.3 Geospatial technique for deforestation vulnerability analysis

Two vulnerability analysis techniques include Frequency Ratio (FR) method and Logistic Regression Analysis are here investigated for deforestation vulnerability index classification in this study. The summary of each technique is described as following.

2.3.1 Frequency Ratio (FR) method

Frequency ratio is the ratio of occurrence probability to non-occurrence probability for specific attributes (Vijith and Madhup, 2007). In the case of a landslide, if we set the landslide occurrence event to be represented by a factor, "A" and this factor's attributes are denoted by "B", then the frequency ratio of B is the conditional probability ratio. If this ratio is greater than l, then the relationship between a landslide and the factor's class or type is strong. If the ratio is less than l, then the relationship between a landslide and the factor's class or type is weak (Zezere et al., 2004; Lee and Sambath, 2006). The spatial relationship between a landslide occurrence location and each landslide-related factor was derived using the frequency ratio model. For calculating the frequency ratio, a contingency table was made for each of the landslide-related factors. Then the area ratio for landslide occurrence and non- occurrence was calculated for the class or type of each factor and the area ratio for class or type of each factor to total area was calculated. Finally, frequency ratios for the class or type of each factor were calculated by dividing the landslide-occurrence ratio by the area ratio (Vijith and Madhup, 2007).

For example, Pradhan and Lee (2010) used Frequency Ratio method to calculate landslide hazard index (LHI) as

$$LHI = Fr_1 + Fr_2 + Fr_3 + \cdots + Fr_n, \tag{2.6}$$

where LHI is landslide hazard index, Fr is rating of each factor type or range.

The landslide hazard value represents the relative hazard to landslide occurrence. So the greater the frequency ratio value, the higher the hazard to landslide occurrence and the lower the value, the lower the hazard to landslide occurrence. (See Table 2.1).

Table 2.1 Frequency ratio and logistic regression coefficient values for causative factors.

Factor	Class	Pixels in domain	Pixel, % (A)	Landslide occurrence points	Landslide occurrence points, % (B)	Frequency Ratio (B/A)	Coefficients of logistic regression
Slope	0–15º	1709800	57.87	53	11.45	0.20	0.0554
	16–25º	765189	25.90	152	32.83	1.27	
	26–35º	360229	12.19	157	33.91	2.78	
	>35º	119564	4.05	101	21.81	5.39	
Aspect	Flat	1199400	40.59	13	2.80	0.07	-1.7056
	North	206629	6.99	41	8.85	1.27	-0.0727
	Northeast	207860	7.03	51	11.01	1.57	0.1133
	East	228674	7.74	60	12.95	1.67	0.1479
	Southeast	236988	8.02	82	17.71	2.21	0.4637
	South	205108	6.94	58	12.53	1.80	0.2584
	Southwest	206970	7.01	52	11.23	1.60	0.1679
	West	228117	7.72	54	11.66	1.51	0.0322
	Northwest	235036	7.95	52	11.23	1.41	0.0000
Curvature	Concave	770757	26.09	50	10.80	0.41	-0.0001
	Flat	1419529	48.04	45	9.72	0.20	
	Convex	764496	25.87	368	79.48	3.07	
Distance from drainage	0–14 m	325460	11.01	21	4.54		0.0009
	20–36 m	347537	11.76	43	9.29		
	40–56 m	298382	10.10	61	13.17		
	58–76 m	285453	9.66	58	12.53		
	78–100 m	310971	10.52	48	10.37		
	101–130 m	296818	10.05	52	11.23		
	131–169 m	273396	9.25	48	10.37		
	170–222 m	275609	9.33	49	10.58		
	223–331 m	272270	9.21	55	11.88		
Distance from drainage	332-2,064m	268886	9.10	28	6.05	0.66	0.0009
Geology	Granite	2195706	76.65	461	99.57	2.29	1.0542
	Marine clay, sand and gravel	668834	23.35	2	0.43	0.02	-1.8516
Soil	Rengam-bukit temiang association	289450	10.03	96	20.73	2.07	10.9673
	Selangor-kangkong association	34197	1.18	0	0.00	0.00	0.6377
	Local alluvium-colluvium association	373655	12.94	13	2.81	0.22	10.0145
	Serong series	80436	2.79	0	0.00	0.00	0.5953
	Steep land	1506818	52.20	341	73.65	1.41	10.1995

Table 2.1 (Continued).

Factor	Class	Pixels in domain	Pixel, %[a]	Landslide occurrence points	Landslide occurrence points, %[b]	Frequency ratio[b/a]	Coefficients of logistic regression
Soil	Kuala kedah-permatang association	187057	6.48	0	0.00	0.00	2.7604
	Urban land	413813	14.33	13	2.81	0.20	9.9792
	Rengam	1329	0.05	0	0.00	0.00	0.0000
Distance from lineament	0–89 m	297410	10.07	45	9.72	0.97	0.0001
	90–180 m	307232	10.40	48	10.37	1.00	
	181–275 m	293932	9.95	62	13.39	1.35	
	276–377 m	294078	9.95	63	13.61	1.37	
	378–494 m	294927	9.98	54	11.66	1.17	
	495–640 m	294365	9.96	54	11.66	1.17	
	641–841 m	294059	9.95	74	15.98	1.61	
	842–1,150 m	292980	9.92	50	10.80	1.09	
	1,151–1,777 m	293193	9.92	13	2.81	0.28	
	1,778–5,317 m	292606	9.90	0	0.00	0.00	
Land cover	Water Body	73106	2.49	1	0.23	0.09	0.0000
	Settlement	678841	23.15	45	10.27	0.44	0.9230
	Forest	1468084	50.07	295	67.35	1.35	0.4509
	Urban	205767	7.02	17	3.88	0.55	0.6901
	Bare Land	60200	2.05	24	5.48	2.67	0.7638
	Agriculture	446124	15.22	56	12.79	0.84	0.9315
NDVI	-73–18	291092	10.05	33	7.13	0.71	-0.0168
	-17–1	300254	10.37	31	6.70	0.65	
	2–21	297248	10.26	47	10.15	0.99	
	22–32	315879	10.91	48	10.37	0.95	
	33–37	358384	12.37	44	9.50	0.77	
	38–40	322673	11.14	61	13.17	1.18	
	41–43	373180	12.89	57	12.31	0.96	
	44–45	226395	7.82	54	11.66	1.49	
NDVI	46–48	242836	8.38	45	9.72	1.16	-0.0168
	49–61	168249	5.81	43	9.29	1.60	
Precipitation	2,613–2,651 mm	310554	10.51	39	8.42	0.80	0.0052
	2,652–1,676 mm	305133	10.33	13	2.81	0.27	
	2,677–2,695 mm	298684	10.11	31	6.70	0.66	
	2,696–2,707 mm	298405	10.10	24	5.18	0.51	
	2,708–2,718 mm	292410	9.90	49	10.58	1.07	
	2,719–2,730 mm	292990	9.92	44	9.50	0.96	
	2,731–2,742 mm	293306	9.93	41	8.86	0.89	
	2,743–2,753 mm	293819	9.94	73	15.77	1.59	
	2,754–2,763 mm	293702	9.94	68	14.69	1.48	
	2,764–2,772 mm	275779	9.33	81	17.49	1.87	

Source: Pradhan and Lee (2010)

2.3.2 Logistic Regression Analysis

Regression is a method to discover the empirical relationships between a binary dependent and several independent categorical and continuous variables (McCullagh and Nelder, 1989 cited in Arsanjani, Helbich, Kainz and Boloorani, 2013). There are two basic approaches to assess spatial dependency within a regression framework: firstly, building a more complex model incorporating, e.g., an autoregressive structure (Anselin, 1988 cited in Arsanjani et al., 2013) and, secondly, designing a spatial sampling plot to enlarge the distance interval between sampled points. Spatial sampling leads to a smaller sample size that loses certain information and conflicts with the large sample of asymptotic normality of maximum likelihood method, upon which logistic regression is based. In general, systematic sampling and stratified random sampling are two approved sampling methods in logistic regression. Systematic sampling reduces spatial dependency, whereas random sampling is capable of representing population, but does not efficiently reduce spatial dependency, local spatial dependency in particular (Huang, Zhang and Wu, 2009). Nonetheless, it is a reasonable approach to eliminate spatial autocorrelation and a reasonable design of a spatial sampling scheme will provide an ideal balance between the two sides (Xie, Huang, Claramunt and Chandamouli, 2005). Hence, the stratified random sampling technique was chosen (Arsanjani et al., 2013).

Pradhan and Lee (2010) explored logistic regression allows one to form a multivariate regression relationship between a dependent variable and several independent variables. Logistic regression, which is a multivariate analysis model, is useful for predicting the presence or absence of a characteristic or outcome based on values of a set of predictor variables. The advantage of logistic regression is that, through addition of an appropriate link function to the usual linear regression model, the variables may be either continuous or discrete, or any combination of both types and they do not necessarily have normal distributions. In the case of multi-regression analysis, the factors must be numerical and in the case of discriminant analysis, the variables must have a normal distribution. In the current situation, the dependent variable is a binary variable representing presence or absence of landslide. Where the dependent variable is binary, the logistic link function is applicable (Atkinson and Massari 1998). For this study, the dependent variable must be input as either 0 or 1, so the model applies well to landslide possibility analysis. Logistic regression coefficients can be used to estimate ratios for each of the independent variables in the model.

Quantitatively, the relationship between the occurrence and its dependency on several variables can be expressed as:

$$P = \frac{1}{1+e^{-Z}}, \tag{2.7}$$

where P is the probability of an event occurring. In this situation, the value P is the estimated probability of landslide occurrence. The probability varies from 0 to 1 on an S-shaped curve and Z is the linear combination. It follows that logistic regression involves fitting an equation of the following form to the data:

$$Z = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_nx_n, \tag{2.8}$$

where b_0 is the intercept of the model, the b_i $(i = 0; 1; 2; 3; \ldots; n)$ are the slope coefficients of the logistic regression model and the x_i $(i = 0; 1; 2; 3; \ldots; n)$ are the independent variables. The linear model formed is then a logistic regression of the presence or absence of landslides (present conditions) on the independent variables (pre-failure conditions).

For example, Pradhan and Lee (2010) applied logistic regression model to assess the spatial relationship between landslide-occurrence and factors affecting landslides in Penang Island, Malaysia. In their study, the spatial databases of each factor were converted to ASCII format files to be used in the statistical package SPSS. The correlations between landslide and each factor were calculated. The "continuous data" such as slope, curvature, distance from drainage, distance from lineament, NDVI and precipitation were treated as "scale" in SPSS whereas aspect, land cover, geology and soil layer were taken as "nominal" data. The logistic regression coefficient for each of the thematic layers was computed, where each of the continuous thematic layers have only single coefficient values and, on the other hand, nominal or discrete thematic layers show coefficients for each discrete class (See Table 2.1). Finally, the probability that predicts the possibility of landslide occurrence was calculated using the spatial database, data from Table 2.1 and Equations 2.7 and 2.8.

2.4 Literature reviews

The literature reviews relate to this study are here summarized concluding the CA-Markov Model, the Land Change Modeler, the CLUE-S Model, the Frequency Ratio and the Logistic Regression Analysis.

2.4.1 CA-Markov Model

Peterson et al. (2009) applied remote sensing observations over areas of the former Soviet Union suggested that there may be important ongoing influences on forested landscapes resulting from divergent land use and forest management associated with the Soviet versus post-Soviet eras. As the Russian Federation implements its new Forest Code and associated regulations, knowledge of existing forest patterns and trends, plus the development of methods with which to understand the landscape-level influence of different forest management strategies is increasingly important. They developed spatial–temporal models and projections of forest patterns and trends over Soviet and early post-Soviet forest management eras for a study site in the Lake Baikal region in southern Siberia. They used Landsat-derived land-cover data, logistic regressions and CA-Markov methods to characterize patterns and trends 1975–1989 and 1990–2001 and to develop predictive scenarios through 2013. Relationships of forest types (Conifer, Mixed and Deciduous) and Agriculture to other explanatory environmental variables indicated mostly consistent forest environment relationships, but some different spatial relationships between eras were found for Cut and Regeneration disturbance types. Landscape proportional trends showed greater differences between eras. Cut proportions observed via Landsat in 2001 were approximately 74% lower and the area of Conifer observed was approximately 14% higher, than modeled proportions predicted for 2001 using 1975–1989 Soviet era transition rates. The proportion of Cut projected for 2013 was about 80% lower when based on early post-Soviet era probabilities. Overall, modeled results indicate that should early post-Soviet trends continue, low rates of logging, some agricultural abandonment, regrowing forests especially near access routes, increases in deciduous cover, along with continued or increased fire events in mixed and conifer forests will define the landscape. Should forest management change, for example to Soviet era rates and patterns of harvest, different outcomes are projected. More broadly, results highlight the real and prospective effects that divergent management strategies can have on forested landscapes and demonstrate that land-cover data combined with emerging spatial temporal modeling methods provide an approach to understand and project the complex and ongoing influences associated with changing forest management at landscape scales.

Arsanjani et al. (2013) applied this research analyses the suburban expansion in the metropolitan area of Tehran, Iran. A hybrid model consisting of logistic regression model, CA-Markov model was designed to improve the performance of the standard logistic regression model. Environmental and socio-economic variables dealing with urban sprawl were operationalized to create a probability surface of spatiotemporal states of built-up land use for the years 2006, 2016 and 2026. For validation, the model was evaluated by means of relative operating characteristic values for different sets of variables. The approach was calibrated for 2006 by cross comparing of actual and simulated land use maps. The achieved outcomes represent a match of 89% between simulated and actual maps of 2006, which was satisfactory to approve the calibration process. Thereafter, the calibrated hybrid approach was implemented for forthcoming years. Finally, future land use maps for 2016 and 2026 were predicted by means of this hybrid approach. The simulated maps illustrate a new wave of suburban development in the vicinity of Tehran at the western border of the metropolis during the next decades.

2.4.2 Land Change Modeler

Islam and Ahmed (2011) applied Land Change Modeler to evaluate the LULC change in Dhaka City based on the need and purpose to predict future scenario of Dhaka City. Dhaka being a mega city has been challenged by numerous difficulties like unplanned urbanization, traffic congestion, water logging etc. Land use classification and analysis is performed using a GIS and Remote sensing technique and GIS aided "Markov Cellular Automata" technique is used to model the LULC change. Based on the past trend (from 1991 to 2008) of LULC change, the future land use map of Dhaka city for the year of 2020 and 2050 has been generated. And collected maps and images were sorted and classified for analysis and interpretation. Landsat TM image of 1991 and Google image of 2008 were employed in that study to produce land use classification based on Anderson modified version method. IDRISI's Land Change Modeler (LCM) was used to analyze the land use/cover changes between various classes during the period 1991-2008. It is assumed that this kind of research will contribute to shaping the urban form of the city in a planned manner. So, that Dhaka can be a much more livable and planned city in near future.

Nagabhatla, Finlayson and Sellamuttu (2012) applied the two components of the study reflect assessment and change analysis of a tropical wetland in Sri Lanka. The first section explains spatial classification using pixel level-disaggregated image analysis and refined aggregated image analysis and comparison of information extracted by all methods to analyze a better classifier. The second section illustrates change analysis calibrating the land change modeler (LCM) [IDRISI-Andes]. Key observations: a) visual interpretation provides comprehensive blueprint of the wetland scape compared to supervise and unsupervised classifiers b) change in landscape pattern reflect substantial transition in wetland use. Validation using field coordinates and socioeconomic data showed kappa value (%) of 87.

2.4.3 CLUE-S Model

Verburg, Overmars, Huigen, de Groot and Veldkamp (2006) discussed and illustrated the role of LULC change modeling approaches with CLUE-S model for assessing the threats and trade-offs of protecting the designated nature areas. At the national level different scenarios of LUCC and implementation of the protected area policy are evaluated and discussed based on a spatially explicit land use allocation model. For one of the main national parks, the Northern Sierra Madre Nature Park, a detailed analysis is presented based on in-depth knowledge of the region. Furthermore, deforestation and forest degradation are the most important LUCC processes in the Philippines. These processes are an important threat to the highly rated biodiversity of the country. Only a small fraction of the natural forest that once covered the country remains. In spite of different policies that aim to reduce logging recent commercial deforestation, illegal logging and agricultural expansion pose an important threat to the remaining forest areas. The two modeling approaches discussed in this paper aim at different scales and provide complementary types of information to support the planning and management of nature conservation strategies. The combination of LUCC analysis at different scales respects the hierarchical organization of the land use system and addresses different levels of protected area management. The results indicate that LUCC models are useful tools to inform protected area management as long as the selection of the model approach is based on the research and policy questions at the appropriate scale.

Erdogan, Nurlu and Erdem (2011) used CLUE-S for land use changes modelling of Karaburun Peninsula. In the research, the model was calibrated using historical data describing the land use patterns between 1984 and 2010. Land use maps for these dates were derived from LANDSAT TM images. The validation process based on multiple resolution technique shows the ability of the CLUE-S model to predict the land-use changes at the research area. Scenario for future development was defined based on Environmental Plan for Manisa-Kutahya-Izmir Planning Region. Demand of land use classes for 2025 was determined according to the plan. Land use changes were modelled between 2010 and 2025.

2.4.4 Frequency Ratio

Karim, Jalileddin and Ali (2011) claimed that landslide study is one of the important issues in development of projects including construction of dams, setting up highways, development towns and villages, construction of industrial facilities and water channels. In the study, zoning landslides of Deylaman region, Siah-kal, in the East of Guilan province has been investigated. At first, by field views, the ground truth map of landslide was prepared and crossed by each of lithology, distance from faults, distance from roads, slope, aspect, land cover and precipitation layers in GIS. For zoning landslide, the Frequency Ratio (FR) method was used. Results showed that slope aspect and land use were the most important factors in the occurrence of landslides in Deylaman region. Finally, the zoning map of landslide risk were classified in five categories including very high, high, moderate, low and very low risk classes.

Pradhan and Lee (2010) summarized findings of landslide hazard analysis on Penang Island, Malaysia, using frequency ratio, logistic regression and artificial neural network models with the aid of GIS tools and remote sensing data. A SPOT 5 satellite pan sharpened image acquired in January 2005 was used for land-cover classification supported by a topographic map. The above digitally processed images were subsequently combined in a GIS with ancillary data, for example topographical (slope, aspect, curvature, drainage), geological (litho types and lineaments), soil types and normalized difference vegetation index (NDVI) data and used to construct a spatial database using GIS and image processing. Three landslide hazard maps were constructed on the basis of landslide inventories and thematic layers, using frequency ratio, logistic regression and artificial neural network models. Further, each thematic layer's weight was determined by the back-propagation training method and landslide hazard indices were calculated using the trained back-propagation weights. The results of the analysis were verified and compared using the landslide location data and the accuracy observed was 86.41, 89.59 and 83.55% for frequency ratio, logistic regression and artificial neural network models, respectively.

2.4.5 Logistic Regression Analysis

Mon, Mizoue, Htun, Kajisa and Yoshida, (2012) stated that deforestation and forest degradation in the tropics have importance to the global carbon budget and biodiversity conservation disproportionately greater than the area concerned. Many studies have examined the patterns and processes of deforestation, but information about factors influencing forest degradation is still limited. In their study, they examined the factors influencing both deforestation and forest degradation in production forests of the central Bago Mountain area, Myanmar, which have been managed under the Myanmar Selection System (MSS) since 1856. They used forest canopy density maps derived from 1989 and 2006 satellite imagery together with environmental factors, locational attributes and selective logging records in logistic regression models. Their results showed that elevation and distance to the nearest town strongly influenced the likelihood of both deforestation and forest degradation, while logging intensity and distance to the nearest village were correlated only with the likelihood of forest degradation and not deforestation. They concluded that selective logging in the study area did not cause forest degradation provided that logging intensity was below the allowable cut prescribed under the MSS, but above that intensity, the likelihood of forest degradation was markedly increase.

Arekhi (2011) applied logistic regression to predict spatial distribution of deforestation and detects factors influencing forest degradation of Northern forests of Ilam province, Iran. In the study, effects of six factors including distance from road and settlement areas, forest fragmentation index, elevation, slope and distance from the forest edge on the forest deforestation were studied. In order to evaluate the changes in forest, images related to TM 1988, ETM+2001 and ETM+2007 were processed and classified. In order to assess deforestation factors, forest and non-forest classes were applied. The logistic regression method is used for modeling and estimating the spatial distribution of deforestation. The results showed that about 19,294 ha of forest areas were deforested within 19 years. Modeling results also indicated that more deforestation occurred in the fragmented forest cover and in the areas of proximity to forest/non forest edge. Furthermore, slope and distance from road and settlement areas had negative relationships with deforestation rates. Meanwhile, deforestation rate was decreased with increasing elevation. Finally, a simple spatial model was presented that it was able to predict the location of deforestation by using logistic regression. The validation was also tested using ROC approach which was found to be 0.96.

CHAPTER III

EQUIPMENT, DATA AND METHODOLOGY

Equipment, data and details of research methodology including LULC extraction and LULC change evaluation, LULC prediction, deforestation vulnerability analysis and deforestation hotspot and forest protection unit allocation are here explained in this chapter.

3.1 Equipment

Equipment include hardware and software are summarized as below:

- Garmin Handheld GPS Model Oregon 450,
- Desktop Computer, Notebook,
- Digital camera,
- ERDAS Imagine (image rectification, change detection analysis),
- ESRI ArcMap (visual interpretation, spatial analysis, geoprocessing and deforestation vulnerability analysis using Frequency Ratio),
- IDRISI (LULC prediction with CA-Markov model, Land Change Modeler and deforestation vulnerability analysis using logistic regression analysis, ROC operation),
- CLUE-S (LULC prediction), and
- SPSS software (logistic regression analysis for CLUE-S model).

3.2 Data

Collection and preparation data include remotely sensed data and GIS data is summarized in Table 3.1.

3.3 Research methodology

Overview framework of research methodologies include Component 1: LULC extraction and LULC change evaluation; Component 2: Optimum geospatial model identification and LULC prediction; Component 3: Deforestation vulnerability analysis and zonation and Component 4: Deforestation hotspot and forest protection unit allocation is displayed in Figure 3.1. Detail of each component is separately described in the following sections.

Table 3.1 List of data collection and preparation for analysis and modeling in the study.

Data	Data collection	Data Preparation	Source	Component
Remote Sensing	B&W orthophoto data in 1995	Geometric correction	MNRE	1
	Color orthophoto data in 2002	(Reference data)	LDD	1
	THEOS data in 2014	Geometric correction	GISTDA	1
GIS Data	Administrative boundary	-	DEQP	1, 2, 3 and 4
	National parks	-	DNP	1, 2, 3 and 4
	National reserved forest	-	RFD	1, 2, 3 and 4
	LULC in 2002	-	OAE	1
	Contour line with 2 meters interval	DEM creation with 25 x 25 m	DPT	2 and 3
	Elevation (m)	Create from DEM		2 and 3
	Slope (%)	Create from DEM		2 and 3
	Distance from road (m)	Buffering	PSO of MOT	2 and 3
	Distance from settlement (m)	Buffering	LULC data	2 and 3
	Distance from water body (m)	Buffering	LULC data	2 and 3
	Soil (soil fertility)	-	LDD	2 and 3
	Population density (People/sq. km)	Calculation from population by sub-district area	DOPA	2 and 3
	The average income of the population (baht/person/sub-district)	Calculation from personal income by sub-district area	CDD	2 and 3

Note: MNRE: Ministry of Natural Resources and Environment; LDD: Land Development Department; GISTDA: Geo-Informatics and Space Technology Development Agency; DEQP: Department of Environmental Quality Promotion; DNP: Department of National Parks, Wildlife and Plant Conservation; RFD: Royal Forest Department; OAE: Office of Agricultural Economics; DPT: Department of Public Work and Town & Country Planning (Phuket); PSO of MOT: Permanent Secretary Office, Ministry of Transport; DOPA: Department of Province Administration; CDD: Community Development Department.

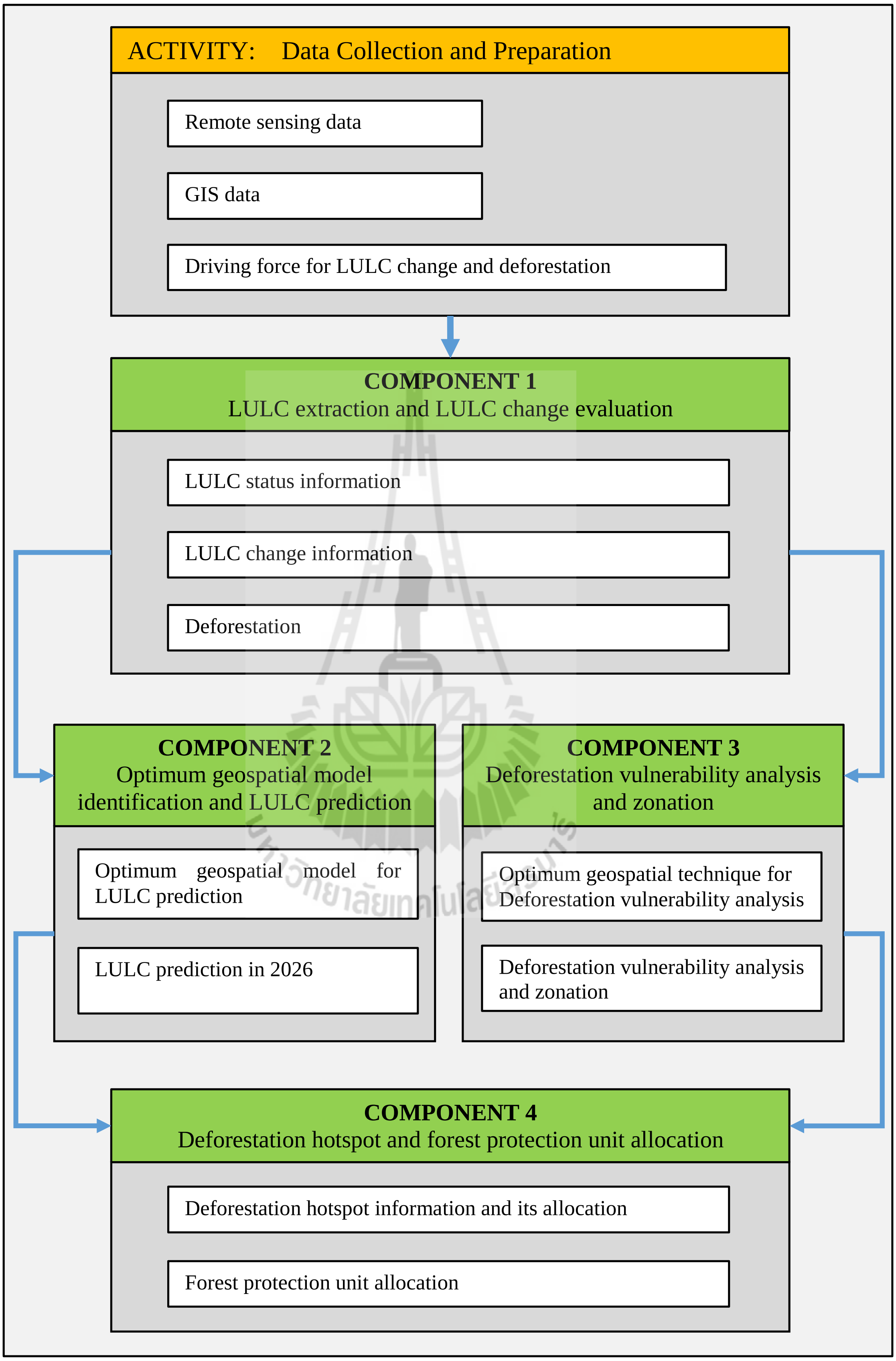


Figure 3.1 Overview framework of research methodology.

3.3.1 LULC extraction and LULC change evaluation

Workflow of the Component I: LULC extraction and LULC change evaluation is displayed as schematic diagram in Figure 3.2.

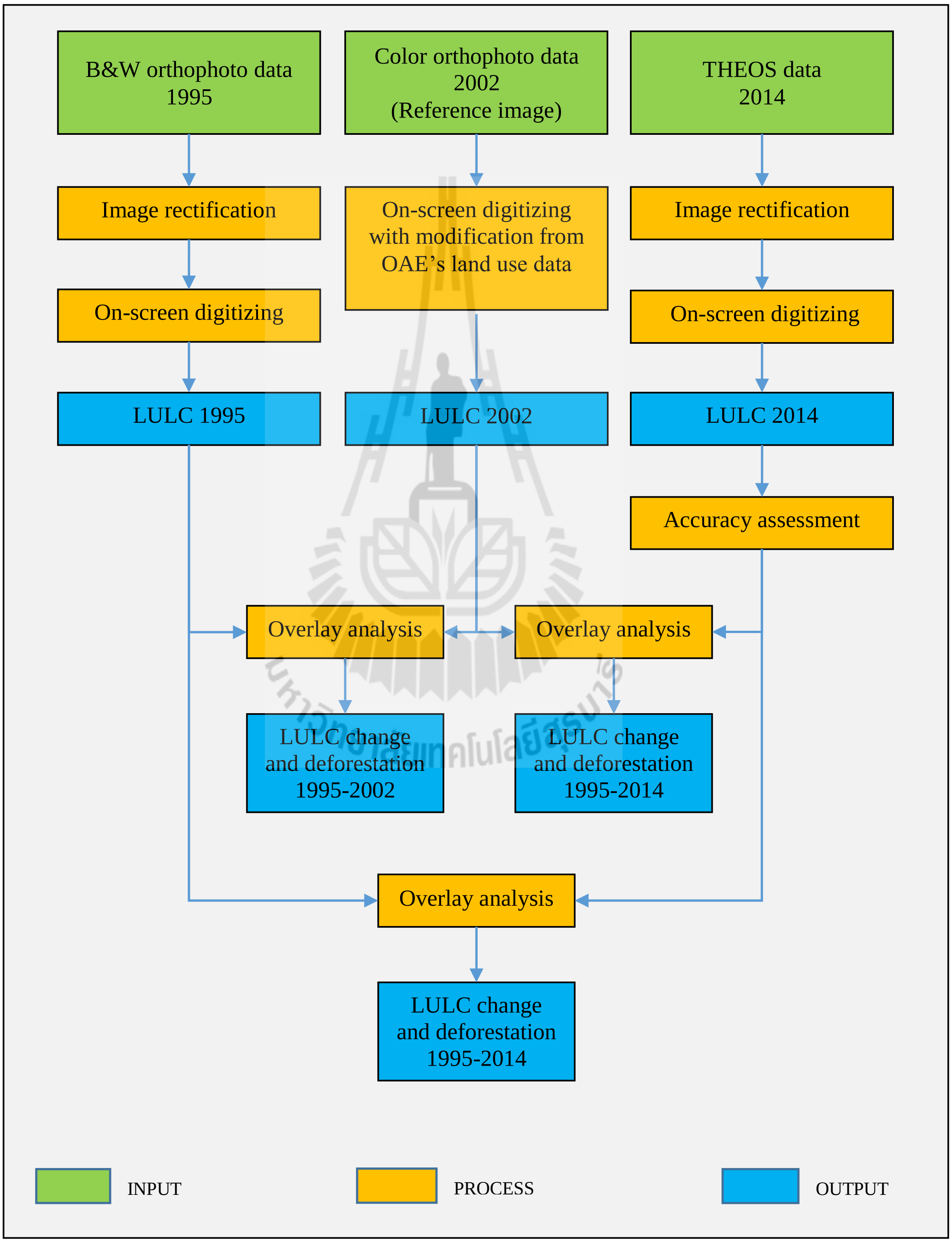
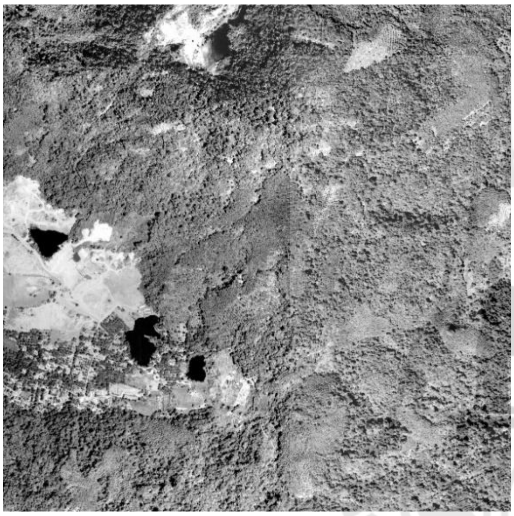
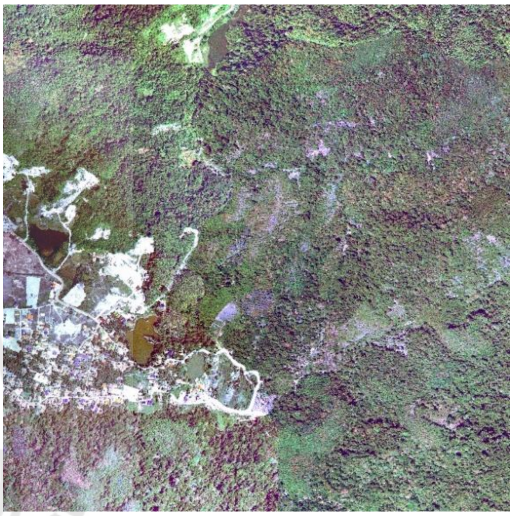


Figure 3.2 Schematic diagram for input, process and output of Component 1.

Herein, three dataset of remotely sensed data include black and white orthophoto image in 1995, color orthophoto image in 2002, and THEOS image in 2014 (see example in Figure 3.3) are visually interpreted for LULC type of Phuket Island via on-screen digitizing with enhancement of percent clip stretching at the scale of 1:10,000 based on the modified land use classification scheme of the OAE in 2009.



(a) B&W orthophoto image in 1995



(b) Color orthophoto image in 2002

(c) THEOS data in March 2014, composite bands: 123 (RGB)

Figure 3.3 Example data: (a) B&W orthophoto image, (b) color orthophoto image, and (c) THEOS data.

The output of LULC in 2014 is used to assess accuracy with overall accuracy and Kappa hat coefficient of agreement based on a stratified random sampling points using multinomial distribution theory with desired level of confident 95 percent and a precision of 5 percent by ground survey 2015.

After that, status of LULC in Phuket Island and 15 protected forest areas from three dates are subsequently assessed in raster format with cell size of 25 x 25 m under GIS environment. In addition LULC change and deforestation during 1995 - 2002, 2002 - 2014 and 1995 - 2014 are extracted using overlay analysis.

3.3.2 Optimum geospatial model identification and LULC prediction

Under this component, two main tasks include (1) an optimum geospatial model identification for LULC prediction and (2) LULC prediction in 2026. Schematic diagram for input, process and output of the Component 2 is displayed in Figure 3.4. The detail of each task is separately described in the following sections.

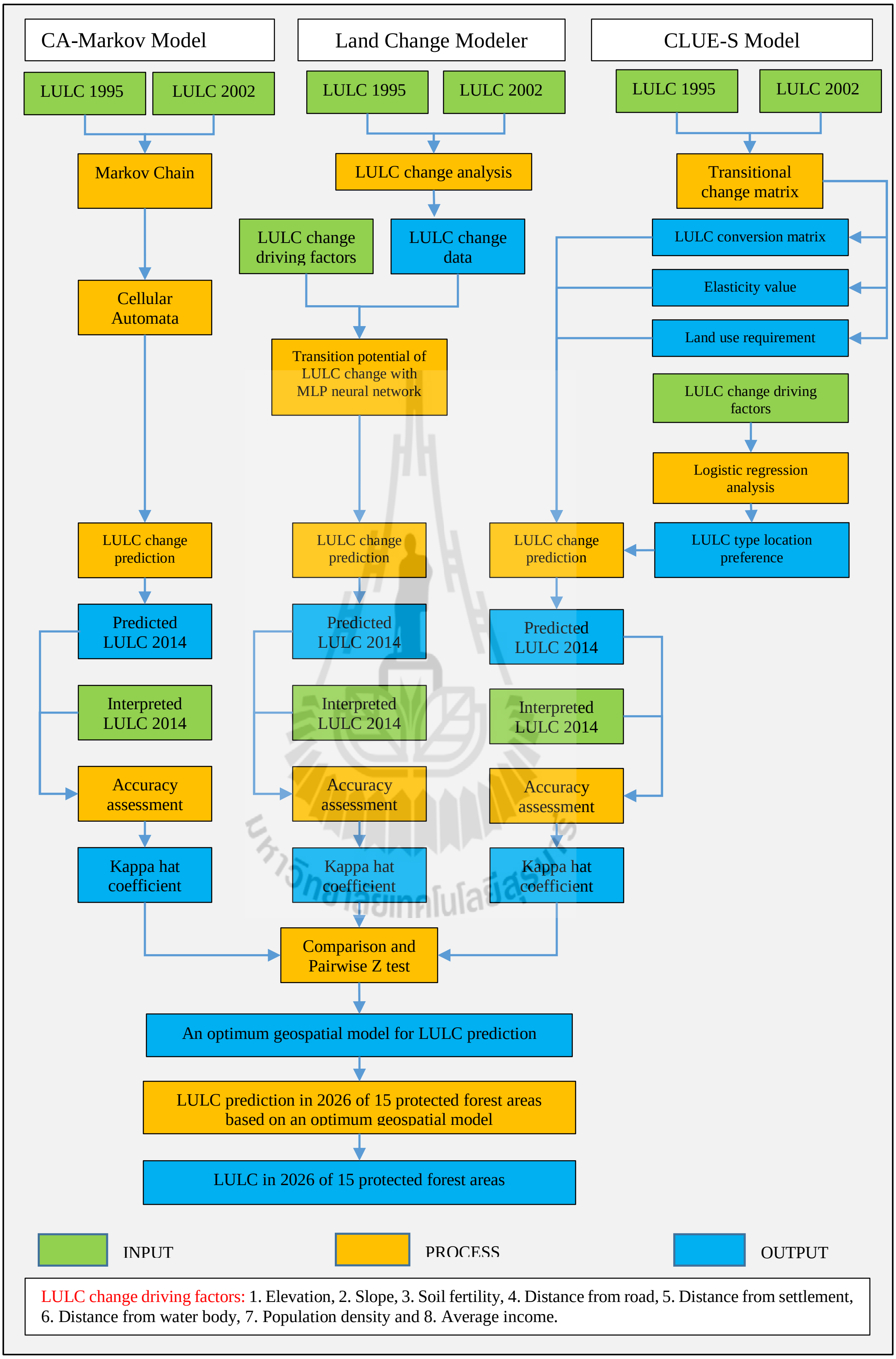


Figure 3.4 Schematic diagram for input, process and output of Component 2.

Task 1: An optimum geospatial model for LULC prediction

Under this sub-component, three geospatial models for LULC prediction include CA-Markov model, Land Change Modeler and CLUE-S model are firstly applied for LULC in 2014 prediction.

For CA-Markov model, two main input data: LULC in 1995 and 2002 are used to predict LULC in 2014 with Markov Chain and Cellular Automata. Meanwhile Land Change Model requires LULC in 1995 and 2002 as basic input with LULC change driving factors (see Table 1.2) for LULC change are applied to predict LULC in 2014 based on LULC change analysis and transition potential of LULC change with MLP neural network. Likewise, CLUE-S model requires LULC in 1995 and 2002 with LULC change driving factors to predict LULC in 2014. Herein LULC in 1995 and 2014 are used to analyze transitional LULC change for extracting LULC conversion matrix, elasticity values and land use requirement. Additionally LULC change driving factors are used to identify LULC type location preference by logistic regression analysis for allocating LULC type in 2014.

Subsequently, the predicted LULC in 2014 from each model is compared with the interpreted LULC in 2014 to identify an optimum model for LULC prediction based on Kappa hat coefficient with pairwise Z test. Herewith, Kappa hat coefficient (KHAT) among three geospatial models for LULC prediction in each protected forest area are examined significantly different as suggested by (Congalton and Green, 2009) as below.

$$Z = \frac{|\widehat{K_1} - \widehat{K_2}|}{\sqrt{\widehat{var}(\widehat{K_1}) + \widehat{var}(\widehat{K_2})}}, \tag{3.1}$$

where Z is normalized and standard normal distribution,

$\widehat{K_1}$ is KHAT of the first geospatial model,

$\widehat{K_2}$ is KHAT of the second geospatial model,

$\widehat{var}(\widehat{K_1})$ is variance of KHAT of the first geospatial model, and

$\widehat{var}(\widehat{K_2})$ is variance of KHAT of the second geospatial model.

Meanwhile, variance of KHAT is calculated using following equation:

$$\widehat{var}(\widehat{K}) = \frac{1}{n}\left\{\frac{\theta_1(1-\theta_1)}{(1-\theta_2)^2} + \frac{2(1-\theta_1)(2\theta_1\theta_2-\theta_3)}{(1-\theta_2)^3} + \frac{(1-\theta_1)^2(\theta_4-4\theta_2{}^2)}{(1-\theta_2)^4}\right\}, \tag{3.2}$$

where $\theta_1 = \frac{1}{n}\sum_{i=1}^{k} n_{ii}$,

$\theta_2 = \frac{1}{n^2}\sum_{i=1}^{k} n_{i+}n_{+i}$,

$\theta_3 = \frac{1}{n^2}\sum_{i=1}^{k} n_{ii}(n_{i+} + n_{+i})$, and

$\theta_4 = \frac{1}{n^3}\sum_{i=1}^{k}\sum_{j=1}^{k} n_{ij}(n_{j+} + n_{+i})^2$.

In practice, given the null hypothesis H_0: ($\widehat{K_1}$ - $\widehat{K_2}$) = 0 and the alternative H_1 : ($\widehat{K_1}$ - $\widehat{K_2}$) $\neq 0$, H_0 is rejected if $Z \geq Z_{\alpha/2}$, where $\alpha/2$ is the confidence level of the two-tailed Z test and the degrees of freedom are assumed to be ∞ (infinity).

Task 2: LULC prediction in 2026

The identified optimum geospatial model for LULC prediction in the previous task is directly applied to predict LULC in 2026 for each protected forest area (national parks and national reserved forest areas).

3.3.3 Deforestation vulnerability analysis and zonation

Under this component, two main tasks include (1) an optimum geospatial technique for deforestation vulnerability analysis (DVA) and (2) deforestation vulnerability zonation are implemented as shown in Figure 3.5. The detail of each task is separately described in the following sections.

Task 1: An optimum geospatial technique for DVA

Under this sub-component, two geospatial techniques for deforestation vulnerability analysis include Frequency Ratio (FR) and Logistic Regression Analysis (LRA) are firstly applied for deforestation vulnerability analysis based on deforested area between 1995 and 2002.

Under FR method, the spatial relationships between deforested area between 1995 and 2002 location and each driving factor and its class on deforestation occurrence are firstly calculated frequency ratio (Fr) and each factor's frequency ratio values are summed to calculate the deforestation vulnerability index (DVI) as:

$$DVI = Fr_1 + Fr_2 + Fr_3 + \cdots Fr_n. \tag{3.3}$$

Meanwhile, LRA is used to associate the deforested area between 1995 and 2002 with driving factors on deforestation and to generate deforestation vulnerability index (DVI) with 100 samples. In practice, multivariate regression analysis is firstly used to identify the linear relationship (Z) between the deforestation occurrence and its deforestation factors ($x_1, x_2, x_3, \cdots, x_n$) as:

$$Z = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_nx_n. \tag{3.4}$$

After that, the probability value of related to x is then transformed into nonlinear relationship by logistic curve to create DVI as probability value using following equation:

$$DVI = \frac{1}{1+e^{-z}}. \tag{3.5}$$

Subsequently, the derived DVI from each method (FR and LRA) is further classified into 5 zones (very low, low, moderate, high and very high) with natural break classification method for accuracy assessment using ROC and correctness by proportional weighting method. Herein deforestation vulnerability zones are compared with deforest area between 2002 and 2014. In this study ROC is calculated with threshold of 100% under IDRISI software. Meanwhile, correctness by proportional weighting method is calculated total score using multiplication method between numbers of pixels of actual deforested area during 2002-2014 in each deforestation vulnerability zone with its weight. Herein weight of deforestation vulnerability zone from very low, low, moderate, high and very high are 1, 2, 3, 4 and 5, respectively. The geospatial technique which provide higher accuracy is chosen as an optimum geospatial technique for DVA and zonation based deforested area between 2002 and 2014 in the next step.

Task 2: Deforestation vulnerability analysis and zonation

The derived optimum geospatial technique of deforestation vulnerability analysis is used to create deforestation vulnerability index for each protected forest areas based on deforested area between 2002 and 2014 with its driving factor. The derived deforestation vulnerability index is further reclassify into 5 deforestation vulnerability zones: very low, low, moderate, high and very high using natural break classification method.

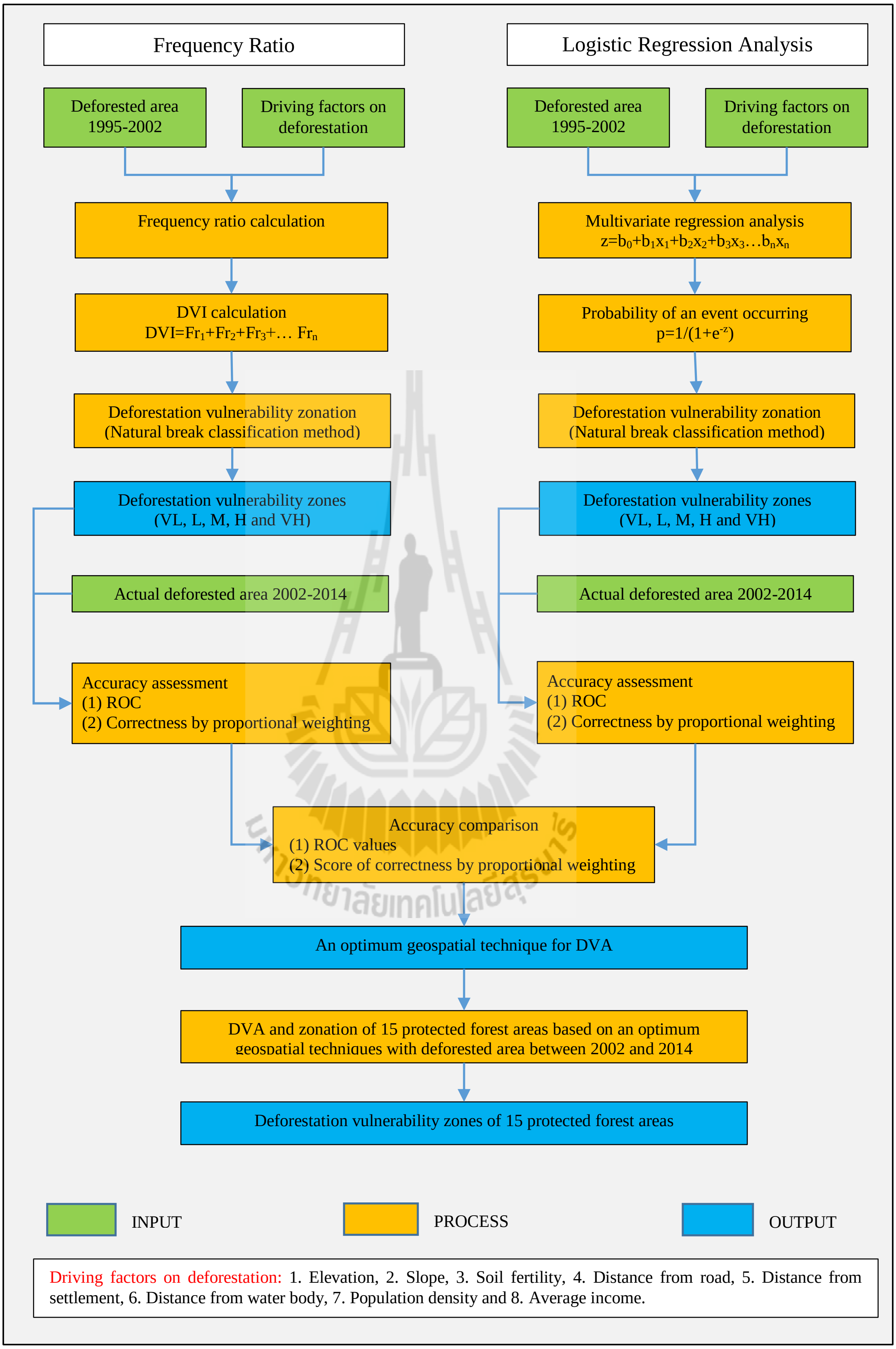


Figure 3.5 Schematic diagram for input, process and output of Component 3.

3.3.4 Deforestation hotspot and forest protection unit allocation

Under this component, two main tasks include (1) deforestation hotspot allocation and (2) forest protection unit allocation are conducted as shown in Figure 3.6. The detail of each task is separately described in the following sections.

Task 1: Deforestation hotspot allocation

The predicted deforestation areas between 2014 and 2026, which is extracted from actual LULC data in 2014 and predicted LULC data in 2026 and deforestation vulnerability zones of each protected forest area are combined by overlay analysis for deforestation hotspots allocation. The predicted deforestation areas, which have areas equal or greater than 1,600 sq. m (1 Rai) in each deforestation vulnerability zone, is identified as deforestation hotspot. These hotspots are further used for forest protection unit allocation in the next step.

Task 2: Forest protection unit allocation

The derived deforestation hotspot areas which are equal or greater than 10,000 sq. m (or 6.25 Rai) and located in moderate, high and very high deforestation vulnerability zones in each protected forest area are firstly extracted and then identified the centroid of polygon to locating forest protection unit.

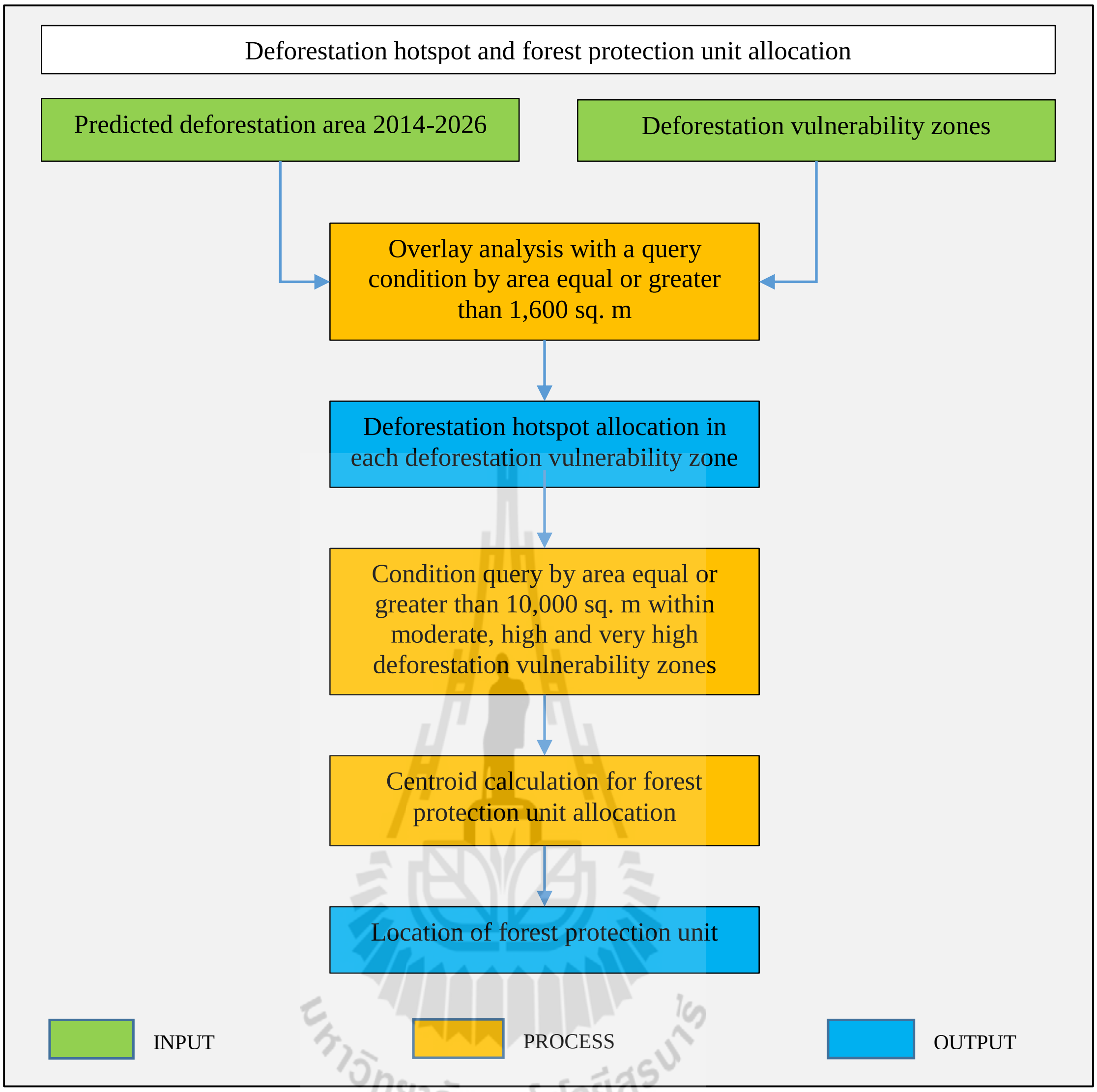


Figure 3.6 Schematic diagram for input, process and output of Component 4.

CHAPTER IV

LULC ASSESSMENT AND ITS CHANGE AND DEFORESTATION

Results of LULC assessment and its change and deforestation between 1995 and 2014, which were extracted using visual interpretation of the three different remotely sensed dataset in 1995, 2002 and 2014 of Phuket Island and GIS analyses are described and discussed in this chapter.

4.1 Historical and recent LULC assessment

Historical and recent status of LULC types in 1995, 2002 and 2014 of Phuket Island visually interpreted using element of photo interpretation (tone/color, size, shape, pattern, texture, shadow and site/situation/ association), are firstly described. Table 4.1 shows an example of photo interpretation keys of LULC type from remotely sensed data. After that, the historical and recent status of LULC types of 15 protected forest areas in Phuket Island extracted by GIS analysis are summarized.

Table 4.1 Photo interpretation key of LULC type in Phuket Island.

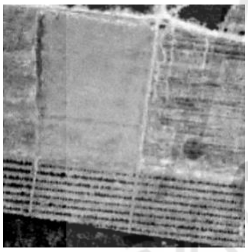
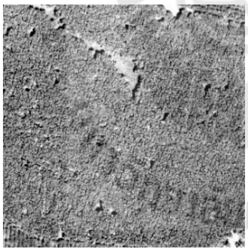
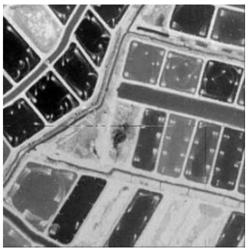
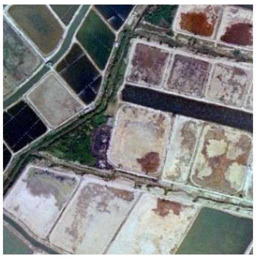
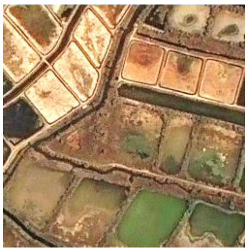
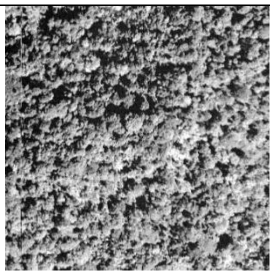
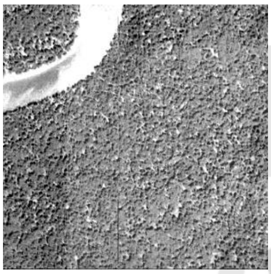
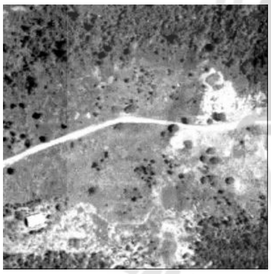
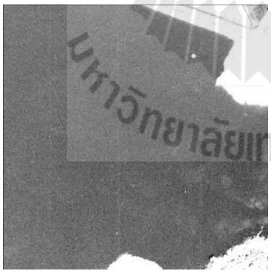
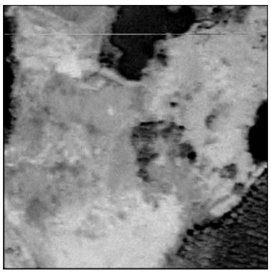
LULC type	B&W orthophoto	Color orthophoto	THEOS image
Urban and built-up area			
Paddy field			
Field crop and horticulture			
Orchard and perennial trees			
Aquaculture area			
Idle land			

Table 4.1 (Continued).

LULC type	B&W orthophoto	Color orthophoto	THEOS image
Evergreen forest			
Mangrove forest			
Scrub			
Water body			
Miscellaneous land (pits land)			

4.1.1 LULC assessment of Phuket Island in 1995, 2002 and 2014

In 1995, orchard and perennial trees was the most dominant in the study area; it covered an area of 217.265 sq. km or 41.56% (Figure 4.1). At the same time, others were urban and built-up area, paddy field, field crop and horticulture, aquaculture area, idle land, evergreen forest, mangrove forest, scrub, water body and miscellaneous land covered an area of 66.909 sq. km or 12.80%, 6.351 sq. km or 1.21%, 1.518 sq. km or 0.29%, 8.759 sq. km or 1.68%, 53.964 sq. km or 10.32%, 94.780 sq. km or 18.13%, 26.744 sq. km or 5.12%, 28.160 sq. km or 5.39%, 13.951 sq. km or 2.67% and 4.436 sq. km or 0.85%, of the study area, respectively.

In 2002, orchard and perennial trees was still the most dominant in the study area; it covered an area of 210.960 sq. km or 40.35% (Figure 4.2). Meanwhile, others were urban and built-up area, paddy field, field crop and horticulture, aquaculture area, idle land, evergreen forest, mangrove forest, scrub, water body and miscellaneous land covered an area of 78.817 sq. km or 15.07%, 4.438 sq. km or 0.85%, 1.953 sq. km or 0.37%, 9.614 sq. km or 1.84%, 53.114 sq. km or 10.16%, 90.356 sq. km or 17.28%, 25.724 sq. km or 4.92%, 28.849 sq. km or 5.52%, 14.231 sq. km or 2.72% and 4.779 sq. km or 0.91%, of the study area, respectively.

In 2014, orchard and perennial trees was the most dominant in the study area; it covered an area of 196.239 sq. km or 37.53% of Phuket Island (Figure 4.3). For the time being, others were urban and built-up area, paddy field, field crop and horticulture, aquaculture area, idle land, evergreen forest, mangrove forest, scrub, water body and miscellaneous land covered an area of 126.276 sq. km or 24.15%, 2.710 sq. km or 0.52%, 1.447 sq. km or 0.28%, 8.724 sq. km or 1.67%, 33.631 sq. km or

6.43%, 81.489 sq. km or 15.59%, 25.154 sq. km or 4.81%, 26.329 sq. km or 5.04%, 14.536 sq. km or 2.78% and 6.302 sq. km or 1.21%, of the study area, respectively.

In addition, area and percentage of LULC types of Phuket Island in three dates are compared and summarized in Table 4.2 and Figure 4.4 and 4.5. As results, it shows a dramatic increasing of urban and built-up areas between 1995 and 2014. On the contrary, areas of orchard and perennial trees and evergreen forest have been continuously decreased during the same period. Likewise, Figure 4.5 shows a dynamic LULC pattern change between 1995 and 2014 that the percentage area of agriculture land including paddy field, field crop and horticulture, orchard and perennial trees, aquaculture area and idle land have been gradually decreased from 55.06% to 46.43% of the total area while the percentage of urban and built-up area drastically increased from 12.80% to 24.15%.

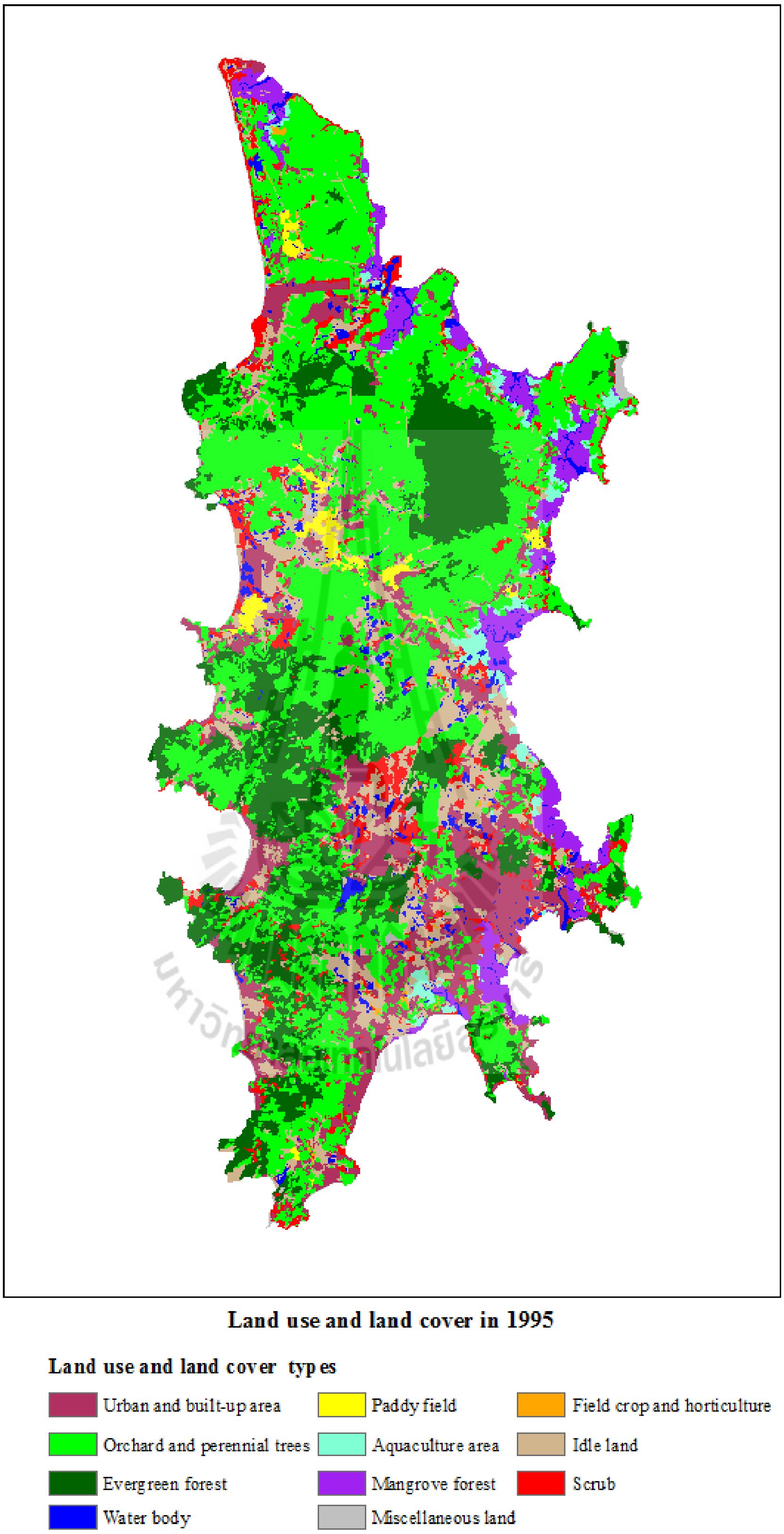


Figure 4.1 Distribution of LULC pattern for Phuket Island in 1995.

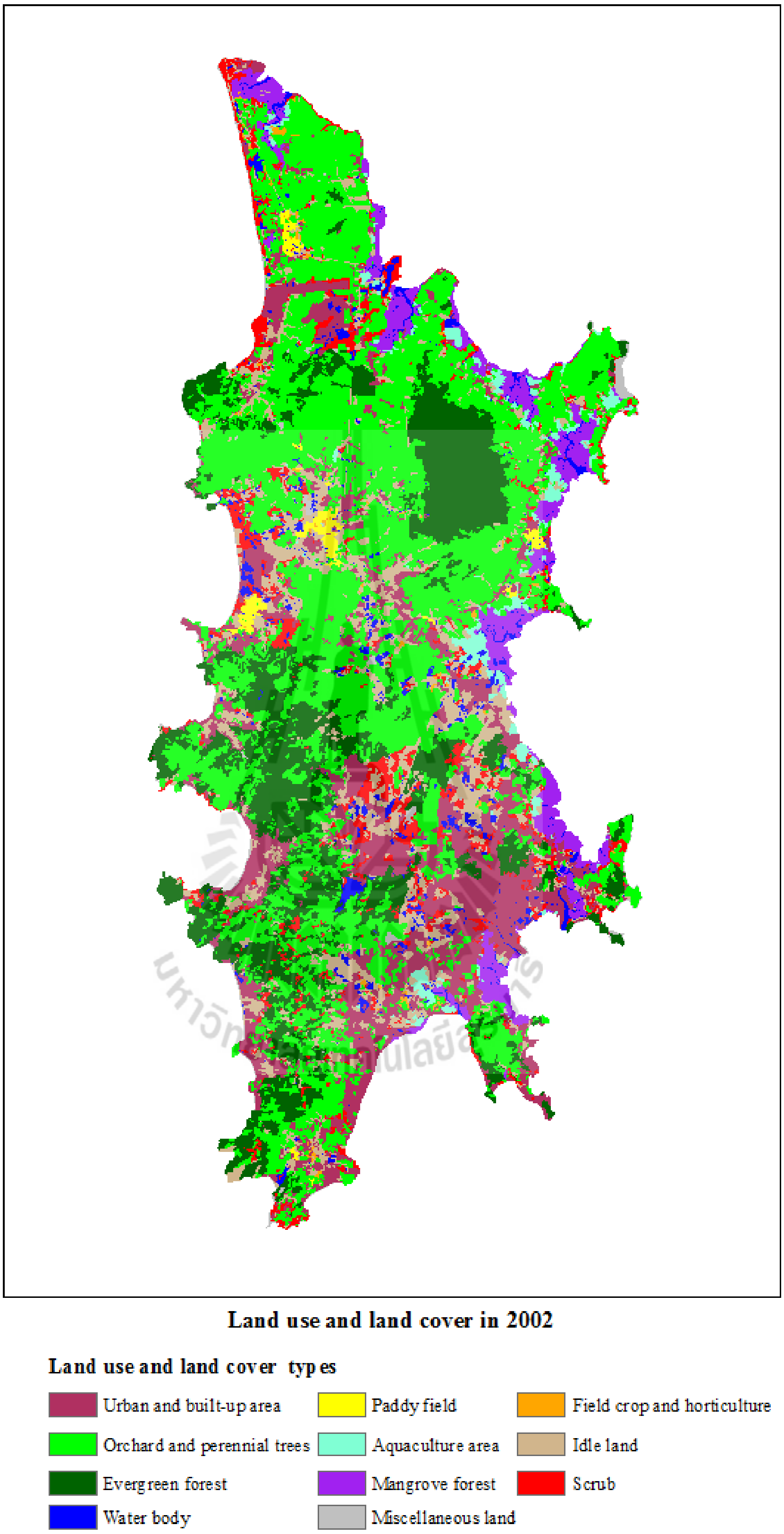


Figure 4.2 Distribution of LULC pattern for Phuket Island in 2002.

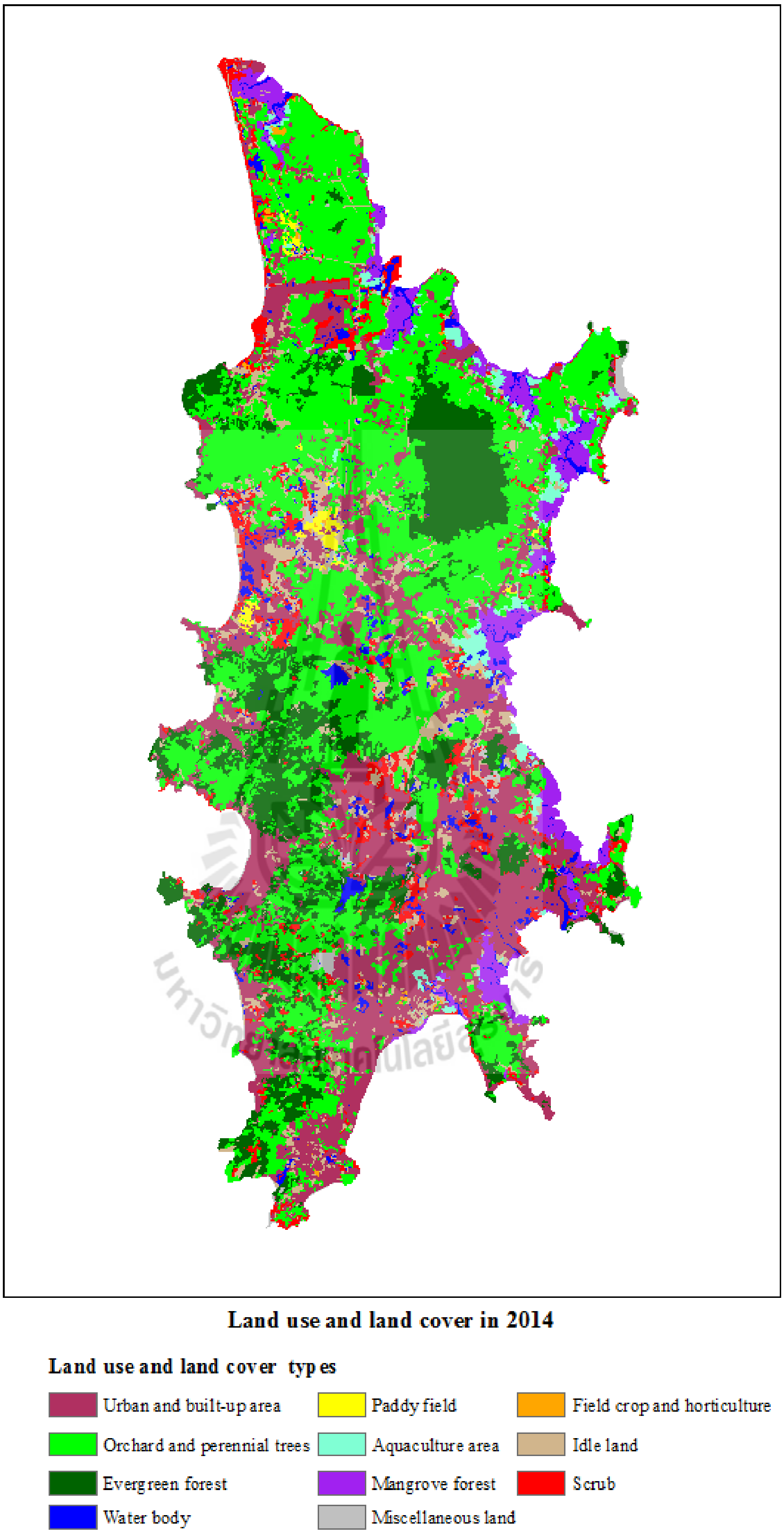


Figure 4.3 Distribution of LULC pattern for Phuket Island in 2014.

Table 4.2 Area and percentage for LULC of Phuket island in 1995, 2002, and 2014.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	66.909	12.80	78.817	15.07	126.276	24.15
Paddy field	6.351	1.21	4.438	0.85	2.710	0.52
Field crop and horticulture	1.518	0.29	1.953	0.37	1.447	0.28
Orchard and perennial trees	217.265	41.56	210.960	40.35	196.239	37.53
Aquaculture area	8.759	1.68	9.614	1.84	8.724	1.67
Idle land	53.964	10.32	53.114	10.16	33.631	6.43
Evergreen forest	94.780	18.13	90.356	17.28	81.489	15.59
Mangrove forest	26.744	5.12	25.724	4.92	25.154	4.81
Scrub	28.160	5.39	28.849	5.52	26.329	5.04
Water body	13.951	2.67	14.231	2.72	14.536	2.78
Miscellaneous land	4.436	0.85	4.779	0.91	6.302	1.21
Total	**522.836**	**100.00**	**522.836**	**100.00**	**522.836**	**100.00**

Furthermore, 743 randomly stratified sampling points based on multinomial distribution theory with desired level of confident 95 percent and a precision of 5 percent are used for accuracy assessment of LULC data in 2014 (Figure 4.6). The accuracy assessment of the interpreted LULC in 2014 by ground survey in 2015 is 98.38% for overall accuracy and 97.89% for Kappa hat coefficient. The producer's accuracy of each LULC type varies between 81.40% and 100% while the user's accuracy of each LULC type ranges from 87.50% to 100%. Based on Fitzpatrick-Lins (1981), Kappa hat coefficient more than 80 percent represents strong agreement or accuracy between the interpretation map and the ground reference information. Detail of producer's accuracy and user's accuracy is summarized in Table 4.3.

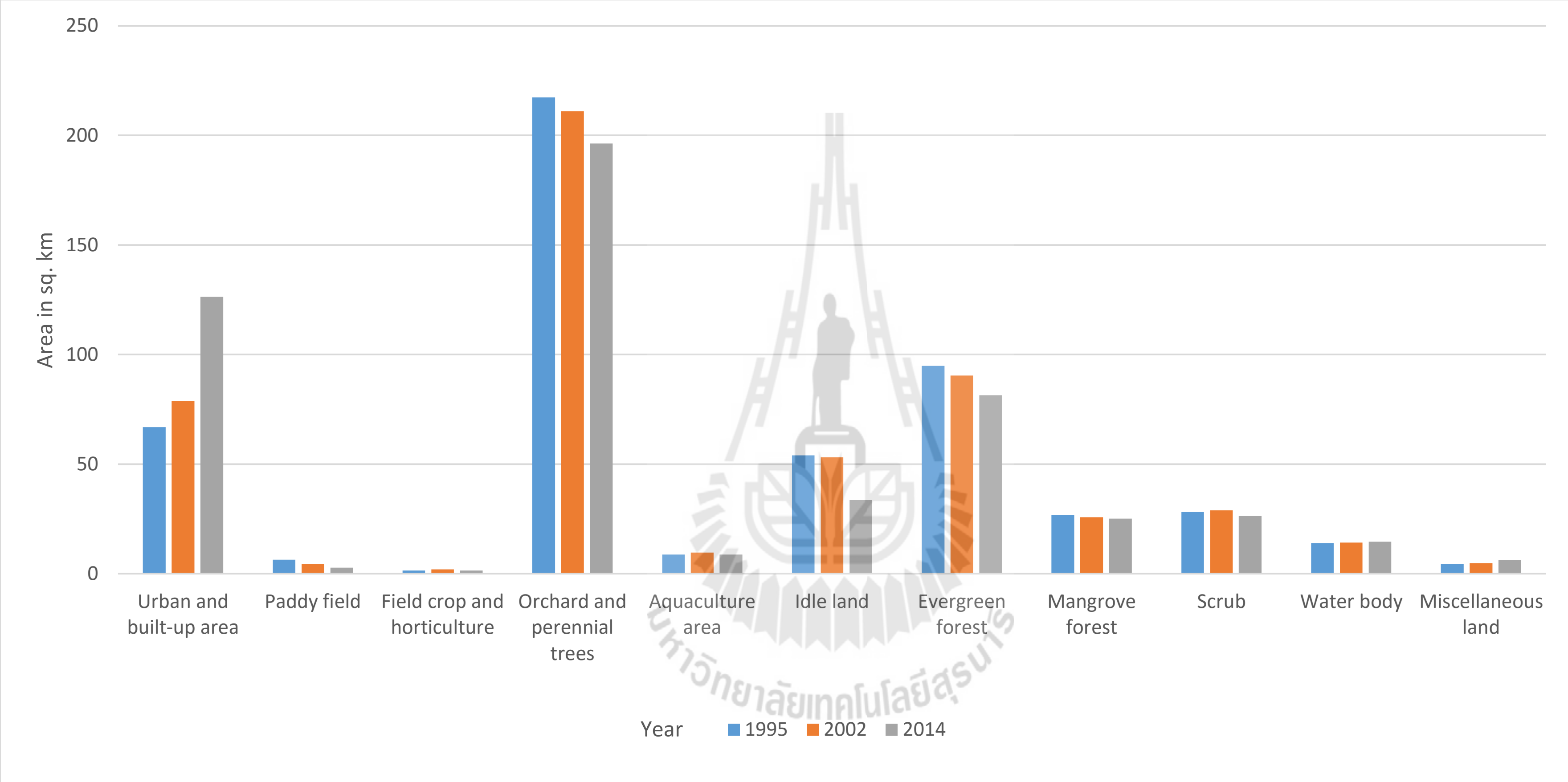


Figure 4.4 Comparison of LULC distribution in Phuket Island in 1995, 2002, and 2014.

Table 4.3 Error matrixes and accuracy assessment of LULC for Phuket Island in 2014.

(Unit: point)

LULC 2014 by Visual interpretation	Ground truth data											
	Ur	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Rf**	**Wa**	**Mi**	**Total**	**User's accuracy (%)**
Urban and built-up area (Ur)	179											179	100
Paddy field (Pa)		4										4	100
Field crop and horticulture (Fch)			2									2	100
Orchard and perennial trees (Op)				277					3			280	98.93
Aquaculture area (Aq)					12							12	100
Idle land (Id)				1		42			4		1	48	87.50
Evergreen forest (Ef)							117					117	100
Mangrove forest (Mf)								36				36	100
Scrub (Sc)						1			35			36	97.22
Water body (Wa)										11		11	100
Miscellaneous land (Mi)						1			1		16	18	88.89
Total	179	4	2	278	12	44	117	36	43	11	17	743	100
Producer's accuracy (%)	100	100	100	99.64	100	95.45	100	100	81.40	100	94.12	100	
Over all accuracy (%)	98.38												
Kappa hat coefficient (%)	97.89												

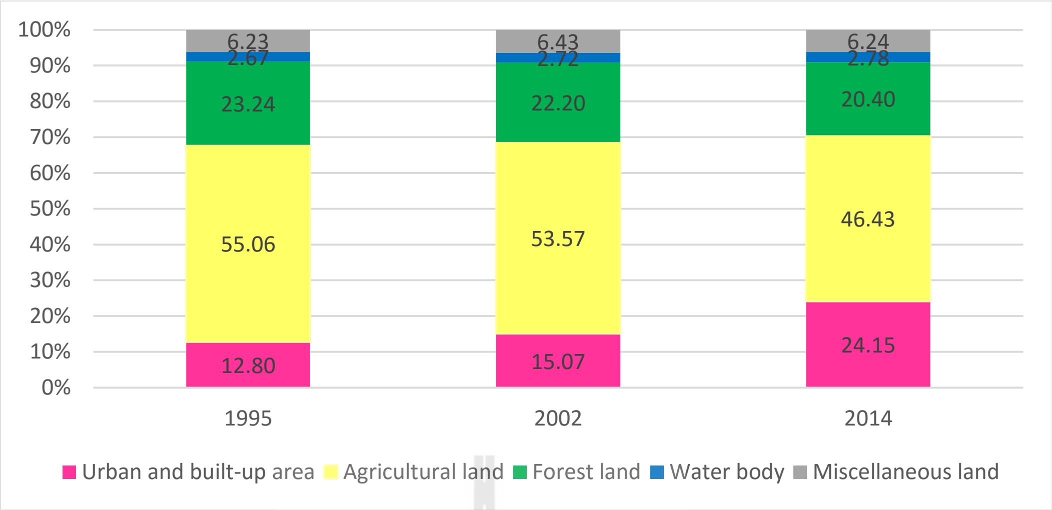


Figure 4.5 Dynamic LULC pattern change of Phuket Island between 1995 and 2014.

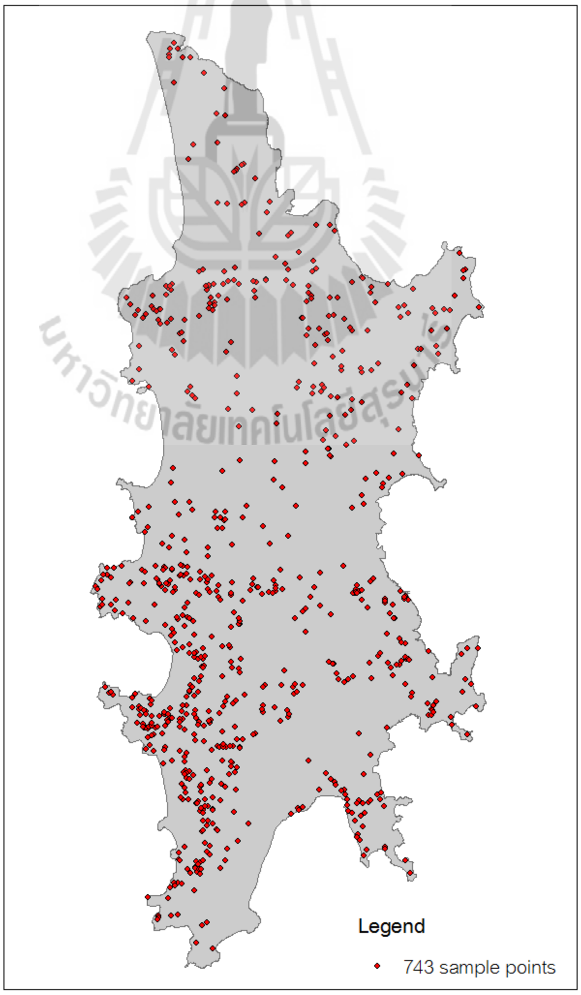


Figure 4.6 Distribution of sample points for accuracy assessment.

4.1.2 LULC assessment of protected forest area in 1995, 2002, and 2014

Likewise, LULC assessment of Phuket Island within boundary and its buffer area with distance of 2.5 km of 15 protected forest areas are intersected with three LULC data to assess LULC of each protected forest area. Herein areas and the percentage of LULC of 15 each protected forest area are separately summarized based on its boundary and boundary with buffer area in Tables 4.4 to 4.33, respectively. In addition, distribution of LULC of 15 protected forest areas are displayed in Figures 4.7 to 4.21.

Table 4.4 Area and percentage of LULC in Sirinath MNP boundary.

LULC	**1995**		**2002**		**2014**	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	1.023	4.83	1.308	6.18	2.621	12.38
Field crop and horticulture	0.033	0.16	0.059	0.28	0.087	0.41
Orchard and perennial trees	10.901	51.51	10.671	50.42	10.231	48.34
Idle land	1.880	8.88	1.806	8.53	1.350	6.38
Evergreen forest	3.433	16.22	3.328	15.73	3.107	14.68
Mangrove forest	0.111	0.52	0.111	0.52	0.111	0.52
Scrub	2.634	12.45	2.682	12.67	2.516	11.89
Water body	0.393	1.85	0.412	1.95	0.428	2.02
Miscellaneous land	0.756	3.57	0.788	3.72	0.713	3.37
Total	21.163	100.00	21.163	100.00	21.163	100.00

Table 4.5 Area and percentage of LULC in Sirinath MNP with buffer area.

LULC	**1995**		**2002**		**2014**	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	6.779	8.46	7.973	9.95	12.173	15.20
Paddy field	1.663	2.08	1.021	1.28	0.621	0.78
Field crop and horticulture	0.581	0.73	0.739	0.92	0.764	0.95
Orchard and perennial trees	42.520	53.09	42.346	52.87	41.302	51.57
Aquaculture area	0.471	0.59	0.511	0.64	0.575	0.72
Idle land	7.884	9.84	8.039	10.04	6.644	8.29
Evergreen forest	6.709	8.38	5.433	6.78	4.526	5.65
Mangrove forest	2.942	3.67	2.949	3.68	2.934	3.66
Scrub	6.669	8.33	6.915	8.63	6.543	8.17
Water body	2.535	3.17	2.641	3.30	2.752	3.44
Miscellaneous land	1.341	1.67	1.527	1.91	1.262	1.58
Total	80.094	100.00	80.094	100.00	80.094	100.00

Table 4.6 Area and percentage of LULC of Khao Phra Thaeo WCDEC.

