PREDICTION OF FOREST TYPE DISTRIBUTION USING ECOLOGICAL MODELING IN PING BASIN, THAILAND

Yaowaret Jantakat

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

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การทำนายการกระจายชนิดป่าโดยอาศัยแบบจำลองทางนิเวศวิทยาในลุ่มน้ำปิง ประเทศไทย

นางสาวเยาวเรศ จันทะคัต

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต

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มหาวิทยาลัยเทคโนโลยีสุรนารี

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

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เยาวเรศ จันทะคัต : การทำนายการกระจายของชนิดป่าโดยอาศัยแบบจำลองทางนิเวศวิทยาในลุ่มน้ำปิง ประเทศไทย (PREDICTION OF FOREST TYPE DISTRIBUTION USING ECOLOGICAL MODELING IN PING BASIN, THAILAND) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.สุวิทย์ อ๋องสมหวัง, 230 หน้า.

วัตถุประสงค์หลักของการศึกษาคือ การจำแนกและการประเมินปัจจัยทางกายภาพ สำหรับการกระจาย ของชนิดป่าด้วยการวิเคราะห์ปัจจัย และการพัฒนาแบบจำลองทางนิเวศวิทยาป่าไม้ สำหรับการกระจาย ของชนิดป่าโดยอาศัยแบบจำลอง ENFA ในการศึกษา อาศัยข้อมูลการสำรวจทรัพยากรป่าไม้ในปี พ.ศ. 2540 ของกรมอุทยานแห่งชาติ สัตว์ป่าและพันธุ์พืช สำหรับกำหนดพื้นที่ศึกษา ซึ่งครอบคลุมบริเวณลุ่มน้ำย่อย 13 ลุ่มของลุ่มน้ำปิงทางตอนเหนือของประเทศไทย ข้อมูลการสำรวจทรัพยากรป่าไม้ถูกแบ่งข้อมูลออกเป็น 2 ชุดคือ ชุดข้อมูลสำหรับสร้างแบบการจำลองและชุดข้อมูลสำ หรับตรวจสอบความสมเหตุสมผล สำหรับ ข้อมูลกายภาพ ที่ใช้สำหรับการจำลองทางนิเวศวิทยาป่าไม้ ประกอบด้วย ข้อมูลภูมิอากาศ (ปริมาณน้ำฝนและอุณหภูมิ) ภูมิประเทศ ดินและธรณีวิทยา ใน การศึกษาครั้งนี้ นำข้อมูลปริมาณน้ำฝน และอุณหภูมิจากกรมอุตุนิยมวิทยา มาสร้างเป็น 19 ตัวแปรด้านภูมิอากาศทางชีววิทยาด้วยแบบจำลอง BIOCLIM และคัดเลือกเหลือเพียง 10 ตัวแปรสำหรับใช้ในการสร้างแบบจำลองทางนิเวศวิทยาป่าไม้ ส่วนข้อมูลภูมิประเทศซึ่งประกอบด้วยระดับความสูง ความลาดชัน และทิศทางด้านลาด สกัดจากแบบจำลองความสูงเชิงเลข ในขณะเดียวกัน พื้นที่ลาดชันเชิงซ้อน ของ กลุ่มชุดดิน ของกรมพัฒนาที่ดินได้ถูกจำแนกเพิ่มตามคุณลักษณะทางธรณีของกรมทรัพยากรธรณี

ในการจำแนกและการประเมินปัจจัยทางด้านกายภาพสำหรับการกระจาย ของชนิดป่าโดยอาศัย การวิเคราะห์ปัจจัย พบว่า ความแปรผัน สะสมของตัวแปร สูงสุด ประกอบด้วย 10 ข้อมูลภูมิอากาศ 3 ข้อมูลภูมิประเทศ และ 1 ข้อมูลดิน ได้แก่ ป่าเต็งรัง คิดเป็นร้อยละ 95.35 และความแปรผัน สะสมของตัวแปรต่ำสุดได้แก่ ป่าดิบชื้นและดิบแล้ง คิดเป็น ร้อยละ 90.18 ตัวแปรกายภาพดังกล่าวจะถูกใช้เพื่อทำนายการกระจายของชนิดป่าด้วยแบบจำลอง ENFA ผลการศึกษา พบว่า ค่าดัชนี ความเหมาะสม ถิ่นที่อยู่อาศัย ของ ชนิด ป่าที่ดีที่สุดของป่าแต่ละชนิด ประกอบด้วย ปัจจัยทางด้านกายภาพที่เหมือนกันคือ อุณหภูมิ เฉลี่ยรายปี อุณหภูมิสูงสุดรายเดือนเฉลี่ย อุณหภูมิต่ำสุดรายเดือนเฉลี่ย และระดับความสูง จากนั้น ค่าดัชนีความเหมาะสมถิ่นที่อยู่อาศัยของชนิดป่าที่ดีที่สุดของแต่ละชนิดป่าถูกแบ่งออกเป็น 3 ระดับ (ความเหมาะสม ต่ำ ปานกลางและสูง) ด้วยวิธี การแบ่งตามธรรมชาติ (natural break method) และนำมารวมเข้าด้วยกัน โดยอาศัย การกำหนด รหัสพิเศษเฉพาะและการปฏิบัติการแบบบวกของการวิเคราะห์เชิงพื้นที่ของระบบสารสนเทศภูมิศาสตร์ เพื่อ

สร้างแผนที่การกระจายของชนิดป่า ผลที่ได้รับคือ แผนที่การกระจายของชนิดป่า ประกอบด้วย ป่าเบญจพรรณ (ร้อยละ 15.31) ป่าเต็งรัง (ร้อยละ 32.81) ป่ารอยต่อชนิดป่าแบบผลัดใบ (ร้อยละ 14.35) ป่าสนเขา (ร้อยละ 1.63) ป่าดิบชื้นและป่าดิบแล้ง (ร้อยละ 1.29) ป่าดิบเขา (ร้อยละ 1.21) ป่ารอยต่อชนิดป่าแบบไม่ผลัดใบ (ร้อยละ 16.32) ป่ารอยต่อผสมระหว่างชนิดป่าแบบ ผลัดใบและไม่ผลัดใบ (ร้อยละ 9.02) และพื้นที่ที่ไม่เหมาะสมเป็นป่า (ร้อยละ 8.06) นอกจากนี้ พบว่า ความถูกต้องโดยรวมและความสอดคล้องสัมประสิทธิ์แคปปา ของแผนที่การกระจาย ของชนิดป่า มีค่าเท่ากับ ร้อยละ 75.78 และ ร้อยละ 68.76 ตามลำดับ ในขณะ เดียวกัน ความถูกต้อง โดยรวมของการประเมินความถูกต้องแบบฟัซซีที่อาศัยกฎข้อบังคับทางตรรกศาสตร์แบบฟัซซี มีค่าเท่ากับร้อยละ 97.66

จากผลการศึกษาสามารถสรุปได้ว่า ปัจจัยทางกายภาพ ซึ่งประกอบด้วย อุณหภูมิเฉลี่ยรายปี อุณหภูมิสูงสุดรายเดือนเฉลี่ย อุณหภูมิต่ำสุดรายเดือนเฉลี่ย และระดับความสูง สามารถนำมาใช้จัดสร้างแผนที่การกระจายของชนิดป่าโดย ENFA ได้อย่างมีประสิทธิภาพ ผลลัพธ์ที่ได้รับ สามารถนำไปใช้ในการ ฟื้นฟูทรัพยากรป่าไม้ให้เหมาะสมกับลักษณะทาง ภูมิอากาศและ ภูมิประเทศของนิเวศวิทยาป่าไม้

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา______________________

ปีการศึกษา 2554 ลายมือชื่ออาจารย์ที่ปรึกษา__________________

YAOWARET JANTAKAT : PREDICTION OF FOREST TYPE DISTRIBUTION USING ECOLOGICAL MODELING IN PING BASIN, THAILAND. THESIS ADVISOR : ASST. PROF. SUWIT ONGSOMWANG, Dr. rer. Nat. 230 PP.

PREDICTION OF FOREST TYPE/ ECOLOGICAL MODELING/ FACTOR ANALYSIS/ ECOLOGICAL NICHE FACOR ANALYSIS (ENFA) /PING BASIN

The main objectives of the study are to identify and evaluate physical factors for forest type distribution using factor analysis and to develop forest ecological model for predicting forest type distribution using ENFA. In this study, 13 watersheds of upper Ping Basin in Northern Thailand were selected as the study area based on the forest inventory data 2007 of DNP that were divided into 2 datasets: one dataset for modeling and another dataset for validating. Additionally, physical data were used for ecological modeling and include climate (rainfall and temperature), topography, soil and geology. Herein, rainfall and temperature data from TMD were used to generate 19 bio-climatic variables with BIOCLIM model and 10 of them were selected for forest ecological modeling. Topographic data including elevation, slope and aspect were extracted from DEM while slope complex area of soil group data of LDD was further classified based on characteristics of geological formation from DMR.

For identification and evaluation of physical factors for forest type distribution using factor analysis, it was found that the highest cumulative variance of variables including 10 climatic data, 3 topographic data, and 1 soil data was dry dipterocarp forest (95.35%) while moist and dry evergreen forest provided the lowest cumulative variance of variables (90.18%). These physical variables were used to predict forest type distribution using ENFA model. The results showed the best forest habitat suitability index of each forest type composed of the same physical variables: mean annually temperature, mean monthly maximum temperature, mean monthly minimum temperature, and elevation. After that, the best forest habitat suitability indices from each forest type were firstly reclassified into three classes (low, moderate and high) using natural break method. Then, they were combined together using an assigned unique coding and addition operation of GIS spatial analysis for generating forest type distribution map. As a result, forest type distribution map included mixed deciduous forest (15.31%), dry dipterocarp forest (32.81%), deciduous ecotone (14.35%), coniferous forest (1.63%), moist and dry evergreen forest (1.29%), hill evergreen forest (1.21%), evergreen ecotone (16.32%), deciduous and evergreen ecotone (9.02%), and unsuitable forest area (8.06%). In addition, it was found that overall accuracy and kappa hat coefficient of agreement of forest type distribution map were 75.78% and 68.76%, respectively. In the meantime, overall accuracy of fuzzy accuracy assessment based on fuzzy logical rule was 97.66%.

In conclusion, it appears that physical factors include mean annual temperature, mean monthly maximum temperature, mean monthly minimum temperature, and elevation can be effectively used to create forest type distribution map using ENFA. The obtained output can be used for rehabilitation of forest resource to fit with climate and terrain of forest ecology.

School of Remote Sensing — Student's Signature______________________

Academic Year 2011 — Advisor's Signature______________________

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Yaowaret Jantakat

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LIST OF ABBREVIATIONS

RFD	=	Royal Forest Department
DNP	=	Department of National Parks, Wildlife and Plant Conservation
FIO	=	Forest Industry Organization
PPT	=	Petroleum Authority of Thailand
NGOs	=	Non-Government Organizations
CBD	=	Convention on Biological Diversity
UNCED	=	United Nations Conference on Environment and Development
IUCN	=	International Union for Conservation of Nature
USDA	=	United States Department of Agriculture Forest Service
ENFA	=	Ecological Niche Factor Analysis
DEM	=	Digital Elevation Model
TMD	=	Thailand Meteorological Department
LDD	=	Land Development Department
DMR	=	Department of Mineral Resources
CCA	=	Canonical Correspondence Analysis
GLMs	=	Generalized Linear Models
GAMs	=	Generalized Additive Models
PCA	=	Principal Component Analysis
SOC	=	Soil Organic Carbon
USDA	=	United States Department of Agriculture

LIST OF ABBREVIATIONS (Continued)

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CHAPTER I

INTRODUCTION

1.1 Background

Forest rehabilitation which includes reforestation and afforestation plays an important role in forest conservation in Thailand. Two main responsible sectors in these activities are government agencies e.g. Royal Forest Department (RFD) and Department of National Parks, Wildlife and Plant Conservation (DNP) and Forest Industry Organization (FIO) and private agencies (e.g. Petroleum Authority of Thailand (PPT) and Non-Government Organizations (NGOs) (e.g. Green World Foundation and Greenpeace Southeast Asia). However, forest area is continuously decreased that appear explicitly in forest statistics of RFD, forest area of Thailand had been reduced from 1973 to 1998 based on visual interpretation of satellite imageries at the scale of 1:250,000. In 2000 RFD changed the scale of satellite imageries into 1:50,000 and reported that forest cover was about 33.15 percent of the country area. Also, in 2004 forest cover of Thailand was about 32.66 percent of the country area (see detail in Table 1.1). Based on forest statistic data in both periods (1973-1998 and 2000-2004), forest cover of Thailand still continuously decreases. Thus, forest rehabilitation activities in Thailand are very important. These activities should be taken place in national reserved forest, national parks and wildlife sanctuary with basic knowledge of forest ecosystem. In addition, these tasks associate to international

Table 1.1 Comparison of forest area in Thailand during 1973-2004 (Royal Forest Department, 2004).

Year	Forest area (sq.km)	Percent	Sources
1973	221,707.00	43.21	Based on visual interpretation of satellite imageries at scale of 1:250,000
1976	198,417.00	38.67	Based on visual interpretation of satellite imageries at scale of 1:250,000
1978	175,224.00	34.15	Based on visual interpretation of satellite imageries at scale of 1:250,000
1982	156,600.00	30.52	Based on visual interpretation of satellite imageries at scale of 1:250,000
1985	150,866.00	29.40	Based on visual interpretation of satellite imageries at scale of 1:250,000
1988	143,803.00	28.03	Based on visual interpretation of satellite imageries at scale of 1:250,000
1989	143,417.00	27.95	Based on visual interpretation of satellite imageries at scale of 1:250,000
1991	136,698.00	26.64	Based on visual interpretation of satellite imageries at scale of 1:250,000
1993	133,554.00	26.03	Based on visual interpretation of satellite imageries at scale of 1:250,000
1995	131,485.00	25.62	Based on visual interpretation of satellite imageries at scale of 1:250,000
1998	129,722.00	25.28	Based on visual interpretation of satellite imageries at scale of 1:250,000
2000	170,110.78	33.15	Based on visual interpretation of satellite imageries at scale of 1:50,000
2004	167,590.98	32.66	Based on visual interpretation of satellite imageries at scale of 1:50,000

Note: 1. Existing forest area in this table means evergreen, pine, mangrove, mixed deciduous, dry dipterocarp, scrub, swamp, bamboo and forest plantation in the national forest reserves, national parks, wildlife sanctuaries, forest working plan (an area of 5 hectare (31.25 rai) or more with tree taller than 5 meters or more with canopy covering more than 10% of the ground area) and forest concession areas or other forest areas where can be detected by LANDSAT–TM imageries at the scale 1:50,000 and 1:250,000 but not including rubber plantations and orchards.

2. The area of Thailand (513,115.02 sq. km) is based on the calculation of Royal Thai Survey Department in 1978 and declared by cabinet resolution on 12 July 1983.

3. Percent of forest area during 1973-2004 was compared to the whole area of Thailand.

strategies of the Convention on Biological Diversity (CBD) and Agenda 21 from the United Nations Conference on Environment and Development (UNCED). The study of forest ecosystem is essentially designated to contribute to regional and local conservation with forest rehabilitation. These rehabilitations are not only reserved in situ but they should be required ex situ conservation (International Union for Conservation of Nature (IUCN), 2002).

In fundamental of forest ecology, Kutintara (1999) stated that the basic understanding of relationship between environmental factors and vegetation covers is the critical one of ecological goals for ecologists. Likewise, Jarvis (2000) mentioned significantly that geography and environmental science are also linked with ecology, because there are spatial and environmental implications of how and why ecological systems function. Generally, the environmental elements are divided into two major groups (Laughlin, Abella, and Covington, 2007): biotic (plants, animals, microorganism, and human) and abiotic (energy and physical environment). Especially, the physical factors (e.g. soil, climate, geology, topography, and forest fire) are always used to classify forest type distribution because they are obvious to understand relationship between them (Nakwa et al., 2008; Horsch, 2003; Young and Giese, 2003; United States Department of Agriculture Forest Service (USDA), 2002; and Aber et al., 2001).

At present, modeling plays important role in many fields and is directly applied for prediction or simulation of specific phenomena. Ecological modeling has been widely accepted in earth surface modeling that is a powerful tool for analyzing long-term decision problems (Larocque et al., 2011; Yue, Jorgensen, and Larocque, 2010; and Solidoro, Bandelj, Cossarini, Libralato, and Canu, 2009), and can depict the interactions and changes of environmental elements and simulate the dynamics of spatial and temporal patterns in ecosystems (Muller, Breakling, Jopp, and Reuter, 2011; and Gotelli, 2008). However, ecosystems are the set of environmental conditions and resources that allow a given organisms or species to survive and grow to reproduce in master limiting factors called “potential ecological niches” (Barve et al., 2011 and Peterson et al., 2011) that ecologists have always been used to approach a variety of important problems which include resource use, geographical diversity, and many aspects of community composition and structure (McGill et al., 2006).

Herein, ecological niche modeling, namely Ecological Niche Factor Analysis (ENFA) will be applied in this study for prediction of forest type distribution based on the physical factors which define probability of forest types. The expected output from this research in form of forest ecological model and forest distribution will be beneficial for forest rehabilitation in disturbed forest land or abandoned land.

1.2 Research objectives

In this study, forest type distribution in watersheds of upper Ping Basin, Thailand is created by limiting physical factors and ecological model. The specific objectives of forest type distribution for ecological modeling are as follows:

(1) To identify and evaluate physical factors as ecological niche for each forest type

(2) To develop forest ecological models for predicting forest type distribution

1.3 Scope and limitations of the study

1.3.1 Scope of the study

(1) The study area located in 13 watersheds of Ping Basin in Northern Thailand that were selected from considering forest inventory data in national forest resources monitoring information system of DNP.

(2) Five forest types (mixed deciduous forest, dry dipterocarp forest, coniferous forest, hill evergreen forest, moist and dry evergreen forest) were determined for this study based on considered from forest inventory data in the study area based on the similarly environmental conditions for forest ecological modeling.

(3) Basic physical factors of forest types in study area, were characterized with a long term data, and were extracted under GIS based on reliable reporting of identified-physical factors for forest types in Thailand from Kutintara (1999) as summarized in Table 1.2.

(4) Evaluation of significant physical factors of each forest types in the study area was obtained from factor analysis.

(5) Prediction of forest type distribution were derived from ENFA models that had been processed in a format of raster data with cell size 30 x 30 m. because this study requires to maintain quality of the highest resolution of Digital Elevation Model (DEM).

1.3.2 Limitations of the study

Data limitation

This study used the collected data from various related agencies that were available and publicized. The limitation of data in this study can be summarized as follows:

Table 1.2 Summarization of identified-physical factors for forest types in Thailand (Kutintara, 1999).

Forest Types	Physical factors						
	Soil	**Temp.**	**Rainfall**	**Elevation**	**Wind speed**	**Fire**	**Season**
			1. Evergreen forests				
1.1 Mangrove forest	Mud and flooding	26-38°C	N	N	N	N	N
1.2 Swamp forest	Highly acid soil	N	N	N	N	N	N
1.3 Beach forest	Sand is so highly and salt	N	N	N	Blowing salt vapour	N	N
1.4 Tropical rain forest	Highly deep soil and highly moisture	>20°C	>1,600 mm/year				
1.4.1 Lower tropical rain forest				< 600 m	N	N	N
1.4.2 Upper tropical rain forest				~600-900 m	N	N	N
1.5 Dry evergreen forest	Clay or sandy clay		~1,000-2,000 mm/year	~100-800 m	N	N	Dry periods
1.6 Coniferous forest or Pine forest	Soil include so highly acid	very low	N	~1,000-1,800 m	N	N	N
1.7 Hill evergreen forest	Highly deep soil	<20°C	N	>1,200 m	N	N	N
1.7.1 Lower hill evergreen forest				~1,200-1,800 m	N	N	N
1.7.2 Upper hill evergreen forest				>2,000 m	N	N	N
			2. Deciduous Forests				
2.1 Mixed deciduous forest	Low moist soil, shallow soil, rock appearance,	N	1,200-1,400 mm/year	50-800 m and >800 m		For some areas	Dry periods
2.2 Deciduous dipterocarp forest	Highly sandy soil, shallow soil and laterit	N	~ 900-1,200 mm/year	50-1,000 m		December -March every year	N

Note: N = No reported

(1) In modeling and prediction of forest types, this study had used forest inventory data year 2007 from the Department of National Parks, Wildlife and Plant Conservation (DNP) that only 406 of 902 inventory points in the study area were recorded as forest points that included 15 of coniferous forest, 5 of moist evergreen forest, 14 of dry evergreen forest, 83 of hill evergreen forest, 164 of mixed deciduous forest, and 179 of dry dipterocarp forest.

(2) Interpolation surface of rainfall and temperature was analysed with long-term climatological data for 30-year period (1971-2000) from 21 mainly northern-climate stations of Thailand Meteorological Department (TMD).

(3) Provincial soil data year 1984 at the scale 1:100,000 from Land Development Department (LDD) were used for this study that was seen by slope complex area 71.51% of the study area and covered 86% of all studied-forest inventory points. Therefore, slope complex area of such soil layer was classified to use for this study only based on provincial geology layer year 2006 and 2008 at scale 1:250,000 from the Department of Mineral Resources (DMR).

Limitation of field survey

Some checked areas of the study area were not accessed because of barrier topography and weather.

1.4 Benefit of the study

(1) To know results of identifying and evaluating physical factors as ecological niche for each forest type based on factor analysis. This result will be useful for consideration of significantly physical variables for forest ecological modeling.

(2) To obtain results of developing forest ecological model for predicting forest type distribution based on ENFA. This result will be useful for rehabilitation of forest resource with suitable physical factors.

(3) To use alternative technique for forest distribution mapping when remotely sensed data is not available. Furthermore, forest type distribution map can be used effectively as basic data for forest rehabilitation based on ecological suitability.

CHAPTER II

LITERATURE REVIEWS

2.1 Concept of forest ecology

The word "ecology", first used by Haeckel (1866), was described as the scientific study of the interactions between organisms and their environment (Begon, Townsend, and Harper, 2006 and Townsend, Begon, and Harper, 2008). Ecology deals with organisms, populations, communities, ecosystems and the biosphere (Dash, 2001). Similarly, a term of forest means an area inhabited by more than one organism, forest ecology most often concentrates on the level of the population, community or ecosystem (Burton, Messier, Smith, and Adamowicz, 2003 and Kimmins, 2004). Generally, forest ecology is scoped with the components and functions of forest ecosystem which is dominated by trees and other woody vegetation (Verne, 2007 and Waring and Running, 2007), and is studied with characteristics and methodological approaches with other areas of terrestrial plant ecology (Singh and Garg, 2007). In fact, forest ecosystem is the interaction of plant communities to abiotic and biotic environments that compose of producers, consumers and decomposers (Tieh and Pask, 2007), can be illustrated by Figure 2.1. The abiotic characteristics are nonliving factors such as atmospheric gases, temperature (ranges and changes), fire, and wind through other components (e.g., mineral nutrients, and water (Jarvis, 2000). For biotic characteristics, interacting among organisms, such as competition and predation, may lead to spatial structuring even in a completely homogenous space (Turner, Garner, and O'Nell, 2001). As a conclusion, a plant community is a particularly vivid dominance in forest ecosystem at work.

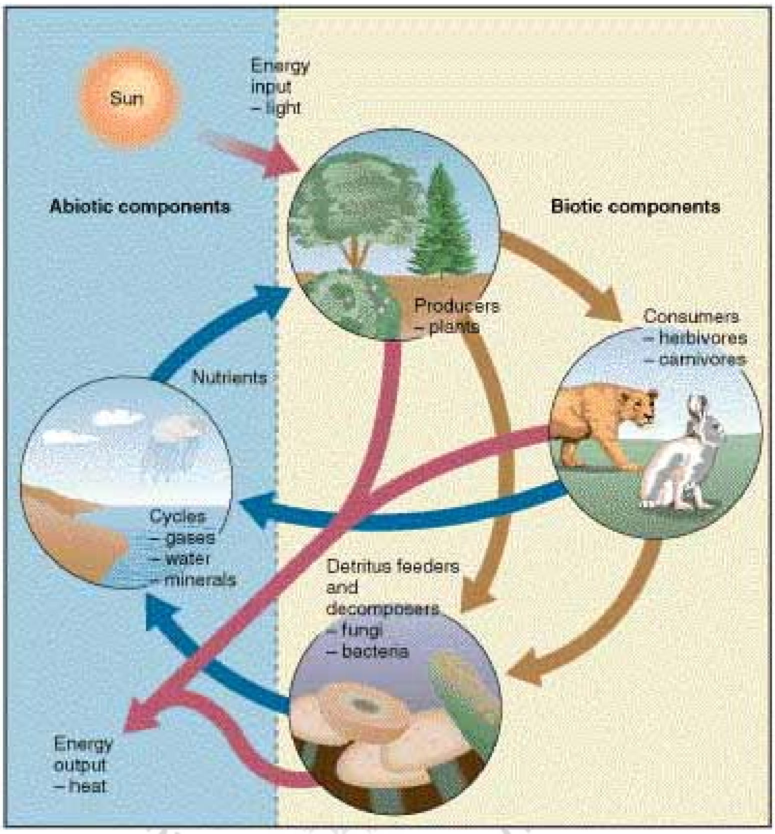


Figure 2.1 The relationship between biotic and abiotic factors in forest ecosystem with the movement of nutrients (blue arrows), energy (red arrows) and both (brown arrows) (Tieh and Pask, 2007).

2.2 Concept of plant community

When only assemblage of plants, is a habitat where is considered and called "plant community" (Agarwal, 2008). Habitat is an organism or a species population lives, for example, a terrestrial habitat (e.g., forest, grassland, tundra, and desert) and an aquatic habitat (e.g., fresh water and estuarine or marine) (Gillbert and Anderson, 2004 and Sutherland and Hill, 2002). In addition, Cox and Moore (2005) stated that the study of plant communities has developed as an independent area of ecology (sometimes termed “vegetation science”) mainly because the plant components of communities are often the most evident features. Consequently, concepts of plant community can be grouped into two main approaches: community unit concept and continuum concept (Cox and Moore, 2005; Leps and Smilaver, 2003; Faber-Langendoen 2001; and Kutintara, 1999).

2.2.1 Community unit concept

The community unit concept is one of the most important principles in ecological thought and practice (Faber-Langendoen, 2001). The idea of community unit concept emphasizes the fact that diverse organism live together in an orderly manner and the impact of the community to be recognised is that the organisms grow as the community grows (Agarwal, 2008). Actually, Kutintara (1999) cited that community unit concept is similarly to study a hierarchical structure and unique of plant community as shown in Table 2.1. However, Morrison, Marcot, and Mannan, 2006) stated that the community unit concept is the particular idea; is difficult to prove and disprove because there are variation in biotic communities with observing in nature.

Table 2.1 Example for identification of community unit concept (Du Rietz, 1930).