LULC	**1995**		**2002**		**2014**	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.026	0.13	0.026	0.13	0.039	0.19
Orchard and perennial trees	1.492	7.32	1.485	7.29	1.561	7.67
Idle land	0.050	0.25	0.073	0.36	0.043	0.21
Evergreen forest	18.783	92.22	18.768	92.14	18.708	91.85
Water body	0.016	0.08	0.016	0.08	0.016	0.08
Total	20.368	100.00	20.368	100.00	20.368	100.00

Table 4.7 Area and percentage of LULC of Khao Phra Thaeo WCDEC with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	3.493	3.91	3.823	4.28	8.832	9.88
Paddy field	1.209	1.35	0.464	0.52	0.068	0.08
Field crop and horticulture	0.119	0.13	0.145	0.16	0.103	0.11
Orchard and perennial trees	46.666	52.20	45.255	50.62	42.631	47.68
Aquaculture area	2.279	2.55	2.944	3.29	2.873	3.21
Idle land	3.193	3.57	5.004	5.60	3.794	4.24
Evergreen forest	22.328	24.97	22.271	24.91	22.024	24.63
Mangrove forest	7.536	8.43	7.018	7.85	6.844	7.65
Scrub	1.471	1.64	1.308	1.46	0.938	1.05
Water body	1.098	1.23	1.150	1.29	1.162	1.30
Miscellaneous land	0.013	0.01	0.022	0.02	0.136	0.15
Total	89.404	100.00	89.404	100.00	89.404	100.00

Table 4.8 Area and percentage of LULC of Khao Mai Kaew NRF.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.083	1.14	0.094	1.29	0.144	1.98
Orchard and perennial trees	6.666	91.22	6.354	86.95	6.548	89.61
Idle land	0.119	1.63	0.420	5.75	0.154	2.11
Evergreen forest	0.346	4.74	0.346	4.74	0.324	4.43
Scrub	0.093	1.27	0.093	1.27	0.106	1.45
Water body	0.000	0.00	0.000	0.00	0.006	0.08
Miscellaneous land	0.000	0.00	0.000	0.00	0.026	0.35
Total	7.308	100.00	7.308	100.00	7.308	100.00

Table 4.9 Area and percentage of LULC of Khao Mai Kaew NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	5.102	11.82	5.993	13.89	7.411	17.17
Paddy field	0.961	2.23	0.856	1.98	0.501	1.16
Field crop and horticulture	0.218	0.51	0.294	0.68	0.328	0.76
Orchard and perennial trees	26.038	60.33	24.764	57.38	24.559	56.91
Aquaculture area	0.411	0.95	0.438	1.02	0.594	1.38
Idle land	2.603	6.03	2.915	6.75	2.003	4.64
Evergreen forest	0.346	0.80	0.346	0.80	0.324	0.75
Mangrove forest	2.244	5.20	2.235	5.18	2.109	4.89
Scrub	3.485	8.08	3.454	8.00	3.401	7.88
Water body	1.486	3.44	1.579	3.66	1.601	3.71
Miscellaneous land	0.263	0.61	0.284	0.66	0.327	0.76
Total	43.158	100.00	43.158	100.00	43.158	100.00

Table 4.10 Area and percentage of LULC of Khao Bang Khanun NRF.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	0.017	0.23	0.109	1.49	0.134	1.84
Orchard and perennial trees	3.361	46.10	4.362	59.82	4.809	65.95
Idle land	0.013	0.17	0.013	0.17	0.041	0.57
Evergreen forest	3.799	52.10	2.646	36.29	2.098	28.77
Scrub	0.046	0.63	0.064	0.87	0.064	0.87
Water body	0.050	0.69	0.050	0.69	0.050	0.69
Miscellaneous land	0.006	0.08	0.048	0.66	0.096	1.31
Total	7.291	100.00	7.291	100.00	7.291	100.00

Table 4.11 Area and percentage of LULC of Khao Bang Khanun NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	4.729	8.94	5.623	10.63	7.898	14.93
Paddy field	0.280	0.53	0.095	0.18	0.056	0.11
Field crop and horticulture	0.039	0.07	0.074	0.14	0.093	0.17
Orchard and perennial trees	30.973	58.56	31.163	58.91	30.679	58.00
Aquaculture area	0.140	0.26	0.223	0.42	0.226	0.43
Idle land	4.051	7.66	3.974	7.51	3.341	6.32
Evergreen forest	7.731	14.62	6.374	12.05	5.478	10.36
Mangrove forest	1.279	2.42	1.279	2.42	1.147	2.17
Scrub	2.731	5.16	2.928	5.54	2.773	5.24
Water body	0.754	1.43	0.801	1.51	0.813	1.54
Miscellaneous land	0.186	0.35	0.360	0.68	0.392	0.74
Total	52.894	100.00	52.894	100.00	52.894	100.00

Table 4.12 Area and percentage of LULC of Khao Sam Liam NRF.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Field crop and horticulture	0.000	0.00	0.003	0.10	0.003	0.10
Orchard and perennial trees	2.712	89.02	2.698	88.55	2.700	88.63
Aquaculture area	0.008	0.25	0.014	0.47	0.014	0.47
Idle land	0.007	0.23	0.030	0.98	0.014	0.47
Evergreen forest	0.248	8.12	0.240	7.88	0.240	7.88
Mangrove forest	0.025	0.82	0.025	0.82	0.025	0.82
Scrub	0.041	1.35	0.031	1.03	0.044	1.46
Water body	0.000	0.00	0.001	0.02	0.001	0.02
Miscellaneous land	0.006	0.21	0.004	0.14	0.004	0.14
Total	3.046	100.00	3.046	100.00	3.046	100.00

Table 4.13 Area and percentage of LULC of Khao Sam Liam NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.421	2.27	0.433	2.33	1.062	5.72
Field crop and horticulture	0.011	0.06	0.039	0.21	0.033	0.18
Orchard and perennial trees	9.481	51.08	8.994	48.46	8.902	47.96
Aquaculture area	1.505	8.11	1.689	9.10	1.562	8.41
Idle land	0.589	3.18	0.968	5.22	0.702	3.78
Evergreen forest	0.581	3.13	0.569	3.06	0.538	2.90
Mangrove forest	3.848	20.73	3.768	20.30	3.745	20.18
Scrub	0.773	4.17	0.741	3.99	0.608	3.28
Water body	0.462	2.49	0.463	2.50	0.463	2.50
Miscellaneous land	0.891	4.80	0.898	4.84	0.947	5.10
Total	18.561	100.00	18.561	100.00	18.561	100.00

Table 4.14 Area and percentage of LULC of Khao Kamala NRF.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.846	1.78	1.083	2.28	2.661	5.61
Orchard and perennial trees	19.047	40.14	19.213	40.49	20.257	42.69
Idle land	1.738	3.66	1.834	3.86	1.453	3.06
Evergreen forest	23.821	50.20	23.493	49.51	21.393	45.09
Scrub	1.884	3.97	1.652	3.48	1.529	3.22
Water body	0.051	0.11	0.054	0.11	0.084	0.18
Miscellaneous land	0.063	0.13	0.121	0.25	0.072	0.15
Total	47.448	100.00	47.448	100.00	47.448	100.00

Table 4.15 Area and percentage of LULC of Khao Kamala NRF with buffer area.

LULC	**1995**		**2002**		**2014**	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	17.715	12.89	21.354	15.53	36.396	26.48
Paddy field	1.101	0.80	1.063	0.77	0.554	0.40
Field crop and horticulture	0.174	0.13	0.256	0.19	0.128	0.09
Orchard and perennial trees	50.023	36.39	49.314	35.87	45.896	33.39
Aquaculture area	0.395	0.29	0.421	0.31	0.336	0.24
Idle land	20.988	15.27	18.398	13.38	10.684	7.77
Evergreen forest	33.941	24.69	33.056	24.05	29.731	21.63
Mangrove forest	0.068	0.05	0.068	0.05	0.123	0.09
Scrub	8.507	6.19	8.823	6.42	7.917	5.76
Water body	3.776	2.75	3.822	2.78	4.104	2.99
Miscellaneous land	0.776	0.56	0.888	0.65	1.594	1.16
Total	137.464	100.00	137.464	100.00	137.464	100.00

Table 4.16 Area and percentage of LULC of Khao Nak Keod NRF.

LULC	**1995**		**2002**		**2014**	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.663	1.76	1.292	3.44	2.976	7.93
Field crop and horticulture	0.012	0.03	0.012	0.03	0.019	0.05
Orchard and perennial trees	14.649	39.01	15.074	40.14	16.264	43.31
Aquaculture area	0.000	0.00	0.000	0.00	0.007	0.02
Idle land	1.183	3.15	1.478	3.93	0.963	2.56
Evergreen forest	19.126	50.94	17.571	46.79	15.170	40.40
Scrub	1.682	4.48	1.939	5.16	1.948	5.19
Water body	0.153	0.41	0.143	0.38	0.156	0.42
Miscellaneous land	0.083	0.22	0.042	0.11	0.048	0.13
Total	37.550	100.00	37.550	100.00	37.550	100.00

Table 4.17 Area and percentage of LULC of Khao Nak Keod NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	20.218	17.87	24.950	22.05	39.651	35.05
Paddy field	0.168	0.15	0.128	0.11	0.000	0.00
Field crop and horticulture	0.290	0.26	0.296	0.26	0.151	0.13
Orchard and perennial trees	37.264	32.94	35.206	31.12	30.742	27.17
Aquaculture area	0.004	0.00	0.024	0.02	0.008	0.01
Idle land	13.239	11.70	12.562	11.10	6.093	5.39
Evergreen forest	32.164	28.43	30.041	26.55	26.119	23.09
Scrub	6.283	5.55	6.469	5.72	6.149	5.44
Water body	2.664	2.35	2.643	2.34	2.461	2.18
Miscellaneous land	0.838	0.74	0.813	0.72	1.758	1.55
Total	113.131	100.00	113.131	100.00	113.131	100.00

Table 4.18 Area and percentage of LULC of Khao Tosae NRF.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.023	2.40	0.023	2.40	0.027	2.86
Orchard and perennial trees	0.034	3.60	0.034	3.60	0.031	3.33
Evergreen forest	0.882	94.00	0.882	94.00	0.880	93.80
Total	0.938	100.00	0.938	100.00	0.938	100.00

Table 4.19 Area and percentage of LULC of Khao Tosae NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	12.257	42.87	13.612	47.61	17.049	59.64
Paddy field	0.000	0.00	0.000	0.00	0.000	0.00
Field crop and horticulture	0.079	0.28	0.082	0.29	0.000	0.00
Orchard and perennial trees	2.956	10.34	2.503	8.76	1.807	6.32
Aquaculture area	0.325	1.14	0.325	1.14	0.289	1.01
Idle land	3.693	12.92	2.985	10.44	0.898	3.14
Evergreen forest	3.021	10.57	2.838	9.93	2.549	8.92
Mangrove forest	2.794	9.77	2.662	9.31	2.501	8.75
Scrub	1.991	6.96	2.108	7.37	1.935	6.77
Water body	1.416	4.95	1.416	4.95	1.314	4.60
Miscellaneous land	0.057	0.20	0.057	0.20	0.245	0.86
Total	28.588	100.00	28.588	100.00	28.588	100.00

Table 4.20 Area and percentage of LULC of Khlong U-Tapao NRF.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.106	4.23	0.106	4.23	0.113	4.53
Orchard and perennial trees	0.182	7.29	0.174	6.99	0.163	6.51
Aquaculture area	0.153	6.11	0.142	5.69	0.142	5.69
Idle land	0.040	1.60	0.058	2.33	0.069	2.78
Mangrove forest	1.878	75.25	1.878	75.25	1.871	74.97
Scrub	0.059	2.38	0.059	2.38	0.059	2.38
Water body	0.078	3.13	0.078	3.13	0.078	3.13
Total	2.495	100.00	2.495	100.00	2.495	100.00

Table 4.21 Area and percentage of LULC of Khlong U-Tapao NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.850	3.91	1.093	5.03	1.969	9.07
Paddy field	0.099	0.45	0.090	0.41	0.044	0.20
Field crop and horticulture	0.388	1.78	0.449	2.07	0.458	2.11
Orchard and perennial trees	12.805	58.96	12.458	57.36	11.967	55.10
Aquaculture area	0.416	1.92	0.410	1.89	0.387	1.78
Idle land	0.963	4.43	0.938	4.32	0.779	3.59
Evergreen forest	0.014	0.06	0.014	0.06	0.014	0.06
Mangrove forest	2.807	12.92	2.814	12.96	2.799	12.89
Scrub	2.176	10.02	2.208	10.16	2.043	9.40
Water body	0.913	4.20	0.948	4.36	0.971	4.47
Miscellaneous land	0.288	1.33	0.298	1.37	0.288	1.33
Total	21.719	100.00	21.719	100.00	21.719	100.00

Table 4.22 Area and percentage of LULC of Khlong Tha Maphrao NRF.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.014	0.38	0.014	0.38	0.046	1.28
Orchard and perennial trees	0.138	3.87	0.131	3.67	0.128	3.57
Aquaculture area	0.207	5.79	0.192	5.37	0.264	7.40
Idle land	0.083	2.31	0.118	3.31	0.083	2.33
Mangrove forest	2.606	72.92	2.593	72.56	2.508	70.19
Scrub	0.236	6.61	0.228	6.38	0.228	6.38
Water body	0.290	8.12	0.298	8.33	0.288	8.06
Miscellaneous land	0.000	0.00	0.000	0.00	0.028	0.79
Total	3.573	100.00	3.573	100.00	3.573	100.00

Table 4.23 Area and percentage of LULC of Khlong Tha Maphrao NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	3.384	7.96	4.189	9.85	5.604	13.18
Field crop and horticulture	0.053	0.12	0.063	0.15	0.041	0.10
Orchard and perennial trees	24.404	57.38	22.891	53.83	22.622	53.19
Aquaculture area	0.652	1.53	1.018	2.39	1.153	2.71
Idle land	1.911	4.49	2.349	5.52	1.383	3.25
Evergreen forest	3.059	7.19	3.026	7.12	2.762	6.49
Mangrove forest	4.534	10.66	4.206	9.89	3.967	9.33
Scrub	2.748	6.46	2.918	6.86	2.852	6.71
Water body	1.718	4.04	1.798	4.23	1.808	4.25
Miscellaneous land	0.067	0.16	0.070	0.16	0.338	0.79
Total	42.528	100.00	42.528	100.00	42.528	100.00

Table 4.24 Area and percentage of LULC of Khlong Para NRF.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	0.058	1.73	0.088	2.60	0.196	5.81
Orchard and perennial trees	0.214	6.37	0.207	6.15	0.215	6.39
Aquaculture area	0.393	11.66	0.686	20.39	0.646	19.19
Idle land	0.126	3.75	0.034	1.02	0.026	0.78
Mangrove forest	2.236	66.44	1.971	58.58	1.964	58.38
Scrub	0.060	1.78	0.089	2.64	0.028	0.84
Water body	0.278	8.27	0.290	8.62	0.290	8.62
Total	3.365	100.00	3.365	100.00	3.365	100.00

Table 4.25 Area and percentage of LULC of Khlong Para NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	1.036	2.58	1.105	2.75	2.734	6.80
Field crop and horticulture	0.031	0.08	0.059	0.15	0.053	0.13
Orchard and perennial trees	20.920	52.00	20.093	49.95	19.264	47.89
Aquaculture area	1.977	4.91	2.523	6.27	2.461	6.12
Idle land	1.367	3.40	1.898	4.72	1.608	4.00
Evergreen forest	4.809	11.95	4.809	11.95	4.781	11.88
Mangrove forest	7.858	19.53	7.403	18.40	7.291	18.12
Scrub	0.993	2.47	1.044	2.59	0.685	1.70
Water body	1.228	3.05	1.276	3.17	1.289	3.21
Miscellaneous land	0.013	0.03	0.021	0.05	0.065	0.16
Total	40.230	100.00	40.230	100.00	40.230	100.00

Table 4.26 Area and percentage of LULC of Khlong Bangrong NRF.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	0.037	0.79	0.037	0.79	0.039	0.84
Orchard and perennial trees	0.469	10.05	0.354	7.59	0.411	8.81
Aquaculture area	0.620	13.30	0.794	17.03	0.806	17.28
Idle land	0.126	2.69	0.185	3.97	0.106	2.28
Mangrove forest	3.282	70.40	3.154	67.65	3.150	67.57
Scrub	0.014	0.29	0.024	0.51	0.035	0.75
Water body	0.109	2.35	0.109	2.35	0.109	2.33
Miscellaneous land	0.006	0.12	0.006	0.12	0.006	0.13
Total	4.662	100.00	4.662	100.00	4.662	100.00

Table 4.27 Area and percentage of LULC of Khlong Bangrong NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	1.311	3.47	1.397	3.69	3.013	7.97
Paddy field	0.454	1.20	0.454	1.20	0.058	0.15
Field crop and horticulture	0.046	0.12	0.124	0.33	0.055	0.15
Orchard and perennial trees	18.968	50.14	18.080	47.80	17.763	46.96
Aquaculture area	2.384	6.30	2.731	7.22	2.629	6.95
Idle land	1.270	3.36	2.088	5.52	1.629	4.31
Evergreen forest	3.746	9.90	3.733	9.87	3.663	9.68
Mangrove forest	6.319	16.71	6.079	16.07	6.043	15.98
Scrub	1.643	4.34	1.433	3.79	1.197	3.16
Water body	0.816	2.16	0.830	2.19	0.846	2.24
Miscellaneous land	0.869	2.30	0.878	2.32	0.932	2.46
Total	37.828	100.00	37.828	100.00	37.828	100.00

Table 4.28 Area and percentage of LULC of Khlong Tarau NRF.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	0.004	0.09	0.004	0.09	0.046	0.94
Field crop and horticulture	0.001	0.03	0.001	0.03	0.001	0.03
Orchard and perennial trees	0.044	0.91	0.044	0.91	0.039	0.82
Aquaculture area	1.186	24.55	1.186	24.55	1.185	24.54
Idle land	0.095	1.97	0.131	2.71	0.253	5.24
Mangrove forest	2.863	59.29	2.862	59.27	2.839	58.80
Scrub	0.206	4.26	0.171	3.55	0.043	0.88
Water body	0.424	8.79	0.424	8.79	0.423	8.75
Miscellaneous land	0.006	0.12	0.006	0.12	0.000	0.00
Total	4.829	100.00	4.829	100.00	4.829	100.00

Table 4.29 Area and percentage of LULC of Khlong Tarau NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	3.420	8.97	4.233	11.10	8.534	22.39
Paddy field	0.386	1.01	0.386	1.01	0.158	0.41
Field crop and horticulture	0.141	0.37	0.303	0.80	0.097	0.25
Orchard and perennial trees	17.412	45.67	17.028	44.67	15.673	41.11
Aquaculture area	2.606	6.84	2.657	6.97	2.293	6.02
Idle land	5.711	14.98	5.403	14.17	3.823	10.03
Evergreen forest	0.971	2.55	0.967	2.54	0.658	1.73
Mangrove forest	4.309	11.30	4.268	11.19	4.356	11.43
Scrub	1.456	3.82	1.078	2.83	0.919	2.41
Water body	1.569	4.12	1.617	4.24	1.450	3.80
Miscellaneous land	0.141	0.37	0.183	0.48	0.162	0.42
Total	38.123	100.00	38.123	100.00	38.123	100.00

Table 4.30 Area and percentage of LULC of Khlong Tajin NRF.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	0.600	9.82	0.917	15.01	1.521	24.90
Orchard and perennial trees	0.139	2.27	0.096	1.57	0.081	1.33
Aquaculture area	0.238	3.90	0.238	3.90	0.251	4.11
Idle land	0.603	9.86	0.423	6.93	0.169	2.77
Evergreen forest	0.063	1.03	0.063	1.03	0.063	1.03
Mangrove forest	3.842	62.88	3.751	61.39	3.506	57.38
Scrub	0.310	5.07	0.300	4.91	0.178	2.91
Water body	0.313	5.13	0.320	5.24	0.322	5.27
Miscellaneous land	0.002	0.03	0.002	0.03	0.018	0.30
Total	6.109	100.00	6.109	100.00	6.109	100.00

Table 4.31 Area and percentage of LULC of Khlong Tajin NRF with buffer area.

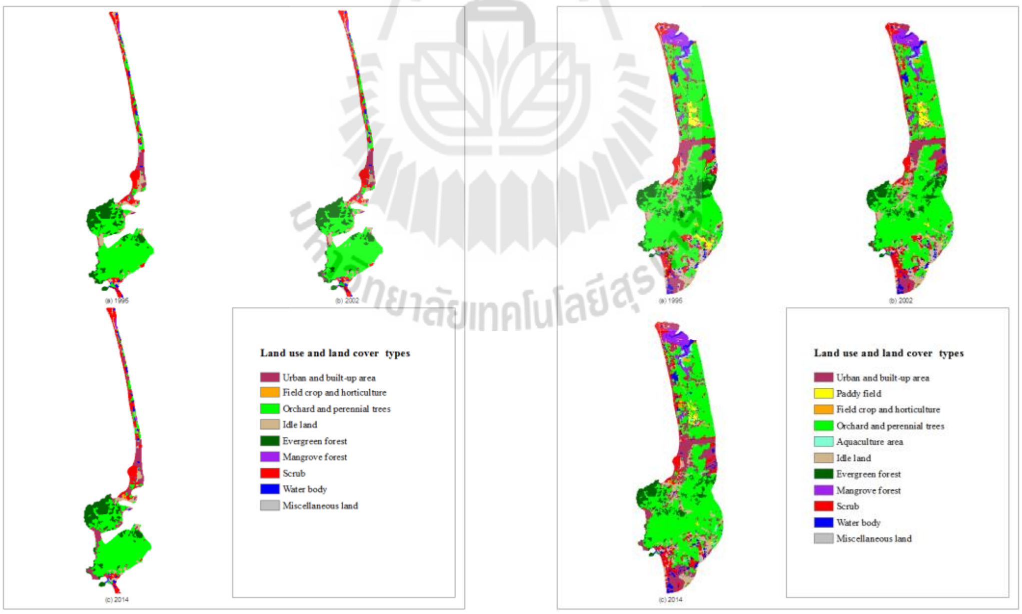
LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	9.886	28.79	10.843	31.57	14.837	43.20
Field crop and horticulture	0.079	0.23	0.103	0.30	0.021	0.06
Orchard and perennial trees	5.483	15.97	5.114	14.89	4.185	12.19
Aquaculture area	0.863	2.51	0.904	2.63	0.828	2.41
Idle land	4.034	11.75	3.254	9.48	1.162	3.38
Evergreen forest	4.896	14.26	4.796	13.96	4.380	12.75
Mangrove forest	4.546	13.24	4.432	12.91	4.134	12.04
Scrub	2.581	7.51	2.879	8.38	2.528	7.36
Water body	1.519	4.42	1.535	4.47	1.489	4.34
Miscellaneous land	0.456	1.33	0.483	1.40	0.778	2.27
Total	34.342	100.00	34.342	100.00	34.342	100.00

Table 4.32 Area and percentage of LULC of Khlong Khopee NRF.

LULC	1995		2002		2014	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	0.428	10.83	0.773	19.55	0.975	24.66
Orchard and perennial trees	0.034	0.85	0.034	0.85	0.028	0.71
Aquaculture area	0.126	3.19	0.129	3.26	0.097	2.45
Idle land	0.189	4.79	0.101	2.55	0.144	3.65
Mangrove forest	2.877	72.76	2.593	65.57	2.572	65.05
Scrub	0.207	5.23	0.233	5.88	0.043	1.07
Water body	0.076	1.93	0.076	1.93	0.080	2.02
Miscellaneous land	0.016	0.41	0.016	0.41	0.015	0.38
Total	3.954	100.00	3.954	100.00	3.954	100.00

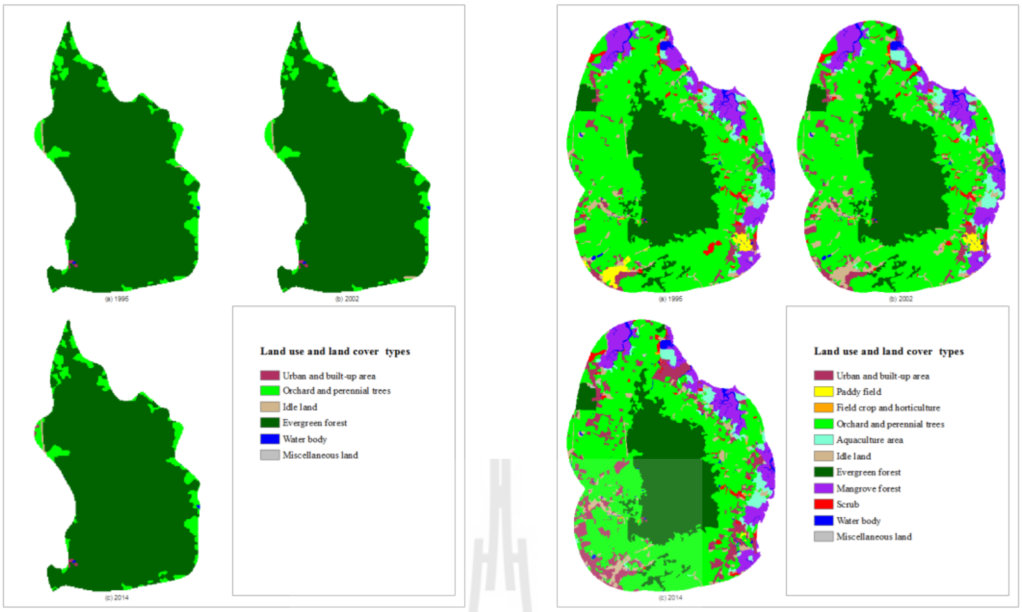
Table 4.33 Area and percentage of LULC of Khlong Khopee NRF with buffer area.

LULC	1995		2002		2014	
	sq. km	**%**	**sq. km**	**%**	**sq. km**	**%**
Urban and built-up area	14.481	42.49	16.386	48.08	19.814	58.14
Field crop and horticulture	0.123	0.36	0.114	0.34	0.106	0.31
Orchard and perennial trees	5.567	16.33	5.413	15.88	4.428	12.99
Aquaculture area	1.098	3.22	1.093	3.21	0.662	1.94
Idle land	3.936	11.55	2.700	7.92	1.459	4.28
Evergreen forest	2.367	6.94	2.129	6.25	1.867	5.48
Mangrove forest	3.858	11.32	3.526	10.35	3.477	10.20
Scrub	1.518	4.45	1.577	4.63	1.194	3.50
Water body	1.056	3.10	1.039	3.05	0.930	2.73
Miscellaneous land	0.078	0.23	0.103	0.30	0.146	0.43
Total	34.082	100.00	34.082	100.00	34.082	100.00



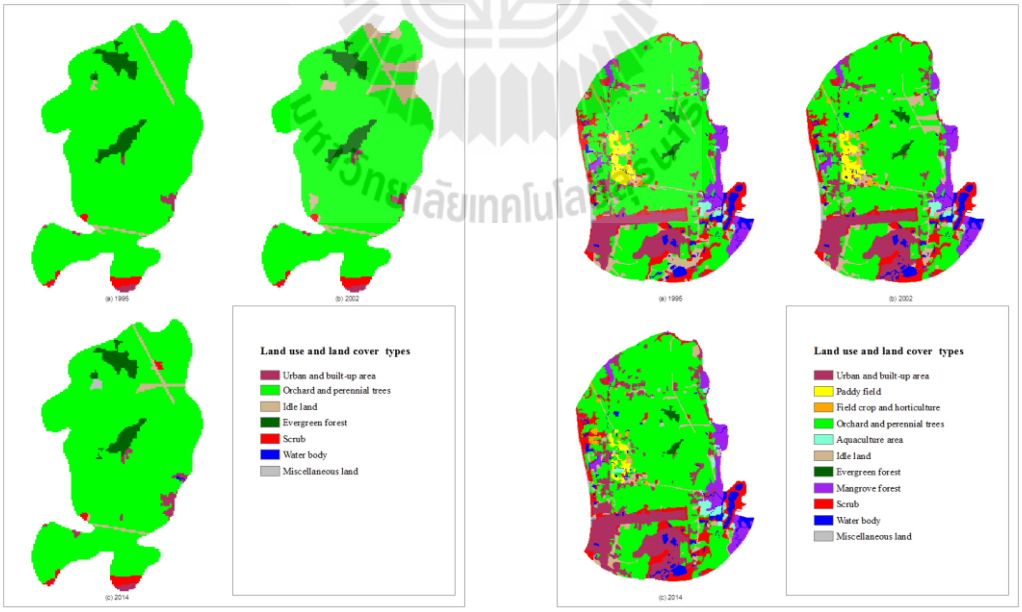
(a) **(b)**

Figure 4.7 LULC type distribution in Sirinath MNP: (a) legal boundary (b) legal boundary with buffer area.



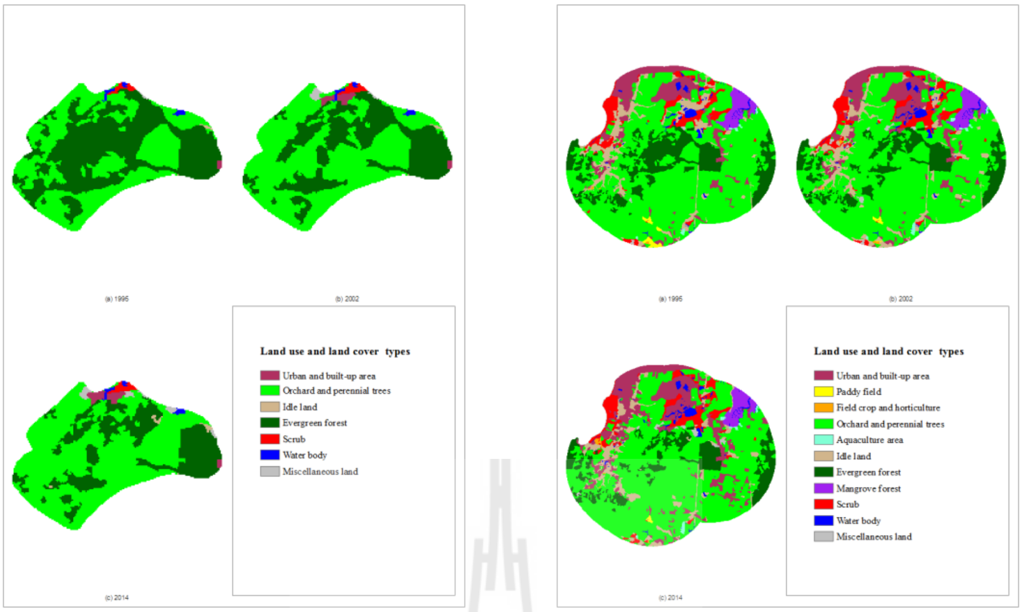
(a) **(b)**

Figure 4.8 LULC type distribution in Khao Phra Thaeo WCDEC: (a) legal boundary (b) legal boundary with buffer area.



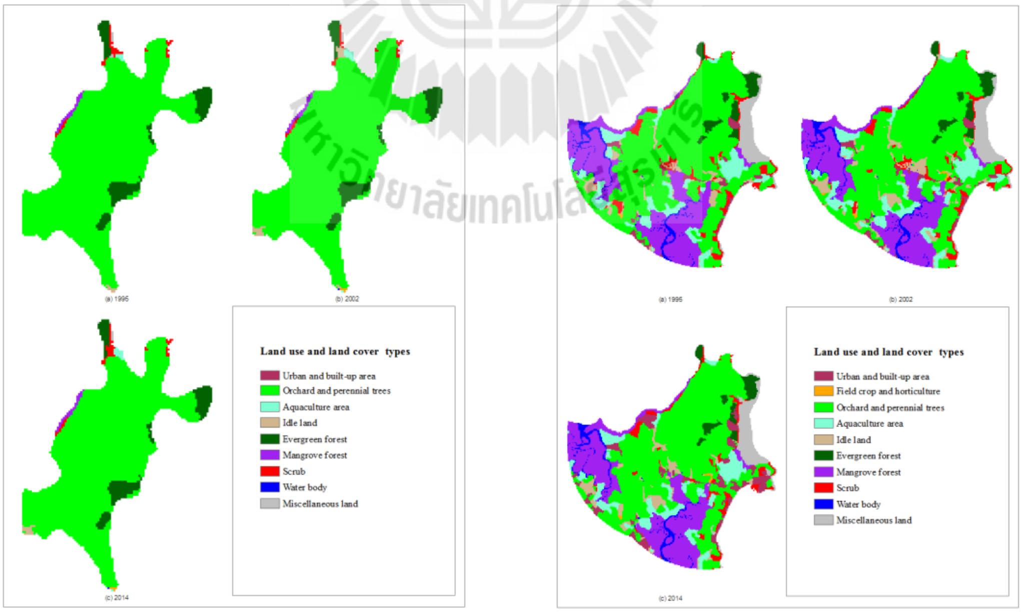
(a) (b)

Figure 4.9 LULC type distribution in Khao Mai Kaew NRF: (a) legal boundary (b) legal boundary with buffer area.



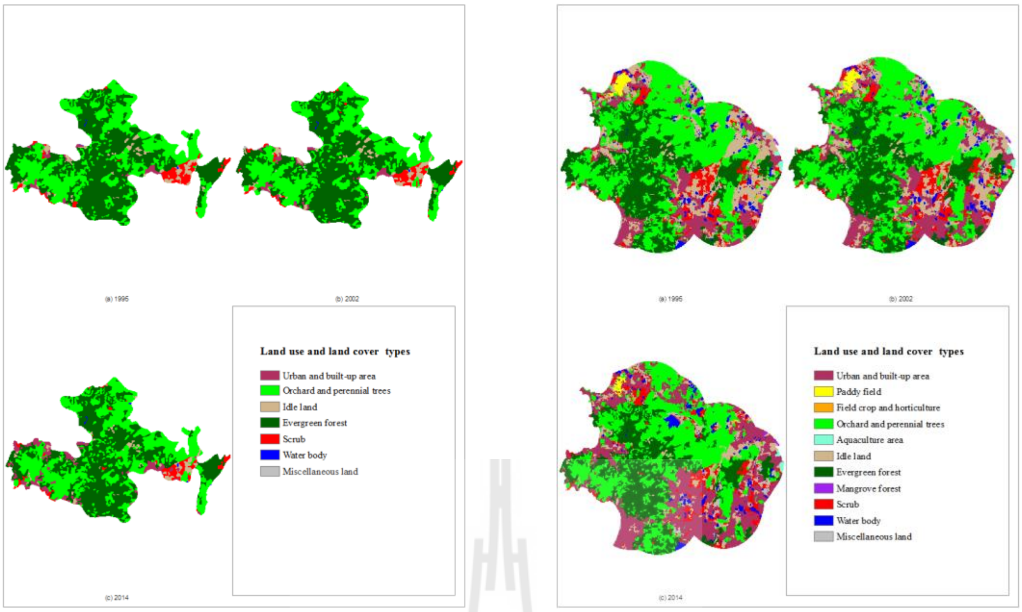
(a) **(b)**

Figure 4.10 LULC type distribution in Khao Bang Khanun NRF: (a) legal boundary (b) legal boundary with buffer area.



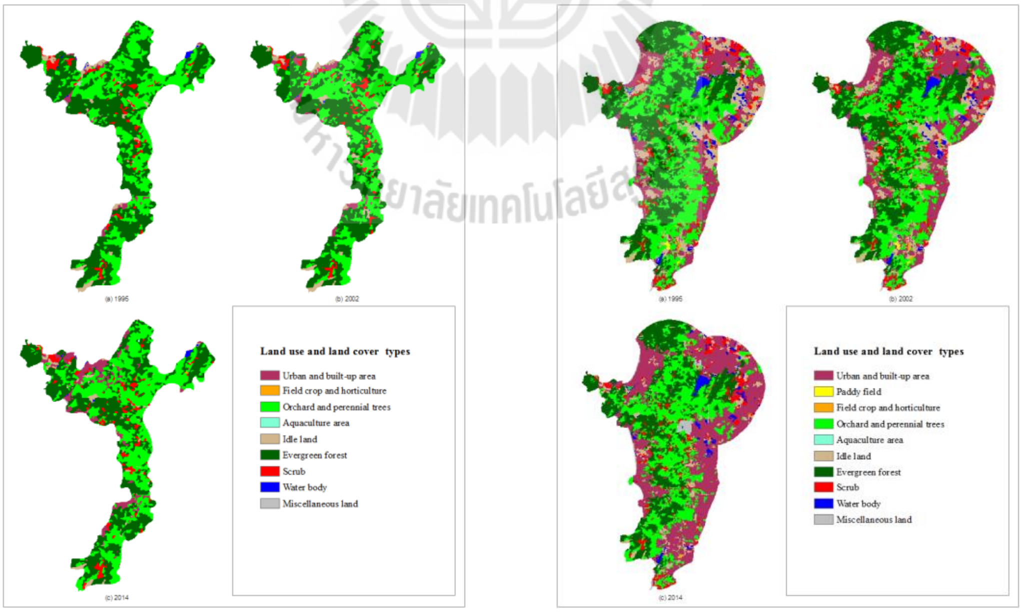
(a) **(b)**

Figure 4.11 LULC type distribution in Khao Sam Liam NRF: (a) legal boundary (b) legal boundary with buffer area.



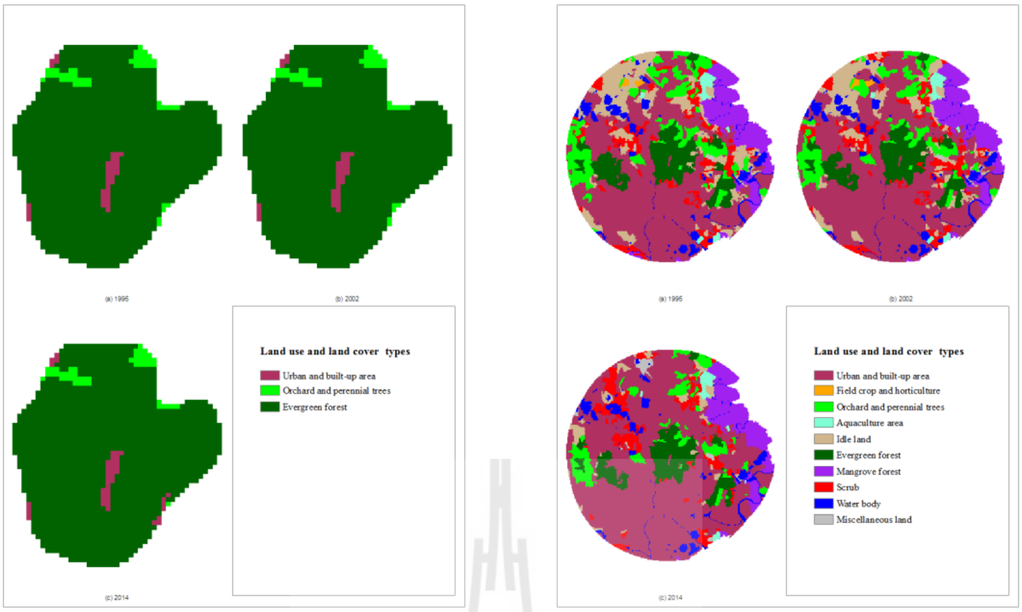
(a) **(b)**

Figure 4.12 LULC type distribution in Khao Kamala NRF: (a) legal boundary (b) legal boundary with buffer area.



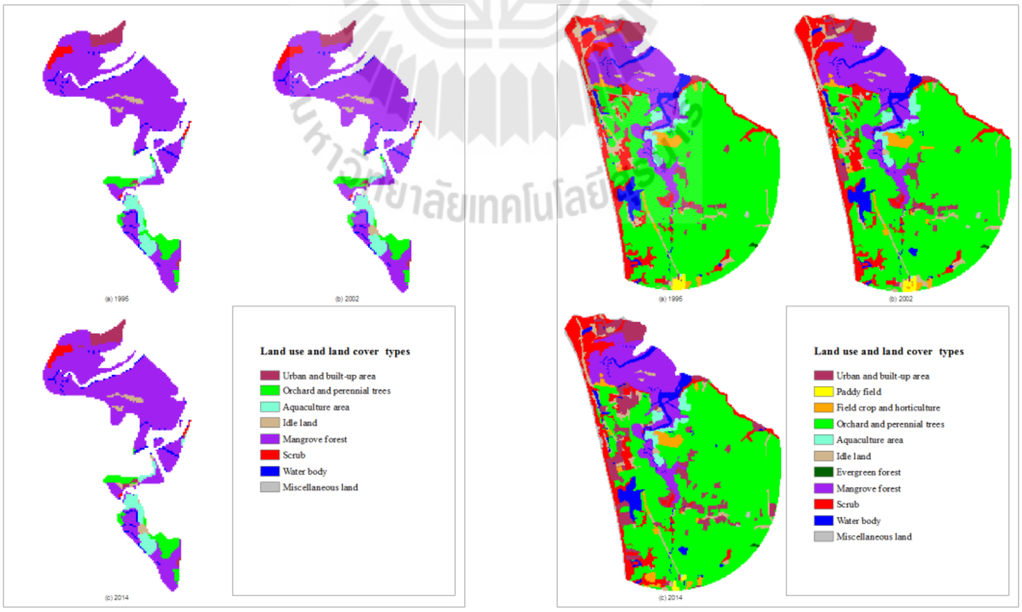
(a) **(b)**

Figure 4.13 LULC type distribution in Khao Nak Keod NRF: (a) legal boundary (b) legal boundary with buffer area.



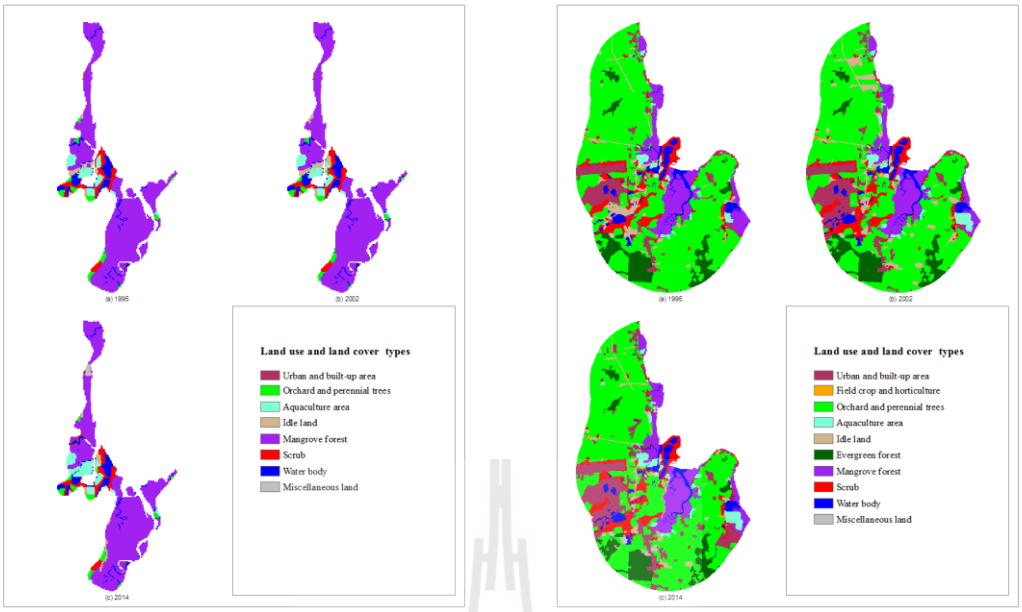
(a) **(b)**

Figure 4.14 LULC type distribution in Khao Tosae NRF: (a) legal boundary (b) legal boundary with buffer area.



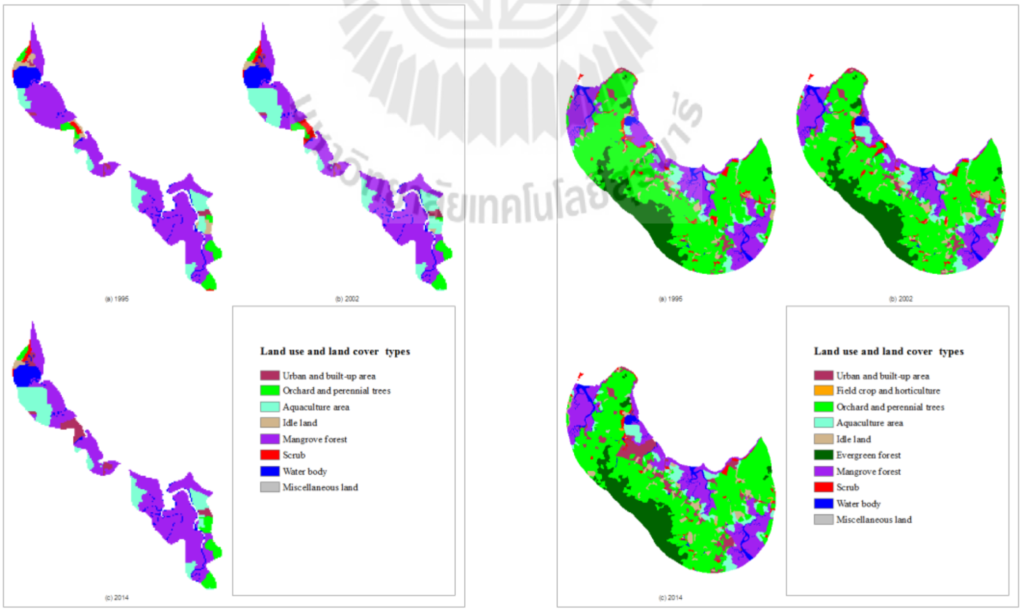
(a) **(b)**

Figure 4.15 LULC type distribution in Khlong U-Tapao NRF: (a) legal boundary (b) legal boundary with buffer area.



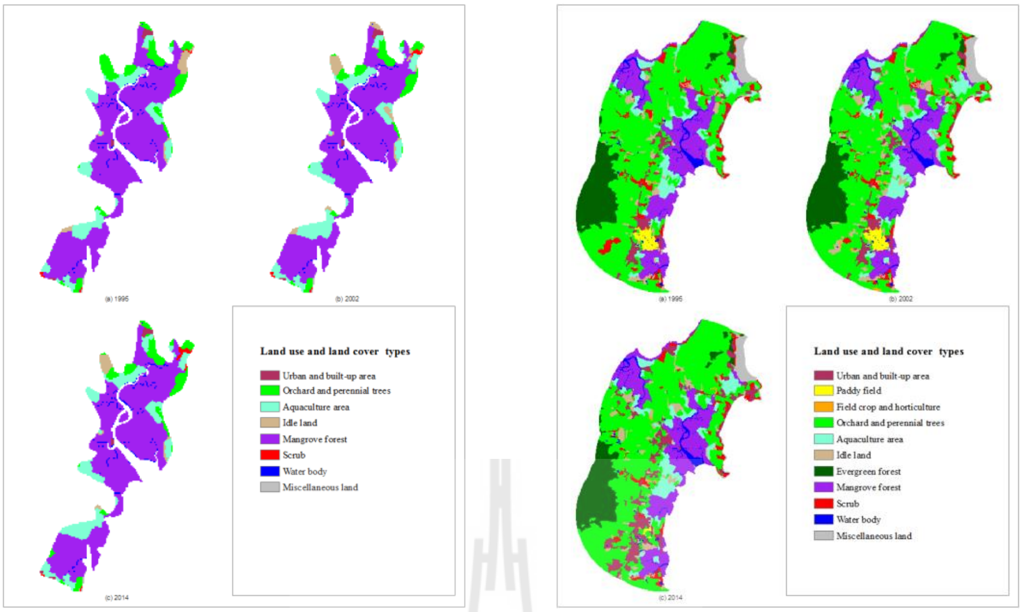
(a) **(b)**

Figure 4.16 LULC type distribution in Khlong Tha Maphrao NRF: (a) legal boundary (b) legal boundary with buffer area.



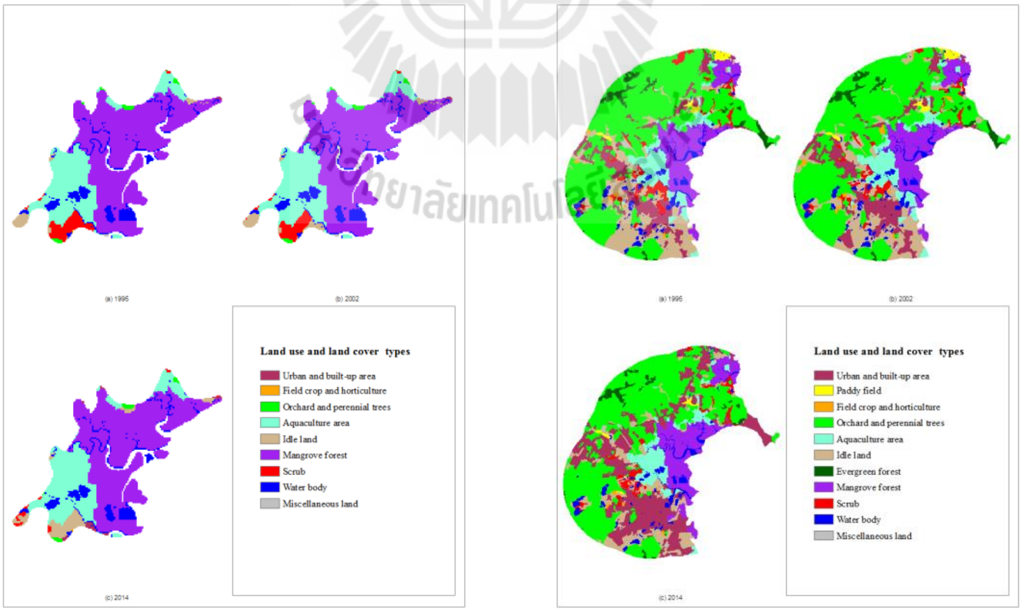
(a) **(b)**

Figure 4.17 LULC type distribution in Khlong Para NRF: (a) legal boundary (b) legal boundary with buffer area.



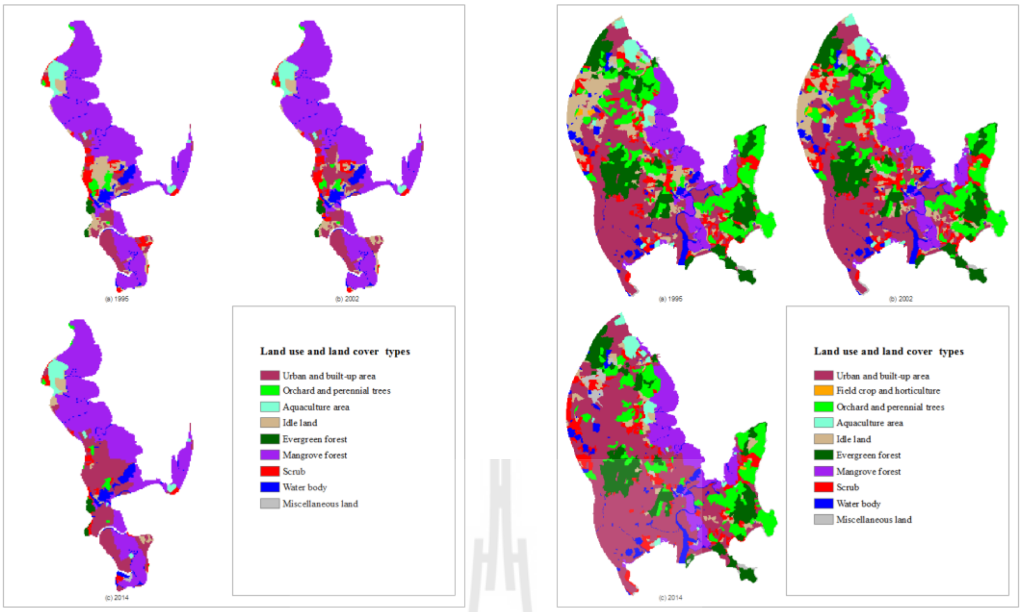
(a) **(b)**

Figure 4.18 LULC type distribution in Khlong Bangrong NRF: (a) legal boundary (b) legal boundary with buffer area.



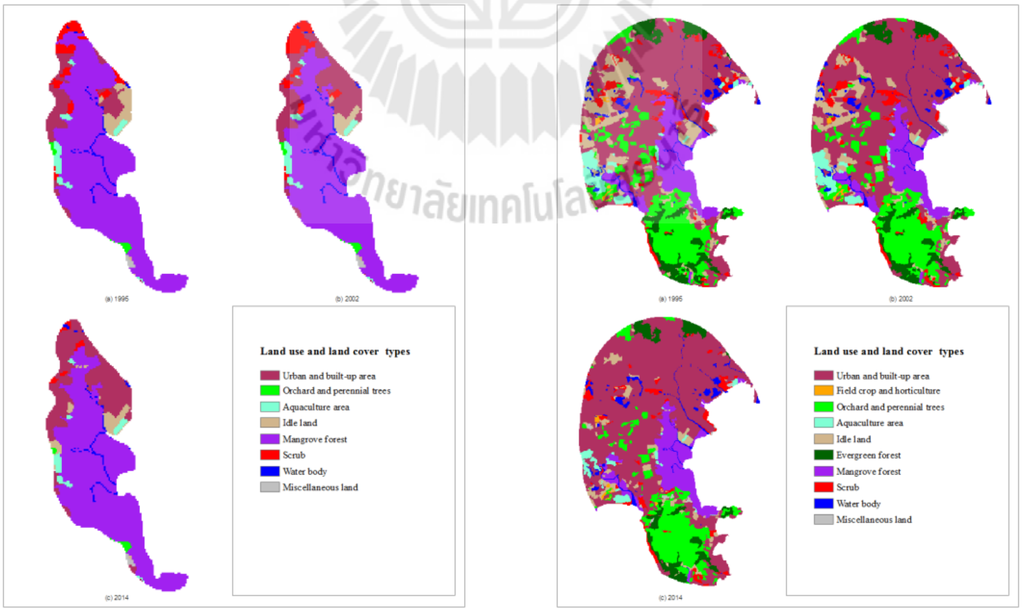
(a) **(b)**

Figure 4.19 LULC type distribution in Khlong Tarau NRF: (a) legal boundary (b) legal boundary with buffer area.



(a) **(b)**

Figure 4.20 LULC type distribution in Khlong Tajin NRF: (a) legal boundary (b) legal boundary with buffer area.



(a) **(b)**

Figure 4.21 LULC type distribution in Khlong Khopee NRF: (a) legal boundary (b) legal boundary with buffer area.

As results, the status of LULC in each protected forest area can be further elaborated in the following sections.

(1) Sirinath MNP

Main LULC type of Sirinath national park in 1995, 2002, and 2014 was orchard and perennial trees which covered area of about 52%, 50% and 48% of the total area in mainland, respectively. Meanwhile, the forest areas occupied about 17%, 16% and 15%, respectively. The result shows that the forest area had been continuously decreased and it can be used as indicator of deforestation in the near future due to an increasing of urban and built-up area.

(2) Khao Phra Thaeo WCDEC

Main LULC type of Khao Phra Thaeo WCDEC in 1995, 2002, and 2014 was evergreen forest which covered area of about 92%, 92% and 92% of the total area, respectively. At the same time, other LULC types included urban and built-up area, orchard and perennial trees, idle land and water body. The result reveals that forest area is quite stable and there is no indicator of deforestation in the near future.

(3) Khao Mai Kaew NRF

Main LULC type of Khao Mai Kaew NRF in 1995, 2002, and 2014 was orchard and perennial trees that covered area of about 91%, 87% and 90% of the total area, respectively. At the same time, evergreen forest occupied area about 5%, 5% and 4%, respectively. The result reveals that forest area is rather stable and there is no indication of deforestation in the near future.

(4) Khao Bang Khanun NRF

Main LULC type of Khao Bang Khanun NRF in 1995, 2002, and 2014 was orchard and perennial trees which covered area of about 46%, 60% and 66%

of the total area, respectively. At the same times, evergreen forest occupied area about 52%, 36% and 29%, respectively. The result shows that forest area had dramatically decreased meanwhile orchard and perennial trees continuously increased. This finding strongly implies an indication of deforestation in the near future due to an increasing of orchard and perennial trees.

(5) Khao Sam Liam NRF

Main LULC type of Khao Sam Liam NRF in 1995, 2002, and 2014 was orchard and perennial trees which covered area of about 89%, 89% and 89% of the total area, respectively. Meanwhile, evergreen forest occupied area about 9%, 9% and 9%, respectively. The result reveals that orchard and perennial trees as main LULC type and forest area is rather stable. There is no indication of deforestation in the near future.

(6) Khao Kamala NRF

Two dominant LULC types of Khao Kamala NRF in 1995, 2002, and 2014 were evergreen forest and orchard and perennial trees. Evergreen forest covered area of about 50%, 50% and 45% of the total area while orchard and perennial trees covered area of 40%, 40% and 43%, respectively. The result reveals that orchard and perennial trees have been increased while forest areas have been decreased. This finding strongly implies indication of deforestation in the near future due to an increasing of urban and built-up area and orchard and perennial trees.

(7) Khao Nak Keod NRF

Two dominant LULC types of Khao Nak Keod NRF in 1995, 2002, and 2014 were evergreen forest and orchard and perennial trees. Evergreen forest covered area of about 51%, 47% and 40% of the total area while orchard and perennial trees covered area of 39%, 40% and 43%, respectively. The result reveals that orchard and perennial trees have been increased while forest areas have been decreased. This finding strongly implies indication of deforestation in the near future due to an increasing of urban and built-up area and orchard and perennial trees.

(8) Khao Tosae NRF

Main LULC type Khao Tosae NRF in 1995, 2002, and 2014 was evergreen forest which covered area of about 94%, 94% and 94% of the total area, respectively. Meanwhile, other LULC types included urban and built-up area and orchard and perennial trees. The result reveals that forest area is quite stable and there is no indication of deforestation in the near future.

(9) Khlong U-Tapao NRF

Main LULC type Khlong U-Tapao NRF in 1995, 2002, and 2014 was mangrove forest which covered area of about 75%, 75% and 75% of the total area, respectively. Meanwhile, other LULC types included urban and built-up area, orchard and perennial trees, aquaculture area, idle land, scrub and water body. The result reveals that forest area is quite stable and there is no indication of deforestation in the near future.

(10) Khlong Tha Maphrao NRF

Main LULC type Khlong Tha Maphrao NRF in 1995, 2002, and 2014 was mangrove forest that covered area of about 73%, 73% and 70% of the total area, respectively. At the same time, other LULC types included urban and built-up area, orchard and perennial trees, aquaculture area, idle land, scrub, water body and miscellaneous land. The result shows that forest areas have been continuously decreased and it can be used as indicator of deforestation in the near future due to an increasing of aquaculture area.

(11) Khlong Para NRF

Main LULC type Khlong Para NRF in 1995, 2002, and 2014 was mangrove forest which covered area of about 66%, 59% and 58% of the total area, respectively. At the same time, other LULC types included urban and built-up area, orchard and perennial trees, aquaculture area, idle land, scrub and water body. The result shows that forest areas have been continuously decreased and it can be used as indicator of deforestation in the near future due to an increasing of urban and built-up area.

(12) Khlong Bangrong NRF

Main LULC type Khlong Bangrong NRF in 1995, 2002, and 2014 was mangrove forest which covered area of about 70%, 68% and 68% of the total area, respectively. Meanwhile, other LULC types included urban and built-up area, orchard and perennial trees, aquaculture area, idle land, scrub, water body and miscellaneous land. The result shows that forest area is rather stable and there is no indication of deforestation in the near future.

(13) Khlong Tarau NRF

Main LULC type Khlong Tarau NRF in 1995, 2002, and 2014 was mangrove forest that covered area of about 59%, 59% and 59% of the total area, respectively. Meanwhile, other LULC types included urban and built-up area, field crop and horticulture, orchard and perennial trees, aquaculture area, idle land, scrub, water body and miscellaneous land. The result shows that forest area is rather stable and there is no indication of deforestation in the near future because other LULC types are also stable.

(14) Khlong Tajin NRF

Main LULC type Khlong Tajin NRF in 1995, 2002, and 2014 was mangrove forest which covered area of about 63%, 61% and 57% of the total area, respectively. Meanwhile, other LULC types included urban and built-up area, orchard and perennial trees, aquaculture area, evergreen forest, idle land, scrub, water body and miscellaneous land. The result shows that mangrove forest have been continuously decreased and it can be used as indicator of deforestation in the near future due to an increasing of urban and built-up area.

(15) Khlong Khopee NRF

Main LULC type Khlong Khopee NRF in 1995, 2002, and 2014 was mangrove forest which covered area of about 73%, 66% and 65% of the total area, respectively. Meanwhile, other LULC types included urban and built-up area, orchard and perennial trees, aquaculture area, idle land, scrub, water body and miscellaneous land. The result shows that mangrove forest areas have been continuously decreased and it implies as indicator of deforestation in the near future due to an increasing of urban and built-up area.

In summary, indicator of deforestation due to LULC change between 1995 and 2014 of 15 protected forest area is summarized in Table 4.34.

Table 4.34 Indicator of deforestation due to LULC change between 1995 and 2014 of 15 protected forest areas.

Protected forest area	Indicator of deforestation
Sirinath MNP	Increasing of urban and built-up area
Khao Phra Thaeo WCDEC	No indicator of deforestation
Khao Mai Kaew NRF	No indicator of deforestation
Khao Bang Khanun NRF	Increasing of orchard and perennial trees.
Khao Sam Liam NRF	No indicator of deforestation
Khao Kamala NRF	Increasing of urban and built-up area and orchard and perennial trees
Khao Nak Keod NRF	Increasing of urban and built-up area and orchard and perennial trees
Khao Tosae NRF	No indicator of deforestation
Khlong U-Tapao NRF	No indicator of deforestation
Khlong Tha Maphrao NRF	Increasing of aquaculture area
Khlong Para NRF	Increasing of urban and built-up area.
Khlong Bangrong NRF	No indicator of deforestation
Khlong Tarau NRF	No indicator of deforestation
Khlong Tajin NRF	Increasing of urban and built-up area.
Khlong Khopee NRF	Increasing of urban and built-up area.

4.2 LULC change assessment between 1995 and 2014

LULC change assessment was here report at two levels: Phuket Island and 15 protected forest areas. Herein LULC change between 1995 and 2002, and 2002 and 2014 as short period of time and 1995 and 2014 as long period of time are summarized in the next two sections.

4.2.1 LULC Change of Phuket Island

1) LULC change between 1995 and 2002

The transitional LULC change matrix of Phuket Island between 1995 and 2002 is displayed in Table 4.35 while the LULC change map is presented in Figure 4.22. It shows the trend of increasing coverage areas of 11.9081, 0.4356, 0.8550, 0.6894, 0.2806, and 0.3431 sq. km (or 1.7012, 0.0622, 0.1221, 0.0985, 0.0401, and 0.0490 sq. km per annum) in 2002 for urban and built-up area, field crop and horticulture, aquaculture area, scrub, water body, and miscellaneous land, respectively. Most of the increased area came from orchard and perennial trees. Herewith urban and built-up area, field crop and horticulture, aquaculture area, scrub, water body, and miscellaneous land change rate are 2.2776%, 0.0833%, 0.1635%, 0.1319%, 0.0537%, and 0.0656%, respectively.

The other LULC types such as paddy field, orchard and perennial trees, idle land, evergreen forest and mangrove forest have shown significant decreased in this period, where decreased area are 1.9125, 6.3050, 0.8500, 4.4238, and 1.0206 sq. km or 0.2732, 0.9007, 0.1214, 0.6320, and 0.1458 sq. km per annum, respectively, together with annual change rate of 0.3658%, 1.2059%, 0.1626%, 0.8461%, and 0.1952%, respectively.

2) LULC change between 2002 and 2014

The quantitative detail of LULC change for Phuket Island in terms of gain and loss between 2002 and 2014 is presented as transitional LULC change matrix in Table 4.36 and LULC change map is displayed in Figure 4.23. It shows an increasing areas of 47.4625, 0.3044, and 1.5231 sq. km (or 3.9552, 0.0254, and 0.1269 sq. km per annum) for urban and built-up area, water body, and miscellaneous land, respectively. Most of an increasing area came from orchard and perennial trees and idles land. Herewith change rate of urban and built-up area, water body, and miscellaneous land are 9.0777%, 0.0582%, and 0.2913%, respectively.

The other LULC types such as paddy field, field crop and horticulture, orchard and perennial trees, aquaculture area, idle land, evergreen forest, mangrove forest, and scrub have been shown significantly decreased in this period whereas decreased area are 1.7281, 0.5063, 14.7206, 0.8906, 19.4838, 8.8706, 0.5700, and 2.5200 sq. km (or 0.1440, 0.0422, 1.2267, 0.0742, 1.6236, 0.7392, 0.0475, and 0.2100 sq. km per annum), respectively with annual change rate of 0.3305%, 0.0968%, 2.8155%, 0.1703%, 3.7265%, 1.6966%, 0.1090%, and 0.4820%, respectively.

3) LULC change between 1995 and 2014

The quantitative LULC change for Phuket Island in terms of gain and loss between 1995 and 2014 as the transitional LULC change matrix is displayed in Table 4.37 while LULC change map is presented in Figure 4.24. It shows an increasing areas of 59.3706, 0.5850, and 1.8663 sq. km (or 3.1248, 0.0308, and 0.0982 sq. km per annum) for urban and built-up area, water body, and miscellaneous land, respectively. Most of the increasing area came from orchard and perennial trees and idle land. Herewith change rate of urban, and built-up area, water body, and miscellaneous land are 11.3553%, 0.1119%, and 0.3569 %, respectively.

The other LULC types such as paddy field, field crop and horticulture, orchard and perennial trees, aquaculture area, idle land, evergreen forest, mangrove forest, and scrub have been shown significantly decreased in this period whereas decreased areas are 3.6406, 0.0706, 21.0256, 0.0356, 20.3338, 13.2944, 1.5906, and 1.8306 sq. km (or 0.1916, 0.0037, 1.1066, 0.0019, 1.0702, 0.6997, 0.0837, and 0.0963 sq. km per annum), respectively with annual change rate of 0.6963%, 0.0135%, 4.0214%, 0.0068%, 3.8890%, 2.5427%, 0.3042%, and 0.3501%, respectively.

In summary, the derived results imply that causes of deforestation are the conversion of forest land to be urban and built-up area and expansion of agricultural land. Meanwhile, Phuket Province has a drastically increasing in number of population in the last decade due to tourism growth (Department of Provincial Administration, 2013) and has emerged as Thailand's strongest hotel market (LaSalle, 2013). This finding of driving factors is also agreed with many previous studies on deforestation in Thailand (Panayotou and Sungsawan, 1989; Panayotou and Parasuk, 1990; Tongpan, Panayotou, Jetanavanich, and Mahi, 1990).

Table 4.35 LULC change areas of Phuket Island for year between 1995 and 2002.

(Unit: sq. km)

LULC 1995	LULC 2002											
	Ur	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**	**Total**
Urban and built-up area (Ur)	66.9094	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	66.9094
Paddy field (Pa)	0.0288	4.4013	0.0544	0.0919	0.0388	1.7038	0.0000	0.0000	0.0056	0.0263	0.0000	6.3506
Field crop and horticulture (Fch)	0.0781	0.0000	1.3150	0.0469	0.0081	0.0650	0.0000	0.0000	0.0000	0.0044	0.0000	1.5175
Orchard and perennial trees (Op)	3.8169	0.0369	0.3794	206.8888	0.1175	5.6481	0.0000	0.0000	0.1281	0.0563	0.1931	217.2650
Aquaculture area (Aq)	0.0081	0.0000	0.0000	0.0100	8.6200	0.1081	0.0000	0.0000	0.0013	0.0119	0.0000	8.7594
Idle land (Id)	5.9175	0.0000	0.1231	1.1738	0.2894	43.2369	0.0000	0.0263	2.9044	0.2444	0.0488	53.9644
Evergreen forest (Ef)	0.6281	0.0000	0.0000	2.2469	0.0000	0.6888	90.0794	0.0000	1.0606	0.0088	0.0719	94.7844
Mangrove forest (Mf)	0.3138	0.0000	0.0000	0.0000	0.4756	0.0919	0.0000	25.6975	0.0969	0.0506	0.0181	26.7444
Scrub (Sc)	1.0250	0.0000	0.0813	0.5019	0.0650	1.4825	0.2813	0.0000	24.6413	0.0256	0.0563	28.1600
Water body (Wa)	0.0488	0.0000	0.0000	0.0000	0.0000	0.0875	0.0000	0.0000	0.0113	13.8031	0.0000	13.9506
Miscellaneous land (Mi)	0.0431	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	4.3956	4.4406
Total	78.8175	4.4381	1.9531	210.9600	9.6144	53.1144	90.3606	25.7238	28.8494	14.2313	4.7838	522.8463
Area of change (sq. km)	11.9081	-1.9125	0.4356	-6.3050	0.8550	-0.8500	-4.4238	-1.0206	0.6894	0.2806	0.3431	
Percent of change (%)	2.2776	-0.3658	0.0833	-1.2059	0.1635	-0.1626	-0.8461	-0.1952	0.1319	0.0537	0.0656	
annual change rate (sq. km)	1.7012	-0.2732	0.0622	-0.9007	0.1221	-0.1214	-0.6320	-0.1458	0.0985	0.0401	0.0490	

Table 4.36 LULC change areas of Phuket Island for year between 2002 and 2014.

(Unit: sq. km)

LULC 2002	**LULC 2014**										
	Ur	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**	**Total**
Urban and built-up area (Ur)	78.6169	0.0000	0.0000	0.0050	0.0000	0.1619	0.0000	0.0000	0.0338	0.0000	0.0000	78.8175
Paddy field (Pa)	0.7000	2.6419	0.0000	0.5750	0.0750	0.3019	0.0000	0.0000	0.0025	0.0356	0.1063	4.4381
Field crop and horticulture (Fch)	0.4431	0.0000	1.1156	0.2331	0.0000	0.1231	0.0000	0.0000	0.0306	0.0075	0.0000	1.9531
Orchard and perennial trees (Op)	19.7406	0.0000	0.1856	184.9613	0.0581	4.4869	0.0000	0.0000	0.2300	0.5113	0.7863	210.9600
Aquaculture area (Aq)	0.7563	0.0000	0.0000	0.0838	8.1306	0.3750	0.0000	0.2038	0.0350	0.0300	0.0000	9.6144
Idle land (Id)	16.4906	0.0681	0.0863	4.5750	0.2994	24.8688	0.0038	0.1663	5.0288	0.5825	0.9450	53.1144
Evergreen forest (Ef)	2.5444	0.0000	0.0000	4.3663	0.0069	0.7975	81.0338	0.0000	1.2150	0.0756	0.3213	90.3606
Mangrove forest (Mf)	0.3988	0.0000	0.0000	0.0400	0.0469	0.2738	0.0000	24.7800	0.0994	0.0244	0.0606	25.7238
Scrub (Sc)	5.4763	0.0000	0.0419	1.3500	0.0875	1.8125	0.4525	0.0000	19.1938	0.1106	0.3244	28.8494
Water body (Wa)	0.6100	0.0000	0.0006	0.0138	0.0138	0.2769	0.0000	0.0038	0.0919	13.1531	0.0675	14.2313
Miscellaneous land (Mi)	0.5031	0.0000	0.0169	0.0363	0.0056	0.1525	0.0000	0.0000	0.3688	0.0050	3.6956	4.7838
Total	126.2800	2.7100	1.4469	196.2394	8.7238	33.6306	81.4900	25.1538	26.3294	14.5356	6.3069	522.8463
Area of change (sq. km)	47.4625	-1.7281	-0.5063	-14.7206	-0.8906	-19.4838	-8.8706	-0.5700	-2.5200	0.3044	1.5231	
Percent of change (%)	9.0777	-0.3305	-0.0968	-2.8155	-0.1703	-3.7265	-1.6966	-0.1090	-0.4820	0.0582	0.2913	
Annual change rate (sq. km)	3.9552	-0.1440	-0.0422	-1.2267	-0.0742	-1.6236	-0.7392	-0.0475	-0.2100	0.0254	0.1269	

Table 4.37 LULC change areas of Phuket Island for year between 1995 and 2014.

(Unit: sq. km)

LULC 1995	LULC 2014											
	Ur	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**	**Total**
Urban and built-up area (Ur)	66.7719	0.0000	0.0000	0.0000	0.0000	0.1038	0.0000	0.0000	0.0338	0.0000	0.0000	66.9094
Paddy field (Pa)	1.0856	2.6338	0.0350	0.6894	0.1169	1.5944	0.0000	0.0000	0.0113	0.0781	0.1063	6.3506
Field crop and horticulture (Fch)	0.4050	0.0000	0.8906	0.1256	0.0000	0.0700	0.0000	0.0000	0.0194	0.0069	0.0000	1.5175
Orchard and perennial trees (Op)	25.1200	0.0288	0.3200	183.2019	0.1600	6.5388	0.0000	0.0000	0.4619	0.5663	0.8675	217.2650
Aquaculture area (Aq)	0.8006	0.0000	0.0000	0.0731	7.2581	0.3900	0.0000	0.1725	0.0363	0.0288	0.0000	8.7594
Idle land (Id)	20.9263	0.0475	0.1181	3.4369	0.4963	20.9650	0.0963	0.1925	5.8975	0.6838	1.1044	53.9644
Evergreen forest (Ef)	3.4631	0.0000	0.0000	6.9044	0.0069	0.9856	81.1075	0.0000	1.8456	0.1206	0.3506	94.7844
Mangrove forest (Mf)	0.8169	0.0000	0.0000	0.0431	0.5013	0.3031	0.0000	24.7850	0.1431	0.0731	0.0788	26.7444
Scrub (Sc)	5.8356	0.0000	0.0663	1.7194	0.1738	2.2994	0.2863	0.0000	17.4381	0.1069	0.2344	28.1600
Water body (Wa)	0.6219	0.0000	0.0000	0.0219	0.0106	0.2700	0.0000	0.0038	0.0919	12.8663	0.0644	13.9506
Miscellaneous land (Mi)	0.4331	0.0000	0.0169	0.0238	0.0000	0.1106	0.0000	0.0000	0.3506	0.0050	3.5006	4.4406
Total	126.2800	2.7100	1.4469	196.2394	8.7238	33.6306	81.4900	25.1538	26.3294	14.5356	6.3069	522.8463
Area of change (sq. km)	59.3706	-3.6406	-0.0706	-21.0256	-0.0356	-20.3338	-13.2944	-1.5906	-1.8306	0.5850	1.8663	
Percent of change (%)	11.3553	-0.6963	-0.0135	-4.0214	-0.0068	-3.8890	-2.5427	-0.3042	-0.3501	0.1119	0.3569	
Annual change rate (sq. km)	3.1248	-0.1916	-0.0037	-1.1066	-0.0019	-1.0702	-0.6997	-0.0837	-0.0963	0.0308	0.0982	

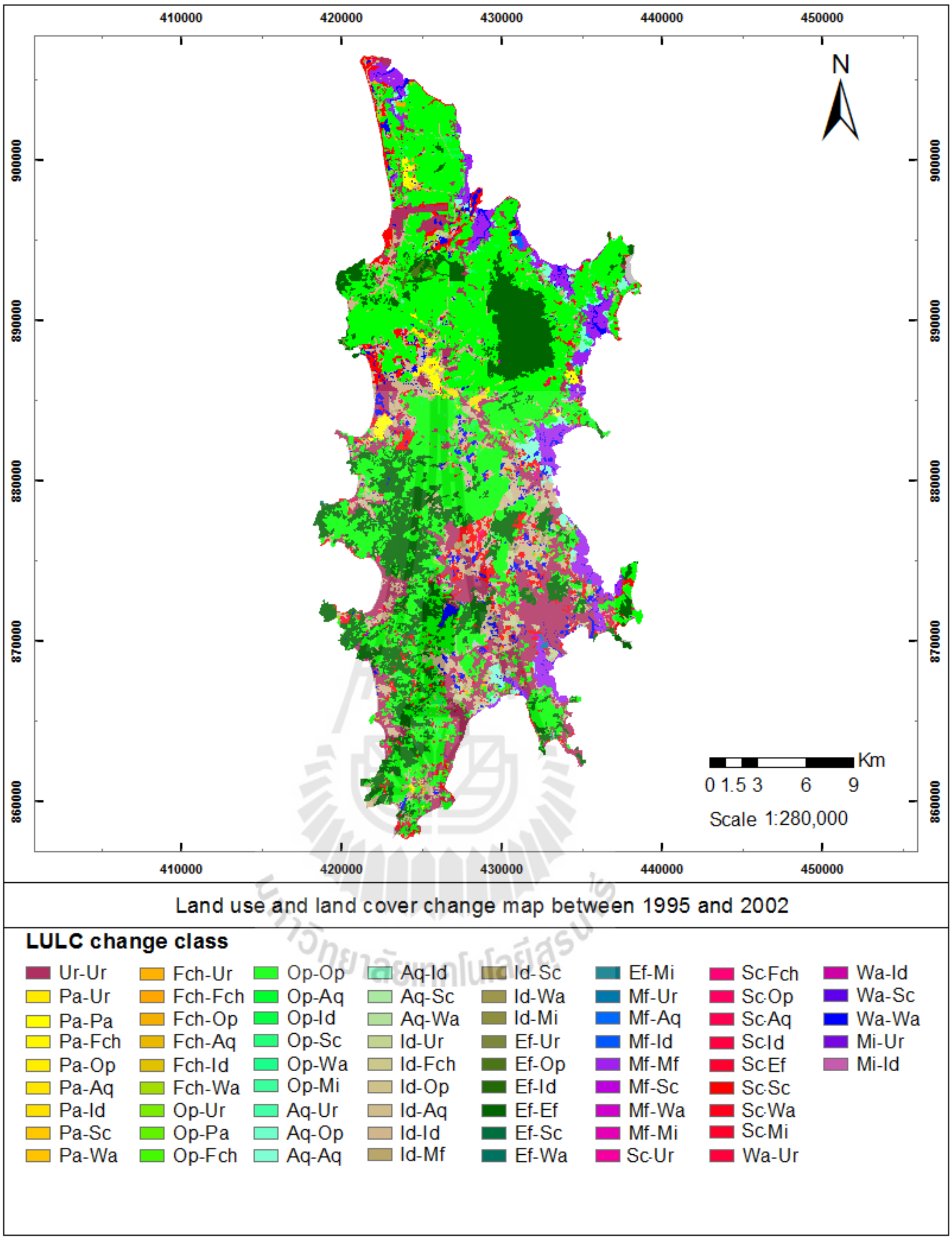


Figure 4.22 LULC change of Phuket Island for year between 1995 and 2002.

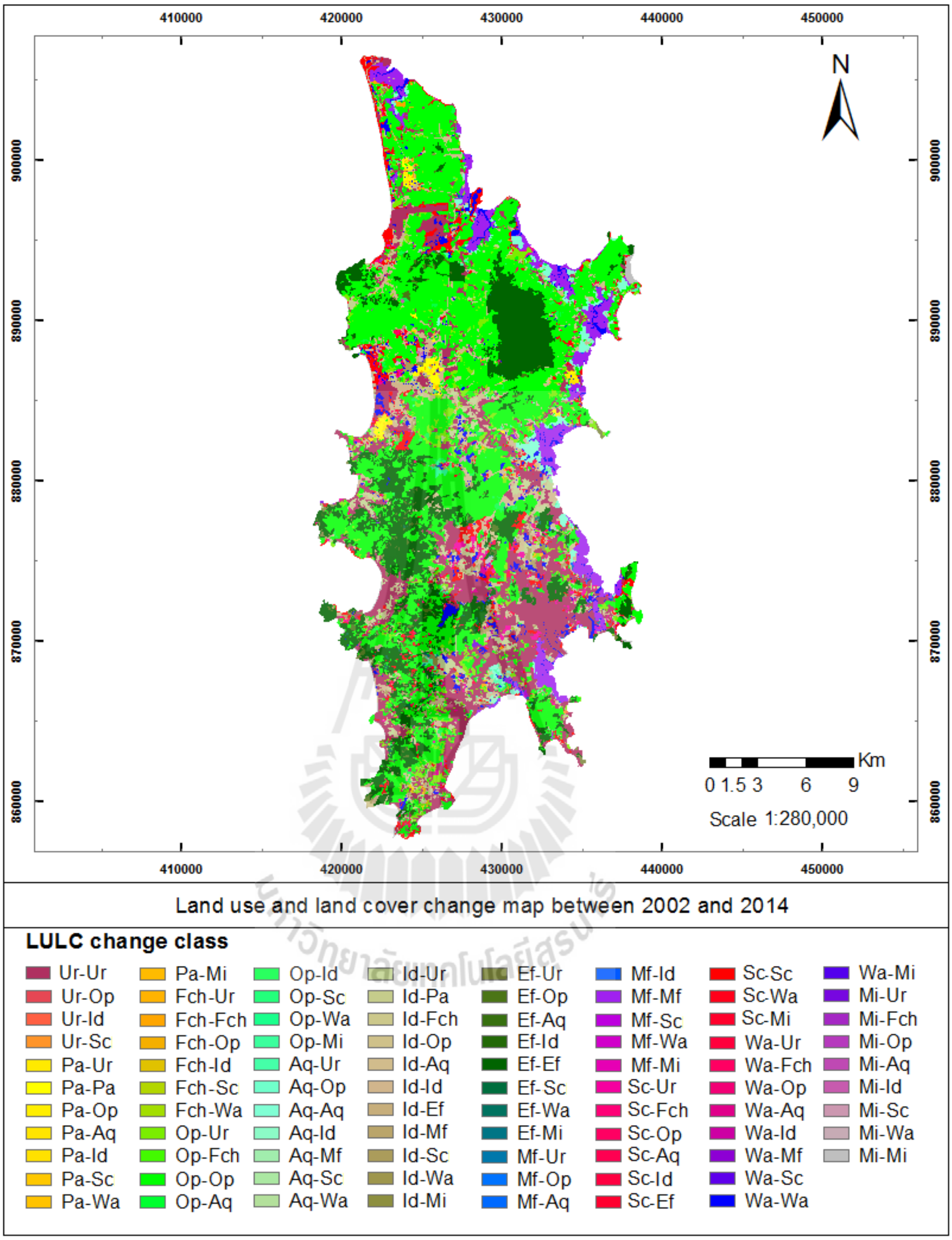


Figure 4.23 LULC change of Phuket Island for year between 2002 and 2014.

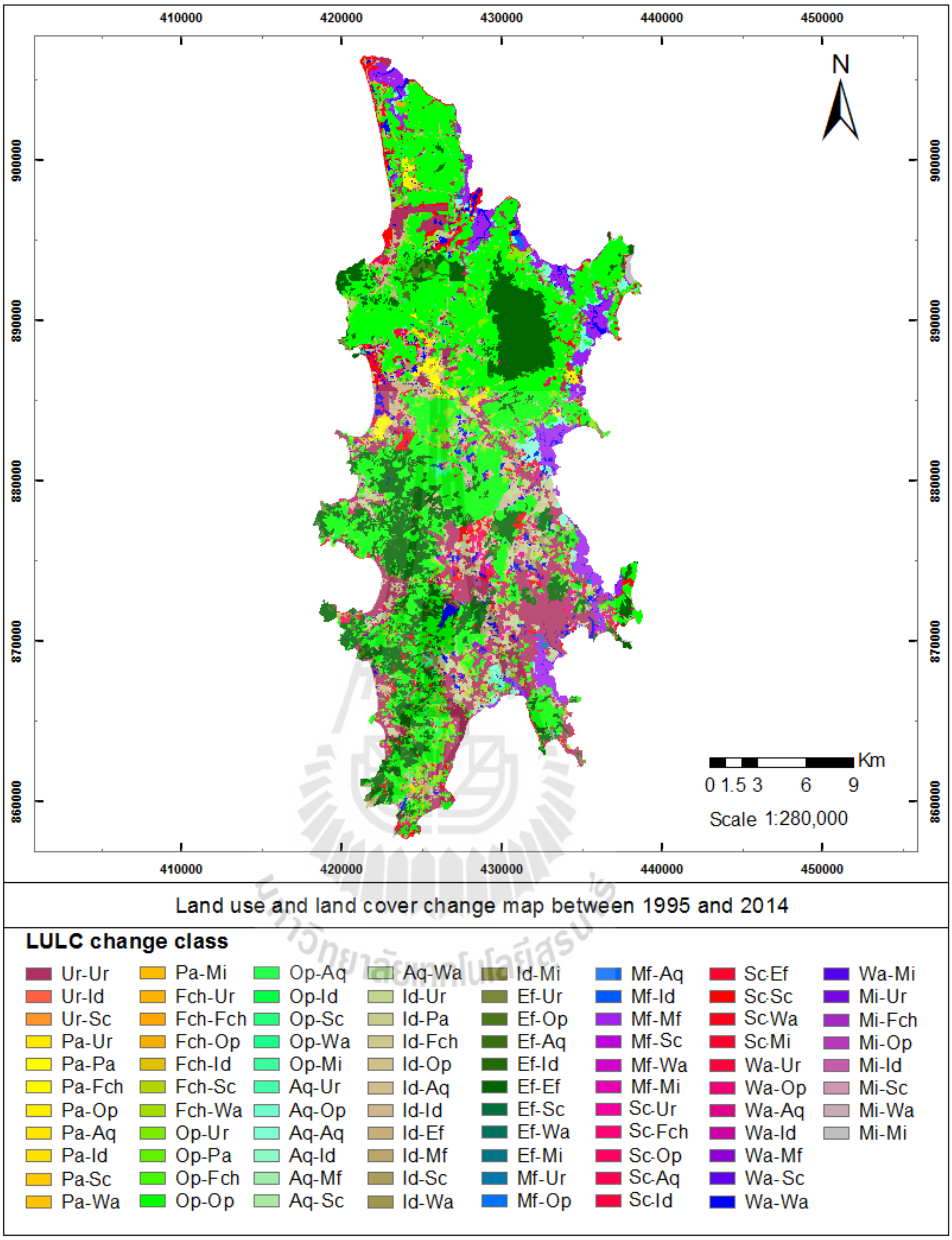


Figure 4.24 LULC change of Phuket Island for year between 1995 and 2014.

4.2.2 LULC Change of 15 protected forest areas

Likewise Phuket Island, the quantitative LULC change of 15 protected forest areas was also extracted using standard transitional change matrix in three periods (1995-2002, 2002-2014 and 1995-2014). The summary of LULC change and annual rate of each protected forest area between 1995 and 2014 is presented in Tables 4.38 to 4.52.

Table 4.38 LULC change between 1995 and 2014 with annual rate of Sirinath MNP.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	1.023	1.308	2.621	0.2850	1.3130	1.5980	0.0407	0.1094	0.0841
Field crop and horticulture	0.033	0.059	0.087	0.0260	0.0280	0.0540	0.0037	0.0023	0.0028
Orchard and perennial trees	10.901	10.671	10.231	-0.2300	-0.4400	-0.6700	-0.0329	-0.0367	-0.0353
Idle land	1.880	1.806	1.350	-0.0740	-0.4560	-0.5300	-0.0106	-0.0380	-0.0279
Evergreen forest	3.433	3.328	3.107	-0.1050	-0.2210	-0.3260	-0.0150	-0.0184	-0.0172
Mangrove forest	0.111	0.111	0.111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Scrub	2.634	2.682	2.516	0.0480	-0.1660	-0.1180	0.0069	-0.0138	-0.0062
Water body	0.393	0.412	0.428	0.0190	0.0160	0.0350	0.0027	0.0013	0.0018
Miscellaneous land	0.756	0.788	0.713	0.0320	-0.0750	-0.0430	0.0046	-0.0063	-0.0023
Total	21.163	21.163	21.163	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.39 LULC change between 1995 and 2014 with annual rate of Khao Phra Thaeo WCDEC.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.026	0.026	0.039	0.0000	0.0130	0.0130	0.0000	0.0011	0.0007
Orchard and perennial trees	1.492	1.485	1.561	-0.0070	0.0760	0.0690	-0.0010	0.0063	0.0036
Idle land	0.050	0.073	0.043	0.0230	-0.0300	-0.0070	0.0033	-0.0025	-0.0004
Evergreen forest	18.783	18.768	18.708	-0.0150	-0.0600	-0.0750	-0.0021	-0.0050	-0.0039
Water body	0.016	0.016	0.016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	20.368	20.368	20.368	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.40 LULC change between 1995 and 2014 with annual rate of Khao Mai Kaew NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.083	0.094	0.144	0.0110	0.0500	0.0610	0.0016	0.0042	0.0032
Orchard and perennial trees	6.666	6.354	6.548	-0.3120	0.1940	-0.1180	-0.0446	0.0162	-0.0062
Idle land	0.119	0.420	0.154	0.3010	-0.2660	0.0350	0.0430	-0.0222	0.0018
Evergreen forest	0.346	0.346	0.324	0.0000	-0.0220	-0.0220	0.0000	-0.0018	-0.0012
Scrub	0.093	0.093	0.106	0.0000	0.0130	0.0130	0.0000	0.0011	0.0007
Water body	0.000	0.000	0.006	0.0000	0.0060	0.0060	0.0000	0.0005	0.0003
Miscellaneous land	0.000	0.000	0.026	0.0000	0.0260	0.0260	0.0000	0.0022	0.0014
Total	7.308	7.308	7.308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.41 LULC change between 1995 and 2014 with annual rate of Khao Bang Khanun NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.017	0.109	0.134	0.0920	0.0250	0.1170	0.0131	0.0021	0.0062
Orchard and perennial trees	3.361	4.362	4.809	1.0010	0.4470	1.4480	0.1430	0.0373	0.0762
Idle land	0.013	0.013	0.041	0.0000	0.0280	0.0280	0.0000	0.0023	0.0015
Evergreen forest	3.799	2.646	2.098	-1.1530	-0.5480	-1.7010	-0.1647	-0.0457	-0.0895
Scrub	0.046	0.064	0.064	0.0180	0.0000	0.0180	0.0026	0.0000	0.0009
Water body	0.050	0.050	0.050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Miscellaneous land	0.006	0.048	0.096	0.0420	0.0480	0.0900	0.0060	0.0040	0.0047
Total	7.291	7.291	7.291	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.42 LULC change between 1995 and 2014 with annual rate of Khao Sam Liam NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Field crop and horticulture	0.000	0.003	0.003	0.0030	0.0000	0.0030	0.0004	0.0000	0.0002
Orchard and perennial trees	2.712	2.698	2.700	-0.0140	0.0020	-0.0120	-0.0020	0.0002	-0.0006
Aquaculture area	0.008	0.014	0.014	0.0060	0.0000	0.0060	0.0009	0.0000	0.0003
Idle land	0.007	0.030	0.014	0.0230	-0.0160	0.0070	0.0033	-0.0013	0.0004
Evergreen forest	0.248	0.240	0.240	-0.0080	0.0000	-0.0080	-0.0011	0.0000	-0.0004
Mangrove forest	0.025	0.025	0.025	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Scrub	0.041	0.031	0.044	-0.0100	0.0130	0.0030	-0.0014	0.0011	0.0002
Water body	0.000	0.001	0.001	0.0010	0.0000	0.0010	0.0001	0.0000	0.0001
Miscellaneous land	0.006	0.004	0.004	-0.0020	0.0000	-0.0020	-0.0003	0.0000	-0.0001
Total	3.046	3.046	3.046	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.43 LULC change between 1995 and 2014 with annual rate of Khao Kamala NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.846	1.083	2.661	0.2370	1.5780	1.8150	0.0339	0.1315	0.0955
Orchard and perennial trees	19.05	19.21	20.26	0.1660	1.0440	1.2100	0.0237	0.0870	0.0637
Idle land	1.738	1.834	1.453	0.0960	-0.3810	-0.2850	0.0137	-0.0318	-0.0150
Evergreen forest	23.82	23.49	21.39	-0.3280	-2.1000	-2.4280	-0.0469	-0.1750	-0.1278
Scrub	1.884	1.652	1.529	-0.2320	-0.1230	-0.3550	-0.0331	-0.0103	-0.0187
Water body	0.051	0.054	0.084	0.0030	0.0300	0.0330	0.0004	0.0025	0.0017
Miscellaneous land	0.063	0.121	0.072	0.0580	-0.0490	0.0090	0.0083	-0.0041	0.0005
Total	47.45	47.45	47.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.44 LULC change between 1995 and 2014 with annual rate of Khao Tosae NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.023	0.023	0.027	0.0000	0.0040	0.0040	0.0000	0.0003	0.0002
Orchard and perennial trees	0.034	0.034	0.031	0.0000	-0.0030	-0.0030	0.0000	-0.0003	-0.0002
Evergreen forest	0.882	0.882	0.880	0.0000	-0.0020	-0.0020	0.0000	-0.0002	-0.0001
Total	0.938	0.938	0.938	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.45 LULC change between 1995 and 2014 with annual rate of Khao Nak Keod NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.663	1.292	2.976	0.6290	1.6840	2.3130	0.0899	0.1403	0.1217
Field crop and horticulture	0.012	0.012	0.019	0.0000	0.0070	0.0070	0.0000	0.0006	0.0004
Orchard and perennial trees	14.649	15.074	16.264	0.4250	1.1900	1.6150	0.0607	0.0992	0.0850
Aquaculture area	0.000	0.000	0.007	0.0000	0.0070	0.0070	0.0000	0.0006	0.0004
Idle land	1.183	1.478	0.963	0.2950	-0.5150	-0.2200	0.0421	-0.0429	-0.0116
Evergreen forest	19.126	17.571	15.170	-1.5550	-2.4010	-3.9560	-0.2221	-0.2001	-0.2082
Scrub	1.682	1.939	1.948	0.2570	0.0090	0.2660	0.0367	0.0007	0.0140
Water body	0.153	0.143	0.156	-0.0100	0.0130	0.0030	-0.0014	0.0011	0.0002
Miscellaneous land	0.083	0.042	0.048	-0.0410	0.0060	-0.0350	-0.0059	0.0005	-0.0018
Total	37.550	37.550	37.550	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.46 LULC change between 1995 and 2014 with annual rate of Khlong U-Tapao NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.106	0.106	0.113	0.0000	0.0070	0.0070	0.0000	0.0006	0.0004
Orchard and perennial trees	0.182	0.174	0.163	-0.0080	-0.0110	-0.0190	-0.0011	-0.0009	-0.0010
Aquaculture area	0.153	0.142	0.142	-0.0110	0.0000	-0.0110	-0.0016	0.0000	-0.0006
Idle land	0.040	0.058	0.069	0.0180	0.0110	0.0290	0.0026	0.0009	0.0015
Mangrove forest	1.878	1.878	1.871	0.0000	-0.0070	-0.0070	0.0000	-0.0006	-0.0004
Scrub	0.059	0.059	0.059	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water body	0.078	0.078	0.078	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	2.495	2.495	2.495	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.47 LULC change between 1995 and 2014 with annual rate of Khlong Tha Maphrao NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.014	0.014	0.046	0.0000	0.0320	0.0320	0.0000	0.0027	0.0017
Orchard and perennial trees	0.138	0.131	0.128	-0.0070	-0.0030	-0.0100	-0.0010	-0.0003	-0.0005
Aquaculture area	0.207	0.192	0.264	-0.0150	0.0720	0.0570	-0.0021	0.0060	0.0030
Idle land	0.083	0.118	0.083	0.0350	-0.0350	0.0000	0.0050	-0.0029	0.0000
Mangrove forest	2.606	2.593	2.508	-0.0130	-0.0850	-0.0980	-0.0019	-0.0071	-0.0052
Scrub	0.236	0.228	0.228	-0.0080	0.0000	-0.0080	-0.0011	0.0000	-0.0004
Water body	0.290	0.298	0.288	0.0080	-0.0100	-0.0020	0.0011	-0.0008	-0.0001
Miscellaneous land	0.000	0.000	0.028	0.0000	0.0280	0.0280	0.0000	0.0023	0.0015
Total	3.573	3.573	3.573	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.48 LULC change between 1995 and 2014 with annual rate of Khlong Bangrong NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.037	0.037	0.039	0.0000	0.0020	0.0020	0.0000	0.0002	0.0001
Orchard and perennial trees	0.469	0.354	0.411	-0.1150	0.0570	-0.0580	-0.0164	0.0048	-0.0031
Aquaculture area	0.620	0.794	0.806	0.1740	0.0120	0.1860	0.0249	0.0010	0.0098
Idle land	0.126	0.185	0.106	0.0590	-0.0790	-0.0200	0.0084	-0.0066	-0.0011
Mangrove forest	3.282	3.154	3.150	-0.1280	-0.0040	-0.1320	-0.0183	-0.0003	-0.0069
Scrub	0.014	0.024	0.035	0.0100	0.0110	0.0210	0.0014	0.0009	0.0011
Water body	0.109	0.109	0.109	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Miscellaneous land	0.006	0.006	0.006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	4.662	4.662	4.662	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.49 LULC change between 1995 and 2014 with annual rate of Khlong Para NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.058	0.088	0.196	0.0300	0.1080	0.1380	0.0043	0.0090	0.0073
Orchard and perennial trees	0.214	0.207	0.215	-0.0070	0.0080	0.0010	-0.0010	0.0007	0.0001
Aquaculture area	0.393	0.686	0.646	0.2930	-0.0400	0.2530	0.0419	-0.0033	0.0133
Idle land	0.126	0.034	0.026	-0.0920	-0.0080	-0.1000	-0.0131	-0.0007	-0.0053
Mangrove forest	2.236	1.971	1.964	-0.2650	-0.0070	-0.2720	-0.0379	-0.0006	-0.0143
Scrub	0.060	0.089	0.028	0.0290	-0.0610	-0.0320	0.0041	-0.0051	-0.0017
Water body	0.278	0.290	0.290	0.0120	0.0000	0.0120	0.0017	0.0000	0.0006
Total	3.365	3.365	3.365	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.50 LULC change between 1995 and 2014 with annual rate of Khlong Tarau NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.004	0.004	0.046	0.0000	0.0420	0.0420	0.0000	0.0035	0.0022
Field crop and horticulture	0.001	0.001	0.001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Orchard and perennial trees	0.044	0.044	0.039	0.0000	-0.0050	-0.0050	0.0000	-0.0004	-0.0003
Aquaculture area	1.186	1.186	1.185	0.0000	-0.0010	-0.0010	0.0000	-0.0001	-0.0001
Idle land	0.095	0.131	0.253	0.0360	0.1220	0.1580	0.0051	0.0102	0.0083
Mangrove forest	2.863	2.862	2.839	-0.0010	-0.0230	-0.0240	-0.0001	-0.0019	-0.0013
Scrub	0.206	0.171	0.043	-0.0350	-0.1280	-0.1630	-0.0050	-0.0107	-0.0086
Water body	0.424	0.424	0.423	0.0000	-0.0010	-0.0010	0.0000	-0.0001	-0.0001
Miscellaneous land	0.006	0.006	0.000	0.0000	-0.0060	-0.0060	0.0000	-0.0005	-0.0003
Total	4.829	4.829	4.829	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.51 LULC change between 1995 and 2014 with annual rate of Khlong Tajin NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.600	0.917	1.521	0.3170	0.6040	0.9210	0.0453	0.0503	0.0485
Orchard and perennial trees	0.139	0.096	0.081	-0.0430	-0.0150	-0.0580	-0.0061	-0.0013	-0.0031
Aquaculture area	0.238	0.238	0.251	0.0000	0.0130	0.0130	0.0000	0.0011	0.0007
Idle land	0.603	0.423	0.169	-0.1800	-0.2540	-0.4340	-0.0257	-0.0212	-0.0228
Evergreen forest	0.063	0.063	0.063	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mangrove forest	3.842	3.751	3.506	-0.0910	-0.2450	-0.3360	-0.0130	-0.0204	-0.0177
Scrub	0.310	0.300	0.178	-0.0100	-0.1220	-0.1320	-0.0014	-0.0102	-0.0069
Water body	0.313	0.320	0.322	0.0070	0.0020	0.0090	0.0010	0.0002	0.0005
Miscellaneous land	0.002	0.002	0.018	0.0000	0.0160	0.0160	0.0000	0.0013	0.0008
Total	6.109	6.109	6.109	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.52 LULC change between 1995 and 2014 with annual rate of Khlong Khopee NRF.

LULC Type	Year			LULC change			Annual rate		
	1995	2002	2014	1995-2002	2002-2014	1995-2014	1995-2002	2002-2014	1995-2014
Urban and built-up area	0.428	0.773	0.975	0.3450	0.2020	0.5470	0.0493	0.0168	0.0288
Orchard and perennial trees	0.034	0.034	0.028	0.0000	-0.0060	-0.0060	0.0000	-0.0005	-0.0003
Aquaculture area	0.126	0.129	0.097	0.0030	-0.0320	-0.0290	0.0004	-0.0027	-0.0015
Idle land	0.189	0.101	0.144	-0.0880	0.0430	-0.0450	-0.0126	0.0036	-0.0024
Mangrove forest	2.877	2.593	2.572	-0.2840	-0.0210	-0.3050	-0.0406	-0.0017	-0.0161
Scrub	0.207	0.233	0.043	0.0260	-0.1900	-0.1640	0.0037	-0.0158	-0.0086
Water body	0.076	0.076	0.080	0.0000	0.0040	0.0040	0.0000	0.0003	0.0002
Miscellaneous land	0.016	0.016	0.015	0.0000	-0.0010	-0.0010	0.0000	-0.0001	-0.0001
Total	3.954	3.954	3.954	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

As results, the development of LULC changed area in three period (1995-2002, 2002-2014 considerably as short period of time and 1995-2014 as long period of time) with annual change rate of protected forest area were reported and comparatively compared in table form. It is found that urban and built-up areas have been increased between 1995 and 2014 in 14 protected forest areas, particularly, Sirinath MNP, Khao Kamala, Khao Nak Keod NRFs in evergreen forest and Khlong Tajin NRF in mangrove forest areas have annual increasing rates between 1995 and 2014 of about 0.0841, 0.0955, 0.1217, and 0.0485 sq. km, respectively. Likewise, aquaculture areas have also been increased in mangrove forest national reserved forest area, especially Khlong Para and Khlong Bangrong NRFs with annual rate of 0.0133 and 0.0098 sq. km.

On the contrary, evergreen forest areas have been decreased between 1995 and 2014 within 2 national parks and 6 evergreen forest national reserved forest area. Particularly, Sirinath MNP, Khao Kamala and Khao Nak Keod NRFs have annual decreasing rate between 1995 and 2014 of about 0.0172, 0.1278, and 0.2082 sq. km, respectively. Likewise mangrove forest areas have been also decreased between 1995 and 2014 in all mangrove forest national reserved forest areas. Particularly, Khlong Para, Khlong Tajin and Khlong Khopee NRFs have annual decreasing rate between 1995 and 2014 about 0.0143, 0.0177, and 0.0161 sq. km, respectively.

Meanwhile, other LULC types have been increased or decreased in the specific protected forest areas. Orchard and perennial trees, which frequently situated in evergreen forest NRFs have been increased in Khao Bang Khanun, Khao Kamala, and Khao Nak Keod NRFs during 1995 to 2014 have a tremendous decreasing with annual rate of 0.0762, 0.0637, and 0.0850 sq. km, respectively. In contrast, areas of idle land have a tremendous decreasing in Sirinath MNP, Khao Kamala, and Khao Nak Keod in evergreen forest NRFs and Khlong Tajin mangrove forest NRF with annual rate during 1995 to 2014 of 0.0279, 0.0150, 0.0116, and 0.0228 sq. km, respectively. Unlikely, scrub trees have been minor decreased in Khao Kamala, Khlong Tarau, Khlong Tajin, and Khlong Khopee NRFs while they have been minor increased in Khao

Nak Keod NRF, Likewise, miscellaneous areas of lands had been minor decreased in Sirinath MNP and Khao Nak Keod NRF but they have been minor increased in Khao Bang Khanun NRF.

Detail of annual change rate LULC types in two periods (1995-2002 and 2002-2014) of 15 protected forest areas are comparatively displayed in Figures 4.25 to 4.39. These result can be used to extrapolate the future change of each LULC type. For example, in the near future urban and built-up area tend to increase while idle land tend to decrease in Sirinath MNP.

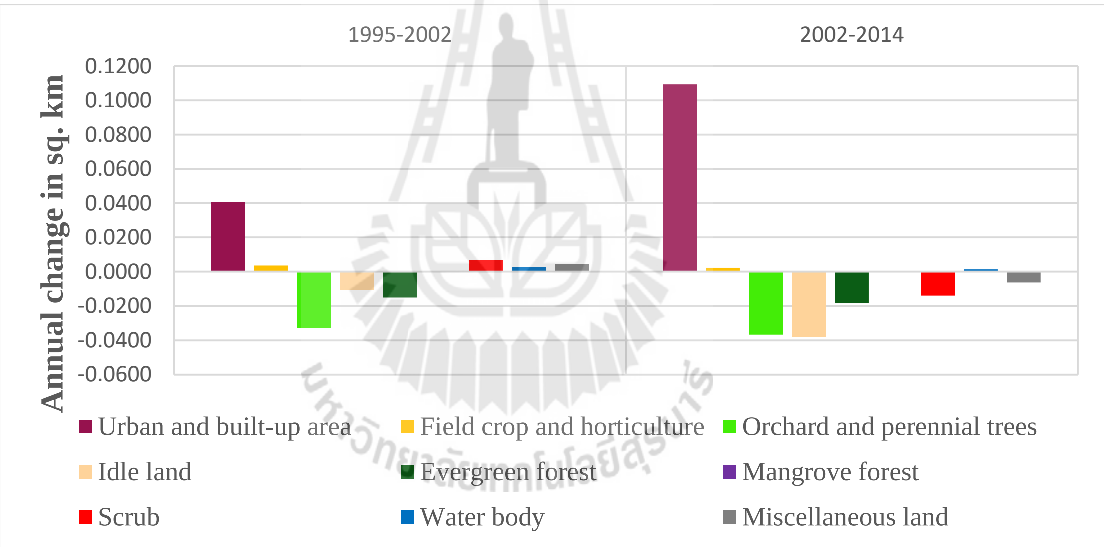


Figure 4.25 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Sirinath MNP.

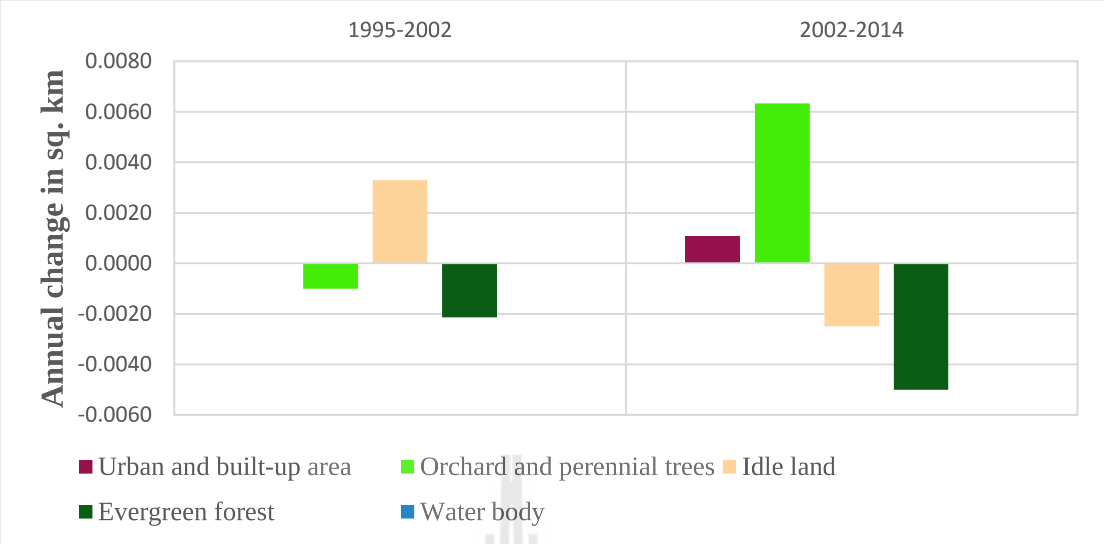


Figure 4.26 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Phra Thaeo WCDEC.

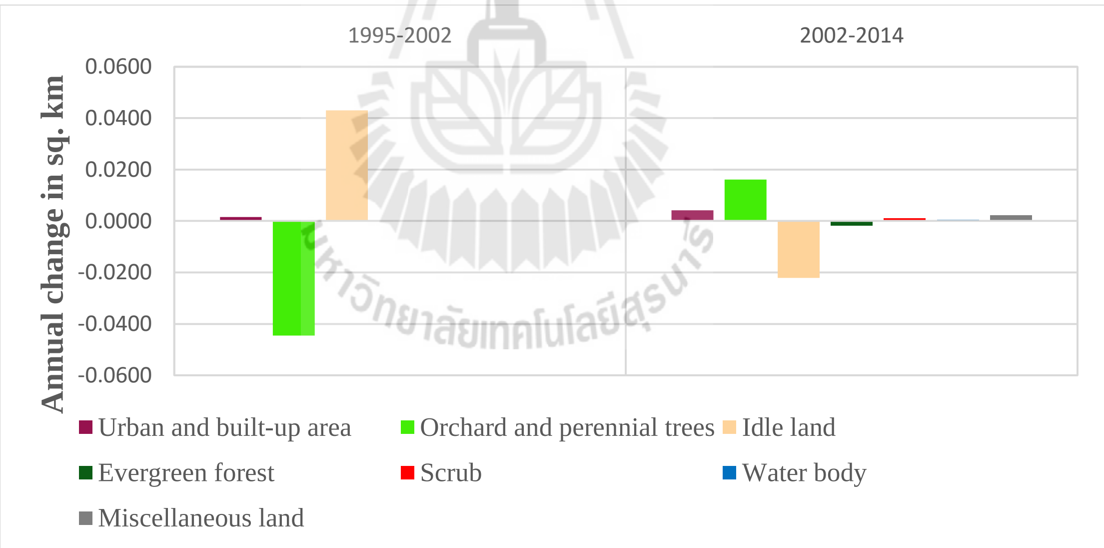


Figure 4.27 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Mai Kaew NRF.

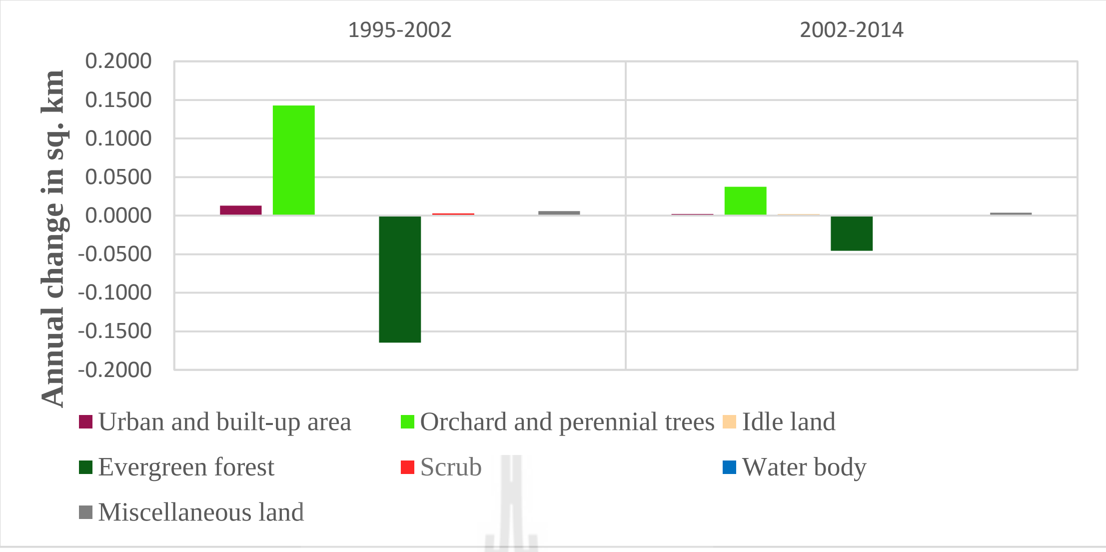


Figure 4.28 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Bang Khanun NRF.

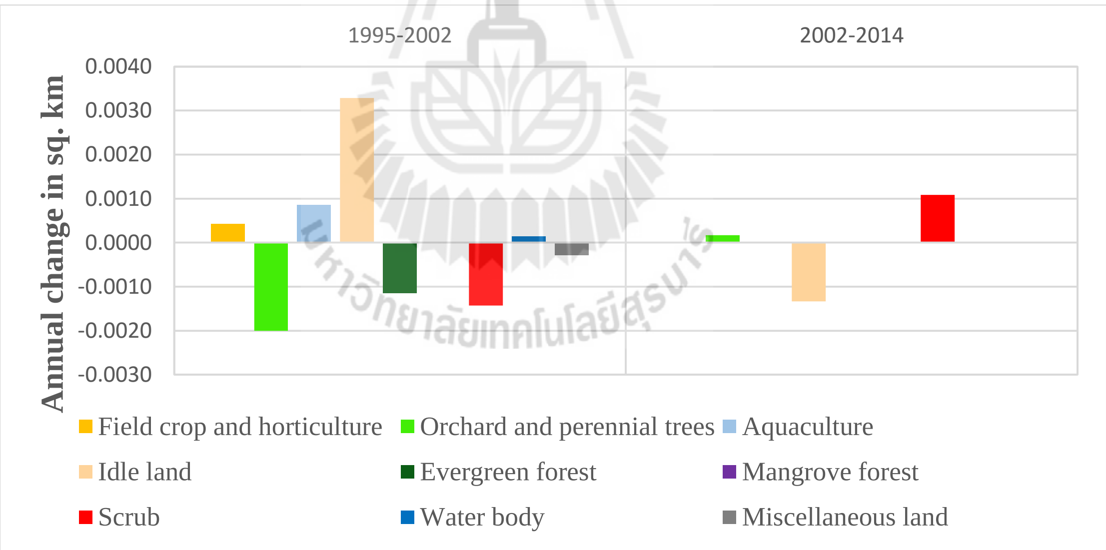


Figure 4.29 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Sam Liam NRF.

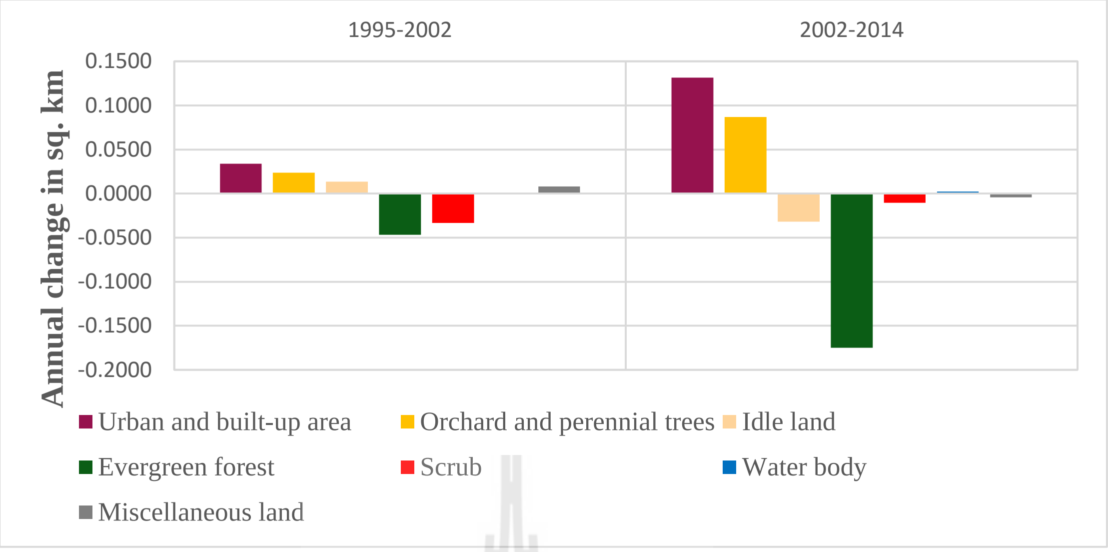


Figure 4.30 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Kamala forest NRF.

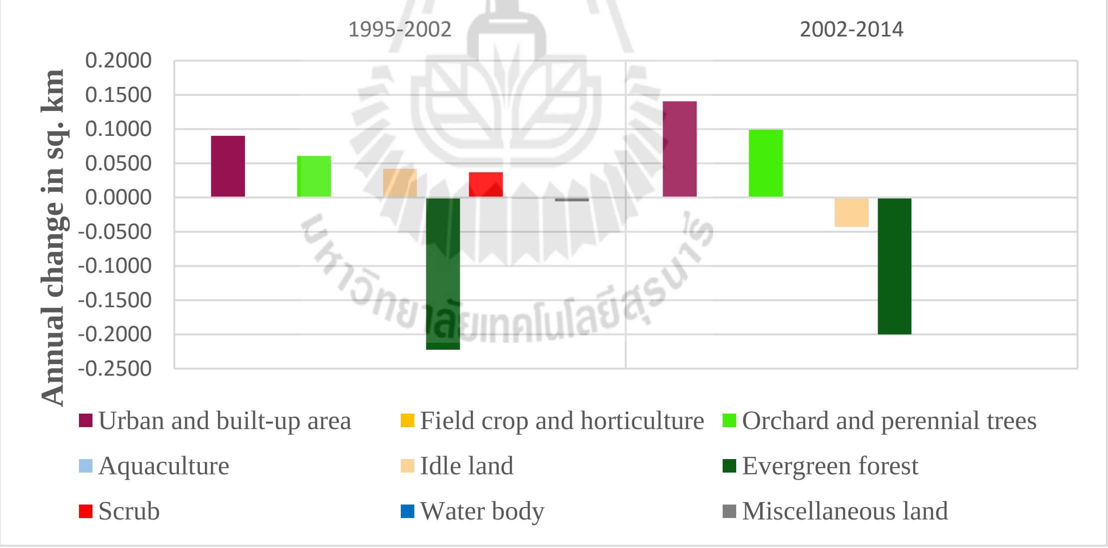


Figure 4.31 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Nak Keod NRF.

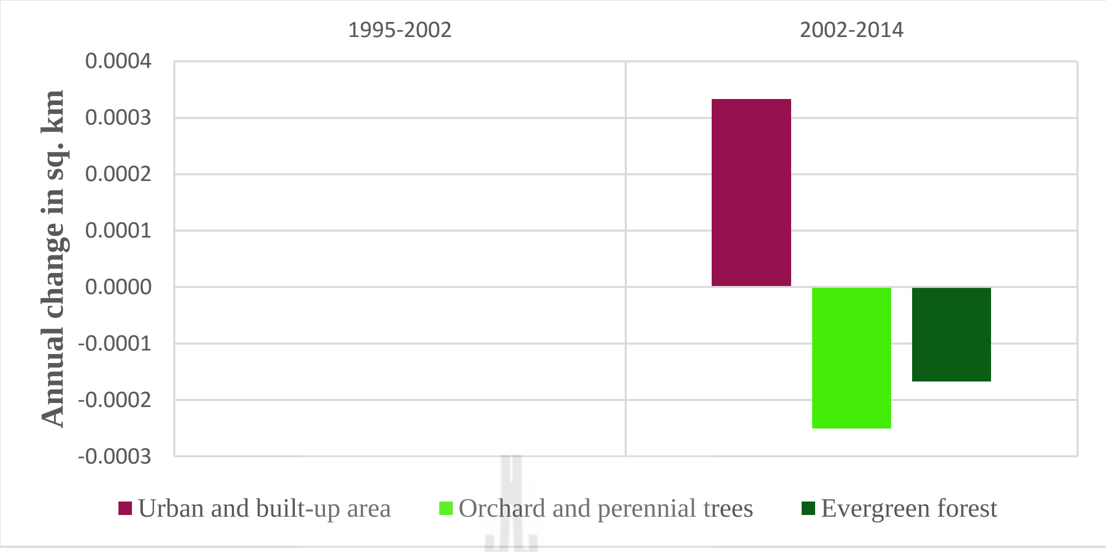


Figure 4.32 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khao Tosae NRF.

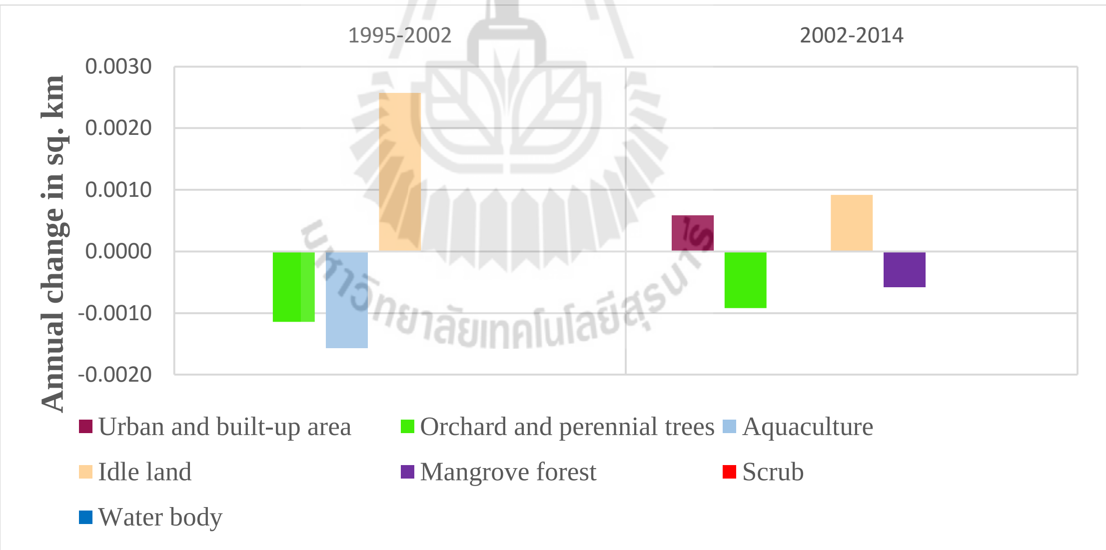


Figure 4.33 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong U-Tapao NRF.

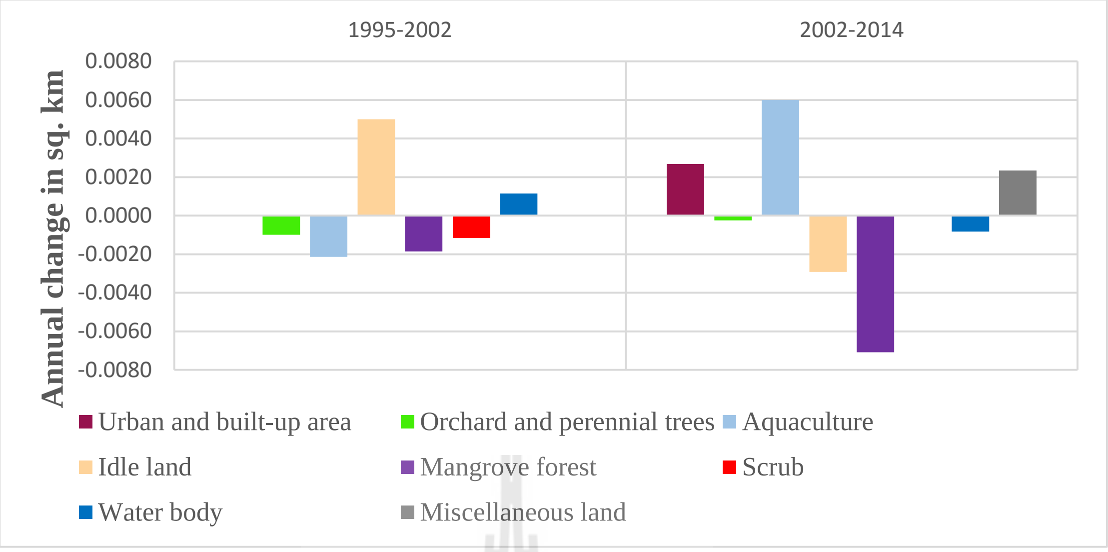


Figure 4.34 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong Tha Maphrao NRF.

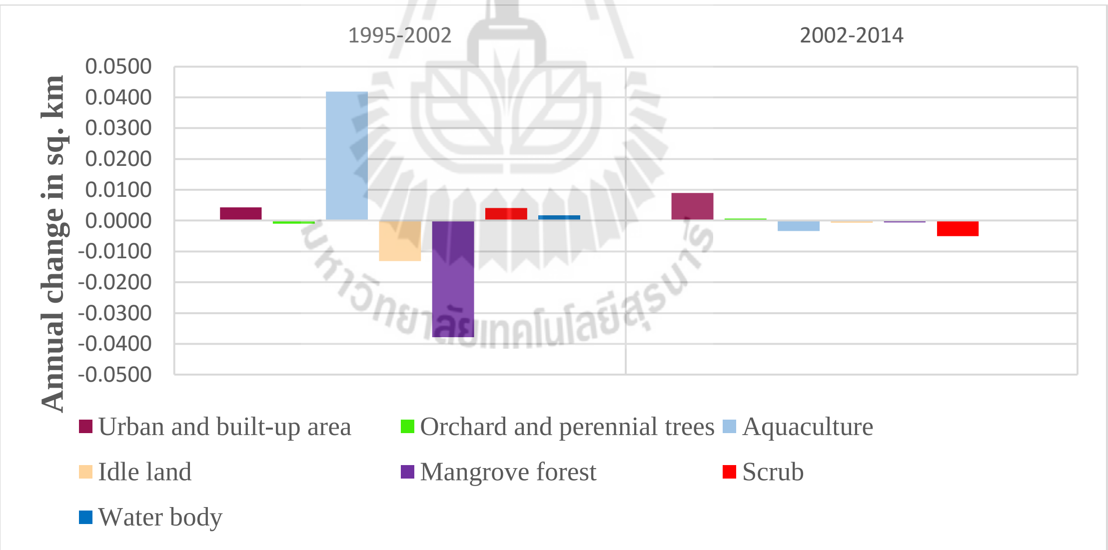


Figure 4.35 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong Para NRF.

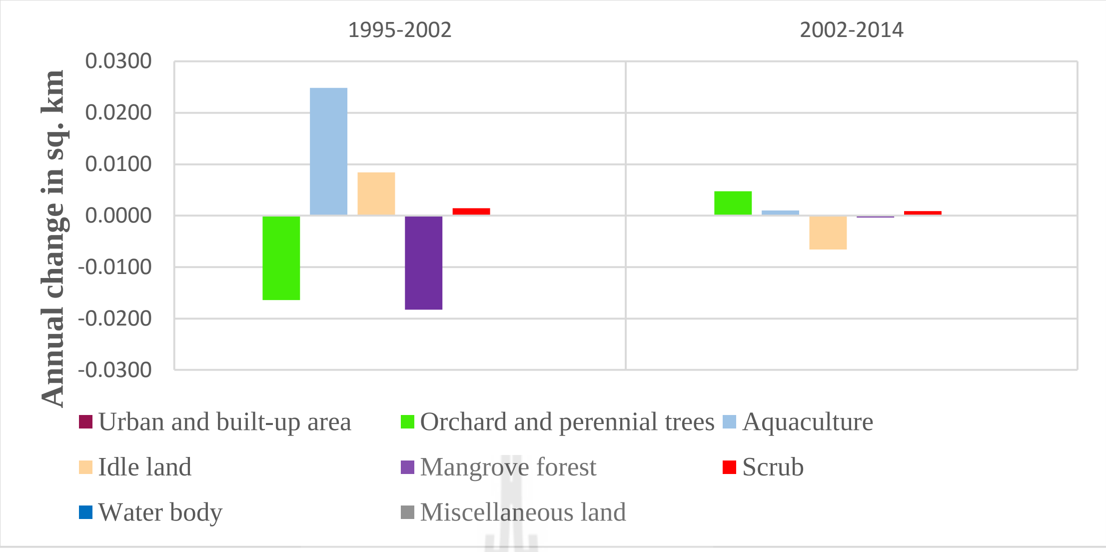


Figure 4.36 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong Bangrong NRF.

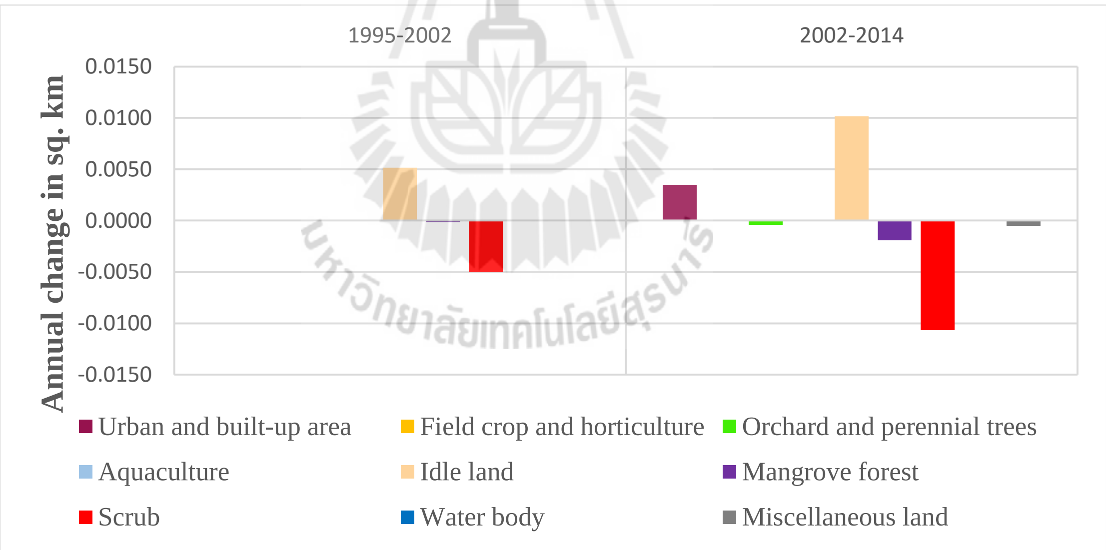


Figure 4.37 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong Tarau NRF.

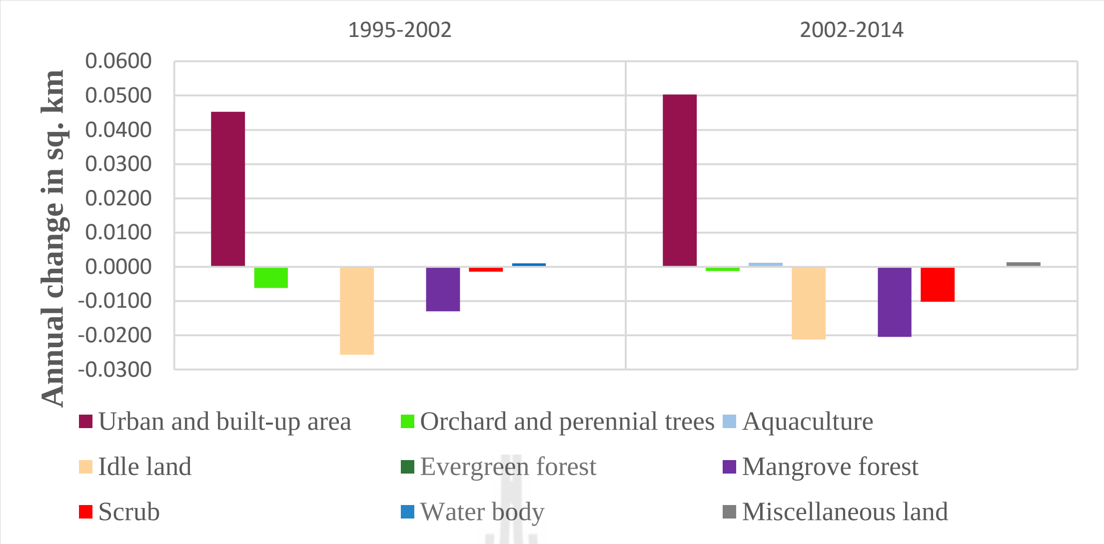


Figure 4.38 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong Tajin NRF.

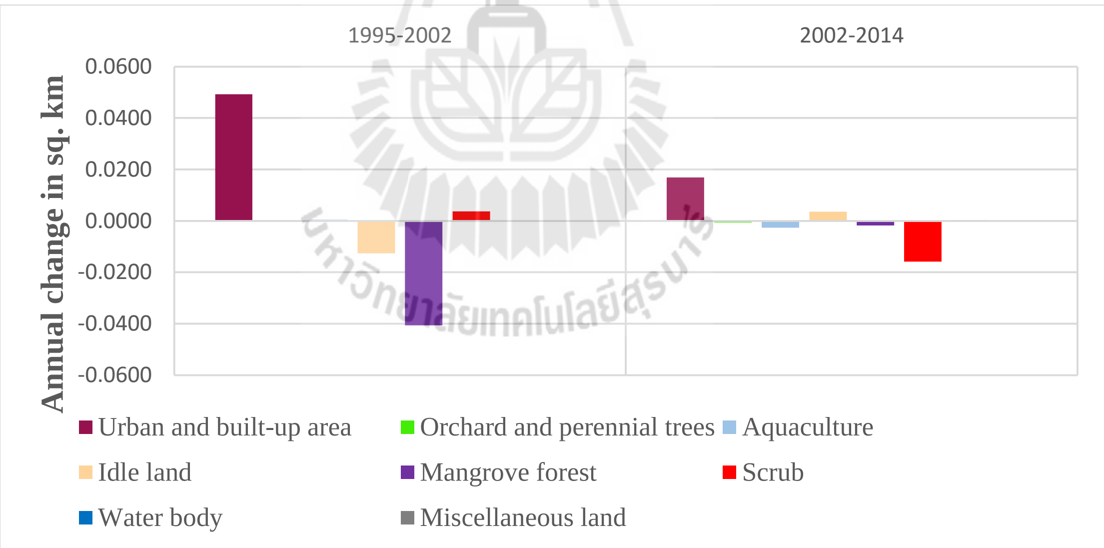


Figure 4.39 Annual change rate of LULC types of the two periods (1995-2002 and 2002-2014) of Khlong Khopee NRF.

4.3 Deforestation between 1995 and 2014

4.3.1 Deforestation in Phuket Island

Based on LULC change data of the three periods (1995-2002, 2002-2014 as short period of time and 1995-2014 as long period of time), deforestation in evergreen and mangrove forests of Phuket Island can be extracted and summarized in Table 4.53. Annual deforestation rate of the three periods of evergreen and mangrove forests and total forest area are comparatively displayed in Figure 4.40.

Table 4.53 Existing forest area and deforestation between 1995 and 2014.

LULC data and deforestation	Forest area in sq. km		
	Evergreen forest	**Mangrove forest**	**Total**
LULC in 1995	94.780	26.744	121.524
LULC in 2002	90.356	25.724	116.080
Deforestation area: 1995-2002	4.424	1.020	5.444
Annual deforestation rate (sq. km)	0.632	0.146	0.778
LULC in 2002	90.356	25.724	116.080
LULC in 2014	81.489	25.154	106.643
Deforestation area: 2002-2014	8.867	0.570	9.437
Annual deforestation rate (sq. km)	0.739	0.047	0.786
LULC in 1995	94.780	26.744	121.524
LULC in 2014	81.489	25.154	106.643
Deforestation area: 1995-2014	13.291	1.590	14.881
Annual deforestation rate (sq. km)	0.699	0.084	0.783

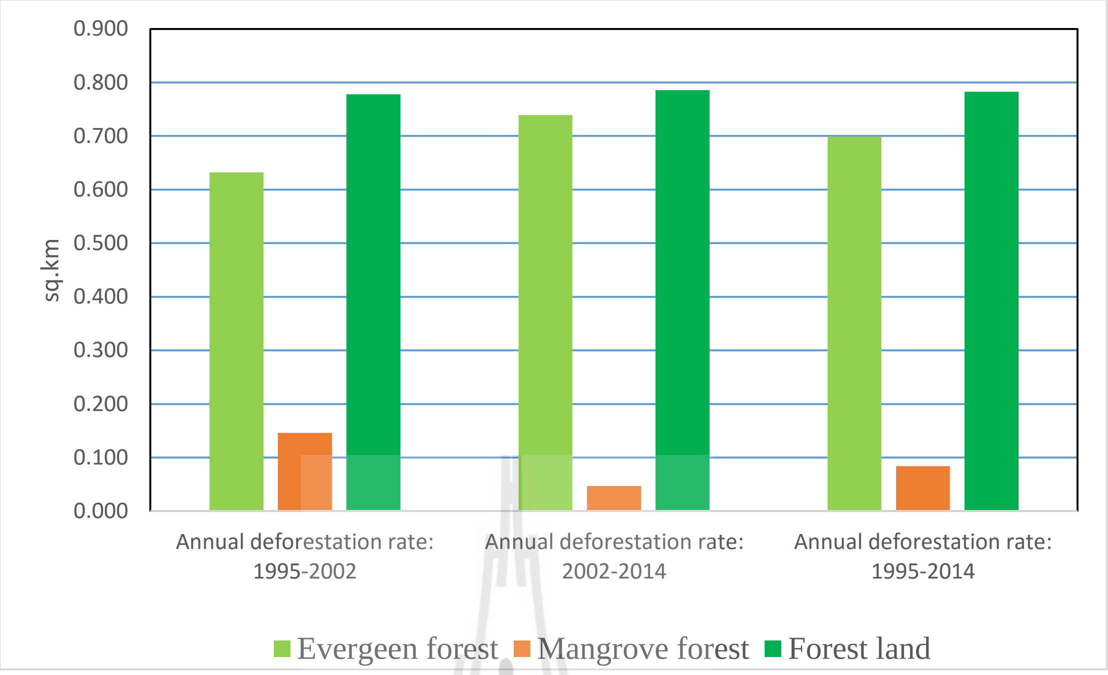


Figure 4.40 Comparison of annual deforestation rate by forest type in three periods.

It is evident that during 1995 to 2002 as short period of time deforestation in Phuket Island was about 5.444 sq. km or 3,402.50 Rai with annual rate of 0.778 sq. km or 486.25 Rai. Meanwhile, areas of evergreen forest are depleted of about 4.424 sq. km or 2,765.00 Rai with annual rate of 0.632 sq. km or 395.00 Rai while areas of mangrove forest are exhausted of about 1.020 sq. km or 637.50 Rai with annual rate of 0.146 sq. km or 91.25 Rai.

In addition, during 2002 to 2014 as short period of time deforestation in Phuket Island was about 9.437 sq. km or 5,898.13 Rai with annual rate of 0.786 sq. km or 491.25 Rai. Meanwhile, areas of evergreen forest are depleted of about 8.867 sq. km or 5,541.88 Rai with annual rate of 0.739 sq. km or 461.88 Rai while areas of mangrove forest are depleted of about 0.570 sq. km or 356.25 Rai with annual rate of 0.047 sq. km or 29.38 Rai.

In addition, during 1995 to 2014 as long period of time deforestation in Phuket Island was about 14.881 sq. km or 9,300.63 Rai with annual rate of 0.783 sq. km or 489.38 Rai. In this period, areas of evergreen forest are depleted of about 13.291 sq. km or 8,306.88 Rai with annual rate of 0.699 sq. km or 436.88 Rai while areas of mangrove forest are depleted of about 1.590 sq. km or 993.75 Rai with annual rate of 0.084 sq. km or 52.50 Rai.

As results, it was found that annual deforestation rate in Phuket Island occurred in evergreen forest is higher than in mangrove forest in two periods (1995-2002 and 2002-2014).

Additionally, the decreasing of forest areas (evergreen and mangrove forest) in 1995, 2002, and 2014 are further explained by simple linear regression analysis between forest area and others major LULC types (urban and built-up area, agricultural land, water bodies, and miscellaneous land) as shown in Figures 4.41 to 4.44.

Results of simple linear regression analysis shows negative relationship between urban and built-up area (x) and forest area (y) with R^2 at 96.82% (see also Figure 4.41) as:

$$y = 136.14 - 0.2359x. \tag{4.1}$$

Likewise, the simple linear regression between water body area (x) and forest area shows negative relationship with R^2 at 98.34% (see Figure 4.43) as:

$$y = 478.13 - 25.519x. \tag{4.2}$$

In contrast, the simple linear regression between agricultural land (paddy field, field crop and horticulture, orchard and perennial trees, aquaculture area and idle land) (x) and forest area (y) shows positive relationship with R^2 at 95.74% (Figure 4.42) as:

$$y = 32.185 + 0.3055x. \tag{4.3}$$

Similarly, the simple linear regression between scrub and miscellaneous land (x) and forest area (y) shows positive relationship with R^2 at 76.94% (Figure 4.44) as:

$$y = 63.167 + 1.672x. \tag{4.4}$$

As results, it can be concluded that when forest areas decrease, areas of urban and built-up and water body increase. In the opposite direction, when forest land decreases, agricultural land, scrub, and miscellaneous land decreases.

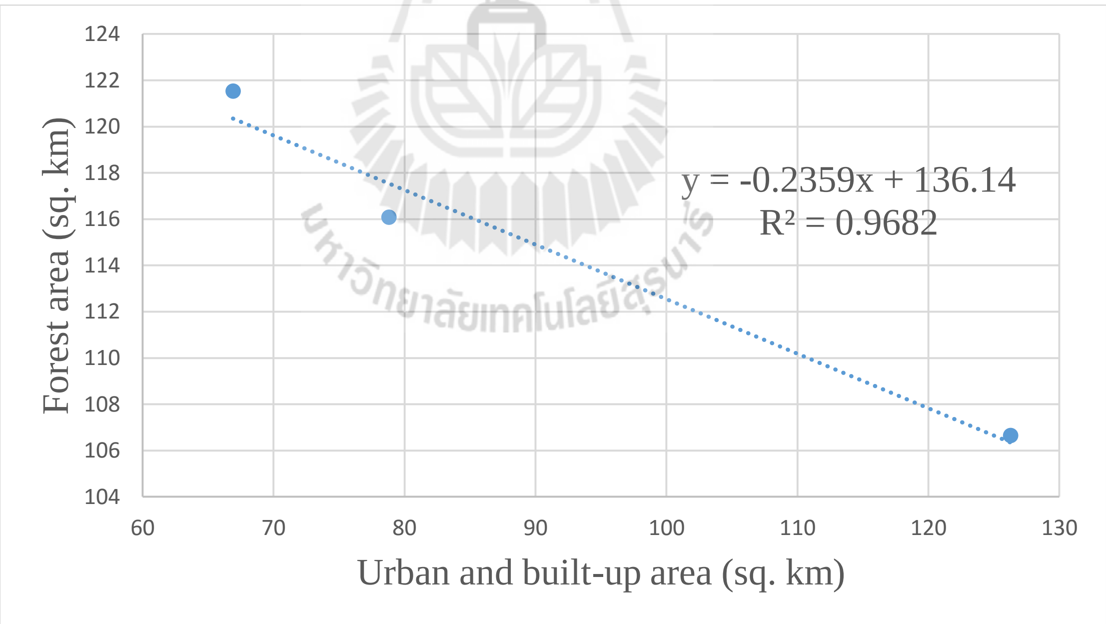


Figure 4.41 Simple linear regression analysis between urban and built-up area and forest area in 1995, 2002, and 2014.

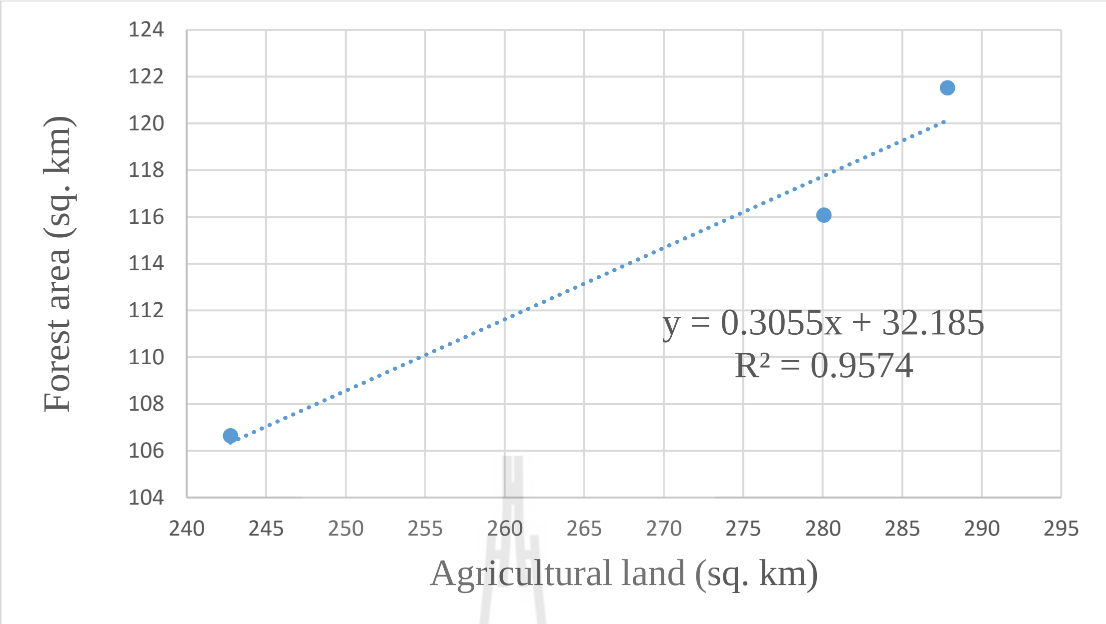


Figure 4.42 Simple linear regression analysis between agricultural land and forest area in 1995, 2002, and 2014.

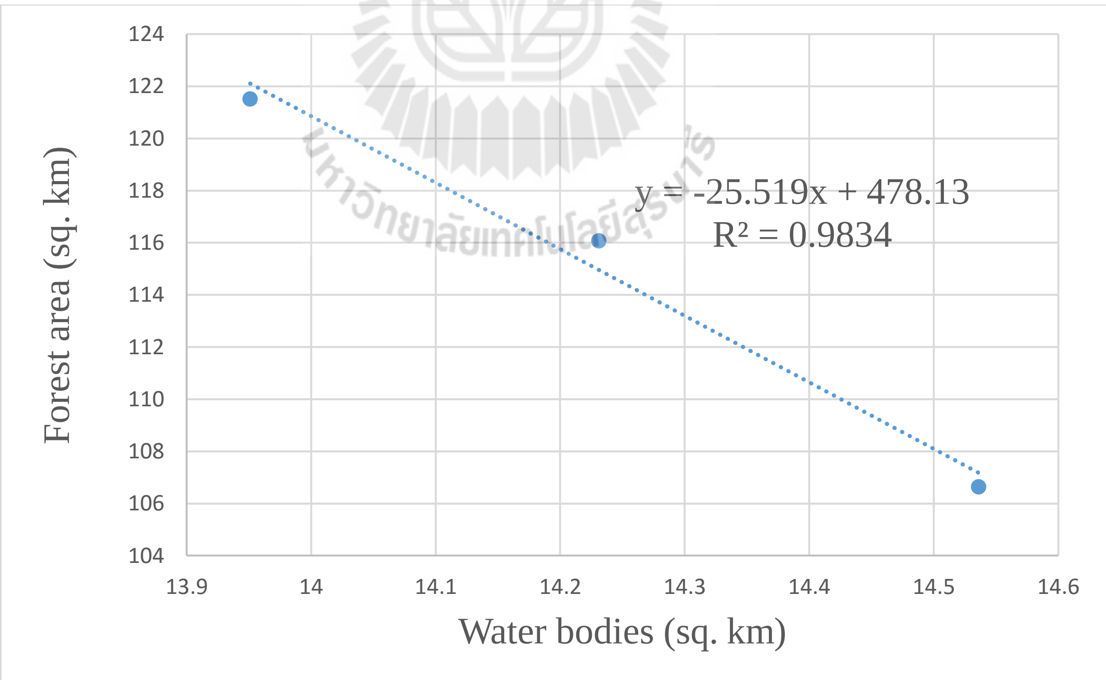


Figure 4.43 Simple linear regression analysis between water body area and forest area in 1995, 2002, and 2014.

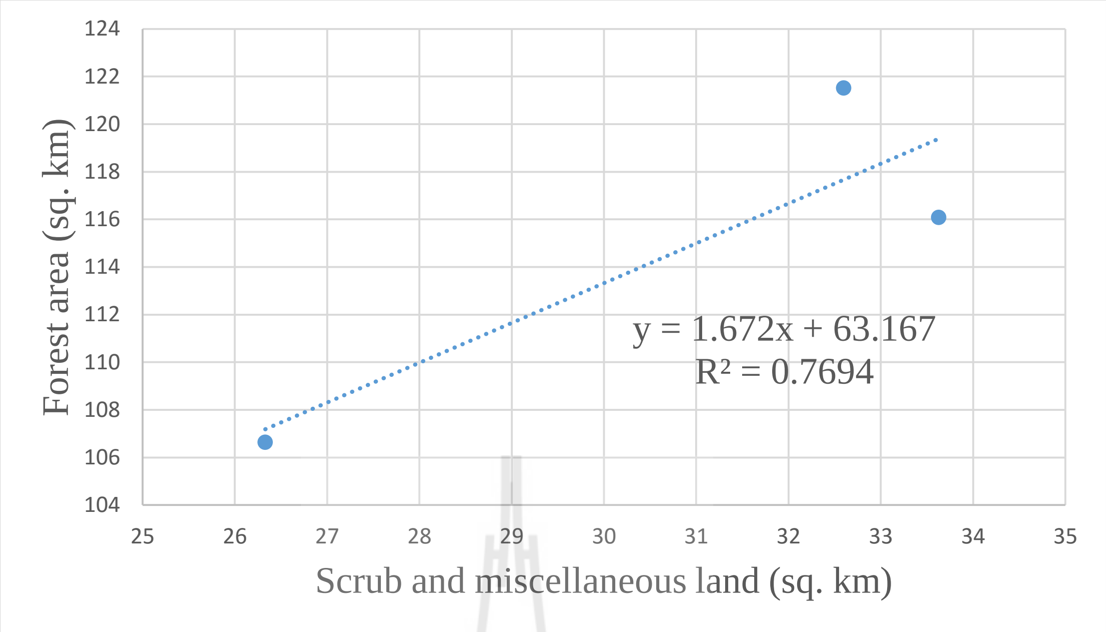


Figure 4.44 Simple linear regression analysis between scrub and miscellaneous land and forest area in 1995, 2002, and 2014.

4.3.2 Deforestation in forest protected area

Based on LULC change data in three periods, deforestation of 15 protected forest areas can be also extracted as summary in Table 4.54. It revealed that during 1995 to 2002 there were three protected forest areas, namely, Khao Mai Keaw, Khao Tosae, and Khlong U-Tapao NRFs, had none deforestation area. The minimum annual deforestation rate in this period occurred in Khlong Tarau NRF with rate of 0.0001 sq. km/year while the maximal annual deforestation rate occurred in Khao Nak Keod NRF with rate of 0.2221sq. km/year. Meanwhile, during 2002 to 2014 there was only one protected forest area, Khao Sam Liam NRF, had none deforestation area. The minimum annual deforestation rate in this period occurred in Khao Tosae NRF with rate of 0.0002 sq. km/year while the maximal annual deforestation rate also occurred in Khao Nak Keod NRF with rate of 0.2001 sq. km/year.

However, during 1995 to 2014 as long period of time all 15 protected forest areas were deforested with variety of deforestation rate. The minimum annual deforestation rate in this period occurred in Khao Tosae NRF with rate of 0.0001 sq. km/year while the maximal annual deforestation rate occurred in Khao Nak Keod NRF with rate of 0.2082 sq. km/year.

Table 4.54 Deforestation area and its rate of 15 protected forest areas.

Deforestation	**1995-2002**		**2002-2014**		**1995-2014**	
	Area	**Rate**	**Area**	**Rate**	**Area**	**Rate**
Sirinath MNP	0.1050	0.0150	0.2213	0.0184	0.3263	0.0172
Khao Phra Thaeo WCDEC	0.0156	0.0022	0.0600	0.0086	0.0756	0.0108
Khao Mai Kaew NRF	0.0000	0.0000	0.0225	0.0019	0.0225	0.0012
Khao Bang Khanun NRF	1.1525	0.1646	0.5488	0.0457	1.7013	0.0895
Khao Sam Liam NRF	0.0075	0.0011	0.0000	0.0000	0.0075	0.0004
Khao Kamala NRF	0.3275	0.0468	2.1006	0.1751	2.4281	0.1278
Khao Nak Keod NRF	1.5550	0.2221	2.4013	0.2001	3.9563	0.2082
Khao Tosae NRF	0.0000	0.0000	0.0019	0.0002	0.0019	0.0001
Khlong U-Tapao NRF	0.0000	0.0000	0.0069	0.0006	0.0069	0.0004
Khlong Tha Maphrao NRF	0.0131	0.0019	0.0844	0.0070	0.0975	0.0051
Khlong Para NRF	0.2644	0.0378	0.0069	0.0006	0.2713	0.0143
Khlong Bangrong NRF	0.1281	0.0183	0.0038	0.0003	0.1319	0.0069
Khlong Tarau NRF	0.0010	0.0001	0.0230	0.0019	0.0240	0.0013
Khlong Tajin NRF	0.0913	0.0130	0.2450	0.0204	0.3363	0.0177
Khlong Khopee NRF	0.2844	0.0406	0.0206	0.0017	0.3050	0.0161
Total	3.9454	0.5635	5.7470	0.4825	9.6924	0.5170

Furthermore, it was found that deforestation area between 1995 and 2002 of 15 protected forest areas was about 3.9454 sq. km or 2,465.8750 Rai with annual deforestation rate of 0.5635 sq. km or 352.1875 Rai while deforestation area between 2002 and 2014 of 15 protected forest areas was about 5.7470 sq. km or 3,591.8750 Rai with annual deforestation rate of 0.4825 sq. km or 301.5625 Rai. In addition, deforestation area between 1995 and 2014 of 15 protected forest areas was about 9.6924 sq. km or 6,057.7500 Rai with annual deforestation rate of 0.5170 sq. km or 323.1250 Rai. These results shows that annual deforestation rate of 15 protected forest areas between 1995 and 2002 was higher than its rate between 2002 and 2014. This finding shows that forest protection activity between 2002 and 2014 is more intensity than its activity between 1995 and 2002.

The characteristics of deforestation in each protected forest area can be elaborated in more detail according to its legal status includes national park (marine national park and wildlife conservation development and extension center) and national reserved forest area (in evergreen and mangrove forest) in the following sections

(1) National park

As long period of time between 1995 and 2014, annual deforestation rate of Sirinath MNP was 0.0172 sq. km or 10.75 Rai meanwhile annual deforestation rate of Khao Phra Thaeo WCDEC was only 0.0108 sq. km or 6.75 Rai. Deforested area and its annual rate of protected forest area is comparatively displayed in Figure 4.45. This phenomena reflects the effectiveness of forest protection in both areas. Khao Phra Thaeo WCDEC is well protected by fencing while Sirinath MNP is located along the beach and close to many settlements (Figure 4.46 and 4.47).

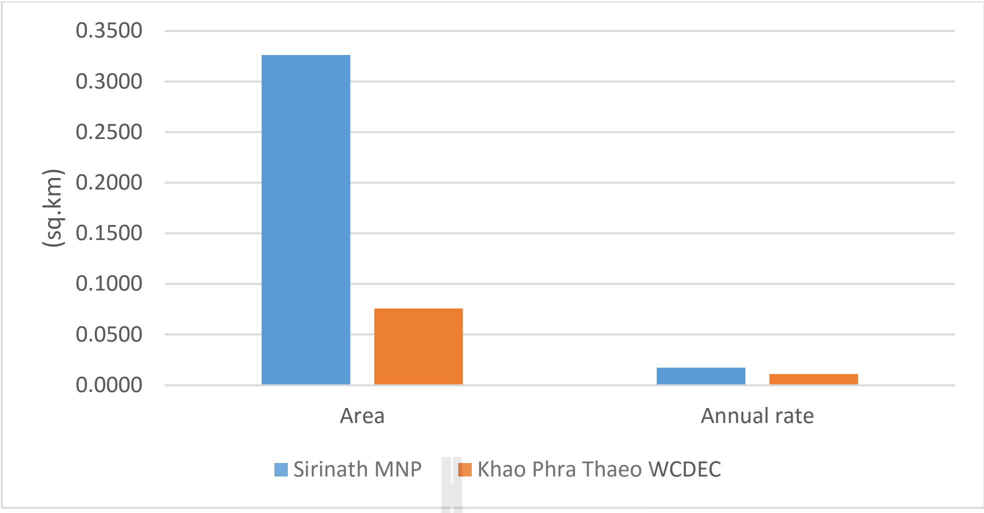


Figure 4.45 Deforested area and its annual rate of Sirinath MNP and Khao Phra Thaeo WCDEC between 1995 and 2014.

Figure 4.46 Boundary pillars of Khao Phra Thaeo WCDEC.

Figure 4.47 House estate in Sirinath MNP.

(2) National reserved forest area in evergreen forest

Deforestation between 1995 and 2014 of Khao Mai Kaew, Khao Bang Khanun, Khao Sam Liam, Khao Kamala, Khao Nak Keod, and Khao Tosae NRFs which situated in evergreen forest were declared by National Reserved Forest act. It is revealed that significant annual rate of deforestation was taken place in Khao Nak Keod, Khao Kamala, and Khao Bang Khanun NRFs with annual rate of 0.2082, 0.1278, and 0.0895 sq. km or 130.13, 79.88, and 55.95 Rai or with area of 3.9563, 2.4281, and 1.7013 sq. km or 2,472.69, 1,517.56, and 1,063.31 Rai, respectively. Meanwhile, insignificant annual rate of deforestation occurred in Khao Tosae, Khao Sam Liam, and Khao Mai Kaew NRFs with annual rate of 0.0001, 0.0004, and 0.0012 sq. km or 0.06, 0.25, and 0.75 Rai or with area of 0.0019, 0.0075, and 0.0225 sq. km or 1.19, 4.69, and 14.06 Rai, respectively. Deforested area and its annual rate of evergreen forest NRFs is comparatively presented in Figure 4.48. The result implies that NRFs with high risk of deforestation in the near future are Khao Nak Keod and Khao Kamala NRFs where can provide a good sea viewing and Khao Bang Khanun NRF locates close to the settlement area.

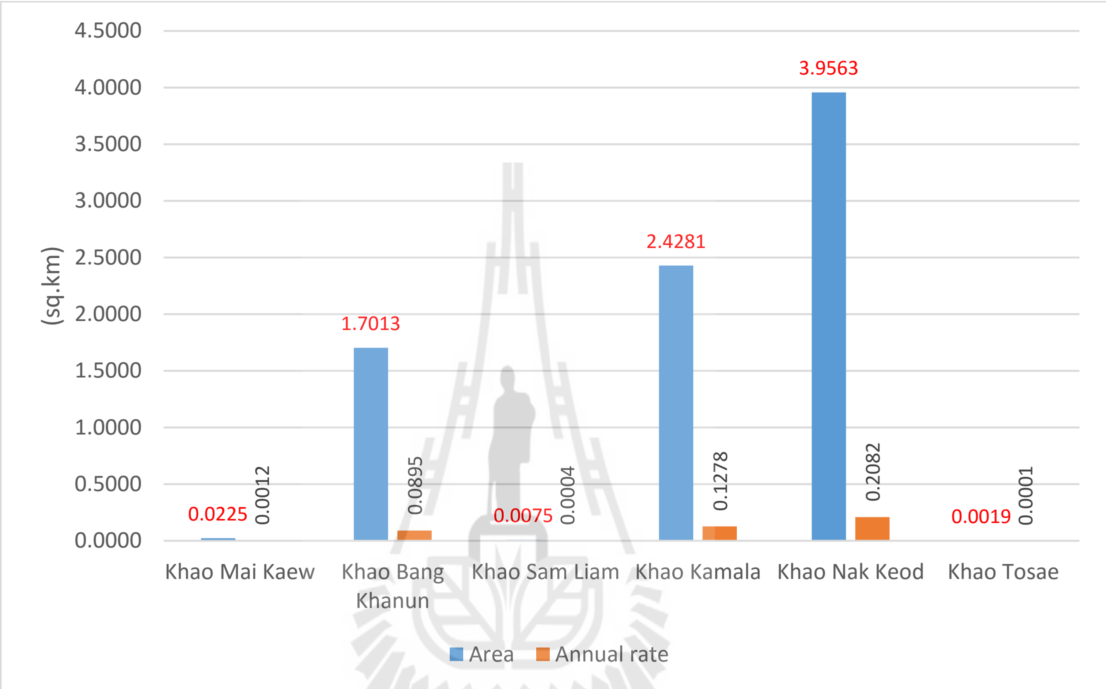


Figure 4.48 Deforested area and its annual rate of evergreen forest NRFs between 1995 and 2014.

(3) National reserved forest area in mangrove forest

Deforestation between 1995 and 2014 of Khlong U-Tapao, Khlong Tha Maphrao, Khlong Para, Khlong Bangrong, Khlong Tarau, Khlong Tajin, and Khlong Khopee NRFs which mostly situate in mangrove forest were also declared by National Reserved Forest act. It is revealed that the high annual rate of deforestation was taken place in Khlong Tajin, Khlong Khopee, and Khlong Para NRFs with annual rate of 0.0177, 0.0161, and 0.0143 sq. km or 11.0625, 10.0625, and 8.9375 Rai or with area of 0.3363, 0.3050, and 0.2713 sq. km or 210.1875, 190.625, and 169.5625 Rai. Meanwhile, moderate annual rate of deforestation occurred in Khlong Bangrong and Khlong Tha Maphrao NRFs with annual rate of 0.0069 and 0.0051 sq. km or 4.3125 and 3.1875 Rai or with area of 0.1319 and 0.0975 sq. km or 82.4375 and 60.9375 Rai, respectively. At the same period, insignificant annual rate of deforestation occurred in Khlong Tarau and Khlong U-Tapao NRFs. Deforested area and its annual rate of mangrove forest NRFs is comparatively presented in Figure 4.49. The result implies that NRF with high risk of deforestation in the near future are Khlong Tajin, Khlong Khopee and Khlong Para NRFs where locateclose to settlement area.

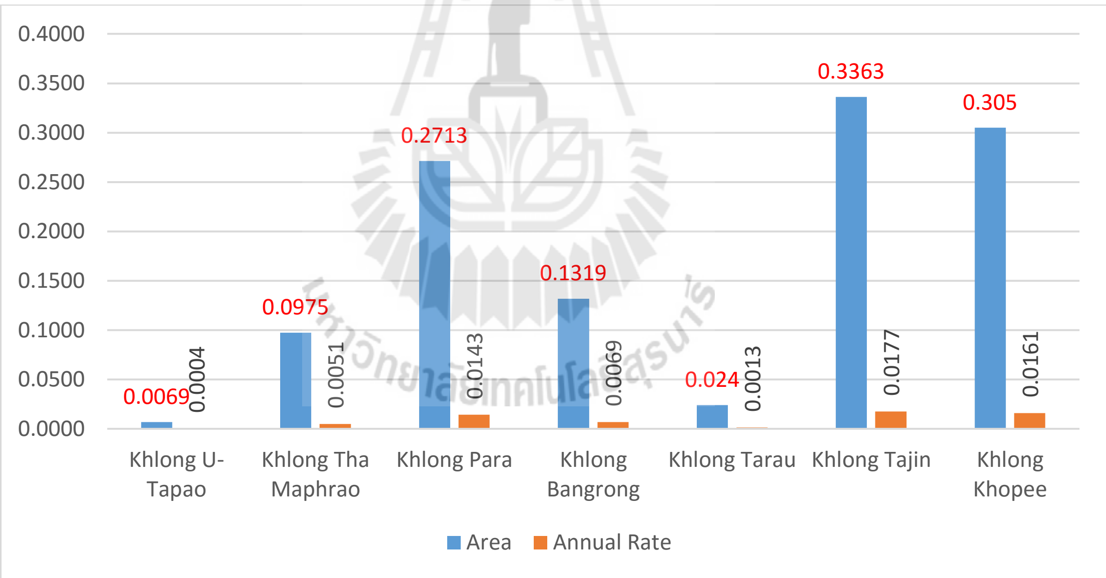


Figure 4.49 Deforested area and its annual rate of mangrove forest NRFs between 1995 and 2014.

CHAPTER V

LAND USE AND LAND COVER PREDICTION

Three main results include an optimum geospatial model for LULC prediction, LULC prediction in 2026 and prediction of deforestation between 2014 and 2026 are described and discussed in this chapter.

5.1 Optimum geospatial model for LULC prediction

Three geospatial model for LULC prediction includes CA-Markov model, Land Change Modeler (LCM) model and CLUE-S model were here applied to examine an optimum geospatial model for LULC prediction. Results of the predicted LULC map in 2014 of 15 protected forest areas from three models are compared with the interpreted LULC in 2014 as reference data for accuracy assessment are shown in Figures 5.1 to 5.15. Area of the predicted LULC type of 15 protected forest areas in 2014 derived from three model are compared with the interpreted LULC data in 2014 area summarized in Tables 5.1 to 5.15.

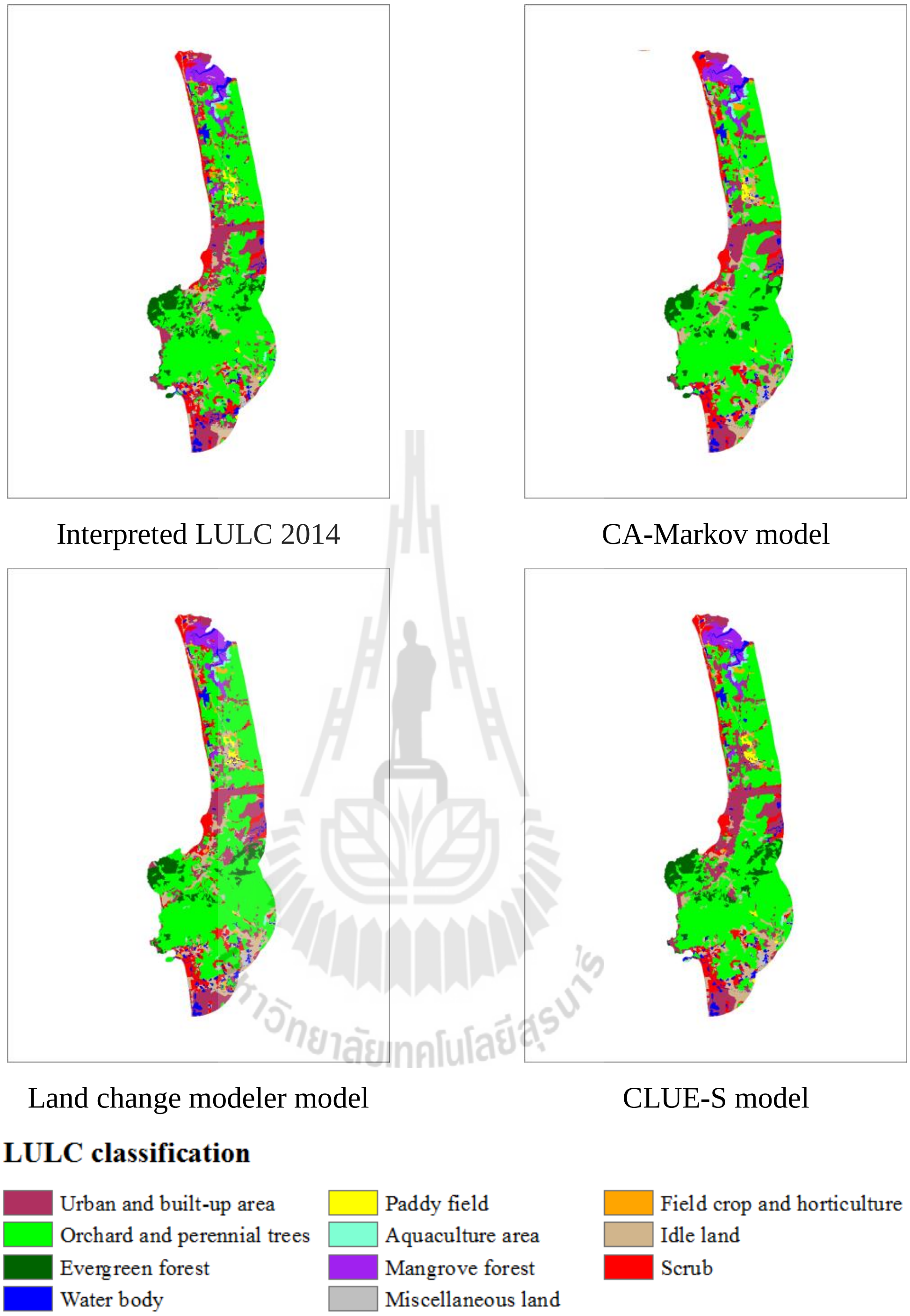


Figure 5.1 Comparison of predicted LULC and reference data of Sirinath MNP.

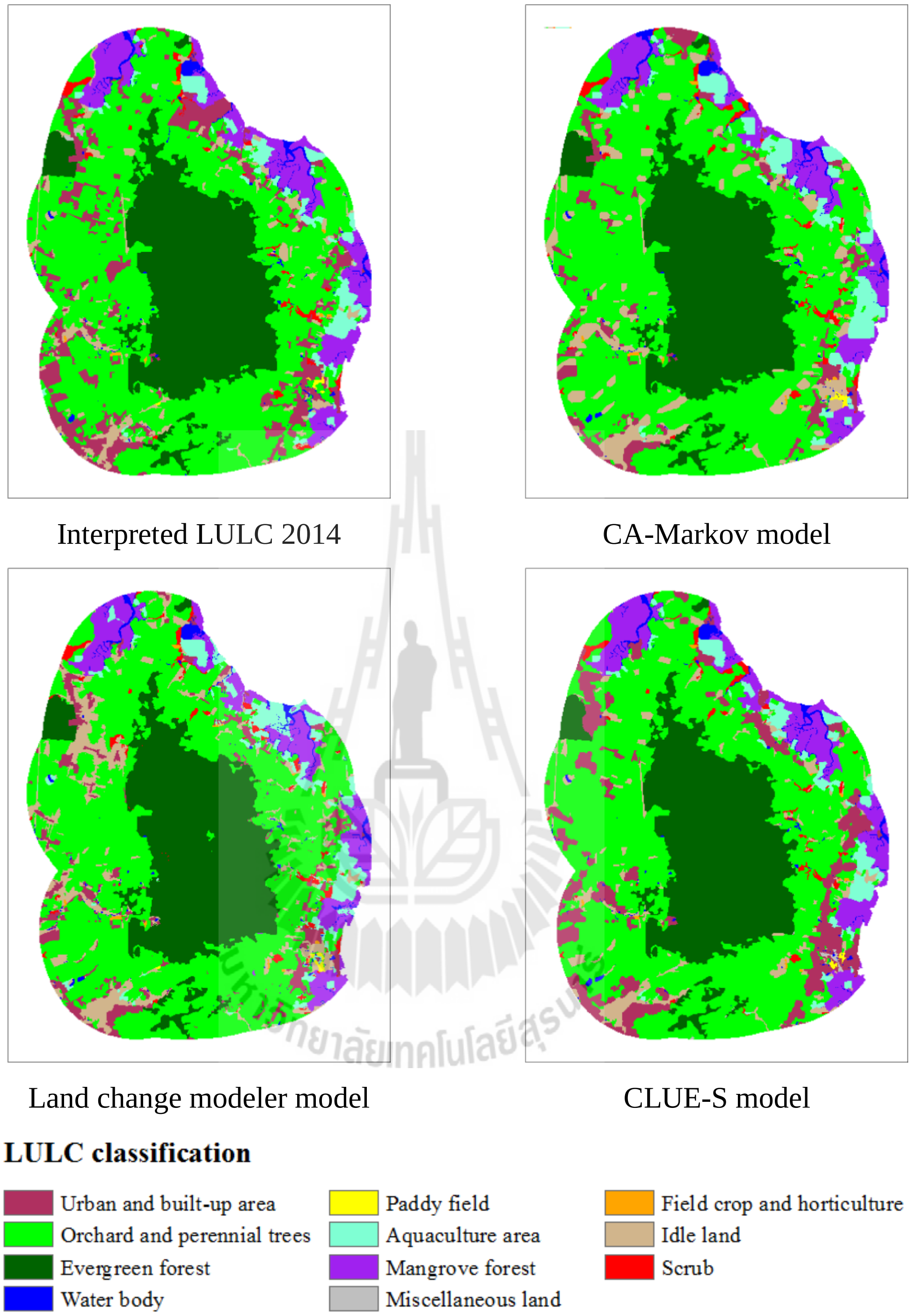


Figure 5.2 Comparison of predicted LULC and reference data of Khao Phra Thaeo WCDEC.