Biological unit	**Synusiae**	**Plant Community**	**Example**
Class	Panformation	Panformation	Deciduous forest
Order	Formation	Formation	Deciduous forest in temperate
Family	Subformation	Subformation	Deciduous forest in temperate
Tribe	Federion	Federion	Deciduous dipterocarp forest
Genus	Association	Association	Deciduous dipterocarp forest scrub type
Section	Consociation	Consociation	*Shorea siamensis* (dominance)
Species	Socion	Sociation	*Shorea siamensis* and *Shorea roxberghii* (dominance)

2.2.2 Continuum concept

Continuum concept is the average number of limits per interval along the gradient should be equal apart from random effects (Cox and Moore, 2005; Maarel, 2005; and Grace and Tilman, 2003). Moreover, the basic advantage of the continuum concept lies in the possibility of studying vegetation through a wide and comprehensive approach (Agarwal, 2008). Then, Sharma (2009) described that continuum concept is naturally characterized in two patterns of ecological amplitude and gradient analysis. In addition, gradient analysis is leaded into concept of climax vegetation and ecological niche (Dash, 2001). Thus, characteristics of continuum concept can be explained as follows:

(1) Ecological amplitude

Ecological amplitude was recognized by Shelford (1937) as the “law of toleration” (Patton, 2010), was defined by Sharma (2009) as different species differ from each other in terms of their demands (requirements) from their environment, and consequently also in respect of the extent to which they can tolerate the fluctuations in their environmental conditions. Krohne (2000) stated to Shelford's law of tolerance (as shown in Figure 2.2). There are both upper and lower limits of physical factors an organism can tolerate (whether they be the limiting factor or not).

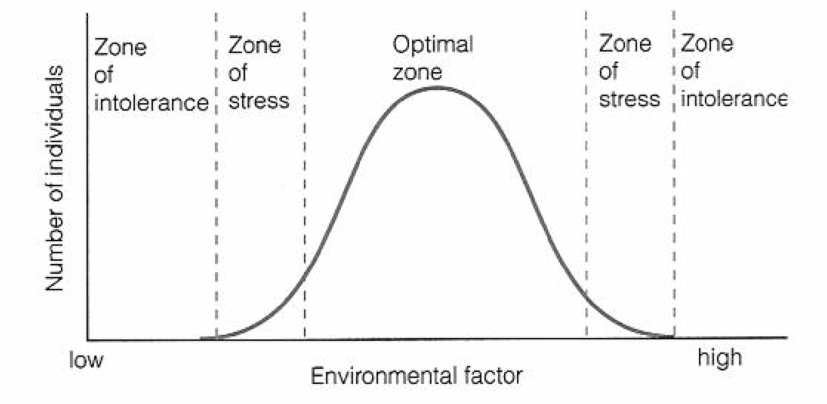


Figure 2.2 Shelford's law of tolerance (Krohne, 2000).

(2) Gradient analysis

Gradient analysis was early defined by Whittaker (1975) that gradient analysis is connected with the continuum concept or with the Gleasonian analysis individualistic concept of plant communities (Chapman and Reiss, 2003 and Leps and Smilaver, 2003) and shown in Figure 2.3. Such meaning of gradient analysis has been broadly evolved by a complex interplay of suggestion and substantiation among techniques, concepts and theory (Lomolino, Sax, and Brown, 2004). Then, Cox and Moore (2005) had mentioned to the description of plant communities with 2 contrast views: Clement's view and Gleason's view. Both views can be expressed graphically in the form shown in Figure 2.4 where the distributions of individual species are depicted along environmental gradient.

(2.1) Clement's view of the plant community: Clement's view regarded the plant community as an organic entity in which the positive interactions and interdependencies between plant species led to their being found in distinct associations that were frequently repeated in nature.

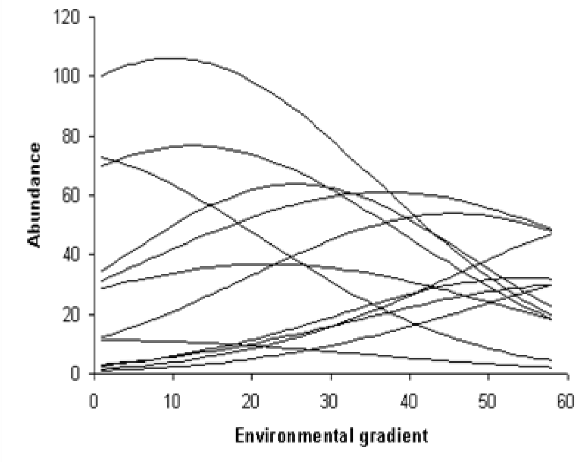
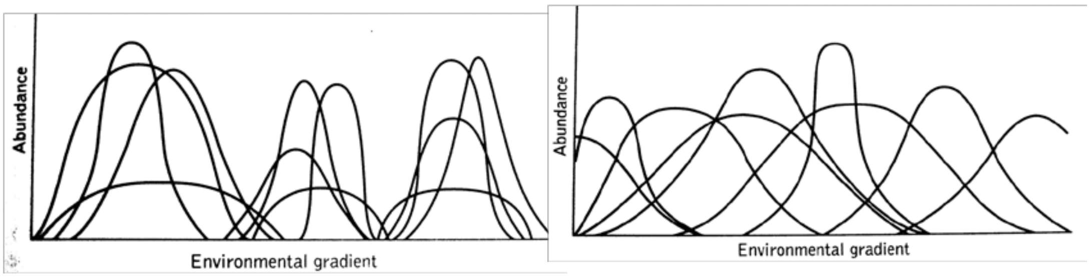


Figure 2.3 Whittaker's gradient analysis (Leps and Smilaver, 2003).

(2.2) Gleason's view of the plant community: Gleason's view emphasized the individual ecological requirements of plant species, pointing out that no two species have quite the same needs. In other words, the distributional or ecological ranges of any two species coincide precisely, and the degree of association between ground flora and canopy is often weaker than one might assume from casual observation.



(a) The model of Clements in which species' requirements coincide, leading to the separation of distinct 'communities'

(b) The 'individualistic' model of Gleason in which each species is distributed independently and no clear 'communities' are apparent.

Figure 2.4 Diagrammatic representation of two models of distributions of individual species (Cox and Moore, 2005).

(3) Climax vegetation

Concept of climax vegetation had been proposed by The US ecologist Whittaker that was relevant to vegetation continuum concept (Kutintara, 1999), was believed that the climax is determined by all the factors which are part of the system, and which have a constant or regularly recurring effect on populations (Vera, 2000). Additionally, climax vegetation was noted also that only 60 percent of the vegetation could be placed in these types and that there was considerable gradation across community boundaries; are determined in term of ecotone (Smithson, Addison, and Atkinson, 2002).

(4) Ecological niche

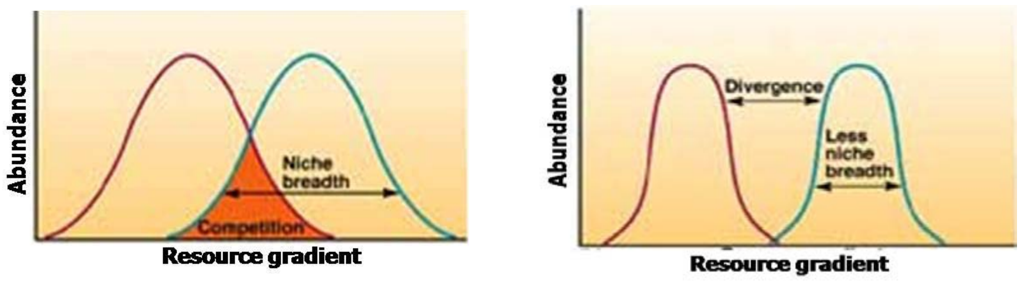
There are limits of tolerance to other components of the environment that all possible factors are not equally important for a given situation or for a given organism (Rana, 2007). This situation is related to niche concept that is defined as "the limit for all important environmental features within which individuals of a species can survive, grow and reproduce" (Begon et al., 2006; 1992). Then, ecologists have invented the concept of an ecological niche to thoughts about the ways in which organisms fit into their environment (Straalen and Roelofs, 2006). Furthermore, ecological niche had been divided into 3 types (Dash, 2001) as follows:

(4.1) Spatial or habitat niche is concerned with the physical space occupied by an organism.

(4.2) Trophic niche refers trophic position (food level) of an organism.

(4.3) Hypervolume niche or multidimensional niche was developed by Hutchison (1965), recognised two niche approaches: fundamental niche and realized niche. The fundamental niche is the maximum abstractly inhabited hypervolume, when the species is not competing with others for its resource. On the remained other, this smaller hypervolume occupied by a species is called the realized niche.

In fact, Hutchison's niche concept has been revealed in a seminal essay more than 50 years ago proposed a formalization of interest in species' niches (Soberon, 2007), driven in part by the urgency of predicting ecological responses to rapid environmental change (Moore, 2009). Moreover, Oris (2010) had presented two niche concepts as shown in Figure 2.5. From Figure 2.5, the first concept (a) indicates that one group gains a larger share of resources while the other will migrate to a new area, become extinct, or change its behavior in a way to minimize competition. The second concept (b) shows that niche specialization can create behavior separation that allows subpopulations of a single species to diverge into separate species.



(a) (b)

(a) One species will have a competitive edge, and will gain a larger share of resources . In while, other species will migrate to a new area, become extinct, or change its behavior in a way to minimize competition

(b) Niche specialization can create behavior separation that allows subpopulations of a single species to diverge into separate species.

Figure 2.5 Niche concepts (Oris, 2010).

2.3 Classification of vegetation on terrestrial biome

A biome is a climatically and geographically defined area of ecologically similar communities of plants, animals and soil organisms that interact with abiotic components of the environment, and each community is separate local ecosystem (Sparrow et al., 2010). There are many vegetation classification systems on terrestrial biome used, although all of them use climate, physiognomy (the general appearance of the vegetation, e.g., desert, grassland, forest) and leaf habitat (evergreen or deciduous) to classify vegetation (Young and Giese, 2003). The choice is between groupings based on features of the physical environment (climate, soil, and topography), the appearance of the vegetation (structure, physiognomy, and seasonal changes), or the actual plant species present (Gupta, 2005). However, concept of vegetation classification has been on 2 basic characteristics: ecology and geography (Sharma, 2009; Ganderton and Coker, 2005; and Kutintara, 1999) as following:

2.3.1 Classification based on ecological basis

Vegetation classifications are widely used in ecological-planning studies largely because vegetation can be used as an indicator of the ecosystem state (Ndubisi, 2002) and then Hakansson (2003) mentioned that the ecological concept on vegetation is classified with regard to varieties of environmental conditions. Again, Sharma (2009) stated that vegetation classification is supposed to vary continuously in space, with each point of the continuum being equally probable that has been supported to the basis of environmental gradient, leads into gradient analysis or ordination. With environmental gradient, there exists also community gradient in nature, for example, on mountains, where with changing altitude, there is gradual change in climatic and edaphic conditions associated with gradual changes in vegetation (Agarwal, 2008). Importantly, vegetation classification on ecological basis is concerned with the physical environment because it can determine the range of the plant communities (Ganderton and Coker, 2005) that can be perceived as discontinuities or as marked gradients called "ecotone" as a transition zone by a very mobile organism that crosses in a short time, while another less mobile organism may perceive it as a patch with narrow borders (Burel and Baudry, 2003).

2.3.2 Classification based on geographical basis

Vegetation classification on geographical basis is related to plant behavior and individual reactions to geographical conditions (Kutintara, 1999) or may be called "biographical basis" (Cox and Moore, 2005 and Ganderton and Coker, 2005) that expressed as a link between the earth sciences (geology and geography) and the life sciences. In principle of this classification, it is based on the natural obstacle of geography (e.g. oceans, the great deserts and the top mountain) as determinant for appearance of various species in different areas with considering principle morphology of dominant species (Smithson et al., 2002). However, this classification was more applied in the geographic classification of animal than the field of plant communities (Goudie, 2001).

2.4 Classification of forest types in Thailand

Thailand lies between the Indo-Chinese and Sundaic (Indo-Malay) regions, and is considered a collective centre of plant diversity from three regional elements: Indo-Burmese, Indo-Chinese and Malaysian (Pooma, 2005). Thailand includes coordination of topography as follows (Department of National Parks, Wildlife and Plant Conservation, 2008):

North is bounded at latitude 20^{o}25’30” where locates Mae Sai district in Chiangrai province.

South is bounded at latitude 5^{o}37’00” where locates Betong district and Yala province.

East is bounded at longitude 105^{o}37’30” where locates Phibun Mangsahan district in Ubon Ratchathani province.

West is bounded at longitude 90^{o}22’00” where locates Mae La Noi district in Mae Hong Son province.

With geographical conditions mentioned above, Thailand includes various forest types: moist evergreen forest, dry evergreen forest, mixed deciduous forest and dry dipterocarp forest, etc. Kutintara (1999) stated classification of forest types in Thailand that has used system of Smittinand (1966). In the first time, distribution of forest types in Thailand was based on annual rainfall and duration of drought

(Lekagul and McNeely, 1977). However, there were other factors for forest type classification that consisted of elevation, soil, climate and fire (Smitinand, 1977). Then, Kutintara (1999) had concluded influence of all mentioned factors for distribution of forest types in Thailand that this study had summarized in Table 1.2. From Table 1.2, classification of forest types in Thailand had been identified by the physical factors (e.g., soil, climate (temperature, rainfall, wind and season), elevation, and fire). Similarly, Santisuk (2006) mentioned influence of environmental factors for forest types in Thailand (e.g., climate, edaphic, elevation, and biotic (fire and human)) that interaction of these factors affects to the gradient and overlay of forest communities such as ecotone between mixed deciduous forest and dry evergreen forest. In this case, Kutintara (1999) had stated ecotone community between swamp forest and terrestrial forest (especially lower tropical rain forest).

2.5 Ecological modeling

There are many academic papers that mentioned ecological modeling. However, Elith and Burgman (2003) had cited to seven main classes of ecological modeling that were analysed for finding of habitat suitability. Each class includes modeling methods, key concepts, data requirements and examples of ecological application that can summarize in Table 2.2 and more details as follows:

Table 2.2 Methods for ecological modeling (Elith and Burgman, 2003).

Methods	Key concepts	Data requirements	Examples of application
Expert system	- Schamberger and O'Neil (year 1986)	Presence-absence	- Birds in the United States by Van Horne and Wiens (year 1991)
Hulls and kernels	- Worton (year 1989)	Presence only	- Black howler monkeys in Belize by Ostro and colleagues (year 1999)
Bioclimatic envelopes	- Busby (year 1991)	Presence	- Kauri pine in New Zealand by Mitchell (year 1992)
Simple multivariate distance methods	- CIFOR (year 1999)	Presence	- Marsupials in Australia by Carpenter and his colleagues (year 1993)
ENFA	Hirzel (year 2001)	Presence	- Ibex in Switzerland by Hirzel by 2001
CCA	- ter Braak (year 1986)	Presence-absence	- Rock outcrop vegetation, United States by Wiser and colleagues (year 1996)
GLMs	- McCullagh and Nelder (year 1989)	Presence-absence	- Myrtle beech in Australia by Lindenmayer and colleagues (year 2000)
GAMs	Hastie and Tibshirani (year 1990)	Presence-absence	- Eucalypts in Australia by Austin and Meyers (year 1996)
Decision trees	Breiman (year 1984)	Presence-absence	- Vegetation mapping in Australia by Keith and Bedward (year 1999)
Neural networks	Aleksander and Morton (year 1990)	Presence-absence	- Himalayan river birds by Manel and colleagues. (year 1999)
Genetic algorithms	Mitchell (year 1996)	Presence-absence	- Ecology and conservation in Australia by Stockwell and colleague (year 1999)
MAXENT	Phillips, Anderson and Schapire (year 2006)	Presence	- Ecology and conservation in USA by Steven, Phillips and Dudik (year 2008)

(1) Expert system

This modeling method had proposed representation of concept relevant to habitat suitability indices that are means of mapping species habitat. The method is based on the judgments of experts who identify critical variables. Habitat Suitability Index (HSI) for a given species represents a conceptual model that relates each relevant measurable variable of the environment to the suitability of a site for the species, usually scaled between 0 and 1. Each variable is represented by a single suitability index that are linked by additive, multiplicative or logical functions that reflect relationships among the variables.

(2) Hulls and kernels

This method is represented by hulls and kernels. Hull constructions and kernels are produced by a delauney tessellation to bound the presence data, calculated the mean length of all connections in this tessellation, and removed those that were α times greater than this mean for specific values of α. Generally, kernel methods comprise of two data patterns: bivariate data and multimodal data. However, multimodal data performs well for distribution of data that are generated as the sum of several bivariate normal distributions.

(3) Bioclimatic envelopes

Climate envelops is likely hulls, based on presence data that is used in conjunction with elevation data and climatic surfaces developed from long-term rainfall, temperature, and radiation records to construct a climate profile for a species. Moreover, tools are used for this modeling method such as ANUCLIM, BIOCLIM and BIOMAP, were taken to analyze a climate-mapping approach to modeling.

(4) Multivariate association analysis is divided into 3 methods as follows:

(4.1) Simple multivariate distance method is the simplest analysis that is usually represented by DOMAIN, is a flexible modeling procedure for mapping potential distributions of plants and animals (Carpenter, Gillison and Winter, 1993). This DOMAIN is applied for a multivariate distance measurement to create habitat suitability maps. Similarly, convex hulls and climate envelopes, it requires only presence records. Concept of DOMAIN is based on defining sites with the similarity of environmental condition that is measured by Gower metric. The Gower metric scales each parameter by its range to equalize the contributions of all parameters to the final similarity measure. There are other examples of ecological application such as wolf distribution in Italy.

(4.2) Ecological Niche Factor Analysis (ENFA) has recently been under theoretical development and has now been released in the BIOMAPPER. ENFA uses presence-only species data. It quantifies the niche that the species occupies by comparing its distribution in an ecological space, defined by one or more variables, with the distribution of all cells (the global distribution) in that space. Then ENFA uses a factor analysis with orthogonal rotations to (1) transform the predictor variables to a set of uncorrelated factors, and (2) construct axes in a way that accounts for all the marginality of the species in the first axes, and that maximizes specialization in the following axes.

(4.3) Canonical Correspondence Analysis (CCA) is a popular multivariate method that models presence-absence species records and deals with spaces of reduced dimensionality is canonical correspondence analysis (CCA). CCA operates at the plot level by analysing the relationships between species presence-absence or abundance data and environmental data. CCA is not limited to estimating direct linear combination, because the constituent variables can be transformed, scaled, or smoothed before being combined in a linear form. Key assumptions of CCA that are ecologically unrealistic and it are not clear whether the method is robust to violations of the assumptions.

(5) Regression analysis is divided into 2 methods as follows:

(5.1) Generalized Linear Models (GLMs) are a broad class of statistical models that include linear regression and analysis of variance. All GLMs have a response (the species data for models of distribution), a predictor (the explanatory variables, commonly environmental data), and a link function that describes the relationship between the expected value of the response and the predictors.

(5.2) Generalized Additive Models (GAMs) are a nonparametric extension of GLMs, in which at least one of the linear or other parametric functions in a GLM is replaced by a smoothed data-dependent function in a GAM. GAM are considered a useful tool for modeling biological systems because the response is not limited to a parametric function, which means that the filled response surface may be a more realistic representation of the true response shape.

(6) Tree-based method consists of recursive partitions of the dimensional space is defined by the predictors into groups that are as homogeneous as possible in terms of the response.

(7) Machine learning is divided into 2 methods as follows

(7.1) Neural network is a feed-forward neural network, parameterized using hidden units in a single layer (selected by cross-validation), with a given weight. This algorithm is commonly used for modeling presence/absence data.

(7.2) Genetic algorithm is an integrated spatial analysis system for predicting distributions of plants and animals with presence and pseudo-absence data.

(8) MAXENT is the true distribution of a species that is represented as a probability distribution on the set of environment conditions in the study area. MAXENT is produced by a model of species probability distribution that respects a set of constraints derived from the occurrence data. The constraints are expressed in terms of simple functions of the environmental variables, called features. Specifically, the mean of each feature is required to be close (within some error bounds) to the empirical average over the presence sites.

In this study, ENFA is implemented for the derivation of each forest type distribution based on presence data to model habitat suitability, and then shows how this information can be used to guide the selection of reforestation areas in a way that explicitly incorporates spatial ecogeographical characteristics of the landscape. ENFA models habitat suitability of each forest type with a range of ecogeographical data. It models landscape characteristics using existing information on species locations to derive information on habitat suitability.

2.6 Literatures reviews

2.6.1 Identification and evaluation of physical factors for distribution of forest type using factor analysis

There are a variety of researches that has used a statistical method for evaluation of physical factors. Herein, the related literatures were focused on the environmental studies that had used factor analysis based on Principal Component Analysis (PCA) technique for evaluation of environmental factors as follows:

Jimenez et al. (2011) identified the physical and chemical soil based on PCA in a dry tropical forest where located in Guanacaste, Costa Rica. The result of PCA revealed a significant of dry dipterocarp forest ($P < 0.0001$). The Soil Organic Carbon (SOC) concentration decreased in particle size fractions (less than 200 μm) aggregates with increasing soil depth. The lowest and highest carbon concentrations were obtained in the fine sand (105 –200 μm) and clay and silt (less than 20 μm) fractions, respectively. Mineral-associated and stable SOC pool increased with depth, and poorly crystalline Fe oxides and ferrihydrite were the most important minerals for SOC stabilization at 40–50 cm depth. The highest SOC pool was found in the old-growth and more than 80 years-old for dry dipterocarp forest, i.e., 228.9 and 150.3 Mg C ha^{-1} respectively, values similar to those obtained in the Atlantic humid forests of Costa Rica. Comparatively to other studies, soils under dry tropical forest at Santa Rosa store a considerable amount of SOC with potentially large CO_2 emissions if this ecosystem is not preserved.

Garbarino et al. (2009) used PCA for exploring the correlation structure of physically environmental variables and anthropogenic disturbances underlying spatial patterns of stand structure variation in two watersheds of Italy.

PCA had used to categorize the number of stand structure response variables to a smaller subset of integrative, synthetic variables for use in the path models.

Deng et al. (2008) studied identification and distribution of functional group and in old-growth tropical montane rain forest on Hainan Island, China. This study implemented factor analysis with PCA technique for categorization of physically environmental factors (topographical factors and soil factor) that were interacted to old-growth tropical montane rain forest. Consequently, 4 components or 4 Functional Groups (FGs) had been selected by considering eigenvalues, percent of variance and cumulative percent. 4 FGs were studied to distribution of old-growth tropical montane rain forest with Two-way Indicator Species Analysis (TWINSPAN). This study found that distribution of old-growth tropical montane rain forest was mainly controlled by topographical factors.

Boruvka et al. (2007) implemented PCA for forest soil acidification assessment in the Jizera Mountains region that is located in the North of Bohemia. In the PCA, five principal components (PC) describing more than 70% of total variation were selected to analyse spatial correlation with stand factors (altitude, slope, aspect, forest type and age, soil unit, limiting, and grass cover) that was processed by cross-variogram.

Shono et al. (2006) studied the pattern of natural regeneration in three 1-year old and three 4-year old native species reforestation sites on degraded lands in Singapore. PCA was analysed to present the type of landscape matrix and seed dispersal become increasingly important in determining succession as the planted saplings grow and canopy cover is restored. PCA using abundance data of all 83 species of woody regeneration recorded revealed two groups floristically similar communities: the three 1-year old sites and the two adjacent 4-year old sites. The first and second components explained 34.4 and 29.3% of the variation in species composition, respectively.

Frazer et al. (2005) studied the fine-scale spatial pattern and heterogeneity of forest canopy structure. PCA was implemented to determine the fine-scale (0.5-33 m) spatial heterogeneity found in the outer surface of a forest canopy. PCA facilitated the separation of individual sample units along unique gradients of spatial pattern and canopy structure based on differences in lacunarity (as a scale-dependent estimate of canopy texture and spatial non-stationarity. measured at nine discrete spatial scales. However, this study found that PCA uncovered two major gradients (canopy cover and gap volume) of spatial heterogeneity from the 10 dimensions of our original lacunarity dataset.

2.6.2 Ecological modeling to predict habitat distribution using Ecological Niche Factor Analysis (ENFA)

This study had reviewed many papers in this topic. Nevertheless, there were some related papers that had been selected to apply for this study as follows:

Lausch et al. (2011) applied ENFA for the importance of the presence of deadwood areas for thirty-two habitat variables for the occurrence of the bark beetle was quantitatively recorded. As a consequence, it was shown over a long model period that the intensity of the bark beetle infestation went through different phases over the 18-year study period. No mono-causal correlations could be found between individual habitat factors and the spread of the bark beetle over the entire model period. On the one hand, these findings underline the complexity of the system; on the other hand, this could be interpreted as a possible explanation for conclusions drawn by previous studies that differ from each other.

Podchong et al. (2009) identified the habitat suitability of Sambar Deer (SD) at Phu-Khieo Wildlife Sanctuary, Thailand that had used ENFA in BIOMAPPER. In this identification of habitat suitability for SD, it was found that a model with categorization of environmental factors was capable of predicting the habitat suitability of SD more reliably than the model with all environmental factors put in together. Moreover, this study had presented modeling and validating of SD data. SD data from surveying 2004-2006 were divided into two main datasets: set of modeling (2004-2005) and set for validating (2006). In model validation, the Absolute Validation Index (AVI) and the Contrast Validation Index (CVI) were used to validate all result models. This study had recommended that a good model should have a high value of both AVI and CVI in the sense that AVI should have value > 0.75 and CVI > 0.3.

Braunisch et al. (2008) focused on median algorithm in BIOMAPPER that was used for predicting habitat suitability of Capercaillie presence data in the Swiss Alps of eastern Switzerland and the Black forest of south-western Germany. In this study, ENFA was modeled by environmental factors and Capercaillie presence data and then this model was used to create habitat suitability in both study areas. Computation of habitat suitability for Capercaillie had used the median algorithm that makes the assumption that, on all ecological niche factors, the median of the species distribution indicates the optimal value of creating habitat suitability.

Acevedo et al. (2007) derived a habitat suitability model of the broom hare and the Pyrenean grey partridge in the Cantabrian Mountains, the north of Spain.

The suitable habitat is modeled by ENFA in BIOMAPPER. This study had meaningful expressed ENFA analysis in two key components of species environmental niches. The first being a Marginality Coefficient, which is a measure of the distance between species niche and the mean environmental conditions of study area, and the second being Tolerance Coefficient, which measures how the species tolerates environmental variations in the analysed territory. A high Marginality Coefficient value indicates that the species' requirements differ considerably from the average habitat conditions in the study area and a Tolerance Coefficient value closer to 0 in a range from 0 to 1 indicates a higher degree of specialization. As a result, habitat suitability analyses showed that the hare and partridge occupy very similar ecological niches, characterized by a high percentage of broom and heather scrublands, high altitude and slope, and limited human accessibility.

Soares and Brito (2007) studied correlations between environmental factors and the distribution of amphibian and reptile species richness were investigated in a climate transition area, Peneda-Geres National Park (PNPG), in North-Western Portugal. Using presence-data at a local-scale (1x1 km), ENFA identified a mixture of climatic (precipitation and number of days with fog), topographical (altitude and relief) and habitat factors (number of water courses and water surfaces, the type of the largest water surface and tree diversity cover), as accurate predictors of species occurrence. Then, 3 factors (e.g., precipitation, number of water surfaces, and tree diversity cover) were suggested for a strong coincidence in this study. Moreover, this prediction of habitat distribution in this study had matched with the observed species richness but suggested larger areas of high species richness.

Hirzel et al. (2006) evaluated the ability of habitat suitability models to predict species presence. This study had compared various evaluators of habitat suitability models in BIOMAPPER. The results showed that AVI, CVI and Boyce index are suitable for predicting only species presence data. However, AVI and CVI are always used for evaluation of habitat suitability models, Boyce index is efficiently for prediction of habitat suitability with high number of validated data or almost cover on the whole study area.

CHAPTER III

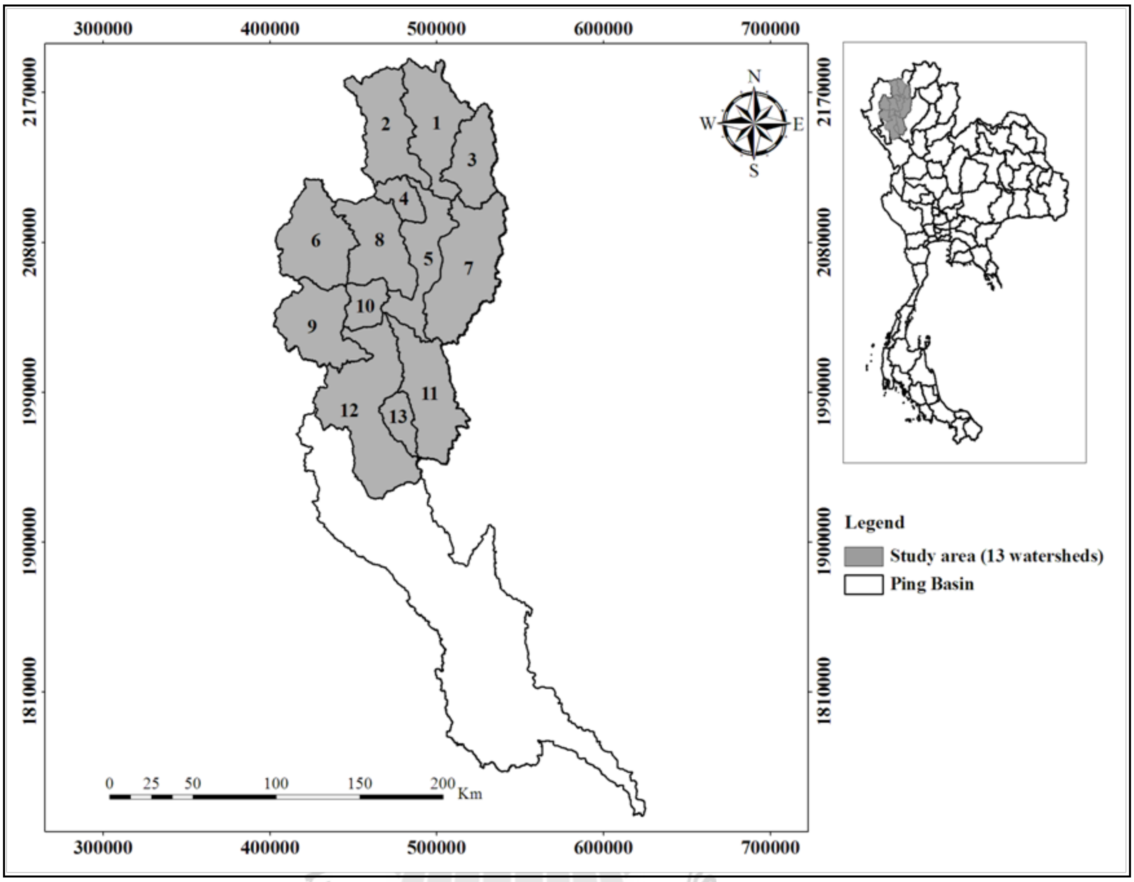
STUDY AREA

This study aims to analyze prediction of forest type distribution based on ecological modeling of physical factors. Thus, the study area is depicted by the characteristics of its physical data and forest inventory data and its detail can be presented as follows:

3.1 Site location

13 of 20 watersheds located in Ping Basin of northern Thailand were selected as the study area for this study (Figure 3.1). It covers area of 22,473.66 sq.km (65% of Ping Basin) where situates approximately from latitudes 17° to 20° North toward longitudes 98° to 100° East or 1925648 – 2190195 North toward 402478 – 542869 East in UTM coordinate system (WGS 1984 and Zone 47N). Moreover, Hydro and Agro Informatics Institute (2007) mentioned that Ping Basin is 1 of 3 first-order river system in Thailand and has been intensively managed and developed because of the critical water resource for Thailand. Therefore, the study area is a part of Ping Basin that has been obtained with the projects of water resource management and development. Additionally, the study area is covered by administration of 4 north provinces: Chiang Mai, Lumphun, Tak, and Mae Hong Son. With stated provinces, they are prominent tourism in Thailand so access of the study area comprises of

highways and railways that are good connectivity of network from other regions of Thailand.



Note: 1 = Upper Part of Mae Nam Ping, 2 = Mae Nam Taeng, 3 = Nam Mae Ngat, 4 = Nam Mae Rim, 5 = Second Part of Mae Nam Ping, 6 = Upper Part of Nam Mae Chaem, 7 = Nam Mae Kuang, 8 = Nam Mae Ngan, 9 = Lower Part of Nam Mae Chaem, 10 = Nam Mae Klang, 11 = Nam Mae Li, 12 = Third Part of Mae Nam Ping and 13 = Nam Mae Hat

Figure 3.1 The study area with 13 watersheds in Ping Basin of northern Thailand**.**

3.2 Topography

Generally, the topographic characteristic of the northern Thailand includes the series of complex mountains where the study area sites in this region too. With stated condition of mountainous topography, the study area includes range of elevation from

0 m to 2,775 m above mean sea level (MSL) as shown in Figure 3.2. On western of the study area, the highest of significant ridge (2,775 m) is appeared in this location. Conversely, the eastern and upper in the study area (elevation between 0 - 500 m) are flat and gentle slope nature where is used for agriculture and urban. Moreover, the study area is an important part of Ping Basin in the north region of Thailand which is essentially water resource to surrounding the north provinces through lower areas in central region.

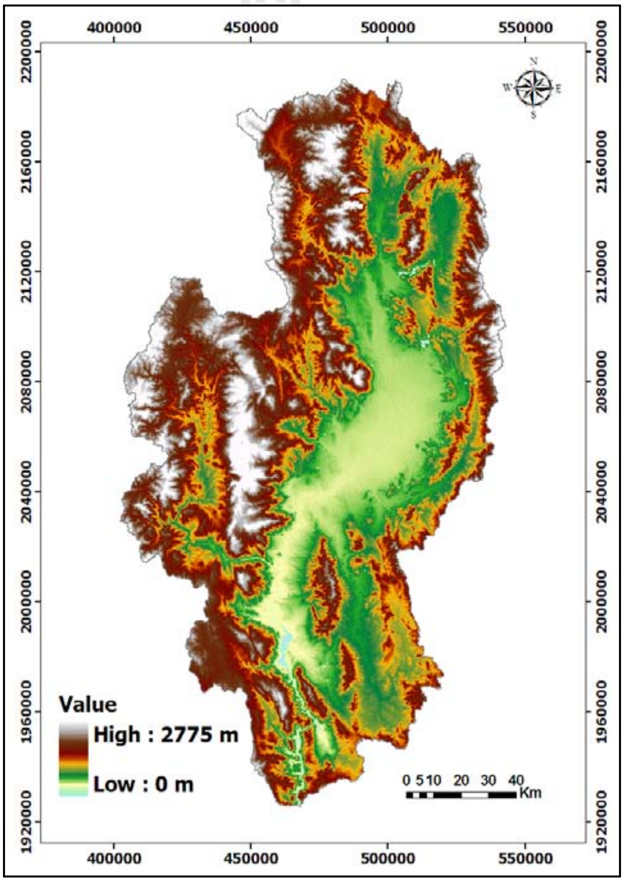
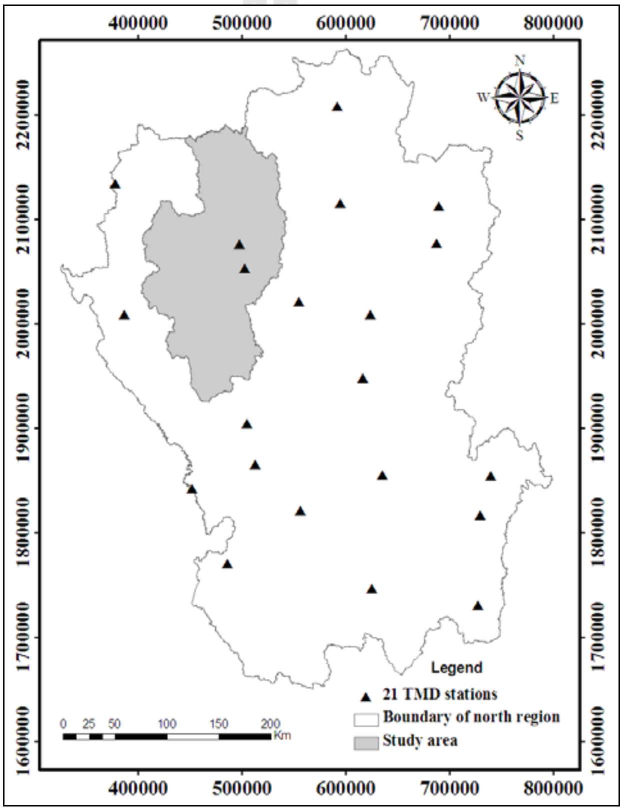


Figure 3.2 Elevation of the study area.

3.3 Climate

In Thailand, TMD is the mainly responsible agency for detection of the climatic data. Therefore, report of climatic data in this study has used 21 main climatic stations of TMD where are situated in the north Thailand and cover the whole of the study area (Figure 3.3). Consequently, the climatic characteristics in the study area and the north Thailand can be annually summarized by using the latest 30 years (1971-2000) mean data of 21 climatic stations (Table 3.1).



Note: 1 = Mae Hong Son, 2 = Mae Sariang, 3 = Chaing Mai, 4 = Lumphun, 5 = Tak, 6 = Mae Sot, 7 = Bhumibol Dam, 8 = Umphang, 9 = Chaing Rai, 10 = Phayao, 11 = Nan, 12 = Tha Wang Pha, 13 = Phrae, 14 = Utraradit, 15 = Kamphang Phet, 16 = Phitsanulok, 17 = Phetchabun, 18 = Lom Sak, 19 = Wichiang Buri, 20 = Lumpang, and 21 = Nakhon Sawan

Figure 3.3 Location of 21 TMD stations for this study.

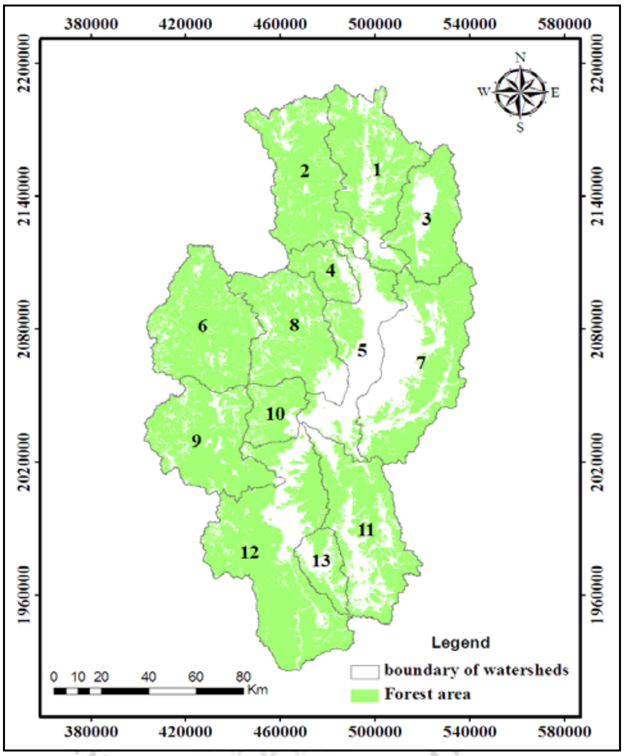
Table 3.1 Summarized overall of annually mean climatic data (1971-2000) with 21 TMD stations in northern Thailand.

Stations	Temp. (°C)			Rain. (mm)	Evap. (mm)	Humid. (%)	Max. Wind (Knots)
	Max	Min	Mean				
1. Mae Hong Son	33.00	20.10	25.40	1282.30	1492.30	74.00	81.00
2. Mae Sariang	32.70	19.90	25.40	1139.70	1323.10	77.00	50.00
3. Chaing Mai	31.90	20.40	25.60	1134.00	1639.00	71.00	64.00
4. Lumphun	32.90	20.50	26.10	962.40	1734.40	71.00	50.00
5. Tak	33.40	22.40	27.20	1053.80	1871.20	69.00	45.00
6. Mae Sot	32.10	20.50	25.40	1395.30	1590.90	76.00	58.00
7. Bhumibol Dam	33.30	22.20	27.30	1035.90	1633.00	69.00	40.00
8. Umphang	30.80	17.80	23.30	1427.50	1301.90	78.00	30.00
9. Chaing Rai	30.80	18.80	24.20	1702.20	1309.10	76.00	64.00
10. Phayao	31.60	20.10	25.30	1095.90	1471.80	73.00	64.00
11. Nan	32.60	20.30	25.60	1237.30	1244.50	78.00	40.00
12. Tha Wang Pha	31.80	19.70	25.20	1396.30	1464.50	80.00	38.00
13. Phrae	33.00	21.20	26.20	1081.90	1682.30	75.00	49.00
14. Utraradit	33.90	22.00	27.30	1410.30	1607.00	73.00	63.00
15. Kamphang Phet	33.50	22.70	27.40	1280.30	1429.40	75.00	50.00
16. Phitsanulok	33.40	23.10	27.70	1335.60	1647.60	71.00	52.00
17. Phetchabun	33.40	21.90	26.90	1079.10	1596.30	73.00	50.00
18. Lom Sak	33.00	21.70	26.70	1044.30	1660.10	73.00	34.00
19. Wichiang Buri	33.50	22.30	27.80	1204.20	1720.90	73.00	46.00
20. Lumpang	33.10	20.60	25.90	1060.00	1462.10	74.00	57.00
21. Nakhon Sawan	34.10	23.30	28.20	1077.40	2018.00	70.00	50.00

Note: Temp. = Temperature, Rain. = Rainfall, Evap. = Evaporation, Humid. = Relative Humidity

3.4 Forest area

Based on the digital forest data of the Royal Forest Department in 2007 forest area in the study area is about 16,947.38 Sq.km (75.41%) as shown in Figure 3.4. Detail of forest area in each watershed is summarized in Table 3.2.



Note: - Data in this figure had been analyzed by this study based on forest map of Royal Forest Department, (2007).

- 1 = Mae Hong Son, 2 = Mae Sariang, 3 = Chaing Mai, 4 = Lumphun, 5 = Tak, 6 = Mae Sot, 7 = Bhumibol Dam, 8 = Umphang, 9 = Chaing Rai, 10 = Phayao, 11 = Nan, 12 = Tha Wang Pha, 13 = Phrae, 14 = Utraradit, 15 = Kamphang Phet, 16 = Phitsanulok, 17 = Phetchabun, 18 = Lom Sak, 19 = Wichiang Buri, 20 = Lumpang, and 21 = Nakhon Sawan

Figure 3.4 Forest area and non-forest area of the study area.

Table 3.2 Forest areas of 13 watersheds in Ping Basin.

No.	Watershed name	Area (sq.km)	Forest area (sq.km)	Percent of forest area
1	Upper Part of Mae Nam Ping	1,974.14	1,539.61	77.99
2	Mae Nam Taeng	1,957.87	1,723.45	88.03
3	Nam Mae Ngat	1,284.69	998.94	77.76
4	Nam Mae Rim	508.10	372.09	73.23
5	Second Part of Mae Nam Ping	1,616.49	535.92	33.15
6	Upper Part of Nam Mae Chaem	2,061.43	1,849.92	89.74
7	Nam Mae Kuang	2,734.35	1,675.36	61.27
8	Nam Mae Ngan	1,833.47	1,469.21	80.13
9	Lower Part of Nam Mae Chaem	1,834.25	1,569.33	85.56
10	Nam Mae Klang	616.34	516.18	83.75
11	Nam Mae Li	2,080.63	1,429.26	68.69
12	Third Part of Mae Nam Ping	3,451.53	2,885.90	83.61
13	Nam Mae Hat	520.37	382.21	73.45
	Sum	**22,473.66**	**16,947.38**	**75.41**

Note: Data in this table had been analyzed by this study based on forest map of Royal Forest Department, (2007).

3.5 Soil and geology

3.5.1 Soil

Soil data, at scale 1:100,000, from Land Development Department (LDD) is used to study characteristics of soil groups in the study area. LDD has publicly explained on LDD website (http://www.ldd.go.th) that soil groups are described by the similar characteristics of soil series, are entirely categorized into 62 soil groups. 27 soil groups are found in the study area (Table 3.3). Based on digital soil group data, soil group no. 62 (area of slope complex) is appeared by 16,070.96 Sq.km (71.51%) and other soil groups are about 6,402.70 Sq.km (28.49%) as shown in Figure 3.5.

Table 3.3 Soil groups in the study area.

No.	Description
4	This soil group consists of very deeply and very fine textures that develops from alluvial terraces at flood plain. Slope is not very highly. Soils in this group are Phimai (Pm) and Ratchaburi (Rb) series.
5	This soil group includes very deeply and fine textures that develops from alluvial terraces, bad drain, and so slowly surface runoff and permeability. Soils is in this group are Phan (Ph) and Hang Dong (Hd) series.
6	This soil group is very deeply and fine texture that develops from alluvial terraces at slightly slope 0-2%. Drain is not well therefore surface runoff and permeability are so slowly. Soils in this group are Phan (Ph), Nakhon Phanom (Nn), Manorom (Mn), and Chumsaeng (Cs) series.
15	This group of soils is not well drained and deep fine-silty texture that develops from alluvial terraces at low river levee with slightly slope 0-2%. Soils in this group are Nakhon Pathom (Np) and Mae Tha (Mta) series.
16	This soil group is very deep and fine-silty texture that develops from alluvial terraces or fan. They are not well drained through surface runoff and permeability. Soils in this group are Hin Kong (Hk) and Lampang (Lp) series.
17	This soil group is very deep and fine-loamy texture that develops from alluvial terraces at low river levee with slightly slope 0-2%. Drain is not good so surface runoff and per permeability are slowly through low soil fertility. Soils in this group are Roi-et (Re) series.
21	This soil group is deeply; moderate drained and moderate fertility. This soil is developed from alluvium that occur lower of flatly river levee. Soils in this group are Sapphaya (Sa) and Phetchaburi (Pb) series.
22	This group of soils is of poorly drained; coarse-textured that occur on low-lying terrain. They are very low fertility. Soils in this group are Num Krachai (Ni), Sansai (Sai) and Sri Thon (St) series.
24	This group of soils is of deeply; moderate drained and the lowest fertility. Soils in this group are Ubon (Ub), Ban Bueng (Bbg), and Tha Uthen (Tu) series.
28	This group of soil is very deeply and very fine-texture that that occur on undulating with slope 2-8%. This soil is developed from alluvial terraces or fan. Soils in this group are Wang Chomphu (Wc), Lop Buri (Lb) and Watthana (Wa) series.
29	This group of soils is well drained and deep fine-textured that occupies erosional surfaces and alluvial terraces or fans in dry areas of the country. Soil fertility is moderately low. Soils in this group are Ban Chong (Bg), Chiang Khon (Cg), Choke Chai (Ci), Mae Taeng (Mt), Nong Mot (Nm), Pak Chong (Pc) and Sung Nern (Sn) series.
30	This group of soils is so deeply, well-drained, and moderate fertility. Soils in this group are Doi Pui (Dp) and Chiang Saen (Ce) series.
33	This soil group is deeply and fine-silty texture that appear on undulating with slope 1-3%. This soil is developed from alluvial terraces or river levee where is well drained, surface runoff is slowly. Soils in this group are Kamphaeng Saen (Ks) and Dong Yang En (Don) series.
35	This soil group is low fertility that appears on erosional slope. Some area is strongly acid. Soils in this group are Don Rai (Dr), Dan Sai (Ds), Hang Chat (Hc), Korat (Kt), Mab Bon (Mb), Satuk (Suk), Warin (Wn), and Yasothon (Yt). Soils in this group are Chiang Mai (Cm), Tha Muang (Tm), Don Ched (Dc), and Chumphon Buri (Chp).
38	This soil group is deeply, well-drained and loam-sandy that develops from alluvial terraces. This soil is appeared on flatly river levee with slope 0-2% .
40	This group of soils is well-drained, deep and coarse-textured that develops from alluvial deposits or wash materials on the uplands of alluvial terraces, fans or erosional surface in the areas of low precipitation. They are low fertility. Soils in this group are Chakra Rat (Ckr), Chum Puang (Cpg), Hup Krapong (Hg), Huay Thalang (Ht), San Patong (Sp), Pak Thong Chai (Ptc) and Yang Talat (Yl) series.

Table 3.3 (Continued).

44	This group of soils is deep sandy, somewhat excessively drained that occur on alluvial terraces, fans and wash surface. Its parent material is closely related to coarse grained clastic rocks and coarse grained igneous rocks in areas of low precipitation. Soil fertility is very low. Soils in this group are Chan Tuk (Cu), Dan Khun Thot (Dk) and Nam Phong (Ng) series.
46	This group of soils is shallow soil, well-drained (5 m of yearly water table for) and laterit-clay that appear on undulating and rolling area. Soils in this group are Chiang Khan (Ck), Phu Sana (Ps), Kabin Buri (Kb), Surin (Su), and Pong Tong (Po) series.
47	This group of soils is shallow to fine-grained bed rock. It occupies erosional surface, hills and mountains in low precipitation areas. Soils in this group are Li (li), Muak Lek (Ml), Sop Prap (So), Nakhon Sawan (Ns), Pong Namron (Pon) and Tali (Tl) series.
48	This group of soils is shallow to coarse-grained bed rock. They commonly occur on erosional surface, hills and mountains. Soils in this group are 27 Mae Rim (Mr), Nam Chun (Ncu), Payao (Pao), Wangnam Khieo (Wk) and Tayang (Ty) series.
49	This group of soils is sandy or shale, very shallow, well-drained and low fertility. Soils in this group are Phon Phisai (Pp), Sakon (Sk), and Borabu (Bb) series.
52	This group includes all soils that are shallow calcareous layer in low precipitation areas. Dark surface layer of alkaline that is friable in moist condition. Fertility is high. Soils in this group are Bung Chanang (Bng) and Takhli (Tk) series.
56	This group of soils is similar to soil group No. 55. The main difference is coarser-textured and coarse, grained classic weathered-rock layer i.e. sandstone and equivalent rocks that are found at 50 - 100 cm depth. This group of soils is Lad Ya (Ly), Pu Sana (Ps), Bo Thai (Bo) and Phon Ngarm (Png) series.
58	This soil group is likely soil group no. 57 that includes a strong acid on low land that is not well-drained. There is soil series: Narathiwat.
59	This soil group is bad drained and low fertility that occur plain. This soil is developed from alluvial terraces.
60	This soil group is deeply, well-drained, and moderate fertility that appear on alluvial terraces at river levee.
62	This group of soils includes all steep lands with more than 35 percent slopes (SC: slope complex). Soil qualities vary as geological setting of the areas. This group of soils should restrict their uses to woodland, watershed protection and wildlife conservation.
GL	Gullied land
GrSC	Granite derived soils complex
RL	Rock Land
ShSC	Shale derived soils complex
W	Water

Note: Details of soil groups are published by Land Development Department (2011) at http://giswebldd.ldd.go.th/

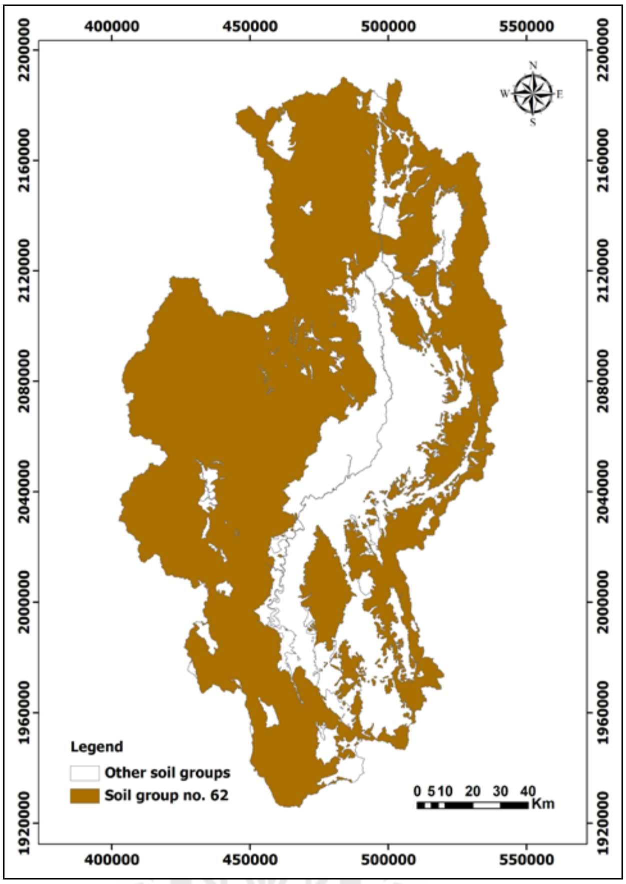


Figure 3.5 Area of slope complex (soil group no.62) in the study area.

3.5.2 Geology

The geological data at scale 1:250,000 from Department of Mineral Resources (DMR) had been analyzed to study geological structure in the study area. This study found that 32 geological formations are in the study area (Figure 3.6). More details of geological formation characteristics is described in Table 3.4. Based on digital geological data, sedimentary and metamorphic rock type is mostly appeared as 85.77% and 14.23% of igneous rock in the study area.

Table 3.4 Geological formations in the study area.