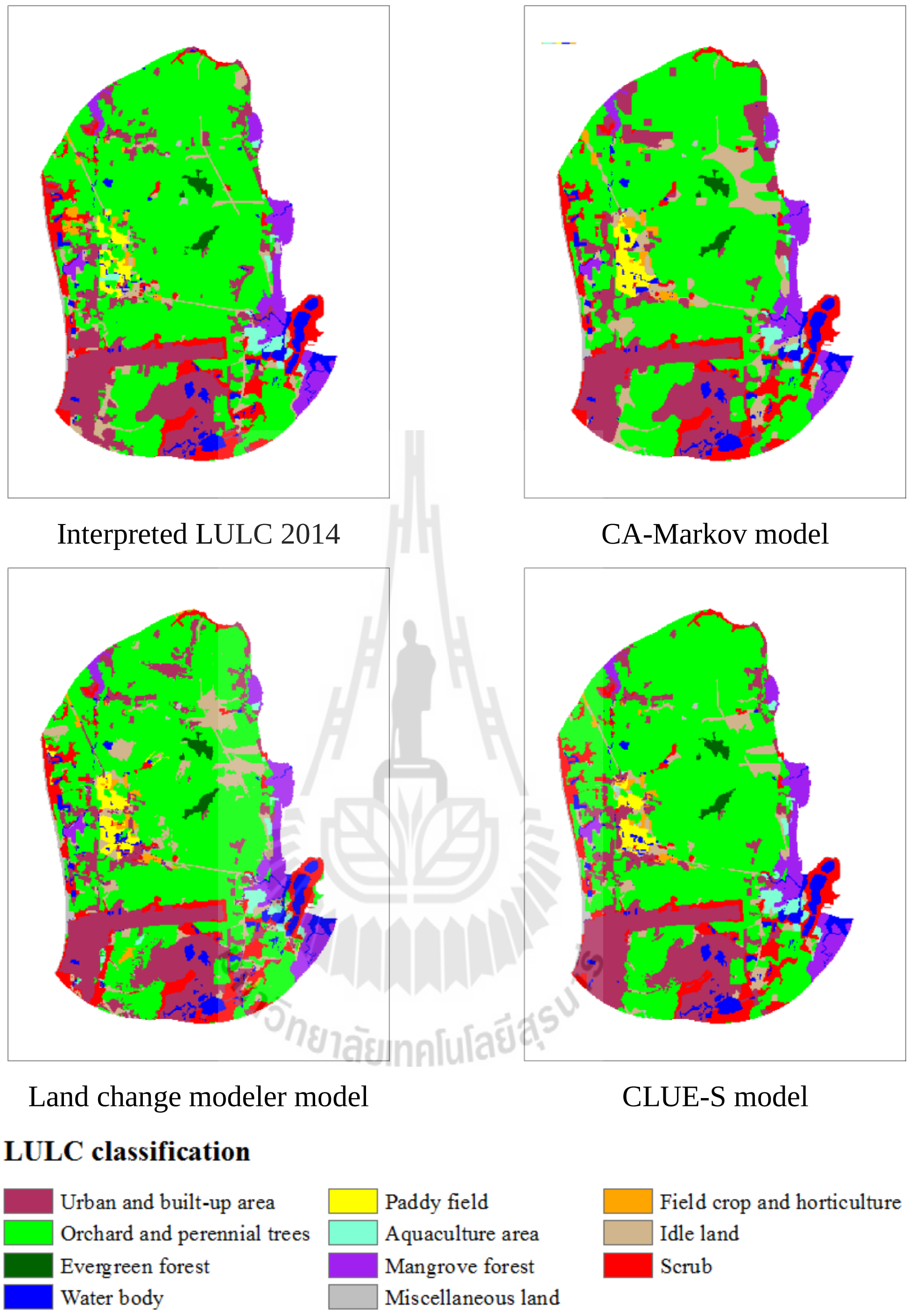


Figure 5.3 Comparison of predicted LULC and reference data of Khao Mai Kaew NRF.

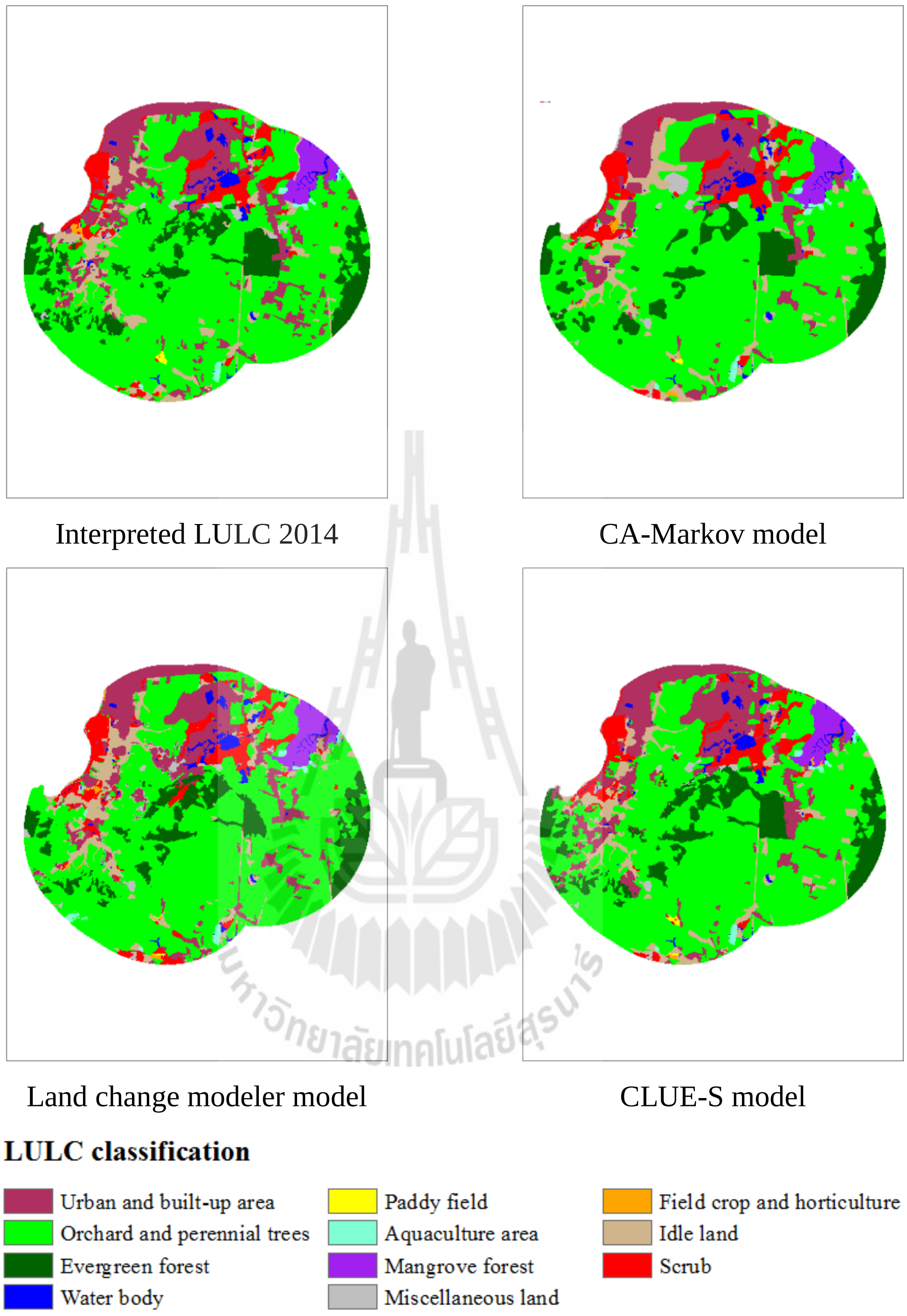


Figure 5.4 Comparison of predicted LULC and reference data of Khao Bang Khanun NRF.

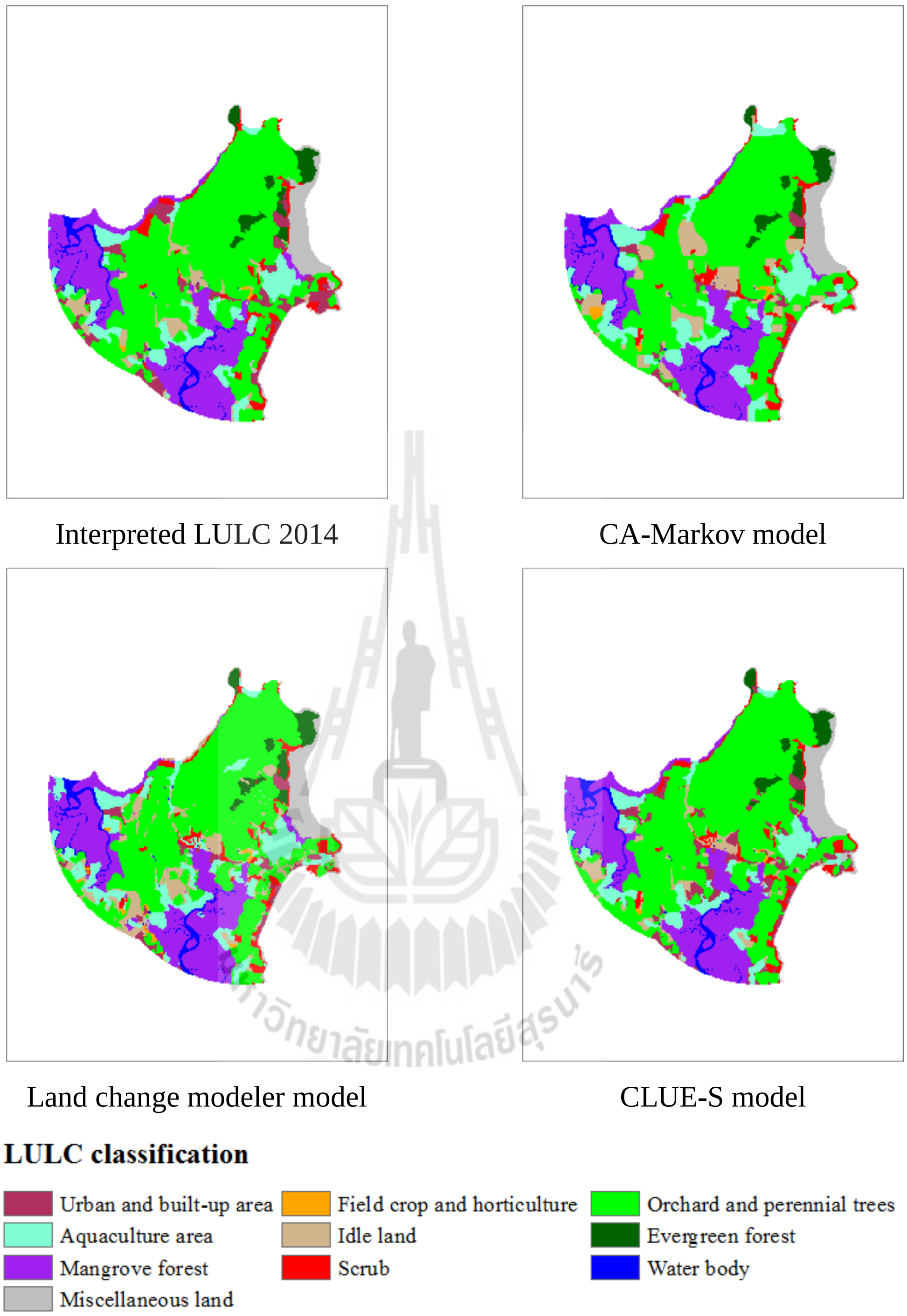


Figure 5.5 Comparison of predicted LULC and reference data of Khao Sam Liam NRF.

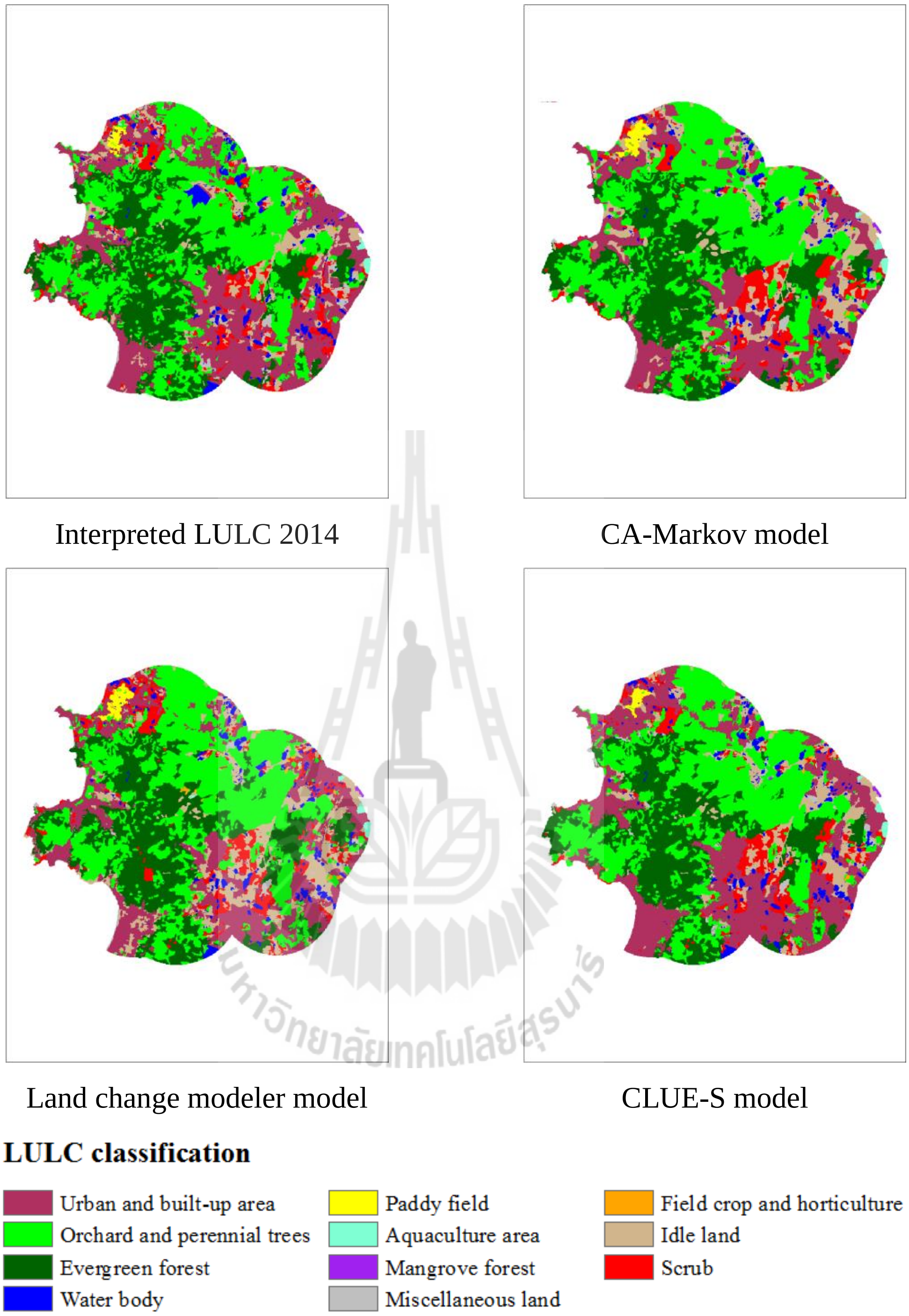


Figure 5.6 Comparison of predicted LULC and reference data of Khao Kamala NRF.

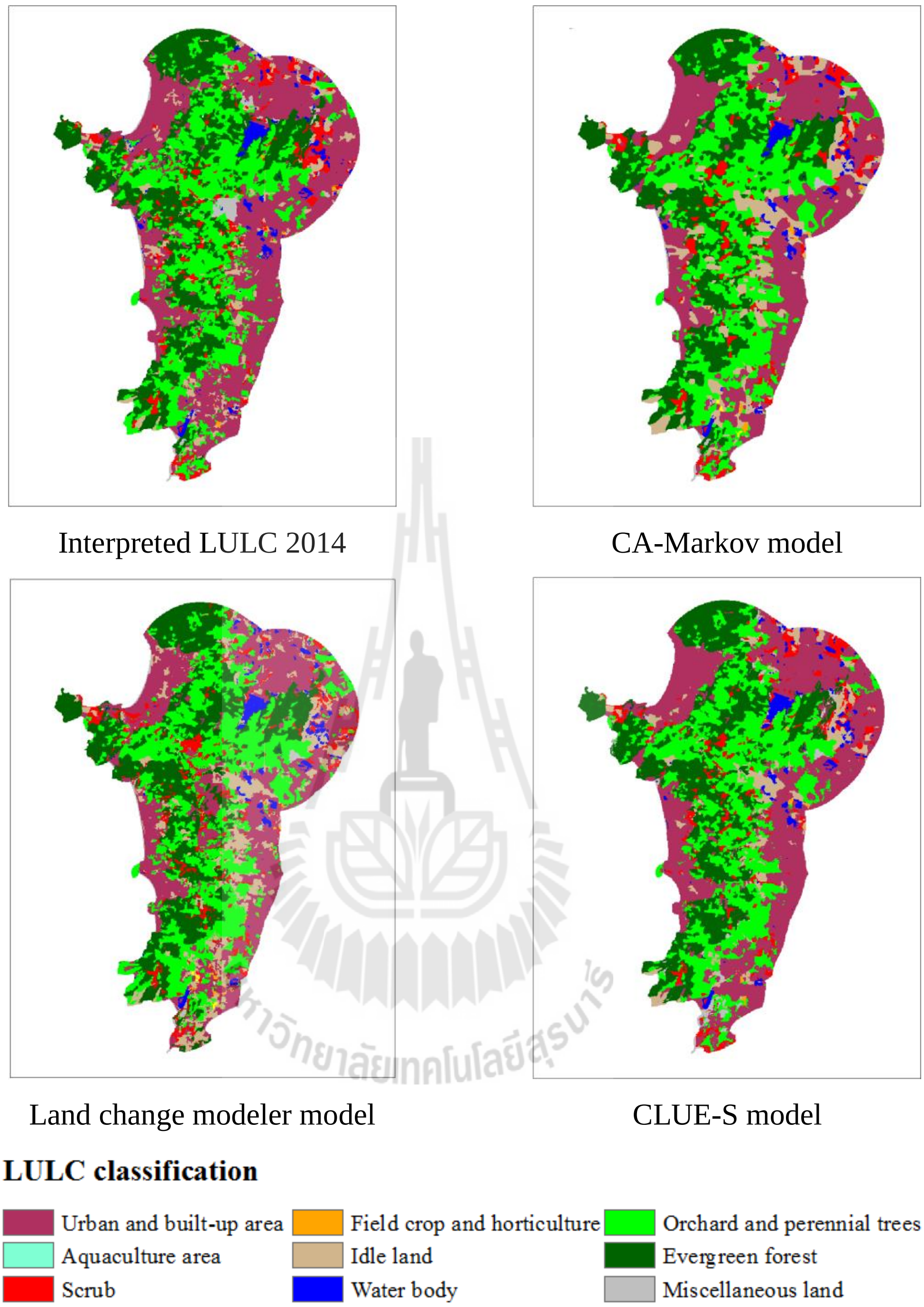


Figure 5.7 Comparison of predicted LULC and reference data of Khao Nak Keod NRF.

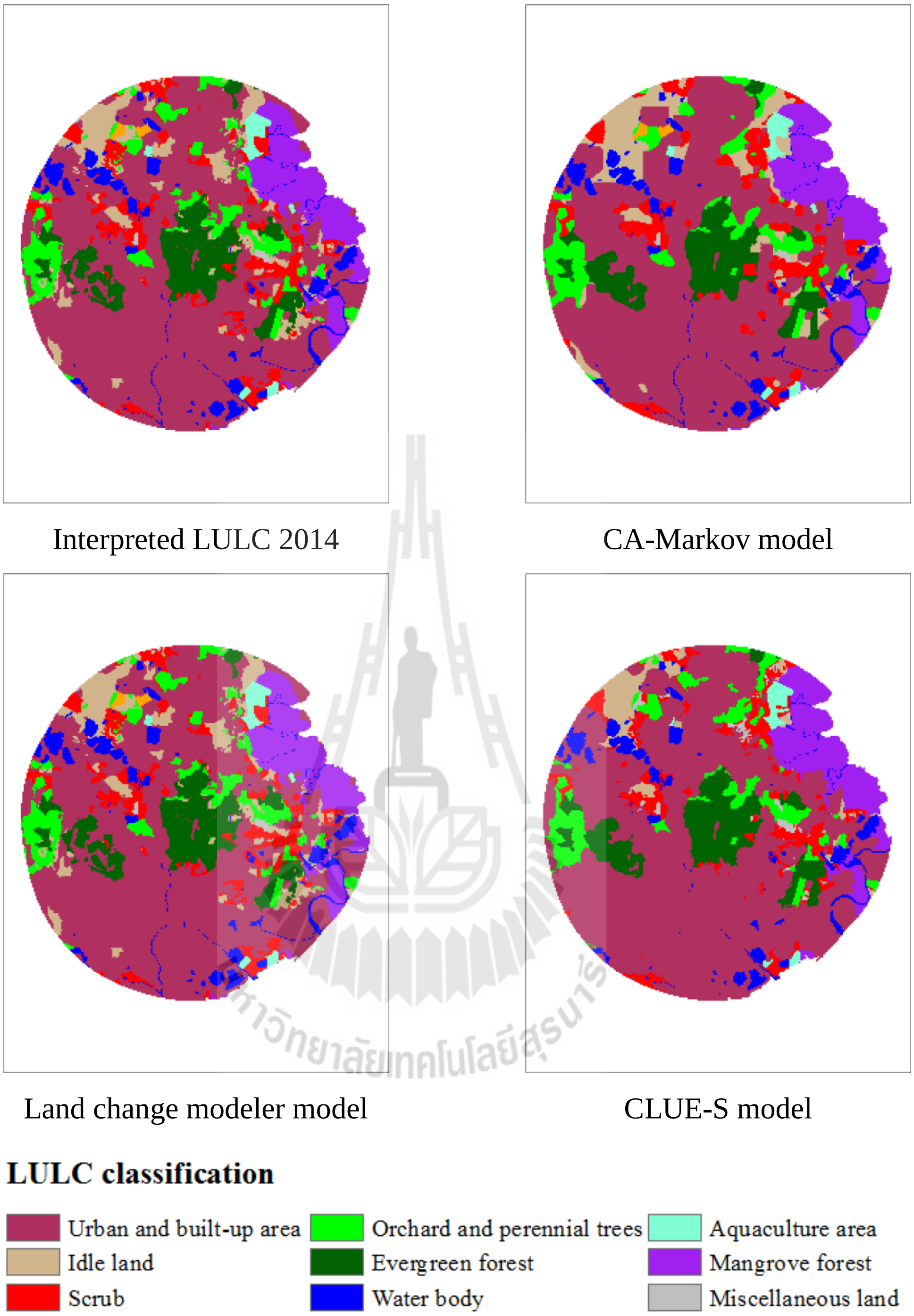


Figure 5.8 Comparison of predicted LULC and reference data of Khao Tosae NRF.

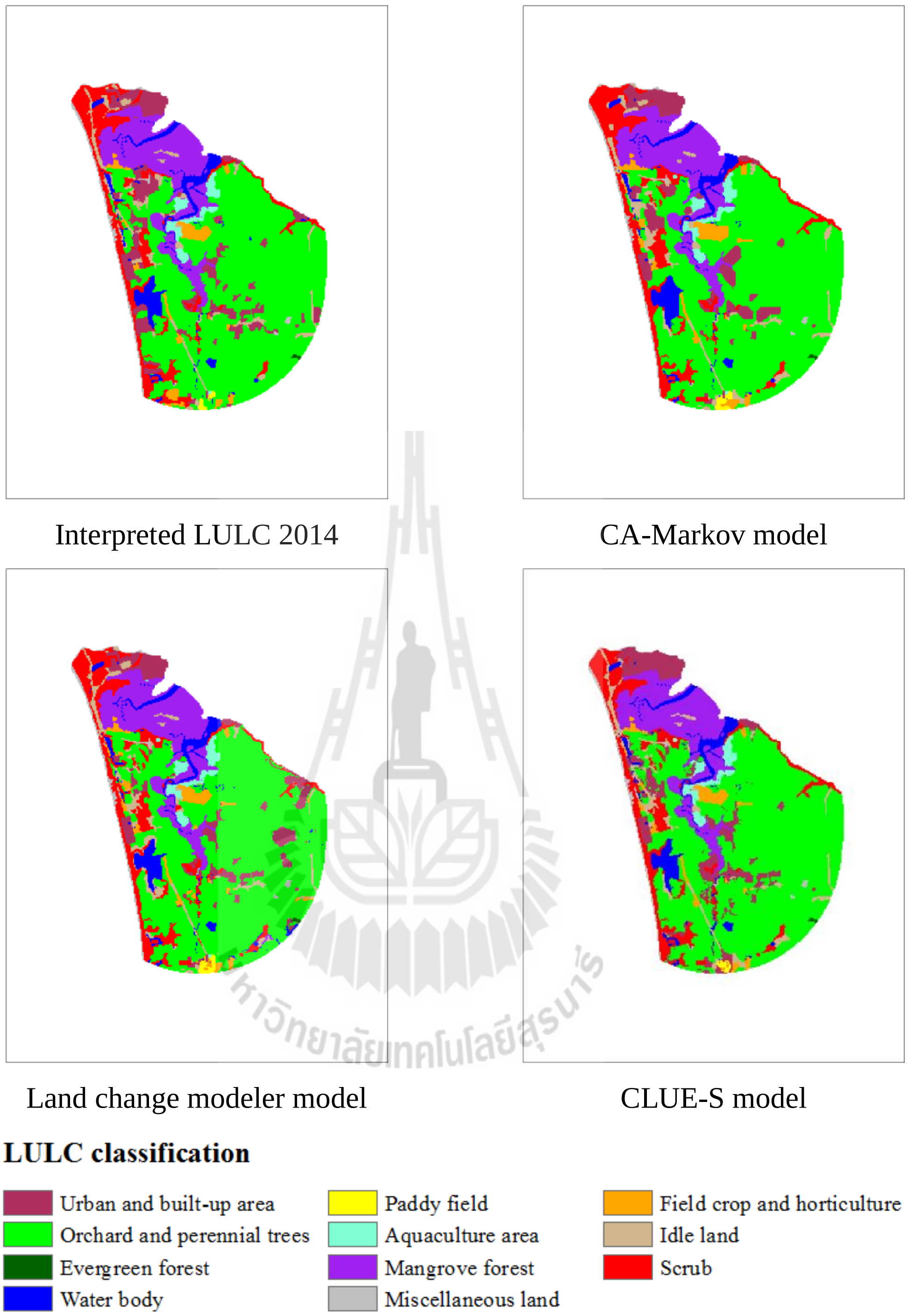


Figure 5.9 Comparison of predicted LULC and reference data of Khlong U-Tapao NRF.

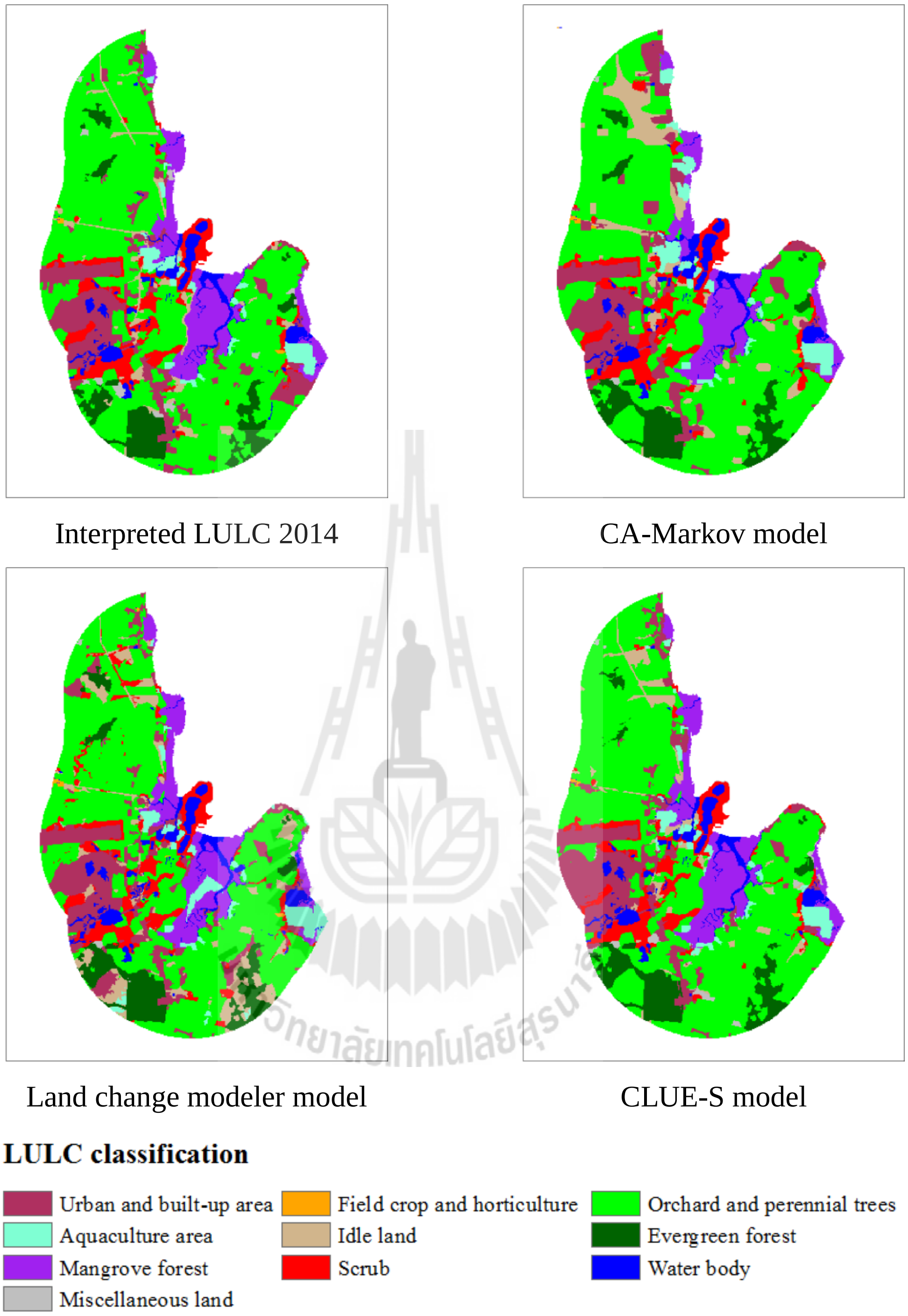


Figure 5.10 Comparison of predicted LULC and reference data of Khlong Tha Maphrao NRF.

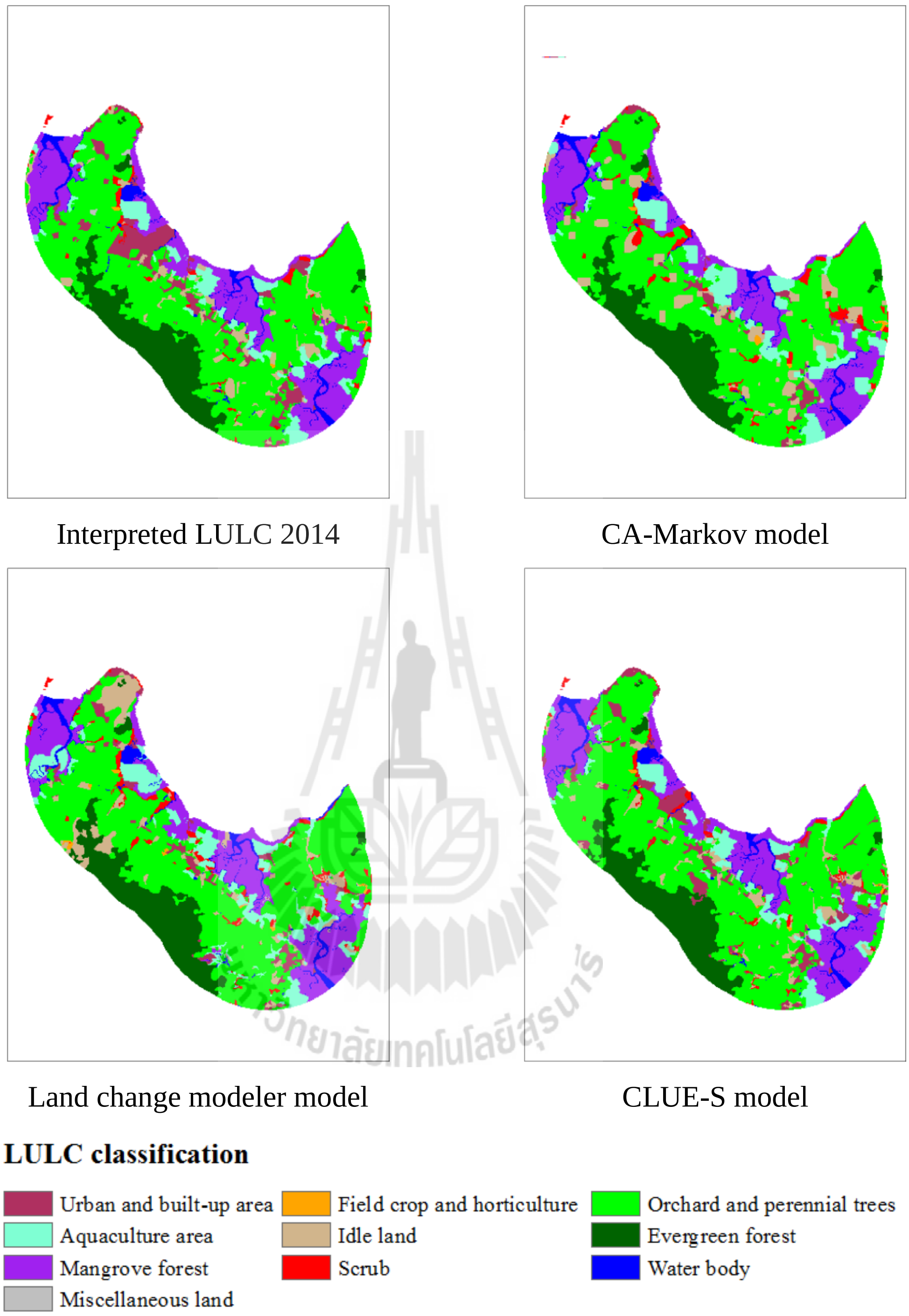


Figure 5.11 Comparison of predicted LULC and reference data of Khlong Para NRF.

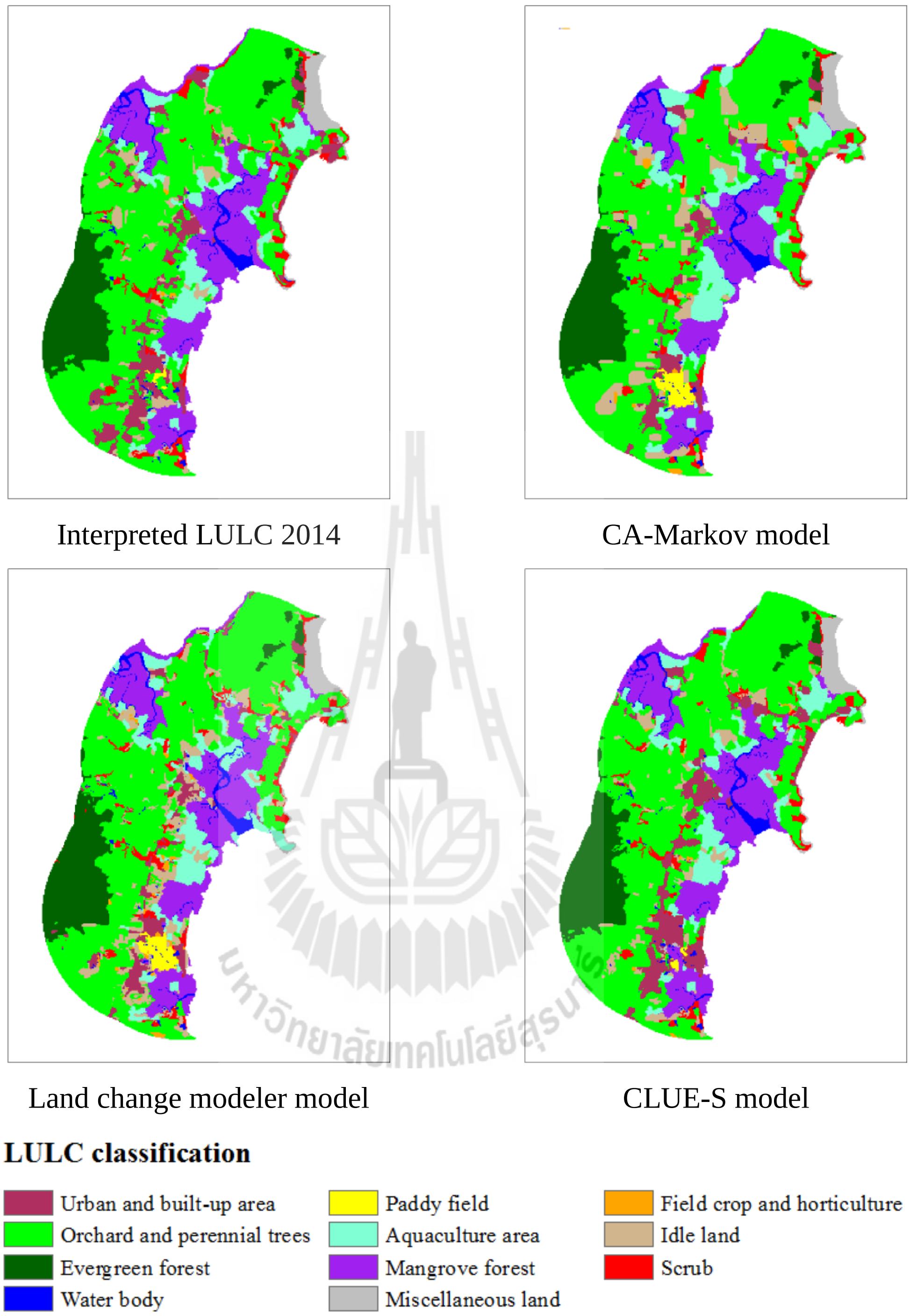


Figure 5.12 Comparison of predicted LULC and reference data of Khlong Bangrong NRF.

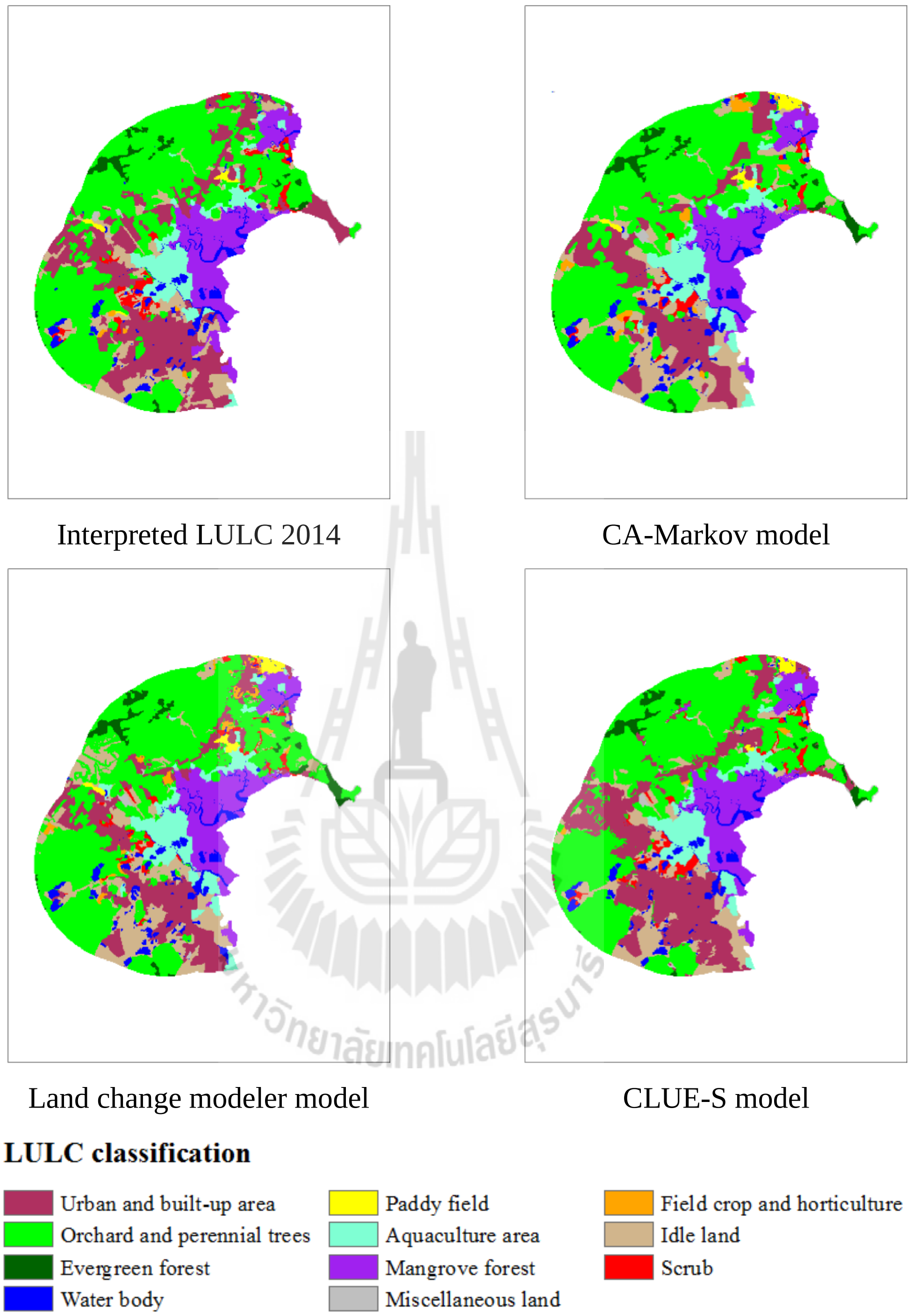


Figure 5.13 Comparison of predicted LULC and reference data of Khlong Tarau NRF.

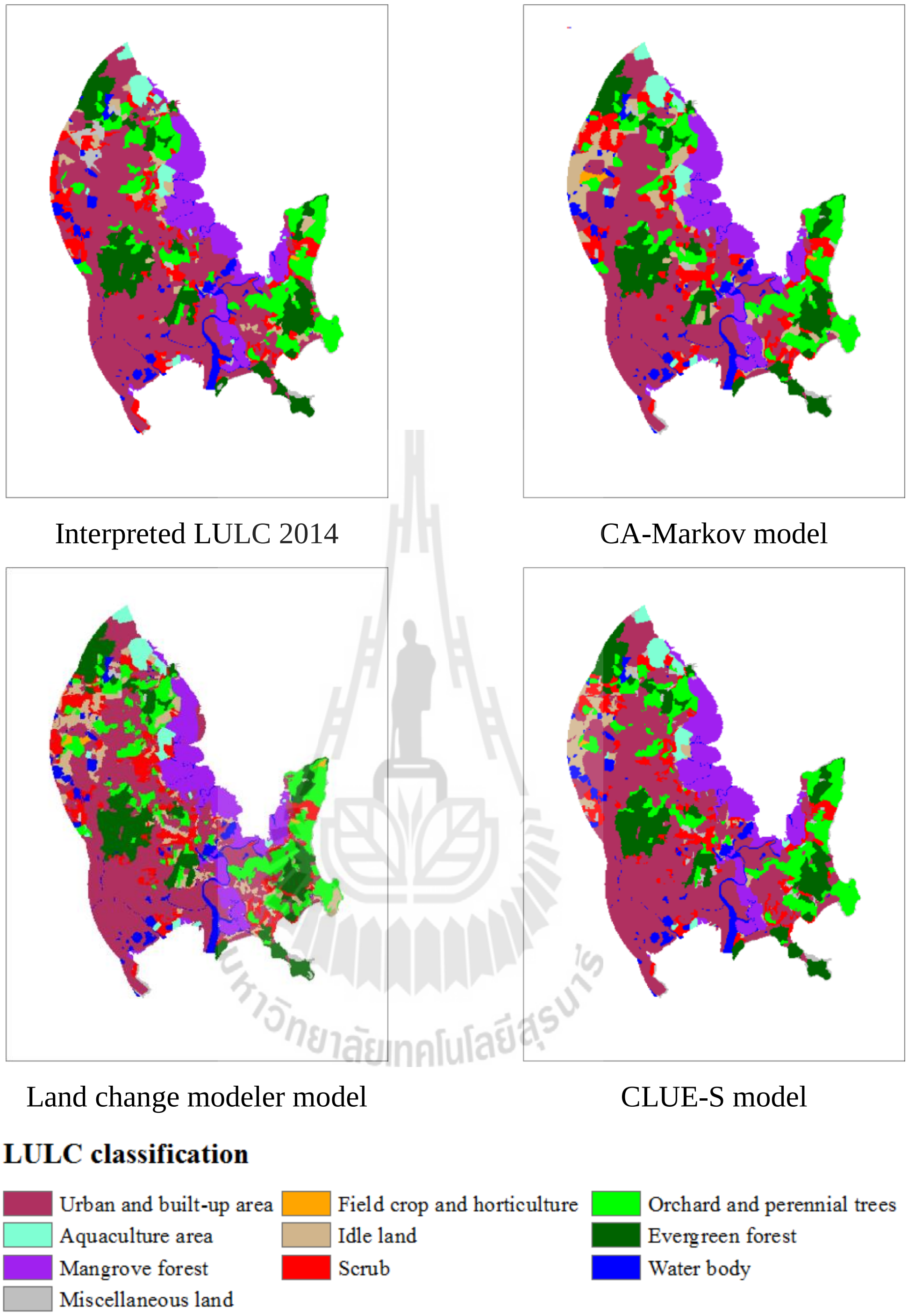


Figure 5.14 Comparison of predicted LULC and reference data of Khlong Tajin NRF.

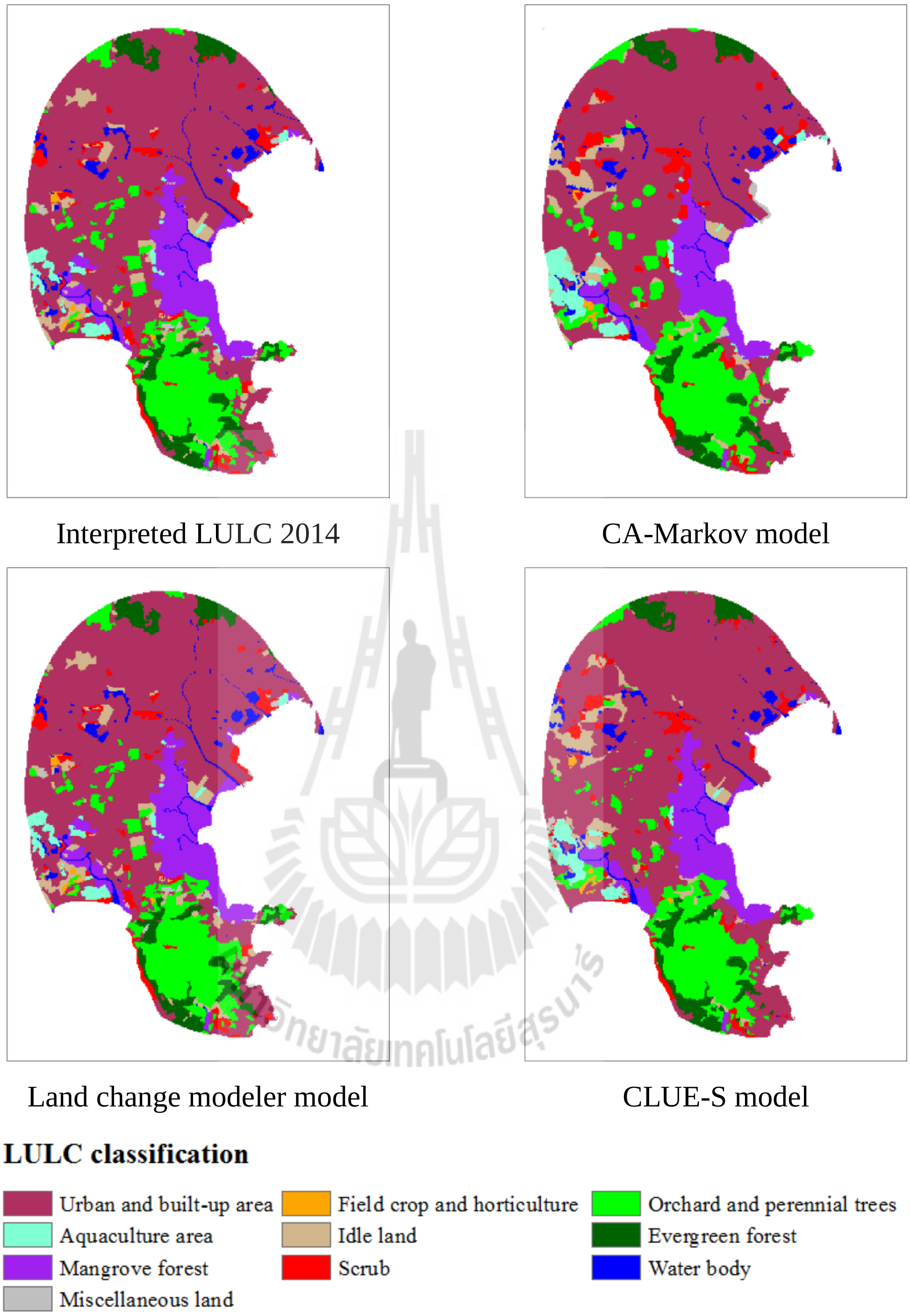


Figure 5.15 Comparison of predicted LULC and reference data of Khlong Khopee NRF.

Table 5.1 Area of predicted LULC in 2014 by three models and reference data of Sirinath MNP.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	9.978	9.986	12.173	12.173
Paddy field	0.467	0.465	0.621	0.621
Field crop and horticulture	0.966	0.986	0.763	0.764
Orchard and perennial trees	41.708	41.563	41.302	41.302
Aquaculture area	0.572	0.578	0.573	0.575
Idle land	7.837	7.815	6.644	6.644
Evergreen forest	3.806	3.783	4.525	4.526
Mangrove forest	2.949	2.962	2.933	2.934
Scrub	7.258	7.315	6.543	6.543
Water body	2.733	2.804	2.750	2.752
Miscellaneous land	1.819	1.835	1.266	1.260
Total	80.093	80.093	80.093	80.093

Table 5.2 Area of predicted LULC in 2014 by three models and reference data of Khao Phra Thaeo WCDEC.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	4.480	4.488	8.832	8.832
Paddy field	0.089	0.093	0.068	0.068
Field crop and horticulture	0.146	0.186	0.100	0.103
Orchard and perennial trees	43.255	43.086	42.630	42.631
Aquaculture area	3.975	4.091	2.872	2.873
Idle land	6.536	6.566	3.794	3.794
Evergreen forest	22.271	22.176	22.023	22.024
Mangrove forest	6.238	6.218	6.843	6.844
Scrub	1.191	1.223	0.944	0.938
Water body	1.201	1.244	1.163	1.162
Miscellaneous land	0.022	0.035	0.136	0.136
Total	89.404	89.404	89.404	89.404

Table 5.3 Area of predicted LULC in 2014 by three models and reference data of Khao Mai Kaew NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	7.568	7.560	7.411	7.411
Paddy field	0.677	0.707	0.501	0.501
Field crop and horticulture	0.394	0.406	0.326	0.328
Orchard and perennial trees	22.943	22.761	24.559	24.559
Aquaculture area	0.408	0.479	0.594	0.594
Idle land	3.215	3.209	2.003	2.003
Evergreen forest	0.346	0.346	0.324	0.324
Mangrove forest	2.220	2.220	2.109	2.109
Scrub	3.429	3.416	3.407	3.401
Water body	1.674	1.735	1.600	1.601
Miscellaneous land	0.284	0.319	0.323	0.327
Total	43.158	43.158	43.158	43.158

Table 5.4 Area of predicted LULC in 2014 by three models and reference data of Khao Bang Khanun NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	7.123	7.126	7.897	7.898
Paddy field	0.020	0.021	0.055	0.056
Field crop and horticulture	0.119	0.119	0.093	0.093
Orchard and perennial trees	31.058	30.975	30.679	30.679
Aquaculture area	0.293	0.362	0.223	0.226
Idle land	3.689	3.682	3.340	3.341
Evergreen forest	4.628	4.586	5.477	5.478
Mangrove forest	1.279	1.279	1.152	1.147
Scrub	3.196	3.210	2.773	2.773
Water body	0.869	0.881	0.815	0.813
Miscellaneous land	0.621	0.654	0.391	0.392
Total	52.894	52.894	52.894	52.894

Table 5.5 Area of predicted LULC in 2014 by three models and reference data of Khao Sam Liam NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	0.433	0.454	1.060	1.062
Field crop and horticulture	0.101	0.117	0.033	0.033
Orchard and perennial trees	8.295	8.256	8.901	8.902
Aquaculture area	2.131	2.126	1.561	1.562
Idle land	1.336	1.335	0.703	0.702
Evergreen forest	0.546	0.549	0.537	0.538
Mangrove forest	3.662	3.648	3.745	3.745
Scrub	0.696	0.701	0.614	0.608
Water body	0.463	0.466	0.463	0.463
Miscellaneous land	0.898	0.909	0.944	0.947
Total	18.561	18.561	18.561	18.561

Table 5.6 Area of predicted LULC in 2014 by three models and reference data of Khao Kamala NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	27.009	27.011	36.396	36.396
Paddy field	1.003	1.003	0.554	0.554
Field crop and horticulture	0.306	0.389	0.131	0.128
Orchard and perennial trees	48.124	47.993	45.896	45.896
Aquaculture area	0.421	0.458	0.339	0.336
Idle land	15.166	15.064	10.684	10.684
Evergreen forest	31.666	31.595	29.729	29.731
Mangrove forest	0.068	0.068	0.123	0.123
Scrub	8.931	8.926	7.917	7.917
Water body	3.845	3.887	4.103	4.104
Miscellaneous land	0.926	1.071	1.591	1.594
Total	137.464	137.464	137.464	137.464

Table 5.7 Area of predicted LULC in 2014 by three models and reference data of Khao Nak Keod NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	32.585	32.584	39.651	39.651
Paddy field	0.083	0.085	0.000	0.000
Field crop and horticulture	0.296	0.289	0.151	0.151
Orchard and perennial trees	31.981	31.939	30.743	30.742
Aquaculture area	0.036	0.056	0.002	0.008
Idle land	11.532	11.527	6.093	6.093
Evergreen forest	26.785	26.768	26.120	26.119
Scrub	6.522	6.518	6.150	6.149
Water body	2.568	2.596	2.463	2.461
Miscellaneous land	0.745	0.769	1.759	1.758
Total	113.131	113.131	113.131	113.131

Table 5.8 Area of predicted LULC in 2014 by three models and reference data of Khao Tosae NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	15.547	15.543	17.049	17.049
Field crop and horticulture	0.082	0.086	0.000	0.000
Orchard and perennial trees	1.873	1.874	1.806	1.807
Aquaculture area	0.325	0.325	0.288	0.289
Idle land	2.130	2.121	0.898	0.898
Evergreen forest	2.553	2.551	2.549	2.549
Mangrove forest	2.452	2.449	2.500	2.501
Scrub	2.160	2.165	1.934	1.935
Water body	1.409	1.416	1.320	1.314
Miscellaneous land	0.057	0.057	0.245	0.245
Total	28.588	28.588	28.588	28.588

Table 5.9 Area of predicted LULC in 2014 by three models and reference data of Khlong U-Tapao NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	1.501	1.498	1.971	1.969
Paddy field	0.075	0.077	0.046	0.044
Field crop and horticulture	0.546	0.549	0.454	0.458
Orchard and perennial trees	11.920	11.886	11.967	11.967
Aquaculture area	0.396	0.401	0.388	0.387
Idle land	0.893	0.896	0.780	0.779
Evergreen forest	0.014	0.014	0.014	0.014
Mangrove forest	2.828	2.826	2.799	2.799
Scrub	2.248	2.254	2.044	2.043
Water body	1.000	1.005	0.971	0.971
Miscellaneous land	0.298	0.314	0.284	0.288
Total	21.718	21.718	21.718	21.718

Table 5.10 Area of predicted LULC in 2014 by three models and reference data of Khlong Tha Maphrao NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	5.689	5.683	5.604	5.604
Field crop and horticulture	0.063	0.079	0.041	0.041
Orchard and perennial trees	20.574	20.528	22.623	22.622
Aquaculture area	1.566	1.572	1.150	1.153
Idle land	2.679	2.679	1.383	1.383
Evergreen forest	2.974	2.973	2.764	2.762
Mangrove forest	3.696	3.699	3.969	3.967
Scrub	3.293	3.300	2.854	2.852
Water body	1.925	1.943	1.806	1.808
Miscellaneous land	0.070	0.074	0.336	0.338
Total	42.528	42.528	42.528	42.528

Table 5.11 Area of predicted LULC in 2014 by three models and reference data of Khlong Para NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	1.199	1.246	2.733	2.734
Field crop and horticulture	0.104	0.126	0.054	0.053
Orchard and perennial trees	18.977	18.856	19.266	19.264
Aquaculture area	3.440	3.496	2.461	2.461
Idle land	2.438	2.434	1.609	1.608
Evergreen forest	4.809	4.809	4.781	4.781
Mangrove forest	6.705	6.693	7.292	7.291
Scrub	1.179	1.172	0.686	0.685
Water body	1.358	1.363	1.287	1.289
Miscellaneous land	0.021	0.036	0.062	0.065
Total	40.230	40.230	40.230	40.230

Table 5.12 Area of predicted LULC in 2014 by three models and reference data of Khlong Bangrong NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	1.584	1.591	3.013	3.013
Paddy field	0.454	0.454	0.058	0.058
Field crop and horticulture	0.243	0.281	0.061	0.055
Orchard and perennial trees	16.733	16.706	17.763	17.763
Aquaculture area	3.481	3.479	2.629	2.629
Idle land	2.965	2.963	1.628	1.629
Evergreen forest	3.718	3.711	3.663	3.663
Mangrove forest	5.734	5.706	6.043	6.043
Scrub	1.207	1.190	1.196	1.197
Water body	0.830	0.856	0.844	0.846
Miscellaneous land	0.878	0.892	0.931	0.932
Total	37.828	37.828	37.828	37.828

Table 5.13 Area of predicted LULC in 2014 by three models and reference data of Khlong Tarau NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	5.501	5.494	8.533	8.534
Paddy field	0.386	0.386	0.164	0.158
Field crop and horticulture	0.506	0.511	0.096	0.097
Orchard and perennial trees	16.428	16.404	15.673	15.673
Aquaculture area	2.724	2.736	2.293	2.293
Idle land	4.818	4.821	3.823	3.823
Evergreen forest	0.959	0.959	0.658	0.658
Mangrove forest	4.236	4.199	4.354	4.356
Scrub	0.666	0.672	0.919	0.919
Water body	1.678	1.691	1.451	1.450
Miscellaneous land	0.221	0.251	0.159	0.162
Total	38.123	38.123	38.123	38.123

Table 5.14 Area of predicted LULC in 2014 by three models and reference data of Khlong Tajin NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	12.253	12.254	14.836	14.837
Field crop and horticulture	0.133	0.139	0.021	0.021
Orchard and perennial trees	4.529	4.525	4.187	4.185
Aquaculture area	0.950	0.960	0.824	0.828
Idle land	2.399	2.399	1.164	1.162
Evergreen forest	4.653	4.633	4.381	4.380
Mangrove forest	4.263	4.243	4.135	4.134
Scrub	3.106	3.100	2.528	2.528
Water body	1.537	1.558	1.488	1.489
Miscellaneous land	0.519	0.530	0.779	0.777
Total	34.341	34.341	34.341	34.341

Table 5.15 Area of predicted LULC in 2014 by three models and reference data of Khlong Khopee NRF.

(Unit: sq. km)

LULC types	CA-Markov	LCM	CLUE-S	LULC in 2014
Urban and built-up area	18.801	18.800	19.813	19.814
Field crop and horticulture	0.099	0.103	0.113	0.106
Orchard and perennial trees	5.129	5.123	4.441	4.428
Aquaculture area	1.076	1.084	0.662	0.662
Idle land	1.463	1.453	1.446	1.459
Evergreen forest	1.777	1.779	1.866	1.867
Mangrove forest	3.026	3.024	3.476	3.477
Scrub	1.569	1.563	1.189	1.194
Water body	1.009	1.011	0.929	0.930
Miscellaneous land	0.133	0.143	0.146	0.146
Total	34.082	34.082	34.082	34.082

As results, it was found that the interpreted and predicted LULC areas from three models of each protected forest area are not significantly different and the predicted LULC areas from each model are highly correlated with interpreted LULC area as summary in Table 5.16. Herewith, the LULC areas of each protected forest area which were predicted by CLUE-S model provide the highest correlation coefficient with value of 1 and LCM provide the lowest correlation coefficient with value of 0.974698. However, the implementation of LULC prediction using CLUE-S model or LCM requires driving factors for LULC type allocation and a number steps for operation when they are compared with CA-Markov model.

Table 5.16 Correlation coefficient between interpreted and predicted LULC areas of three models in each protected forest area.

Protected forest area	Interpreted LULC area with		
	CA-Markov model	**LCM**	**CLUE-S model**
Sirinath MNP	0.997217	0.997215	1.000000
Khao Phra Thaeo WCDEC	0.991855	0.991720	1.000000
Khao Mai Kaew NRF	0.998073	0.998090	1.000000
Khao Bang Khanun NRF	0.998868	0.998819	1.000000
Khao Sam Liam NRF	0.990348	0.990538	1.000000
Khao Kamala NRF	0.978533	0.978908	1.000000
Khao Nak Keod NRF	0.981844	0.981953	1.000000
Khao Tosae NRF	0.996200	0.996245	1.000000
Khlong U-Tapao NRF	0.998796	0.998766	1.000000
Khlong Tha Maphrao NRF	0.996920	0.996913	1.000000
Khlong Para NRF	0.992745	0.992790	1.000000
Khlong Bangrong NRF	0.990158	0.990201	1.000000
Khlong Tarau NRF	0.974816	0.974698	1.000000
Khlong Tajin NRF	0.987714	0.988010	1.000000
Khlong Khopee NRF	0.998178	0.998194	0.999999

In addition, the significant driving factors and their coefficient and ROC values by logistic regression analysis for each LULC type location preference of each protected forest area under CLUE-S model is summarized in Tables 5.17 to 5.31. The common top three driving factors for urban and built-up area among protected forest areas are distance from settlement (X_6), distance from road (X_5), and distance from water body (X_7). The common driving factors for paddy field from 9 protected forest areas are average income (X_9), distance from road (X_5), slope (X_2), and distance from settlement (X_6). At the same time, the most common driving factors for field crop and horticulture among 15 protected forest areas are distance from water body (X_7), elevation (X_1), slope (X_2), and population density (X_8) while slope (X_2), distance from road (X_5) and distance from settlement (X_6) are the dominant driving factors for orchards and perennial trees. Meanwhile elevation (X_1), distance from settlement (X_6), and distance from road (X_5) are common factors for aquaculture area while elevation (X_1), distance from settlement (X_6), and distance from water body (X_7) are common factors for idle land. In the meantime, the most common dominant factors for evergreen forest are distance from settlement (X_6), elevation (X_1), slope (X_2), and distance from water body (X_7) while the most common dominant factors for mangrove forest are distance from road (X_5), elevation (X_1), and distance from settlement (X_6). Meanwhile, elevation (X_1), slope (X_2), low fertility soil (X_3), moderate fertility (X_4), distance from road (X_5), distance from settlement (X_6), and distance from water body (X_7) are common factors of scrub. In addition, the dominant driving factors for water body among protected forest areas are distance from water body (X_7) and distance from settlement (X_6) while dominant driving factors for miscellaneous land are elevation (X_1), distance from road (X_5), distance from settlement (X_6), population density (X_8), and average income (X_9). In summary, the most common driving factor for LULC types, except paddy field that exist in 9 protected forest areas, is distance from settlement (X_6). This finding is similar to the previous works of Panayotou and Sungsawan, (1989); Tongpan, Panayotou, Jetanavanich and Mehi, (1990); TFSMP, (1993); Siangwan, (2008); Arekhi, (2011); and Khoi, 2011.

Meanwhile ROC which represents the goodness of fit for logistic regression analysis varies between 0.500 and 0.999. As a result, ROC values can be here acceptance because they vary between 0.5 (completely random) and 1.0 (perfect discrimination) as suggestion by Pontius and Schneider (2001).

Table 5.17 Significant location factor of each LULC type and its coefficient of Sirinath MNP.

Driving forces	Ur	Pa	Fch	Op	Aq	Id	Ef	Mf	Sc	Wa	Mi
Constant	11.6623	-7.4309	-3.0463	-9.962	-10.4503	-8.9494	-1.5631	2.5175	-0.9937	1.2296	-7.9137
Elevation (X_1)	-0.0067		-0.0416	0.0237	-0.1233	-0.0883	-0.0056	-0.1368	-0.0428	-0.0406	-0.1003
Slope (X_2)	-0.0275	-0.1039		0.02	0.0259		0.0385		0.0339		
Soil_l (X_3)						-1.3565	-1.0421				-1.8392
Soil_m (X_4)				1.0683							
Distance from road (X_5)	-0.0039	0.0019		-0.0009	0.0024	-0.0005	0.0006	0.0056	-0.001		0.0014
Distance from settlement (X_6)	-0.0048		0.001	0.0015	0.0025	0.0014	0.0015	0.0031	0.0022	0.0009	0.0026
Distance from water body (X_7)	-0.0004	-0.0064	-0.0028	0.0008	-0.0047	-0.0007	0.0012	-0.0053	-0.0019	-0.1208	
Population density (X_8)	-0.0124		-0.0057	0.0088		0.0098	-0.0092	-0.0146			0.0055
Average income (X_9)	-0.0005	0.0003		0.0004	0.0005	0.0005	-0.0001	-0.0002	-0.0001		0.0003
ROC	0.895	0.841	0.749	0.842	0.898	0.780	0.927	0.918	0.781	0.989	0.855

Table 5.18 Significant location factor of each LULC type and its coefficient of Khao Phra Thaeo WCDEC.

Driving forces	Ur	Pa	Fch	Op	Aq	Id	Ef	Mf	Sc	Wa	Mi
Constant	-0.6582	-156.4224	171.5994	-4.6912	-12.8723	-22.7695	9.9649	204.9227	7.4898	1.0095	13.5771
Elevation (X_1)	-0.0519	-0.3838	-0.0234	-0.0048	-0.5078	-0.0415	0.0157	-0.0964	-0.0782		
Slope (X_2)				0.0036	-0.0273	0.0026	0.0356		0.0286		
Soil_l (X_3)	-0.4577			-0.1014			-0.3359				
Soil_m (X_4)					-0.2925	-0.8199			-0.9517		
Distance from road (X_5)	-0.0066	0.0101	-0.0101	-0.0049	-0.0017	-0.0036	0.0047	0.0060	-0.0021		
Distance from settlement (X_6)	-0.0264	-0.0120		0.0007	0.0017	-0.0002	0.0010		0.0009	0.0011	
Distance from water body (X_7)	0.0003	-0.0051	-0.0020	0.0006	0.0005	0.0004	0.0004	-0.0025	-0.0006	-0.1447	
Population density (X_8)	0.0077	0.0149	-0.1820	0.0086	0.0070	0.0220	-0.0010	-0.2193	-0.0115		-0.1595
Average income (X_9)	0.0002	0.0089	-0.0088	0.0002	0.0007	0.0011	-0.0009	-0.0103	-0.0005		
ROC	0.990	0.946	0.799	0.773	0.963	0.735	0.985	0.976	0.832	0.994	0.798

Table 5.19 Significant location factor of each LULC type and its coefficient of Khao Mai Kaew NRF.

Driving forces	**Ur**	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	13.5843	244.2557	228.5199	-1.1355	5.9397	5.1640	-20.8716	2.0300	-8.9197	-2.4943	117.2240
Elevation (X_1)	0.0050			0.0106	-0.8533	-0.0444	0.0173	-0.2332	-0.0059		-0.1841
Slope (X_2)	-0.0579			0.0248		0.0237	0.1096		0.0417		
Soil_l (X_3)				1.0300							
Soil_m (X_4)									-0.5689		
Distance from road (X_5)	-0.0026			-0.0010		-0.0016		0.0065	-0.0019		
Distance from settlement (X_6)	-0.0097			0.0029	0.0023	0.0021	0.0054	0.0029	0.0021	0.0009	0.0033
Distance from water body (X_7)	-0.0018	-0.0056	-0.0045	0.0025			0.0076		-0.0025	-0.1000	
Population density (X_8)	-0.0546			0.0168					0.0166	0.0155	-0.1094
Average income (X_9)		-0.0187	-0.0176	-0.0004	-0.0005	-0.0006		-0.0004	0.0002		-0.0075
ROC	0.922	0.822	0.796	0.848	0.957	0.732	0.996	0.955	0.762	0.987	0.911

Table 5.20 Significant location factor of each LULC type and its coefficient of Khao Bang Khanun NRF.

Driving forces	**Ur**	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	16.4332	-180.8864	-6.4979	-11.2643	-191.8253	-3.9634	-114.5508	-214.2221	-2.4164	0.9628	-92.4445
Elevation (X_1)				0.0069		-0.1021	0.0061	-0.4569	-0.0346		-0.0451
Slope (X_2)	-0.0362			0.0227		0.0168	0.0305		0.0261		
Soil_l (X_3)	-1.3385					-2.0013	-0.8767				-2.4184
Soil_m (X_4)				-1.3946							
Distance from road (X_5)	-0.0071			0.001		-0.0011	0.0016	0.0133	-0.0016		
Distance from settlement (X_6)	-0.0037			0.0016		0.0014	0.0007		0.0014		0.0021
Distance from water body (X_7)	-0.0004		-0.0028	0.0005		0.0003			-0.0019	-0.1249	
Population density (X_8)	-0.0065			0.0047		-0.0128	-0.1337				-0.1497
Average income (X_9)	-0.0009	0.0114		0.0006	0.0122	0.0004	0.0092	0.0139			0.008
ROC	0.911	0.800	0.685	0.837	0.800	0.797	0.918	0.996	0.739	0.991	0.808

Table 5.21 Significant location factor of each LULC type and its coefficient of Khao Sam Liam NRF.

Driving forces	Ur	Fch	Op	Aq	Id	Ef	Mf	Sc	Wa	Mi
Constant	4.6721	-3.2461	-0.4739	1.4318	-0.6411	-7.9717	-0.8558	-2.9956	3.3615	-6.1702
Elevation (X_1)		-0.1767	0.0692	-0.4187	-0.0384	0.0130	-0.0598	-0.0327		-0.1743
Slope (X_2)		0.0738	0.0095		0.0172	0.0427	-0.0338	0.0435		-0.0657
Soil_l (X_3)				-0.2041	-0.3065					
Soil_m (X_4)		-13.6974	0.2178			-1.5402	-1.8149			-1.1123
Distance from road (X_5)		-0.0073	-0.0059	-0.0011	-0.0046	0.0011	0.0032	-0.0026		0.0057
Distance from settlement (X_6)	-0.2812		0.0009	0.0006		-0.0020	0.0017	-0.0009		-0.0034
Distance from water body (X_7)	-0.0007	-0.0011	-0.0009	-0.0004	-0.0010	0.0024	-0.0017	0.0004	-0.2781	0.0042
Population density (X_8)										
Average income (X_9)										
ROC	0.999	0.929	0.903	0.918	0.792	0.928	0.929	0.792	0.999	0.986

Table 5.22 Significant location factor of each LULC type and its coefficient of Khao Kamala NRF.

Driving forces	Ur	Pa	Fch	Op	Aq	Id	Ef	Mf	Sc	Wa	Mi
Constant	2.178309	33.787087	-4.810738	-1.246446	-3.004848	-1.556812	-2.610618	-10.351984	-2.788988	3.073983	-4.500796
Elevation (X_1)	-0.009489			-0.002667	-0.458512	-0.007551	0.007413		-0.005511		-0.018797
Slope (X_2)	-0.036238		-0.112859	0.015849	-0.091234	-0.026289	0.026672		0.016347	-0.053371	
Soil fertility (low) (X_3)	-0.312318			-0.255119			-1.830934		-0.185260		-0.913493
Soil fertility (moderate) (X_4)			-12.780673			-0.177871		-17.245476			
Distance from road (X_5)	-0.003293		0.004121	0.001129	0.006072		-0.000587	0.007683	-0.000286		0.001542
Distance from settlement (X_6)	-0.009549			0.001253	0.002858	0.001518	-0.000263		0.000937	0.000869	
Distance from water body (X_7)	0.000427		-0.003455	0.000054		-0.001150	0.000239		-0.001789	-0.245439	0.000457
Population density (X_8)	0.000334			-0.001468	0.000642	-0.000296	-0.000196		-0.000067		-0.001562
Average income (X_9)	0.000010	-0.003705	-0.000030	-0.000009	-0.000044	-0.000002	0.000002		0.000006		
ROC	0.950	0.947	0.885	0.821	0.987	0.767	0.912	0.996	0.731	0.999	0.693

Table 5.23 Significant location factor of each LULC type and its coefficient of Khao Nak Keod NRF.

Driving forces	Ur	Pa	Fch	Op	Aq	Id	Ef	Sc	Wa	Mi
Constant	0.838003	28.125852	-2.430787	0.083198	-0.419227	-1.125344	-2.129395	-2.440567	1.440469	-4.157766
Elevation (X_1)	-0.010025		-0.059552	0.000297	-0.253819	-0.014077	0.004719	-0.000705	0.010016	-0.055487
Slope (X_2)	-0.034124		-0.064831	0.009375	-0.436658	-0.026872	0.020969	-0.001901	-0.060838	0.025305
Soil_l (X_3)				-0.629438			-2.008496		-0.273757	
Soil_m (X_4)	0.281176					-0.642708		-0.712275		-1.056461
Distance from road (X_5)	-0.001436			-0.000687		0.000511	0.001383	-0.000199	0.000746	-0.001026
Distance from settlement (X_6)	-0.017231		0.002288	0.000351	0.009244	0.001664	-0.000449	0.000935	0.000333	
Distance from water body (X_7)	0.000138		-0.000906	0.000069	-0.003527	-0.000412	0.000073	-0.000503	-0.069632	0.001324
Population density (X_8)	0.000619		-0.001498	-0.000532	-0.008151	-0.000060	-0.000180		-0.000309	-0.000205
Average income (X_9)	0.000006	-0.003516	-0.000034	-0.000013	-0.000059	0.000001	0.000008		-0.000007	0.000005
ROC	0.956	0.913	0.920	0.681	0.975	0.806	0.858	0.622	0.992	0.837

Table 5.24 Significant location factor of each LULC type and its coefficient of Khao Tosae NRF.

Driving forces	Ur	Fch	Op	Aq	Id	Ef	Mf	Sc	Wa	Mi
Constant	2.019387	67.349499	-2.287673	0.703845	-1.518631	-3.917097	0.566777	-1.933095	5.095491	-5.785400
Elevation (X_1)	-0.013453		-0.003557	-0.469958		0.032646	-0.165553	-0.013122		
Slope (X_2)	-0.035010		0.026670	-0.283253		0.020327		0.026256		0.053233
Soil_l (X_3)					-0.007094	-1.474941			-1.418980	-1.099974
Soil_m (X_4)	-0.381758				-0.265286		-4.968499	-0.237872		
Distance from road (X_5)	-0.004145		-0.000889	0.006059	-0.001029		0.000566	-0.000556		-0.002510
Distance from settlement (X_6)	-0.029804		0.000551	-0.004578	0.002403	0.001915	0.008571	0.000782		0.006057
Distance from water body (X_7)	0.001236		0.002522		-0.000948	0.002189	-0.001963	-0.001085	-0.290815	-0.002775
Population density (X_8)		-0.122720	-0.000222	0.001831	-0.000511	0.000501	0.000332			
Average income (X_9)	0.000006		-0.000024	-0.000189	0.000014	-0.000027	-0.000090	-0.000006		
ROC	0.959	0.723	0.822	0.954	0.721	0.959	0.969	0.598	0.999	0.822

Table 5.25 Significant location factor of each LULC type and its coefficient of Khlong U-Tapao NRF.

Driving forces	**Ur**	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	0.05010	-3.10416	-2.19240	-3.39840	-3.08023	-1.69650	-56.71170	-1.31330	-1.92585	0.98288	-4.40220
Elevation (X_1)	-0.13710		-0.01570	0.14070	-0.05640	-0.13030	0.14540	-0.09050	-0.11710		-0.14980
Slope (X_2)	0.02149	-0.06780		-0.03200	0.03375	0.01391		-0.00961	0.06160	-0.03330	-0.03022
Soil_l (X_3)				2.14832							
Soil_m (X_4)							-9.21610				
Distance from road (X_5)	-0.01084	0.01475	-0.00650	-0.00270	0.00343	-0.00613		0.00641	-0.00032	-0.00060	-0.00099
Distance from settlement (X_6)	-0.00614	-0.01563		-0.00042		0.00043	0.02650	0.00040	0.00138	0.00050	0.00256
Distance from water body (X_7)	0.00200	-0.00665	-0.00280	0.00160	-0.00497	0.00118	0.01739	-0.00359	0.00022	-0.07840	0.00170
Population density (X_8)											
Average income (X_9)											
ROC	0.902	0.969	0.761	0.844	0.825	0.782	0.999	0.849	0.739	0.984	0.804

Table 5.26 Significant location factor of each LULC type and its coefficient of Khlong Tha Maphrao NRF.

Driving forces	**Ur**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	18.8723	-6.5472	-7.6354	-5.5030	-23.4687	-33.5798	-0.4212	-7.6233	-6.7977	-17.1011
Elevation (X_1)	-0.0073		0.0116	-0.6415	-0.0304	0.0331	-0.2333			
Slope (X_2)	-0.0468	0.0511	0.0286			0.0324		0.0270	-0.0322	
Soil_l (X_3)			-0.8962							
Soil_m (X_4)						-1.5453	-14.5016	-1.3622		
Distance from road (X_5)	-0.0064		-0.0026			0.0057	0.0079	-0.0036	-0.0014	-0.0100
Distance from settlement (X_6)	-0.0093		0.0022	0.0008	0.0019	0.0007	0.0011	0.0018	0.0019	0.0038
Distance from water body (X_7)	-0.0002	-0.0049	0.0009	-0.0007		0.0011		-0.0031	-0.0573	
Population density (X_8)	-0.1158		0.0428		0.2658			0.0247	0.0318	0.0445
Average income (X_9)	0.0006		-0.0002	0.0004	-0.0026	0.0018	-0.0001			
ROC	0.953	0.825	0.835	0.958	0.753	0.963	0.972	0.785	0.986	0.936

Table 5.27 Significant location factor of each LULC type and its coefficient of Khlong Para NRF.

Driving forces	**Ur**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	1.70823	0.40481	-1.20226	-0.24278	-0.64390	-5.16848	-3.08397	-2.99561	3.12473	-0.59505
Elevation (X_1)	-0.01397		0.01510	-0.52562	-0.01762	0.03523	-0.08633	-0.03875	-0.03796	-0.39851
Slope (X_2)	-0.03077	-0.05916	0.01115	-0.07546	-0.04344	0.04932	0.02495	0.03594		-0.13086
Soil_l (X_3)			-0.70636			-1.11995				
Soil_m (X_4)	-0.38910			-0.62254	-0.51562		-2.35993			
Distance from road (X_5)	-0.00285		-0.00286	0.00297	-0.00097	0.00348	0.00320	-0.00148		-0.00693
Distance from settlement (X_6)	-0.02420		0.00341	0.00075	0.00097	-0.00502	0.00687	0.00230		0.00363
Distance from water body (X_7)	0.00066	-0.00282		-0.00119	-0.00138	0.00133	0.00120		-0.25080	
Population density (X_8)	0.00009	-0.00885	-0.00088	0.00020	-0.00075	0.00061	-0.00017			
Average income (X_9)	0.00000		0.00002	-0.00004	0.00002	-0.00003	-0.00001	0.00001		-0.00008
ROC	0.998	0.943	0.777	0.935	0.791	0.983	0.915	0.750	0.992	0.860

Table 5.28 Significant location factor of each LULC type and its coefficient of Khlong Bangrong NRF.

Driving forces	**Ur**	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	3.8926	-1.5274	-5.1392	-1.7772	-0.9534	-3.4622	-7.3364	-2.5368	-4.5031	-0.1071	-8.1550
Elevation (X_1)	-0.0507	-0.9066		-0.0051	-0.4687	-0.0213	0.0325	-0.0760	-0.0357		-0.2402
Slope (X_2)		-0.2985		0.0382			0.0261	-0.0418	0.0470		
Soil_l (X_3)											
Soil_m (X_4)							-2.1564	-1.3009			
Distance from road (X_5)	-0.0067	0.0210		-0.0030		-0.0013	0.0025	0.0056		0.0018	0.0065
Distance from settlement (X_6)	-0.0353	-0.0172		0.0025	0.0032	0.0017	0.0017	0.0028	0.0016	-0.0927	
Distance from water body (X_7)		-0.0032				-0.0006	0.0006	-0.0021			0.0042
Population density (X_8)											
Average income (X_9)											
ROC	0.993	0.981	0.500	0.804	0.919	0.688	0.984	0.945	0.754	0.982	0.979

Table 5.29 Significant location factor of each LULC type and its coefficient of Khlong Tarau NRF.

Driving forces	**Ur**	**Pa**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	-0.9757	4.1600	-5.1138	-2.6766	-0.5310	2.6595	-16.3610	8.0621	-3.3798	1.1174	203.9699
Elevation (X_1)		-0.6199		0.0567	-0.6207	-0.0512		-0.0693	-0.0802		
Slope (X_2)	-0.0468	-0.2862		0.0358		0.0098	0.0269		0.0589		
Soil_l (X_3)	-0.5259			0.6556			-2.0750				
Soil_m (X_4)			-16.0891		-16.0465			-1.2337			
Distance from road (X_5)	-0.0054	0.0049		0.0003		-0.0013		0.0041	-0.0023		
Distance from settlement (X_6)	-0.0074	-0.0063		0.0007	0.0031	0.0019	0.0008	0.0025	0.0018	0.0007	
Distance from water body (X_7)	0.0004			0.0010		0.0008	0.0019	-0.0016	-0.0012	-0.1425	0.0033
Population density (X_8)	0.0087	-0.0291		-0.0050			0.0097	-0.0182			-0.2050
Average income (X_9)	0.0001					-0.0003	0.0006	-0.0005			-0.0107
ROC	0.932	0.967	0.568	0.900	0.950	0.723	0.937	0.970	0.753	0.995	0.882

Table 5.30 Significant location factor of each LULC type and its coefficient of Khlong Tajin NRF.

Driving forces	**Ur**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	1.63657	-23.80561	-3.10970	-1.46453	-1.77611	-0.89023	-3.07521	-2.10704	2.87573	0.15113
Elevation (X_1)			0.01026	-0.68942	0.00258	0.03680	-0.12929	-0.00293		-0.06842
Slope (X_2)	-0.03798	-0.14225	0.03449		-0.01468	0.02715	-0.02220	0.01465	-0.02679	
Soil_l (X_3)						-1.17474				-1.62788
Soil_m (X_4)	-0.36364		-0.22384	-17.94303	-0.56986		-6.54756	-0.56769		
Distance from road (X_5)	-0.00238		-0.00170	0.00219		-0.00023	0.00063	-0.00142	-0.00051	-0.00192
Distance from settlement (X_6)	-0.04309		0.00108			-0.00045	0.00806	0.00094		0.00171
Distance from water body (X_7)	0.00033	-0.05647	0.00076	0.00320	-0.00095	0.00106	-0.00217	-0.00019	-0.18032	0.00128
Population density (X_8)		0.00207	-0.00097		-0.00054	0.00118	-0.00141	-0.00005		0.00086
Average income (X_9)	0.00001		0.00005		0.00002	-0.00012	0.00010		-0.00001	-0.00013
ROC	0.974	0.820	0.804	0.947	0.662	0.917	0.949	0.601	0.996	0.828

Table 5.31 Significant location factor of each LULC type and its coefficient of Khlong Khopee NRF.