Symbol	Age	Formation/Group	Description
Qa	Quaternary	-	Alluvial deposit, gravel, sand, slit and clay.
Qc			Colluvial and residual deposits: gravel, sand, silt, laterite, and rock fragments.
Qff			Flood plain deposits: overbank clay, gray to light gray, partly intercalated with gravelly sand lens.
Qt			Terrace deposits: gravel, sand, silt, clay, and laterite.
Tmm	Tertiary	-	Semi-consolidated claystone and siltstone, red to brownish red; lignite, calcareous claystone, mudstone; ligneous claystone with calcareous parting, gastropods, fish, ostracods; conglomerate, sandstone, white to light-gray, moderately sorted; shale.
k	Cretaceous	-	Sandstone, mudstone and red.
J	Jurassic	-	Conglomerate, red; sandstone, brownish red; interbedded with shale, and mudstone.
TrJ	Triassic-Jurassic	-	Conglomerate, sandstone reddish brown, intercalation with shale and mudstone
Trl	Triassic	-	Basal conglomerate, red, calcareous; shale, gray interbedded with siltstone and sandstone.
Trm			Migmatite: undifferentiated granitic rocks and relics of gneiss, schist, quartzite, and sandstone.
Trpk			Limestone, dark gray, medium-bedded to massive; minor sandstone and mudstone at the middle part.
Trgr			Intrusive igneous rock: granodiorite, diorite and monzodiorite.
Trhh		Hong Hoi Formation	Mudstone, gray to dark gray, intercalated sandstone, thin– to thick-bedded, common with bivalve Halobia sp., Daonella sp.
Trpt		Phra That Formation	Sandstone, siltstone, and conglomerate, red.
PTrv	Permian-Triassic	-	Rhyolite, andesite, ash-flow tuff, volcanic breccia, rhyolitic tuff and andesitic tuff.
Pngl	Permian	Ngao Group	Tuffaceous sandstone, sandstone, shale, gray to grayish green , limestone in the upper part.
Png2			Limestone, bedded and massive, gray, black, interbedded with shale and sandstone.
Pr		Ratburi Group	Limestone, dolomitic limestone, with nodular and bedded chert; dolomite; with fusulinids, brachiopods, corals, and bryozoans.
CP	Carboniferous-Permian	Kaeng Krachan Group	Sandstone, argillaceous limestone, shale, and chert.
CPk			Pebbly mudstone, shale, siltstone, chert, tuffaceous sandstone, quartzose sandstone, dark gray, greenish gray, and brown; with brachipods, and bryozoans, corals.

Table 3.4 (Continued).

Symbol	Age	Formation/Group	Description
C	Carboniferous	-	Conglomerate, sandstone, shale, slate, chert, and limestone.
C2			Conglomeratic phyllite, phyllite, meta-tuffaceous sandstone, and slate.
Cb			Basic igneous rocks: quartz-gabbro with dike rocks.
Cgr			Granite, anatexitic, foliated, and cataclastic.
DC	Devonian-Carboniferous	-	Chert, tuff, limestone, and volcanics, mostly metamorphosed.
DCv			Spilitic basalt and tuff.
SDCtp	Silurian-Devonian-Carboniferous	-	Black shale, chert, and siltstone, dark gray, calcareous; limestone, thin-bedded and nodular; locally with graptolite, tentaculite, nautiloid, and trilobite.
SD	Silurian-Devonian	-	Phyllite, carbonaceous phyllite, and quartzitic phyllite.
O	Ordovician	-	Argillaceous limestone and limestone, gray and pink; dolomitic limestone and schistose marble; with interbedded shale, calcareous, and sandy; shale; with nautiloids, brachipods, and trilobites.
EO	Cambrian-Ordovician	-	Marble, banded and quartz-mica schist.
E	Cambrian	-	Quartzite, orthoquartzite, sandstone, and calcareous shale.
PreE	Pre-Cambrian	-	Limestone, dolomitic limestone, with nodular and bedded chert; dolomite; with fusulinids, brachiopods, corals, and bryozoans.

Note: Details of geological formations are described in the provincial geology layer of Department of Mineral Resources (2006) and (2008).

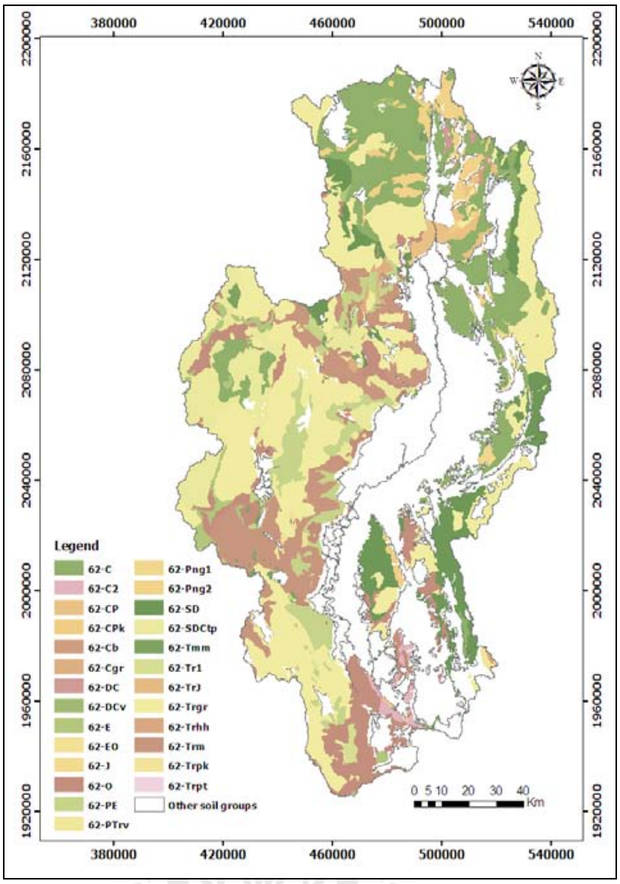


Figure 3.6 Geological formations of the study area.

3.6 Forest inventory data

Forest inventory data year 2007 of Department of National Parks, Wildlife and Plant Conservation (DNP) had been recorded with 902 inventory points that were 460 points of forest plot and 442 points of non-forest plot. In 460 forest inventory points, there were grouped into two main forest types: 117 of evergreen forest (15 of Coniferous Forest (CF), 5 of Moist Evergreen Forest (MEF), 14 of Dry Evergreen Forest (DEF), and 83 of Hill Evergreen Forest (HEF)) and 343 of deciduous forest (164 of Mixed Deciduous Forest (MDF) and 179 of Dry Dipterocarp Forest (DDF)) as shown in Table 3.5.

Table 3.5 Summary for forest inventory data year 2007 of DNP in the study area.

No.	Watersheds	Total	NF	F	Forest points for each forest types					
					Evergreen forest				Deciduous forest	
					CF	MEF	DEF	HEF	MDF	DDF
1	Upper Part of Mae Nam Ping	77	31	46	1	0	0	2	27	16
2	Mae Nam Mae Taeng	77	30	47	2	0	2	20	13	10
3	Nam Mae Ngat	53	18	35	0	1	0	8	11	15
4	Nam Mae Rim	22	8	14	0	0	2	4	6	2
5	Second Part of Mae Nam Ping	64	48	16	1	0	3	1	4	7
6	Upper Part of Nam Mae Chaem	85	20	65	9	2	2	18	16	18
7	Nam Mae Kuang	110	49	61	0	0	0	11	25	25
8	Nam Mae Ngan	71	27	44	0	1	2	9	20	12
9	Lower Part of Nam Mae Chaem	75	34	41	0	1	1	3	17	19
10	Nam Mae Klang	25	15	10	0	0	2	2	3	3
11	Nam Mae Li	85	59	26	0	0	0	1	10	15
12	Third Part of Mae Nam Ping	138	90	48	2	0	0	4	10	32
13	Nam Mae Hat	20	13	7	0	0	0	0	2	5
	Total	**902**	**442**	**460**	**15**	**5**	**14**	**83**	**164**	**179**

Note: - NF = Non-forest, F = Forest, EF = Evergreen Forest, CF = Coniferous Forest, MEF = Moist Evergreen Forest, DEF = Dry Evergreen Forest (DEF), HEF = Hill Evergreen Forest, DF = Deciduous Forest, MDF = Mixed Deciduous Forest, and DDF = Dry Dipterocarp Forest.

In practice, forest inventory data in Thailand by DNP has been surveyed every five years with same positions and points to monitor changing of forest communities. Forest inventory points usually collected with a uniform spacing size of 20 x 20 km. but forest inventory data year 2007 of Ping Basin was surveyed with spacing size 5 x 5 km grid. Ping basin had been specially studied from National Parks, Wildlife and Plant Conservation Department of Thailand and International Tropical Timber Organization during 2004-2007 to protect deforestation in such main Basin of

Thailand. Each forest inventory point includes 5 circular plots (1 plot which located on intersection grid of 5 x 5 km (Figure 3.7a) is assigned as permanent plot while other 4 plots are temporary plot (as shown Figure 3.7b)). In each plot are superimposed by concentric circular plots (Figure 3.7c). Each circular plot is designed to collect a specific forest inventory data (Table 3.6). In this study, identified forest type in permanent plot had been selected for studying forest ecological model because is a key component of a long-term ecological research program.

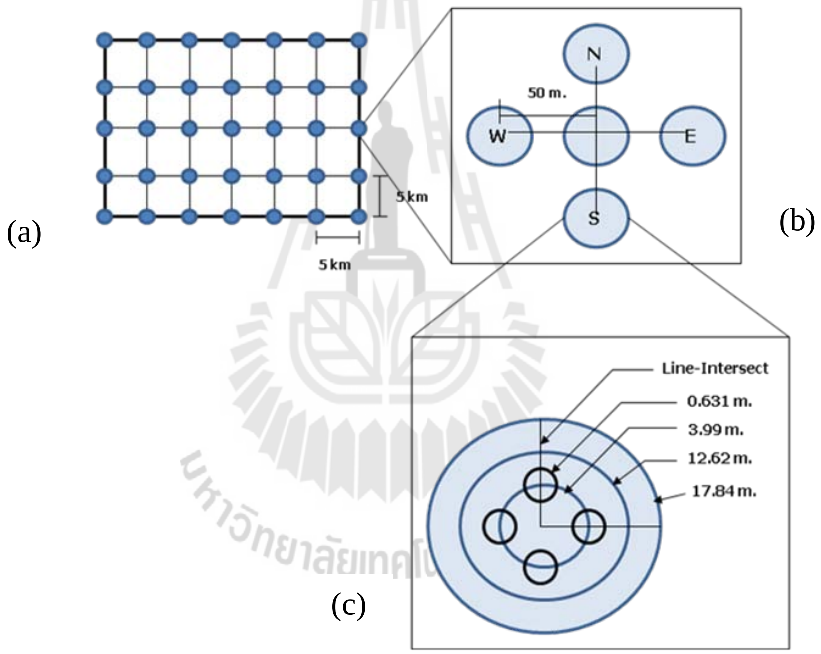


Figure 3.7 Designing of sampling plots for forest inventory data (Department of National Parks, Wildlife and Plant Conservation (DNP) and International Tropical Timber Organization, 2007): (a) systematic sampling with grid size of 5 x 5 km, (b) permanent plot at center sampling point with 4 directional of temporary plots, and (c) concentric circular plots for forest inventory data in each sampling plot.

Table 3.6 Ground data gathered and sampling method (Department of National Parks, Wildlife and Plant Conservation (DNP) and International Tropical Timber Organization, 2007)**.**

Data Gathered	**Sampling Method**			
	Plot Type	**Number**	**Radius (m)**	**Total Area (ha)**
1) Seedling density	Circular	4	0.631	0.0005
2) Understory vegetation & sapling density	Circular	1	3.99	0.0050
3) Bamboo and erect rattan length & tree stump volume; site description	Circular	1	12.62	0.0500
4) Tree attributes; human & natural disturbance; wildlife habitat use	Circular	1	17.84	0.1000
5) CWD, rattan & climbers volume and length	17.84 m Line-intersect	2	-	-

CHAPTER IV

RESEARCH METHODOLOGY

In this study, there are four main components to fulfill research methodology as schematic display in Figure 4.1. Detail in each component can be here explained as follows:

4.1 Data collection

Under this component, bio-physical data related to forest ecological modeling for forest type distribution prediction were collected from the concerned agencies. Characteristics and sources of the collected data were summarized in Table 4.1.

4.1.1 Forest inventory data

Forest inventory data of Thailand year 2007 had been collected from DNP that was stored in national forest resources monitoring information system. This system consists of two formats: (1) the vector based GIS data for identification of plot and (2) spreadsheet data of a Microsoft Excel for description of forest inventory data in each plot that includes number of cluster, location in UTM coordinate, forest type, tree species, density of trees, volume of trees, and sapling and seedling.

4.1.2 Physical data

Physical data which will be used in forest ecological modeling include climate (rainfall and temperature), topography, soil and geology. These physical factors can describe the important details of data as follows:

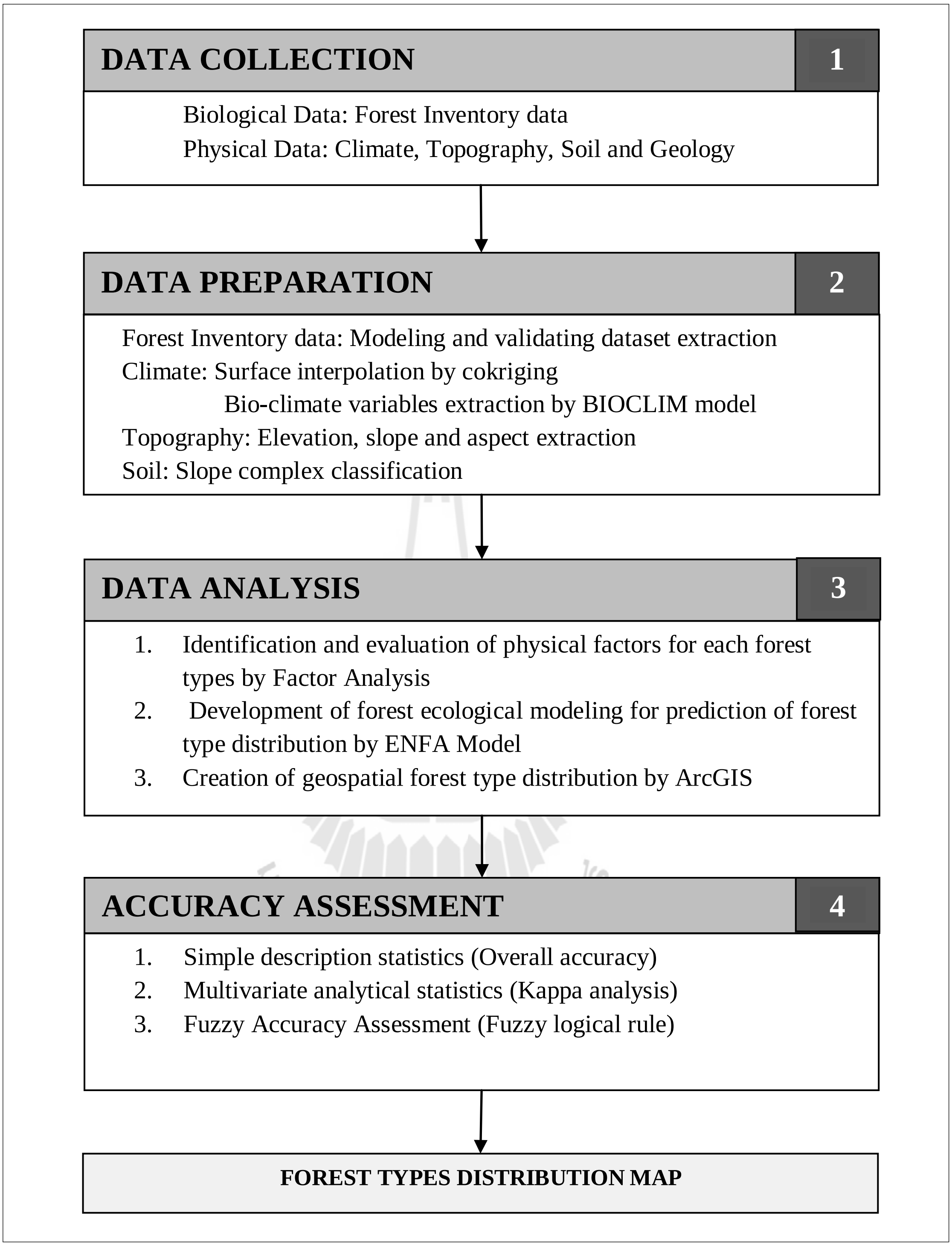


Figure 4.1 Four main components of research methodology.

Table 4.1 Details of data collection for this study.

Category	**Data characteristic**	**Source**
(1) Forest inventory data year 2007	- Vector based GIS data for identification of plot - Spreadsheet data for description of forest inventory data	Department of National Parks, Wildlife and Plant Conservation (DNP)
(2) Climate data of Thailand for 30-year period (1971-2000)	- Spreadsheet data - Paper report	Thailand Meteorological Department (TMD)
(3) Digital Elevation Model (DEM) year 2008	- Raster based GIS data with cell size of 30 x 30 m	Chulalongkorn University
(4) Provincial soil data year 1984 (Chiang Mai, Mae Hong Son, Lumphun and Tak)	- Vector based GIS data from input map scale 1:100,000	Land Development Department (LDD)
(5) Provincial geology data: - Chiang Mai, Mae Hong Son, and Lumphun in 2006 - Tak in 2008	- Vector based GIS data from input map scale 1:250,000	Department of Mineral Resources (DMR)

(1) Climate data

Climatological data of Thailand for 30-year period (1971-2000) from TMD are used for this study that are formally observed and summarized every 30 years (e.g. climatological data 1961-1990 and climatological data 1971-2000). These climate data are published in both a Microsoft Excel spreadsheet and a paper report. In observation of climate data, TMD stations of Thailand is analyzed as synoptic stations (they are concerned with the distribution of meteorological conditions over a wide area at a given time) where is recorded by 5 to 8 observations at 3 hourly intervals are taken at 01:00, 04:00, 07:00, 10:00, 13:00, 16:00, 19:00 and 22:00 local standard time. Moreover, TMD has used the standard exposure instruments of climate detection that are accepted in both national and international levels.

(2) Topography data

The Digital Elevation Model (DEM) with cell size 30 x 30 m was acquired from Chulalongkorn University for representation topographic characteristic. The DEM was developed from the refinement of 90 x 90 m DEM of the Shuttle Radar Topographic Mission (SRTM) data. This DEM was used to generate slope and aspect data.

(3) Soil group data

The provincial soil data of Chiang Mai, Mae Hong Son, Lumphun and Tak provinces in year 1984 at the scale 1:100,000 were collected from the LDD. This soil group data are recorded in vector based GIS format with the detailed reconnaissance soil survey. Herewith, soil groups are classified from soil series and association of soil series based on the United States Department of Agriculture (USDA) system or called “soil taxonomy” (Soil Survey Division, 1993).

(4) Geology data

The provincial geological data of Chiang Mai, Mae Hong Son, and Lumphun in 2006 and Tak in 2008 at scale 1:250,000 were collected from DMR. The main characteristic of geological dada are rock units, rock group, rock type, symbols and name of geological formation, age (year), upper ages, lower ages, and description of geological formation.

4.2 Data preparation

Under this component, data quality of all collected data had been firstly checked and then transformed into GIS in UTM coordinate system (WGS 1984 and Zone 47N). Each collected data was prepared for data analysis in the next component. Preparation of each bio-physical data can be described as follows:

4.2.1 Forest inventory data

Forest inventory data had been divided into 2 datasets: one dataset for modeling and another dataset for validating (Table 4.2). Both datasets were sampled by the stratified systematic random sampling. In practice, all point data of forest inventory are transformed into vector based GIS.

Table 4.2 Dataset of forest inventory data for modeling and validating.

Forest inventory data of each forest type	Number of plots	Number of plots for modeling	Number of plots for validating
1. Coniferous Forest (CF)	15	8	7
2. Moist and Dry Evergreen Forest (MDEF)	19	11	8
3. Hill Evergreen Forest (HEF)	83	46	37
4. Mixed Deciduous Forest (MDF)	164	83	81
5. Dry Dipterocarp Forest (DDF)	179	93	86
Total	**460**	**241**	**219**

4.2.2 Climatic data: rainfall and temperature

Two main climatic data influencing forest type distribution in Thailand (as mentioned in Table 1.2) include rainfall and temperature data were used to generate bio-climatic factors (variables) with BIOCLIM model. The characteristic of rainfall and temperature data are the monthly mean data of 30 years (1971-2000) of climate data of Thailand from TMD. Basic rationale and operational techniques applied for rainfall and temperature data preparation are here summarized as following:

4.2.2.1 Rationale

The application of long term observed monthly mean rainfall and temperature data (1971-2000) is based on assumption that the forest communities in the study area are characterized as “climax community”. Herein the monthly mean rainfall and temperature data is firstly spatially interpolated by integration of 3 topographic variables (elevation, latitude, longitude) using cokriging technique based on a simple mathematical formula (Boer et al., 2001) as following:

$$Z(s_i) = (f(s_i) + \in (s_i) \qquad i = 1,2,\ldots,n \qquad (4.1)$$

Where $Z(s_i)$ is the predicted variable that is decomposed into a randomly deterministic trend ($f(s_i)$) of additional covariates based on the weighted sum. The autocorrelated errors form is defined as $\in (s_i)$. Then, 3 correlated variables for the cokriging are determined as elevation is $q_1(s)$, longitude is $q_2(s)$ and latitude is $q_3(s)$ including climatic data being the variable of main interest in the study area. The empirical cross-semivariance function can be estimated as:

$$\hat{\gamma}(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [z(s_i) - z(s_i + h)][q_1(s_i) - q_1(s_i + h)][q_2(s_i) - q_2(s_i + h)]\,[q_3(s_i) - q_3(s_i + h)] \qquad (4.2)$$

where *n(h)* is the number of data pairs where four variables are measured at a Euclidean distance h, $z(s_i)$ and $z(s_i + h)$ are data of predicted variable, and $q_{1-3}(s_i)$ and $q_{1-3}(s_i + h)$ are data of covariate. The interpolation value at an arbitrary point s_0 in the study area where there is the realization of the (locally) best linear unbiased predictor can be written as the weighted sum of measurements:

$$\hat{f}(s_0) = \sum_{i=1}^{m_1} w_{1i} z(s_i) + \sum_{j=1}^{m_2} w_{2j}\, q_1(s_i) + \sum_{j=1}^{m_3} w_{3j}\, q_2(s_i) + \sum_{j=1}^{m_4} w_{4j}\, q_3(s_i) \qquad (4.3)$$

Where m_1 is still the number of measurements of ($z(s_i)$) at ith location within an automatically defined radius from s_0 (out of the modeling data set), and m_2, m_3, and m_4 is the number of meteorological stations within an automatically defined radius from s_0 (out of the modeling and validation set). The weights w_{1i}, w_{2j}, w_{3j} and w_{4j} can be determined using the semivariance functions and the cross-semivariance function. As a result, the best of sub types and semivariogram model will be selected based on the least Root Mean Square Error (RMSE) for three monthly temperature data. Finally, the results of surface interpolation of rainfall and temperature using cokriging are then used for BIOCLIM model which is applied to generate bioclimatic parameters derived from climate surface.

4.2.2.2 Operational techniques

For preparation of rainfall and temperature data for forest type distribution, there are 4 main operations to implement in this study as display in schematic diagram in Figure 4.2. Details of each operation are summarized as follows:

(1) Extracting and arranging data

The monthly rainfall and temperature data for 30-year period (1971-2000) in Microsoft Excel spreadsheet format from 21 selected northern meteorological stations of TMD in northern region were firstly extracted and then joined with topographic variables (elevation, latitude, longitude) and arranged as attribute tables for GIS operation. The detail of attribute tables for monthly mean rainfall, monthly mean maximum temperature and monthly mean minimum temperature are presented in Appendix A.1 - A.3, respectively.

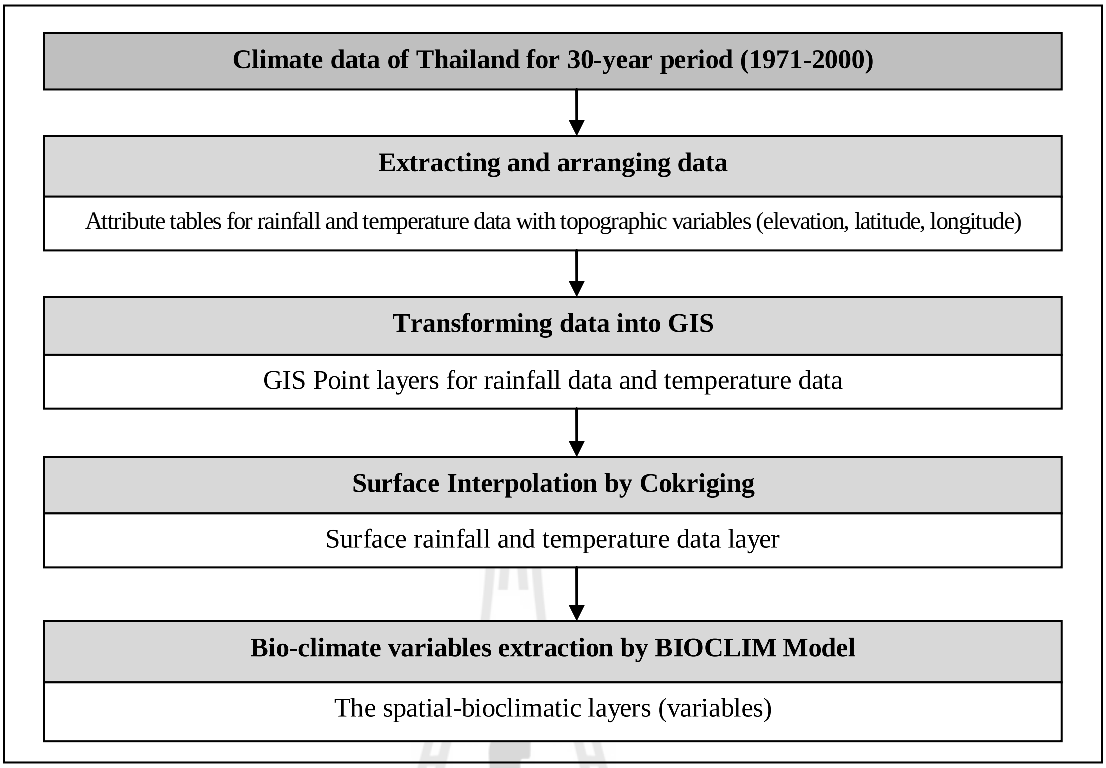


Figure 4.2 Operational techniques for preparation of climatological data.

(2) Transforming data into GIS

Location of 21 meteorological stations with 2 attribute tables for rainfall and temperature data had been linked and transformed into GIS as point data. The output is 2 point layers: layer of rainfall data and layer of temperature data.

(3) Surface Interpolation by Cokriging

Cokriging technique under ArcGIS 9.2 was selected for rainfall and temperature interpolation because this technique was able to include 3 topographic variables: elevation, longitude and latitude in operation. In addition, assessment of cokriging interpolation was further conducted by comparison with other interpolation techniques excluding additional-topographical covariates for finding the best results. In practice, following steps were implemented:

(3.1) Surface interpolation with cokriging technique

The point layers of rainfall and temperature were used to interpolate based on cokriging technique with cell size of 30 x 30 m. In cokriging technique, there are 4 different cokriging sub-types: Ordinary CoKriging (OCK), Universal CoKriging (UCK), Simple CoKriging (SCK), and Distinctive CoKriging (DCK). Each cokriging sub-types includes 11 semivariogram models: Circular (Cir), Spherical (Sph), Tetraspherical (Tsph), pentaspherical (Psph), exponential (Exp), Gaussian (Gau), Rational Quadratic (RQ), Hole Effect (HE), K-Bessle (K-B), J-Bessel (J-B), and Stable (Stab). Then, the best monthly results of cokriging for rainfall and temperature were selected by the minimum Root Mean Square Error (RMSE). Details of the best results for rainfall and temperature with cokriging are summarized in Appendix A.4 - A.5.