Driving forces	**Ur**	**Fch**	**Op**	**Aq**	**Id**	**Ef**	**Mf**	**Sc**	**Wa**	**Mi**
Constant	1.708227	0.404811	-1.202261	-0.242781	-0.643897	-5.168482	-3.083970	-2.995612	3.124725	-0.595047
Elevation (X_1)	-0.013973		0.015103	-0.525620	-0.017615	0.035231	-0.086325	-0.038745	-0.037958	-0.398511
Slope (X_2)	-0.030768	-0.059156	0.011151	-0.075457	-0.043442	0.049319	0.024945	0.035938		-0.130862
Soil_l (X_3)			-0.706359		-0.515620	-1.119954				
Soil_m (X_4)	-0.389104			-0.622542			-2.359933			
Distance from road (X_5)	-0.002850		-0.002857	0.002965	-0.000969	0.003478	0.003196	-0.001484		-0.006927
Distance from settlement (X_6)	-0.024196		0.003410	0.000750	0.000969	-0.005017	0.006870	0.002297		0.003629
Distance from water body (X_7)	0.000663	-0.002821		-0.001193	-0.001381	0.001325	0.001200			
Population density (X_8)	0.000091	-0.008847	-0.000875	0.000201	-0.000748	0.000612	-0.000172			
Average income (X_9)	0.000003		0.000017	-0.000043	0.000023	-0.000028	-0.000005	0.000005	-0.250804	-0.000081
ROC	0.946	0.880	0.868	0.945	0.731	0.950	0.928	0.632	0.999	0.943

Furthermore, the accuracy assessment of three geospatial models for LULC prediction in each protected forest area is compared and summarized in Table 5.32. According to overall accuracy and Kappa hat coefficient values which were evaluated by wall-to-wall accuracy assessment with the interpreted LULC data in 2014 as reference data, an optimum geospatial model for LULC prediction in 9 protected forest areas including Sirinath MNP, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Nak Keod NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, and Khlong Bangrong NRF is CLUE-S model. While CA-Markov model is an optimum geospatial prediction model for prediction LULC in 6 protected forest areas included Khao Kamala NRF, Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee NRF. This finding suggests the effect of driving factor on LULC type allocation of CLUE-S model. However, CA-Markov model, which was here operated without transitional suitability data or driving factors for LULC prediction, can provide Kappa hat coefficient higher than CLUE-S model in 6 protected forest areas. This result implies the least influence of driving factors used in CLUE-S model.

In summary, it was suggested that the most optimum geospatial model for LULC prediction is CLUE-S and CA-Markov while the least optimum geospatial model for LULC prediction is LCM. This finding is similar with the previous study of Ongsomwang and Pimjai (2014). They found that CA-Markov model can provided thematic accuracy (overall accuracy and Kappa hat coefficient) for LULC prediction higher than LCM.

In this study, the derived optimum geospatial model for each protected forest area was further used to predict LULC in 2026 according to accuracy assessment and its complexity for implementation.

Table 5.32 Accuracy assessment of three models of each protected forest area.

Protected forest area	**CA-Markov**		**LCM**		**CLUE-S**	
	Overall	**Kappa**	**Overall**	**Kappa**	**Overall**	**Kappa**
Sirinath MNP	84.09	76.99	82.82	75.18	**85.60**	**79.18**
Khao Phra Thaeo WCDEC	88.47	83.35	89.94	81.82	**88.83**	**83.89**
Khao Mai Kaew NRF	86.20	78.87	84.57	76.46	**89.39**	**83.27**
Khao Bang Khanun NRF	85.05	75.96	83.41	73.36	**87.33**	**79.66**
Khao Sam Liam NRF	87.87	83.32	86.64	81.64	**91.06**	**87.46**
Khao Kamala NRF	**80.28**	**74.33**	78.37	71.85	79.72	73.36
Khao Nak Keod NRF	77.20	69.94	72.76	64.09	**78.09**	**70.52**
Khao Tosae NRF	83.04	**73.76**	80.00	69.06	**83.70**	73.57
Khlong U-Tapao NRF	**90.78**	**86.03**	89.91	84.74	89.73	84.40
Khlong Tha Maphrao NRF	84.89	78.48	83.05	75.88	**88.66**	**83.29**
Khlong Para NRF	87.38	82.43	85.56	79.94	**90.21**	**86.26**
Khlong Bangrong NRF	86.30	81.57	84.89	79.69	**89.35**	**85.40**
Khlong Tarau NRF	**82.18**	**76.50**	79.68	73.22	81.06	74.80
Khlong Tajin NRF	**83.32**	**78.77**	80.29	74.92	82.23	76.56
Khlong Khopee NRF	83.85	**74.88**	81.85	71.77	**84.15**	74.74

Furthermore, results of pairwise Z-test between an optimum geospatial model with other models for LULC prediction by each protected forest area is summarized in Table 5.33. As result, it was found that Kappa hat accuracies from an optimum geospatial model for LULC prediction of 15 protected forest areas were statistically significantly different from other models except Khao Tosae and Khlong Khopee NRFs. Herewith Kappa hat accuracies of CLUE-S model for LULC prediction in both NRFs were not significantly different at 90% or 95% or 100% confidential level when they were compared with an optimum geospatial model (CA-Markov model). These results can be confirmed the justification of optimum geospatial model for LULC prediction as described above.

Table 5.33 Pairwise Z test between an optimum geospatial model with other models for LULC prediction by each protected forest area.

Protected forest area	Optimum geospatial model	Pair-wise Z test	KHAT1	KKAT2	VAR1	VAR2	Z statistic	Two-tail confidential level		
								90%	95%	100%
Sirinath MNP	CLUE-S	CA-Markov, CLUE-S	0.769869453	0.791755862	0.00000211	0.00000193	10.88	1.65	1.96	2.58
		LCM, CLUE-S	0.751833127	0.791755862	0.00000223	0.00000193	19.58	1.65	1.96	2.58
Khao Phra Thaeo WCDEC	CLUE-S	CA-Markov, CLUE-S	0.833524429	0.838859504	0.00000141	0.00000139	3.19	1.65	1.96	2.58
		LCM, CLUE-S	0.818204909	0.838859504	0.00000150	0.00000139	12.16	1.65	1.96	2.58
Khao Mai Kaew NRF	CLUE-S	CA-Markov, CLUE-S	0.788740131	0.832716837	0.00000396	0.00000333	16.28	1.65	1.96	2.58
		LCM, CLUE-S	0.764604778	0.832716837	0.00000427	0.00000333	24.70	1.65	1.96	2.58
Khao Bang Khanun NRF	CLUE-S	CA-Markov, CLUE-S	0.759578002	0.832716837	0.00000374	0.00000333	27.50	1.65	1.96	2.58
		LCM, CLUE-S	0.764604778	0.832716837	0.00000427	0.00000333	24.70	1.65	1.96	2.58
Khao Sam Liam NRF	CLUE-S	CA-Markov, CLUE-S	0.833205397	0.874552134	0.00000653	0.00000517	12.09	1.65	1.96	2.58
		LCM, CLUE-S	0.816428591	0.874552134	0.00000705	0.00000517	16.62	1.65	1.96	2.58
Khao Kamala NRF	CA- Markov	CA- Markov, LCM	0.743292168	0.718549895	0.00000115	0.00000122	16.07	1.65	1.96	2.58
		CA-Markov, CLUE-S	0.743292168	0.733599857	0.00000115	0.00000120	6.32	1.65	1.96	2.58
Khao Nak Keod NRF	CLUE-S	CA-Markov, CLUE-S	0.699385048	0.705230816	0.00000159	0.00000162	3.26	1.65	1.96	2.58
		LCM, CLUE-S	0.640905455	0.705230816	0.00000178	0.00000162	34.89	1.65	1.96	2.58
Khao Tosae NRF	CA- Markov	CA- Markov, LCM	0.737559398	0.690568129	0.00000699	0.00000795	12.16	1.65	1.96	2.58
		CA- Markov, CLUE-S	**0.737559398**	**0.735749874**	**0.00000699**	**0.00000752**	**0.47**	**1.65**	**1.96**	**2.58**
Khlong U-Tapao NRF	CA- Markov	CA- Markov, LCM	0.737559398	0.847417641	0.00000699	0.00000585	30.65	1.65	1.96	2.58
		CA-Markov, CLUE-S	0.737559398	0.843977286	0.00000699	0.00000594	29.59	1.65	1.96	2.58
Khlong Tha Maphrao NRF	CLUE-S	CA-Markov, CLUE-S	0.784774751	0.832854359	0.00000375	0.00000316	18.29	1.65	1.96	2.58
		LCM, CLUE-S	0.758827951	0.832854359	0.00000411	0.00000316	27.46	1.65	1.96	2.58
Khlong Para NRF	CLUE-S	CA-Markov, CLUE-S	0.824309018	0.862604306	0.00000319	0.00000264	15.87	1.65	1.96	2.58
		LCM, CLUE-S	0.799355398	0.862604306	0.00000355	0.00000264	25.43	1.65	1.96	2.58
Khlong Bangrong NRF	CLUE-S	CA-Markov, CLUE-S	0.815671095	0.853974813	0.00000343	0.00000289	15.24	1.65	1.96	2.58
		LCM-CLUE-S	0.796879833	0.853974813	0.00000366	0.00000289	22.31	1.65	1.96	2.58
Khlong Tarau NRF	CA- Markov	CA- Markov , LCM	0.765045314	0.732203214	0.00000398	0.00000442	11.33	1.65	1.96	2.58
		CA-Markov, CLUE-S	0.765045314	0.748024882	0.00000398	0.00000430	5.92	1.65	1.96	2.58
Khlong Tajin NRF	CA- Markov	CA- Markov, LCM	0.787667443	0.749152687	0.00000402	0.00000459	13.12	1.65	1.96	2.58
		CA-Markov, CLUE-S	0.787667443	0.765594612	0.00000402	0.00000464	7.50	1.65	1.96	2.58
Khlong Khopee NRF	CA- Markov	CA- Markov, LCM	0.748830636	0.717651667	0.00000572	0.00000630	8.99	1.65	1.96	2.58
		CA-Markov, CLUE-S	**0.748830636**	**0.747420613**	**0.00000572**	**0.00000598**	**0.41**	**1.65**	**1.96**	**2.58**

5.2 LULC prediction in 2026

The derived optimum geospatial model of each protected forest area was here used to predict LULC in 2026. Results of LULC prediction in 2026 of each protected forest area is displayed in Figures 5.16 to 5.30. Meanwhile area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of each protected forest area within its boundary and with buffer zone is summarized and compared in Tables 5.34 to 5.48. These results provide the possibility of LULC change within boundary of protected forest area and with buffer zone between 2014 and 2026, especially the increasing of urban and built-up areas.

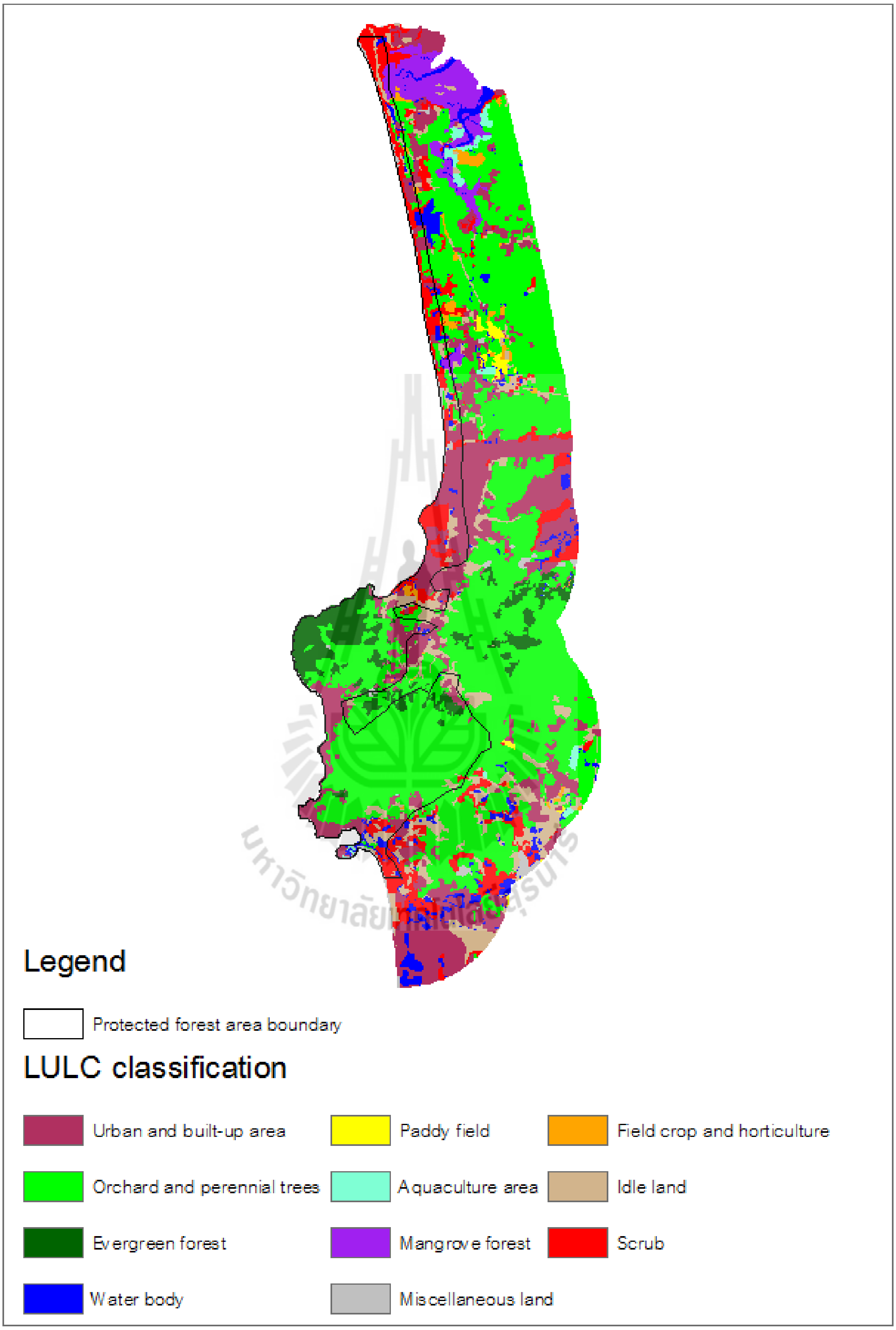


Figure 5.16 Distribution of predicted LULC in 2026 of Sirinath MNP.

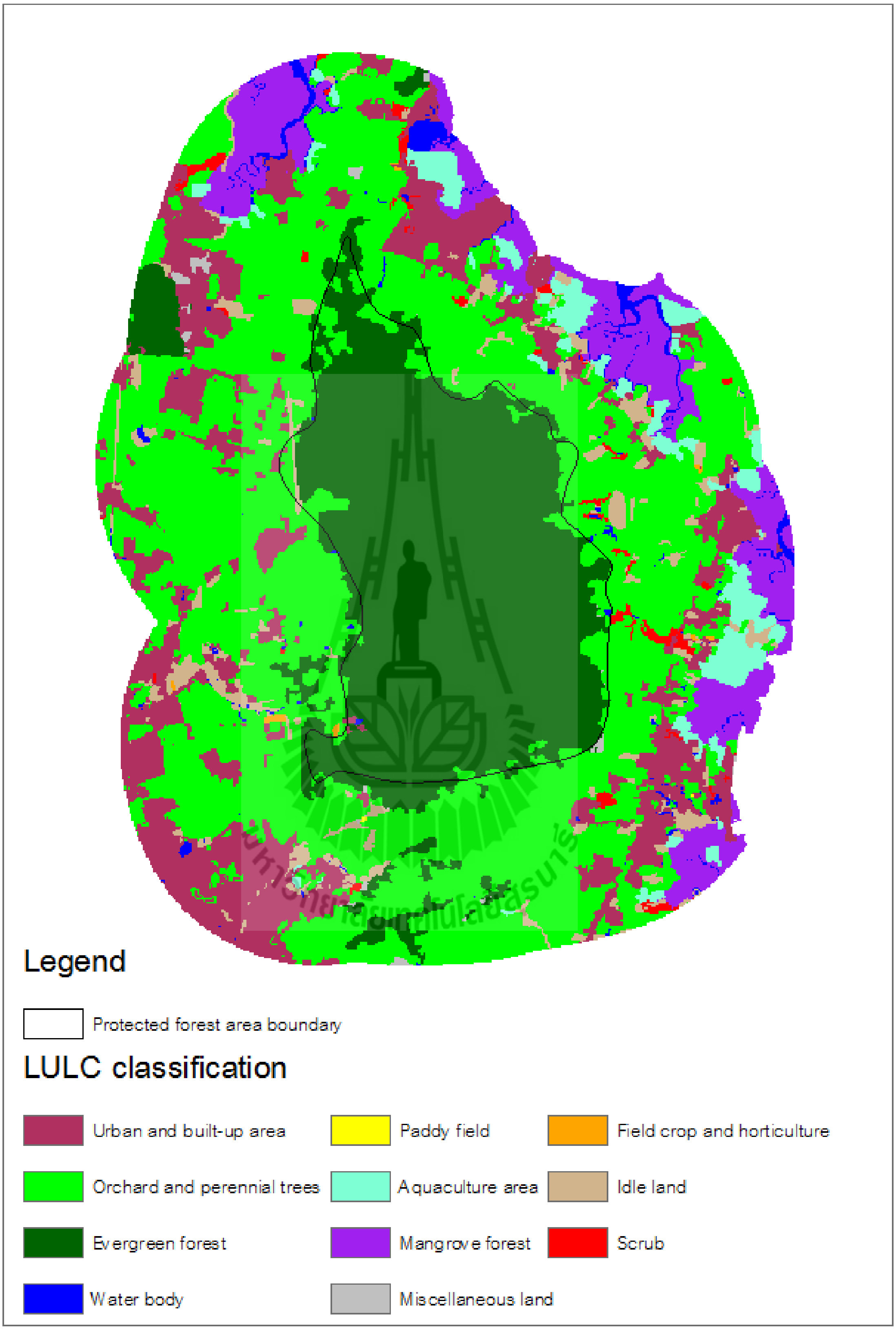


Figure 5.17 Distribution of predicted LULC in 2026 of Khao Phra Thaeo WCDEC.

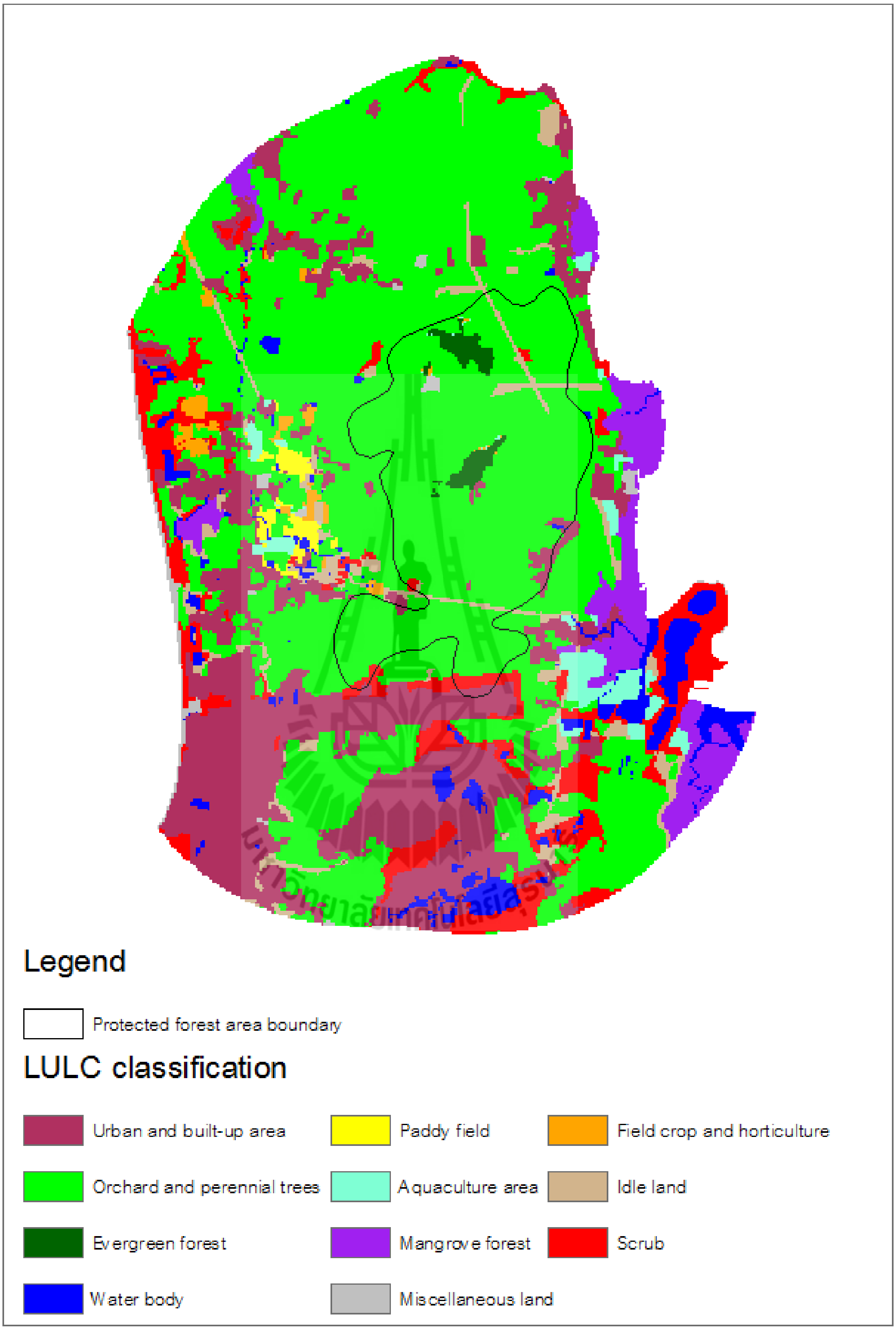


Figure 5.18 Distribution of predicted LULC in 2026 of Khao Mai Kaew NRF.

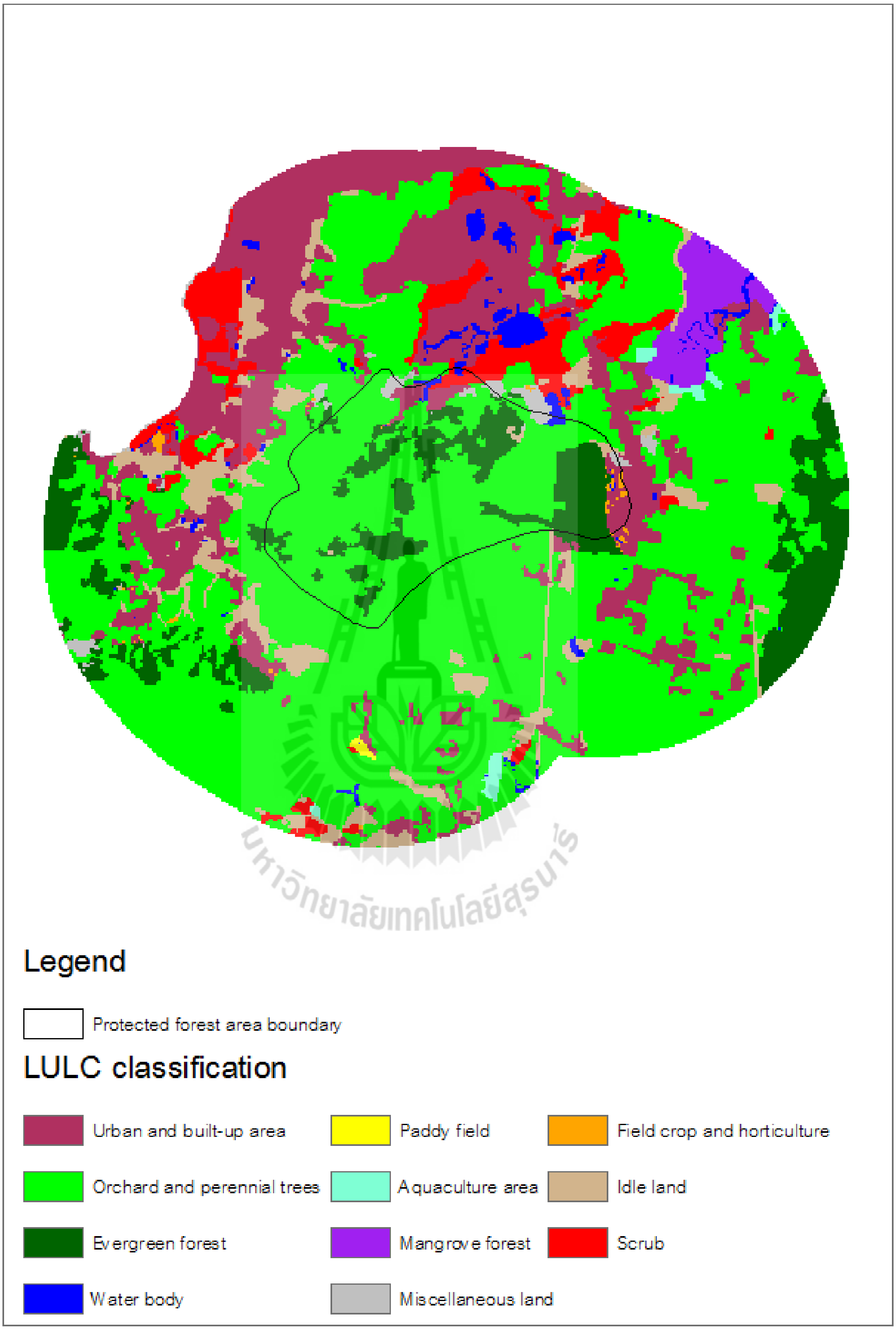


Figure 5.19 Distribution of predicted LULC in 2026 of Khao Bang Khanun NRF.

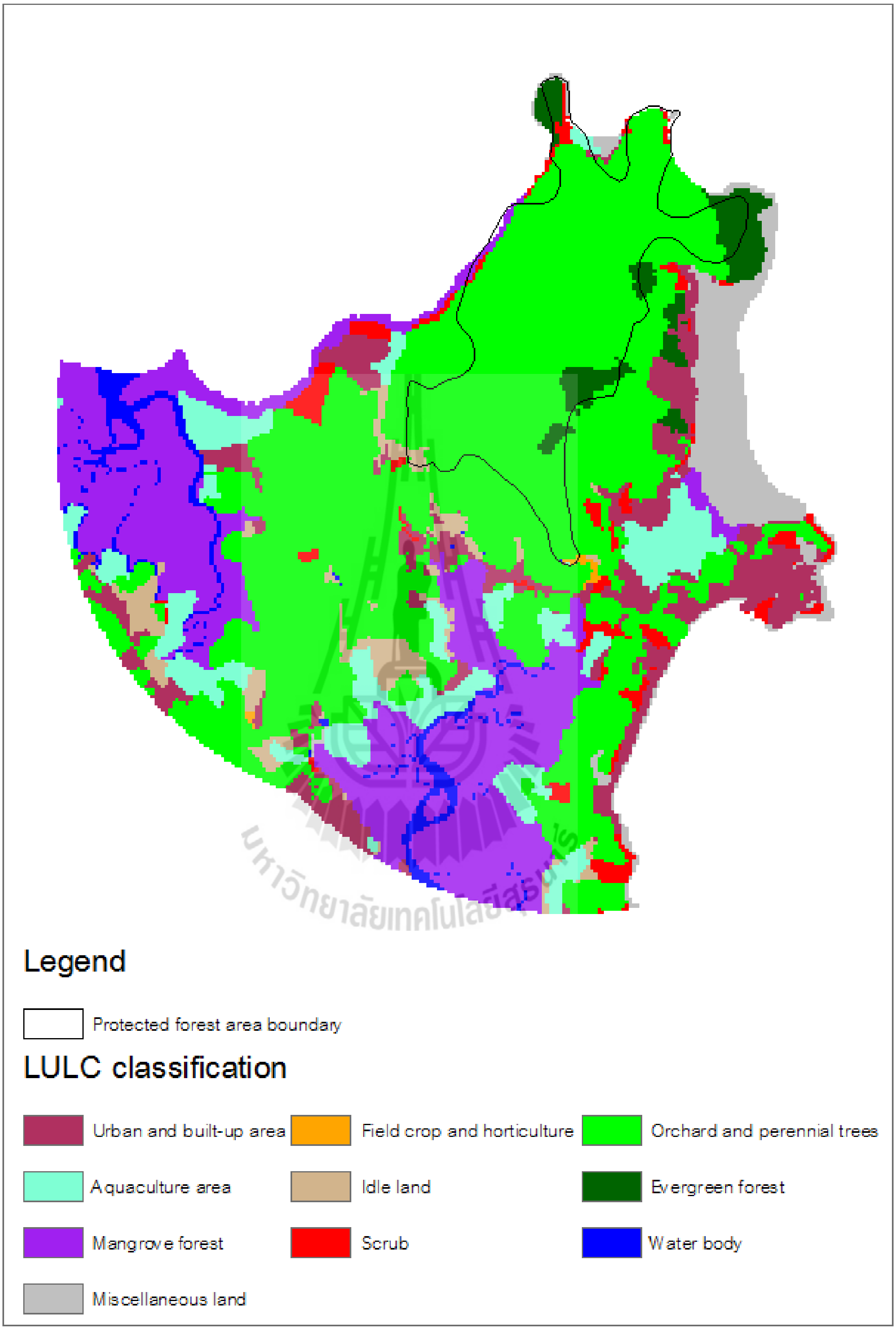


Figure 5.20 Distribution of predicted LULC in 2026 of Khao Sam Liam NRF.

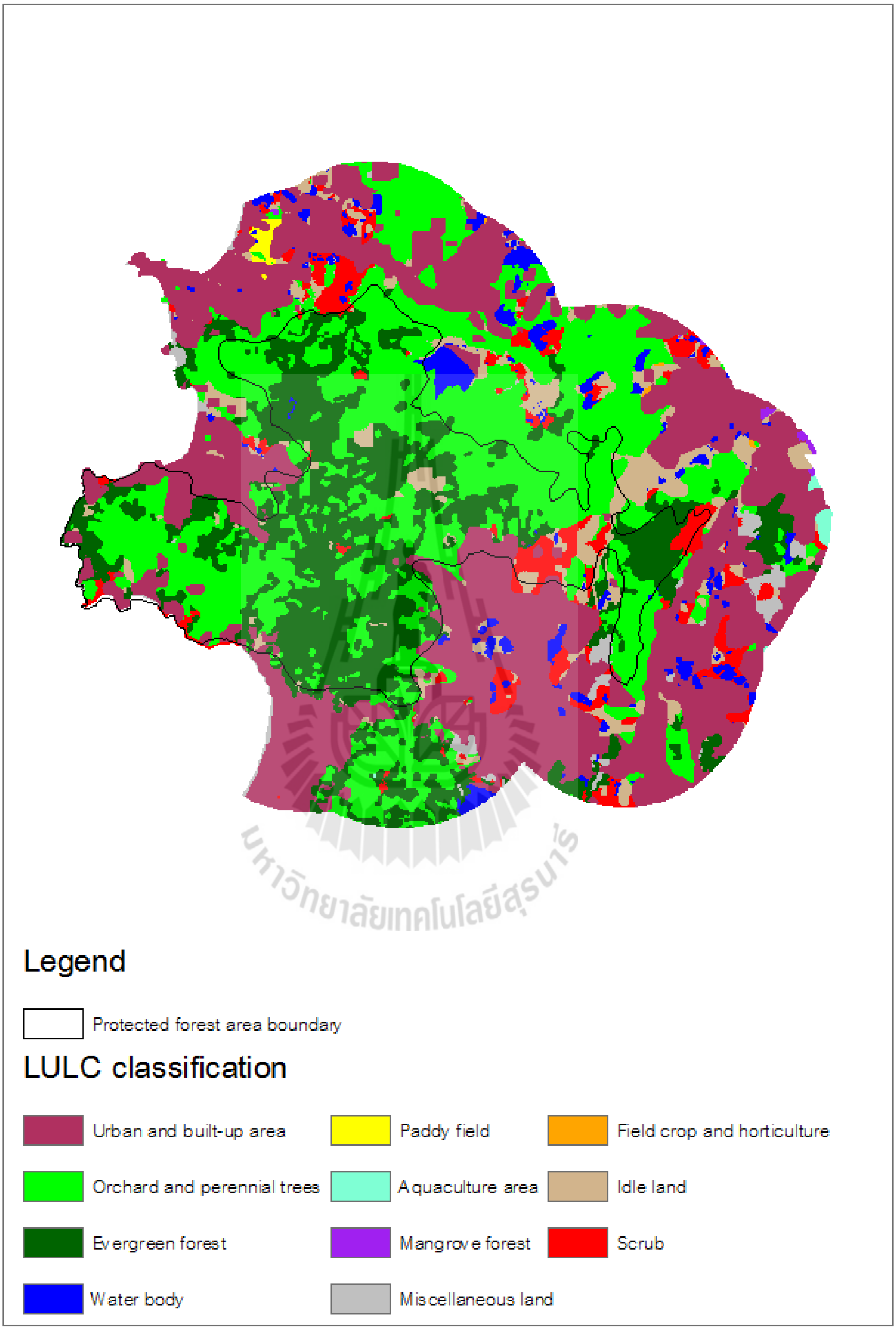


Figure 5.21 Distribution of predicted LULC in 2026 of Khao Kamala NRF.

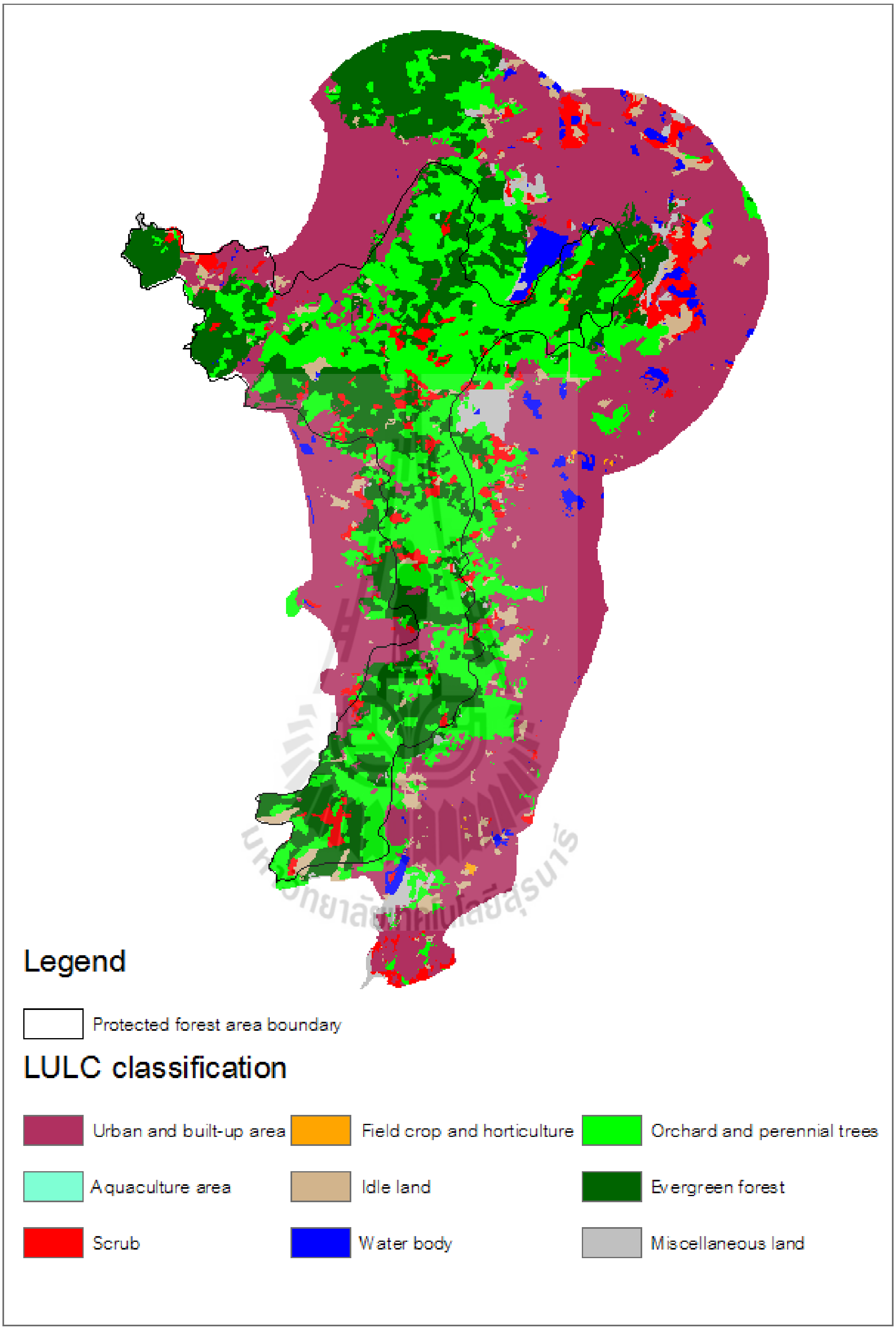


Figure 5.22 Distribution of predicted LULC in 2026 of Khao Nak Keod NRF.

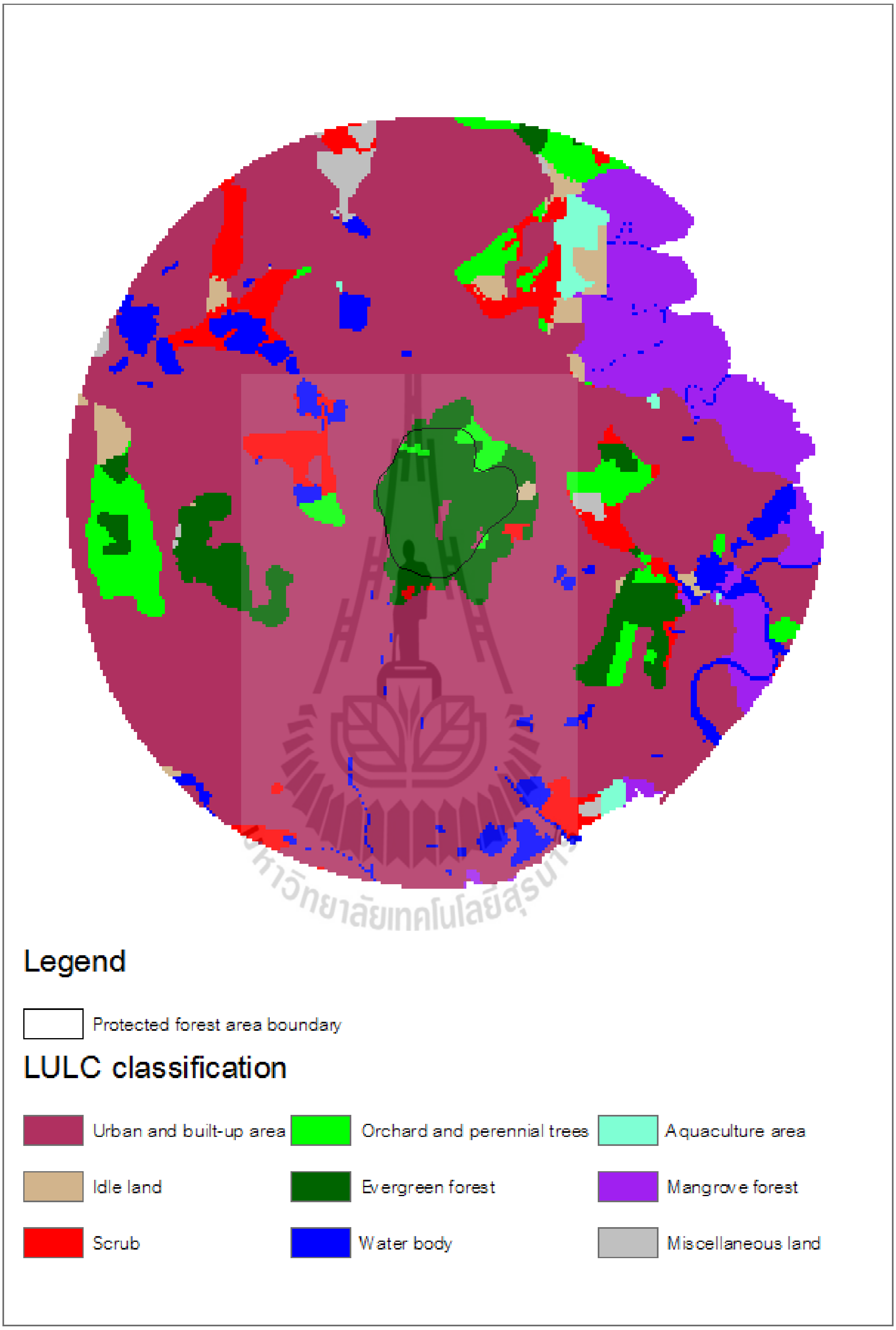


Figure 5.23 Distribution of predicted LULC in 2026 of Khao Tosae NRF.

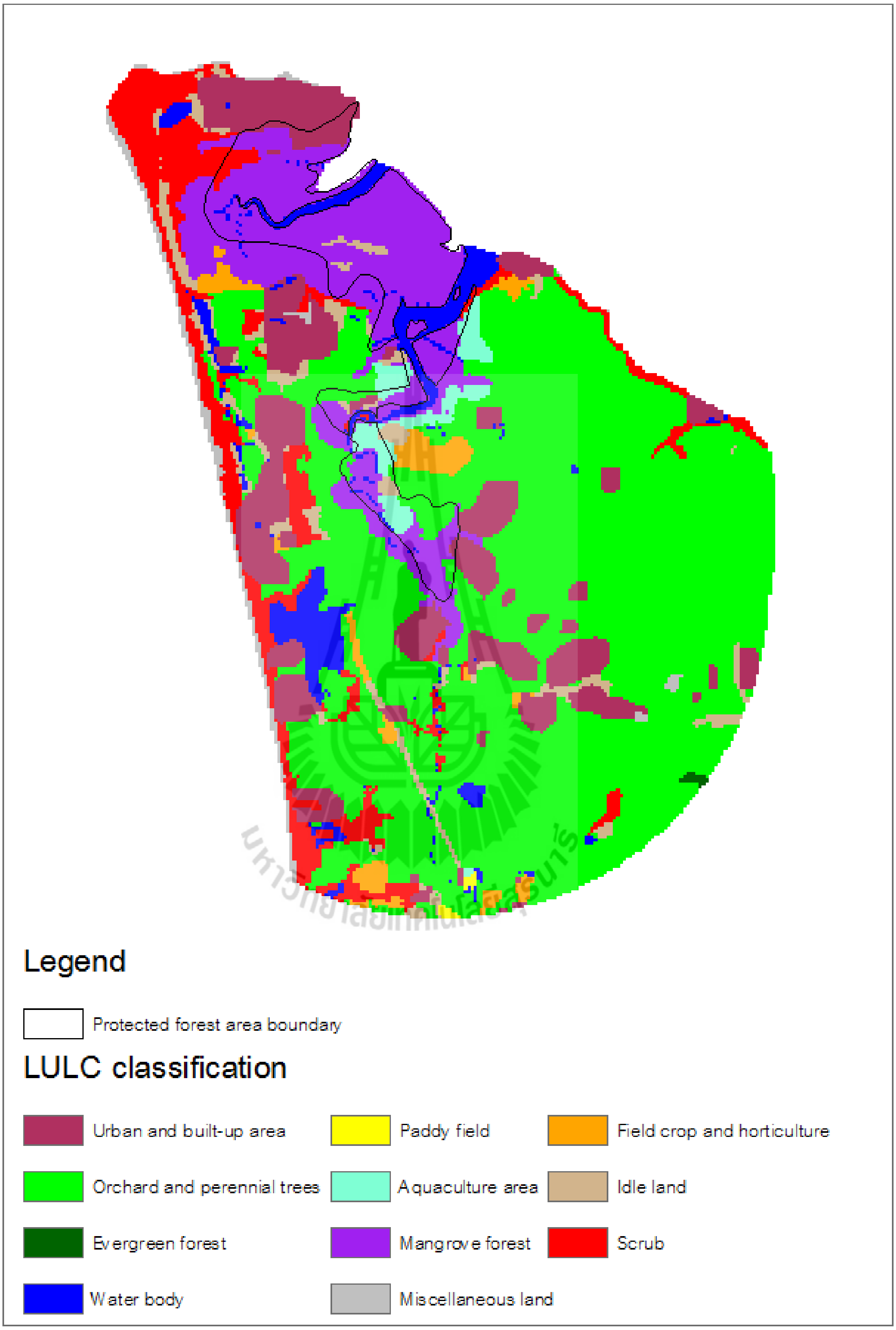


Figure 5.24 Distribution of predicted LULC in 2026 of Khlong U-Tapao NRF.

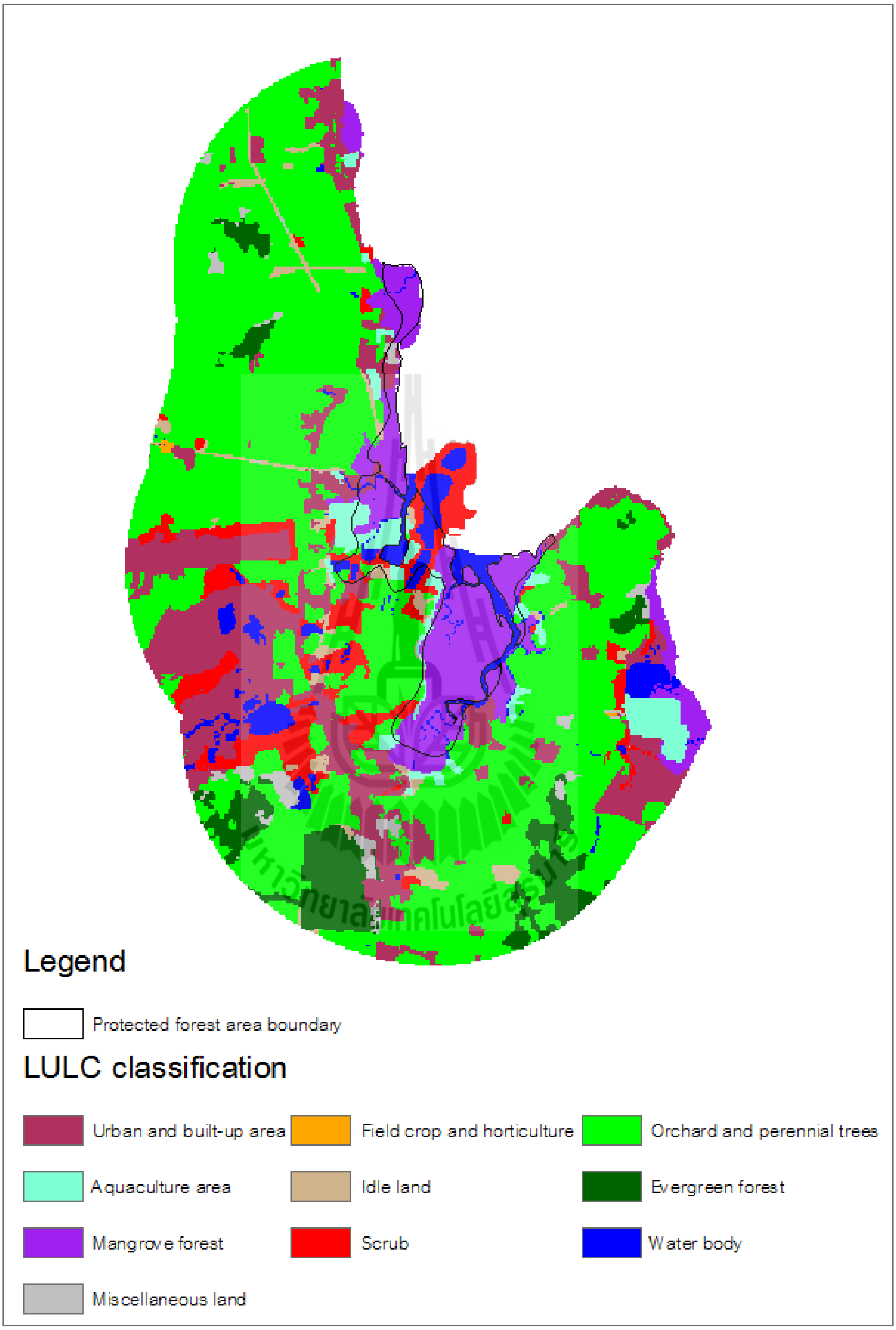


Figure 5.25 Distribution of predicted LULC in 2026 of Khlong Tha Maphrao NRF.

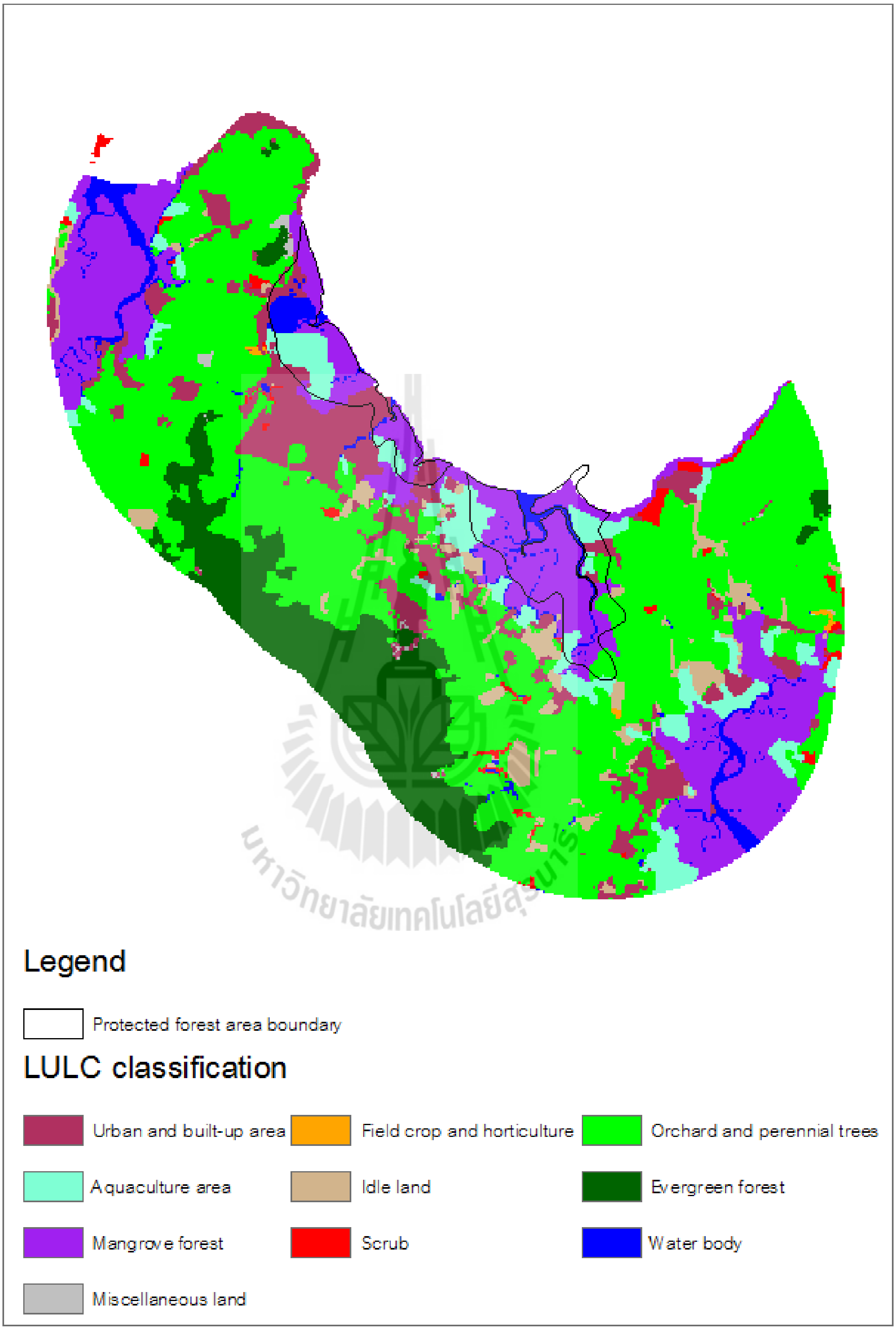


Figure 5.26 Distribution of predicted LULC in 2026 of Khlong Para NRF.

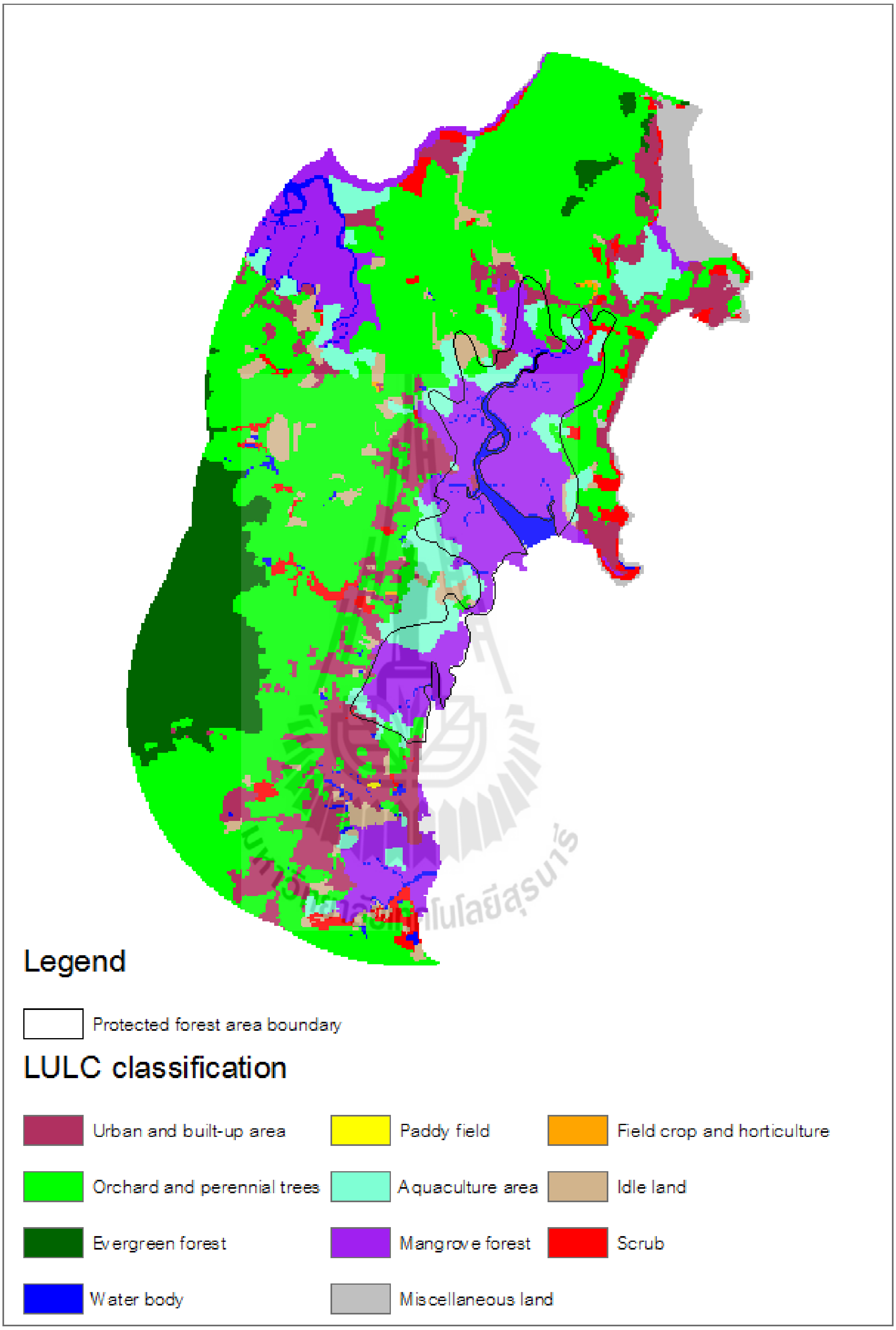


Figure 5.27 Distribution of predicted LULC in 2026 of Khlong Bangrong NRF.

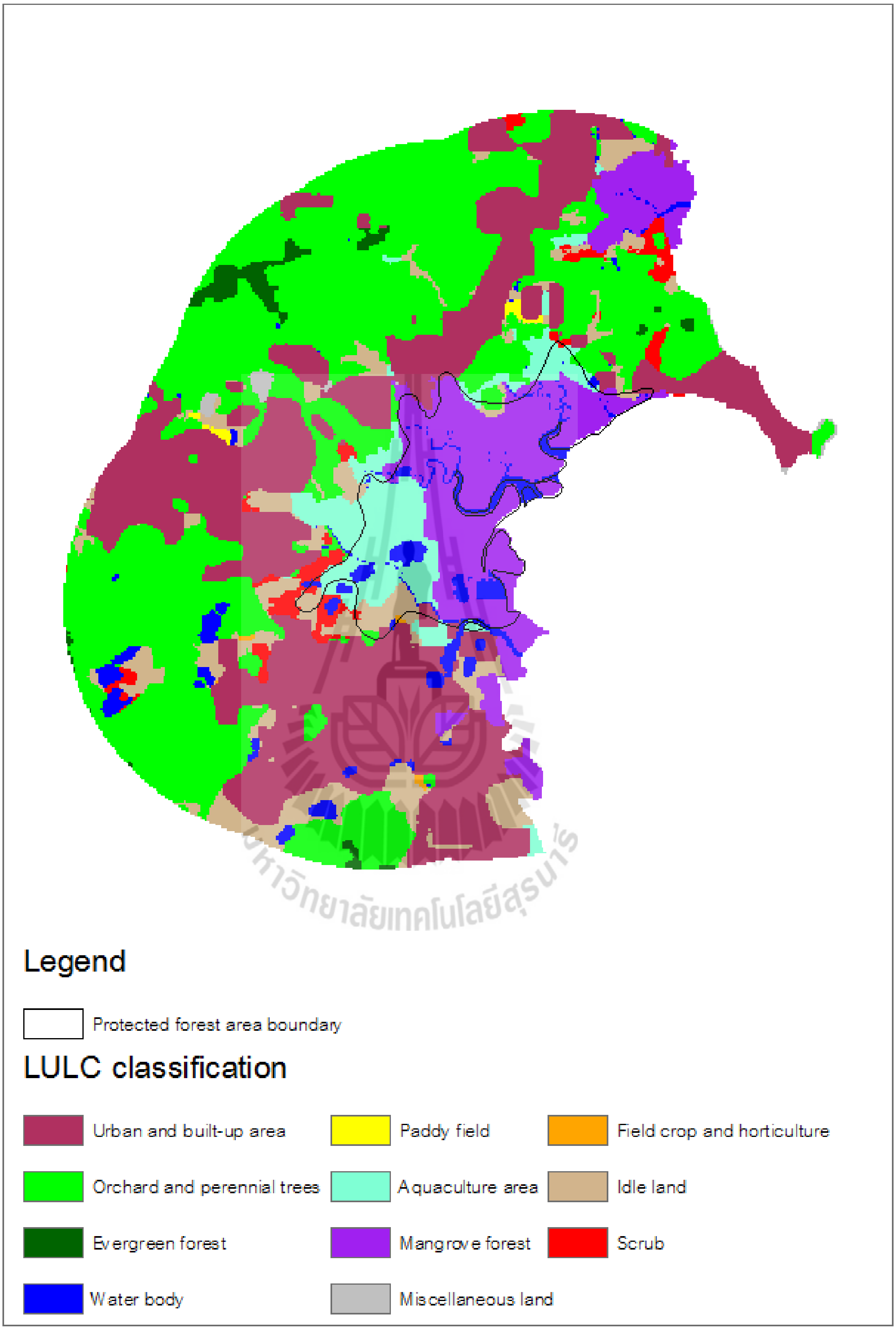


Figure 5.28 Distribution of predicted LULC in 2026 of Khlong Tarau NRF.

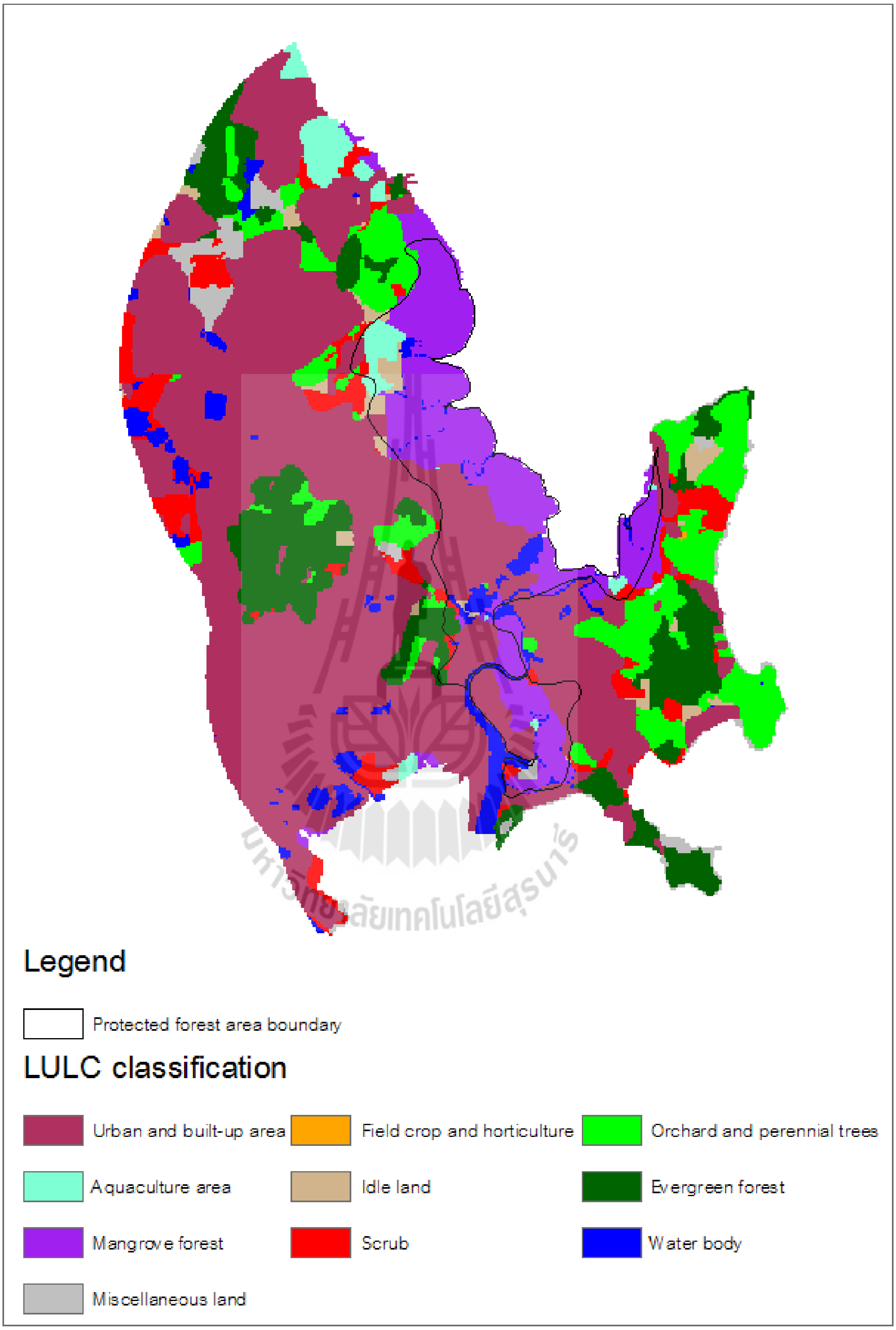


Figure 5.29 Distribution of predicted LULC in 2026 of Khlong Tajin NRF.

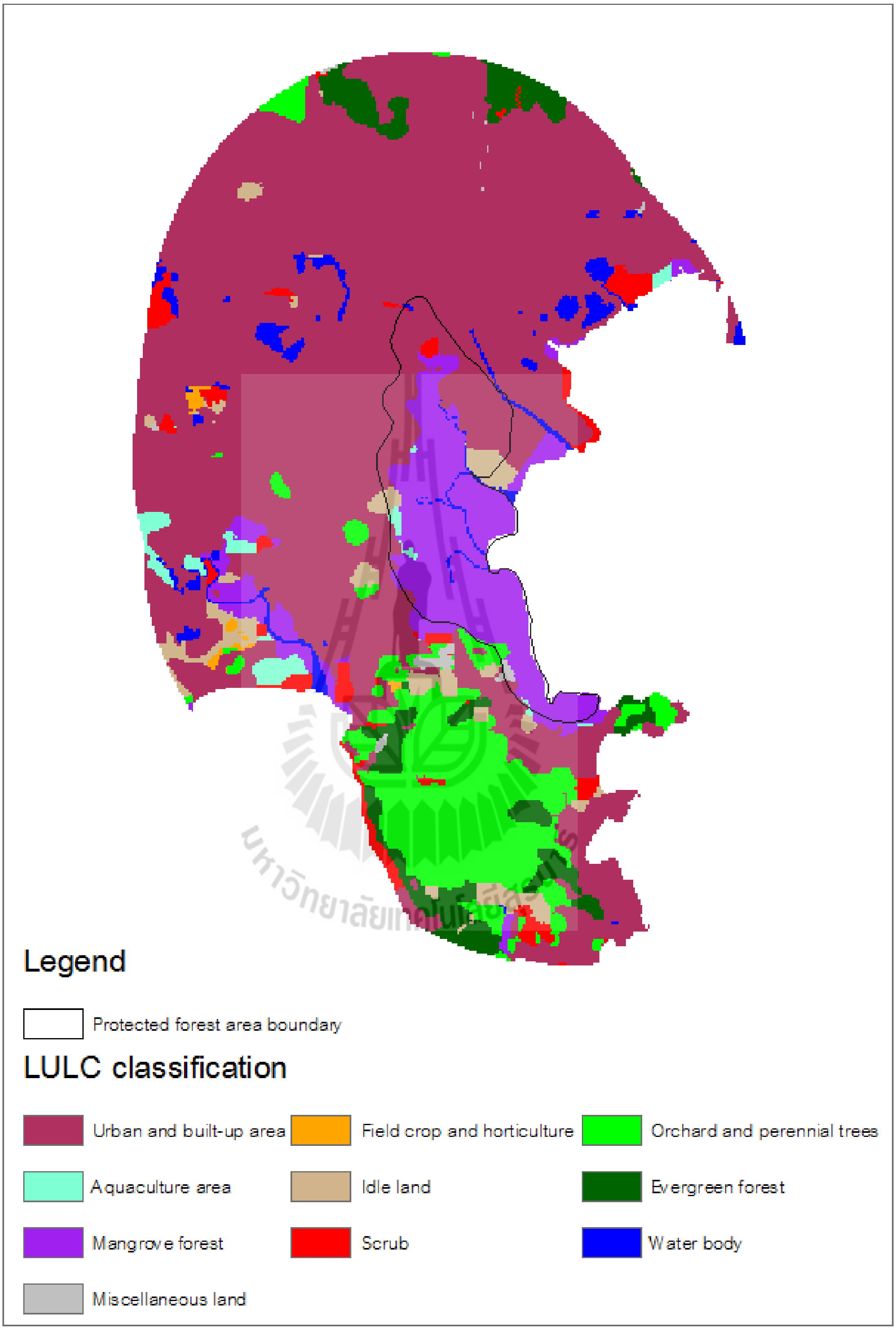


Figure 5.30 Distribution of predicted LULC in 2026 of Khlong Khopee NRF.

Table 5.34 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Sirinath MNP.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	12.173	15.20	16.049	20.04	2.621	12.38	4.234	20.01
Paddy field	0.621	0.78	0.379	0.47	0.000	0.00	0.000	0.00
Field crop and horticulture	0.764	0.95	0.765	0.96	0.087	0.41	0.085	0.40
Orchard and perennial trees	41.302	51.57	39.983	49.92	10.231	48.35	9.767	46.15
Aquaculture area	0.575	0.72	0.606	0.76	0.000	0.00	0.023	0.11
Idle land	6.644	8.30	5.646	7.05	1.350	6.38	1.113	5.26
Evergreen forest	4.526	5.65	3.771	4.71	3.107	14.68	2.503	11.83
Mangrove forest	2.934	3.66	2.918	3.64	0.111	0.52	0.111	0.52
Scrub	6.543	8.17	6.099	7.61	2.516	11.89	2.282	10.78
Water body	2.752	3.44	2.833	3.54	0.428	2.02	0.473	2.23
Miscellaneous land	1.260	1.57	1.043	1.30	0.711	3.36	0.571	2.70
Total	80.093	100.00	80.093	100.00	21.161	100.00	21.161	100.00

Table 5.35 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Phra Thaeo WCDEC.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	8.832	9.88	13.193	14.76	0.039	0.19	0.039	0.19
Paddy field	0.068	0.08	0.007	0.01	0.000	0.00	0.000	0.00
Field crop and horticulture	0.103	0.11	0.073	0.08	0.000	0.00	0.000	0.00
Orchard and perennial trees	42.631	47.68	39.856	44.58	1.561	7.67	1.561	7.67
Aquaculture area	2.873	3.21	2.784	3.11	0.000	0.00	0.000	0.00
Idle land	3.794	4.24	2.953	3.30	0.043	0.21	0.043	0.21
Evergreen forest	22.024	24.63	21.777	24.36	18.708	91.85	18.703	91.83
Mangrove forest	6.844	7.65	6.675	7.47	0.000	0.00	0.000	0.00
Scrub	0.938	1.05	0.679	0.76	0.000	0.00	0.000	0.00
Water body	1.162	1.30	1.163	1.30	0.016	0.08	0.016	0.08
Miscellaneous land	0.136	0.15	0.243	0.27	0.000	0.00	0.005	0.02
Total	89.404	100.00	89.404	100.00	20.368	100.00	20.368	100.00

Table 5.36 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Mai Kaew NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	7.411	17.17	8.767	20.31	0.144	1.98	0.144	1.98
Paddy field	0.501	1.16	0.293	0.68	0.000	0.00	0.000	0.00
Field crop and horticulture	0.328	0.76	0.341	0.79	0.000	0.00	0.011	0.15
Orchard and perennial trees	24.559	56.91	24.034	55.69	6.548	89.61	6.549	89.62
Aquaculture area	0.594	1.38	0.700	1.62	0.000	0.00	0.010	0.14
Idle land	2.003	4.64	1.458	3.38	0.154	2.11	0.154	2.11
Evergreen forest	0.324	0.75	0.303	0.70	0.324	4.43	0.303	4.14
Mangrove forest	2.109	4.89	1.990	4.61	0.000	0.00	0.000	0.00
Scrub	3.401	7.88	3.316	7.68	0.106	1.45	0.106	1.45
Water body	1.601	3.71	1.615	3.74	0.006	0.08	0.006	0.08
Miscellaneous land	0.327	0.76	0.343	0.79	0.026	0.35	0.026	0.35
Total	43.158	100.00	43.158	100.00	7.308	100.00	7.308	100.00

Table 5.37 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Bang Khanun NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	7.898	14.93	10.055	19.01	0.134	1.84	0.284	3.89
Paddy field	0.056	0.11	0.033	0.06	0.000	0.00	0.000	0.00
Field crop and horticulture	0.093	0.17	0.096	0.18	0.000	0.00	0.030	0.41
Orchard and perennial trees	30.679	58.00	30.036	56.78	4.809	65.95	4.809	65.95
Aquaculture area	0.226	0.43	0.226	0.43	0.000	0.00	0.000	0.00
Idle land	3.341	6.32	2.883	5.45	0.041	0.57	0.041	0.57
Evergreen forest	5.478	10.36	4.709	8.90	2.098	28.77	1.918	26.30
Mangrove forest	1.147	2.17	1.026	1.94	0.000	0.00	0.000	0.00
Scrub	2.773	5.24	2.606	4.93	0.064	0.87	0.064	0.87
Water body	0.813	1.54	0.826	1.56	0.050	0.69	0.056	0.76
Miscellaneous land	0.392	0.74	0.400	0.76	0.096	1.31	0.091	1.24
Total	52.894	100.00	52.894	100.00	7.291	100.00	7.291	100.00

Table 5.38 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Sam Liam NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	1.062	5.72	1.653	8.91	0.000	0.00	0.003	0.08
Field crop and horticulture	0.033	0.18	0.025	0.13	0.003	0.10	0.003	0.10
Orchard and perennial trees	8.902	47.96	8.731	47.04	2.700	88.63	2.698	88.55
Aquaculture area	1.562	8.41	1.444	7.78	0.014	0.47	0.014	0.47
Idle land	0.702	3.78	0.527	2.84	0.014	0.47	0.014	0.47
Evergreen forest	0.538	2.90	0.508	2.73	0.240	7.88	0.238	7.82
Mangrove forest	3.745	20.18	3.721	20.05	0.025	0.82	0.025	0.82
Scrub	0.608	3.28	0.498	2.68	0.044	1.46	0.041	1.35
Water body	0.463	2.50	0.463	2.50	0.001	0.02	0.001	0.02
Miscellaneous land	0.947	5.10	0.992	5.34	0.004	0.14	0.009	0.31
Total	18.561	100.00	18.561	100.00	3.046	100.00	3.046	100.00

Table 5.39 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Kamala NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	36.396	26.48	47.954	34.88	2.661	5.61	3.701	7.80
Paddy field	0.554	0.40	0.291	0.21	0.000	0.00	0.000	0.00
Field crop and horticulture	0.128	0.09	0.053	0.04	0.000	0.00	0.000	0.00
Orchard and perennial trees	45.896	33.39	42.248	30.73	20.257	42.69	20.707	43.64
Aquaculture area	0.336	0.24	0.254	0.18	0.000	0.00	0.000	0.00
Idle land	10.684	7.77	7.182	5.22	1.453	3.06	1.522	3.21
Evergreen forest	29.731	21.63	26.806	19.50	21.393	45.09	19.713	41.55
Mangrove forest	0.123	0.09	0.168	0.12	0.000	0.00	0.000	0.00
Scrub	7.917	5.76	6.480	4.71	1.529	3.22	1.645	3.47
Water body	4.104	2.99	4.149	3.02	0.084	0.18	0.081	0.17
Miscellaneous land	1.594	1.16	1.879	1.37	0.072	0.15	0.080	0.17
Total	137.464	100.00	137.464	100.00	47.448	100.00	47.448	100.00

Table 5.40 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Nak Keod NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km²	%	km²	%	km²	%	km²	%
Urban and built-up area	39.651	35.05	50.566	44.70	2.976	7.93	4.372	11.64
Field crop and horticulture	0.151	0.13	0.076	0.07	0.019	0.05	0.019	0.05
Orchard and perennial trees	30.742	27.17	26.569	23.49	16.264	43.31	16.058	42.76
Aquaculture area	0.008	0.01	0.006	0.00	0.007	0.02	0.006	0.01
Idle land	6.093	5.39	3.748	3.31	0.963	2.56	0.852	2.27
Evergreen forest	26.119	23.09	22.739	20.10	15.170	40.40	14.018	37.33
Scrub	6.149	5.44	5.004	4.42	1.948	5.19	1.938	5.16
Water body	2.461	2.18	2.216	1.96	0.156	0.42	0.139	0.37
Miscellaneous land	1.758	1.55	2.208	1.95	0.048	0.13	0.150	0.40
Total	113.131	100.00	113.131	100.00	37.550	100.00	37.550	100.00

Table 5.41 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khao Tosae NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km²	%	km²	%	km²	%	km²	%
Urban and built-up area	17.049	59.64	19.247	67.33	0.027	2.86	0.031	3.33
Orchard and perennial trees	1.807	6.32	1.259	4.41	0.031	3.33	0.029	3.13
Aquaculture area	0.289	1.01	0.251	0.88	0.000	0.00	0.000	0.00
Idle land	0.898	3.14	0.448	1.57	0.000	0.00	0.000	0.00
Evergreen forest	2.549	8.92	2.294	8.03	0.880	93.80	0.878	93.54
Mangrove forest	2.501	8.75	2.351	8.22	0.000	0.00	0.000	0.00
Scrub	1.935	6.77	1.253	4.38	0.000	0.00	0.000	0.00
Water body	1.314	4.60	1.216	4.25	0.000	0.00	0.000	0.00
Miscellaneous land	0.245	0.86	0.268	0.94	0.000	0.00	0.000	0.00
Total	28.588	100.00	28.588	100.00	0.938	100.00	0.938	100.00

Table 5.42 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong U-Tapao NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	1.969	9.07	2.787	12.83	0.113	4.53	0.133	5.31
Paddy field	0.044	0.20	0.022	0.10	0.000	0.00	0.000	0.00
Field crop and horticulture	0.458	2.11	0.450	2.07	0.000	0.00	0.000	0.00
Orchard and perennial trees	11.967	55.10	11.473	52.82	0.163	6.51	0.156	6.26
Aquaculture area	0.387	1.78	0.364	1.68	0.142	5.69	0.141	5.64
Idle land	0.779	3.59	0.674	3.11	0.069	2.78	0.071	2.83
Evergreen forest	0.014	0.06	0.014	0.06	0.000	0.00	0.000	0.00
Mangrove forest	2.799	12.89	2.784	12.82	1.871	74.97	1.858	74.45
Scrub	2.043	9.40	1.878	8.64	0.059	2.38	0.059	2.38
Water body	0.971	4.47	0.993	4.57	0.078	3.13	0.078	3.13
Miscellaneous land	0.288	1.32	0.280	1.29	0.000	0.00	0.000	0.00
Total	21.718	100.00	21.718	100.00	2.495	100.00	2.495	100.00

Table 5.43 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong Tha Maphrao NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	5.604	13.18	6.908	16.24	0.046	1.28	0.113	3.15
Field crop and horticulture	0.041	0.10	0.028	0.06	0.000	0.00	0.000	0.00
Orchard and perennial trees	22.622	53.19	22.055	51.86	0.128	3.57	0.122	3.41
Aquaculture area	1.153	2.71	1.250	2.94	0.264	7.40	0.294	8.24
Idle land	1.383	3.25	0.898	2.11	0.083	2.33	0.044	1.24
Evergreen forest	2.762	6.49	2.521	5.93	0.000	0.00	0.000	0.00
Mangrove forest	3.967	9.33	3.743	8.80	2.508	70.19	2.452	68.62
Scrub	2.852	6.71	2.726	6.41	0.228	6.38	0.228	6.38
Water body	1.808	4.25	1.814	4.27	0.288	8.06	0.292	8.17
Miscellaneous land	0.338	0.79	0.587	1.38	0.028	0.79	0.028	0.79
Total	42.528	100.00	42.528	100.00	3.573	100.00	3.573	100.00

Table 5.44 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong Para NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	2.734	6.80	4.174	10.37	0.196	5.81	0.337	10.01
Field crop and horticulture	0.053	0.13	0.048	0.12	0.000	0.00	0.000	0.00
Orchard and perennial trees	19.264	47.89	18.381	45.69	0.215	6.39	0.193	5.72
Aquaculture area	2.461	6.12	2.394	5.95	0.646	19.19	0.619	18.39
Idle land	1.608	4.00	1.442	3.58	0.026	0.78	0.002	0.06
Evergreen forest	4.781	11.88	4.753	11.81	0.000	0.00	0.000	0.00
Mangrove forest	7.291	18.12	7.182	17.85	1.964	58.38	1.925	57.21
Scrub	0.685	1.70	0.454	1.13	0.028	0.84	0.000	0.00
Water body	1.289	3.21	1.299	3.23	0.290	8.62	0.290	8.62
Miscellaneous land	0.065	0.16	0.104	0.26	0.000	0.00	0.000	0.00
Total	40.230	100.00	40.230	100.00	3.365	100.00	3.365	100.00

Table 5.45 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong Bangrong NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	3.013	7.97	4.404	11.64	0.039	0.84	0.143	3.06
Paddy field	0.058	0.15	0.008	0.02	0.000	0.00	0.000	0.00
Field crop and horticulture	0.055	0.15	0.028	0.07	0.000	0.00	0.000	0.00
Orchard and perennial trees	17.763	46.96	17.164	45.37	0.411	8.81	0.338	7.24
Aquaculture area	2.629	6.95	2.519	6.66	0.806	17.28	0.798	17.11
Idle land	1.629	4.31	1.280	3.38	0.106	2.28	0.099	2.12
Evergreen forest	3.663	9.68	3.595	9.50	0.000	0.00	0.000	0.00
Mangrove forest	6.043	15.98	6.006	15.88	3.150	67.57	3.141	67.37
Scrub	1.197	3.16	0.997	2.64	0.035	0.75	0.030	0.64
Water body	0.846	2.24	0.848	2.24	0.109	2.33	0.109	2.33
Miscellaneous land	0.932	2.46	0.980	2.59	0.006	0.13	0.006	0.13
Total	37.828	100.00	37.828	100.00	4.662	100.00	4.662	100.00

Table 5.46 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong Tarau NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	8.534	22.39	11.923	31.28	0.046	0.94	0.057	1.18
Paddy field	0.158	0.41	0.075	0.20	0.000	0.00	0.000	0.00
Field crop and horticulture	0.097	0.25	0.029	0.08	0.001	0.03	0.001	0.03
Orchard and perennial trees	15.673	41.11	14.291	37.49	0.039	0.82	0.039	0.82
Aquaculture area	2.293	6.02	1.971	5.17	1.185	24.54	1.107	22.92
Idle land	3.823	10.03	2.786	7.31	0.253	5.24	0.270	5.59
Evergreen forest	0.658	1.73	0.448	1.18	0.000	0.00	0.000	0.00
Mangrove forest	4.356	11.43	4.431	11.62	2.839	58.80	2.885	59.75
Scrub	0.919	2.41	0.753	1.98	0.043	0.88	0.028	0.58
Water body	1.450	3.80	1.277	3.35	0.423	8.75	0.441	9.14
Miscellaneous land	0.162	0.42	0.139	0.37	0.000	0.00	0.000	0.00
Total	38.123	100.00	38.123	100.00	4.829	100.00	4.829	100.00

Table 5.47 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong Tajin NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	14.837	43.21	17.642	51.37	1.521	24.90	1.873	30.66
Field crop and horticulture	0.021	0.06	0.006	0.02	0.000	0.00	0.000	0.00
Orchard and perennial trees	4.185	12.19	3.383	9.85	0.081	1.33	0.024	0.39
Aquaculture area	0.828	2.41	0.752	2.19	0.251	4.11	0.237	3.88
Idle land	1.162	3.38	0.547	1.59	0.169	2.77	0.143	2.33
Evergreen forest	4.380	12.75	3.998	11.64	0.063	1.03	0.063	1.02
Mangrove forest	4.134	12.04	3.866	11.26	3.506	57.38	3.325	54.42
Scrub	2.528	7.36	1.913	5.57	0.178	2.91	0.086	1.40
Water body	1.489	4.34	1.414	4.12	0.322	5.27	0.333	5.44
Miscellaneous land	0.777	2.26	0.821	2.39	0.018	0.30	0.028	0.45
Total	34.341	100.00	34.341	100.00	6.109	100.00	6.109	100.00

Table 5.48 Comparison of area and its percentage of existing LULC in 2014 and predicted LULC in 2026 of Khlong Khopee NRF.

LULC	Boundary and buffer zone				Within boundary			
	2014		2026		2014		2026	
	km^2	%	km^2	%	km^2	%	km^2	%
Urban and built-up area	19.814	58.14	22.146	64.98	0.975	24.66	1.138	28.77
Field crop and horticulture	0.106	0.31	0.091	0.27	0.000	0.00	0.000	0.00
Orchard and perennial trees	4.428	12.99	3.611	10.59	0.028	0.71	0.021	0.54
Aquaculture area	0.662	1.94	0.399	1.17	0.097	2.45	0.046	1.15
Idle land	1.459	4.28	0.964	2.83	0.144	3.65	0.111	2.80
Evergreen forest	1.867	5.48	1.642	4.82	0.000	0.00	0.000	0.00
Mangrove forest	3.477	10.20	3.364	9.87	2.572	65.05	2.510	63.48
Scrub	1.194	3.50	0.901	2.64	0.043	1.07	0.029	0.73
Water body	0.930	2.73	0.833	2.44	0.080	2.02	0.078	1.96
Miscellaneous land	0.146	0.43	0.131	0.39	0.015	0.38	0.023	0.57
Total	34.082	100.00	34.082	100.00	3.954	100.00	3.954	100.00

5.3 Deforestation prediction between 2014 and 2026

According to the predicted LULC change between 2014 and 2026 of 15 protected forest areas as reported in the previous section, deforestation area of each protected forest area can be predicted and explained in detail. Figures 5.31 to 5.45 showed predicted deforestation map of each protected forest area which was extracted from LULC change between 2014 and 2026. The predicted deforested area and its percentage and annual rate of deforestation is summarized in Table 5.49. Meanwhile annual deforestation rate of 15 protected forest areas between 2014 and 2026 is comparatively presented in Figure 5.46.

Figure 5.31 Predictive deforestation area between 2014 and 2026 of Sirinath MNP.

Figure 5.32 Predictive deforestation area between 2014 and 2026 of Khao Phra Thaeo WCDEC.

Figure 5.33 Predictive deforestation area between 2014 and 2026 of Khao Mai Kaew NRF.

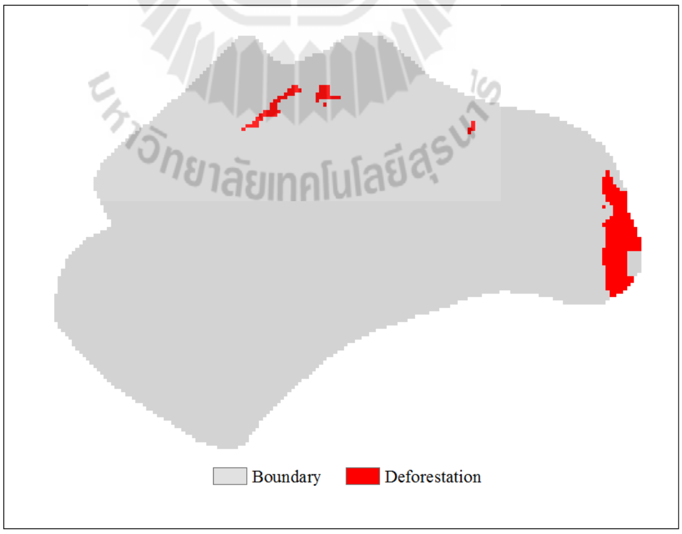


Figure 5.34 Predictive deforestation area between 2014 and 2026 of Khao Bang Khanun NRF.

Figure 5.35 Predictive deforestation area between 2014 and 2026 of Khao Sam Liam NRF.

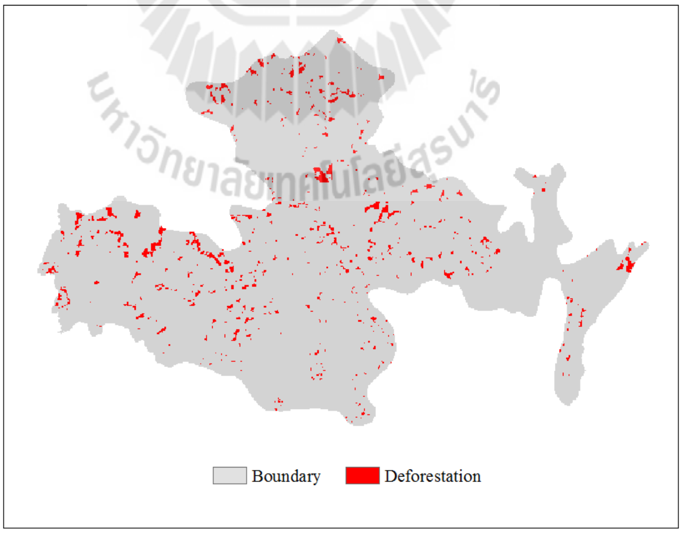


Figure 5.36 Predictive deforestation area between 2014 and 2026 of Khao Kamala NRF.

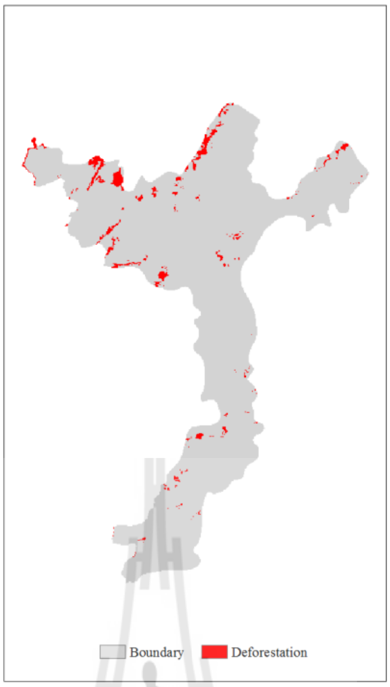


Figure 5.37 Predictive deforestation area between 2014 and 2026 of Khao Nak Keod NRF.

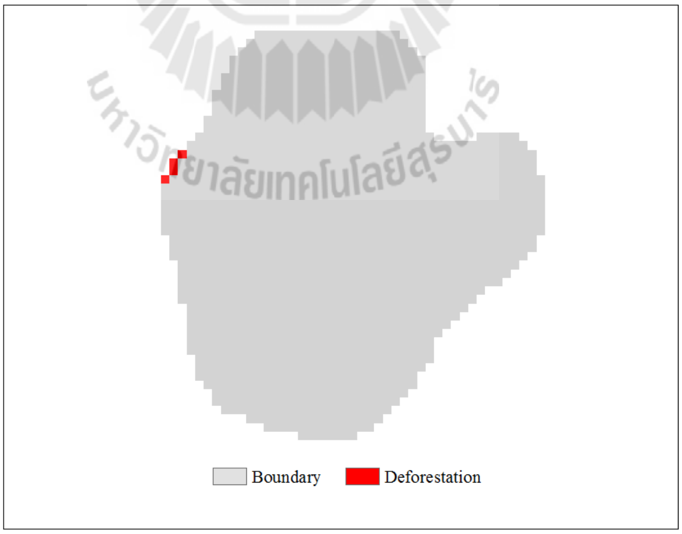


Figure 5.38 Predictive deforestation area between 2014 and 2026 of Khao Tosae NRF.

Figure 5.39 Predictive deforestation area between 2014 and 2026 of Khlong U-Tapao NRF.

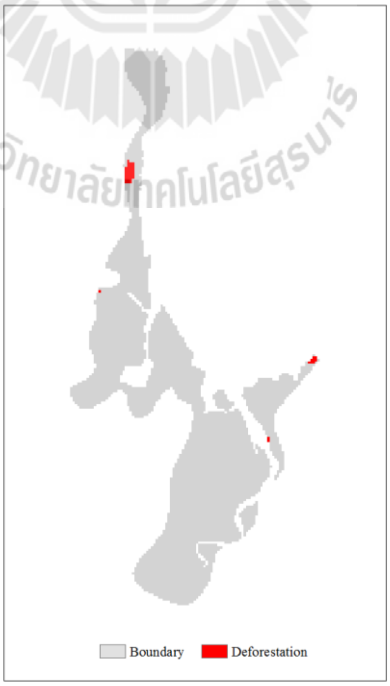


Figure 5.40 Predictive deforestation area between 2014 and 2026 of Khlong Tha Maphrao NRF.

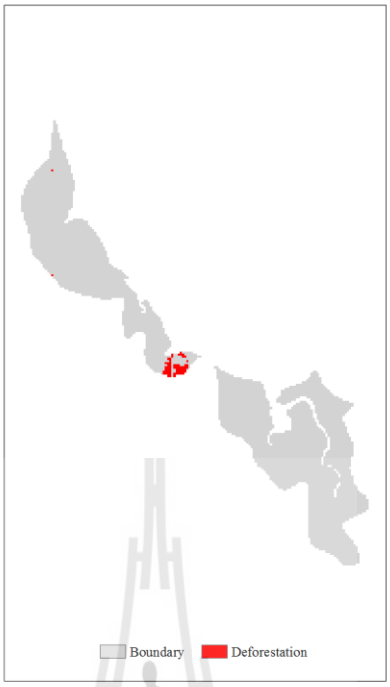


Figure 5.41 Predictive deforestation area between 2014 and 2026 of Khlong Para NRF.

Figure 5.42 Predictive deforestation area between 2014 and 2026 of Khlong Bangrong NRF.

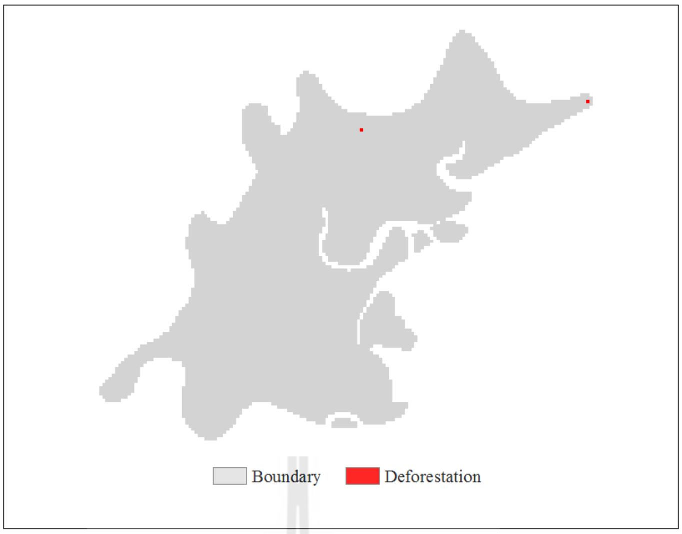


Figure 5.43 Predictive deforestation area between 2014 and 2026 of Khlong Tarau NRF.

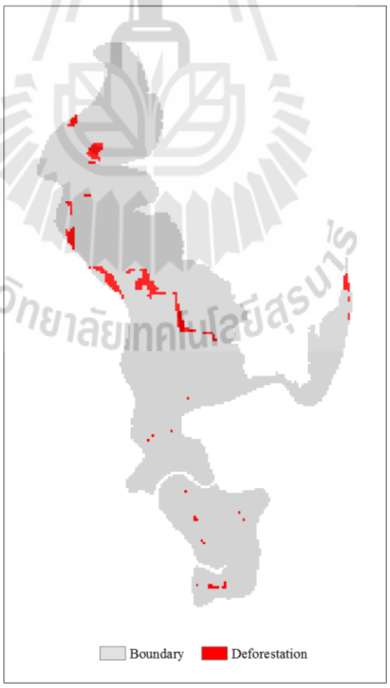


Figure 5.44 Predictive deforestation area between 2014 and 2026 of Khlong Tajin NRF.

Figure 5.45 Predictive deforestation area between 2014 and 2026 of Khlong Khopee NRF.

Table 5.49 Predictive deforestation area between 2014 and 2026 of each protected forest area.

Protected forest area	Total area (sq. km)	Forest area in 2014 (sq. km)	Deforested area		Percent of total area	Percent of forest area in 2014	Annual deforestation rate between 2014 and 2026	
			(sq. km)	(Rai)			(sq. km)	(Rai)
Sirinath MNP	21.161	3.218	0.6038	377.34	2.8534	18.7632	0.0503	31.45
Khao Phra Thaeo WCDEC	20.368	18.708	0.005	3.13	0.0245	0.0267	0.0004	0.26
Khao Mai Kaew	7.308	0.324	0.0213	13.28	0.2915	6.5741	0.0018	1.11
Khao Bang Khanun	7.291	2.098	0.18	112.5	2.4688	8.5796	0.015	9.38
Khao Sam Liam	3.046	0.265	0.0019	1.17	0.0624	0.7170	0.0002	0.10
Khao Kamala	47.448	21.393	1.68	1050	3.5407	7.8530	0.14	87.50
Khao Nak Keod	37.55	15.17	1.1525	720.31	3.0692	7.5972	0.096	60.03
Khao Tosae	0.938	0.88	0.0025	1.56	0.2665	0.2841	0.0002	0.13
Khlong U-Tapao	2.495	1.871	0.0131	8.2	0.5251	0.7002	0.0011	0.68
Khlong Tha Maphrao	3.573	2.508	0.0275	17.19	0.7697	1.0965	0.0023	1.43
Khlong Para	3.365	1.964	0.0394	24.61	1.1709	2.0061	0.0033	2.05
Khlong Bangrong	4.662	3.15	0.0094	5.86	0.2016	0.2984	0.0008	0.49
Khlong Tarau	4.829	2.839	0.0013	0.78	0.0269	0.0458	0.0001	0.07
Khlong Tajin	6.109	3.569	0.1813	113.28	2.9678	5.0799	0.0151	9.44
Khlong Khopee	3.954	2.572	0.0631	39.45	1.5959	2.4533	0.0053	3.29

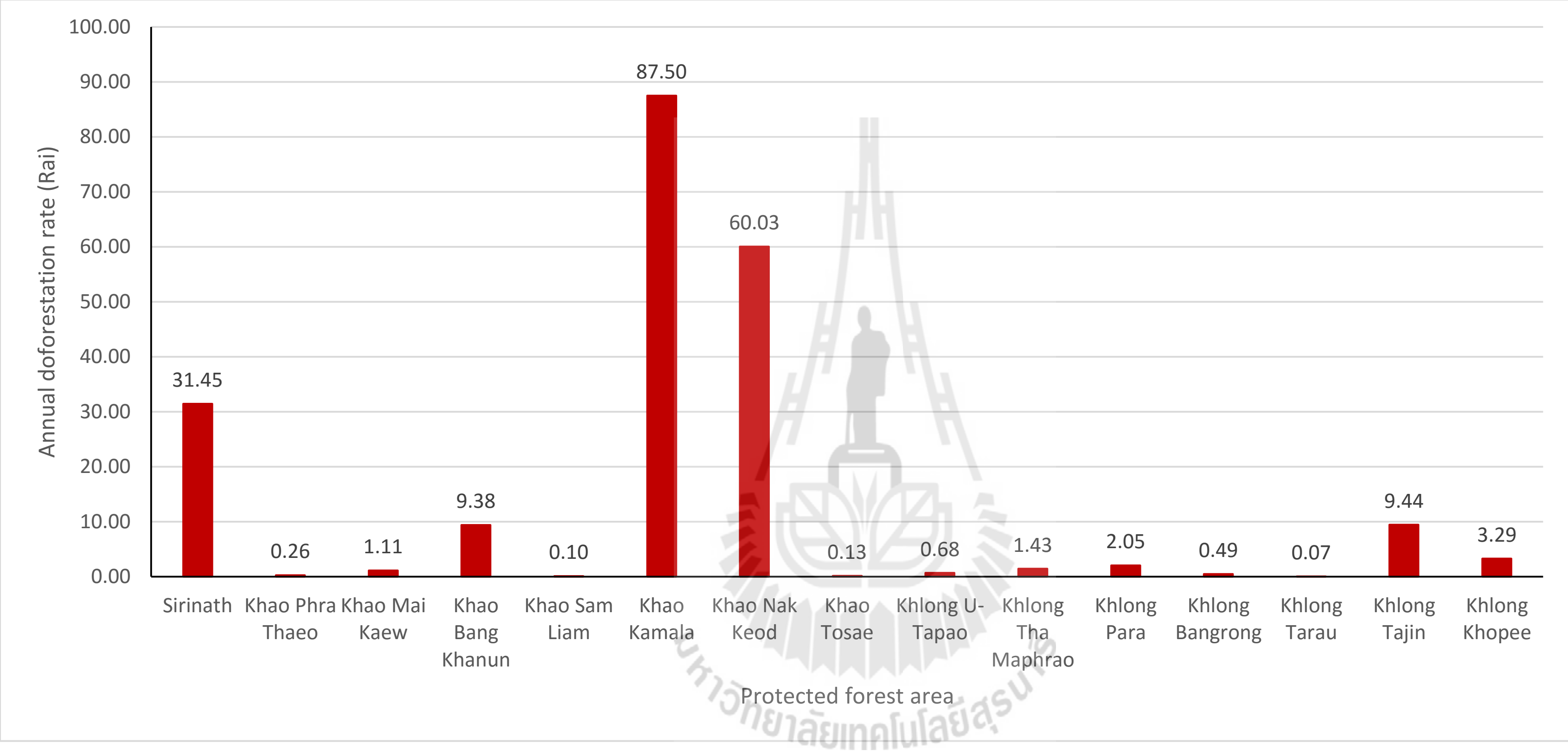


Figure 5.46 Comparison of annual predictive deforested rate of 15 protected forest areas between 2014 and 2026.

As results, it was found that annual highest deforestation rate occurred in Khao Kamala NRF with value of 0.1400 sq. km or 87.50 Rai while annual lowest deforestation rate occurred in Khong Tarau NRF with value of 0.0001 sq. km or 0.07 Rai. Meanwhile the highest percentage of deforestation from the existing forest area in 2014 was found in Sirinath MNP with value of 18.7632% and the lowest percentage of deforestation from the existing forest area in 2014 occurred in Khao Phra Thaeo WCDEC with value of 0.0267%. These results infer about deforestation vulnerability and its severity in each protected forest areas.

The characteristics of predictive deforestation in 15 protected forest areas can be elaborated in more detail according to its legal status includes national park (marine national park and wildlife conservation development and extension center) and national reserved forest area (in evergreen and mangrove forest) as below.

5.3.1 National park

Both Sirinath MNP and Khao Phra Thaeo WCDEC were established by National Park act since 1981 and 1977. It was found that annual predictive deforestation rate of Sirinath MNP with value of 0.0503 sq. km or 31.45 Rai is rather high when it is compared with Khao Phra Thaeo WCDEC with value of 0.0004 sq. km/year or 0.26 Rai/year. Likewise percent of predictive deforestation area from the existing forest area in 2014 of Sirinath MNP was 18.7632% which is very high when it is compared with Khao Phra Thaeo WCDEC with value of 0.0267%.

5.3.2 National reserved forest area in evergreen forest

Khao Mai Kaew, Khao Bang Khanun, Khao Sam Liam, Khao Kamala, Khao Nak Keod and Khao Tosae NRFs were announced by National Reserved Forest act in 1985, 1945, 1979, 1969, 1973 and 1973, respectively. It was revealed that high rate of predictive deforestation occurs in Khao Kamala and Khao Nak Keod NRFs with area of 0.1400 sq. km/year or 87.50 Rai/year and 0.0960 sq. km/year or 60.03 Rai/year, respectively. Meanwhile, the low rate of predictive deforestation occurs in Khao Sam Liam, Khao Tosae and Khao Mai Kaew with area of 0.0002 sq. km/year or 0.10 Rai/year, 0.0002 sq. km/year or 0.13 Rai/year and of 0.0018 sq. km/year or 1.11 Rai/year, respectively. The comparison of annual predictive deforestation rate of evergreen forest NRFs between 2014 and 2026 is presented in Figure 5.47.

However, the severity of deforestation based on percentage of deforestation from the existing forest area in 2014 is very high in Khao Bang Khanun, Khao Kamala and Khao Nak Keod NRFs with value of 8.5796%, 7.8530% and 7.5972%, respectively. Therefore, these areas should be frequently patrolled by forest ranger.

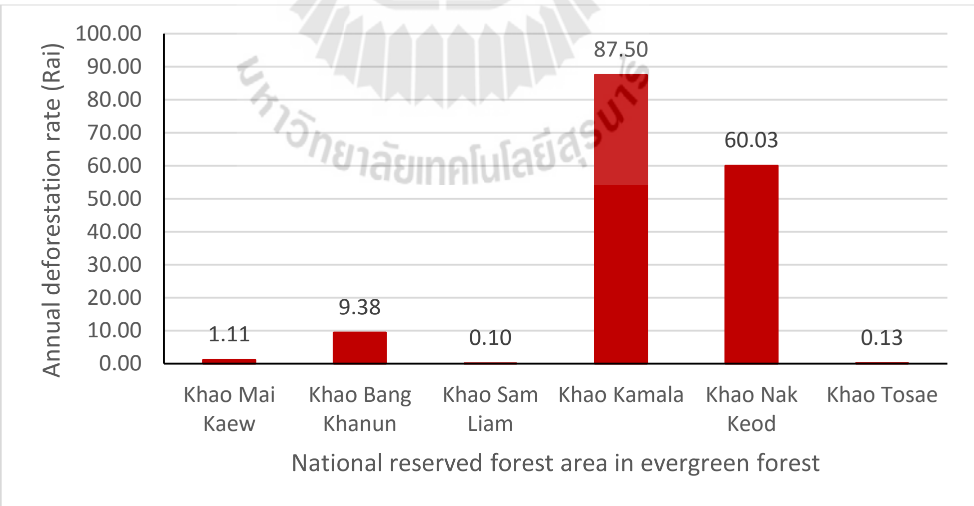


Figure 5.47 Comparison of annual predictive deforestation rate of evergreen forest NRF between 2014 and 2026.

5.3.3 National reserved forest area in mangrove forest

Khlong U-Tapao NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, Khlong Bangrong NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee NRF were announced by National Reserved Forest act in 1964, 1963, 1963, 1968, 1964, 1958 and 1962, respectively. It was revealed that high rate of predictive deforestation occurs in Khlong Tajin NRF with area of 0.0011 sq. km/year or 0.68 Rai/year while moderate deforestation rate of predictive LULC occurs in Khlong Tha Maphrao NRF, Khlong Para NRF, and Khlong Khopee NRF and low deforestation rate occurs Khlong U-Tapao NRF, Khlong Bangrong NRF, and Khlong Tarau NRF. The comparison of annual predictive deforestation rate of mangrove forest NRF between 2014 and 2026 is presented in Figure 5.48. As results, the high severity of deforestation based on percentage of deforestation from the existing forest area in 2014 is also Khlong Tajin NRF with value of 5.0799%. Therefore, mangrove forest NRF with high risk of deforestation in the future is Khlong Tajin NRF.

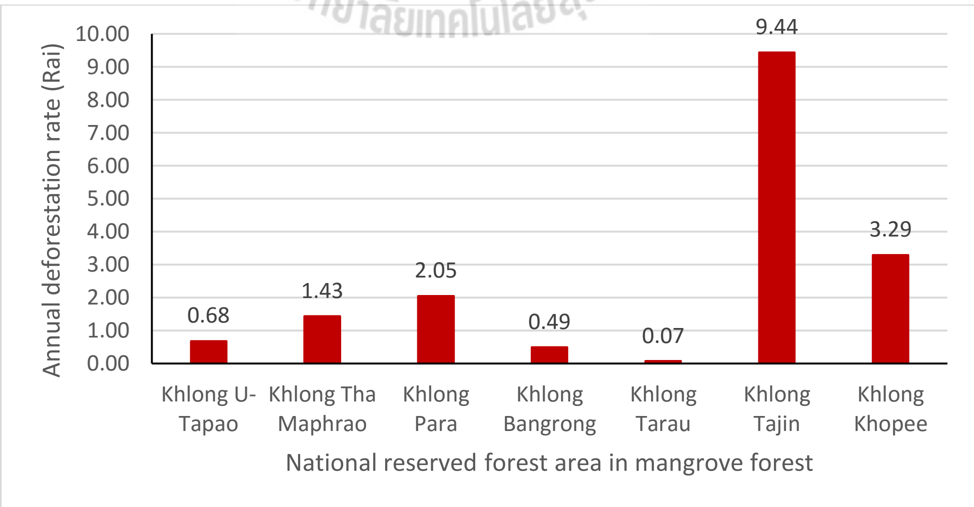


Figure 5.48 Comparison of annual predictive deforested rate of national reserved forest area in mangrove forest between 2014 and 2026.

Furthermore, it can be observed that annual predictive deforestation rate of Sirinath MNP, Khao Mai Kaew NRF, Khao Kamala NRF, Khao Tosae NRF, and Khlong U-Tapao NRF between 2014 and 2026 is higher than actual annual deforestation rate occurring during 1995 and 2014. On the contrary, actual annual deforestation rate between 1995 and 2014 of Khao Phra Thaeo WCDEC, Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Nak Keod NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, Khlong Bangrong NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee NRF tend to decrease between 2014 and 2026. Comparison of actual and predictive deforestation rate of each protected forest area with gain and loss is presented in detail in Table 5.50.

Table 5.50 Comparison of actual and predictive deforestation rate of each protected forest area.

No	Protected forest area	Annual deforestation rate (sq. km)			Remark
		1995-2014	2014-2026	Change	
1	Sirinath MNP	0.0172	0.0503	0.0331	Loss
2	Khao Phra Thaeo WCDEC	0.0108	0.0004	-0.0104	Gain
3	Khao Mai Kaew NRF	0.0012	0.0018	0.0006	Loss
4	Khao Bang Khanun NRF	0.0895	0.015	-0.0745	Gain
5	Khao Sam Liam NRF	0.0004	0.0002	-0.0002	Gain
6	Khao Kamala NRF	0.1278	0.14	0.0122	Loss
7	Khao Nak Keod NRF	0.2082	0.096	-0.1122	Gain
8	Khao Tosae NRF	0.0001	0.0002	0.0001	Loss
9	Khlong U-Tapao NRF	0.0004	0.0011	0.0007	Loss
10	Khlong Tha Maphrao NRF	0.0051	0.0023	-0.0028	Gain
11	Khlong Para NRF	0.0143	0.0033	-0.011	Gain
12	Khlong Bangrong NRF	0.0069	0.0008	-0.0061	Gain
13	Khlong Tarau NRF	0.0013	0.0001	-0.0012	Gain
14	Khlong Tajin NRF	0.0177	0.0151	-0.0026	Gain
15	Khlong Khopee NRF	0.0161	0.0053	-0.0108	Gain

CHAPTER VI

DEFORESTATION VULNERABILITY ANALYSIS

An optimum geospatial method for deforestation vulnerability analysis, deforestation vulnerability analysis and zonation, and forest area in 2014 and deforestation vulnerability zonation were here explained and discussed.

6.1 Optimum geospatial method for deforestation vulnerability analysis

Two geospatial method for deforestation vulnerability analysis included Frequency Ratio (FR) and Logistic Regression Analysis (LRA) were here used to create deforestation vulnerability index based on driving factors on deforestation (see Table 1.2) and deforested area between 1995 and 2002. Number of protected forest area as frequency with high probability of deforestation occurrence (frequency ratio more than 1.0) by class of driving factor is summarized in Table 6.1. In principle, the frequency ratio for specific classes of each factors are above 1 indicating very high probability of deforestation occurrence. In contrast, frequency ratios for other classes of factors are below 1, indicating a low probability of deforestation occurrence.

As results, deforestation with high probability in protected forest area is frequently occurs at elevation of 0-100 m, at slope of 16-35% or 35-60%, with moderate soil fertility and distance from road, settlement and water body between 0 and 500 m.

Meanwhile, socio-economic factors include number of population and average income on deforestation with high probability which are represented at sub-district level, are directly related with protected forest area location.

At the same time, the derived multiple linear equation of LRA of each protected forest area is also summarized in Table 6.2. As results it was found that top three dominant driving factors on deforestation among 15 protected forest areas are soil fertility (X_3), distance from road (X_4), and elevation (X_1).

Table 6.1 Summary of frequency ratio with high probability of deforestation occurrence of each protected forest area based on driving factors on deforestation and deforested area between 1995 and 2002.

Deforestation factor and classes	Protected forest area															Frequency
	SN	PT	MK	BK	SL	KL	NK	TS	UT	TM	PR	BR	TR	TJ	KP	
Elevation																
0-100 m	0.59	1.31	1.04	0.63	1.09	1.09	0.60	1.02	1.00	1.06	1.13	1.14	1.07	1.03	1.03	12 of 15
100-200 m	4.45	0.00	0.00	3.90	0.00	0.94	1.51	0.49	0.00	0.10	0.00	0.00	0.00	0.00	0.20	3 of 15
200-300 m	0.00	0.00	0.00	0.00	0.00	1.30	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2 of 15
300-400 m	0.00	0.00	0.00	0.00	0.00	0.23	2.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Slope																
0-8%	0.23	1.86	1.69	0.32	0.23	0.49	0.28	0.72	0.60	1.69	1.78	1.67	1.18	0.93	0.81	6 of 15
8-16%	1.27	0.60	0.00	1.27	0.85	1.08	1.05	0.85	3.77	0.35	0.49	0.88	1.48	1.06	0.92	7 of 15
16-35%	1.93	0.23	0.00	1.63	1.77	1.54	1.61	2.11	0.00	0.21	0.10	0.18	0.34	1.23	1.74	8 of 15
35-60%	2.54	0.11	0.00	2.14	2.23	1.30	1.49	2.76	0.00	0.08	0.00	0.09	0.00	1.07	2.03	8 of 15
> 60%	2.14	0.22	0.00	1.47	2.79	1.05	1.41	1.10	0.00	0.34	0.00	0.00	0.00	0.00	1.52	6 of 15
Soil fertility																
Low	0.34	1.52	1.08	0.46	0.16	0.67	0.25	0.70	1.01	1.12	1.29	1.26	1.16	0.71	0.90	7 of 15
Moderate	3.63	0.21	0.00	3.13	3.87	1.34	1.71	2.58	0.00	0.19	0.07	0.13	0.29	2.13	1.35	8 of 15
Distance from road																
0-500 m	1.05	1.11	1.02	1.06	1.05	1.17	0.99	1.10	1.03	0.88	1.03	1.10	1.21	1.10	1.06	13 of 15
500-1000 m	0.69	0.86	0.00	0.53	0.66	0.12	1.23	0.27	0.00	2.73	0.89	0.48	0.00	0.37	0.23	2 of 15
Distance from settlement																
0-500 m	0.17	1.54	0.55	0.07	1.52	1.15	0.54	1.04	0.00	1.32	1.82	1.28	1.40	1.07	1.03	10 of 15
500-1000 m	0.89	0.79	2.53	0.89	0.34	1.11	1.56	0.00	2.49	0.31	0.35	1.07	0.65	0.23	0.61	4 of 15
1000-1500 m	3.22	0.21	0.00	3.16	0.00	0.68	1.91	0.00	0.00	0.78	0.00	0.08	0.00	0.00	0.00	3 of 15
1500-2000 m	13.78	0.00	0.00	10.89	4.25	0.24	3.84	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	5 of 15
> 2000 m	27.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15

Table 6.1 (Continued).

Deforestation factor and classes	Protected forest area															Frequency
	SN	PT	MK	BK	SL	KL	NK	TS	UT	TM	PR	BR	TR	TJ	KP	
Distance from water bodies																
0-500	0.17	1.83	1.61	0.21	1.78	0.69	0.67	1.12	1.44	1.81	1.63	1.40	1.29	1.20	1.00	11 of 15
500-1000	1.77	0.37	0.00	1.12	0.00	1.19	1.13	0.63	0.00	0.15	0.05	0.74	0.46	0.33	0.98	4 of 15
1000-1500	4.80	0.00	0.00	3.37	0.00	1.34	1.29	0.00	0.00	0.06	0.00	0.00	0.00	1.52	1.49	6 of 15
1500-2000	2.41	0.00	0.00	0.84	0.46	0.15	2.32	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	6 of 15
> 2000	0.00	0.00	0.00	0.00	0.53	4.54	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Population density (person/sq.km)																
Sakhu (88)	1.50	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	2 of 15
Karon (169)	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Kamala (229)	0.00	0.00	0.00	0.00	0.00	1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Pa Khlok (317)	0.00	0.88	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.48	1.00	2.22	0.00	0.00	2 of 15
Thep Kasattri (335)	2.54	1.23	0.00	1.04	0.00	0.00	0.00	0.00	0.00	1.87	2.05	0.00	0.00	0.00	0.00	5 of 15
Ko Keao (365)	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0 of 15
Mai Khao (547)	0.01	0.00	1.19	0.00	0.00	0.00	0.00	0.00	1.00	0.06	0.00	0.00	0.00	0.00	0.00	2 of 15
Rawai (729)	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Kathu (819)	0.00	0.00	0.00	0.00	0.00	1.20	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Choeng Thale (878)	0.39	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Si Sunthon (1036)	0.00	0.58	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Talat Nuea (1083)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	1.72	2 of 15
Talat Yai (1840)	0.00	0.00	0.00	0.00	0.00	3.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.28	1 of 15
Rutsada (1849)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	1.36	0.00	1 of 15
Wichit (1944)	0.00	0.00	0.00	0.00	0.00	3.08	0.16	3.43	0.00	0.00	0.00	0.00	0.00	0.00	1.06	3 of 15
Pa Tong (2542)	0.00	0.00	0.00	0.00	0.00	2.94	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2 of 15
Chalong (4112)	0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	1 of 15

Table 6.1 (Continued).

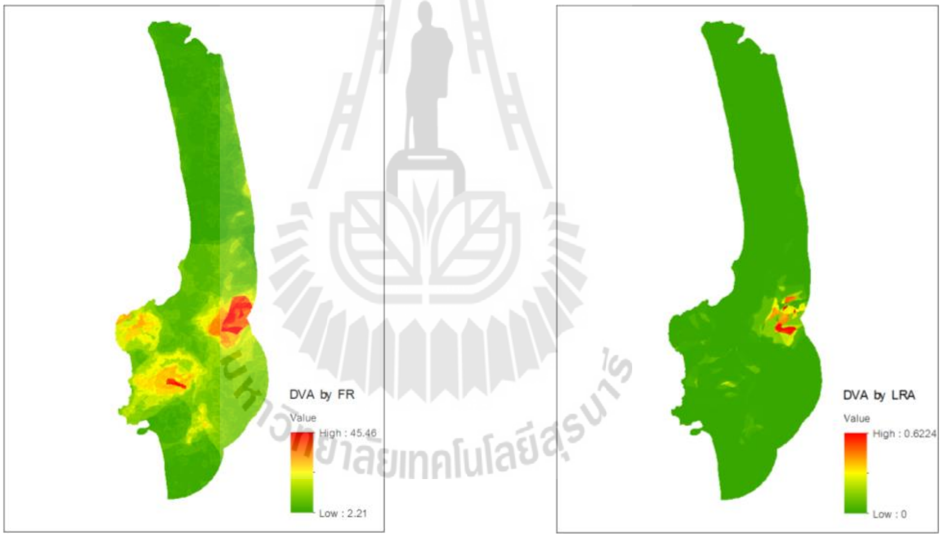
Deforestation factor and classes	Protected forest area															Frequency
	SN	PT	MK	BK	SL	KL	NK	TS	UT	TM	PR	BR	TR	TJ	KP	
Average income (Baht/person)																
Rutsada (51115)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	1.36	0.00	1 of 15
Pa Khlok (69313)	0.00	0.88	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.48	1.00	2.22	0.00	0.00	3 of 15
Si Sunthon (80166)	0.00	0.58	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Ko Keao (87056)	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0 of 15
Thep Kasattri (93391)	2.54	1.23	0.00	1.04	0.00	0.00	0.00	0.00	0.00	1.87	2.05	0.00	0.00	0.00	0.00	5 of 15
Kamala (98329)	0.00	0.00	0.00	0.00	0.00	1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Kathu (106462)	0.00	0.00	0.00	0.00	0.00	1.20	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Sakhu (106940)	1.50	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	2 of 15
Choeng Thale (108398)	0.39	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Pa Tong (114955)	0.00	0.00	0.00	0.00	0.00	2.94	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2 of 15
Mai Khao (116365)	0.01	0.00	1.19	0.00	0.00	0.00	0.00	0.00	1.00	0.06	0.00	0.00	0.00	0.00	0.00	2 of 15
Talat Nuea (119459)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	1.72	1 of 15
Karon (121046)	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Talat Yai (122531)	0.00	0.00	0.00	0.00	0.00	3.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.28	1 of 15
Rawai (136128)	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Wichit (142743)	0.00	0.00	0.00	0.00	0.00	3.08	0.16	3.43	0.00	0.00	0.00	0.00	0.00	0.00	1.06	3 of 15
Chalong (146772)	0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	1 of 15

Table 6.2 Summary of multiple linear equation of LRA of each protected forest area based on driving factors on deforestation and deforested area between 1995 and 2002.

Protected forest area	Constant	Coefficient								ROC
		X_1	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**	**X_7**	**X_8**	
Sirinath MNP	-8.031	-0.100	0.066	**1.578**	**-2.486**	**1.361**	0.590	-0.224	0.153	0.973
Khao Phra Thaeo WCDEC	-6.091	0.166	**-0.467**	-0.309	**1.070**	-0.247	**-1.065**	0.158	0.441	0.779
Khao Mai Kaew NRF	-20.600	**18.693**	-15.304	**-17.716**	-15.372	1.114	**-18.763**	0.839	4.769	0.983
Khao Bang Khanun NRF	-7.577	0.145	0.009	**0.619**	**-2.172**	**1.675**	0.399	-0.267	0.221	0.954
Khao Sam Liam NRF	-20.140	**-14.749**	-0.431	-0.476	-0.891	-0.167	-0.372	**7.201**	**2.059**	0.901
Khao Kamala NRF	-7.931	**-0.818**	0.137	**1.154**	**-0.975**	-0.014	0.535	0.106	0.124	0.855
Khao Nak Keod NRF	-8.065	-0.150	0.018	**2.027**	**-0.444**	**0.459**	-0.031	-0.015	0.060	0.874
Khao Tosae NRF	-8.344	**-0.898**	0.250	**1.239**	-0.854	-0.528	**-1.323**	0.410	0.026	0.781
Khlong U-Tapao NRF	-20.723	-1.672	0.548	-4.389	**-16.949**	1.721	**-17.082**	**7.000**	0.000	0.956
Khlong Tha Maphrao NRF	-7.585	**2.599**	-0.692	**1.945**	0.951	-0.699	**-2.001**	1.243	-0.824	0.897
Khlong Para NRF	-376,812.003	**-12.653**	-1.009	-0.588	0.085	-1.593	-2.945	**113,047.745**	**-37,682.112**	0.943
Khlong Bangrong NRF	-20.306	**-14.868**	-0.751	**-1.258**	-0.786	-0.078	-0.451	**8.442**	0.313	0.870
Khlong Tarau NRF	-8.127	**1.601**	-0.254	**1.144**	**1.191**	-0.940	-0.222	-0.232	-0.057	0.852
Khlong Tajin NRF	-9.444	-0.055	-0.221	**1.794**	**-1.076**	0.335	**-1.357**	0.392	-0.207	0.894
Khlong Khopee NRF	-7.368	-0.290	**0.353**	**0.431**	**-0.451**	0.181	-0.335	0.292	-0.068	0.785
Frequency		**8 of 15**	**2 of 15**	**11 of 15**	**9 of 15**	**3 of 15**	**6 of 15**	**4 of 15**	**2 of 15**	

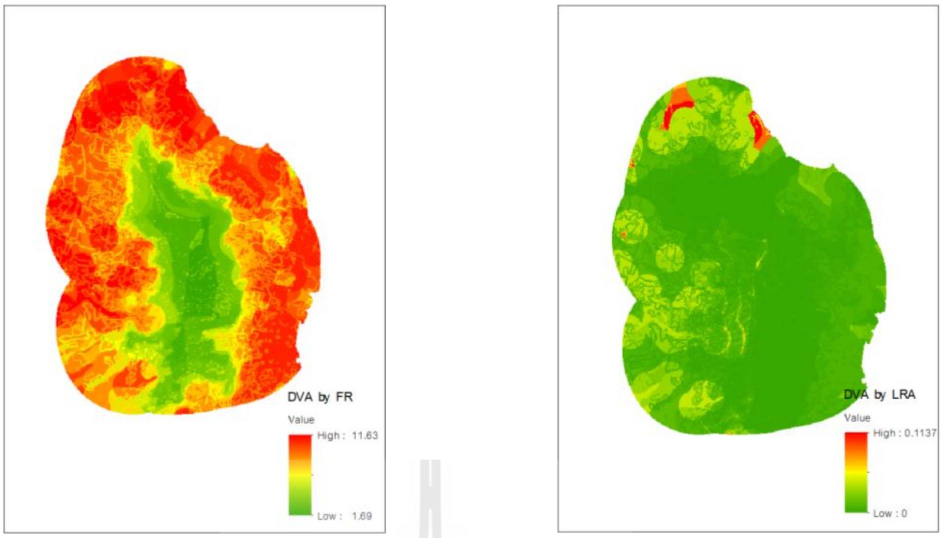
Note: X_1: Elevation; X_2: Slope; X_3: Soil fertility; X_4: Distance from road; X_5: Distance from settlement; X_6: Distance from water bodies; X_7: Population density; and X_8: Average income.

Results of deforestation vulnerability index from FR and LRA methods based on deforestation area between 1995 and 2002 of 15 protected forest areas is presented in Figures 6.1 to 6.15. Results show similar and dissimilar pattern of deforestation vulnerability index of two methods. The minimum and maximum value of deforestation vulnerability index using two methods is presented in Table 6.3. These derived results were reclassified by natural break method into 5 deforestation vulnerability zones: very low, low, moderate, high and very high for accuracy assessment by ROC and correctness by proportional weighting method as shown a result in Table 6.4.



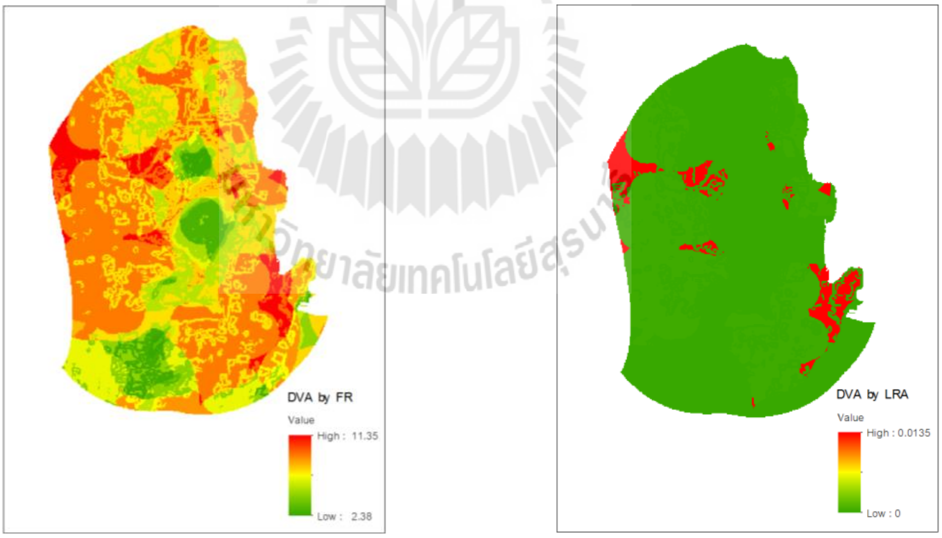
Frequency Ratio Logistic regression analysis

Figure 6.1 Distribution of deforestation vulnerability index of Sirinath MNP.



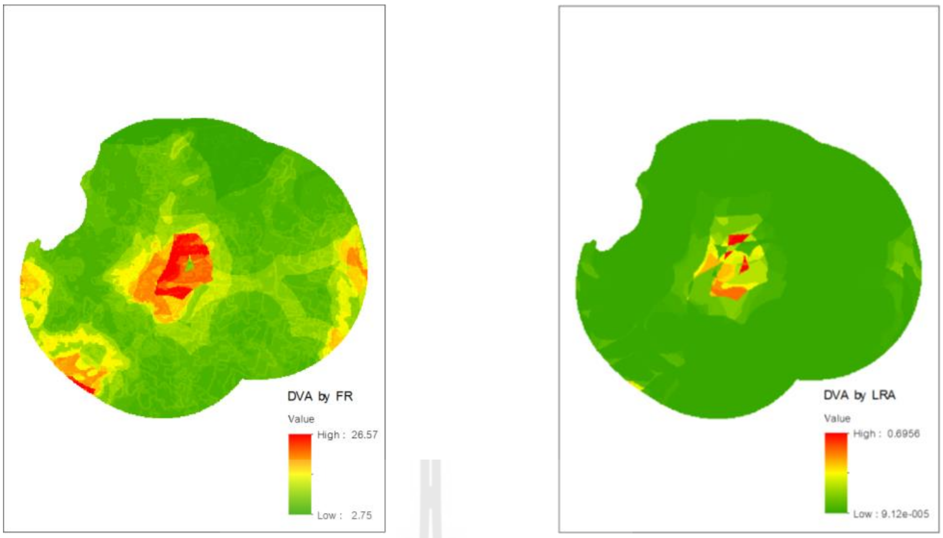
Frequency Ratio Logistic regression analysis

Figure 6.2 Distribution of deforestation vulnerability index of Khao Phra Thaeo WCDEC.



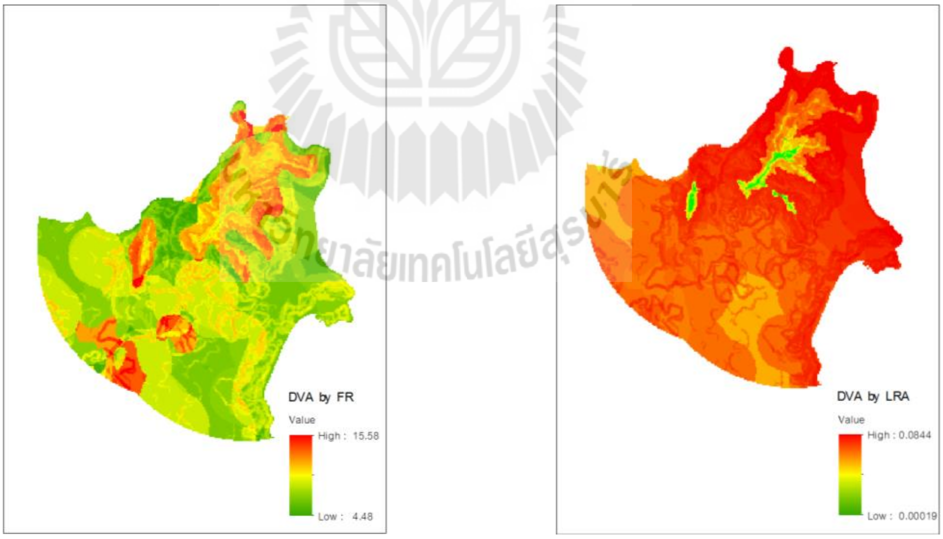
Frequency Ratio Logistic regression analysis

Figure 6.3 Distribution of deforestation vulnerability index of Khao Mai Kaew NRF.



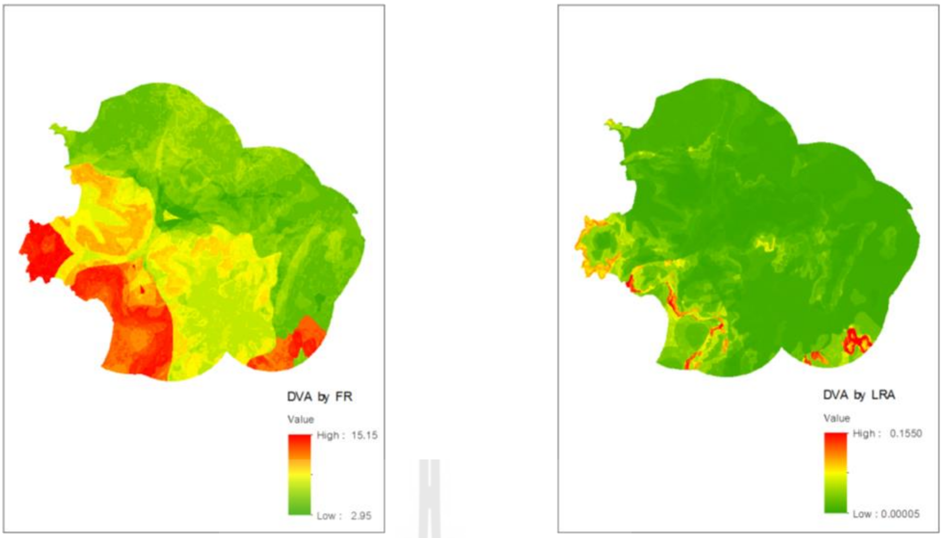
Frequency Ratio Logistic regression analysis

Figure 6.4 Distribution of deforestation vulnerability index of Khao Bang Khanun NRF.



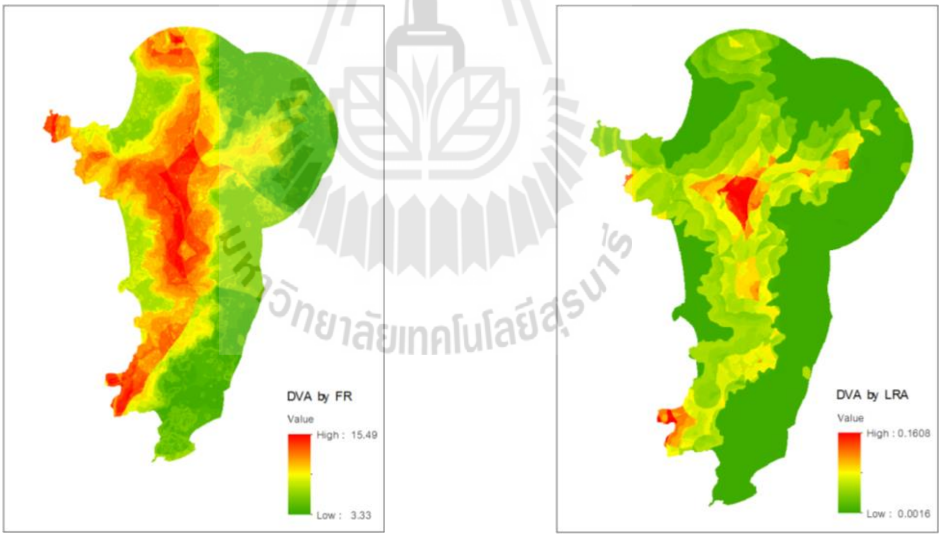
Frequency Ratio Logistic regression analysis

Figure 6.5 Distribution of deforestation vulnerability index of Khao Sam Liam NRF.



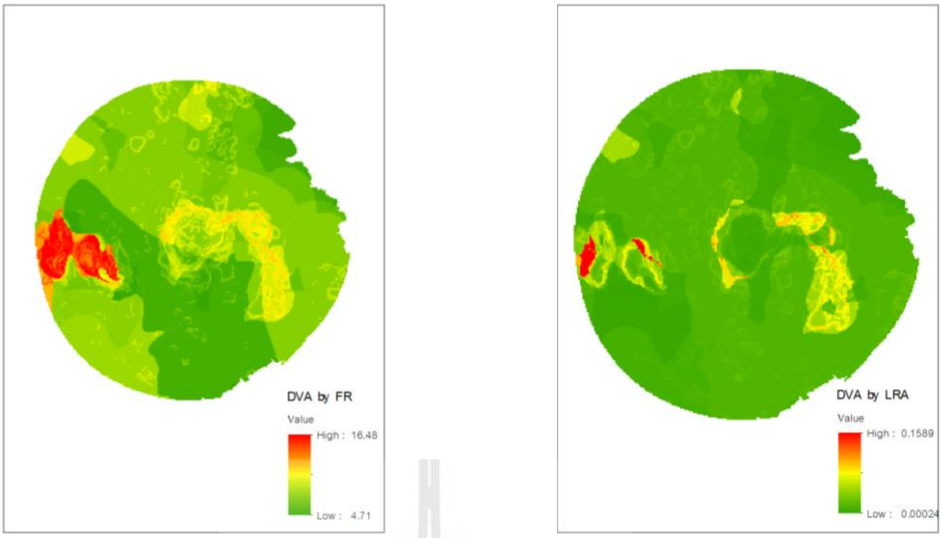
Frequency Ratio   Logistic regression analysis

Figure 6.6 Distribution of deforestation vulnerability index of Khao Kamala NRF.



Frequency Ratio   Logistic regression analysis

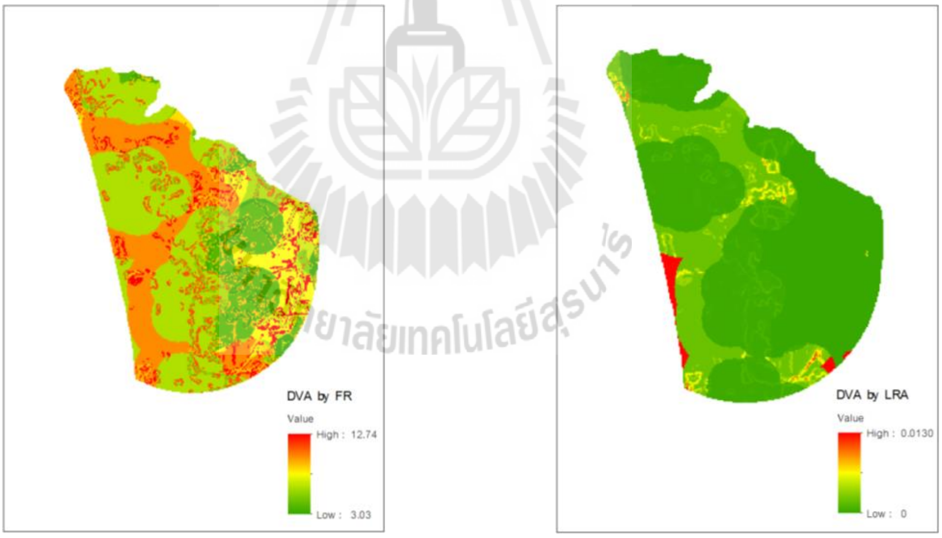
Figure 6.7 Distribution of deforestation vulnerability index of Khao Nak Keod NRF.



Frequency Ratio

Logistic regression analysis

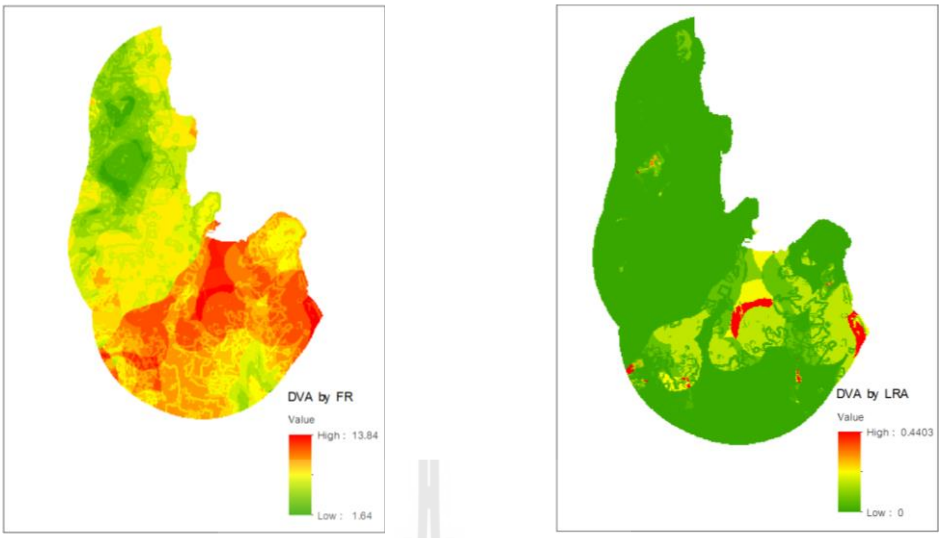
Figure 6.8 Distribution of deforestation vulnerability index of Khao Tosae NRF.



Frequency Ratio

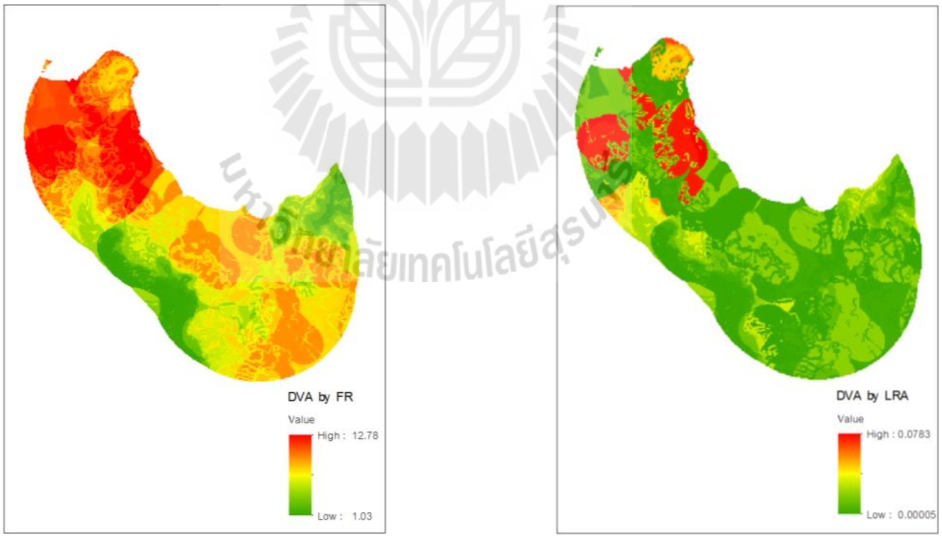
Logistic regression analysis

Figure 6.9 Distribution of deforestation vulnerability index of Khlong U-Tapao NRF.



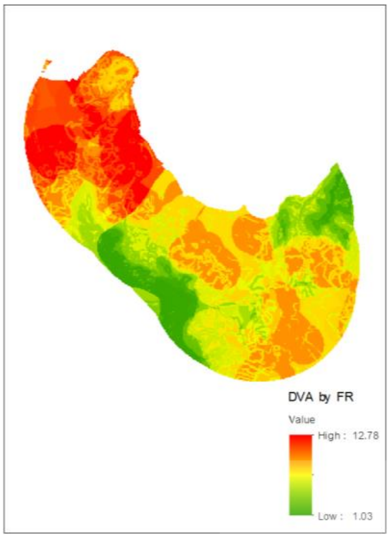
Frequency Ratio Logistic regression analysis

Figure 6.10 Distribution of deforestation vulnerability index of Khlong Tha Maphrao NRF.

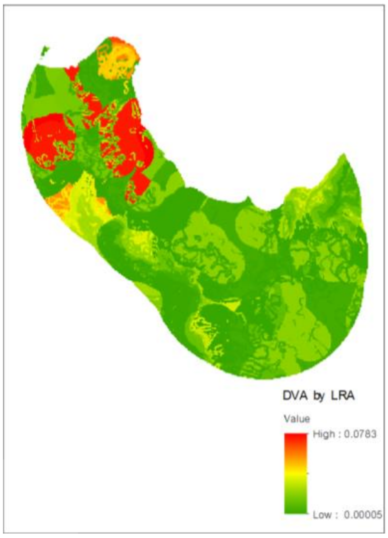


Frequency Ratio Logistic regression analysis

Figure 6.11 Distribution of deforestation vulnerability index of Khlong Para NRF.

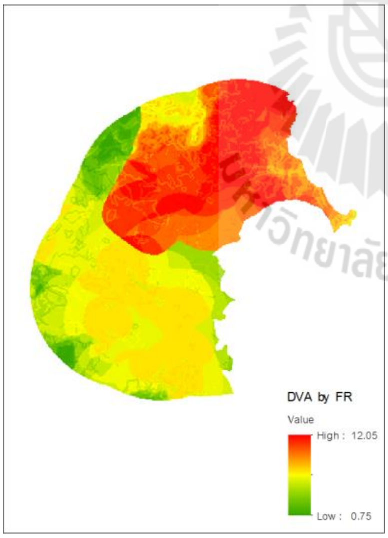


Frequency Ratio

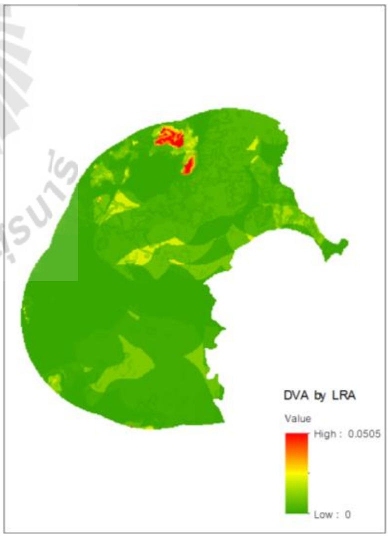


Logistic regression analysis

Figure 6.12 Distribution of deforestation vulnerability index of Khlong Bangrong NRF.

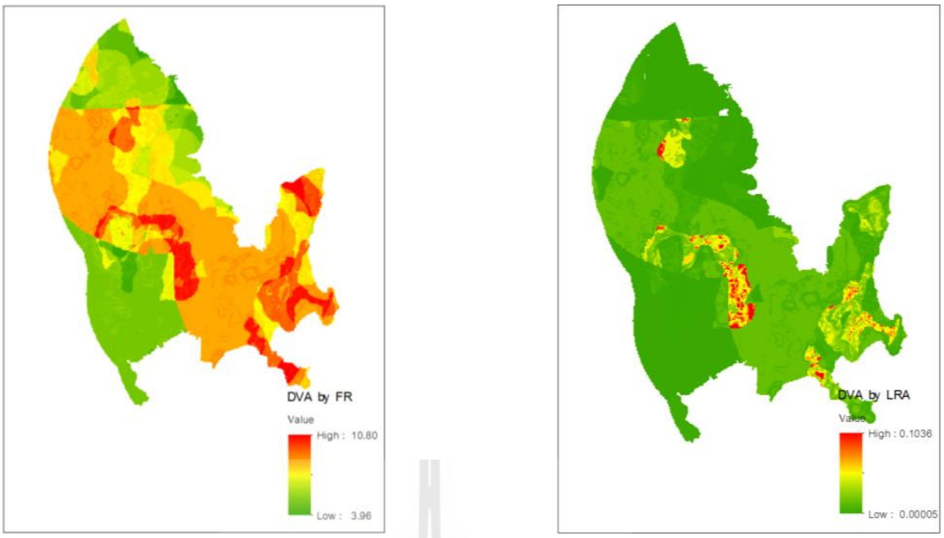


Frequency Ratio



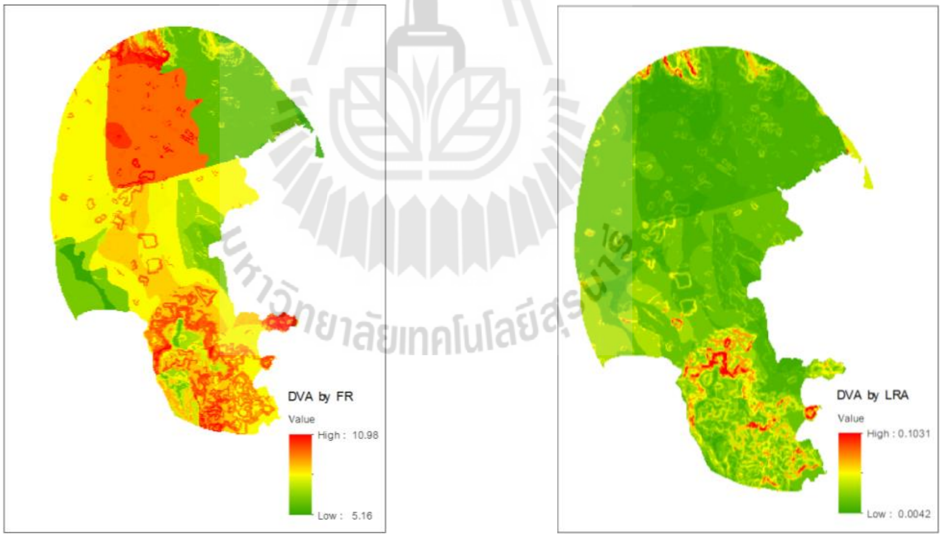
Logistic regression analysis

Figure 6.13 Distribution of deforestation vulnerability index of Khlong Tarau NRF.



Frequency Ratio Logistic regression analysis

Figure 6.14 Distribution of deforestation vulnerability index of Khlong Tajin NRF.



Frequency Ratio Logistic regression analysis

Figure 6.15 Distribution of deforestation vulnerability index of Khlong Khopee NRF.

Table 6.3 Minimum and maximum value of deforestation vulnerability index of 15 protected forest areas using FR and LRA method.

Protected forest area	FR		LRA	
	Minimum	Maximum	Minimum	Maximum
Sirinath MNP	2.21	45.46	0	0.6224
Khao Phra Thaeo WCDEC	1.69	11.63	0	0.1137
Khao Mai Kaew NRF	2.38	11.35	0	0.0053
Khao Bang Khanun NRF	2.75	26.57	0.0001	0.6956
Khao Sam Liam NRF	4.48	15.58	0.0002	0.0844
Khao Kamala NRF	2.95	15.15	0	0.155
Khao Nak Keod NRF	3.33	15.49	0.0016	0.1608
Khao Tosae NRF	4.71	16.48	0.0002	0.1589
Khlong U-Tapao NRF	3.03	12.74	0	0.013
Khlong Tha Maphrao NRF	1.64	13.84	0	0.4403
Khlong Para NRF	1.03	12.78	0	0.0783
Khlong Bangrong NRF	2.13	9.85	0.0001	0.0502
Khlong Tarau NRF	0.75	12.05	0	0.0505
Khlong Tajin NRF	3.96	10.8	0	0.068
Khlong Khopee NRF	5.16	10.98	0.0042	0.1031

Table 6.4 Accuracy assessment of deforestation vulnerability analysis of 15 protected forest areas using FR and LRA.

Protected forest area	ROC value		Total score	
	FR	LRA	FR	LRA
Sirinath MNP	0.928	0.874	4,590	3,258
Khao Phra Thaeo WCDEC	0.610	0.591	2,282	1,848
Khao Mai Kaew NRF	0.692	0.488	970	324
Khao Bang Khanun NRF	0.776	0.695	4,191	3,614
Khao Sam Liam NRF	0.849	0.754	210	195
Khao Kamala NRF	0.802	0.786	19,764	10,857
Khao Nak Keod NRF	0.875	0.864	26,712	20,494
Khao Tosae NRF	0.734	0.745	2,123	2,165
Khlong U-Tapao NRF	0.769	0.796	83	25
Khlong Tha Maphrao NRF	0.825	0.790	3,340	2,200
Khlong Para NRF	0.845	0.780	1,065	714
Khlong Bangrong NRF	0.741	0.691	879	626
Khlong Tarau NRF	0.761	0.820	2,397	1,657
Khlong Tajin NRF	0.892	0.900	2,397	1,376
Khlong Khopee NRF	0.804	0.842	2,721	2,100

Based on the result of accuracy assessment using ROC method, FR is an optimum geospatial technique for deforestation vulnerability analysis in 10 protected forest areas including Sirinath MNP, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khlong Tha Maphrao NRF, Khlong Para NRF and Khlong Bangrong NRF. Meanwhile LRA is an optimum geospatial technique for deforestation vulnerability analysis in 5 protected forest areas including Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Tarau NRF, Khlong Tajin NRF and Khlong Khopee NRF. These results implies that accuracy of the FR and LRA methods depend on location of study site. This finding was agreed with the previous study of Lee and Pradhan (2006) who applied FR and LRA methods for landslide hazard mapping at Selangor, Malaysia. They found that the FR method with accuracy of 93.04% can predict landslide hazard better than LRA method with accuracy of 90.34%. Meanwhile Pradhan and Lee (2010) also applied both methods for landslide hazard analysis on Penang Island, Malaysia and they found that LRA method with accuracy of 89.59% can predict landslide hazard better than FR method with accuracy of 86.41%.

However, result of accuracy assessment using correctness by proportional weighting method shows that FR provides total score higher than LRA in all protected forest areas. Finally, FR therefore is selected as optimum geospatial technique for deforestation vulnerability analysis based on deforestation area between 2002 and 2014 for deforestation vulnerability zonation.

6.2 Deforestation vulnerability analysis and zonation

The deforestation vulnerability analysis of 15 protected forest areas was conducted again using FR based on driving factors on deforestation (see Table 1.2) and deforestation area between 2002 and 2014. Figures 6.16 to 6.30 display deforestation vulnerability zonation of 15 protected forest areas and frequency ratio with high probability of deforestation occurrence of each protected forest area is summarized in Table 6.5. Detail of the frequency ratio of deforestation occurrence using FR method of 15 protected forest areas is summarized in Tables 1 to 15 in Appendix**.** Area and percentage deforestation of vulnerability zonation with and without buffer zone 2.5 km of 15 protected forest areas is summarized in Tables 6.6 to 6.9, respectively. Similarly, the proportional percentage of deforestation vulnerability zone of 15 protected forest areas with and without buffer zone 2.5 km is compared in displayed in Figure 6.31 and Figure 6.32, respectively.

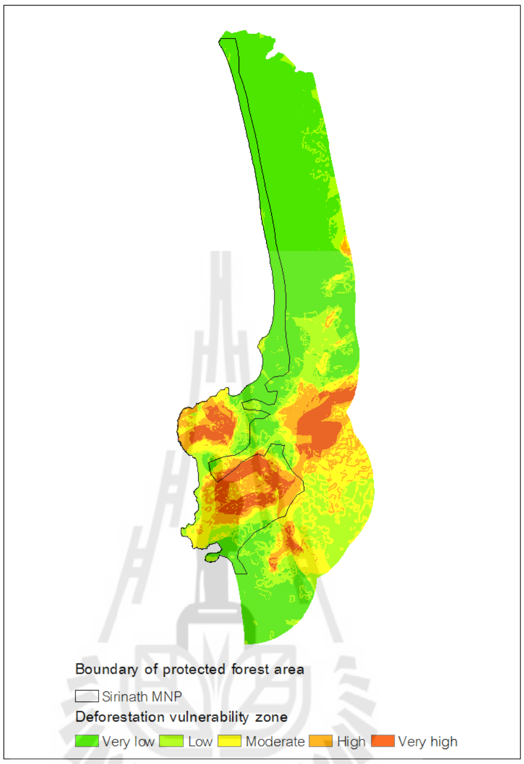


Figure 6.16 Deforestation vulnerability zonation of Sirinath MNP.

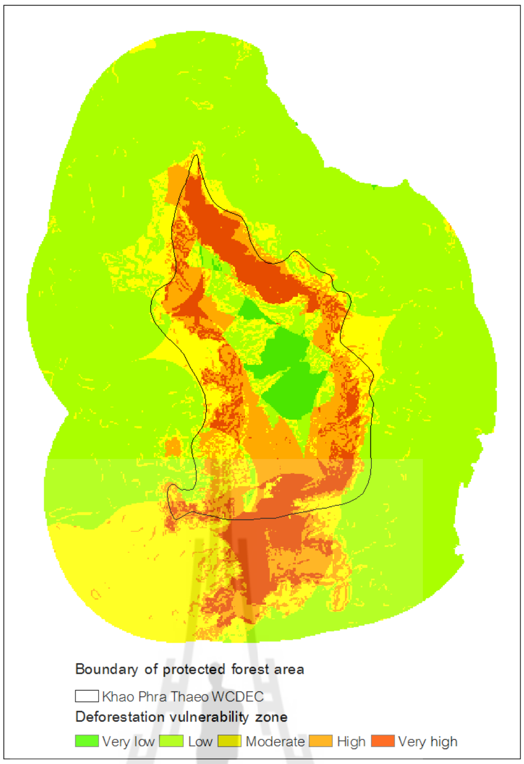


Figure 6.17 Deforestation vulnerability zonation of Khao Phra Thaeo WCDEC.

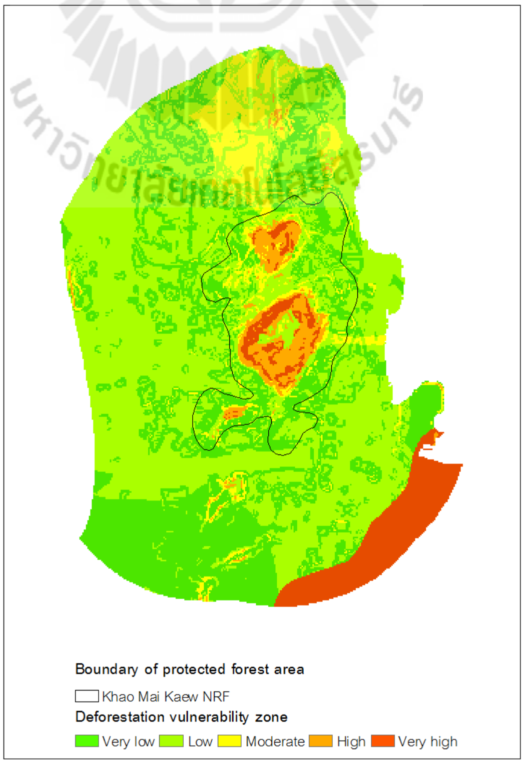


Figure 6.18 Deforestation vulnerability zonation of Khao Mai Kaew NRF.

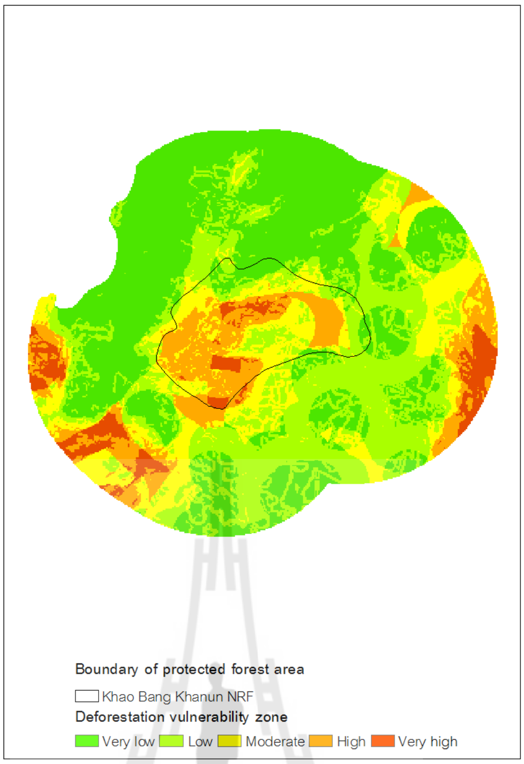


Figure 6.19 Deforestation vulnerability zonation of Khao Bang Khanun NRF.

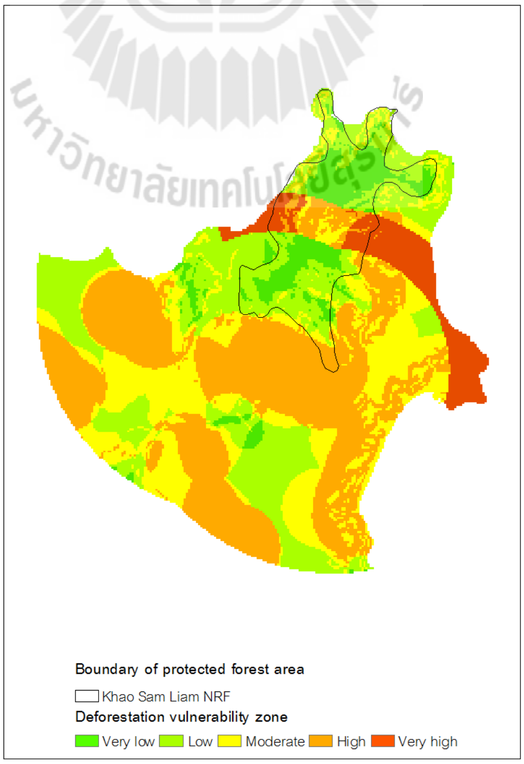


Figure 6.20 Deforestation vulnerability zonation of Khao Sam Liam NRF.

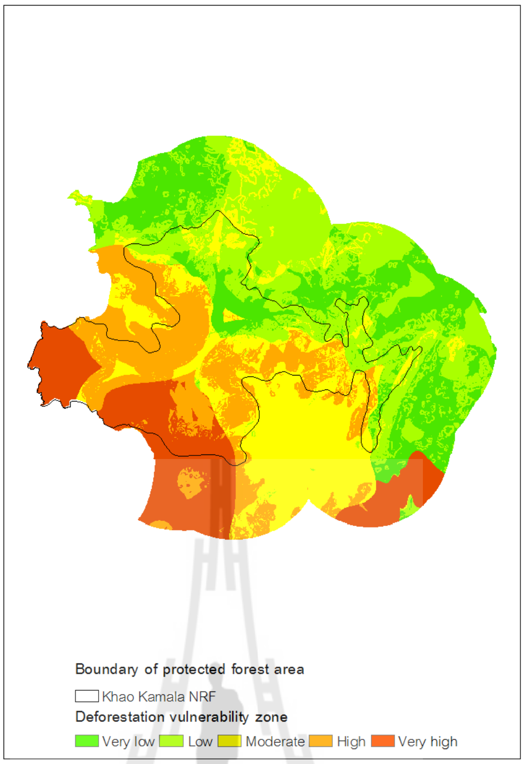


Figure 6.21 Deforestation vulnerability zonation of Khao Kamala NRF.

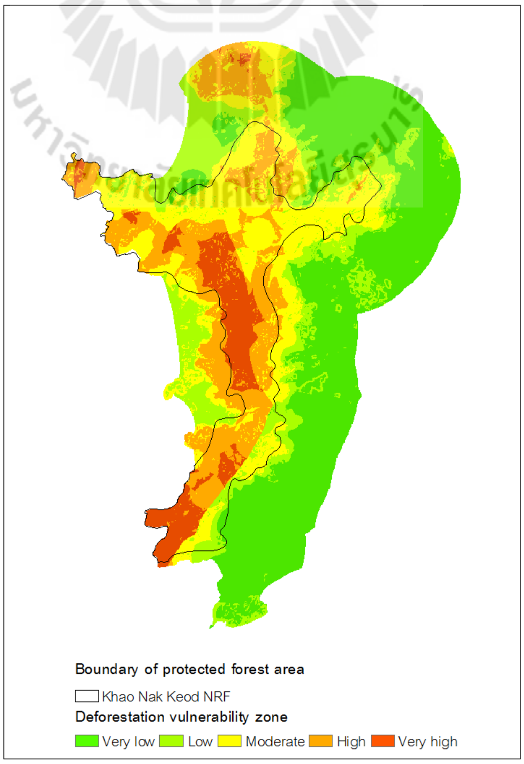


Figure 6.22 Deforestation vulnerability zonation of Khao Nak Keod NRF.

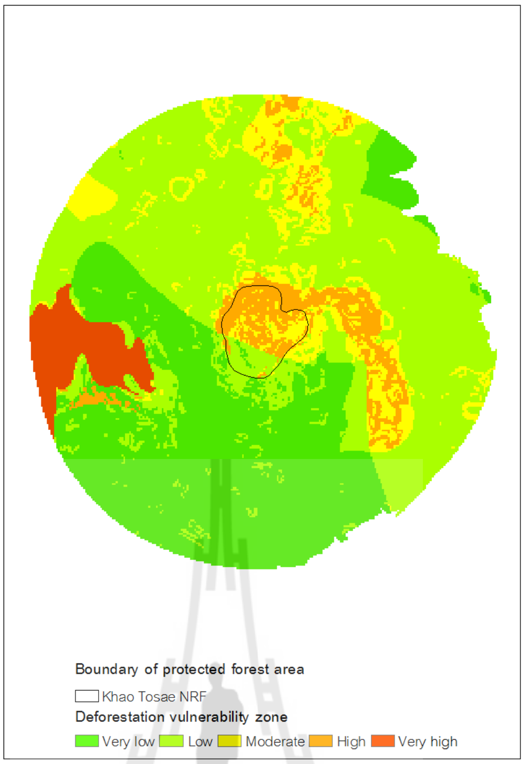


Figure 6.23 Deforestation vulnerability zonation of Khao Tosae NRF.

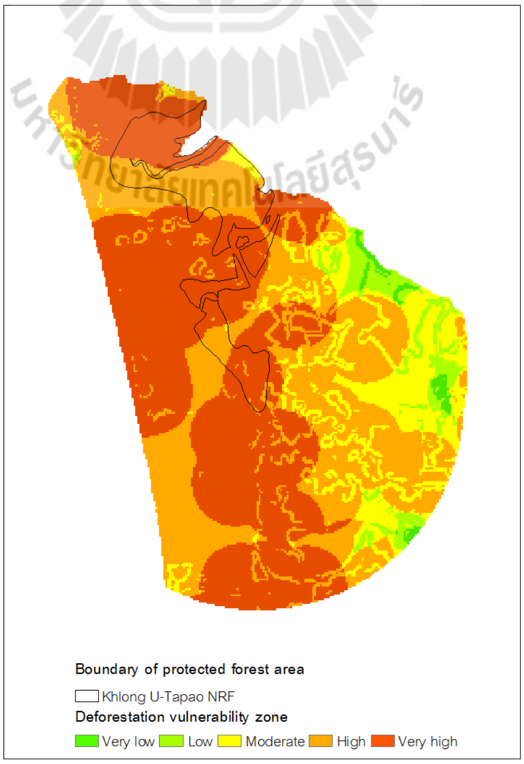


Figure 6.24 Deforestation vulnerability zonation of Khlong U-Tapao NRF.

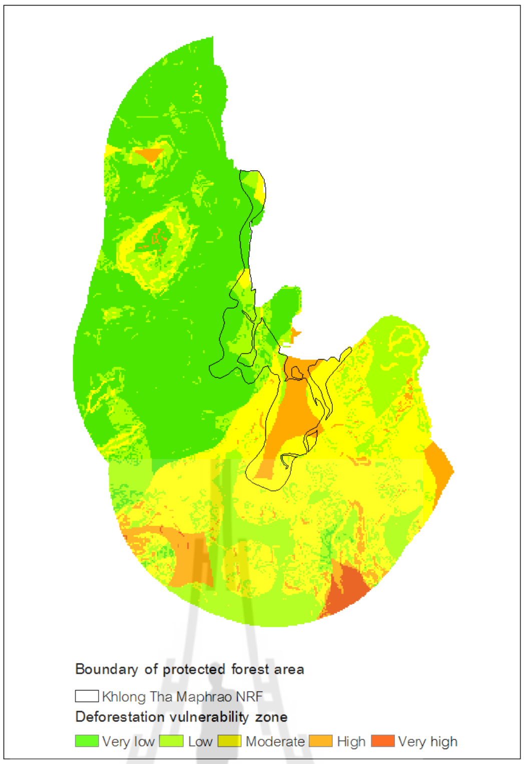


Figure 6.25 Deforestation vulnerability zonation of Khlong Tha Maphrao NRF.

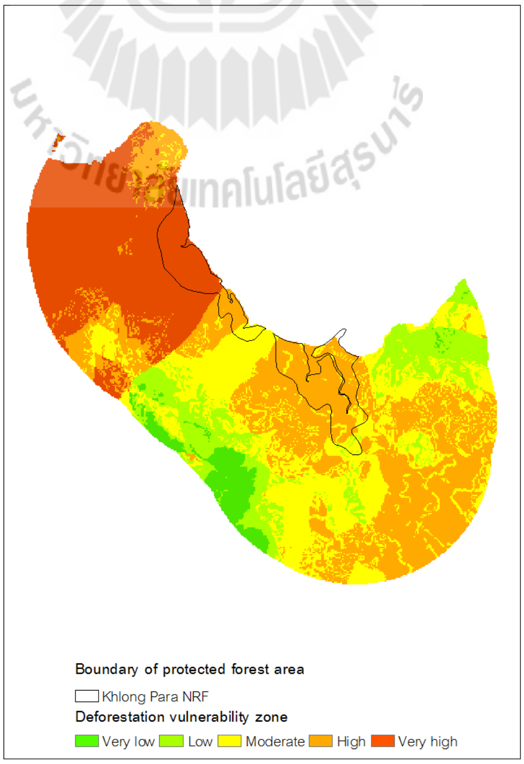


Figure 6.26 Deforestation vulnerability zonation of Khlong Para NRF.

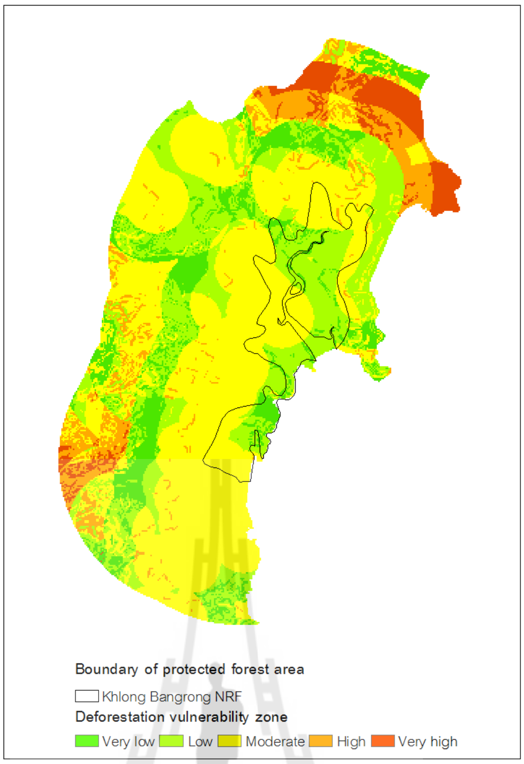


Figure 6.27 Deforestation vulnerability zonation of Khlong Bangrong NRF.

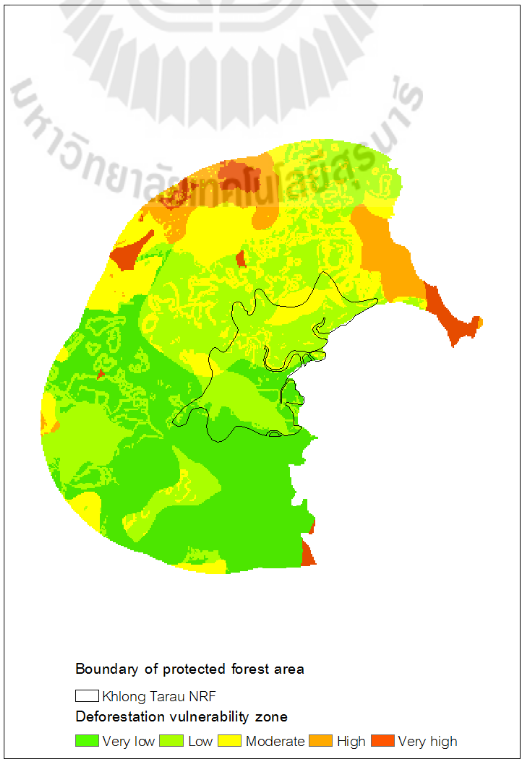


Figure 6.28 Deforestation vulnerability zonation of Khlong Tarau NRF.

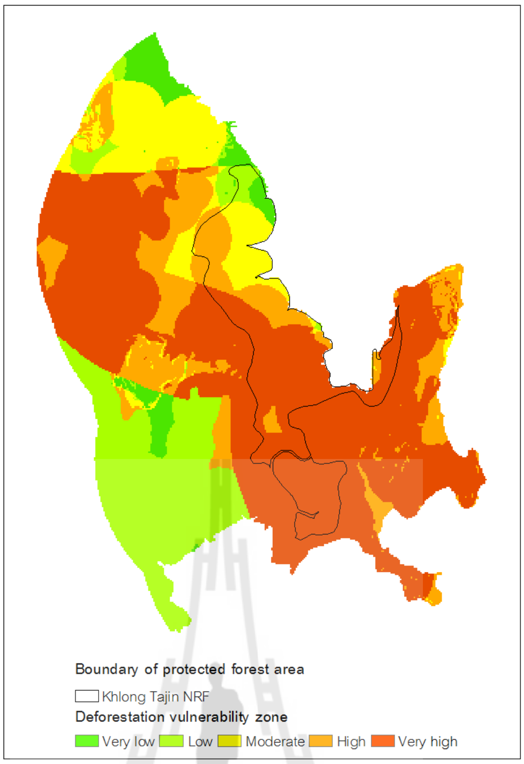


Figure 6.29 Deforestation vulnerability zonation of Khlong Tajin NRF.

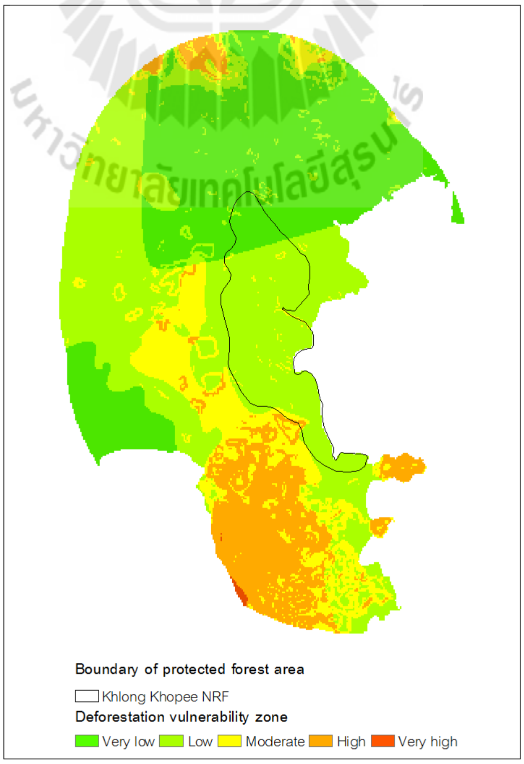


Figure 6.30 Deforestation vulnerability zonation of Khlong Khopee NRF.