(3.2) Assessment of cokriging interpolation

The best results of cokriging technique from the previous step were assessed by comparing to other interpolation techniques included Inverse Distance Weighted (IDW), Global Polynomial Interpolation (GPI), Local Polynomial Interpolation (LPI),: Radial Basis Functions (RBF) (that include 5 sub-types: Completely Regularized Spline (CRS), Spline with Tension (SWT), Multiquadric (MQ), Inverse Multiquadric (IMQ), Thin Plate Spline (TPS)) and kriging. The kriging technique was operated as same as the operation of cokriging method. In this step, the best results of all interpolation techniques were compared by 3 error estimators: Mean Absolute Error (MAE), providing a measure of how far the estimate can be in error, ignoring its sign; Mean Relative Error (MRE), providing a measure of how far the estimate can be in error relative to the measured mean; Root Mean Square Error

(RMSE), providing a measure that is sensitive to outliers. Generally these error estimators were calculated by subtraction between actual value and predicted value. Therefore, error estimators for prediction of mean monthly rainfall and mean monthly temperature (maximum and minimum temperature) were analyzed by both interpolations including additional-topographical covariates (i.e. cokriging) and excluding information (i.e. IDW, GPI, LPI, RBF, and kriging). The comparative results of error with MAE, MRE and RMSE for rainfall and maximum and minimum temperature interpolation using cokriging, IDW, GPI, LPI, RBF, and kriging are summarized in Appendix A.6 - A.8.

(4) Bio-climate variables extraction by BIOCLIM model

The surface interpolation of monthly rainfall and temperature from previous operation were used to generate 19 bio-climatic variables using BIOCLIM model under DIVA-GIS software in Table 4.3. The spatial output of 19 bio-climatic variables is shown in Appendix A.9.

Then, 19 bio-climatic variables are examined the redundancy among the variables using correlation analysis. Herein, coefficient value is lower than 0.7, is selected while is higher than 0.7, is considered which one represented bio-climate variable. Then, it was found that there are 10 of 19 bio-climatic variables can be selected for data analysis based on correlation coefficient values (Appendix A.10). These bio-climate variables include (1) BIO1: mean annually temperature, (2) BIO2: mean diurnal range, (3) BIO4: Temperature Seasonality, (4) BIO5: Annually Maximum Temperature, (5) BIO6: Annually Minimum Temperature, (6) BIO7: Annually Temperature Range, (7) BIO12: Mean Annually Precipitation, (8) BIO13: Annually Maximum Precipitation, (9) BIO14: Annually Minimum Precipitation and

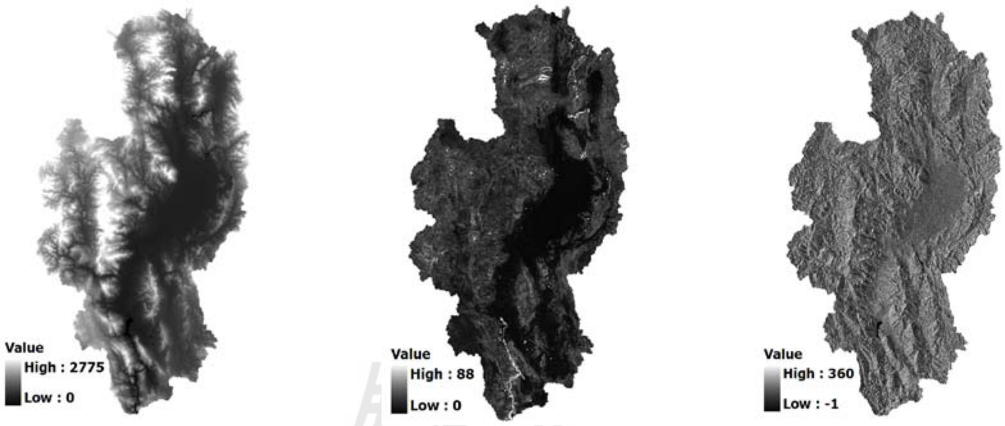
(10) BIO15: Precipitation Seasonality. These 10 selected bio-climate variables also conform to the identified climate factor of Kutintara (1999).

Table 4.3 List of bio-climatic variables of BIOCLIM model.

Bio. Var.	Description
BIO1	**Mean Annually Temperature (AMT):** the mean of all the monthly mean temperatures. On other word, each monthly mean temperature is the mean of that month's maximum and minimum temperature.
BIO2	**Mean Diurnal Range (MDR)**: monthly mean range of maximum and minimum temperature or the difference between that month's maximum and minimum temperature.
BIO3	**Isothermality (I)**: this is derived from portion of BIO2 and BIO7 or this compares the day-to-night temperature oscillation versus the summer-to-winter temperature oscillation. A value of 100 would represent a site where the diurnal temperature range is equal to the annual temperature range. A value of 50 would indicate a location where the diurnal temperature range is half of the annual temperature range.
BIO4	**Temperature Seasonality (TS) or Temperature Coefficient of Variation (TCV)**: this is derived from Standard Deviation (SD) of BIO1 and multiplied by 100. SD of the monthly mean temperatures expressed as a percentage of the mean of those temperatures.
BIO5	**Annually Maximum Temperature (AMTmax)**: the highest temperature of any monthly maximum temperature.
BIO6	**Annually Minimum Temperature (AMTmin)**: the lowest temperature of any monthly minimum temperature.
BIO7	**Annually Temperature Range (ATR)**: this is derived from BIO5 and BIO6. On other word, the difference between annually maximum (BIO5) and minimum temperature (BIO6).
BIO8	**Mean Temperature of Wettest Quarter (MTWQ)**: the wettest quarter of the year is determined (to the nearest month), and the mean temperature of this period is calculated.
BIO9	**Mean Temperature of Driest Quarter (MTDQ)**: the driest quarter of the year is determined (to the nearest month), and the mean temperature of this period is calculated.
BIO10	**Mean Temperature of Warmest Quarter (MTWQ)**: the warmest quarter of the year is determined (to the nearest month), and the maximum temperature of this period is calculated.
BIO11	**Mean Temperature of Coldest Quarter (MTCQ)**: the coldest quarter of the year is determined (to the nearest month), and the minimum temperature of this period is calculated.
BIO12	**Mean Annually Precipitation (AMP)**: the sum of all the monthly precipitation estimation.
BIO13	**Annually Maximum Precipitation (AMaxP) or Precipitation of Wettest Month (PWM)**: the highest precipitation of any monthly maximum precipitation.
BIO14	**Annually Minimum Precipitation (AMinP) or Precipitation of Driest Month (PDM)**: the lowest precipitation of any monthly minimum precipitation.
BIO15	**Precipitation Seasonality (PS) or Precipitation Coefficient of Variation (PCV)**: this is derived from Standard Deviation (SD) of BIO12 and multiplied by 100. SD of the monthly mean temperatures expressed as a percentage of the mean of those precipitations.
BIO16	**Precipitation of Wettest Quarter (PWQ)**: the wettest quarter of the year is determined (to the nearest month), and the mean precipitation of this period is calculated.
BIO17	**Precipitation of Driest Quarter (PDQ)**: the driest quarter of the year is determined (to the nearest month), and the mean precipitation of this period is calculated.
BIO18	**Precipitation of Warmest Quarter (PWQ)**: the warmest quarter of the year is determined (to the nearest month), and the mean precipitation of this period is calculated.
BIO19	**Precipitation of Coldest Quarter (PCQ)**: the coldest quarter of the year is determined (to the nearest month), and the mean precipitation of this period is calculated.

4.2.3 Topographic data

Topographic data is an important input for this study that comprises of elevation (m), slope (degree) and aspect (direction) as shown in Figure 4.3. Elevation data had directly extracted from Digital Elevation Model (DEM) while slope and aspect were derived using standard GIS technique from DEM.



(a) Elevation (m) **(b) Slope (percent)** **(c) Aspect (degree)**

Figure 4.3 Topographic data: (a) elevation, (b) slope, and (c) aspect.

4.2.4 Soil group data

In principle, soil data directly influence to forest type distribution in Thailand as stated in Table 1.2. In this study, provincial soil data (Chiang Mai, Mae Hong Son, Lumphun and Tak) from LDD at soil group level was selected as one factor for prediction of forest type distribution under forest ecological model. However, soil group of study area are mostly classified as slope complex (about 71.5 %). In addition, when point of forest inventory data overlaid to soil group, it was found that 86% of all forest inventory points are located in area of slope complex. Consequently, different forest types from forest inventory data were not different in soil characteristic due to slope complex. Therefore, modified soil group in slope complex are here characterized based on geological formation. Basic rationales and operational techniques applied for soil data preparation can be briefly summarized as following:

4.2.4.1 Rationale

Simonson (1989) had mentioned that the first United State soil classification system was based largely on the underlying geological characteristics. Therefore, slope complex area of soil group layer is here further classified according to geological layer using overlay technique of GIS. The results can reflect to more understand the influence of geological characteristics on slope complex area.

4.2.4.2 Operational techniques

For preparation of soil data for forest type distribution, there are 2 main operations to implement in this study as shown in Figure 4.4 and more details as below:

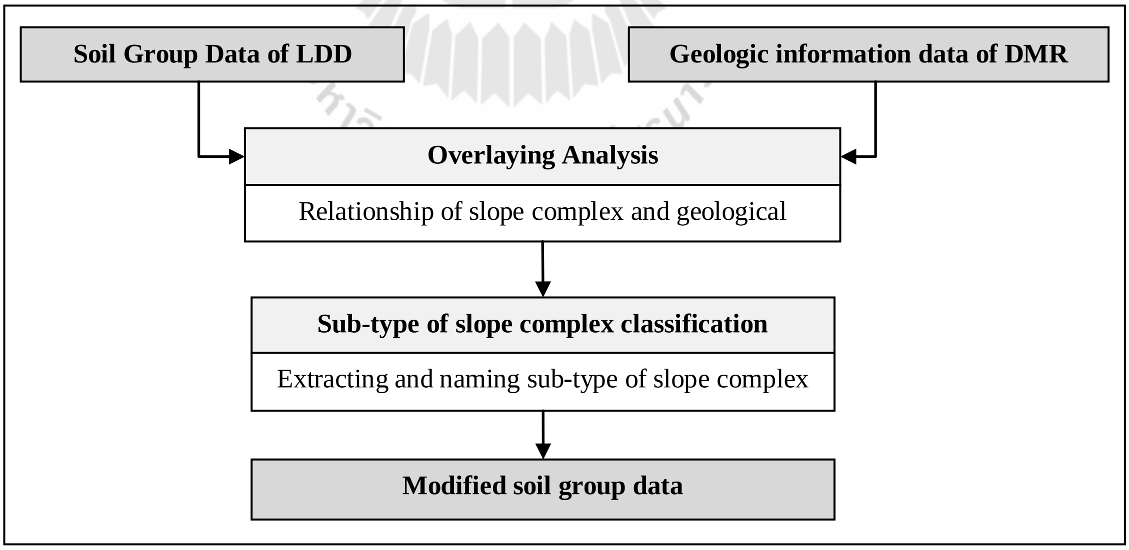


Figure 4.4 Method and processing for soil classification in slope complex.

(1) Overlay Analysis

Soil data consisting of 27 soil groups were overlaid with 32 geological formations of geological data under Spatial Analysis of ArcGIS 9.2 to extract the relationship of slope complex with geological formations.

(2) Sub-type of slope complex classification

Based on relationship of slope complex (soil group no. 62) and geological formations from overlay analysis (Table 4.4), sub-type of slope complex are here separately extracted and assigned as new modified soil group units of slope complex . The name of modified soil group in slope complex area in each sub-unit is systematic assigned by adding symbols of geological formation given by the DMR after slope complex (soil group no. 62). For example, slope complex (soil group no.62) which is superimposed over C (Carboniferous) geological formation will be named as “62-C”. As a result, there are 30 sub-types of slope complex and modified soil type from slope complex of the study area (as shown in Figure 4.5).

Table 4.4 Relationship between slope complex and geological information.

No.	Soil Group	Geological formations	Named soil
1	62 (Slope complex)	C (Carboniferous)	62-C
2		C2 (Carboniferous)	62-C2
3		CP (Carboniferous-Permian)	62-CP
4		CPk (Carboniferous-Permian with Kaeng Krachan Group)	62-Cpk
5		Cb (Carboniferous)	62-Cb
6		Cgr (Carboniferous)	62-Cgr
7		DC (Devonian-Carboniferous)	62-DC
8		DCv (Devonian-Carboniferous)	62-DCv
9		E (Cambrian)	62-E
10		EO (Cambrian-Ordovician)	62-EO
11		J (Jurassic)	62-J
12		O (Ordovician)	62-O
13		PE (Cambrian)	62-PE
14		PTrv (Permian-Triassic)	62-PTrv
15		Png1 (Permian with Ngao Group)	62-Png1
16		Png2 (Permian with Ngao Group)	62-Png2
17		SD (Silurian-Devonian)	62-SD
18		SDCtp (Silurian-	62-SDCtp
19		Tmm (Tertiary)	62-Tmm
20		Tr1 (Triassic)	62-Tr1
21		TrJ (Triassic-Jurassic)	62-TrJ
22		Trgr (Granite)	62-Trgr
23		Trhh (Triassic with Hong Hoi Formation)	62-Trhh
24		Trm (Triassic)	62-Trm
25		Trpk (Triassic)	62-Trpk
26		Trpt (Triassic with Phra That Formation)	62-Trpt

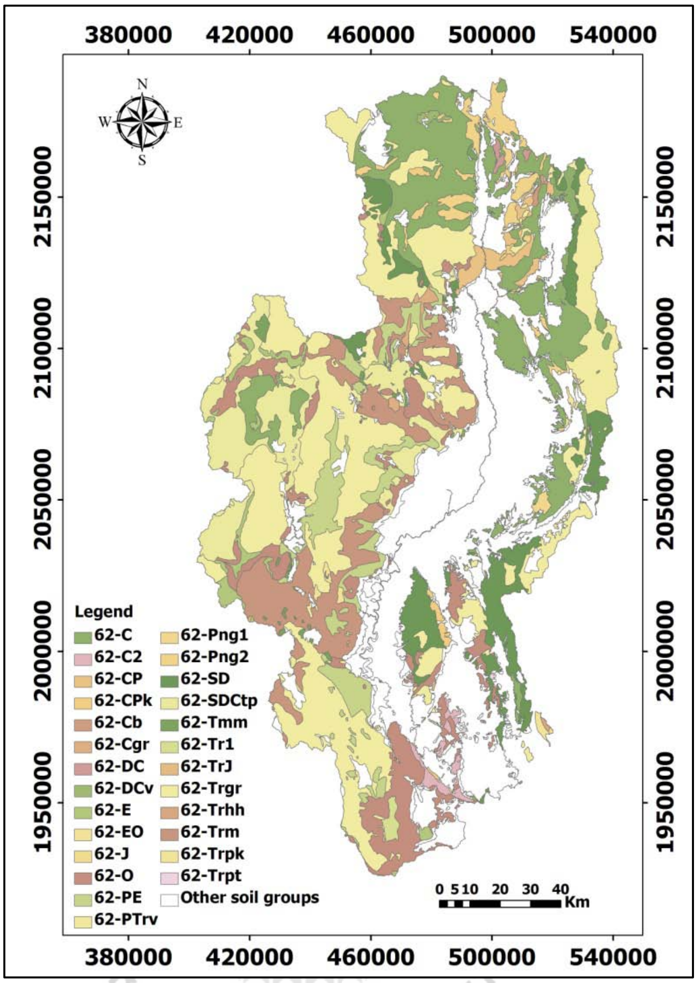


Figure 4.5 The soil layer for this study.

4.3 Data analysis

Under this component, three sub-components are arranged for data analysis includes (1) identification and evaluation of physical factors as ecological niche for each forest type, (2) development of forest ecological models for prediction of forest type distribution, and (3) combination of forest type layers.

4.3.1 Identification and evaluation of physical factors for each forest type

All 3 physical factors including 10 climatic variables, 3 topographic variables and 1 soil variable (Table 4.5), had been prepared in the previous component are here used to identify and evaluate with factor analysis under SPSS software. In practice, 2 operations under this sub-component are implemented as shown in Figure 4.6.

Table 4.5 14 selected-physical variables.

No.	Factor	Variables	Data range
1	Climate	BIO1: Mean annually temperature (°C)	14.80 – 27.40
2	Climate	BIO2: Mean monthly temperature range (°C)	11.70 – 13.10
3	Climate	BIO4: Mean annually temperature seasonality (Std. Deviation)	2.02 – 2.69
4	Climate	BIO5: Mean monthly maximum temperature (°C)	24.90 – 39.00
5	Climate	BIO6: Mean monthly minimum temperature (°C)	2.60 – 15.40
6	Climate	BIO7: Mean annually temperature range (°C)	22.30 – 24.90
7	Climate	BIO12: Mean annually precipitation (mm)	897.00 – 1,355.00
8	Climate	BIO13: Mean monthly maximum precipitation (mm)	167.00 – 308.00
9	Climate	BIO14: Mean monthly minimum precipitation (mm)	4.00 – 23.00
10	Climate	BIO15: Mean precipitation seasonality (Std. Deviation)	66.00 – 87.00
11	Topography	Elevation (m)	0.00 – 2,775.00
12	Topography	Slope (%)	0.00 – 88.00
13	Topography	Aspect (direction)	-1 – 360
14	Soil	Modified soil	Qualitative data

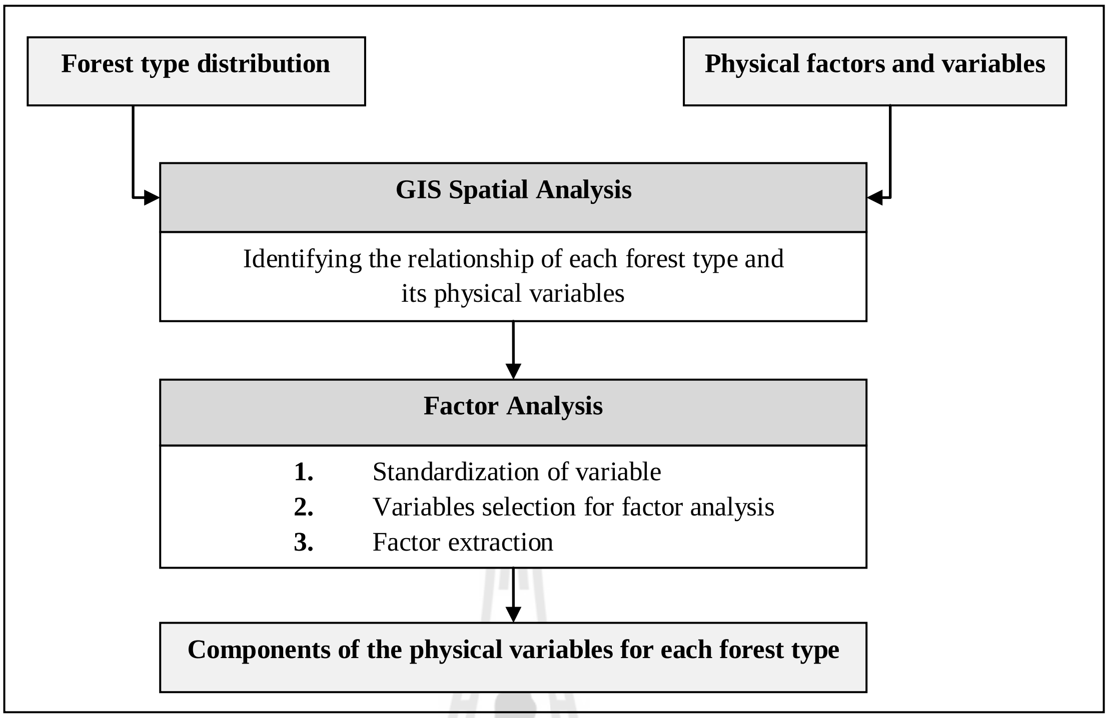


Figure 4.6 Identification and evaluation of physical factors for each forest type by factor analysis.

(1) GIS spatial analysis

The prepared each forest type and physical layers from previous component were firstly used to identify theirs spatial relationship. The output of this operation is the relationship of each forest type and its physical factors in form of the attribute table. Then each attribute data of forest type were exported in format of spreadsheet for factor analysis in the next operation. The quantitative data of main 5 forest types include Mixed Deciduous Forest (MDF), Dry Dipterocarp Forest (DDF), Coniferous Forest (CF), Moist Evergreen Forest (MEF), Dry Evergreen Forest (DEF), and Hill Evergreen Forest (HEF) are presented in Appendix B.1 – B.5.

(2) Factor analysis

In principle, factor analysis is data reduction technique and summarization of observed variables in terms of common underlying dimensions or factors (Assembly's Statistical Directorate and the Local Government Data Unit, 2008). Quantitative data of physical factors for each forest type were here used to evaluated by factor analysis based on Principle Component Analysis (PCA) under SPSS software. Factors which have eigenvalues greater than 1 will be here extracted. In practice, the major step of factor analysis can be summarized as following.

(2.1) Standardization of variable

As the values of the selected 14 variables in each forest type for factor analysis have different ranges and units among them (Table 4.6). Consequently, it is necessary to normalize these values before variable selection for factor analysis, so that the mean value of all variables is set to 0 and their standard deviation value is set to 1 (Table 4.7).

Table 4.6 Summaries of basic statistics between 14 physical variables and 5 forest types before standardization.

Var.	Forest inventory data														
	MDF			DDF			CF			MDEF			HEF		
	Range	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**
BIO1	20.30-26.50	24.11	12.6	21.20-26.90	24.61	11.08	21.60-24.20	23.05	7.17	21.00-23.80	22.41	9.31	15.80-24.80	22.05	14.45
BIO2	11.80-12.80	12.16	2.19	11.80-12.90	12.22	2.63	11.90-12.70	12.11	2.46	11.90-12.50	12.16	1.57	11.90-12.80	12.15	1.84
BIO4	2.20-2.66	2.44	1.14	2.17-2.65	2.41	1.25	2.18-2.60	2.39	1.07	2.23-2.58	2.37	0.96	2.05-2.58	2.4	1.11
BIO5	30.60-38.00	34.83	15.15	32.10-38.30	35.51	14.4	32.00-35.70	33.97	9.63	31.60-35.00	33.24	10.05	26.10-36.00	32.72	16.41
BIO6	7.40-14.10	11.34	13.45	8.40-14.50	11.93	12.14	8.70-11.50	10.36	7.45	8.20-11.20	9.67	9.6	3.50-12.00	9.27	14.55
BIO7	22.90-24.60	23.50	3.58	22.80-24.50	23.61	4.24	23.30-24.40	23.61	3.31	23.20-24.00	23.56	2.12	22.60-24.40	23.45	3.10
BIO12	917.00-1338.00	1094.54	115.81	900.00-1328.00	1086.84	105.91	921.00-1201.00	1036.87	90.69	962.00-1280.00	1030.89	72.24	929.00-1286	1086.77	90.97
BIO13	170.00-298.00	217.19	34.00	167.00-295.00	216.97	30.16	171.00-235.00	191.4	19.43	169.00-258.00	188.37	19.55	169.00-276.00	199.72	20.85
BIO14	4.00-17.00	7.65	2.50	4.00-19.00	8.41	3.18	4.00-16.00	7.6	3.33	5.00-12.00	8.37	1.64	5.00-18.00	8.27	2.22
BIO15	71.00-86.00	79.73	3.04	69.00-86.00	79.47	3.66	72.00-82.00	78.53	2.97	75.00-80.00	77.21	1.58	70.00-85.00	77.52	2.51
Elevation	287.00-1438.00	712.44	228.55	274.00-1377.00	666.54	211.67	654.00-1227.00	1020.6	143.74	782.00-1361.00	1122.95	182.72	471.00-2339.00	1160.22	265.47
Slope	1.67-92.08	28.97	16.15	2.43-73.74	25.71	16.1	2.43-45.11	20.93	11.22	7.68-44.29	25.41	12.1	3.33-94.01	34.04	17.81
Aspect	2.12-358.70	177.74	106.27	1.04-356.99	175.57	103.23	17.93-284.74	160.47	96.15	4.32-351.38	169.7	117.5	2.08-349.32	204.81	98.82
Soil*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: * is Qualitative data, CF is Coniferous Forest, MDEF is Moist and Dry Evergreen Forest, HEF is Hill Evergreen Forest, MDF is Mixed Deciduous Forest, and DDF is Dry Dipterocarp Forest (DDF), BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (Std. Deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (Std. Deviation)

Table 4.7 Summaries of basic statistics between 14 physical variables and 5 forest types after standardization.

Var.	Forest inventory data														
	MDF			DDF			CF			MDEF			HEF		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
BIO1	-0.845-0.992	0	1	-0.753-0.990	0	1	-0.459-0.984	0	1	-0.760-0.988	0	1	-0.866-0.994	0	1
BIO2	-0.724-0.933	0	1	-0.855-0.951	0	1	-0.893-0.969	0	1	-0.652-0.924	0	1	-0.554-0.904	0	1
BIO4	-0.814-0.873	0	1	-0.871-0.797	0	1	-0.866-0.584	0	1	-0.713-0.735	0	1	-0.589-0.651	0	1
BIO5	-0.719-0.976	0	1	-0.609-0.963	0	1	-0.692-0.957	0	1	-0.573-0.978	0	1	-0.765-0.987	0	1
BIO6	-0.799-0.992	0	1	-0.688-0.990	0	1	-0.510-0.984	0	1	-0.698-0.988	0	1	-0.824-0.994	0	1
BIO7	-0.814-0.879	0	1	-0.871-0.903	0	1	-0.866-0.891	0	1	-0.713-0.802	0	1	-0.647-0.686	0	1
BIO12	-0.643-0.923	0	1	-0.521-0.901	0	1	-0.480-0.850	0	1	-0.609-0.801	0	1	-0.647-0.753	0	1
BIO13	-0.567-0.923	0	1	-0.581-0.901	0	1	-0.478-0.850	0	1	-0.405-0.801	0	1	-0.510-0.753	0	1
BIO14	-0.841-0.933	0	1	-0.915-0.951	0	1	-0.899-0.969	0	1	-0.673-0.924	0	1	-0.758-0.904-	0	1
BIO15	-0.841-0.684	0	1	-0.915-0.737	0	1	-0.899-0.584	0	1	-0.673-0.536	0	1	-0.758-0.466	0	1
Elevation	-0.845-0.356	0	1	-0.753-0.340	0	1	-0.719-0.379	0	1	-0.760-0.445	0	1	-0.866-0.199	0	1
Slope	-0.349-0.356	0	1	-0.301-0.296	0	1	-0.297-0.320	0	1	-0.543-0.344	0	1	-0.151-0.165	0	1
Aspect	-0.184-0.076	0	1	-0.147-0.116	0	1	-0.482-0.300	0	1	-0.543-0.129	0	1	-0.367-0.354	0	1
Soil*	-0.841-0.684	0	1	-0.472-0.383	0	1	-0.482-0.320	0	1	-0.160-0.188	0	1	-0.510-0.171	0	1

Note: * is transformed into quantitative data, CF is Coniferous Forest, MDEF is Moist and Dry Evergreen Forest, HEF is Hill Evergreen Forest, MDF is Mixed Deciduous Forest, and DDF is Dry Dipterocarp Forest (DDF), BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (Std. Deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (Std. Deviation)

(2.2) Variables selection for factor analysis

There were two statistical methods: Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity had been initially used to identify significant variables based on correlation matrix and correlation coefficient among them (Appendix B.6 – B.11). Based on Friel (2009) the variable with KMO value of greater than 0.5 and Bartlett's test of sphericity with 0.00 were considered as significant values ($p < 0.001$). In this study, KMO of each forest type was higher than 0.60 whereas Bartlett's test of sphericity was 0.00. Therefore, 14 physical variables were appropriately for factor analysis.