Table 6.5 Summary of frequency ratio with high probability of deforestation occurrence of each protected forest area based on driving factors on deforestation and deforested area between 2002 and 2014.

Deforestation factor and classes	Protected forest area															Frequency
	SN	PT	MK	BK	SL	KL	NK	TS	UT	TM	PR	BR	TR	TJ	KP	
Elevation																
0-100 m	0.81	0.80	0.90	0.83	1.09	0.80	0.67	1.04	1.00	0.94	1.01	1.05	0.86	1.03	0.96	6 of 15
100-200 m	2.43	2.09	3.99	2.22	0.00	1.38	1.58	0.03	0.00	2.22	1.45	1.01	0.60	0.00	2.07	10 of 15
200-300 m	2.27	1.87	0.00	1.13	0.00	1.01	1.60	0.00	0.00	0.00	0.00	0.00	11.04	0.00	0.00	6 of 15
300-400 m	0.00	0.00	0.00	0.00	0.00	1.53	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2 of 15
>400	0.00	0.00	0.00	0.00	0.00	2.03	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Slope																
0-8%	0.26	1.01	1.25	0.51	0.77	0.23	0.23	0.67	1.17	0.98	1.23	0.90	0.60	0.93	0.59	4 of 15
8-16%	1.19	0.69	0.08	0.89	0.74	0.98	1.06	1.39	1.06	0.51	0.50	0.65	1.55	1.06	1.09	7 of 15
16-35%	1.87	0.87	0.42	1.47	1.19	1.53	1.59	2.01	0.00	0.93	0.85	1.02	1.79	1.23	2.25	10 of 15
35-60%	2.33	1.53	2.90	2.04	1.95	1.66	1.62	1.54	0.00	2.45	1.04	2.08	1.54	1.07	2.90	14 of 15
> 60%	3.75	1.00	4.51	2.56	0.00	1.68	1.40	4.02	0.00	2.05	0.59	0.35	1.18	0.00	5.21	10 of 15
Soil fertility																
Low	0.53	0.90	0.92	0.72	1.29	0.31	0.24	0.77	1.01	0.96	1.15	1.00	0.37	0.71	0.62	4 of 15
Moderate	2.87	1.15	2.06	2.09	0.00	1.71	1.73	2.20	0.00	1.24	0.52	0.99	3.73	2.13	2.27	11 of 15
Distance from road																
0-500 m	0.86	1.11	1.02	0.77	1.14	1.03	0.93	0.97	1.03	0.88	1.04	1.00	1.16	1.10	1.05	10 of 15
500-1000 m	2.94	0.89	0.00	3.29	0.00	0.94	1.78	1.59	0.00	3.42	0.84	1.12	0.27	0.37	0.37	6 of 15
1000-1500 m	0.00	0.00	0.00	0.00	0.00	0.59	2.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Distance from settlement																
0-500 m	0.56	0.75	0.96	0.43	1.85	0.71	0.74	1.03	1.48	0.87	1.21	1.31	0.66	1.07	0.98	6 of 15
500-1000 m	1.85	0.86	1.27	2.19	0.00	1.55	1.58	0.00	0.00	1.49	1.01	0.16	1.62	0.20	1.31	9 of 15
1000-1500 m	2.17	2.09	0.00	1.53	0.00	1.72	2.12	0.00	0.00	0.12	0.54	1.67	1.70	0.00	0.00	7 of 15
1500-2000 m	6.94	1.86	0.00	8.85	0.00	1.06	0.84	0.00	0.00	0.00	0.00	1.31	0.10	0.00	0.00	5 of 15

Table 6.5 (Continued).

Deforestation factor and classes	Protected forest area															Frequency
	SN	PT	MK	BK	SL	KL	NK	TS	UT	TM	PR	BR	TR	TJ	KP	
Distance from water bodies																
0-500	0.35	0.97	0.99	0.79	1.01	0.56	0.57	0.86	1.41	1.27	1.26	0.83	0.46	1.23	0.81	5 of 15
500-1000	2.48	0.75	0.85	1.36	0.00	1.08	1.14	1.51	0.00	0.59	0.66	0.26	0.64	0.25	1.06	6 of 15
1000-1500	1.85	1.46	1.49	0.72	0.00	1.55	1.53	0.00	0.00	0.46	0.00	2.28	18.55	0.00	2.19	8 of 15
1500-2000	2.01	1.79	0.00	1.57	5.22	1.67	2.30	0.00	0.00	4.17	1.35	3.77	39.42	0.00	2.13	10 of 15
> 2000	0.00	0.00	0.00	0.00	0.18	3.73	4.51	0.00	0.00	0.00	0.00	0.41	0.00	0.00	19.87	3 of 15
Population density (person/sq.km)																
Sakhu (88)	1.09	0.00	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	1 of 15
Karon (169)	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Kamala (229)	0.00	0.00	0.00	0.00	0.00	1.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Pa Khlok (317)	0.00	0.92	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.67	1.00	1.68	0.00	0.00	3 of 15
Thep Kasattri (335)	2.66	0.96	4.89	1.29	0.00	0.00	0.00	0.00	0.00	1.49	1.67	0.00	0.00	0.00	0.00	5 of 15
Ko Keao (365)	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.31	0.00	0 of 15
Mai Khao (547)	0.05	0.00	0.88	0.00	0.00	0.00	0.00	0.00	1.00	0.48	0.00	0.00	0.00	0.00	0.00	1 of 15
Rawai (729)	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Kathu (819)	0.00	0.00	0.00	0.00	0.00	0.01	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Choeng Thale (878)	0.89	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Si Sunthon (1036)	0.00	1.46	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	1 of 15
Talat Nuea (1083)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0 of 15
Talat Yai (1840)	0.00	0.00	0.00	0.00	0.00	49.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.36	1 of 15
Rutsada (1849)	0.00	0.00	0.00	0.00	0.00	0.13	0.00	1.15	0.00	0.00	0.00	0.00	0.00	1.36	0.00	2 of 15
Wichit (1944)	0.00	0.00	0.00	0.00	0.00	1.95	0.45	5.18	0.00	0.00	0.00	0.00	0.00	0.00	1.50	3 of 15
Pa Tong (2542)	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Chalong (4112)	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15

Table 6.5 (Continued).

Deforestation factor and classes	Protected forest area															Frequency
	SN	PT	MK	BK	SL	KL	NK	TS	UT	TM	PR	BR	TR	TJ	KP	
Average income (Baht/person)																
Rutsada (51115)	0.00	0.00	0.00	0.00	0.00	0.13	0.00	1.15	0.00	0.00	0.00	0.00	0.00	1.36	0.00	2 of 15
Pa Khlok (69313)	0.00	0.92	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.67	1.00	1.68	0.00	0.00	3 of 15
Si Sunthon (80166)	0.00	1.46	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	1 of 15
Ko Keao (87056)	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.31	0.00	0 of 15
Thep Kasattri (93391)	2.66	0.96	4.89	1.29	0.00	0.00	0.00	0.00	0.00	1.49	1.67	0.00	0.00	0.00	0.00	5 of 15
Kamala (98329)	0.00	0.00	0.00	0.00	0.00	1.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Kathu (106462)	0.00	0.00	0.00	0.00	0.00	0.01	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Sakhu (106940)	1.09	0.00	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	1 of 15
Choeng Thale (108398)	0.89	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Pa Tong (114955)	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Mai Khao (116365)	0.05	0.00	0.88	0.00	0.00	0.00	0.00	0.00	1.00	0.48	0.00	0.00	0.00	0.00	0.00	1 of 15
Talat Nuea (119459)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0 of 15
Karon (121046)	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 of 15
Talat Yai (122531)	0.00	0.00	0.00	0.00	0.00	49.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.36	1 of 15
Rawai (136128)	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15
Wichit (142743)	0.00	0.00	0.00	0.00	0.00	1.95	0.45	5.18	0.00	0.00	0.00	0.00	0.00	0.00	1.50	3 of 15
Chalong (146772)	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 of 15

Table 6.6 Area of deforestation vulnerability zonation of 15 protected forest areas with buffer zone.

Protect forest area	Area of deforestation vulnerability zonation (sq.km)					
	Very low	Low	Moderate	High	Very high	Total
Sirinath MNP	39.48	14.48	11.24	8.50	6.41	80.09
Khao Phra Thaeo WCDEC	1.86	54.17	16.41	9.82	7.14	89.40
Khao Mai Kaew NRF	13.85	21.92	3.10	1.42	2.86	43.16
Khao Bang Khanun NRF	20.08	15.97	8.37	6.05	2.43	52.89
Khao Sam Liam NRF	1.29	4.80	4.47	6.76	1.24	18.56
Khao Kamala NRF	24.61	37.81	29.16	25.14	20.75	137.46
Khao Nak Keod NRF	43.05	19.30	23.79	19.05	7.95	113.13
Khao Tosae NRF	9.77	12.52	3.14	1.78	1.37	28.59
Khlong U-Tapao NRF	0.19	0.90	2.86	7.92	9.86	21.72
Khlong Tha Maphrao NRF	16.42	10.12	12.49	3.06	0.44	42.53
Khlong Para NRF	1.46	4.56	10.63	13.36	10.22	40.23
Khlong Bangrong NRF	4.17	9.34	18.76	3.59	1.97	37.83
Khlong Tarau NRF	12.59	12.95	8.22	3.03	1.33	38.12
Khlong Tajin NRF	1.38	6.13	3.86	5.53	17.43	34.34
Khlong Khopee NRF	11.81	13.26	4.63	4.35	0.04	34.08

Table 6.7 Percentage of deforestation vulnerability zonation of 15 protected forest areas with buffer zone.

Protect forest area	Area of deforestation vulnerability zonation in percent					
	Very low	Low	Moderate	High	Very high	Total
Sirinath MNP	49.29	18.08	14.03	10.61	8.00	100.00
Khao Phra Thaeo WCDEC	2.07	60.59	18.35	10.99	7.99	100.00
Khao Mai Kaew NRF	32.09	50.80	7.18	3.30	6.63	100.00
Khao Bang Khanun NRF	37.96	30.19	15.83	11.44	4.59	100.00
Khao Sam Liam NRF	6.97	25.88	24.09	36.39	6.68	100.00
Khao Kamala NRF	17.90	27.50	21.21	18.29	15.10	100.00
Khao Nak Keod NRF	38.05	17.06	21.03	16.84	7.03	100.00
Khao Tosae NRF	34.18	43.81	10.97	6.24	4.80	100.00
Khlong U-Tapao NRF	0.89	4.12	13.15	36.46	45.39	100.00
Khlong Tha Maphrao NRF	38.60	23.80	29.37	7.19	1.03	100.00
Khlong Para NRF	3.64	11.32	26.43	33.21	25.40	100.00
Khlong Bangrong NRF	11.03	24.69	49.61	9.48	5.20	100.00
Khlong Tarau NRF	33.02	33.96	21.57	7.95	3.49	100.00
Khlong Tajin NRF	4.02	17.86	11.25	16.11	50.76	100.00
Khlong Khopee NRF	34.65	38.89	13.59	12.75	0.12	100.00

Table 6.8 Area of deforestation vulnerability zonation of 15 protected forest areas within its boundary.

Protect forest area	Area of deforestation vulnerability zonation (sq.km)					
	Very low	Low	Moderate	High	Very high	Total
Sirinath MNP	7.429	2.766	3.362	4.013	3.591	21.161
Khao Phra Thaeo WCDEC	1.846	2.725	4.200	6.808	4.788	20.368
Khao Mai Kaew NRF	2.175	2.592	0.672	1.299	0.569	7.308
Khao Bang Khanun NRF	0.561	1.328	2.124	2.824	0.454	7.291
Khao Sam Liam NRF	1.032	1.085	0.321	0.362	0.246	3.046
Khao Kamala NRF	3.640	8.613	8.773	16.703	9.719	47.448
Khao Nak Keod NRF	0.476	3.203	13.796	12.402	7.674	37.550
Khao Tosae NRF	0.019	0.201	0.203	0.515	0.000	0.938
Khlong U-Tapao NRF	0.000	0.000	0.067	0.966	1.462	2.495
Khlong Tha Maphrao NRF	0.877	0.647	1.146	0.903	0.000	3.573
Khlong Para NRF	0.000	0.013	0.416	1.808	1.129	3.365
Khlong Bangrong NRF	0.460	1.960	2.235	0.007	0.000	4.662
Khlong Tarau NRF	1.031	3.048	0.750	0.000	0.000	4.829
Khlong Tajin NRF	0.171	0.188	0.902	1.134	3.716	6.109
Khlong Khopee NRF	0.500	3.324	0.119	0.011	0.000	3.954

Table 6.9 Percentage of deforestation vulnerability zonation of 15 protected forest areas within its boundary.

Protect forest area	Area of deforestation vulnerability zonation in percent					
	Very low	Low	Moderate	High	Very high	Total
Sirinath MNP	35.11	13.07	15.89	18.96	16.97	100.00
Khao Phra Thaeo WCDEC	9.06	13.38	20.62	33.43	23.51	100.00
Khao Mai Kaew NRF	29.76	35.47	9.19	17.78	7.79	100.00
Khao Bang Khanun NRF	7.7	18.21	29.13	38.74	6.23	100.00
Khao Sam Liam NRF	33.87	35.62	10.55	11.88	8.08	100.00
Khao Kamala NRF	7.67	18.15	18.49	35.2	20.48	100.00
Khao Nak Keod NRF	1.27	8.53	36.74	33.03	20.44	100.00
Khao Tosae NRF	2	21.45	21.65	54.9	0	100.00
Khlong U-Tapao NRF	0	0	2.68	38.73	58.59	100.00
Khlong Tha Maphrao NRF	24.54	18.1	32.08	25.28	0	100.00
Khlong Para NRF	0	0.39	12.35	53.71	33.54	100.00
Khlong Bangrong NRF	9.87	42.04	47.94	0.15	0	100.00
Khlong Tarau NRF	21.36	63.11	15.53	0	0	100.00
Khlong Tajin NRF	2.79	3.07	14.76	18.56	60.82	100.00
Khlong Khopee NRF	12.65	84.08	3	0.27	0	100.00

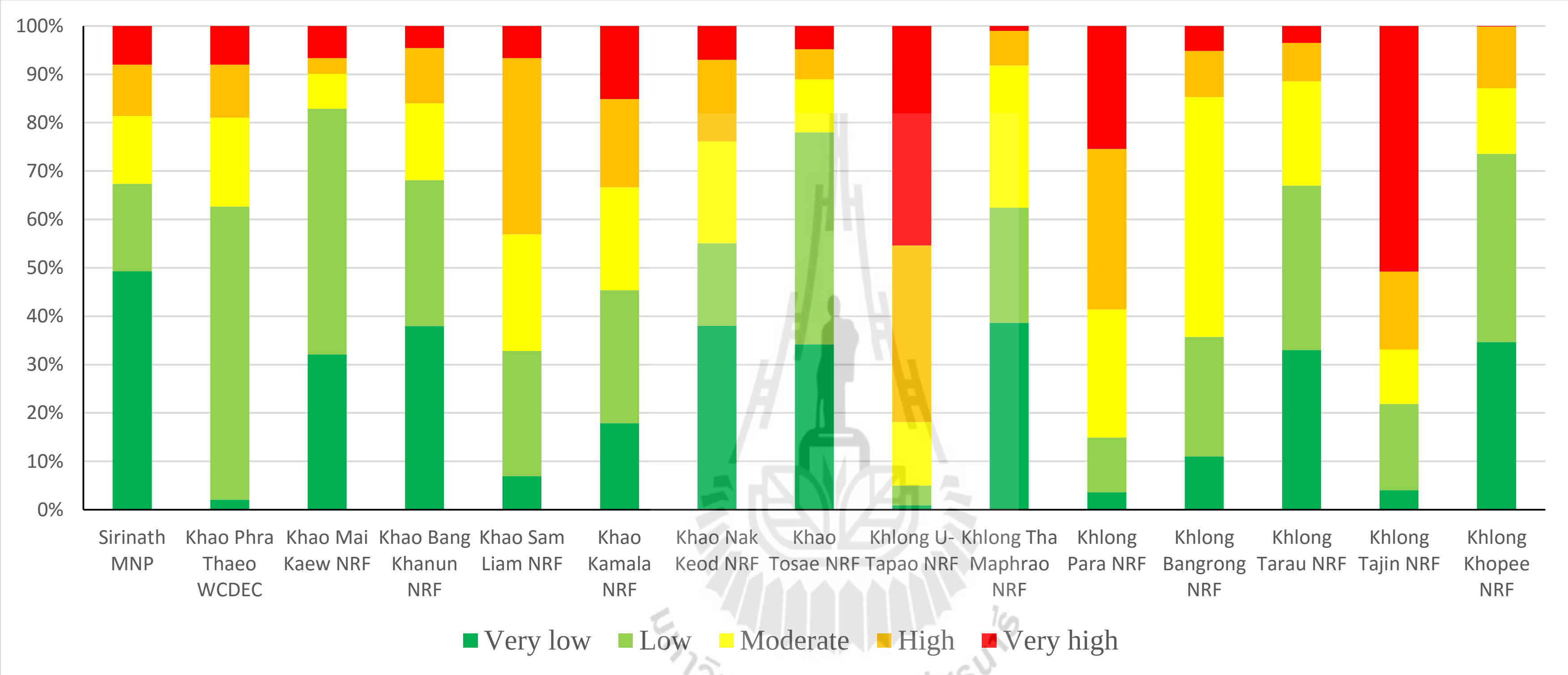


Figure 6.31 Proportional percentage of each deforestation vulnerability zone comparison of 15 protected forest areas with buffer zone.

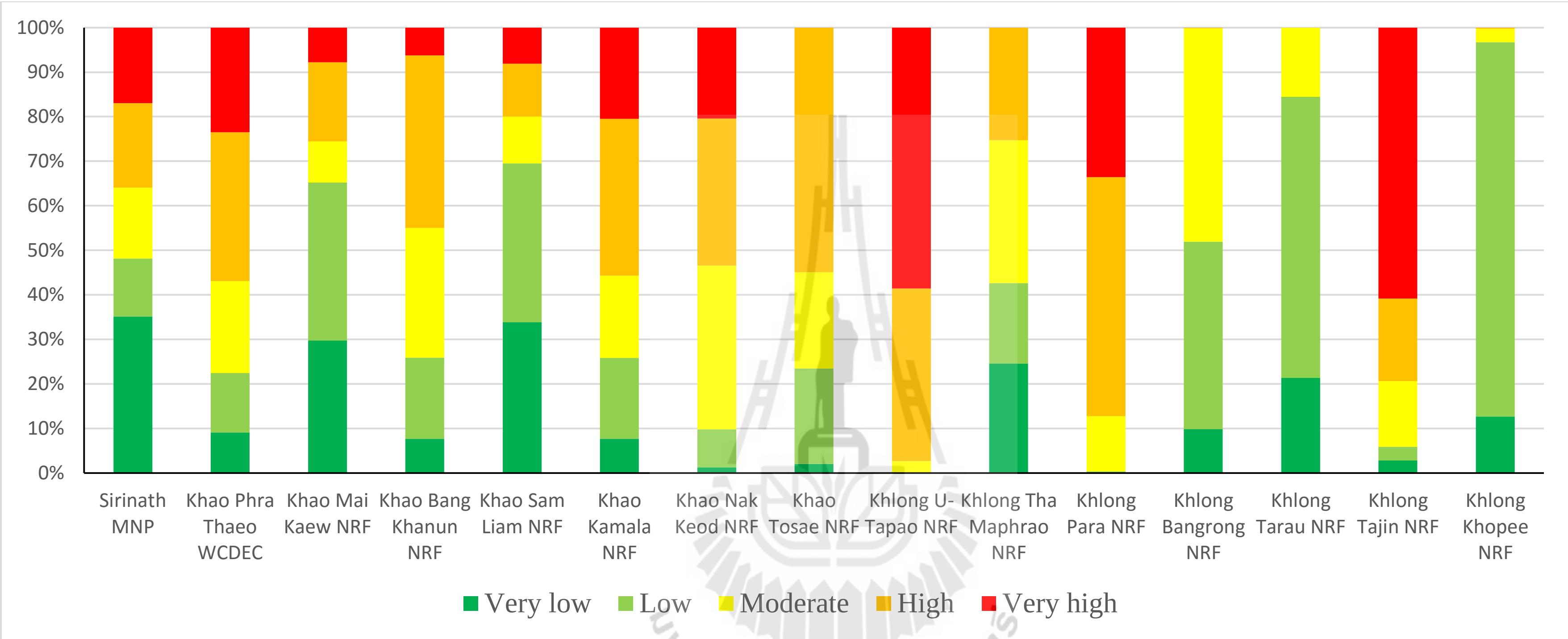


Figure 6.32 Proportional percentage of each deforestation vulnerability zone comparison of 15 protected forest areas within boundary.

According to deforestation vulnerability zonation with and without buffer zone, percentage of deforestation vulnerability zones in two boundaries can be used classified deforestation risk of 15 protected forest areas into two categories: low and high with specific condition as below.

Low deforestation risk. The additive percentage of very low and low deforestation vulnerability zones equals or more than 50% or the additive value of two zones is higher than the additive percentage of high and very high deforestation vulnerability zones.

High deforestation risk. The additive percentage of high and very high deforestation vulnerability zones equals or more than 50% or the additive value of two zones is higher than the additive percentage of very low and low high deforestation vulnerability zones.

Based on deforestation vulnerability zonation with buffer zone, it was found that there are 11 protected forest areas with low risk of deforestation including Sirinath MNP, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Bang Khanun NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khao Tosae NRF, Khlong Tha Maphrao NRF, Khlong Bangrong NRF, Khlong Tarau NRF, and Khlong Khopee NRF. In contrast, there are 4 protected forest areas with high risk of deforestation including Khao Sam Liam NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF.

Meanwhile, it was found that there are only 7 protected forest area with low risk of deforestation based on deforestation vulnerability zonation without buffer zone including Sirinath MNP, Khao Mai Kaew NRF, Khao Sam Liam NRF, Khlong Tha Maphrao NRF, Khlong Bangrong NRF, Khlong Tarau NRF, and Khlong Khopee NRF.

On the contrary, there are 8 protected forest areas with high risk of deforestation included Khao Phra Thaeo WCDEC, Khao Bang Khanun NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF.

As results, there are 9 common protected forest areas which are categorized as the same deforestation risk levels included Sirinath MNP, Khao Mai Kaew NRF, Khlong U-Tapao NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, Khlong Bangrong NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee NRF. It was also observed that all 9 protected forest areas are situated along the coastal zone area. Particularly, all of NRFs where locate in mangrove forest included Khlong U-Tapao NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, Khlong Bangrong NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee are categorized as the same risk level based on deforestation vulnerability zonation with or without buffer zone. This finding shows the effect of forest accessibility and proximity factors on deforestation vulnerability analysis.

6.3 Forest area in 2014 and deforestation vulnerability zonation

The relationship of the existing forest area in 2014 and deforestation vulnerability zonation of 15 protected forest areas without buffer zone by overlay analysis is presented in Tables 6.10 and 6.11.

Table 6.10 Area of forest area in 2014 in each deforestation vulnerability zone of 15 protected forest areas without buffer zone.

Protect forest area	Forest area in 2014 in deforestation vulnerability zones (sq.km)					
	Very low	Low	Moderate	High	Very high	Total
Sirinath MNP	0.224	1.276	1.616	0.102	0.000	3.218
Khao Phra Thaeo WCDEC	1.458	2.180	5.178	8.335	1.556	18.708
Khao Mai Kaew NRF	0.014	0.049	0.108	0.108	0.044	0.324
Khao Bang Khanun NRF	0.325	0.785	0.797	0.086	0.105	2.098
Khao Sam Liam NRF	0.044	0.158	0.053	0.008	0.002	0.265
Khao Kamala NRF	1.504	4.608	8.921	3.945	2.415	21.393
Khao Nak Keod NRF	0.029	2.054	7.418	5.382	0.287	15.170
Khao Tosae NRF	0.175	0.653	0.053	0.000	0.000	0.880
Khlong U-Tapao NRF	0.000	0.000	0.064	0.794	1.013	1.871
Khlong Tha Maphrao NRF	0.648	1.009	0.852	0.000	0.000	2.508
Khlong Para NRF	0.000	0.000	0.016	1.514	0.435	1.964
Khlong Bangrong NRF	0.068	1.891	1.191	0.000	0.000	3.150
Khlong Tarau NRF	2.839	0.000	0.000	0.000	0.000	2.839
Khlong Tajin NRF	0.005	0.338	0.901	2.267	0.059	3.569
Khlong Khopee NRF	2.541	0.031	0.000	0.000	0.000	2.572

Table 6.11 Percent of forest area in 2014 in each deforestation vulnerability zone of 15 protected forest areas.

Protect forest area	Forest area in 2014 in deforestation vulnerability zones (percent)					
	Very low	Low	Moderate	High	Very high	Total
Sirinath MNP	6.97	39.65	50.21	3.17	0.00	100
Khao Phra Thaeo WCDEC	7.79	11.65	27.68	44.55	8.32	100
Khao Mai Kaew NRF	4.44	15.25	33.40	33.40	13.51	100
Khao Bang Khanun NRF	15.49	37.43	37.99	4.08	5.01	100
Khao Sam Liam NRF	16.75	59.67	20.05	2.83	0.71	100
Khao Kamala NRF	7.03	21.54	41.70	18.44	11.29	100
Khao Nak Keod NRF	0.19	13.54	48.90	35.48	1.89	100
Khao Tosae NRF	19.89	74.15	5.97	0.00	0.00	100
Khlong U-Tapao NRF	0.00	0.00	3.41	42.43	54.16	100
Khlong Tha Maphrao NRF	25.82	40.22	33.96	0.00	0.00	100
Khlong Para NRF	0.00	0.00	0.80	77.06	22.14	100
Khlong Bangrong NRF	2.16	60.04	37.80	0.00	0.00	100
Khlong Tarau NRF	100.00	0.00	0.00	0.00	0.00	100
Khlong Tajin NRF	0.14	9.46	25.24	63.52	1.65	100
Khlong Khopee NRF	98.78	1.22	0.00	0.00	0.00	100

As result shown in Table 6.11 it was revealed that there are 7 protected forest areas including Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Tosae NRF, Khlong Tha Maphrao NRF, Khlong Bangrong NRF, Khlong Tarau NRF, and Khlong Khopee NRF have the existing forest area in 2014 more than 50 percent situate in very low and low deforestation vulnerability zones. In contrast, there are 5 protected forest including Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF have the existing forest area in 2014 more than 50 percent situate in high and very high deforestation vulnerability zones. Meanwhile, there are 3 protected forest areas including Sirinath MNP, Khao Kamala NRF, and Khao Nak Keod NRF have the existing forest area in 2014 approximately 50 percent situate in moderate deforestation vulnerability zones.

This finding can be used as a basic information for forest patrolling program in protected forest area. Particularly, 8 protected forest areas, namely Sirinath MNP, Khao Kamala NRF and Khao Nak Keod NRF, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF which have the existing forest area in 2014 more than 50 percent locates in moderate, high and very high deforestation vulnerability zones, should be frequently patrolled by forest rangers.

CHAPTER VII

DEFORESTATION HOTSPOT AND FOREST PROTECTION UNIT ALLOCATION

Deforestation hotspot and forest protection unit allocation in protected forest areas, which were derived based on the predicted deforestation area between 2014 and 2026 in Chapter V and deforestation vulnerability zones (Chapter VI) are here explained and discussed.

7.1 Deforestation hotspot allocation

The derived predicted deforestation areas between 2014 and 2026 and deforestation vulnerability zones were (very low, low, moderate, high, and very high) here spatially combined to allocate deforestation hotspot with area equal or more than 1,600 sq. m (1 Rai). Number of the predicted deforestation hotspot with deforestation vulnerability zones of 15 protected forest area is presented in Table 7.1. Meanwhile distribution of the predicted deforestation hotspot over deforestation vulnerability zones of 12 protected forest areas is presented in Figures 7.1 to 7.12.

Table 7.1 Number of the predicted deforestation hotspot with deforestation vulnerability zones of 15 protected forest areas.

Protected forest area	Number of deforestation hotspot (Area >= 1600 sq. m or 1 Rai)					
	Very low	**Low**	**Moderate**	**High**	**Very High**	**Total**
Sirinath MNP	16	25	1	-	-	42
Khao Phra Thaeo WCDEC	-	1	-	-	-	1
Khao Mai Kaew NRF	1	3	-	-	-	4
Khao Bang Khanun NRF	4	3	-	-	-	7
Khao Sam Liam NRF	-	-	-	-	-	0
Khao Kamala NRF	14	61	84	37	33	229
Khao Nak Keod NRF	2	25	56	9	-	92
Khao Tosae NRF	-	-	-	-	-	0
Khlong U-Tapao NRF	-	-	-	-	1	1
Khlong Tha Maphrao NRF	1	1	-	-	-	2
Khlong Para NRF	-	-	-	3	-	3
Khlong Bangrong NRF	-	-	2	-	-	2
Khlong Tarau NRF	-	-	-	-	-	0
Khlong Tajin NRF	-	-	3	14	-	17
Khlong Khopee NRF	8	-	-	-	-	8

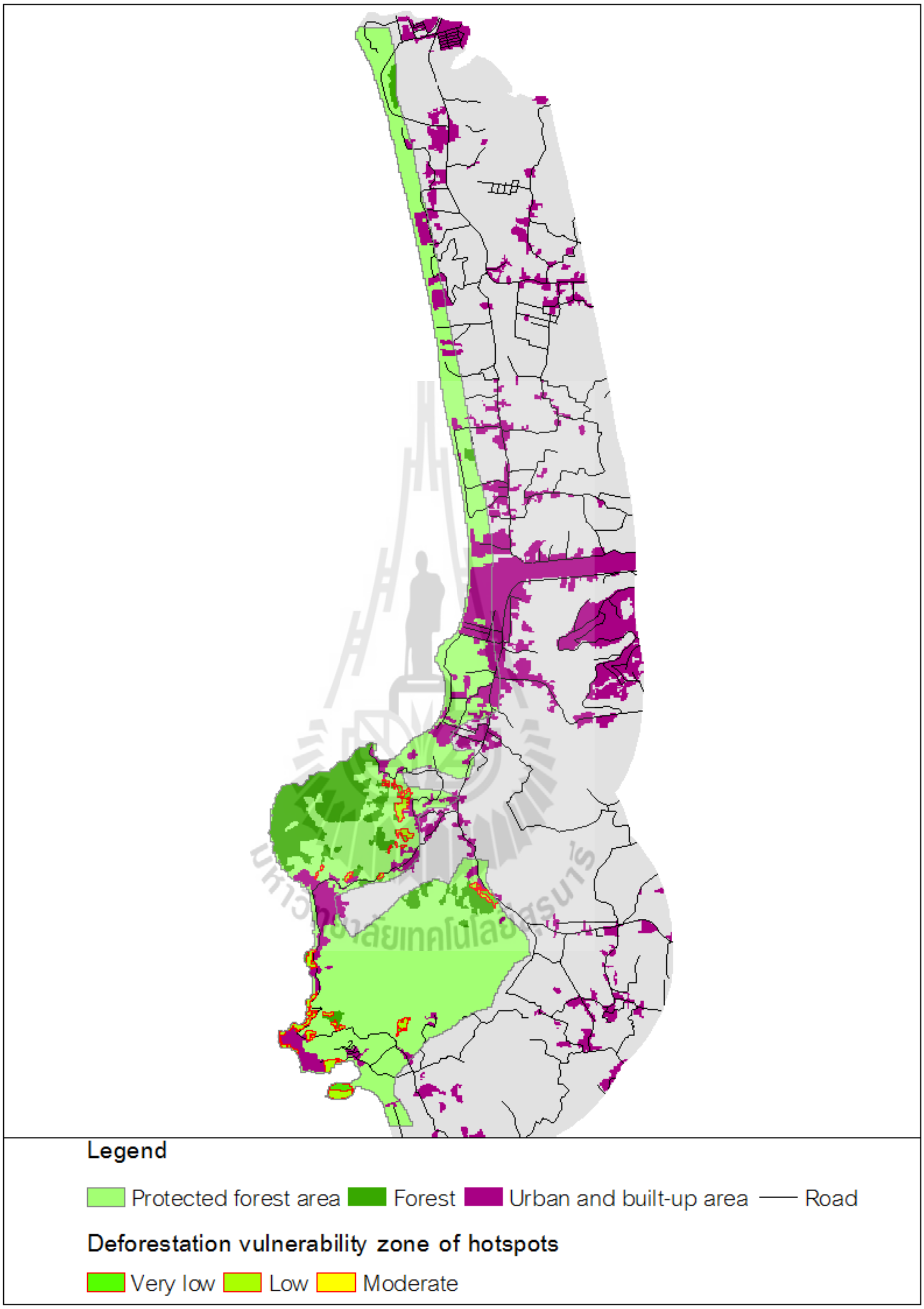


Figure 7.1 Predicted deforestation hotspot over deforestation vulnerability zone of Sirinath MNP.

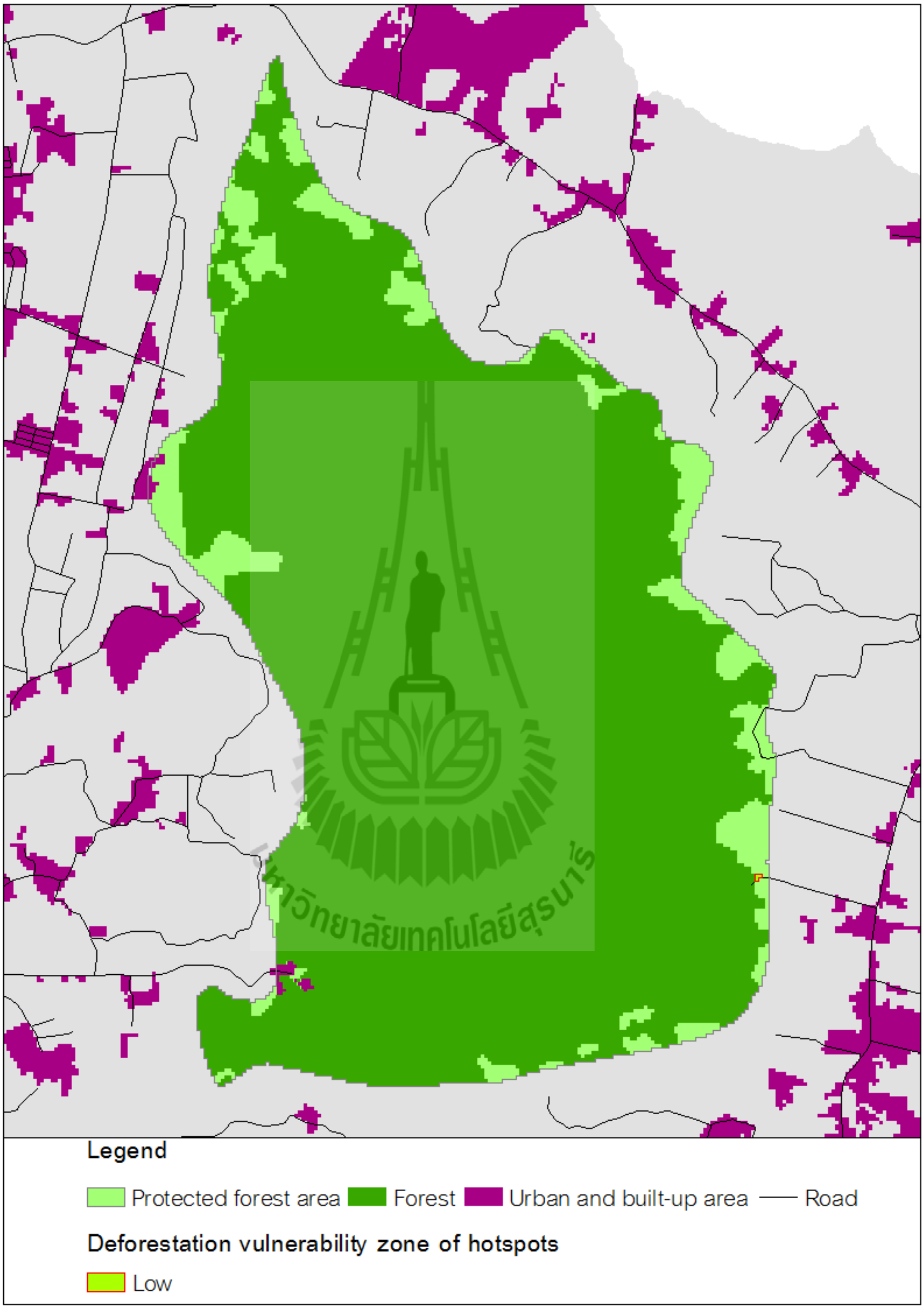


Figure 7.2 Predicted deforestation hotspot over deforestation vulnerability zone of Khao Phra Thaeo WCDEC.

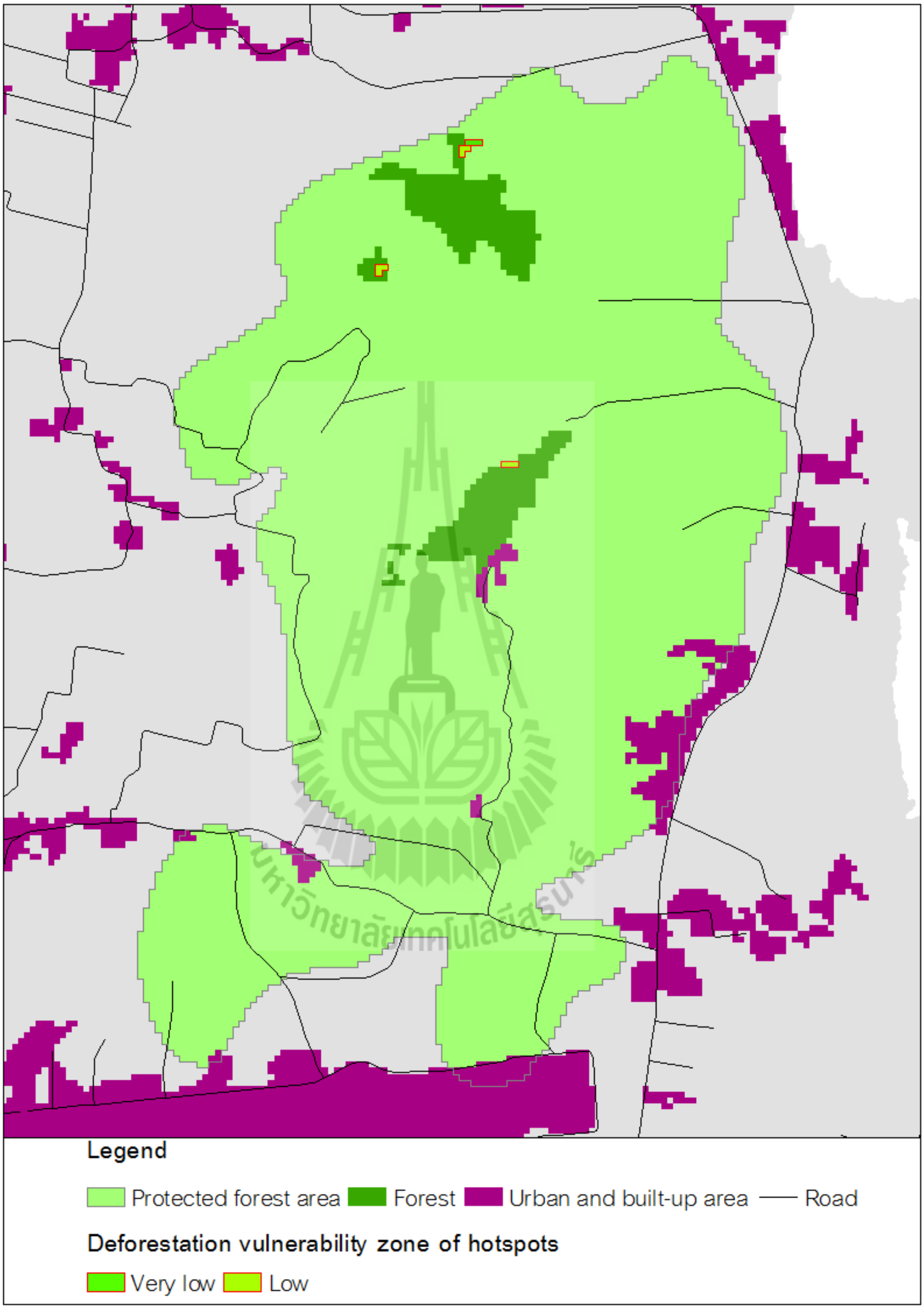


Figure 7.3 Predicted deforestation hotspot over deforestation vulnerability zone of Khao Mai Kaew NRF.

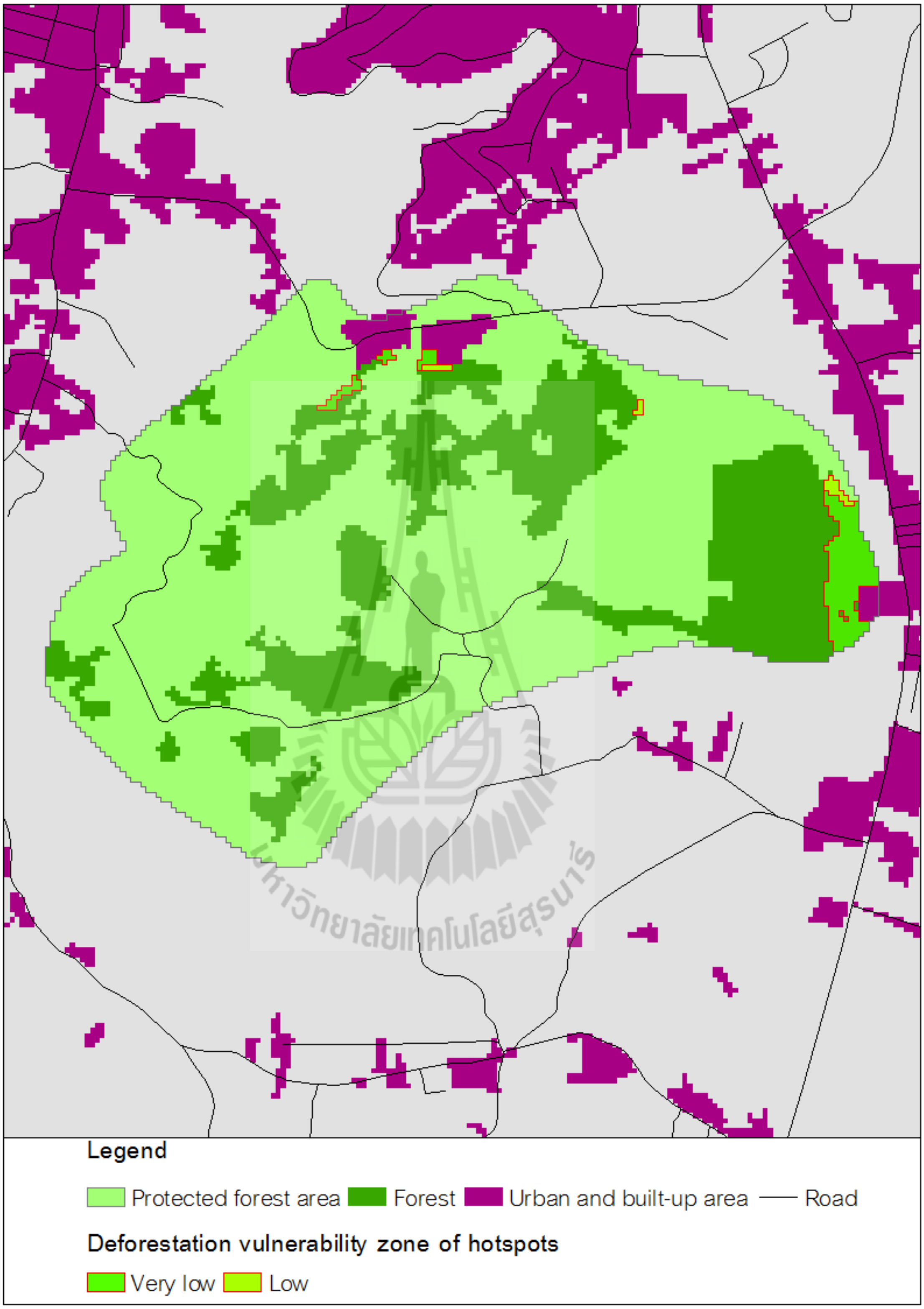


Figure 7.4 Predicted deforestation hotspot over deforestation vulnerability zone of Khao Bang Khanun NRF.

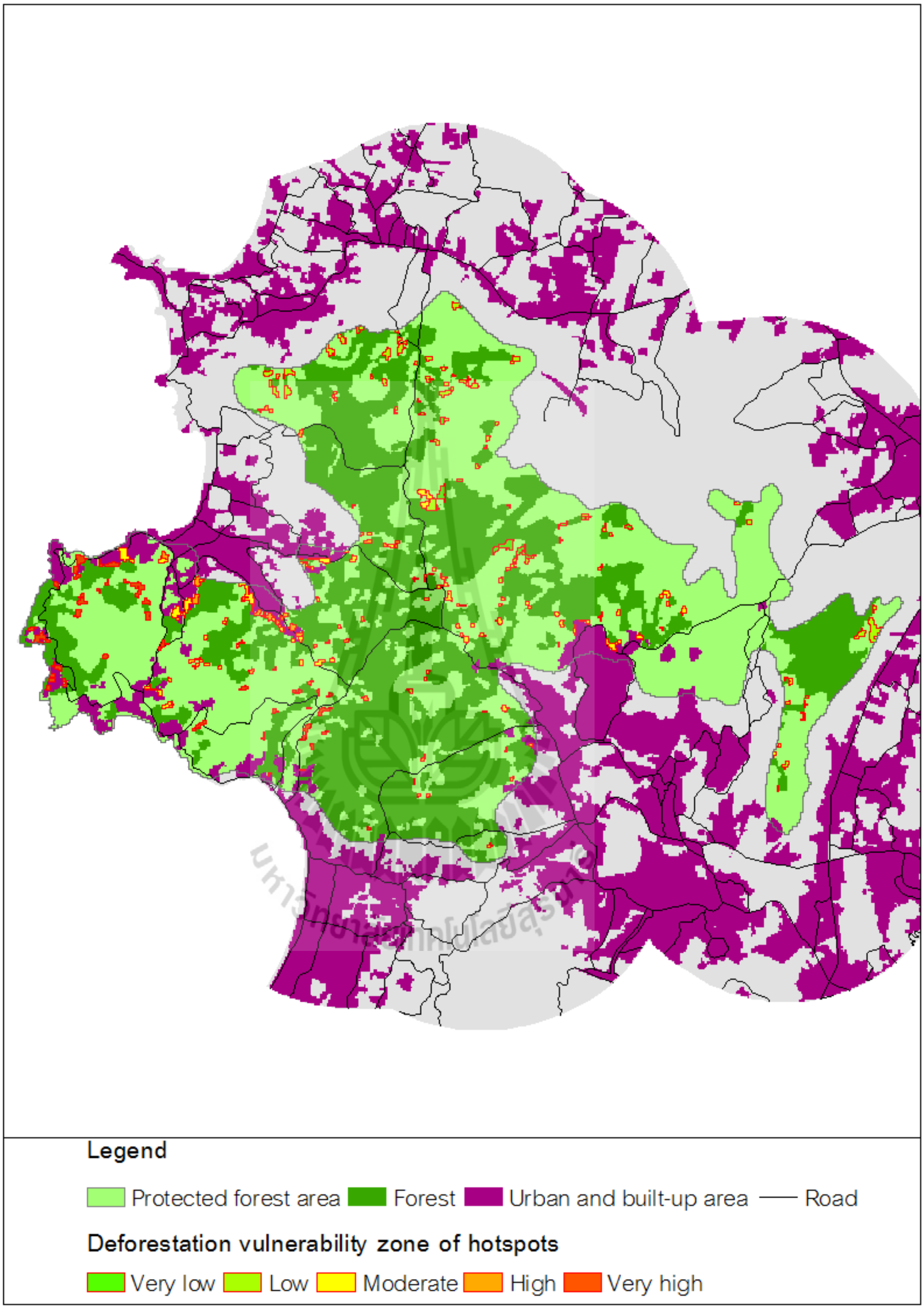


Figure 7.5 Predicted deforestation hotspot over deforestation vulnerability zone of Khao Kamala NRF.

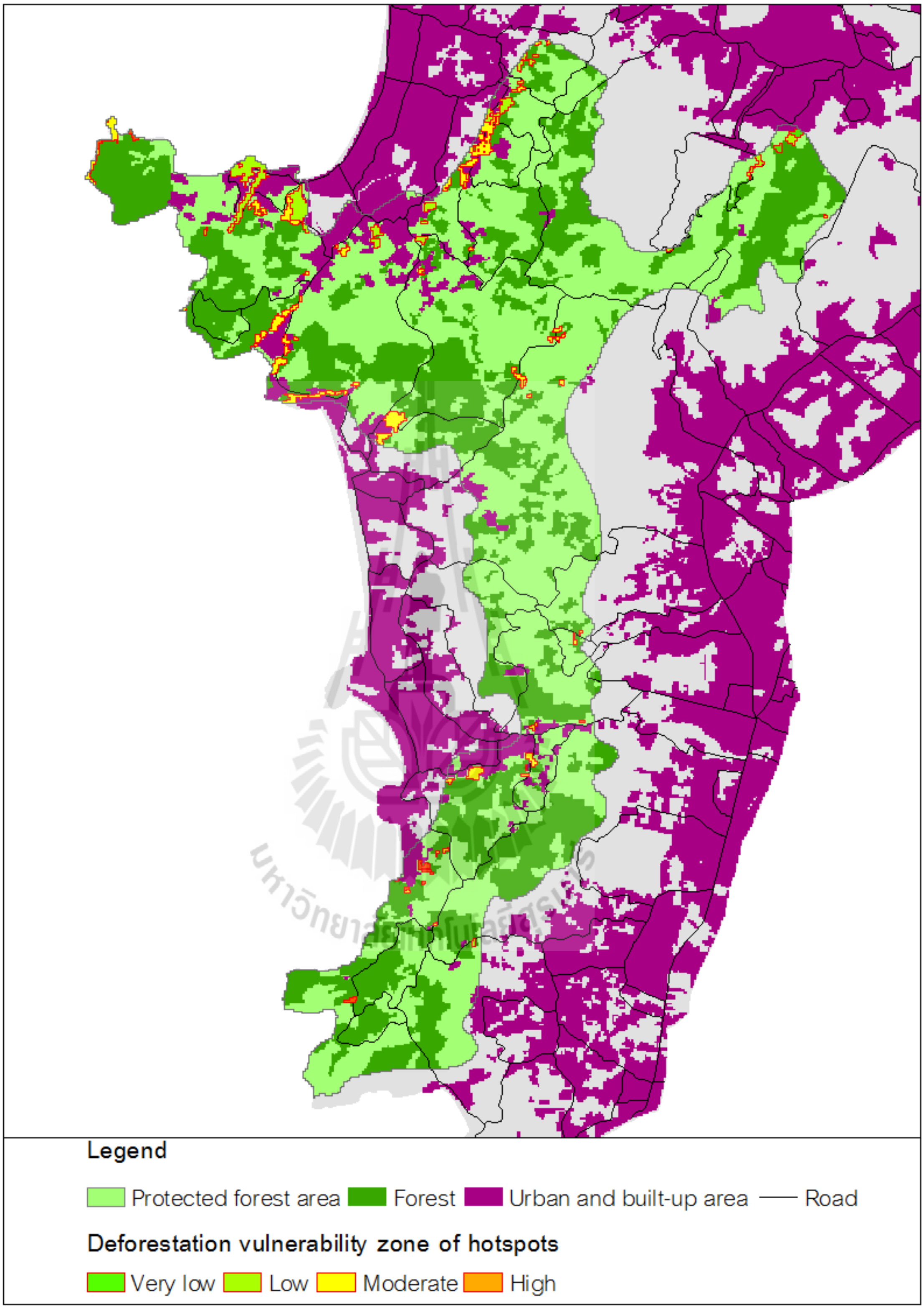


Figure 7.6 Predicted deforestation hotspot over deforestation vulnerability zone of Khao Nak Keod NRF.

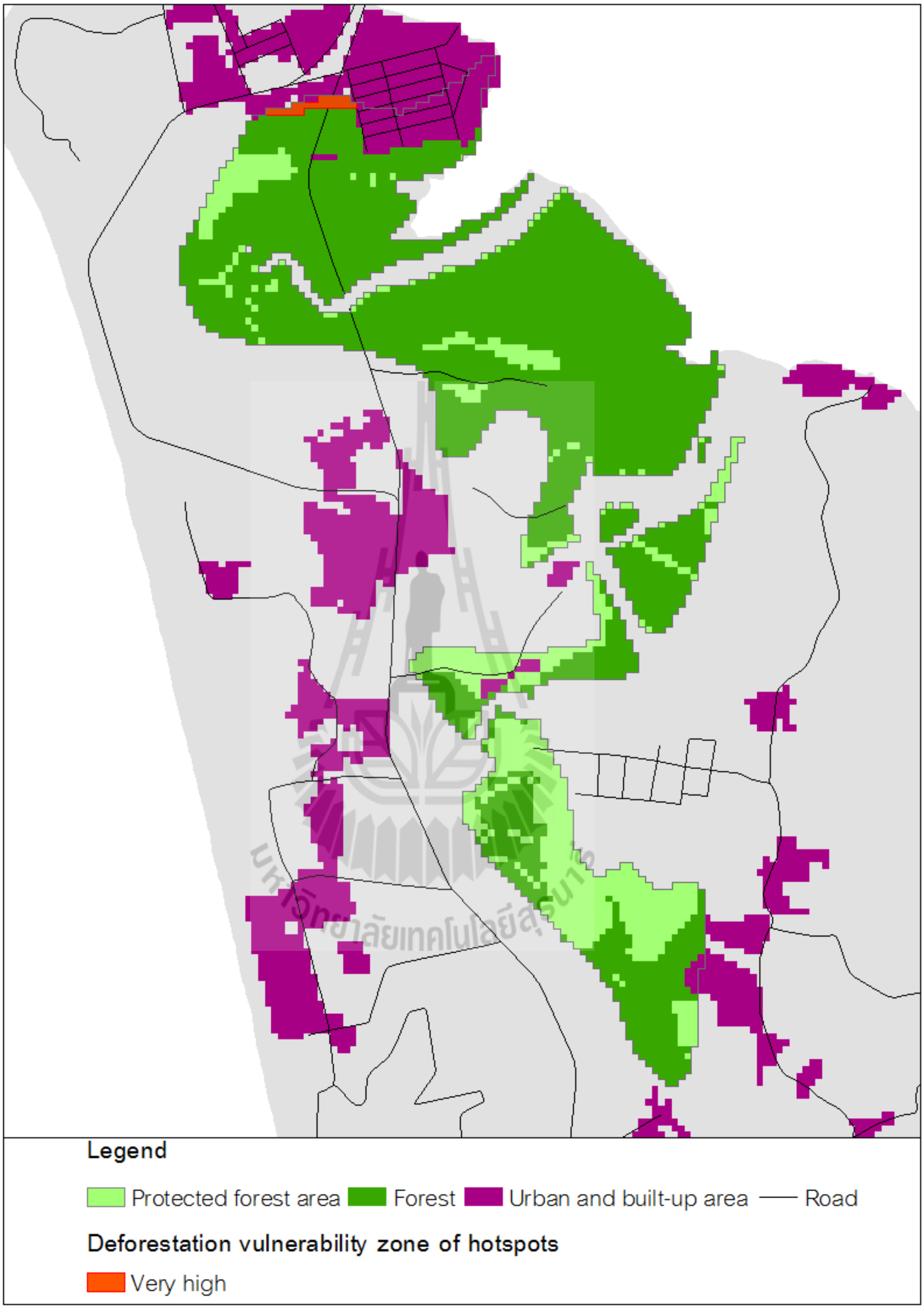


Figure 7.7 Predicted deforestation hotspot over deforestation vulnerability zone of Khlong U-Tapao NRF.

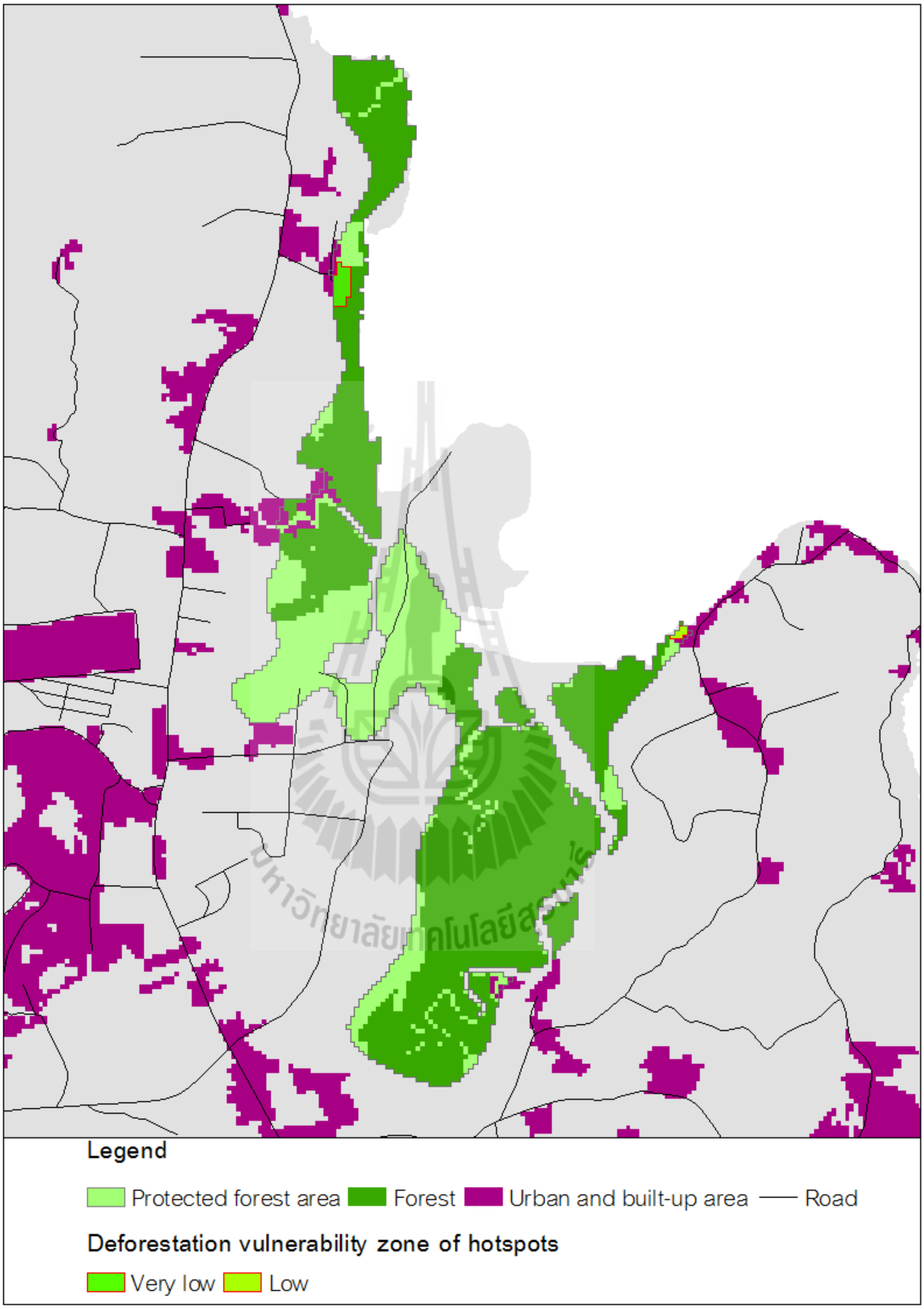


Figure 7.8 Predicted deforestation hotspot over deforestation vulnerability zone of Khlong Tha Maphrao NRF.

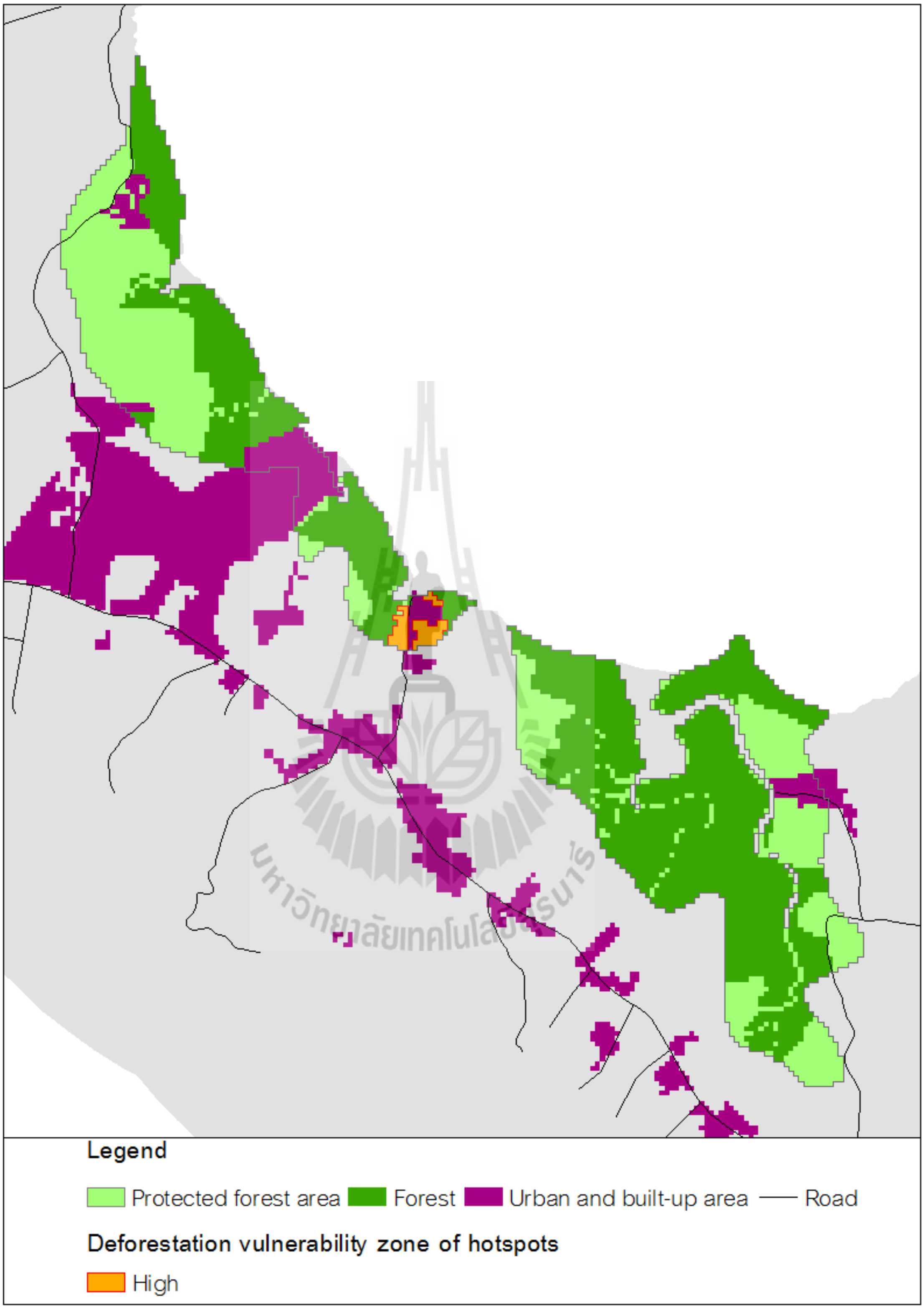


Figure 7.9 Predicted deforestation hotspot over deforestation vulnerability zone of Khlong Para NRF.

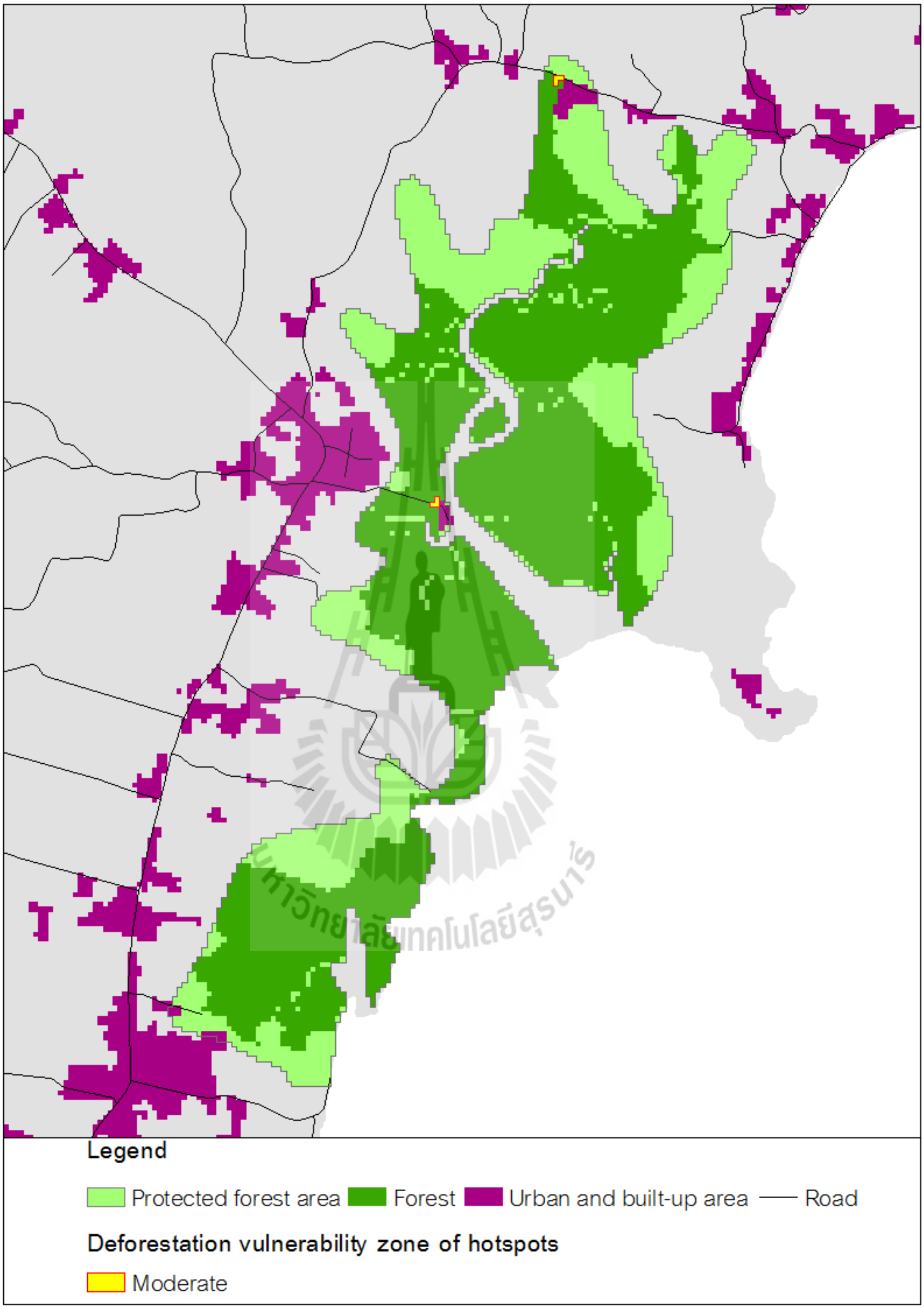


Figure 7.10 Predicted deforestation hotspot over deforestation vulnerability zone of Khlong Bangrong NRF.

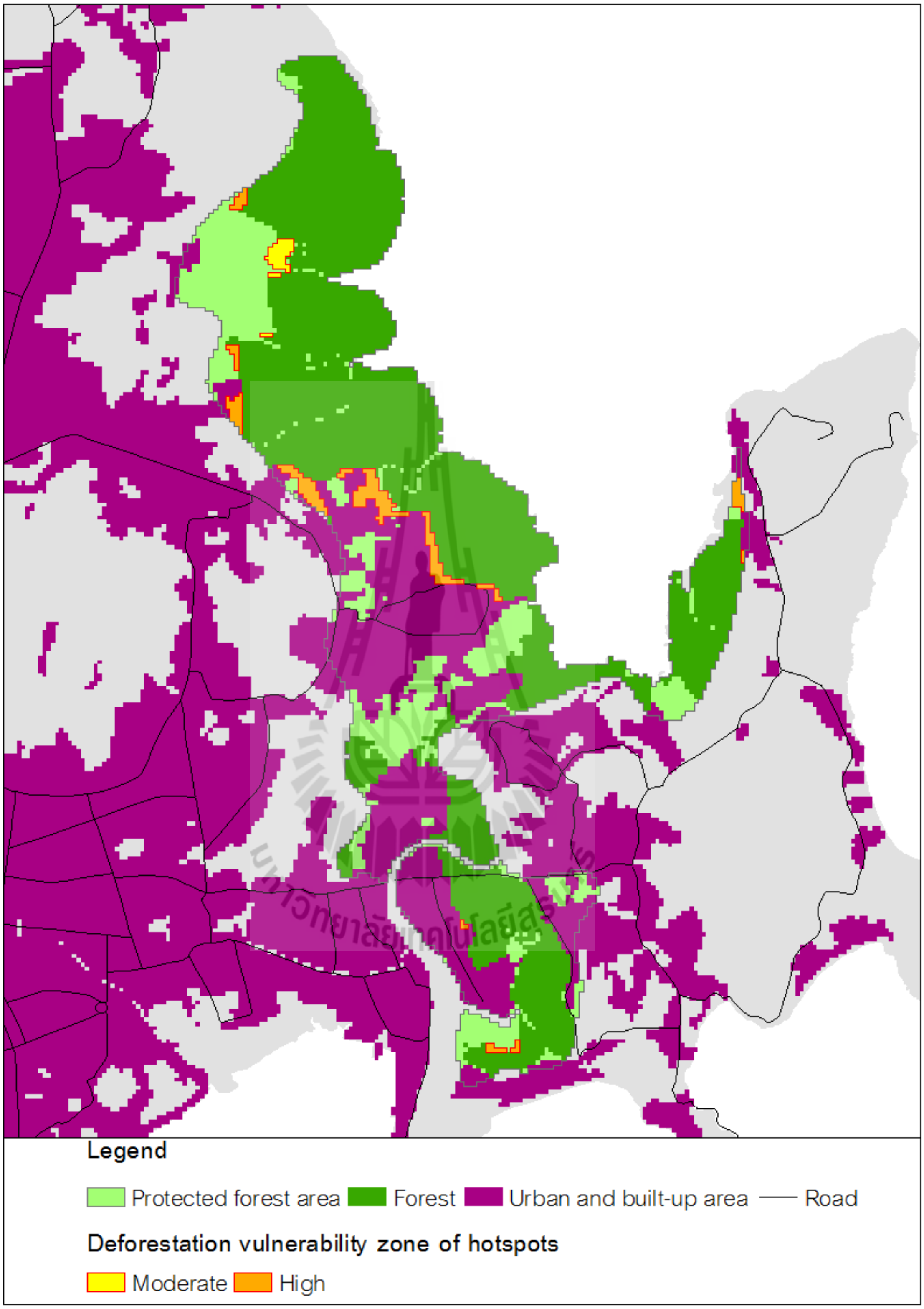


Figure 7.11 Predicted deforestation hotspot over deforestation vulnerability zone of Khlong Tajin NRF.

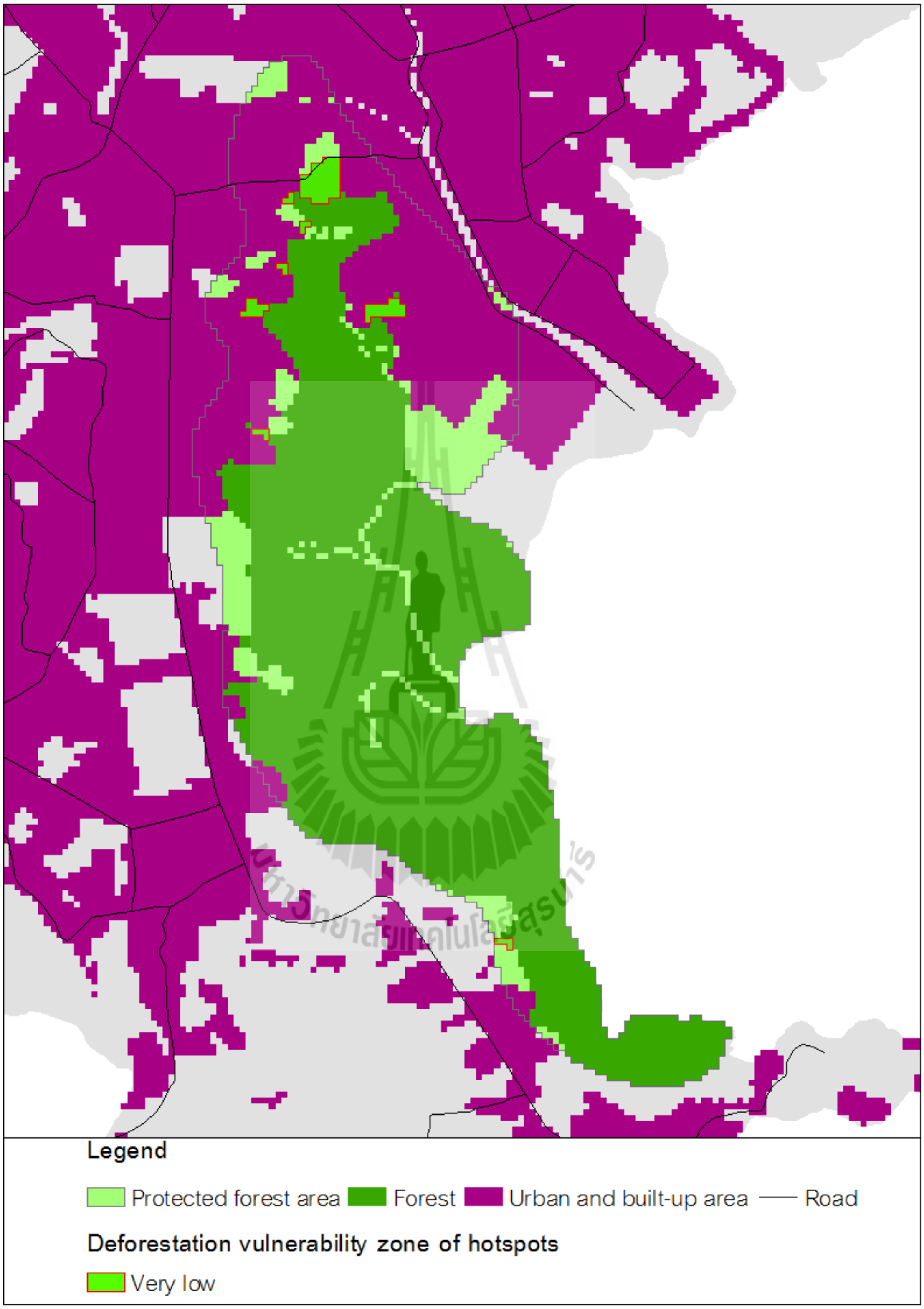


Figure 7.12 Predicted deforestation hotspot over deforestation vulnerability zone of Khlong Khopee NRF.

As results, there were no the predicted deforestation hotspot presented in three protected forest areas included Khao Sam Liam NRF, Khao Tosae NRF, and Khlong Tarau NRF within its boundary. These results infer the low probability of deforestation occurrence in these areas. On contrary, there were 12 protected forest areas which had various number of the predicted deforestation hotspots locating over different deforestation vulnerability zones. Khao Kamala NRF had the highest deforestation hotspot of 229 points while Khao Phra Thaeo WCDEC, Khlong U-Tapao NRF and the lowest hotspot number had the lowest deforestation hotspot of 1 point.

The characteristics of predictive deforestation hotspot in 12 protected forest areas can be elaborated in more detail according to legal status: national park (marine national park and wildlife conservation development and extension center) and national reserved forest area over evergreen and mangrove forests as below.

7.1.1 National park

Sirinath MNR, which had annual predicted deforested rate between 2014 and 2026 at 31.45 Rai, had 42 deforestation hotspots while Khao Phra Thaeo WCDEC which had annual predicted deforested rate at the same period at 0.26 Rai, had only 1 deforestation hotspot. However, most of deforestation hotspots of both national parks located in very low and low deforestation vulnerability zones.

7.1.2 National reserved forest area in evergreen forest

Khao Mai Kaew, Khao Bang Khanun, Khao Sam Liam, Khao Kamala, Khao Nak Keod and Khao Tosae NRFs, which were announced by National Reserved Forest act, mostly located in highland area over evergreen forest. It revealed that Khao Kamala and Khao Nak Keod NRFs with high annual predictive deforestation rate between 2014 and 2026 of 87.50 and 60.03 Rai, respectively had 229 and 92 deforestation hotspots. The most dominate location of deforestation hotspots in both national reserved forest areas were moderate deforestation vulnerability zone (see Table 7.1).

In contrast, Khao Mai Kaew and Khao Bang Khanun NRFs with low annual rate of predictive deforestation in the same period at 1.11 and 9.38 Rai, respectively had only 4 and 7 deforestation hotspots where located in very low and low deforestation vulnerability zones. Likewise, Khao Sam Liam and Khao Tosae NRFs with very low annual rate of predictive deforestation at 1.11 and 9.38 Rai, respectively had no deforestation hotspot.

Furthermore, it was also observed that number of deforestation hotspot in national reserved forest area in evergreen forest is directly related with annual predictive deforestation area between 2014 and 2026. The relationship can be confirmed by simple linear regression analysis as shown in Figure 7.13. Herewith, the relationship between number of deforestation hotspots (x) and annual predictive deforestation rate in Rai showed positive relationship with R^2 at 93.15% as:

$$y = 0.3961x + 4.4571 \quad (7.1)$$

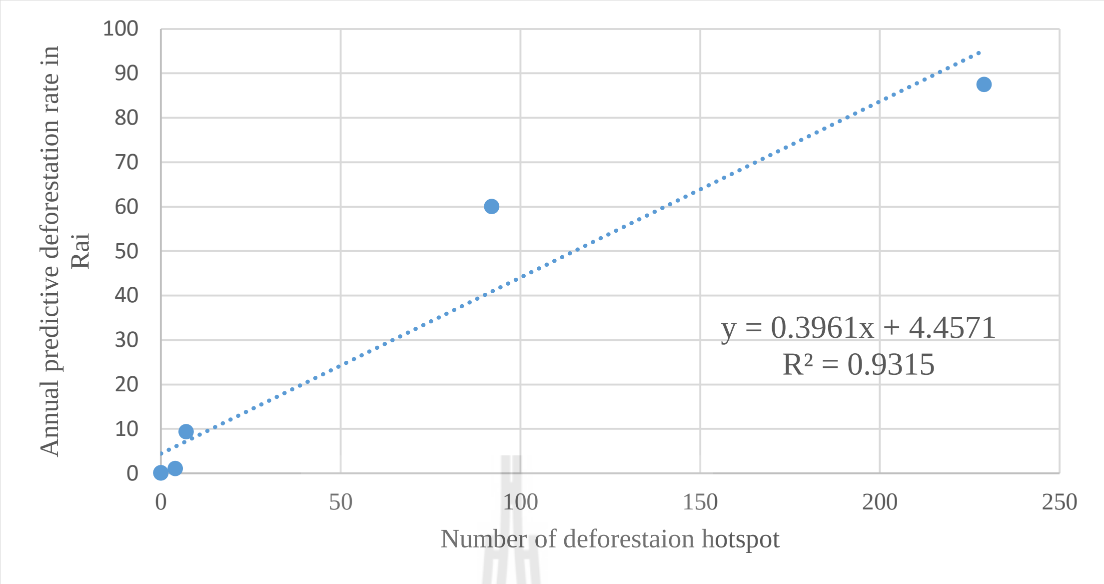


Figure 7.13 Simple linear regression analysis between number of deforestation hotspot and annual predictive deforestation rate between 2014 and 2026 of national reserved forest area in evergreen forest.

7.1.3 National reserved forest area in mangrove forest

In opposite to national reserved forest area in evergreen forest, Khlong U-Tapao, Khlong Tha Maphrao, Khlong Para, Khlong Bangrong, Khlong Tarau, Khlong Tajin and Khlong Khopee NRFs, which were also announced by National Reserved Forest act, mostly situated in lowland and coastal areas over mangrove forest. It revealed that Khlong Tajin and Khlong Khopee NRFs with annual rate of predictive deforestation between 2014 and 2026 at 9.44 and 3.29 Rai, respectively had 17 and 8 deforestation hotspots. The most dominate location of deforestation hotspots in Khlong Tajin NRF located in high deforestation vulnerability zone while all location of deforestation hotspots in Khlong Khopee NRF located in very low deforestation vulnerability zone (see Table 7.1).

In contrast, Khlong Para, Khlong Tha Maphrao, Khlong Bangrong and Khlong U-Tapao NRFs with very low annual rate of predictive deforestation between 2014 and 2026 had 3, 2, 2 and 1 deforestation hotspot, respectively. However, location of deforestation hotspot of Khlong Para and Khlong U-Tapao NRFs located in moderate and high deforestation vulnerability zone, respectively. In addition, Khlong Tarau NRF with annual rate of predictive deforestation between 2014 and 2026 at 0.07 Rai had no deforestation hotspot.

Furthermore, it was also found that number of deforestation hotspot in national reserved forest area in mangrove forest is directly related with annual predictive deforestation area between 2014 and 2026. The relationship can be confirmed by simple linear regression analysis as shown in Figure 7.14. Herewith, the relationship between number of deforestation hotspots (x) and annual predictive deforestation rate in Rai showed positive relationship with R^2 at 97.19% as:

$$y = 0.5348x - 0.0282 \qquad (7.2)$$

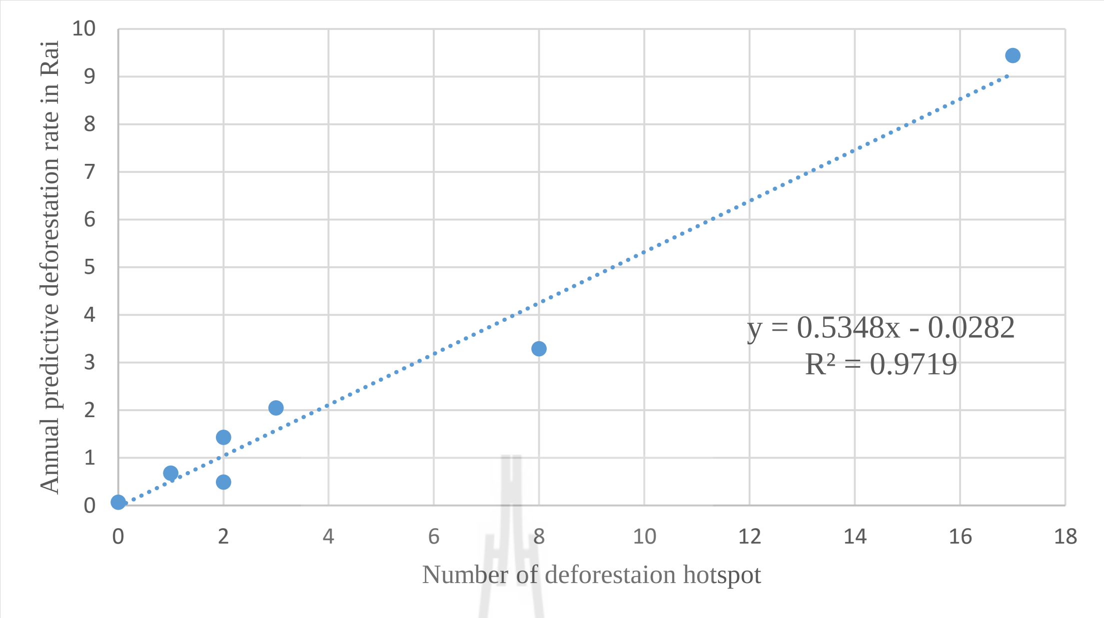


Figure 7.14 Simple linear regression analysis between number of deforestation hotspot and annual predictive deforestation rate between 2014 and 2026 of national reserved forest area in mangrove forest.

These deforestation hotspots can be used as baseline information for forest patrolling program in each protected forest areas. The deforestation hotspots which located on very low and low deforestation vulnerability zones can be patrolled in long period of time due to low probability of deforestation occurrence. On the contrary, the deforestation hotspot which located on moderate, high and very high deforestation vulnerability zones should be patrolled in short period of time due to high probability of deforestation occurrence.

Furthermore, DNP, who responsibilities on national park, forest park, wildlife sanctuary and non-hunting area, RFD who responsibilities on national reserved forest in highland forest and Department of Marine and Coastal Resources (DMCR) who responsibilities on national reserved forest in mangrove forest should frequently monitor land cover by remotely sensed data. Herewith free download data included Landsat 8 of USGS (United State Geological Survey) or Sentinel data of ESA (European Space Agency) can used to detect land cover change over hotspot areas.