Then, communalities which measure the percent of variance in each physical variable for each forest type were computed by the sum of the squared loadings for all variables. In general, communalities show for which measured variables the factor analysis is working best and least well (Garson, 1998). In fact, communality value varies between 0 and 1 and appropriate variables, when variables are less than 30, they should have communality value more than 0.7 (Field, 2005). Owing to the rule, communalities value for each variable in each forest type are computed and evaluated for factor extraction with PCA in the next step as shown Table 4.8.

Table 4.8 Communalities of 14 physical variables for forest types.

Variable	Initial	MDF	DDF	CF	MDEF	HEF
Elevation	1.000	0.851	0.883	0.893	0.912	0.859
Slope	1.000	0.209*	0.414*	0.485*	0.790	0.973
Aspect	1.000	0.071*	0.415*	0.321*	0.820	0.270*
BIO1	1.000	0.974	0.978	0.982	0.996	0.978
BIO2	1.000	0.950	0.950	0.982	0.962	0.923
BIO4	1.000	0.888	0.921	0.965	0.840	0.795
BIO5	1.000	0.976	0.981	0.984	0.993	0.991
BIO6	1.000	0.974	0.979	0.980	0.990	0.980
BIO7	1.000	0.928	0.948	0.935	0.894	0.849
BIO12	1.000	0.920	0.917	0.973	0.972	0.940
BIO13	1.000	0.933	0.930	0.889	0.924	0.805
BIO14	1.000	0.962	0.968	0.959	0.962	0.946
BIO15	1.000	0.877	0.918	0.858	0.841	0.814
Soil	1.000	0.428*	0.405*	0.370*	0.729	0.403*

Note: * Variables with communalities values less than 0.7 are removed.

(2.3) Factor extraction

For this part, PCA had been firstly applied for extraction of initial solution with factor loading. In this study, factors of each forest type with eigenvalues greater than 1 are extracted. Then Varimax rotation was applied to clarify categorization of factors that are well interpreted as components of each forest type. Each component of each forest type had been explained by percentage of variance.

4.3.2 Development of forest ecological modeling for prediction of forest type distribution

Data input for this component consisted of 3 datasets (Table 4.9): (1) forest type datasets from 241 inventory plots for modeling (2) forest type datasets from 219 inventory plots for validation and (3) extracted physical factors dataset for each forest type from factor analysis. These 3 datasets were used for forest ecological modeling with Ecological Niche Factor Analysis (ENFA) in BIOMAPPER 4.0, developed by Hirzel et al. (2007). In this sub-component, there are 4 operations are implemented as shown in Figure 4.7.

Table 4.9 Three datasets for ENFA.

Dataset for Modeling	**Dataset for Validation**	**Extracted physical factors dataset from factor analysis**
1. Eighty-three forest inventory plots for Mixed Deciduous Forest (MDF)	4. Eighty-one forest inventory plots for Mixed Deciduous Forest (MDF)	- MDF1: BIO1, BIO6, BIO5 and elevation - MDF2: BIO14, BIO2, BIO7 and BIO15 - MDF3: BIO13, BIO12 and BIO4
2. Ninety-three forest inventory plots for Dry Dipterocarp Forest (DDF)	5. Eight-six forest inventory plots for Dry Dipterocarp Forest (DDF)	- DDF1: BIO14, BIO2, BIO15 and BIO7 - DDF2: BIO1, BIO6, BIO5 and elevation - DDF3: BIO12, BIO13 and BIO4
3. Eight forest inventory plots for Coniferous Forest (CF)	1. Seven forest inventory plots for Coniferous Forest (CF)	- CF1: BIO2, BIO4, BIO7, BIO14 and BIO15 - CF2: BIO1, BIO5, BIO6 and elevation -. CF3: BIO12 and BIO13
4. Eleven forest inventory plots for Moist and Dry Evergreen Forest (MDEF)	2. Eight forest inventory plots for Moist and Dry Evergreen Forest (MDEF)	- MDEF1: BIO1, BIO5, BIO6 and elevation - MDEF2: BIO2, BIO4, BIO7, BIO14 and BIO15 - MDEF3: BIO12 and BIO13 - MDEF4: slope and aspect
5. Forty-six forest inventory plots for Hill Evergreen Forest (HEF)	3. Thirty-seven forest inventory plots for Hill Evergreen Forest (HEF)	- HEF1: BIO1, BIO6, BIO5 and elevation - HEF2: BIO14, BIO7, BIO15 and BIO2 - HEF3: BIO12, BIO13 and BIO4

Note: -BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (standard deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (standard deviation)

Figure 4.7 Development of forest ecological modeling for predicting forest type distribution.

(1) Discrepancies checking

All 3 datasets were firstly converted into the raster format with 30 x 30 m. resolution and then forest type datasets for modeling and extracted physical factors dataset were simultaneously overlaid to verify discrepancies of datasets (same area, same spatial unit and cell value).

(2) Forest ecological modeling by ENFA

Under this operation, two verified discrepancy datasets (forest type datasets for modeling and extracted physical factors dataset) of each forest type are firstly overlaid with intersection operation for generating the "EcoGeographical Variables" (EGVs) for each variable according to number of variables. Basically, EGVs described quantitatively features between modeling forest type and physical variables. After that, EGVs of each physical variable are used to calculate coefficient of marginality and specialization with respectively variable, for example, elevation EGV with elevation data. According to Hirzel (2002), marginality coefficient accounts for mean distribution of species on the global mean of the study area while specialization coefficient accounts for ration of the species variation and the global variation.

The calculation of marginality and specialization coefficients is separately described as follows:

(2.1) Marginality coefficient

Marginality coefficient of each environmental variable, which is used to measure the distance between forest type niches and the mean environmental conditions of study area are firstly computed as:

$$m_i = \frac{|m_G - m_S|}{1.96\partial\sigma_G} \quad (4.4)$$

Where

m_i is marginality coefficient of each environmental variables;

m_G is the mean of global distribution;

m_S is the mean of species distribution and

σ_G is the variation of the global distribution.

These values vary between -1 to 1. Then, the total of marginality of all variables is computed as:

$$M = \frac{\sqrt{\sum_{i=1}^{n} m_i^2}}{1.96} \tag{4.5}$$

Where

M is total of marginality of all environmental variables

m_i is marginality coefficient of each environmental variable;

(2.2) Specialization coefficient

The specialization coefficient, which is used to measure how the forest types tolerate environmental variations in the analyzed territory are firstly computed as:

$$S_i = \frac{\sigma_G}{\sigma_S} \tag{4.6}$$

Where

S_i is the specialization coefficient of each environmental variables;

σ_G is the standard deviation of the global distribution and

σ_S is the standard deviation of the focal species distribution.

The value ranges from -1 to 1. Then, the total of specialization of all variable is computed as:

$$S = \frac{\sqrt{\sum_{1=1}^{n} S_i^2}}{n} \tag{4.7}$$

Where

S is the total specialization coefficient of all environmental variables;

S_i is the specialization coefficient of each environmental variable.

The outputs from this operation are total marginality coefficient for all variables and the total specialization coefficient for each variable calculations summarizes all EGVs into a few, uncorrelated factors retaining most of the information (Fulgione, Maselli, Pavarese, Rippa, and Rastogi (2009). These coefficients are used to explain the percent of variance of marginality and specialization. Furthermore marginality coefficient and specialization coefficients for each variable are employed for computing Habitat Suitability (HS) for each forest type in the next operation.

(3) Computing habitat suitability index for each forest type

In principle, the habitat suitability index for the focal species builds on a count of all cells from the species distribution that lay as far as or farther apart from the median than the focal cell on a factor axis. This count is normalized in such a way that the suitability index ranges from zero to one. Practically, this is performed by dividing the species range on each selected factor in a series of classes, in such a way that the median would exactly separate two classes. For every cell from the global distribution, we count the number of cells from the species distribution that lay either in the same class or in any class farther apart from the median on the same side (Figure 4.8). Normalization is achieved by dividing twice this number by the total number of cells in the species distribution. Thus, a cell laying in one of the two classes directly adjacent to the median would score one, and a cell laying outside the species distribution would score zero (Hirzel, 2001).

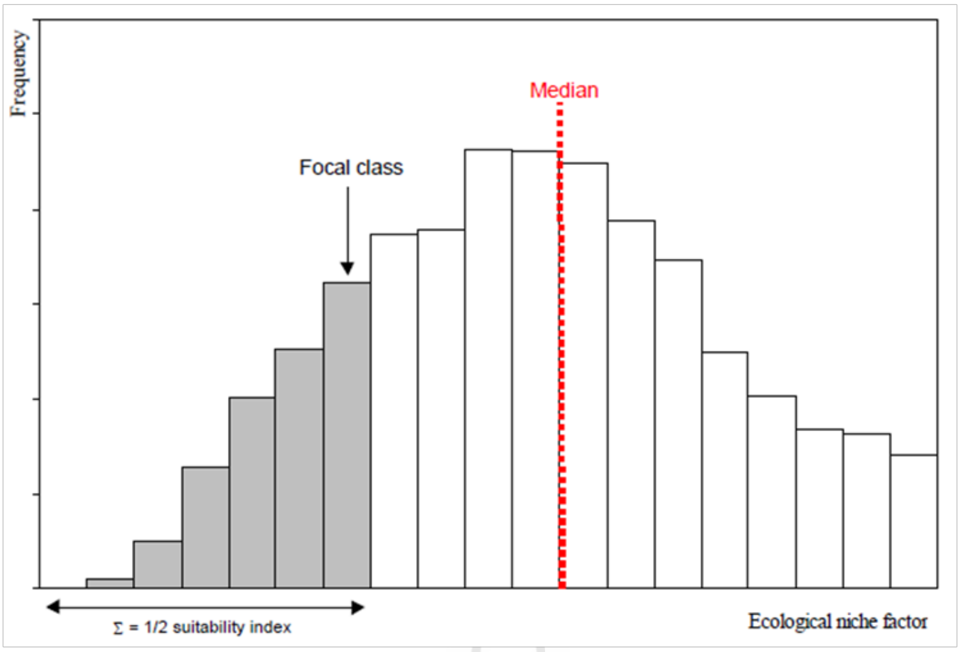


Figure 4.8 Median algorithm for habitat suitability computation (From Hirzel, 2001).

In practice, habitat suitability for each forest type used median algorithm to compare distribution of physical factor for each forest type (ecological niche factor) in form of totally marginality and specialization with forest type distribution. Habitat suitability index based on median algorithm is computed using following equation (Hirzel et al., 2007):

$$H_{(c)} = \frac{1}{\sum_{f=1}^{n_f} W_f} \sum_{f=1}^{n_f} W_f Hm(f,c) \qquad (4.8)$$

Where

$H_{(c)}$ is total habitat suitability index for each forest type;

$Hm(f,c)$ is a partial habitat suitability for each factor (f);

W_f is automatically weighted for each factor (f)

The habitat suitability value varies between 0 and 100 or 0 and 1, from unsuitable to optimal habitat.

In addition, the median algorithm (m) makes the assumption that, on all factors, the median of the species distribution indicates the optimal value. Mathematically, the partial suitability Hm(f, c) of predictor class c along factor f is calculated by following equation with two conditions (Braunisch et al., 2008) as:

If c < median (s) then

$$\mathrm{Hm}(f,c) = 2\sum_{i=1}^{c} S_{f,i} \tag{4.9}$$

If c > median (s) then

$$\mathrm{Hm}(f,c) = 2\sum_{i=c}^{Nc} S_{f,i} \tag{4.10}$$

Where

Hm(f,c) is a habitat suitability for each factor (f) that is computed by forest type occur in each cell (c);

$S_{f,i}$ is number of species presence cells in the i^{th} partial HS of factor (f)

The partial suitability increases from 0 at the tails of the species distribution to 1 for the classes bracketing the median.

(4) Validation of habitat suitability index for each forest type

All derived habitat suitability indices in each forest type are here used to validate with forest inventory datasets using 2 indices: Absolute Validation Index (AVI) and Contrast Validation Index (CVI). Basically, AVI measures accuracy between predicted area and validating dataset. While CVI measures accuracy between predicted location and validating dataset that based on the difference between AVI and ratio of predicted area and study area. According to Hirzel et al. (2004) habitat suitability index validation in BIOMAPPER is done by cross-validation process to compute AVI and CVI. The AVI is the proportion of presence evaluation points falling above some fixed HS threshold (e.g. 0.5); it varies from 0 to 1. The CVI indicates how much the AVI differs from what would have been obtained with a random model, it varies from 0 to AVI value. The output under this operation provides the best habitat suitability index for each forest type. Then, index of each forest type was reclassified into three suitability classes by natural break line method.

4.3.3 Creation of geospatial forest type distribution

In this sub-component, the best of habitat suitability index in each forest type is combined by GIS technique with special unique coding for creating geospatial forest type distribution. Basic rationale and operational techniques applied for geospatial forest type distribution are here briefly described as following:

4.3.3.1 Rationale

To increase the quality and effectiveness of the spatial analysis in the decision making process, Llano and Fonseca (2009) had presented a method for agro-ecological zonation of crops based on the combination of GIS analysis techniques as map overlay, reclassification. Herein the geospatial forest type distribution is combined based on special unique coding of each forest type and then are processed with spatial analyst tool of GIS. This combination method will be useful for new information creation or extraction from various raster data.

4.3.3.2 Operational techniques

There are 2 main operations to implement under this sub-component as shown in Figure 4.9 and more details as below:

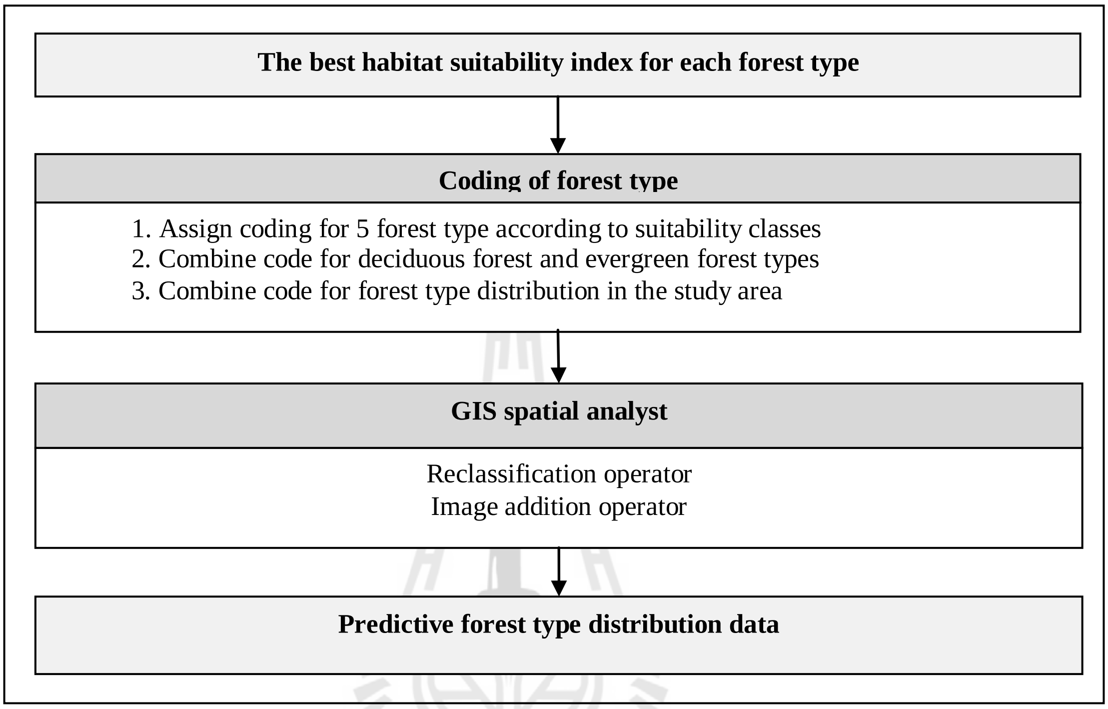


Figure 4.9 Creation of geospatial forest type distribution.

(1) Coding of forest type

Data input for this sub-component are 5 forest type distribution based on habitat suitability classes include (1) Mixed Deciduous Forest, (2) Dry Dipterocarp Forest, (3) Coniferous Forest (4) Moist and Dry Evergreen Forest and (5) Hill Evergreen Forest. In practice, coding of forest type is divided into 2 steps: (1) Coding for each forest type in deciduous forest (MDF and DDF) and coding for each forest type in evergreen forest (CF, MDEF and HEF) as shown in Table 4.10 and Table 4.11, respectively; (2) Coding for combining between deciduous forest and evergreen forest (Appendix C).

In the first step, hierarchical coding system is applied to each forest type according habitat suitability classes (See Figure 4.10 for deciduous forest). Then, code in each forest type (deciduous forest and evergreen forest) is combined by addition for assignation of forest type using maximum operator. For example, MDF with moderate HS (code 2) combined with DDF with high HS (code 30), it will become DDF with code 32. If the suitability class of forest types is equal, it will be assigned as Ecotone. For example, MDF with moderate HS (code 2) combined with DDF with moderate HS (code 20), it will become Deciduous Ecotone with code 22.

In the second step, existing coding for deciduous forest is assigned a new code by multiplication operation by 1000. Then, new code in each deciduous forest type can be combined with evergreen forest type. Two code of deciduous and evergreen are combined by addition for assignation of forest type distribution in study area using maximum operator. For example, DDF with high HS (code 32000) combined with CF with moderate HS (code 112), it will become DDF with code 32112. If the suitability class of deciduous forest types and evergreen forest type is equal at least two types, it will be assigned as Ecotone. For example, DDF with moderate HS (code 22000) combined with CF with moderate HS (code 112), it will become Deciduous and Evergreen Ecotone with code 22112.

Table 4.10 Coding of deciduous forest type.

Mixed deciduous forest		Dry dipterocarp forest		Possibly deciduous forest	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
1	MDF-LHS	10	DDF-LHS	11	Deciduous ecotone
		20	DDF-MHS	21	DDF
		30	DDF-HHS	31	DDF
2	MDF-MHS	10	DDF-LHS	12	MDF
		20	DDF-MHS	22	Deciduous ecotone
		30	DDF-HHS	32	DDF
3	MDF-HHS	10	DDF-LHS	13	MDF
		20	DDF-MHS	23	MDF
		30	DDF-HHS	33	Deciduous ecotone

Note: MDF-LHS = Mixed Deciduous Forest-Low Habitat Suitability, MDF-MHS = Mixed Deciduous Forest-Moderate Habitat Suitability, MDF-HHS = Mixed Deciduous Forest-High Habitat Suitability, DDF-LHS = Dry Dipterocarp Forest-Low Habitat Suitability, DDF-MHS = Dry Dipterocarp Forest-Moderate Habitat Suitability, and DDF-HHS = Dry Dipterocarp Forest-High Habitat Suitability

Table 4.11 Coding for evergreen forest type .

Coniferous forest		Moist and dry evergreen forest		Hill evergreen forest		Possibly evergreen forest	
Code	**Name**	**Code**	**Name**	**Code**	**Name**	**Code**	**Name**
1	CF-LHS	10	MDEF-LHS	100	HEF-LHS	111	Evergreen ecotone
				200	HEF-MHS	211	HEF
				300	HEF-HHS	311	HEF
		20	MDEF-MHS	100	HEF-LHS	121	MDEF
				200	HEF-MHS	221	Evergreen ecotone
				300	HEF-HHS	321	HEF
		30	MDEF-HHS	100	HEF-LHS	131	MDEF
				200	HEF-MHS	231	MDEF
				300	HEF-HHS	331	Evergreen ecotone
2	CF-MHS	10	MDEF-LHS	100	HEF-LHS	112	CF
				200	HEF-MHS	212	Evergreen ecotone
				300	HEF-HHS	312	HEF
		20	MDEF-MHS	100	HEF-LHS	122	Evergreen ecotone
				200	HEF-MHS	222	Evergreen ecotone
				300	HEF-HHS	322	HEF
		30	MDEF-HHS	100	HEF-LHS	132	MDEF
				200	HEF-MHS	232	MDEF
				300	HEF-HHS	332	Evergreen ecotone
3	CF-HHS	10	MDEF-LHS	100	HEF-LHS	113	CF
				200	HEF-MHS	213	CF
				300	HEF-HHS	313	Evergreen ecotone
		20	MDEF-MHS	100	HEF-LHS	123	CF
				200	HEF-MHS	223	CF
				300	HEF-HHS	323	Evergreen ecotone
		30	MDEF-HHS	100	HEF-LHS	133	Evergreen ecotone
				200	HEF-MHS	233	Evergreen ecotone
				300	HEF-HHS	333	Evergreen ecotone

Note: CF-LHS = Coniferous Forest-Low Habitat Suitability, CF-MHS = Coniferous Forest-Moderate Habitat Suitability, CF-HHS = Coniferous Forest-High Habitat Suitability, MDEF-LHS = Moist and Dry Evergreen Forest Forest-Low Habitat Suitability, MDEF-MHS = Moist and Dry Evergreen Forest Forest-Moderate Habitat Suitability, and MDEF-HHS = Moist and Dry Evergreen Forest Forest-High Habitat Suitability

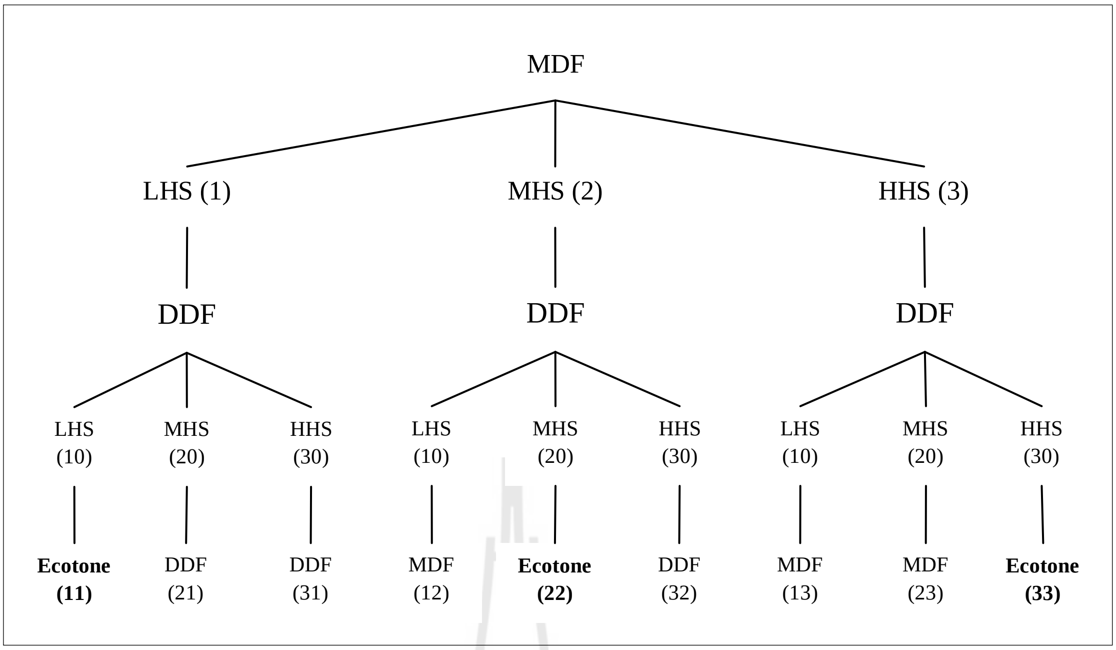


Figure 4.10 Example of hierarchical code system for deciduous forest.

(2) GIS spatial analysis

Under this operation, each forest type with habitat suitability classes are firstly reclassify according to forest type code. Then each forest type of deciduous forest type and evergreen forest type are combined together using image addition. Example of GIS spatial analyst for deciduous forest type combination is schematic displays in Figure 4.11. Finally redundant possibly classes from combination of deciduous forest and evergreen forest and theirs ecotones (Appendix C) are reclassified into 9 classes including (1) Mixed Deciduous Forest (MDF), (2) Dry Dipterocarp Forest (DDF), (3) Deciduous Ecotone (4) Coniferous Forest (CF) (5) Moist and Dry Evergreen Forest (MDEF), (6) Hill Evergreen Forest (HEF), (7) Evergreen Ecotone, (8) Deciduous-Evergreen Ecotone and (9) Unsuitable forest area (Low habitat suitability of all forest types with code 11111).

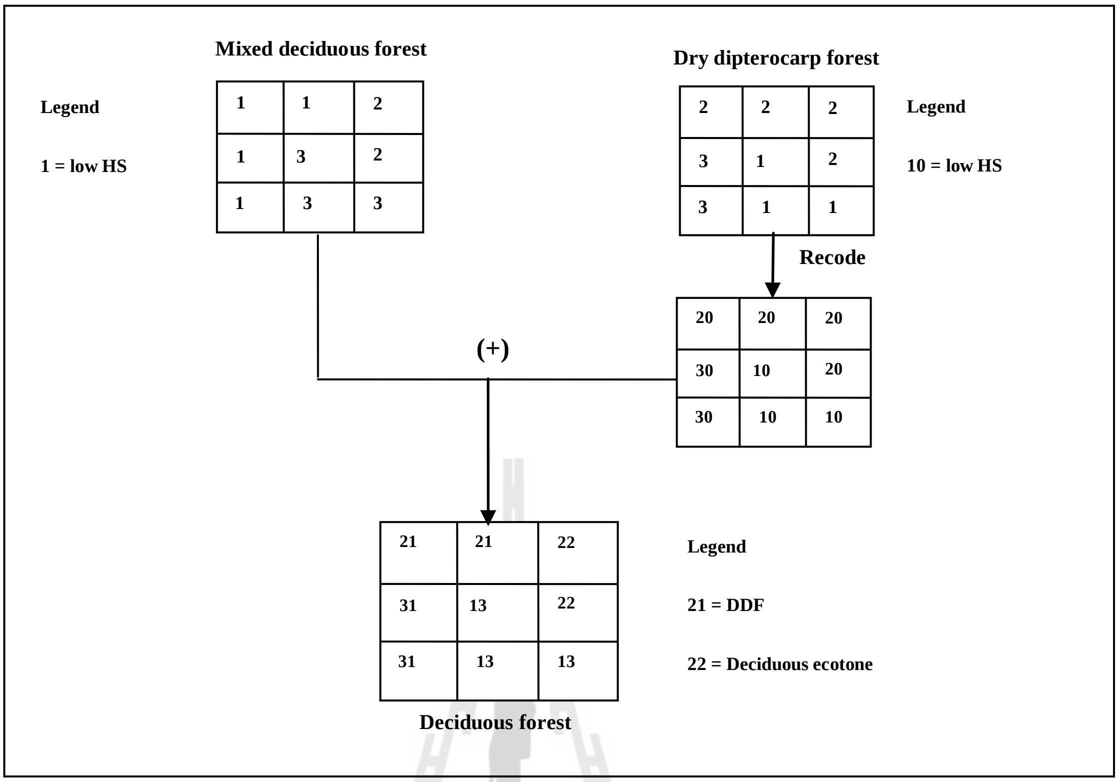


Figure 4.11 GIS spatial analyst for deciduous forest type combination.