7.2 Forest protection unit allocation

The derived deforestation hotspot area of each protected forest area which situated in moderate, high and very high deforestation vulnerability zones with area equal or greater than 10,000 sq. m (or 6.25 Rai) was here used to identify centroid for forest protection unit allocation. Number of the forest protection unit with deforestation vulnerability zones of 15 protected forest areas is presented in Table 7.2 and the distribution of the forest protection unit over deforestation vulnerability zones of 5 protected forest areas is presented in Figures 7.15 to 7.19. Meanwhile the coordinate of forest protection unit of 5 protected forest areas is presented in Tables 7.3 to 7.7.

Table 7.2 Number of the forest protection unit with deforestation vulnerability zones of 15 protected forest areas.

Protected forest area	Number of forest protection unit			
	Moderate	High	Very high	Total
Sirinath MNP	-	-	-	0
Khao Phra Thaeo WCDEC	-	-	-	0
Khao Mai Kaew NRF	-	-	-	0
Khao Bang Khanun NRF	-	-	-	0
Khao Sam Liam NRF	-	-	-	0
Khao Kamala NRF	6	1	8	15
Khao Nak Keod NRF	19	1	-	20
Khao Tosae NRF	-	-	-	0
Khlong U-Tapao NRF	-	-	1	1
Khlong Tha Maphrao NRF	-	-	-	0
Khlong Para NRF	-	2	-	2
Khlong Bangrong NRF	-	-	-	0
Khlong Tarau NRF	-	-	-	0
Khlong Tajin NRF	1	5	-	6
Khlong Khopee NRF	-	-	-	0

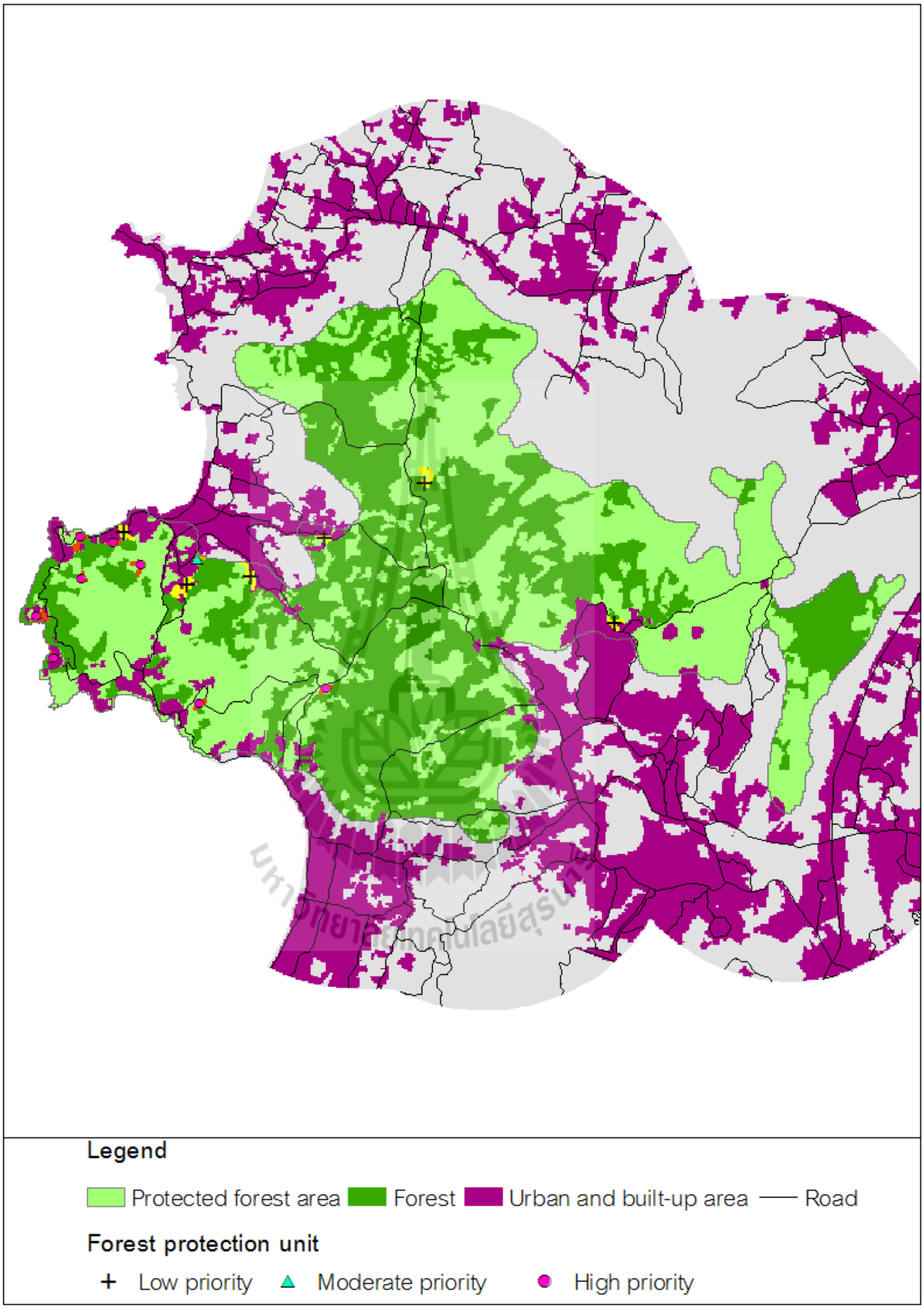


Figure 7.15 Distribution of forest protection unit of Khao Kamala NRF.

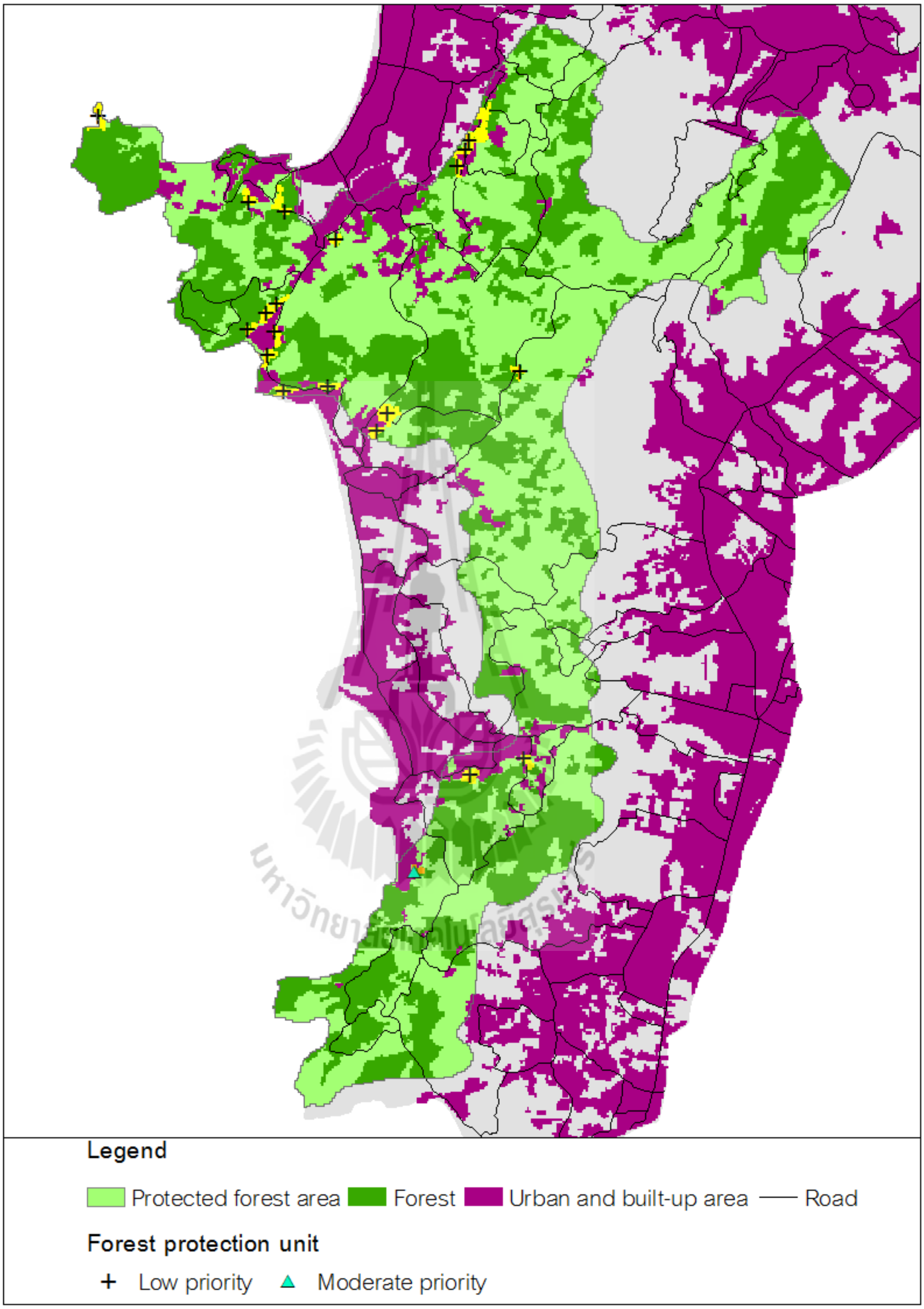


Figure 7.16 Distribution of forest protection unit of Khao Nak Keod NRF.

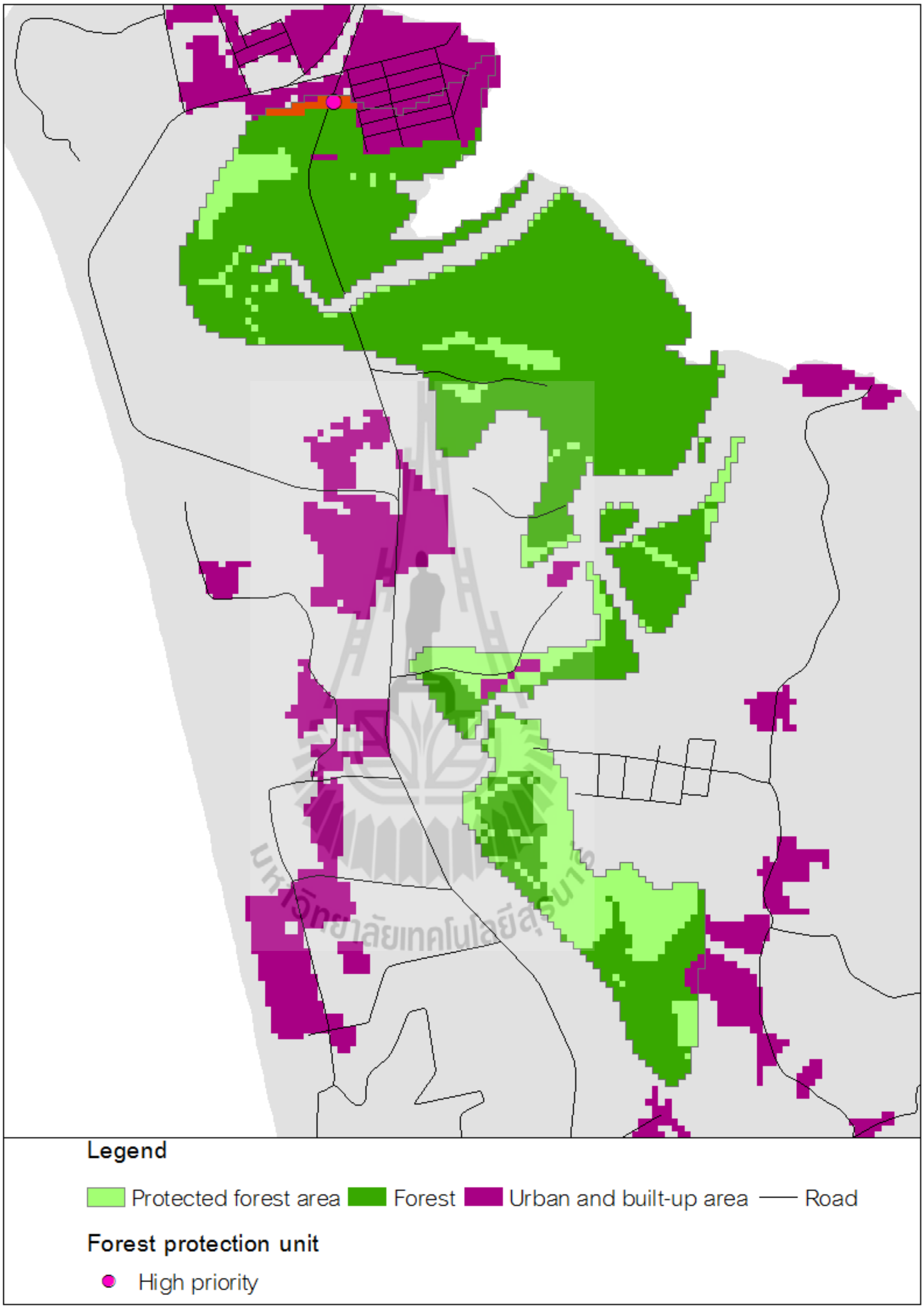


Figure 7.17 Distribution of forest protection unit of Khlong U-Tapao NRF.

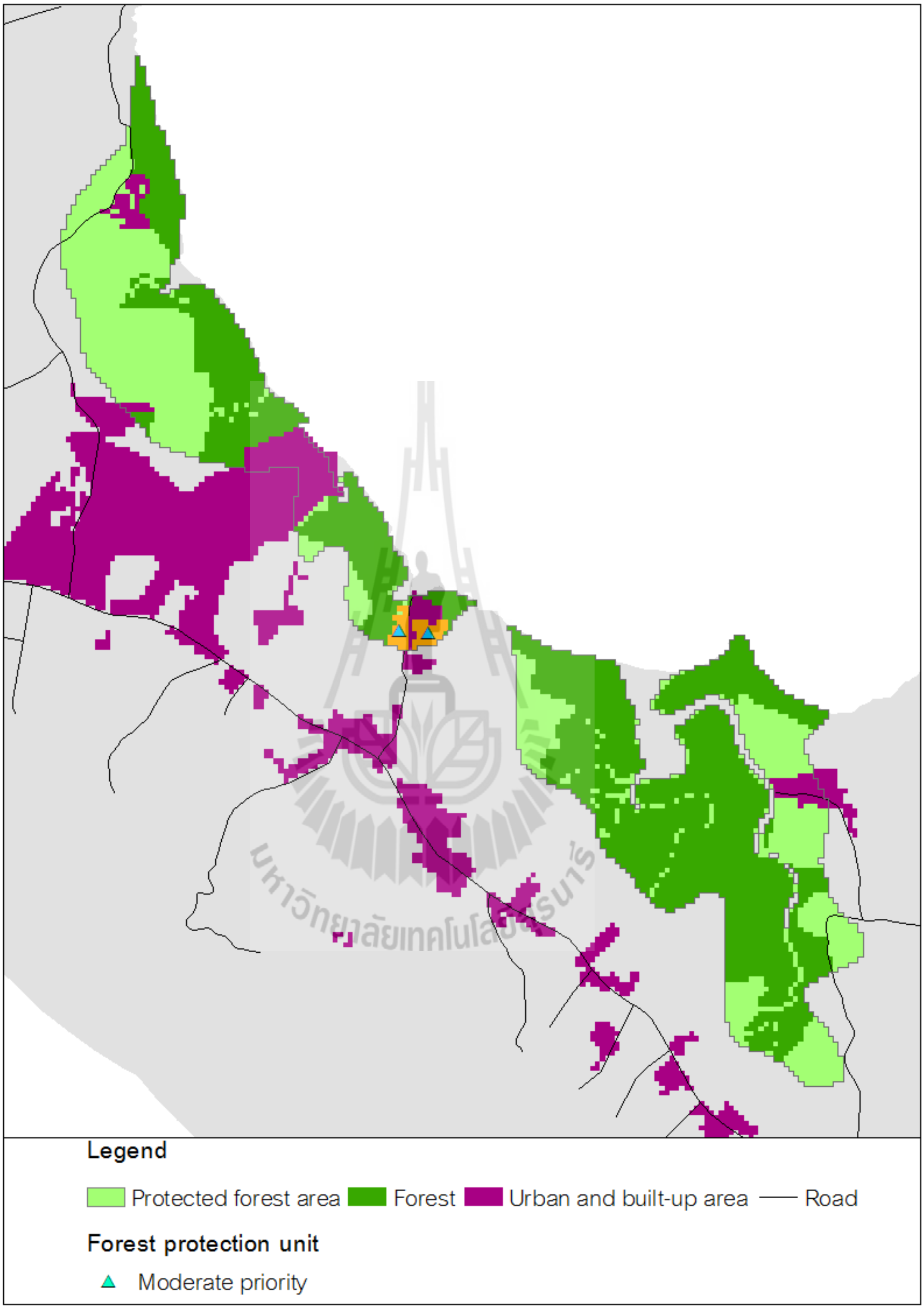


Figure 7.18 Distribution of forest protection unit of Khlong Para NRF.

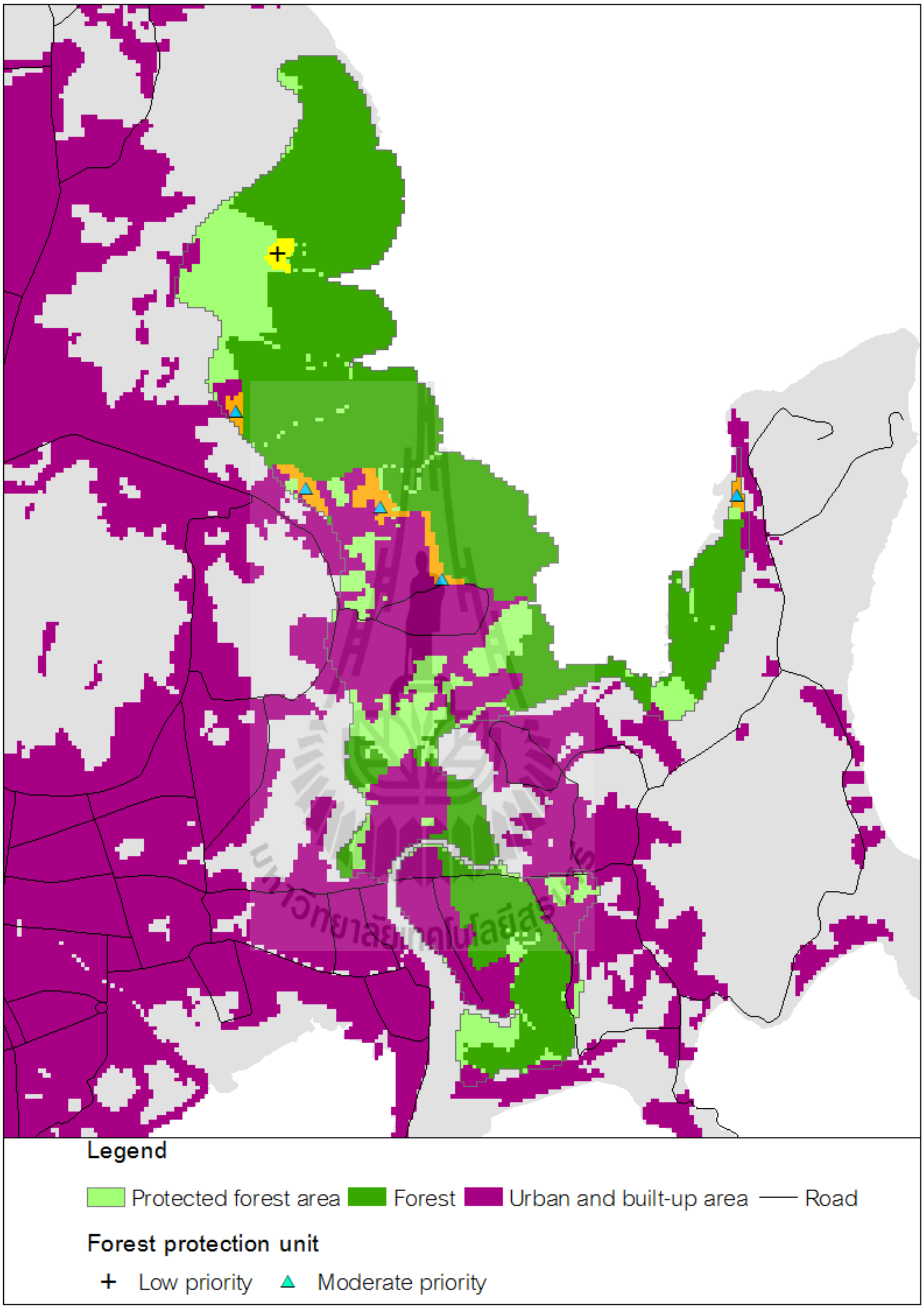


Figure 7.19 Distribution of forest protection unit of Khlong Tajin NRF.

Table 7.3 Location of forest protection unit of Khao Nak Keod NRF.

No.	Deforestation vulnerability zone	X coordinate	Y coordinate
1	Moderate	418910.15	872372.67
2	Moderate	423651.15	872065.17
3	Moderate	423597.40	871945.17
4	Moderate	423495.38	871746.90
5	Moderate	420838.65	871277.67
6	Moderate	421301.15	871165.17
7	Moderate	421946.74	870796.06
8	Moderate	421188.65	869977.67
9	Moderate	421062.96	869858.92
10	Moderate	420826.15	869652.67
11	Moderate	421162.65	869627.67
12	Moderate	421076.15	869327.67
13	Moderate	424294.90	869127.67
14	Moderate	421851.15	868927.67
15	Moderate	421276.15	868865.98
16	Moderate	422604.82	868586.84
17	Moderate	422463.65	868365.17
18	Moderate	424351.15	864190.17
19	Moderate	423657.11	863968.15
20	High	422951.15	862740.17

Table 7.4 Location of forest protection unit of Khao Kamala NRF.

No.	Deforestation vulnerability zone	X coordinate	Y coordinate
1	Moderate	424280.69	879241.11
2	Moderate	419808.32	878500.32
3	Moderate	422781.94	878419.86
4	Very high	419636.57	878357.29
5	Very high	419143.19	878428.61
6	High	420886.94	878103.61
7	Very high	420043.19	878016.11
8	Very high	419168.19	877816.11
9	Moderate	421686.94	877853.61
10	Moderate	420736.94	877728.61
11	Very high	418486.94	877253.61
12	Moderate	427094.08	877158.97
13	Very high	418743.19	876628.61
14	Very high	422793.19	876191.11
15	Very high	420918.19	875953.61

Table 7.5 Location of forest protection unit of Khlong U-Tapao NRF.

No.	Deforestation vulnerability zone	X coordinate	Y coordinate
1	Very high	422425.32	905986.05

Table 7.6 Location of forest protection unit of Khlong Para NRF.

No.	Deforestation vulnerability zone	X coordinate	Y coordinate
1	High	432303.47	893563.81
2	High	432445.44	893550.42

Table 7.7 Location of forest protection unit of Khlong Tajin NRF.

No.	Deforestation vulnerability zone	X coordinate	Y coordinate
1	Moderate	434724.70	875397.03
2	High	434473.70	874473.03
3	High	437421.76	873977.91
4	High	434882.44	874020.24
5	High	435324.70	873909.53
6	High	435687.20	873484.53

There were five protected forest areas included Khao Kamala NRF, Khao Nak Keod NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF required to establish forest protection area over hotspot area equal or more than 10,000 sq. m or 6.25 Rai with number of 15, 20, 1, 2, and 6 units, respectively. As results, it was observed that top three of five protected forest areas, namely Khao Nak Keod, Khao Kamala, and Klong Tajin NRFs with 20, 15, and 6 forest protection units, had the predicted annual deforestation rate between 2014 and 2026 at 0.096 sq. km or 60.03 Rai, 0.140 sq. km or 87.50 Rai and 0.0053 sq. km or 9.44 Rai, respectively. Meanwhile, Khlong Para and Khlong U-Tapao NRFs with 2 and 1 forest protection units had the predicted annual deforestation rate between 2014 and 2026 at 0.0033 sq. km or 2.05 Rai and 0.0011 sq. km or 0.68 Rai, respectively (Table 7.8). The result infers that number of forest protection unit directly relates with annual predictive deforestation rate between 2014 and 2026. The relationship can be confirmed by simple linear regression analysis as shown in Figure 7.20. Herewith, the relationship between number of forest protection unit (x) and annual predictive deforestation rate in Rai showed positive relationship with R^2 at 78.41% as:

$$y = 4.1935x - 4.9632 \tag{7.3}$$

In case of Sirinath MNP, it had annual predictive deforestation rate at 0.0503 sq. km or 31.45 Rai and it was higher than Khlong Tajin NRF but it had none forest protection unit. Because area of one hotspot on moderate deforestation zone was less than 10,000 sq. m or 6.25 Rai.

Table 7.8 Number of deforestation hotspot and forest protection units and annual predicted deforestation of 15 protected forest areas.

Protected forest area	Deforestation Vulnerability zonation					Number of		Deforestation rate	
	VL	L	M	H	VH	Hotspot	Protection Unit	Sq. km/ year	Rai/ Year
Sirinath MNP	16	25	1	-	-	42	0	0.0503	31.45
Khao Phra Thaeo WCDEC	-	1	-	-	-	1	0	0.0004	0.26
Khao Mai Kaew NRF	1	3	-	-	-	4	0	0.0018	1.11
Khao Bang Khanun NRF	4	3	-	-	-	7	0	0.015	9.38
Khao Sam Liam NRF	-	-	-	-	-	0	0	0.0002	0.10
Khao Kamala NRF	14	61	84	37	33	229	15	0.14	87.50
Khao Nak Keod NRF	2	25	56	9	-	92	20	0.096	60.03
Khao Tosae NRF	-	-	-	-	-	0	0	0.0002	0.13
Khlong U-Tapao NRF	-	-	-	-	1	1	1	0.0011	0.68
Khlong Tha Maphrao NRF	1	1	-	-	-	2	0	0.0023	1.43
Khlong Para NRF	-	-	-	3	-	3	2	0.0033	2.05
Khlong Bangrong NRF	-	-	2	-	-	2	0	0.0008	0.49
Khlong Tarau NRF	-	-	-	-	-	0	0	0.0001	0.07
Khlong Tajin NRF	-	-	3	14	-	17	6	0.0151	9.44
Khlong Khopee NRF	8	-	-	-	-	8	0	0.0053	3.29

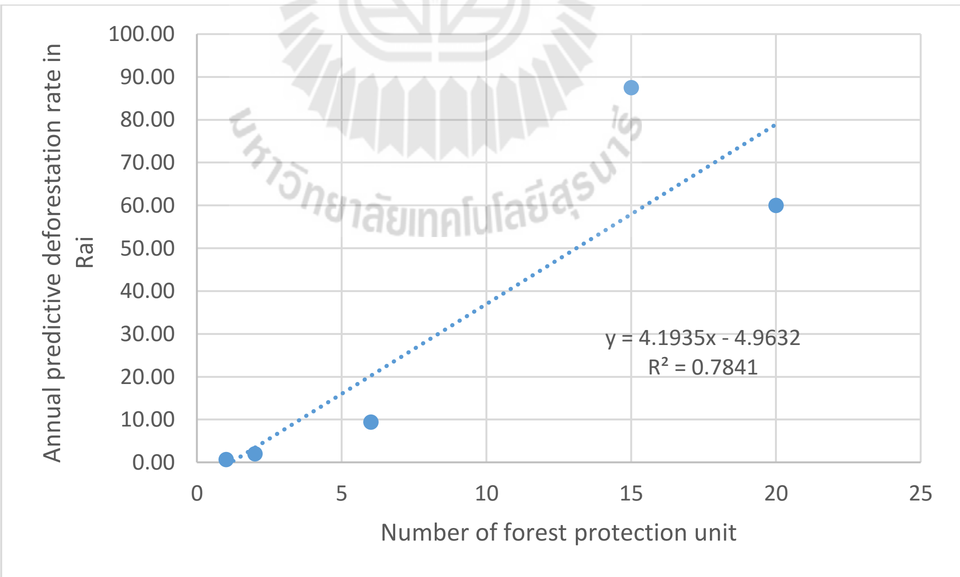


Figure 7.20 Simple linear regression analysis between number of forest protection unit and annual predictive deforestation rate between 2014 and 2026 of 5 national reserved forest areas.

CHAPTER VIII

CONCLUSION AND RECOMMENDATION

Under this chapter, four main findings are reported according objectives in the study which include (1) land use and land cover assessment and its change and deforestation (Chapter IV), (2) land use and land cover prediction (Chapter V), (3) deforestation vulnerability analysis (Chapter VI), and (4) deforestation hotspot and forest protection unit allocation (Chapter VII) are separately concluded and recommended for future research and development.

8.1 Conclusion

8.1.1 LULC assessment of Phuket Island in 1995, 2002 and 2014

Main LULC type of Phuket Island in 1995 and 2002 as historical record and recent LULC data in 2014, which was visually interpreted from black and white orthophoto, color orthophoto and THEOS data, respectively was orchard and perennial trees. At the same period urban and built-up areas of Phuket Island had continuously increased while orchard and perennial trees and evergreen forest, however, had continuously decreased. In addition, the accuracy assessment of the interpreted LULC in 2014 based on 743 random stratified sampling points in 2015 was 97.86% for overall accuracy and 97.05% for Kappa hat coefficient.

8.1.2 LULC assessment of protected forest areas in 1995, 2002, and 2014

The forest areas in 1995, 2002, and 2014 of 8 protected forest areas included Sirinath MNP, Khao Bang Khanun NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, Khlong Tajin NRF, and Khlong Khopee NRF had continuously decreased due to increasing of urban and built-up area or orchard and perennial trees or aquaculture area. Meanwhile the forest areas in the same periods of 7 protected forest areas included Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Sam Liam NRF, Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Bangrong NRF, and Khlong Tarau NRF were rather stable.

8.1.3 LULC change of Phuket Island between 1995 and 2014

The increased LULC types of Phuket Island between 1995 and 2014 were urban and built-up area, water body, and miscellaneous land with annual rate of 3.1248, 0.0308, and 0.0982 sq. km, respectively. On contrary, the decreased LULC types were paddy field, field crop and horticulture, orchard and perennial trees, aquaculture area, idle land, evergreen forest, mangrove forest and scrub with annual rate of 0.1916, 0.0037, 1.1066, 0.0019, 1.0702, 0.6997, 0.0837, and 0.0963 sq. km, respectively.

8.1.4 LULC change of protected forest areas between 1995 and 2004

Urban and built-up area between 1995 and 2014 had been continuously increased in 14 protected forest area, except Khao Sam Liam NRF. On contrary, evergreen and mangrove forest areas in 15 protected forest areas had been continuously decreased.

8.1.5 Deforestation in Phuket Island between 1995 and 2014

During 1995 to 2014 deforestation in Phuket Island was about 14.88 sq. km with annual rate of 0.783 sq. km. In this period, area of evergreen forest was loosen about 13.29 sq. km with annual rate of 0.699 sq. km while area of mangrove forest was loosen about 1.59 sq. km with annual rate of 0.084 sq. km. This finding shows that deforestation takes place in evergreen forest more than mangrove forest.

8.1.6 Deforestation in forest protected area between 1995 and 2014

During 1995 to 2014 all 15 protected forest areas were deforested with various rates. The minimal annual deforestation rate occurred in Khao Tosae NRF with rate of 0.0001 sq. km while the maximal annual deforestation rate occurred in Khao Nak Keod NRF with rate of 0.2082 sq. km. The deforested area of 15 protected forest areas was about 9.6924 sq. km with annual deforestation rate of 0.5170 sq. km. In addition, deforestation between 1995 and 2002 with annual rate of 0.5635 sq.km was higher than deforestation between 2002 and 2014 with annual rate of 0.4825 sq.km. This finding shows that forest protection activity between 2002 and 2014 is more intensive than its activity between 1995 and 2002.

8.1.7 Optimum geospatial model for LULC prediction

Based on accuracy assessment (overall accuracy and Kappa hat coefficient) between the predicted LULC in 2014 from geospatial models: CA-Markov model, Land Change Modeler and CLUE-S model and the interpreted LULC data in 2014 as reference data, an optimum geospatial prediction model for prediction LULC in 9 protected forest areas included Sirinath MNP, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Nak Keod NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, and Khlong Bangrong NRF was

CLUE-S model. While CA-Markov model was an optimum geospatial prediction model for prediction LULC in 6 protected forest areas included Khao Kamala NRF, Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee NRF. The derived optimum geospatial model of each protected forest area was further used to predict LULC in 2026.

8.1.8 LULC prediction in 2026

The derived LULC prediction provides the possibility of LULC change between 2014 and 2026 within boundary of protected forest area and with buffer zone 2.5 km, especially the increasing of urban and built-up area.

8.1.9 Deforestation prediction between 2014 and 2026

Annual highest predictive deforestation rate occurred in Khao Kamala NRF with value of 0.1400 sq.km while annual lowest predictive deforestation rate occurred in Khong Tarau NRF with value of 0.0001 sq.km. Meanwhile the highest percentage of deforestation from the existing forest area in 2014 was found in Sirinath MNP with value of 18.7632 percent and the lowest percentage of deforestation from the existing forest area in 2014 occurred in Khao Phra Thaeo WCDEC with value of 0.0267 percent. These results implies about deforestation vulnerability and its severity in each protected forest areas.

8.1.10 Optimum geospatial method for deforestation vulnerability analysis

Based on accuracy assessment using ROC value, FR method was an optimum geospatial technique for deforestation vulnerability analysis of 10 protected forest areas included Sirinath MNP, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khlong Tha Maphrao NRF, Khlong Para NRF, and Khlong Bangrong NRF.

Meanwhile LRA method was an optimum geospatial technique for deforestation vulnerability analysis of 5 protected forest areas included Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Tarau NRF, Khlong Tajin NRF, and Khlong Khopee NRF. However, result of accuracy assessment using proportional weighted of correctness revealed that FR method provided higher accuracy than LRA method in all protected forest areas. As a result, FR method was chosen as optimum geospatial technique for deforestation vulnerability analysis and zonation based on deforested area between 2002 and 2014.

8.1.11 Deforestation vulnerability analysis and zonation

The deforestation vulnerability analysis of 15 protected forest areas was implemented based on deforestation area between 2002 and 2014 using FR method. The derived deforestation vulnerability indices were further classified into 5 classes: very low, low, moderate, high, and very high.

Based on deforestation vulnerability zonation with buffer zone 2.5 km, it was found that there were 11 protected forest areas with low risk of deforestation included Sirinath MNP, Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khao Bang Khanun NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khao Tosae NRF, Khlong Tha Maphrao NRF, Khlong Bangrong NRF, Khlong Tarau NRF, and Khlong Khopee NRF. In contrast, there were 4 protected forest areas with high risk of deforestation included Khao Sam Liam NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF.

Meanwhile, it was found that there were only 7 protected forest areas with low risk of deforestation based on deforestation vulnerability zonation without buffer zone included Sirinath MNP, Khao Mai Kaew NRF, Khao Sam Liam NRF, Khlong Tha Maphrao NRF, Khlong Bangrong NRF, Khlong Tarau NRF, and Khlong Khopee NRF. On contrary, there were 8 protected forest areas with high risk of deforestation included Khao Phra Thaeo WCDEC, Khao Bang Khanun NRF, Khao Kamala NRF, Khao Nak Keod NRF, Khao Tosae NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF.

8.1.12 Forest area in 2014 and deforestation vulnerability zonation

There were 7 protected forest areas which the existing forest area in 2014 more than 50 percent situated in very low and low deforestation vulnerability zones included Khao Bang Khanun NRF, Khao Sam Liam NRF, Khao Tosae NRF, Khlong Tha Maphrao NRF, Khlong Bangrong NRF, Khlong Tarau NRF, and Khlong Khopee NRF. In contrast, there were 5 protected forest areas which the existing forest area in 2014 more than 50 percent allocated in high and very high deforestation vulnerability zones included Khao Phra Thaeo WCDEC, Khao Mai Kaew NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF. Meanwhile, there were 3 protected forest areas which the existing forest area in 2014 approximately 50 percent situated in moderate deforestation vulnerability zones included Sirinath MNP, Khao Kamala NRF, and Khao Nak Keod NRF.

8.1.13 Deforestation hotspot allocation

There were no the predicted deforestation hotspot with area equal or more than 1,600 sq. m or 1 Rai presented in three protected forest areas included Khao Sam Liam NRF, Khao Tosae NRF, and Khlong Tarau NRF within its boundary. On contrary, there were 12 protected forest areas which had various number of the predicted deforestation hotspots locating over different deforestation vulnerability zones. Khao Kamala NRF had the highest deforestation hotspot of 229 points while

Khao Phra Thaeo WCDEC, Khlong U-Tapao NRF and the lowest hotspot number had the lowest deforestation hotspot of 1 point.

8.1.14 Forest protection unit allocation

There were five protected forest areas included Khao Kamala NRF, Khao Nak Keod NRF, Khlong U-Tapao NRF, Khlong Para NRF, and Khlong Tajin NRF required to establish forest protection area over hotspot area equal or more than 10,000 sq. m or 6.25 Rai with number of 15, 20, 1, 2, and 6 units, respectively.

In conclusion, it appears that integration of geospatial model for LULC prediction and geospatial method for deforestation vulnerability analysis can be used as an efficiently tools for deforestation hotspot and forest protection units allocation to fulfill forest conservation and protection program of the Government.

8.2 Recommendation

In this study, geospatial models (CA-Markov model, Land Change Modeler and CLUE-S model) for LULC prediction and geospatial techniques (FR method and LRA) for deforestation vulnerability analysis were applied to allocate predictive deforestation hotspot and forest protection unit of 15 protected forest areas. Based on this study, the possibly recommendations could be made for further studies as follows:

1) Date of remotely sensed data which are the main input data for LULC assessment and prediction of Phuket Island and its protected forest areas should cover declaration date of national parks and national reserved forest areas and be continuity. Because its can provide more details about dynamics of LULC pattern and its change, especially deforestation of Phuket Island and 15 protected forest areas.

2) Land use requirement for LULC prediction under CLUE-S model should be included spatial policy such as reservoir construction project. Because it can provide a reality of LULC prediction.

3) Proximity of tourist attraction areas, especially beach should be included as driving factor for deforestation vulnerability analysis. Because deforestation is frequently taken place in area close to natural beach or sea view location.

4) FR method as an optimum geospatial method for deforestation vulnerability analysis should be tested in another area or region for verification and validation of the model. The derived result will be useful for forest conservation and protection program in Thailand due to deforestation problem.

REFERENCES

REFERENCES

Aguejdad, R., and Houet, T. (2008). Modeling of urban sprawl using the land change modeler on a French metropolitan Area (Rennes): foresee the unpredictable. In: Symposium “Spatial Landscape Modelling: From Dynamic Approaches to Functional Evaluations”. **Toulouse 2008**. June 3-5.

Akis, S., Peristianis, N., and Warner, J. (1996). Residents’ attitudes to tourism development: The case of Cyprus. **Tourism Management**. 17: 481-494.

Anselin, L. (1988). Spatial Econometrics, Methods and Models. **Kluwer Academic Publishers**. Dordrecht.

Arekhi, S. (2011). Modeling spatial pattern of deforestation using GIS and logistic regression: A case study of northern Ilam forests, Ilam province, Iran. **African Journal of Biotechnology**. 10(72): 16236-16249.

Arsanjani, J. J., Helbich, M., Kainz, W., and Boloorani, A. D. (2013). Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion. **International Journal of Applied Earth Observation and Geoinformation**. 21: 265–275.

Atkinson, P. M., and Massari, R. (1998) Generalized linear modeling of susceptibility to landsliding in the central Apennines. **Italy Comput Geosci**. 24: 373-385.

Bastias-Perez, P., and Var, T. (1995). Perceived impacts of tourism by residents. **Annals of Tourism Research**. 22: 208-210.

Batty, M., Xie Y., and Sun, Z. (1999). Modeling urban dynamics through GIS-based cellular automata. **Computers, Environment and Urban Systems**. 23: 205-233.

Clark Labs. (2013). IDRISI Spotlight, LAND CHANGE MODELER. Clark University.

Congalton, R. G., and Green, K. (2009). Assessing the Accuracy of Remotely Sensed Data, Principles and Practices, Second Edition. **CRC Press, Taylor & Francis Group**. International Standard Book Number-13: 978-1-4200-5512-2.

Department of National Park Wildlife and Plant Conservation (DNP) and Royal Forest Dapartment (RFD). (2009). **Reducing emission from deforestation and degradation in the Tenaserim Biodiversity Corridor**. Thailand. n.p.

Department of Provincial Administration. (2013). Number of population of Phuket Province between 2003 and 2012. **Ministry of Interior** [On-line]. Available: http://service.nso.go.th/nso/web/statseries/tables/58300_Phuket/1.1.3.xls.

Dilley, M., and Boudreau, T. E. (2001). Coming to term with vulnerability: a critique of the food security definition. **Food Policy**. 26: 229-247.

Dyer, P., Gursoy, D., Sharma, B., and Carter, J. (2007). Structural modeling of resident perceptions of tourism and associated development on the Sunshine Coast, Australia. **Tourism Management**. 28: 409-422.

Eastman, J. R. (2009). **IDRISI Taiga, Guide to GIS and Remote Processing**. Worcester, MA. Clark University. 234-256.

Erdogan, N., Nurlu, E., and Erdem, U. (2011). Modelling land use changes in Karaburun by using CLUE-s. **ITU A|Z**. VOL: 8(2): 91-102.

Gontier, M., Mortberg, U., and Balfors, B. (2009). Comparing GIS-based habitat models for applications in EIA and SEA. **Environmental Impact Assessment Review** 30: 8-18.

Hou, X. Y., Chang, B., and Yu, X. F. (2004). Land use change in Hexi corridor based on CA-Markov methods. **Transactions of the CSAE**. 20(5): 286-291.

Huang, B., Zhang, L., and Wu, B. (2009). Spatiotemporal analysis of rural–urban land conversion. **International Journal of Geographical Information Science**. 23(3): 379-398.

Ii, B. L. T., Kasperson, R. E., Matson, P. A., Mccarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., and Schiller, A. (2003) A framework for vulnerability analysis in sustainability science. **Proceedings of the National Academy of sciences of the United States of America**. 100: 8074-8079.

Ilkwon, K., GwanYong, J., SooJin, P., and John, T. (2011). Predicted LULC change in the Soyang River Basin, South Korea. **TERRECO Science Conference**. Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany.

Islam, S., and Ahmed, R. (2011). Land use change prediction in Dhaka city using GIS aided Markov Chain Modeling. **J. Life Earth Sci**. 6: 81-89.

Jiang, G. H., Zhang, F. R., and Kong, X. B. (2009). Determining conversion direction of the rural residential land consolidation in Beijing mountainous areas. **Transactions of the CSAE**. 25(2): 214-221.

Johnson, S. J. (2009). An Evaluation of Land Change Modeler for ArcGIS for Ecological Analysis of Landscape Composition. Master of Science (**Department of Geography and Environmental Resources in the**

Graduate School, Southern Illinois University Carbondale) [On-line]. Available: http://gradworks.umi.com/14/65/1465027.html.

Kaosa-ard, M. (2007). Mekong Tourism: Blessings for All?. **White Lotus**: Bangkok.

Karim, S., Jalileddin, S., and Ali, M. T. (2011). Zoning Landslide by Use of Frequency Ratio Method, Case Study: Deylaman Region. **Middle-East Journal of Scientific Research**. 9(5): 578-583.

Khoi, D. D. (2011). Spatial Modeling of Deforestation and Land Suitability Assessment in the Tam Dao National Park Region, Vietnam. A Dissertation Submitted to the Graduate School of Life and Environmental Sciences, **the University of Tsukuba**. (Doctoral Program in Geoenvironmental Sciences). January 2011.

Khoi, D. D., and Murayama, Y. (2010). Forecasting areas vulnerable to forest conversion in the Tam Dao National Park Region, Vietnam. **Remote Sens.** 2: 1249-1272.

Ko, D., and Stewart, W. P. (2002). A structural equation model of residents' attitudes for tourism development. **Tourism Management**. 23(5): 521-530.

Lambin, E. F., Rounsevell, M. D. A., and Geist, H. J. (2000). Are agricultural land-use models able to predict changes in land-use intensity? **Agriculture, Ecosystems and Environment**. 82: 321-331.

LaSalle, J. L. (2013). OnPoint • Spotlight on Thailand - Hotel Investment Market, Real value in a changing world. **Jones Lang LaSalle's Hotels & Hospitality offices**. January 2013.

Lawton, L. (2005). Resident perceptions of tourism attractions on the Gold Coast of Australia. **Journal of Travel Research**. 44(2): 188-200.

Lee, S., and Pradhan, B. (2006). Probabilistic landslide risk mapping at Penang Island, Malaysia. **Journal of Earth System Sciences**, Vol. 115, No. 6, 1-12.

Lee, S., and Sambath, T. (2006). Landslide susceptibility mapping in the Damrei Romel area, Cambodia using frequency ratio and logistic regression models. **Environ. Geol**. 50: 847-855.

Lepp, A. (2007). Residents' attitudes towards tourism in Bigodi village, Uganda. **Tourism Management**. 28(3): 876-885.

Mather, J. R., and Sdasyuk, G. V. (1991). Global change. Geographical approaches, University of Arizona Press, Tucson, Endeavour. **A Modern Approach to the Protection of the Environment**. Volume 16(3): 289.

McCullagh, P., Nelder, J. (1989). Generalized Linear Models. **CRC Press**, Boca Raton.

Mon, M. S., Mizoue, N., Htun, N. Z., Kajisa, T., and Yoshida, S. (2012). Factors affecting deforestation and forest degradation in selectively logged production forest: A case study in Myanmar. **Forest Ecology and Management**. 267: 190-198.

Nagabhatla, N., Finlayson, C. M., and Sellamuttu, S. S. (2012). Assessment and change analyses (1987-2002) for tropical wetland ecosystem using earth observation and socioeconomic data, **European Journal of Remote Sensing** – 2012. 45: 215-232.

Ongsomwang, S. (2002). Forest Assessment and Conservation in Thailand. **Workshop on Tropical Forest Assessment and Conservation Issues in Southeast Asia**. February 12-14, 2002. Dehra Dun, India**.**

Ongsomwang, S., and Pimjai, M. (2014). Land use and land cover prediction and its impact on surface runoff. **Suranaree J. Sci. Technol**. 22(2):205-223

Panayotou, T., and Sungsawan, S. (1989). An economic study of the causes of tropical deforestation: the case of Northern Thailand. Development Discussion Paper No. 284, **Institute of Economic Development, Havard University**.

Panayotou, T., and Parasuk, C. (1990). Land and Forests: projecting demand and managing encroachment. Thailand Development Research Institute Foundation, Bangkok. **1990 TDRI Year-End Conference: Industrialization Thailand and Its Impact on the Environment, Session: Natural Resources for Future**. Chon Buri TDRI, Bangkok.

Peterson, L. K., Bergen, K. M., Brown, D. G., Vashchuk, L., and Blam, Y. (2009). Forested land-cover patterns and trends over changing forest management eras in the Siberian Baikal region. **Forest Ecology and Management**. 257: 911-922.

Pontius, R. G., and Schneider, L. C. (2001). Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, **USA. Agriculture, Ecosystems and Environment** 85(2001): 239–248.

Pradhan, B., and Lee, S. (2010). Delineation of landslide hazard areas on Penang Island, Malaysia, by using frequency ratio, logistic regression, and artificial neural network models. **Environ Earth Sci**. 60: 1037-1054.

Raksakulthai, V. (2003). CASE STUDY Climate Change Impacts and Adaptation for Tourism in Phuket, Thailand. Asian Disaster Preparedness Center, Disaster Reduction for Safer Communities and Sustainable Development. **Seminar on climate change and severe weather events in ASIA and the Caribbean**. Grand Barbados Beach Resort, Barbados. July 24-25, 2003.

Royal Forest Department. (2010). Forestry Statistics of Thailand during 1961-2008 [On-line]. Available: http://forestinfo.forest.go.th/Content/file/stat2554/TAB1.pdf.

Sae-Tan, A. (2013). Phuket Tourism: Is it Sustainable for Phuketians? [On-line]. Available: http://csr-asia.com/csr-asia-weekly-news-detail.php?id=12108.

Sang, L., Zhang, C., Yang, J., Zhu, D., and Yun, W. (2011). Simulation of land use spatial pattern of towns and villages based on CA–Markov model. **Mathematical and Computer Modelling**. 54: 938-943.

Siangwan, W. (2008). Application of remote sensing and geographic information system for determining encroachment risk area of Khao Sanampriang Wildlife Sanctuary, Kamphangphet Province. Wildlife Conservation, Department of Conservation Area 12th. **the Department of National Park, Wildlife and Plant Conservation**.

TFSMP. (1993). Thai Forestry Sector Master Plan. Volume 5 Subsectoral plan for People and forestry environment. **Royal Forest Department**, Bangkok: 192.

Tongpan, S., Panayotou, T., Jetanavanich, S., and Mahi, C. (1990). Deforestation and poverty: can commercial and social forestry break the vicious cycle? **Research Report No. 2 The 1990 TDRI Year-End Conference**. TDRI, Bangkok.

Untong, A. (2006). Attitude of local residents on tourism impacts: A case study of Chiang Mai and Chiang Rai. **Proceeding 12th Asia Pacific Tourism Association and 4th APacCHRIE Joint Conference**. Hualien, Taiwan, June 26-29, 2006.

Untong, A., Kaosa-ard, M., Ramos, V., Sangkakorn, K., and Rey-Maquieira, J. (2010). Factors Influencing Local Resident Support for Tourism Development: A Structural Equation Model. **The APTA Conference 2010**. Macau, China. July 13-16, 2010.

Václavík, T., and Rogan, J. (2009). Identifying trends in land use/land cover changes in the context of post-socialist transformation in central Europe: a case study of the greater Olomouc region, Czech Republic. **GISci. Remote Sens**. 46: 54-76.

Verburg, P. H. (2010). The CLUE Modelling Framework, The Conversion of Land Use and its Effects, Course material, VU. University Amsterdam, IVM. **Institute for Environmental Studies**, January 2010.

Verburg, P.H., Overmars, K.P., Huigen, M. G.A., de Groot, W.T., and Veldkamp, A., (2006). Analysis of the effect of land use change on protected areas in the Philippines, **Applied Geography**, 26: 153-173.

Vijith, H. V., and Madhu, G. (2007). Application of GIS and frequency radio model in mapping the potential surface failure site in the Poonjar sub-watershed of Meenachil River in Western Ghats of Kerala, Photonirvachak. **Journal of the Indian Society of Remote Sensing**. 35(3): 275-285.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., and Melillo, J. M. (1997). Human domination of Earth's ecosystems. **American Association for the Advancement of Science**. 277(5325): 494-499.

Wang, X. L., and Bao, Y. H. (1999). Study on the methods of land use dynamic change research. **Progress in Geography**. 18(1): 81-87.

Wickramasuriya, R. C, Bregt, A. K., van Delden, H., and Hagen-Zanker, A. (2009). The dynamics of shifting cultivation captured in an extended constrained cellular automata land use model. **Ecological Modelling**. 220: 2302-2309.

Xie, C., Huang, B., Claramunt, C., and Chandramouli, C. (2005). Spatial logistic regression and GIS to model rural-urban land conversion. In: Proceedings of PROCESSUS Second International Colloquium on the Behavioural Foundations of Integrated Land-use and Transportation Models: Frameworks. **Models and Applications**. June 12–15, 2005, University of Toronto, Canada.

Ye, B., and Bai, Z. (2008). Simulating land use/cover changes of Nenjiang County based on CA-Markov model. **Computer and Computing Technologies in Agriculture**. 1: 321-329.

Zezere, J. L., Reis, E., Garcia, R., Oliveira, S., Rodrigues, M. L., Vieira, G., and Ferreira, A. B. (2004). Integration of spatial and temporal data for the definition of different landslide hazard scenarios in the area north of Lisbon (Portugal). **Natural Hazards and Earth System Sciences**. 4: 133-146.

APPENDIX

THE FREQUENCY RATIO OF DEFORESTATION OCCURRENCE USING FREQU ENCY RATIO METHOD BASED ON DEFORESTATION DRIVING FACTORS AND ACTAUL DEFORESTED AREA DURING 2002-2014

Table 1 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Sirinath MNP.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	112917	88.11	1063	71.29	0.81
100-200 m	13946	10.88	394	26.43	2.43
200-300 m	1285	1.00	34	2.28	2.27
	128148	100.00	1491	100.00	
Slope					
0-8%	67052	52.32	206	13.82	0.26
8-16%	19710	15.38	274	18.38	1.19
16-35%	27388	21.37	597	40.04	1.87
35-60%	11888	9.28	322	21.60	2.33
> 60%	2110	1.65	92	6.17	3.75
	128148	100.00	1491	100.00	
Soil fertility					
Low	102307	79.84	629	42.19	0.53
Moderate	25841	20.16	862	57.81	2.87
	128148	100.00	1491	100.00	
Distance from road					
0-500 m	115508	90.14	1151	77.20	0.86
500-1000 m	9941	7.76	340	22.80	2.94
1000-1500 m	2570	2.01	0	0.00	0.00
1500-2000 m	129	0.10	0	0.00	0.00
	128148	100.00	1491	100.00	
Distance from settlement					
0-500 m	88252	68.87	573	38.43	0.56
500-1000 m	32015	24.98	690	46.28	1.85
1000-1500 m	7361	5.74	186	12.47	2.17
1500-2000 m	520	0.41	42	2.82	6.94
	128148	100.00	1491	100.00	
Distance from water bodies					
0-500 m	84827	66.19	346	23.21	0.35
500-1000 m	28710	22.40	827	55.47	2.48
1000-1500 m	11844	9.24	255	17.10	1.85
1500-2000 m	2695	2.10	63	4.23	2.01
> 2000 m	72	0.06	0	0.00	0.00
	128148	100.00	1491	100.00	

Table 1 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Population density (person/sq.km)					
Sakhu	37190	29.02	471	31.59	1.09
Thep Kasattri	25076	19.57	776	52.05	2.66
Mai Khao	44802	34.96	25	1.68	0.05
Choeng Thale	21080	16.45	219	14.69	0.89
	128148	100.00	1491	100.00	
Average income (baht/person)					
Thep Kasattri	25076	19.57	776	52.05	2.66
Sakhu	37190	29.02	471	31.59	1.09
Choeng Thale	21080	16.45	219	14.69	0.89
Mai Khao	44802	34.96	25	1.68	0.05
	128148	100.00	1491	100.00	

Table 2 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khao Phra Thaeo WCDEC.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	109298	76.41	444	61.33	0.80
100-200 m	16059	11.23	170	23.48	2.09
200-300 m	11597	8.11	110	15.19	1.87
300-400 m	5505	3.85	0	0.00	0.00
> 400 m	587	0.41	0	0.00	0.00
	143046	100.00	724	100.00	
Slope					
0-8%	64218	44.89	328	45.30	1.01
8-16%	21346	14.92	75	10.36	0.69
16-35%	32598	22.79	144	19.89	0.87
35-60%	19158	13.39	148	20.44	1.53
> 60%	5726	4.00	29	4.01	1.00
	143046	100.00	724	100.00	
Soil fertility					
Low	86124	60.21	392	54.14	0.90
Moderate	56922	39.79	332	45.86	1.15
	143046	100.00	724	100.00	

Table 2 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Distance from road					
0-500 m	112859	78.90	632	87.29	1.11
500-1000 m	20512	14.34	92	12.71	0.89
1000-1500 m	7852	5.49	0	0.00	0.00
1500-2000 m	1823	1.27	0	0.00	0.00
	143,046	100.00	724.00	100.00	
Distance from settlement					
0-500 m	72862	50.94	277	38.26	0.75
500-1000 m	36965	25.84	161	22.24	0.86
1000-1500 m	17287	12.08	183	25.28	2.09
1500-2000 m	10915	7.63	103	14.23	1.86
> 2000 m	5017	3.51	0	0.00	0.00
	143046	100.00	724	100.00	
Distance from water bodies					
0-500 m	73974	51.71	362	50.00	0.97
500-1000	43482	30.40	164	22.65	0.75
1000-1500 m	17245	12.06	127	17.54	1.46
1500-2000 m	7819	5.47	71	9.81	1.79
> 2000 m	526	0.37	0	0.00	0.00
	143046	100.00	724	100.00	
Population density (person/sq.km)					
Pa Khlok	61974	43.32	288	39.78	0.92
Thep Kasattri	64167	44.86	311	42.96	0.96
Si Sunthon (1036)	16905	11.82	125	17.27	1.46
	143046	100.00	724	100.00	
Average income (baht/person)					
Pa Khlok	61974	43.32	288	39.78	0.92
Si Sunthon	16905	11.82	125	17.27	1.46
Thep Kasattri	64167	44.86	311	42.96	0.96
	143046	100.00	724	100.00	

Table 3 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khao Mai Kaew NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	66341	96.07	206	86.55	0.90
100-200 m	2324	3.37	32	13.45	3.99
200-300 m	387	0.56	0	0.00	0.00
	69052	100.00	238	100.00	
Slope					
0-8%	40766	59.04	176	73.95	1.25
8-16%	11452	16.58	3	1.26	0.08
16-35%	13048	18.90	19	7.98	0.42
35-60%	3400	4.92	34	14.29	2.90
> 60%	386	0.56	6	2.52	4.51
	69052	100.00	238	100.00	
Soil fertility					
Low	63974	92.65	202	84.87	0.92
Moderate	5078	7.35	36	15.13	2.06
	69052	100.00	238	100.00	
Distance from road					
0-500 m	67581	97.87	238	100.00	1.02
500-1000 m	1471	2.13	0	0.00	0.00
	69052	100.00	238	100.00	
Distance from settlement					
0-500 m	53040	76.81	176	73.95	0.96
500-1000 m	14153	20.50	62	26.05	1.27
1000-1500 m	1859	2.69	0	0.00	0.00
	69052	100.00	238	100.00	
Distance from water bodies					
0-500 m	43420	62.88	148	62.18	0.99
500-1000 m	18444	26.71	54	22.69	0.85
1000-1500 m	7028	10.18	36	15.13	1.49
1500-2000 m	160	0.23	0	0.00	0.00
	69052	100.00	238	100.00	
Population density (person/sq.km)					
Sakhu	7388	10.70	0.00	0.00	0.00
Thep Kasattri	3681	5.33	62	26.05	4.89
Mai Khao	57983	83.97	176	73.95	0.88
	69052	100.00	238	100.00	

Table 3 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Average income (baht/person)					
Thep Kasattri	3681	5.33	62	26.05	4.89
Sakhu	7388	10.70	0	0.00	0.00
Mai Khao	57983	83.97	176	73.95	0.88
	69052	100.00	238	100.00	

Table 4 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khao Bang Khanun NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	73143	86.43	1195	71.99	0.83
100-200 m	9907	11.71	431	25.96	2.22
200-300 m	1533	1.81	34	2.05	1.13
300-400 m	48	0.06	0	0.00	0.00
	84631	100.00	1660	100.00	
Slope					
0-8%	39978	47.24	397	23.92	0.51
8-16%	14023	16.57	244	14.70	0.89
16-35%	20132	23.79	580	34.94	1.47
35-60%	8584	10.14	343	20.66	2.04
> 60%	1914	2.26	96	5.78	2.56
	84631	100.00	1660	100.00	
Soil fertility					
Low	67423	79.67	953	57.41	0.72
Moderate	17208	20.33	707	42.59	2.09
	84631	100.00	1660	100.00	
Distance from road					
0-500 m	75833	89.60	1146	69.04	0.77
500-1000 m	7973	9.42	514	30.96	3.29
1000-1500 m	825	0.97	0	0.00	0.00
	84631	100.00	1660	100.00	

Table 4 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Distance from settlement					
0-500 m	55798	65.93	473	28.49	0.43
500-1000 m	22221	26.26	954	57.47	2.19
1000-1500 m	6370	7.53	191	11.51	1.53
1500-2000 m	242	0.29	42	2.53	8.85
	84631	100.00	1660	100.00	
Distance from water bodies					
0-500 m	41718	49.29	650	39.16	0.79
500-1000 m	27811	32.86	742	44.70	1.36
1000-1500 m	11368	13.43	160	9.64	0.72
1500-2000 m	3515	4.15	108	6.51	1.57
> 2000 m	219	0.26	0	0.00	0.00
	84631	100.00	1660	100.00	
Population density (person/sq.km)					
Sakhu	29687	35.08	451	27.17	0.77
Thep Kasattri	47729	56.40	1209	72.83	1.29
Mai Khao	6771	8.00	0	0.00	0.00
Choeng Thale	444	0.52	0	0.00	0.00
	84631	100.00	1660	100.00	
Average income (baht/person)					
Thep Kasattri	47729	56.40	1209	72.83	1.29
Sakhu	29687	35.08	451	27.17	0.77
Choeng Thale	444	0.52	0	0.00	0.00
Mai Khao	6771	8.00	0	0.00	0.00
	84631	100.00	1660	100.00	

Table 5 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khao Sam Liam NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	27332	92.03	105	100.00	1.09
100-200 m	2366	7.97	0	0.00	0.00
	29698	100.00	105	100.00	

Table 5 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Slope					
0-8%	13879	46.73	38	36.19	0.77
8-16%	4563	15.36	12	11.43	0.74
16-35%	6404	21.56	27	25.71	1.19
35-60%	4060	13.67	28	26.67	1.95
> 60%	792	2.67	0	0.00	0.00
	29698	100.00	105	100.00	
Soil fertility					
Low	22977	77.37	105	100.00	1.29
Moderate	6721	22.63	0	0.00	0.00
	29698	100.00	105	100.00	
Distance from road					
0-500 m	25977	87.47	105	100.00	1.14
500-1000 m	3712	12.50	0	0.00	0.00
1000-1500 m	9	0.03	0	0.00	0.00
	29698	100.00	105	100.00	
Distance from settlement					
0-500 m	16075	54.13	105	100.00	1.85
500-1000 m	10129	34.11	0	0.00	0.00
1000-1500 m	2952	9.94	0	0.00	0.00
1500-2000 m	482	1.62	0	0.00	0.00
> 2000 m	60	0.20	0	0.00	0.00
	29698	100.00	105	100.00	
Distance from water bodies					
0-500 m	15463	52.07	55	52.38	1.01
500-1000 m	5006	16.86	0	0.00	0.00
1000-1500 m	3467	11.67	0	0.00	0.00
1500-2000 m	2599	8.75	48	45.71	5.22
> 2000 m	3163	10.65	2	1.90	0.18
	29698	100.00	105	100.00	
Population density (person/sq.km)					
Pa Khlok	29698	100.00	105	100.00	1.00
	29698	100.00	105	100.00	
Average income (baht/person)					
Pa Khlok	29698	100.00	105	100.00	1.00
	29698	100.00	105	100.00	

Table 6 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khao Kamala NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	138850	63.13	2750	50.25	0.80
100-200 m	35686	16.23	1224	22.36	1.38
200-300 m	23567	10.72	591	10.80	1.01
300-400 m	15678	7.13	597	10.91	1.53
> 400 m	6161	2.80	311	5.68	2.03
	219942	100.00	5473	100.00	
Slope					
0-8%	83997	38.19	478	8.73	0.23
8-16%	27547	12.52	669	12.22	0.98
16-35%	49224	22.38	1870	34.17	1.53
35-60%	44676	20.31	1849	33.78	1.66
> 60%	14498	6.59	607	11.09	1.68
	219942	100.00	5473	100.00	
Soil fertility					
Low	111547	50.72	857	15.66	0.31
Moderate	108395	49.28	4616	84.34	1.71
	219942	100.00	5473	100.00	
Distance from road					
0-500 m	184338	83.81	4706	85.99	1.03
500-1000 m	28838	13.11	673	12.30	0.94
1000-1500 m	6410	2.91	94	1.72	0.59
1500-2000 m	356	0.16	0	0.00	0.00
	219942	100.00	5473	100.00	
Distance from settlement					
0-500 m	139405	63.38	2453	44.82	0.71
500-1000 m	42046	19.12	1621	29.62	1.55
1000-1500 m	23783	10.81	1019	18.62	1.72
1500-2000 m	12528	5.70	332	6.07	1.06
> 2000 m	2180	0.99	48	0.88	0.88
	219942	100.00	5473	100.00	
Distance from water bodies					
0-500 m	112424	51.12	1569	28.67	0.56
500-1000 m	57087	25.96	1540	28.14	1.08
1000-1500 m	29985	13.63	1159	21.18	1.55
1500-2000 m	13512	6.14	562	10.27	1.67
> 2000 m	6934	3.15	643	11.75	3.73
	219942	100.00	5473	100.00	

Table 6 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Population density (person/sq.km)					
Kamala	32675	14.86	1366	24.96	1.68
Ko Keao	28083	12.77	383	7.00	0.55
Rawai	25006	0.00	821	15.00	0.00
Kathu	49539	22.52	12	0.22	0.01
Choeng Thale	22932	10.43	143	2.61	0.25
Si Sunthon	41583	18.91	401	7.33	0.39
Talat Yai	1698	0.77	2072	37.86	49.04
Rutsada	13700	6.23	46	0.84	0.13
Wichit	4726	2.15	229	4.18	1.95
	219942	100.00	5473	100.00	
Average income (baht/person)					
Rutsada	13700	6.23	46	0.84	0.13
Si Sunthon	41583	18.91	401	7.33	0.39
Ko Keao	28083	12.77	383	7.00	0.55
Kamala	32675	14.86	1366	24.96	1.68
Kathu	49539	22.52	12	0.22	0.01
Choeng Thale	22932	10.43	143	2.61	0.25
Talat Yai	1698	0.77	2072	37.86	49.04
Rawai	25006	11.37	821	15.00	0.00
Wichit	4726	2.15	229	4.18	1.95
	219942	100.00	5473	100.00	

Table 7 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khao Nak Keod NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	115985	64.08	2980	43.20	0.67
100-200 m	36013	19.90	2175	31.53	1.58
200-300 m	19379	10.71	1185	17.18	1.60
300-400 m	7844	4.33	523	7.58	1.75
> 400 m	1789	0.99	35	0.51	0.51
	181010	100.00	6898	100.00	

Table 7 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Slope					
0-8%	68989	38.11	593	8.60	0.23
8-16%	22358	12.35	903	13.09	1.06
16-35%	43024	23.77	2599	37.68	1.59
35-60%	37099	20.50	2293	33.24	1.62
> 60%	9540	5.27	510	7.39	1.40
	181010	100.00	6898	100.00	
Soil fertility					
Low	88530	48.91	806	11.68	0.24
Moderate	92480	51.09	6092	88.32	1.73
	181010	100.00	6898	100.00	
Distance from road					
0-500 m	167238	92.39	5953	86.30	0.93
500-1000 m	12234	6.76	831	12.05	1.78
1000-1500 m	1155	0.64	109	1.58	2.48
1500-2000 m	383	0.21	5	0.07	0.34
	181010	100.00	6898	100.00	
Distance from settlement					
0-500 m	131953	72.90	3704	53.70	0.74
500-1000 m	33827	18.69	2038	29.54	1.58
1000-1500 m	13740	7.59	1110	16.09	2.12
1500-2000 m	1445	0.80	46	0.67	0.84
> 2000 m	45	0.02	0	0.00	0.00
	181010	100.00	6898	100.00	
Distance from water bodies					
0-500 m	89077	49.21	1933	28.02	0.57
500-1000 m	55943	30.91	2439	35.36	1.14
1000-1500 m	24708	13.65	1444	20.93	1.53
1500-2000 m	10158	5.61	889	12.89	2.30
> 2000 m	1124	0.62	193	2.80	4.51
	181010	100.00	6898	100.00	
Population density (person/sq.km)					
Karon	38222	21.12	3050	44.22	2.09
Rawai	31627	17.47	357	5.18	0.30
Kathu	30047	16.60	644	9.34	0.56
Talat Nuea	1066	0.59	0	0.00	0.00
Rutsada	285	0.16	0	0.00	0.00
Wichit	19663	10.86	338	4.90	0.45
Pa Tong	30192	16.68	1426	20.67	1.24
Chalong	29908	16.52	1083	15.70	0.95
	181010	100.00	6898	100.00	

Table 7 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Average income (baht/person)					
Rutsada	285	0.16	0	0.00	0.00
Kathu	30047	16.60	644	9.34	0.56
Pa Tong	30192	16.68	1426	20.67	1.24
RutsadaTalat Nuea	1066	0.59	0	0.00	0.00
Karon	38222	21.12	3050	44.22	2.09
Rawai	31627	17.47	357	5.18	0.30
Wichit	19663	10.86	338	4.90	0.45
Chalong	29908	16.52	1083	15.70	0.95
	181010	100.00	6898	100.00	

Table 8 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Tosae NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	43896	95.97	718	99.86	1.04
100-200 m	1844	4.03	1	0.14	0.03
	45740	100.00	719	100.00	
Slope					
0-8%	31387	68.62	332	46.18	0.67
8-16%	6490	14.19	142	19.75	1.39
16-35%	5216	11.40	165	22.95	2.01
35-60%	2236	4.89	54	7.51	1.54
> 60%	411	0.90	26	3.62	4.02
	45740	100.00	719	100.00	
Soil fertility					
Low	38379	83.91	464	64.53	0.77
Moderate	7361	16.09	255	35.47	2.20
	45740	100.00	719	100.00	
Distance from road					
0-500 m	40733	89.05	618	85.95	0.97
500-1000 m	4034	8.82	101	14.05	1.59
1000-1500 m	940	2.06	0	0.00	0.00
1500-2000 m	33	0.07	0	0.00	0.00
	45740	100.00	719	100.00	

Table 8 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Distance from settlement					
0-500 m	44273	96.79	719	100.00	1.03
500-1000 m	1412	3.09	0	0.00	0.00
1000-1500 m	55	0.12	0	0.00	0.00
	45740	100.00	719	100.00	
Distance from water bodies					
0-500 m	35243	77.05	479	66.62	0.86
500-1000 m	10125	22.14	240	33.38	1.51
1000-1500 m	372	0.81	0	0.00	0.00
	45740	100.00	719	100.00	
Population density (person/sq.km)					
Talat Nuea	5186	11.34	5	0.70	0.06
Talat Yai	12561	27.46	70	9.74	0.00
Rutsada	25796	56.40	465	64.67	1.15
Wichit	2197	4.80	179	24.90	5.18
	45740	100.00	719	100.00	
Average income (baht/person)					
Rutsada	25796	56.40	465	64.67	1.15
RutsadaTalat Nuea	5186	11.34	5	0.70	0.06
Talat Yai	12561	27.46	70	9.74	0.00
Wichit	2197	4.80	179	24.90	5.18
	45740	100.00	719	100.00	

Table 9 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong U-Tapao NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	34725	99.93	25	100.00	1.00
100-200 m	24	0.07	0	0.00	0.00
	34749	100.00	25	100.00	

Table 9 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Slope					
0-8%	24939	71.77	21	84.00	1.17
8-16%	5262	15.14	4	16.00	1.06
16-35%	4009	11.54	0	0.00	0.00
35-60%	526	1.51	0	0.00	0.00
> 60%	13	0.04	0	0.00	0.00
	34749	100.00	25	100.00	
Soil fertility					
Low	34553	99.44	25	100.00	1.01
Moderate	196	0.56	0	0.00	0.00
	34749	100.00	25	100.00	
Distance from road					
0-500 m	33681	96.93	25	100.00	1.03
500-1000 m	1068	3.07	0	0.00	0.00
	34749	100.00	25	100.00	
Distance from settlement					
0-500 m	23402	67.35	25	100.00	1.48
500-1000 m	11211	32.26	0	0.00	0.00
1000-1500 m	136	0.39	0	0.00	0.00
	34749	100.00	25	100.00	
Distance from water bodies					
0-500 m	24565	70.69	25	100.00	1.41
500-1000 m	5618	16.17	0	0.00	0.00
1000-1500 m	4384	12.62	0	0.00	0.00
1500-2000 m	182	0.52	0	0.00	0.00
	34749	100.00	25	100.00	
Population density (person/sq.km)					
Mai Khao	34749	100.00	25	100.00	1.00
	34749	100.00	25	100.00	
Average income (baht/person)					
Mai Khao	34749	100.00	25	100.00	1.00
	34749	100.00	25	100.00	

Table 10 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong Tha Maphrao NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	64079	94.17	711	88.32	0.94
100-200 m	3579	5.26	94	11.68	2.22
200-300 m	387	0.57	0	0.00	0.00
	68045	100.00	805	100.00	
Slope					
0-8%	35501	52.17	413	51.30	0.98
8-16%	12202	17.93	74	9.19	0.51
16-35%	14952	21.97	165	20.50	0.93
35-60%	4690	6.89	136	16.89	2.45
> 60%	700	1.03	17	2.11	2.05
	68045	100.00	805	100.00	
Soil fertility					
Low	58937	86.61	671	83.35	0.96
Moderate	9108	13.39	134	16.65	1.24
	68045	100.00	805	100.00	
Distance from road					
0-500 m	63644	93.53	627	77.89	0.83
500-1000 m	4401	6.47	178	22.11	3.42
	68045	100.00	805	100.00	
Distance from settlement					
0-500 m	46088	67.73	475	59.01	0.87
500-1000 m	18483	27.16	325	40.37	1.49
1000-1500 m	3474	5.11	5	0.62	0.12
	68045	100.00	805	100.00	
Distance from water bodies					
0-500 m	38203	56.14	573	71.18	1.27
500-1000 m	21819	32.07	152	18.88	0.59
1000-1500 m	7191	10.57	39	4.84	0.46
1500-2000 m	832	1.22	41	5.09	4.17
	68045	100.00	805	100.00	
Population density (person/sq.km)					
Sakhu	3208	4.71	33	4.10	0.87
Pa Khlok	5	0.01	0	0.00	0.00
Thep Kasattri	33985	49.94	598	74.29	1.49
Mai Khao	30847	45.33	174	21.61	0.48
	68045	100.00	805	100.00	

Table 10 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Average income (baht/person)					
Pa Khlok	5	0.01	0	0.00	0.00
Thep Kasattri	33985	49.94	598	74.29	1.49
Sakhu	3208	4.71	33	4.10	0.87
Mai Khao	30847	45.33	174	21.61	0.48
	68045	100.00	805	100.00	

Table 11 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong Para NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	56751	88.17	216	88.89	1.01
100-200 m	4934	7.67	27	11.11	1.45
200-300 m	1737	2.70	0	0.00	0.00
300-400 m	821	1.28	0	0.00	0.00
> 400 m	125	0.19	0	0.00	0.00
	64368	100.00	243	100.00	
Slope					
0-8%	32682	50.77	152	62.55	1.23
8-16%	10050	15.61	19	7.82	0.50
16-35%	12787	19.87	41	16.87	0.85
35-60%	6598	10.25	26	10.70	1.04
> 60%	2251	3.50	5	2.06	0.59
	64368	100.00	243	100.00	
Soil fertility					
Low	49042	76.19	213	87.65	1.15
Moderate	15326	23.81	30	12.35	0.52
	64368	100.00	243	100.00	
Distance from road					
0-500 m	52737	81.93	208	85.60	1.04
500-1000 m	11091	17.23	35	14.40	0.84
1000-1500 m	540	0.84	0	0.00	0.00
	64368	100.00	243	100.00	

Table 11 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Distance from settlement					
0-500 m	31768	49.35	145	59.67	1.21
500-1000 m	21346	33.16	81	33.33	1.01
1000-1500 m	8407	13.06	17	7.00	0.54
1500-2000 m	2455	3.81	0	0.00	0.00
> 2000 m	392	0.61	0	0.00	0.00
	64368	100.00	243	100.00	
Distance from water bodies					
0-500 m	40714	63.25	194	79.84	1.26
500-1000 m	13658	21.22	34	13.99	0.66
1000-1500 m	6750	10.49	0	0.00	0.00
1500-2000 m	2934	4.56	15	6.17	1.35
> 2000 m	312	0.48	0	0.00	0.00
	64368	100.00	243	100.00	
Population density (person/sq.km)					
Pa Khlok	43080	66.93	109	44.86	0.67
Thep Kasattri	21288	33.07	134	55.14	1.67
	64368	100.00	243	100.00	
Average income (baht/person)					
Pa Khlok	43080	66.93	109	44.86	0.67
Thep Kasattri	21288	33.07	134	55.14	1.67
	64368	100.00	243	100.00	

Table 12 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong Bangrong NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	53041	87.64	220	92.05	1.05
100-200 m	4750	7.85	19	7.95	1.01
200-300 m	2587	4.27	0	0.00	0.00
300-400 m	146	0.24	0	0.00	0.00
	60524	100.00	239	100.00	

Table 12 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Slope					
0-8%	29211	48.26	104	43.51	0.90
8-16%	10090	16.67	26	10.88	0.65
16-35%	13219	21.84	53	22.18	1.02
35-60%	6564	10.85	54	22.59	2.08
> 60%	1440	2.38	2	0.84	0.35
	60524	100.00	239	100.00	
Soil fertility					
Low	46474	76.79	184	76.99	1.00
Moderate	14050	23.21	55	23.01	0.99
	60524	100.00	239	100.00	
Distance from road					
0-500 m	51672	85.37	204	85.36	1.00
500-1000 m	7947	13.13	35	14.64	1.12
1000-1500 m	905	1.50		0.00	0.00
	60524	100.00	239	100.00	
Distance from settlement					
0-500 m	31846	52.62	165	69.04	1.31
500-1000 m	18534	30.62	12	5.02	0.16
1000-1500 m	6980	11.53	46	19.25	1.67
1500-2000 m	3085	5.10	16	6.69	1.31
> 2000 m	79	0.13	0	0.00	0.00
	60524	100.00	239	100.00	
Distance from water bodies					
0-500 m	38766	64.05	127	53.14	0.83
500-1000 m	11745	19.41	12	5.02	0.26
1000-1500 m	5545	9.16	50	20.92	2.28
1500-2000 m	3223	5.33	48	20.08	3.77
> 2000 m	1245	2.06	2	0.84	0.41
	60524	100.00	239	100.00	
Population density (person/sq.km)					
Pa Khlok	60524	100.00	239	100.00	1.00
	60524	100.00	239	100.00	
Average income (baht/person)					
Pa Khlok	60524	100.00	239	100.00	1.00
	60524	100.00	239	100.00	

Table 13 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong Tarau NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	57040	93.51	512	80.88	0.86
100-200 m	3066	5.03	19	3.00	0.60
200-300 m	890	1.46	102	16.11	11.04
	60996	100.00	633	100.00	
Slope					
0-8%	37513	61.50	233	36.81	0.60
8-16%	9032	14.81	145	22.91	1.55
16-35%	9969	16.34	185	29.23	1.79
35-60%	3993	6.55	64	10.11	1.54
> 60%	489	0.80	6	0.95	1.18
	60996	100.00	633	100.00	
Soil fertility					
Low	49513	81.17	189	29.86	0.37
Moderate	11483	18.83	444	70.14	3.73
	60996	100.00	633	100.00	
Distance from road					
0-500 m	50557	82.89	606	95.73	1.16
500-1000 m	9601	15.74	27	4.27	0.27
1000-1500 m	838	1.37	0	0.00	0.00
	60996	100.00	633	100.00	
Distance from settlement					
0-500 m	38353	62.88	262	41.39	0.66
500-1000 m	15193	24.91	255	40.28	1.62
1000-1500 m	6523	10.69	115	18.17	1.70
1500-2000 m	927	1.52	1	0.16	0.10
	60996	100.00	633	100.00	
Distance from water bodies					
0-500 m	44462	72.89	211	33.33	0.46
500-1000 m	15185	24.90	101	15.96	0.64
1000-1500 m	1013	1.66	195	30.81	18.55
1500-2000 m	308	0.50	126	19.91	39.42
> 2000 m	28	0.05	0	0.00	0.00
	60996	100.00	633	100.00	
Population density (person/sq.km)					
Pa Khlok	27504	45.09	480	75.83	1.68
Ko Keao	16527	27.10	28	4.42	0.16
Si Sunthon	16965	27.81	125	19.75	0.71
	60996	100.00	633	100.00	

Table 13 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Average income (baht/person)					
Pa Khlok	27504	45.09	480	75.83	1.68
Si Sunthon	16965	27.81	125	19.75	0.71
Ko Keao	16527	27.10	28	4.42	0.16
	60996	100.00	633	100.00	

Table 14 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong Tajin NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	53603	97.56	343	100.00	1.03
100-200 m	1342	2.44	0	0.00	0.00
	54945	100.00	343	100.00	
Slope					
0-8%	33617	61.18	195	56.85	0.93
8-16%	8331	15.16	55	16.03	1.06
16-35%	8978	16.34	69	20.12	1.23
35-60%	3605	6.56	24	7.00	1.07
> 60%	414	0.75	0	0.00	0.00
	54945	100.00	343	100.00	
Soil fertility					
Low	43658	79.46	193	56.27	0.71
Moderate	11287	20.54	150	43.73	2.13
	54945	100.00	343	100.00	
Distance from road					
0-500 m	48324	87.95	331	96.50	1.10
500-1000 m	5218	9.50	12	3.50	0.37
1000-1500 m	1330	2.42	0	0.00	0.00
1500-2000 m	73	0.13	0	0.00	0.00
	54945	100.00	343	100.00	
Distance from settlement					
0-500 m	50587	92.07	338	98.54	1.07
500-1000 m	3920	7.13	5	1.46	0.20
1000-1500 m	438	0.80	0	0.00	0.00
	54945	100.00	343	100.00	

Table 14 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Distance from water bodies					
0-500 m	42055	76.54	324	94.46	1.23
500-1000 m	12029	21.89	19	5.54	0.25
1000-1500 m	591	1.08	0	0.00	0.00
1500-2000 m	270	0.49	0	0.00	0.00
	54945	100.00	343	100.00	
Population density (person/sq.km)					
Ko Keao	6173	11.23	12	3.50	0.31
Talat Nuea	49	0.09	0	0.00	0.00
Talat Yai	9502	17.29	2	0.58	0.03
Rutsada	38622	70.29	329	95.92	1.36
Wichit	599	1.09	0	0.00	0.00
	54945	100.00	343	100.00	
Average income (baht/person)					
Rutsada	38622	70.29	329	95.92	1.36
Ko Keao	6173	11.23	12	3.50	0.31
Talat Nuea	49	0.09	0	0.00	0.00
Talat Yai	9502	17.29	2	0.58	0.03
Wichit	599	1.09	0	0.00	0.00
	54945	100.00	343	100.00	

Table 15 Thematic layers class and favorability values of factors generated with respect to deforestation occurrence of Khlong Khopee NRF.

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Elevation					
0-100 m	52442	96.17	674	92.08	0.96
100-200 m	2089	3.83	58	7.92	2.07
	54531	100.00	732	100.00	
Slope					
0-8%	37907	69.51	302	41.26	0.59
8-16%	7158	13.13	105	14.34	1.09
16-35%	6496	11.91	196	26.78	2.25
35-60%	2541	4.66	99	13.52	2.90
> 60%	429	0.79	30	4.10	5.21
	54531	100.00	732	100.00	

Table 15 (Continued).

Thematic layer class	No. of pixels of class	Percent of class (B)	No. of pixel of deforestation	Percent of deforestation (A)	Frequency ratio (A/B)
Soil fertility					
Low	42001	77.02	351	47.95	0.62
Moderate	12530	22.98	381	52.05	2.27
	54531	100.00	732	100.00	
Distance from road					
0-500 m	50556	92.71	713	97.40	1.05
500-1000 m	3792	6.95	19	2.60	0.37
1000-1500 m	183	0.34	0	0.00	0.00
	54531	100.00	732	100.00	
Distance from settlement					
0-500 m	51173	93.84	673	91.94	0.98
500-1000 m	3358	6.16	59	8.06	1.31
	54531	100.00	732	100.00	
Distance from water bodies					
0-500 m	35710	65.49	390	53.28	0.81
500-1000 m	14851	27.23	212	28.96	1.06
1000-1500 m	2861	5.25	84	11.48	2.19
1500-2000 m	1049	1.92	30	4.10	2.13
> 2000 m	60	0.11	16	2.19	19.87
	54531	100.00	732	100.00	
Population density (person/sq.km)					
Talat Nuea	9168	16.81	22	3.01	0.18
Talat Yai	9338	17.12	45	6.15	0.36
Rutsada	250	0.46	0	0.00	0.00
Wichit	33100	60.70	665	90.85	1.50
Chalong	2675	4.91	0	0.00	0.00
	54531	100.00	732	100.00	
Average income (Baht/person)					
Rutsada	250	0.46	0	0.00	0.00
RutsadaTalat Nuea	9168	16.81	22	3.01	0.18
Talat Yai	9338	17.12	45	6.15	0.36
Wichit	33100	60.70	665	90.85	1.50
Chalong	2675	4.91	0	0.00	0.00
	54531	100.00	732	100.00	

CURRICULUM VITAE

Name Krittawat Boonchoo

Date of Birth 3 April 1972

Place of Birth 52 Soi 6 Pattalung rd., Tubtieng sub-district, Muang district, Trang province, Thailand

Education

2001 Bachelor of Computer Education (Computer Engineering): Faculty of Technical Education, Rajamangala Institute of Technology, Thanyaburi Campus, Thailand

2004 Master of Computer Education (Computer Technology): Faculty of Technical Education, King Mongkut's Institute of Technology North Bangkok, Thailand

Position and Place of Work

Lecturer at Faculty of Science and Fisheries Technology, Rajamangala University of Technology Srivijaya, Trang Campus, Thailand