4.4 Accuracy assessment

Major steps for accuracy assessment of forest type distribution data are conducted in following steps:

(1) Calculation of sample size. Here, sample size based on multinomial distribution was selected to calculate number of sample (N) as following Equation (Congalton and Green, 1999):

$$N = \frac{B\Pi_i(1 \quad \Pi_i)}{b_i^2} \tag{4.11}$$

Where

B is the upper $(\alpha/k) \times 100^{th}$ percentile of the chi square (χ^2) distribution with one degree of freedom,

Π_i ($i = 1,2,\ldots k$) is the proportion of the population in the i^{th} category,

b is the absolute precision of the sample and k is the number of classes

(2) Selection of sampling design. When the study already had the total of sample size (N), now it is necessary to determine the geographic location (x, y) of these samples in the real world. In this study, stratified random sampling technique was applied for locating observing points for accuracy assessment.

(3) Accuracy assessment. After the ground reference information has been collected from the randomly located sites, then the error matrix between ground survey data and predictive forest type data by ENFA are created. After that, accuracy assessment of predictive forest type data is conducted using simple descriptive statistics and Kappa analysis and fuzzification.

(3.1) Simple descriptive statistics

(3.1.1) Overall accuracy

Overall accuracy is defined by dividing the total correct pixels with the total number of pixels.

(3.1.2) Producer's accuracy and omission error

Accuracy of producer is defined by the total number of correct pixels in a category are divided by the total number of the pixels of that category as derived from the reference data. At the same time, omission error is defined by the total number of omitted pixels in a category are divided by the total number of the pixels of that category as derived from the reference data.

(3.1.3) User's accuracy and commission error

Accuracy of user is defined by the total number of correct pixels in each category are divided by the total number of the pixels that were actually classified in that category. In contrary, commission error is defined by the total number of committed pixels in each category are divided by the total number of the pixels that were actually classified in that category.

(3.2) Kappa analysis

The Kappa analysis is a discrete multivariate technique used in accuracy assessment to statistically determine if one error matrix is significantly different from another. This measure of agreement is based on the difference between the actual agreement in the error matrix (i.e., the agreement between the remotely sensed classification and the reference data as indicated by the major diagonal) and the chance agreement that is indicated by the row and column totals (i.e. marginals) (Congalton and Green, 2009).

(3.2.1) Kappa hat coefficient of agreement

Kappa hat coefficient of agreement is measure of agreement or accuracy between the remote sensing-derived classification map and the reference data as indicated by a) the major diagonal and b) the change agreement, which is indicated by the row and column totals as marginals (Congalton and Green, 2009). The Kappa hat coefficient of agreement can be calculated using following:

$$\hat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{k}(x_{i+} \times x_{+i})} \tag{4.12}$$

Where

k is the number of rows (e.g. land-cover classes) in the matrix

x_{ii} is the number of the observation in row i and column i

x_{i+} is the marginal totals for row i

x_{+i} is the marginal totals for column i

N is the total number of observations

Then, a result of the values from kappa analysis can be determined accuracy level based on Landis and Koch (1977), are shown as following:

- Kappa values > 0.80 (i.e., > 80%) represent strong agreement or accuracy between the classification map and the ground reference information.

- Kappa values between 0.40 and 0.80 (i.e. 40% to 80%) represent moderate agreement or accuracy between the classification map and the ground reference information.

- Kappa values < 0.40 (i.e. < 40%) represent poor agreement or accuracy between the classification map and the ground reference information.

(3.2.2) Conditional $\text{Kappa}_{\text{hat}}$ coefficient of agreement

The condition coefficient of agreement (K_c) can be used to calculate agreement between the reference and remote sensing-derived data with change agreement eliminated for and individual class for user accuracies using the equation (Congalton and Green, 2009):

$$\hat{K}_c = \frac{N(x_{ii}) - (x_{i+} \times x_{+i})}{N(x_{i+}) - (x_{i+} \times x_{+i})} \tag{4.13}$$

Where

x_{ii} is the number of observations correctly classified for a particular category (summarized in the diagonal of the matrix)

x_{i+} is marginal totals for row i associated with category

x_{+i} is marginal totals for column i associated with category

N is the total number of observations in the entire matrix.

In addition, producer accuracies can be calculated with the equation as:

$$\hat{K}_c = \frac{N(x_{ii}) - (x_{+i} \times x_{i+})}{N(x_{+i}) - (x_{+i} \times x_{i+})} \tag{4.14}$$

Where

x_{ii} is the number of observations correctly classified for a particular category (summarized in the diagonal of the matrix)

x_{+i} is marginal totals for column i associated with category

x_{i+} is marginal totals for row i associated with category

N is the total number of observations in the entire matrix.

(3.3) Fuzzy accuracy assessment

Gopal and Woodcock (1994) proposed the use of fuzzy sets to “allow for explicit recognition of the possibility that ambiguity might exist regarding the appropriate map label for some locations on the map. The situation of one category being exactly right and all other categories being equally and exactly wrong often does not exist. In this fuzzy set approach, it is recognized that instead of a simple system of correct (agreement) and incorrect (disagreement), there can be a variety of responses such as “absolutely right,” “good answer,” “acceptable,” “understandable but wrong,” and “absolutely wrong.”

Congalton and Green (2009) summarized three relevant methods of fuzzy accuracy assessment including (1) expanding the major diagonal of the error matrix, (2) measuring map class variability, and (3) using a fuzzy error matrix approach. In this study, fuzzy error matrix approach is used to assess predictive forest land use type. According to Congalton and Green (1994), they mentioned that the use of the fuzzy error matrix is a very powerful tool in the accuracy assessment process because the fuzzy error matrix allows the analyst to compensate for situations in which the classification scheme breaks represent artificial distinctions along a continuum of land cover and/or where observer variability is often difficult to control. In this study, fuzzy logical rule that are based on habitat suitability classes of deciduous and evergreen forest and theirs ecotones is pre-defined for fuzzy accuracy assessment as shown in Table 4.12. After that overall accuracy, producer’s accuracy and user’s accuracy are calculated.

Table 4.12 Fuzzy logical rule for fuzzy accuracy assessment.

Predictive forest type	Ground Reference								Condition
	Deciduous Forest			Evergreen Forest				D-E_Ecotone	
	MDF	DDF	D-Ecotone	CF	MDEF	HEF	E_Ecotone		
MDF	R	A	A	W	W	W	W	A with condition	When proportion of D and E in Ecotone are 50:50 or 75:25
DDF	A	R	A	W	W	W	W	A with condition	When proportion of D and E in Ecotone are 50:50 or 75:25
D-Ecotone	A	A	R	W	W	W	W	A	
CF	W	W	W	R	A	A	A	A with condition	When proportion of E and D in Ecotone are 50:50 or 75:25
MDEF	W	W	W	A	R	A	A	A with condition	When proportion of E and D in Ecotone are 50:50 or 75:25
HEF	W	W	W	A	A	R	A	A with condition	When proportion of E and D in Ecotone are 50:50 or 75:25
E-Ecotone	W	W	W	A	A	A	R	A	
D-E-Ecotone	A	A	A	A	A	A	A	R	

Note: R is absolute right, A is acceptable and W is absolute wrong, MDF is Mixed Deciduous Forest, DDF is Dry Dipterocarp Forest (DDF), CF is Coniferous Forest, MDEF is Moist and Dry Evergreen Forest, HEF is Hill Evergreen Forest, D-Ecotone is Deciduous Forest Ecotone, E-Ecotone is Evergreen Forest Ecotone, D-E Ecotone is Deciduous and Evergreen Forest Ecotone.

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CHAPTER V

RESULTS AND DISCUSSIONS

The main results for prediction of forest type distribution using ecological modeling had been separately explained in each specific objective and significant finding.

5.1 Identification of the physical factors for forest type distribution

Basic physical factors of forest types in this study area were identified based on Kutintara (1999) who is an expert in forest ecology and had written a well known textbook, Fundamental Forest Ecology. Herein, significant physical factors for existing forest type based on forest inventory data of DNP in the study area include Mixed Deciduous Forest (MDF), Dry Dipterocarp Forest (DDF), Coniferous Forest (CF), Moist and Dry Evergreen forest (MDEF), and Hill Evergreen Forest (HEF) (Figure 5.1) were collected and prepared for data evaluation using factor analysis.

In this study, the significant physical factors including climate, topography and soil were composed of 10 climatic variables, 3 topographic variables, and 1 soil had been identified for forest type distribution (Table 5.1). Moreover, such spatially physical variables can be presented in Figure 5.2.

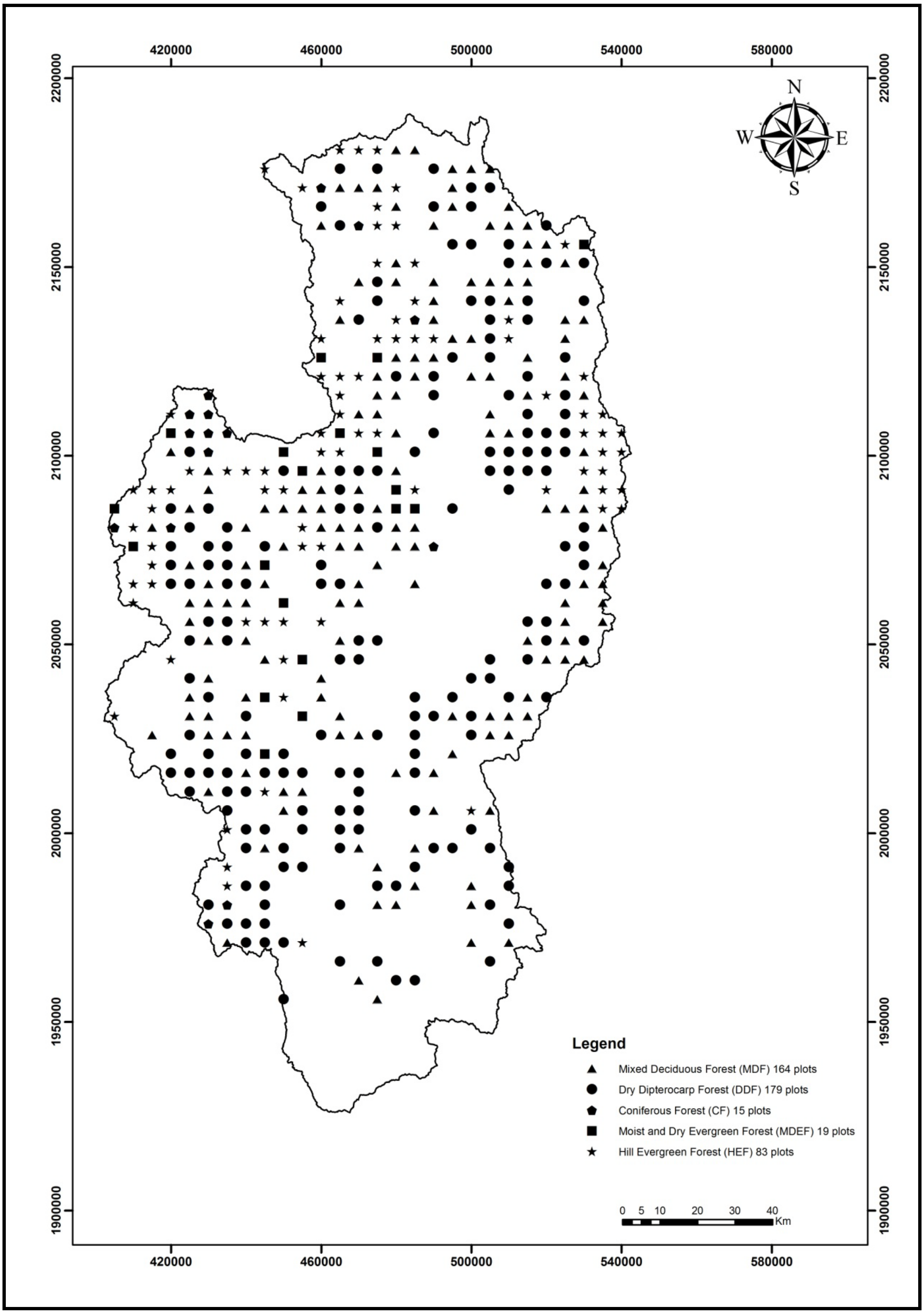
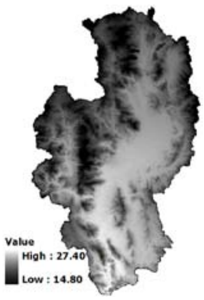


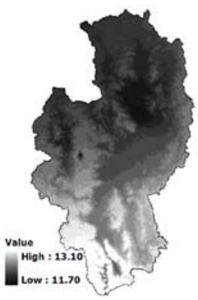
Figure 5.1 Forest inventory data of DNP.

Table 5.1 14 identified significant physical variables for forest type distribution.

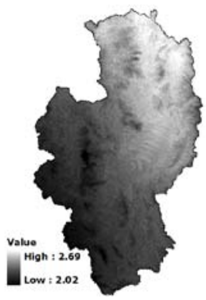
No.	Variables	Data preparation process	Software
1	BIO1: Mean annually temperature (°C)	Interpolation	ArcGIS/DIVA-GIS
2	BIO2: Mean monthly temperature range (°C)	Interpolation	ArcGIS/DIVA-GIS
3	BIO4: Mean annually temperature seasonality (Std. Deviation)	Interpolation	ArcGIS/DIVA-GIS
4	BIO5: Mean monthly maximum temperature (°C)	Interpolation	ArcGIS/DIVA-GIS
5	BIO6: Mean monthly minimum temperature (°C)	Interpolation	ArcGIS/DIVA-GIS
6	BIO7: Mean annually temperature range (°C)	Interpolation	ArcGIS/DIVA-GIS
7	BIO12: Mean annually precipitation (mm)	Interpolation	ArcGIS/DIVA-GIS
8	BIO13: Mean monthly maximum precipitation (mm)	Interpolation	ArcGIS/DIVA-GIS
9	BIO14: Mean monthly minimum precipitation (mm)	Interpolation	ArcGIS/DIVA-GIS
10	BIO15: Mean precipitation seasonality (Std. Deviation)	Interpolation	ArcGIS/DIVA-GIS
11	Elevation (m)	Data Extraction from DEM	ArcGIS
12	Slope (%)	Data Extraction from DEM	ArcGIS
13	Aspect (direction)	Data Extraction from DEM	ArcGIS
14	Modified soil	Overlay Analysis	ArcGIS



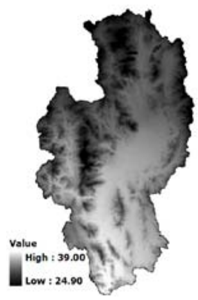
(a) BIO1: Mean annually temperature (°C)



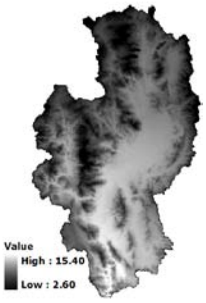
(b) BIO2: Mean monthly temperature range (°C)



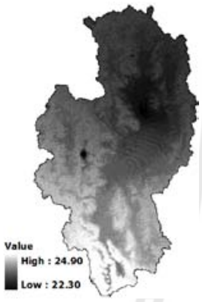
(c) BIO4: Mean annually temperature seasonality (Std. Deviation)



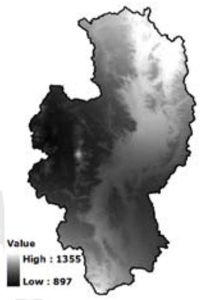
(d) BIO5: Mean monthly maximum temperature (°C)



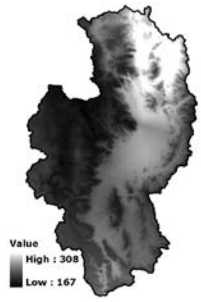
(e) BIO6: Mean monthly minimum temperature (°C)



(f) BIO7: Mean annually temperature range (°C)



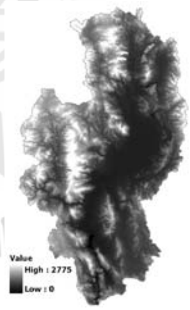
(g) BIO12: Mean annually precipitation (mm)



(h) BIO13: Mean monthly maximum precipitation (mm)

(i) BIO14: Mean monthly minimum precipitation (mm)

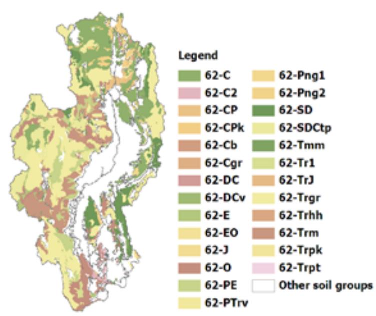
(j) BIO15: Mean precipitation seasonality (Std. Deviation)



(k) Elevation (m)

(l) Slope (%)

(o) Aspect (direction)



(m) Modified soil

Figure 5.2 The identified significant physical variables for forest type distribution.

5.2 Evaluation of the physical factors for forest type distribution by factor analysis

Five forest types from forest inventory data of DNP were here evaluated with 14 the identified physical variables using factor analysis. In fact, the aim of factor analysis is to reduce number of factors with correlation of identified factors. The major steps of factor analysis included standardized data, correlation matrix, KMO and Bartlett's test, total variance explanation, and rotated component matrix with Varimax (Appendix B). The result in each forest type provides the percentage of variance as factor loading in each component with eigenvalues greater than 1. The extracted components in each forest type are synthesized a range value of factor loading according to Comrey and Lee (1992) as below:

Factor loading of 0.71 and higher are considered as excellent relationship;

Factor loading between 0.63-0.70 is considered as very good relationship;

Factor loading of 0.55-0.62 is considered as good relationship;

Factor loading of 0.45-0.54 is considered as fair relationship and;

Factor loading of 0.32-0.44 is considered as poor relationship.

Thus, the main results and synthesis of factor analysis for each forest type can be clarified and interpreted in factor pattern of components. Each component is explained by percentage of variance as factor loading are summarized as following:

5.2.1 Mixed deciduous forest

In mixed deciduous forest, there are 11 of 14 physical variables that were selected from factor analysis. As a result, the first three principal components (named as MDF1, MDF2, and MDF3) were extracted; they account for eigenvalues greater than 1 and all explanation 94.66% of total variation. Each component can be described (Table 5.2) as following:

Table 5.2 Components of mixed deciduous forest with 11 of 14 extracted variables.

No.	Variables	MDF1	MDF2	MDF3
1	BIO1: Mean annually temperature (°C)	**0.99**	0.00	0.00
2	BIO6: Mean monthly minimum temperature (°C)	**0.98**	0.00	-0.17
3	BIO5: Mean monthly maximum temperature (°C)	**0.92**	0.26	-0.26
4	Elevation (m)	**-0.90**	0.00	-0.27
5	BIO14: Mean monthly minimum precipitation (mm)	0.00	**0.96**	-0.21
6	BIO2: mean monthly temperature range (°C)	0.22	**0.95**	-0.11
7	BIO7: mean annually temperature range (°C)	0.24	**0.81**	-0.46
8	BIO15: mean annually precipitation seasonality (SD)	0.21	**-0.79**	0.45
9	BIO13: mean monthly maximum precipitation (mm)	0.00	-0.23	**0.95**
10	BIO12: mean annually precipitation (mm)	-0.16	-0.22	**0.94**
11	BIO4: mean annually temperature seasonality (SD)	-0.18	-0.47	**0.81**
	Initial Eigenvalues	3.82	3.51	3.09
	% of Variance	34.69	31.90	28.07
	Cumulative %	**34.69**	**66.58**	**94.66**

Note: There are 3 physical variables: slope, aspect and soil being removed because value of extracted communality is less than 0.5.

(1) Component 1 or MDF1 is explained by 34.69% of variance that includes 4 physical variables: 3 accounting for temperature (BIO1, BIO5, and BIO6) and 1 accounting for elevation. While 3 temperature variables are positively loaded with this component except elevation; is negatively loaded. Moreover, these physical

variables of MDF1 include range values of factor loading from 0.90 to 0.99, considered as excellent relationship.

(2) Component 2 or MDF2 is explained by 31.90% of variance that includes all 4 climatic variables, 2 accounting for temperature (BIO2 and BIO7) and 2 accounting for rainfall (BIO14 and BIO15). While BIO15 in term of seasonality is negatively loaded with this component, the other climatic variables are positively loaded. Moreover, these physical variables of MDF2 include range values of factor loading from 0.79 to 0.96, considered as excellent relationship.

(3) Component 3 or MDF3 is explained by 28.07% of variance that includes 3 climatic variables, 1 accounting for temperature (BIO4) and 2 accounting for rainfall (BIO12 andBIO13). Such 3 climatic variables are positively loaded with this component. Moreover, these physical variables of MDF3 include range values of factor loading from 0.81 to 0.95, considered as excellent relationship.

As mentioned in the results of mixed deciduous forest above, variance percent of MDF1 is bigger than MDF2 and MDF3 that is accounted for as much of the variability in the data as possible. Therefore, MDF1 is the highest possibility to be characterized as ecological niche of mixed deciduous forest; MDF2 and MDF3 are possibly considered as second and third ecological niche, respectively. For range values based on factor loading, 3 components (MDF1, MDF2, and MDF3) indicated so strength of relationships between physical variables and the extracted components. In addition, this study found that 4 physical variables of MDF1 include mean annual temperature (BIO1), mean monthly minimum temperature (BIO6), mean monthly maximum temperature (BIO5), and elevation are mostly relevant to the identified physical factors of Kutintara (1999).

5.2.2 Dry dipterocarp forest

In dry dipterocarp forest, there are 11 of 14 physical variables that were selected from factor analysis. As a result, the first three principal components (named as DDF1, DDF2, and DDF3) were extracted; they account for eigenvalues greater than 1 and all explanation 95.35% of total variation. Each component can be described (Table 5.3) as following:

Table 5.3 Components of dry dipterocarp forest with 11 of 14 extracted variables.

No.	**Variables**	**DDF1**	**DDF2**	**DDF3**
1	BIO14: Mean monthly minimum precipitation (mm)	**0.97**	0.00	-0.13
2	BIO2: mean monthly temperature range (°C)	**0.96**	0.17	0.00
3	BIO15: mean annually precipitation seasonality (SD)	**-0.91**	0.10	0.26
4	BIO7: mean annually temperature range (°C)	**0.87**	0.21	-0.39
5	BIO1: mean annually temperature (°C)	0.12	**0.98**	-0.12
6	BIO6: mean monthly minimum temperature (°C)	0.14	**0.96**	-0.23
7	BIO5: mean monthly maximum temperature (°C)	0.37	**0.87**	-0.31
8	Elevation (m)	0.25	**-0.86**	-0.29
9	BIO12: mean annually precipitation (mm)	-0.12	-0.21	**0.94**
10	BIO13: mean monthly maximum precipitation (mm)	-0.27	0.00	**0.94**
11	BIO4: mean annually temperature seasonality (SD)	-0.66	-0.17	**0.68**
	Initial Eigenvalues	4.23	3.53	2.73
	% of Variance	38.45	32.07	24.83
	Cumulative %	**38.45**	**70.52**	**95.35**

Note: There are 3 physical variables: slope, aspect and soil being removed because value of extracted communality is less than 0.5.

(1) Component 1 or DDF1 is explained by 38.45% of variance that includes all 4 climatic variables, 2 accounting for temperature (BIO2 and BIO7) and 2 accounting for rainfall (BIO14 and BIO15). While BIO15 in term of seasonality is negatively loaded with this component, the other climatic variables are positively

loaded. Moreover, these physical variables of DDF1 include range values of factor loading from 0.87 to 0.97, considered as excellent relationship.

(2) Component 2 or DDF2 is explained by 32.07% of variance that includes 4 physical variables: 3 accounting for temperature (BIO1, BIO5 and BIO6) and 1 accounting for elevation. While 3 temperature variables are positively loaded with this component except elevation; is negatively loaded. Moreover, these physical variables of DDF2 include range values of factor loading from 0.86 to 0.98, considered as excellent relationship

(3) Component 3 or DDF3 is explained by 24.83% of variance that includes 3 climatic variables, 1 accounting for temperature (BIO4) and 2 accounting for rainfall (BIO12 and BIO13). Such 3 climatic variables are positively loaded with this component. Moreover, these physical variables of DDF3 include range values of factor loading from 0.68 to 0.94, considered the strengthen relationship from good to excellent.

As mentioned in the results of dry dipterocarp forest above, variance percent of DDF1 is bigger than DDF2 and DDF3 that ise accounted for as much of the variability in the data as possible. Therefore, DDF1 is the highest possibility to be characterized as ecological niche of mixed deciduous forest; DDF2 and DDF3 are possibly considered as second and third ecological niche, respectively. For range values based on factor loading, 2 components (DDF1 and DDF2) indicated so strength of relationships between physical variables and the extracted components. On opposite, DDF3 signified such relationships from good to excellent. In addition, this study found that 4 physical variables of DDF2 mean annually temperature (BIO1), mean monthly minimum temperature (BIO6), mean monthly maximum temperature

(BIO5), and elevation are mostly relevant to the identified physical factors of Kutintara (1999).

5.2.3 Coniferous forest

In coniferous forest, there are 11 of 14 physical variables that were selected from factor analysis. As a result, the first three principal components (named as CF1, CF2, and CF3) were extracted; they account for eigenvalues greater than 1 and all explanation 94.98% of total variation. Each component can be described (Table 5.4) as following:

(1) Component 1 or CF1 is explained by 42.27% of variance that is related to 5 climatic variables, 3 accounting for temperature (BIO2, BIO7, and BIO4) and 2 accounting for rainfall (BIO14 and BIO15). While the climatic variables in term of seasonality (BIO15 and BIO4) are negatively loaded with this component, the other variables (BIO2, BIO7, and BIO14) are positively loaded. Moreover, these physical variables of CF1 consist of range values of factor loading from 0.85 to 0.97, considered as excellent relationship.

Table 5.4 Components of coniferous forest with 11 of 14 physical variables.

No.	Variables	CF1	CF2	CF3
1	BIO14: Mean monthly min. precipitation (mm)	**0.97**	0.15	0.12
2	BIO2: Mean monthly temperature range (°C)	**0.93**	0.22	0.26
3	BIO7: Mean annually temperature range (°C)	**0.91**	0.28	-0.10
4	BIO15: Precipitation seasonality (SD)	**-0.87**	0.00	-0.30
5	BIO4: Temperature seasonality (SD)	**-0.85**	-0.22	0.47
6	BIO1: Mean annually temperature (°C)	0.27	**0.96**	0.00
7	BIO6: Mean monthly min. temperature (°C)	0.28	**0.94**	-0.14
8	BIO5: Mean monthly max. temperature (°C)	0.53	**0.83**	-0.14
9	Elevation (m)	0.24	**-0.81**	-0.44
10	BIO12: Mean annually precipitation (mm)	0.20	-0.14	**0.96**
11	BIO13: Mean monthly max. precipitation (mm)	0.00	0.14	**0.92**
	Initial Eigenvalues	4.65	3.39	2.40
	% of Variance	42.27	30.84	21.86
	Cumulative %	**42.27**	**73.11**	**94.98**

Note: There are 3 physical variables: slope, aspect and soil being removed because value of extracted communality is less than 0.5.

(2) Component 2 or CF2 is explained by 30.84% of variance that includes 4 physical variables, 3 accounting for temperature (BIO1, BIO5, and BIO6), and 1 accounting for elevation. While 3 temperature variables are positively loaded with this component except elevation; is negatively loaded. Moreover, these physical variables of CF2 consist of range values of factor loading from 0.81 to 0.96, considered as excellent relationship.

(3) Component 3 or CF3 is explained by 21.86% of variance that includes 2 rainfall variables (BIO12 and BIO13) and are positively loaded with this component. Moreover, these physical variables of CF3 include range values of factor loading from 0.92 to 0.96, considered as excellent relationship.

As mentioned in the results of coniferous forest above, variance percent of CF1 is bigger than CF2 and CF3 that is accounted for as much of the variability in the data as possible. Therefore, CF1 is the highest possibility to be characterized as ecological niche of coniferous forest; CF2 and CF3 are possibly considered as second and third ecological niche, respectively. For range values based on factor loading, such 3 components are indicated so strength of relationships between physical variables and the extracted components. In addition, this study found that 4 physical variables of CF2 include mean annually temperature (BIO1), mean monthly minimum temperature (BIO6), mean monthly maximum temperature (BIO5), and elevation are mostly relevant to the identified physical factors of Kutintara (1999).

5.2.4 Moist and dry evergreen forest

In Moist and Dry Evergreen Forest, all 14 physical variables were selected from factor analysis. As a result, the first five principal components (named as MDEF1, MDEF2, MDEF3, MDEF4, and MDEF5) were extracted; they account for eigenvalues greater than 1 and all explanation 90.18% of total variation. Each component can be described (Table 5.5) as follows:

(1) Component 1 or MDEF1 is explained by 25.98% of variance that includes 4 physical variables, 3 accounting for temperature (BIO1, BIO5, and BIO6) and 1 accounting for elevation. While 3 temperature variables are positively loaded with this component except elevation; is negatively loaded. Moreover, these physical variables of MDEF1 include range values of factor loading from 0.79 to 0.99, considered as excellent relationship.

Table 5.5 Components of moist and dry evergreen forest with 14 extracted variables.

No.	Variables	MDEF1	MDEF2	MDEF3	MDEF4	MDEF5
1	BIO1: Mean annually temperature (°C)	**0.99**	0.00	0.00	0.00	0.00
2	BIO6: Mean monthly min. temperature (°C)	**0.97**	0.00	-0.20	0.00	0.00
3	BIO5: Mean monthly max. temperature (°C)	**0.95**	0.15	-0.27	0.00	0.00
4	Elevation (m)	**-0.79**	0.38	-0.31	0.18	0.13
5	BIO7: Mean annually temperature range (°C)	0.00	**0.98**	0.00	0.00	0.00
6	BIO14: Mean monthly min. precipitation (mm)	-0.14	**0.95**	0.00	0.14	-0.12
7	BIO2: Mean monthly temperature range (°C)	0.00	**0.83**	-0.37	0.00	0.23
8	BIO4: Temperature seasonality (SD)	0.16	**-0.62**	0.58	0.19	-0.23
9	BIO15: Precipitation seasonality (SD)	0.12	**-0.59**	0.39	-0.14	0.55
10	BIO13: Mean monthly max. precipitation (mm)	-0.20	0.00	**0.91**	0.00	0.23
11	BIO12: Mean annually precipitation (mm)	-0.25	-0.28	**0.90**	0.13	-0.11
12	Aspect (direction)	0.12	0.00	0.00	**-0.89**	0.00
13	Slope (percent)	0.11	0.25	0.00	**0.84**	0.12
14	Soil	0.00	0.00	0.00	0.14	**0.84**
	Initial Eigenvalues	3.64	3.62	2.50	1.65	1.22
	% of Variance	25.98	25.88	17.85	11.75	8.72
	Cumulative %	**25.98**	**51.86**	**69.71**	**81.46**	**90.18**

(2) Component 2 or MDEF2 is explained by 25.88% of variance that includes 5 climatic variables, 3 accounting for temperature (BIO2, BIO4, and BIO7) and 2 accounting for rainfall (BIO14 and BIO15). While the climatic variables in term of seasonality (BIO15 and BIO4) are negatively loaded with this component, the other variables (BIO2, BIO7, and BIO14) are positively loaded. Moreover, these physical variables of MDEF2 include range values of factor loading from 0.59 to 0.98, considered the strengthen relationship from good to excellent.

(3) Component 3 or MDEF3 is explained by 17.85% of variance that includes 2 rainfall variables (BIO12 and BIO13) and are positively loaded with this

component. Moreover, these physical variables of MDEF3 include range values of factor loading from 0.90 to 0.91, considered as excellent relationship.

(4) Component 4 or MDEF4 is explained by 11.75% of variance that includes 2 topographic variables (aspect and slope). While aspect is negatively loaded with this component, slope is positively loaded. Moreover, these physical variables of MDEF4 include range values of factor loading from 0.84 to 0.89, considered as excellent relationship.

(5) Component 5 or MDEF5 is explained by 8.72% of variance that includes soil only with 0.84 of factor loading. This factor loading is considered as excellent relationship and is positively loaded with this component.

As mentioned in the results of moist and dry evergreen forest above, variance percent of MDEF1 is bigger than other components and is accounted for as much of the variability in the data as possible. Therefore, MDEF1 is the highest possibility to be characterized as ecological niche of moist and dry evergreen forest; other components are possibly considered as minor ecological niche (that possibility is followed by percent of variance). For range values based on factor loading, 4 components (MDEF1, MDEF3, MDEF4, and MDEF5) indicate so strength of relationships between physical variables and the extracted components. On opposite, MDEF2 signifies such relationships from good to excellent. In addition, this study found that 4 physical variables of MDEF1 include mean annually temperature (BIO1), mean monthly minimum temperature (BIO6), mean monthly maximum temperature (BIO5), and elevation are mostly relevant to the identified physical factors of Kutintara (1999).

5.2.5 Hill evergreen forest

In hill evergreen forest, there are 12 of 14 physical variables that were selected from factor analysis. As a result, the first four principal components (named as HEF1, HEF2, HEF3, and HEF4) were extracted; they account for eigenvalues greater than 1 and all explanation 92.00% of total variation. Each component can be described (Table 5.6) as following:

(1) Component 1 or HEF1 is explained by 36.52% of variance that includes 4 physical variables, 3 accounting for temperature (BIO1, BIO5, and BIO6) and 1 accounting for elevation. While 3 temperature variables are positively loaded with this component except elevation; is negatively loaded. Moreover, these physical variables of HEF1 include range values of factor loading from 0.87 to 0.99, considered as excellent relationship.

Table 5.6 Components of HEF with 12 of 14 extracted variables.

No.	Variables	HEF1	HEF2	HEF3	HEF4
1	BIO1: Mean annually temperature (°C)	**0.99**	0.00	0.00	0.00
2	BIO6: Mean monthly min. temperature (°C)	**0.98**	0.00	-0.11	0.00
3	BIO5: Mean monthly max. temperature (°C)	**0.97**	0.10	-0.20	0.00
4	Elevation (m)	**-0.87**	0.00	-0.33	0.11
5	BIO14: mean monthly minimum precipitation (mm)	0.00	**0.98**	0.00	0.00
6	BIO7: Mean annually temperature range (°C)	0.20	**0.95**	0.00	0.00
7	BIO15: Precipitation seasonality (SD)	0.51	**-0.74**	0.13	0.12
8	BIO2: mean monthly temperature range (°C)	0.52	**0.57**	-0.51	0.00
9	BIO12: mean annually precipitation (mm)	-0.32	0.00	**0.93**	0.00
10	BIO13: mean monthly maximum precipitation (mm)	0.14	0.00	**0.88**	0.11
11	BIO4: mean annually temperature seasonality (SD)	0.14	-0.51	**0.74**	0.00
12	Slope (percent)	-0.12	0.00	0.00	**0.98**
	Initial Eigenvalues	4.38	3.00	2.63	1.02
	% of Variance	36.52	25.04	21.96	8.48
	Cumulative %	**36.52**	**61.56**	**83.51**	**92.00**

Note: There are 2 physical variables: aspect and soil being removed because value of extracted communality is less than 0.5.

(2) Component 2 or HEF2 is explained by 25.04% of variance that includes all 4 climatic variables: 2 accounting for temperature (BIO2 and BIO7) and 2 accounting for rainfall (BIO14 and BIO15). While BIO15 in term of seasonality is negatively loaded with this component, the other climatic variables are positively loaded. Moreover, these physical variables of HEF1 include range values of factor loading from 0.57 to 0.98, considered the strengthen relationship from good to excellent.

(3) Component 3 or HEF3 is explained by 21.96% of variance that includes 3 climatic variables, 2 accounting for rainfall (BIO12 and BIO13) and 1 accounting for temperature (BIO4). Such 3 climatic variables are positively loaded with this component. Moreover, these physical variables of HEF3 include range values of factor loading from 0.74 to 0.93, considered as excellent relationship.

(4) Component 4 or HEF4 is explained by 8.48% of variance that includes only slope that includes 0.98 of factor loading, considered as excellent relationship, and is positively loaded with this component.

As mentioned in the results of hill evergreen forest above, variance percent of HEF1 is bigger than other components and is accounted for as much of the variability in the data as possible. Therefore, HEF1 is the highest possibility to be characterized as ecological niche of hill evergreen forest; other components are possibly considered as minor ecological niche (that possibility is followed by percent of variance). For range values based on factor loading, 3 components (HEF1, HEF3 and HEF4) indicate so strength of relationships between physical variables and the extracted components. On opposite, HEF2 signifies such relationships from good to excellent. In addition, this study found that 4 physical variables of HEF1 include mean annually temperature (BIO1), mean monthly minimum temperature (BIO6), mean monthly maximum temperature (BIO5), and elevation are mostly relevant to the identified physical factors of Kutintara (1999).

Discussion for the results of factor analysis

As results, comparison of cumulative variance from significant principal components with initial eigenvalues greater than 1 in each forest type was displayed in Figure 5.3. It was found that the cumulative variance of Moist and Dry Evergreen Forest (MDEF) provide the lowest percentage of variation. This result might come from the aggregation of two different forest types: Moist Evergreen forest and Dry Evergreen forest as Moist and Dry Evergreen Forest type. Because the number of plots from both forest types is too low for modeling and validating, therefore two forest types are combined in this study. In addition, the important physical factors for all forest types in this study which relevant to the identified factors of Kutintara (1999) are climate (mean annual temperature, mean monthly minimum temperature, and mean monthly maximum temperature), and topography (elevation).

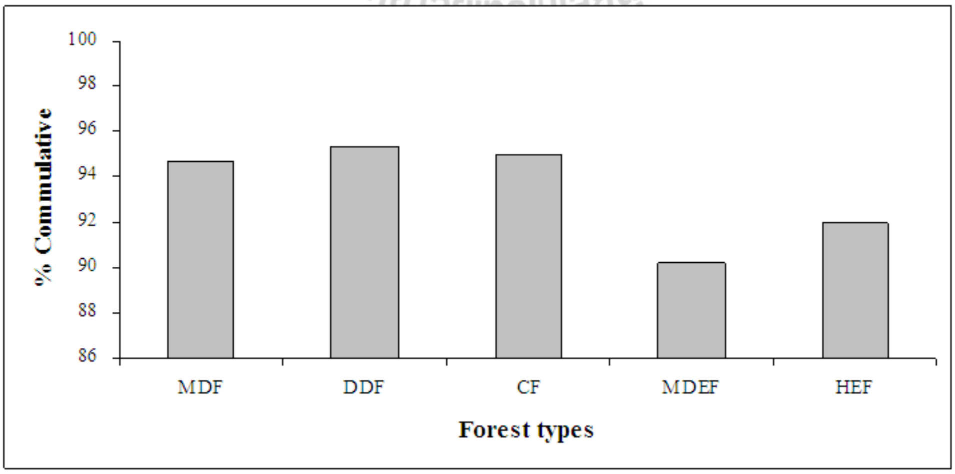


Figure 5.3 Comparison of cumulative variance from significant principal components.

5.3 Development of forest ecological modeling for prediction of forest type distribution by ENFA

Forest ecological modeling of each forest type is developed by ENFA of software BIOMAPPER 4.0. ENFA is similar to principal component analysis (PCA) in that it determines relationships between variables and finds combinations of these variables to produce uncorrelated indices or axes. These axes represent composite factors that explain variability in the data, with the first axis displaying the largest amount of variation (Jensen, 2007). Unlike PCA, however, in ENFA, the axes have direct ecological meaning. The first axis is defined as the “marginality” of the species niche, which describes the mean of the species distribution in relation to the mean of the global (study) distribution. In ENFA this first axis is chosen to account for 100 % of the marginality of the species as well as some proportion of specialization, with the remaining axes maximizing the remaining amount of specialization of the species. The remaining axes explain progressively decreasing amounts of the “niche specialization” of the species. Specialization indicates how restricted the specie’s niche is in relation to the study area (Hirzel et al. 2001).

In practice, the total marginality and specialization coefficients from each variable as EcoGeographical Variables” (EGVs) for each forest type are firstly computed using Eq. 4.1 and 4.2 and Eq. 4.3 and 4.4, respectively then combined to generate global suitability map using median algorithm using Eq. 4.5, 4.6 and 4.7. The value of habitat suitability (HS) index varies from 0 to 100. Finally, all derived habitat suitability indices in each forest type are used to evaluate the best habitat suitability index for each forest type model using Absolute Validation Index (AVI) and Contrast Validation Index (CVI). In BIOMAPPER 4.0, the most accurate model is one that maximizes both the AVI and CVI.

In this study, significant variables in each component of each forest type from factor analysis were used as EGVs to generate 16 models included 3 MDF, 3 DDF, 3 CF, 4 MDEF and 3 HEF (Table 5.7). The main results and synthesis of ENFA for each forest type can be systematic described according to main operational tasks.

5.3.1 Computation of marginality and specialization coefficients and habitat suitability indices

Computation of marginality and specialization coefficients of each component in each forest type for each variable and all variables was separately summarized as shown in Table 5.8 - 5.12. Then, global marginality and specialization coefficients of each component in each forest type were combined together to generate habitat suitability indices using median algorithm as shown in Table 5.13 in form of multivariate model. This model is, in fact, used to predict habitat suitability index for each component in each forest type in the study area based on marginality and specialization coefficient with automatic weighting deriving from each variable. These results are displayed in Figure 5.4 to Figure 5.8.

Table 5.7 Significant variables in each component of each forest type from factor analysis.

Fact	Code	EGVs	MDF			DDF			CF			MDEF				HEF		
			1	2	3	1	2	3	1	2	3	1	2	3	4	1	2	3
Climate	BIO1	Mean annually temperature	✓				✓			✓		✓				✓		
	BIO2	Mean monthly temperature range		✓		✓			✓				✓				✓	
	BIO4	Mean annually temperature seasonality			✓			✓	✓				✓					✓
	BIO5	Mean monthly maximum temperature	✓				✓			✓		✓				✓		
	BIO6	Mean monthly minimum temperature	✓				✓			✓		✓				✓		
	BIO7	Mean annually temperature range		✓		✓			✓				✓				✓	
	BIO12	Mean annually precipitation			✓			✓			✓			✓				✓
	BIO13	Mean monthly maximum precipitation			✓			✓			✓			✓				✓
	BIO14	Mean monthly minimum precipitation		✓		✓			✓				✓				✓	
	BIO15	Mean precipitation seasonality		✓		✓			✓				✓				✓	
Topogr	Elevation	Elevation (m)	✓				✓			✓		✓				✓		
	Slope	Slope (%)													✓			
	Aspect	Aspect (Direction)													✓			

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Table 5.8 Coefficient of marginality and specialization components of mixed deciduous forest.

EGVs	Marginality	Specialization		
		1	2	3
		MDF Component 1		
1) BIO1	**0.718**	0.244	-0.379	0.643
2) BIO5	0.620	-0.362	**0.708**	**-0.748**
3) BIO6	0.243	**0.690**	-0.582	0.111
4) Elevation	-0.204	0.577	0.124	0.123
Overall	0.085	6.475		
% of Explanation	92%	6%	1%	1%
		MDF Component 2		
1) BIO14	**-0.667**	0.378		
2) BIO15	0.561	**0.639**		
3) BIO2	0.327	-0.617		
4) BIO7	0.364	0.263		
Overall	0.187	13.277		
% of Explanation	97%	3%		
		MDF Component 3		
1) BIO4	**1.000**	-0.050	-0.080	
2) BIO12	0.000	**-0.830**	-0.460	
3) BIO13	0.090	0.560	**0.890**	
Overall	0.132	3.437		
% of Explanation	79%	17%	4%	

Note: Positive and negative signs of marginality and specialization coefficient indicate each ecological model prefer higher or lower than the global distribution in each particular variable of environment.

Table 5.9 Coefficient of marginality and specialization components of dry dipterocarp forest.

EGVs	**Marginality**	**Specialization**	
		1	2
DDF Component 1			
1) BIO15	**0.668**	-0.435-	
2) BIO14	-0.366	0.286	
3) BIO2	0.434	-0.406	
4) BIO7	0.481	**0.751**	
Overall	0.172	13.033	
% of Explanation	99%	1%	
DDF Component 2			
1) BIO1	**0.572**	-0.351	0.209
2) BIO6	0.521	-0.330	0.578
3) Elevation	-0.449	0.042	0.170
4) BIO5	0.447	**0.875**	**-0.770**
Overall	0.275	6.202	
% of Explanation	91%	7%	1%
DDF Component 3			
1) BIO4	**0.830**	0.300	-0.550
2) BIO13	0.550	-0.580	**0.840**
3) BIO12	0.100	**0.750**	-0.050
Overall	0.122	2.555	
% of Explanation	49%	43%	8%

Note: Positive and negative signs of marginality and specialization coefficient indicate each ecological model prefer higher or lower than the global distribution in each particular variable of environment.

Table 5.10 Coefficient of marginality and specialization components of coniferous forest.

EGVs	**Marginality**	**Specialization**
	CF Component 1	
1) BIO14	**-0.765**	-0.022
2) BIO7	0.369	0.608
3) BIO4	0.358	0.058
4) BIO15	0.324	-0.338
5) BIO2	0.212	**-0.716**
Overall	0.226	28.425
% of Explanation	94%	6%
	CF Component 2	
1) elevation	**0.903**	-0.027
2) BIO6	-0.396	0.259
3) BIO1	-0.159	**-0.911**
4) BIO5	-0.058	0.319
Overall	0.446	17.139
% of Explanation	80%	20%
	CF Component 3	
1) BIO13	**-0.910**	-0.410
2) BIO12	-0.410	**0.910**
Overall	0.251	2.132
% of Explanation	51%	50%

Note: Positive and negative signs of marginality and specialization coefficient indicate each ecological model prefer higher or lower than the global distribution in each particular variable of environment.

Table 5.11 Coefficient of marginality and specialization components of moist and dry evergreen forest.

EGVs	**Marginality**	**Specialization**
	MDEF Component 1	
1) Elevation	**0.862**	0.111
2) BIO6	-0.444	0.386
3) BIO1	-0.217	0.136
4) BIO5	-0.115	**-0.906**
Overall	0.636	11.079
% of Explanation	40%	60%
	MDEF Component 2	
1) BIO7	**0.704**	0.670
2) BIO2	0.658	**-0.698**
3) BIO4	0.219	0.044
4) BIO13	0.112	0.032
5) BIO15	0.101	-0.246
Overall	0.117	38.817
% of Explanation	98%	1%
	MDEF Component 3	
1) BIO12	**-0.860**	-0.510
2) BIO13	-0.510	**0.860**
Overall	0.262	2.333
% of Explanation	31%	69%
	MDEF Component 2	
1) Aspect	**1.000**	0.070
2) Slope	-0.070	**1.000**
Overall	0.033	3.504
% of Explanation	12%	88%

Note: Positive and negative signs of marginality and specialization coefficient indicate each ecological model prefer higher or lower than the global distribution in each particular variable of environment.

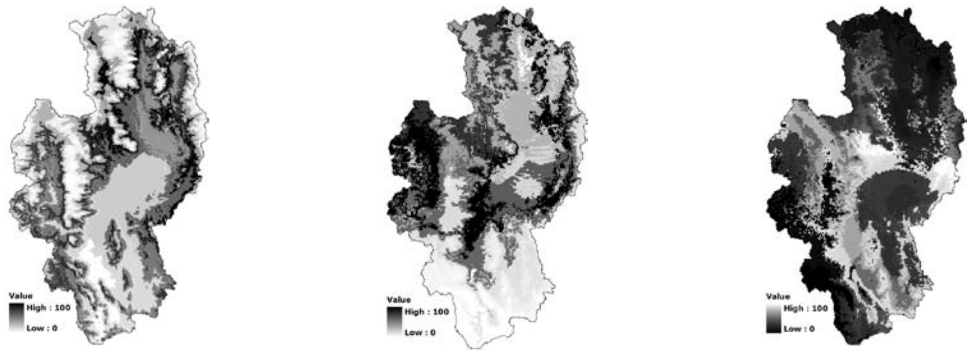
Table 5.12 Coefficient of marginality and specialization components of hill evergreen forest.

EGVs	**Marginality**	**Specialization**	
		1	2
	HEF Component 1		
1) Elevation	**0.805**	0.047	-0.296
2) BIO6	-0.510	0.495	-0.645
3) BIO1	-0.247	-0.287	-0.123
4) BIO5	-0.175	**-0.819**	**0.694**
Overall	0.746	7.262	
% of Explanation	75%	24%	1%
	HEF Component 2		
1) soil	**0.979**	-0.074	0.048
2) BIO2	0.125	-0.42	0.533
3) BIO7	0.124	**0.842**	**-0.783**
4) BIO14	-0.095	-0.06	0.259
5) BIO15	0.045	0.326	0.183
Overall	0.497	10.836	
% of Explanation	78%	21%	1%
	HEF Component 3		
1) BIO13	**-0.800**	**0.510**	-0.550
2) BIO4	0.570	-0.280	-0.170
3) BIO12	0.210	-0.280	**0.820**
Overall	0.145	2.261	
% of Explanation	18%	67%	15%

Note: Positive and negative signs of marginality and specialization coefficient indicate each ecological model prefer higher or lower than the global distribution in each particular variable of environment.

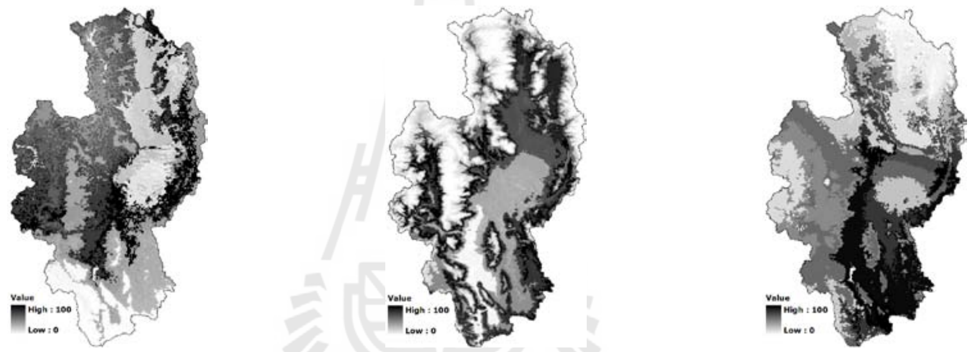
Table 5.13 Habitat suitability model in each component of each forest type.

Forest Type	**Component**	**Model**
MDF	MDF-1	$H_{(MDF1)} = [1/(1.725+0.268+0.007+0.001)] * [1.725\ H_{(marg.,c)} + 0.268\ H_{(spec.1,c)} + 0.007\ H_{(spec.2,c)} + 0.001\ H_{(spec.3,c)}]$
	MDF-2	$H_{(MDF2)} = [1/(1.968+0.027)] * [1.968\ H_{(marg.,c)} + 0.027\ H_{(spec.1,c)}]$
	MDF-3	$H_{(MDF3)} = [1/(1.787+0.169+0.444)] * [1.787\ H_{(marg.,c)} + 0.169\ H_{(spec.1,c)} + 0.444\ H_{(spec.2,c)}]$
DDF	DDF-1	$H_{(DDF1)} = [1/(1.988+0.007)] * [1.988\ H_{(marg.,c)} + 0.007\ H_{(spec.1,c)}]$
	DDF-2	$H_{(MDF2)} = [1/(1.912+0.069+0.011)] * [1.912\ H_{(marg.,c)} + 0.069\ H_{(spec.1,c)} + 0.011\ H_{(spec.2,c)}]$
	DDF-3	$H_{(MDF3)} = [1/(1.489+0.435+0.077)] * [1.489\ H_{(marg.,c)} + 0.435\ H_{(spec.1,c)} + 0.077\ H_{(spec.2,c)}]$
CF	CF-1	$H_{(CF1)} = [1/(1.942+0.055)] * [1.194\ H_{(marg.,c)} + 0.055\ H_{(spec.,c)}]$
	CF-2	$H_{(CF2)} = [1/(1.805+0.187)] * [1.805\ H_{(marg.,c)} + 0.187\ H_{(spec.,c)}]$
	CF-3	$H_{(CF3)} = [1/(1.514+0.486)] * [1.514\ H_{(marg.,c)} + 0.486\ H_{(spec.,c)}]$
MDEF	MDEF-1	$H_{(MDEF1)} = [1/(1.389+0.606)] * [1.389\ H_{(marg.,c)} + 0.606\ H_{(spec.,c)}]$
	MDEF-2	$H_{(MDEF2)} = [1/(1.984+0.014)] * [1.984\ H_{(marg.,c)} + 0.014\ H_{(spec.,c)}]$
	MDEF-3	$H_{(MDEF3)} = [1/(1.984+0.014)] * [1.984\ H_{(marg.,c)} + 0.014\ H_{(spec.,c)}]$
	MDEF-4	$H_{(MDEF4)} = [1/(1.120+0.880)] * [1.120\ H_{(marg.,c)} + 0.880\ H_{(spec.,c)}]$
HEF	HEF-1	$H_{(HEF1)} = [1/(1.747+0.243+0.006)] * [1.747\ H_{(marg.,c)} + 0.243\ H_{(spec.1,c)} + 0.006\ H_{(spec.2,c)}]$
	HEF-2	$H_{(HEF1)} = [1/(1.898+0.096+0.005)] * [1.898\ H_{(marg.,c)} + 0.096\ H_{(spec.1,c)} + 0.005\ H_{(spec.2,c)}]$
	HEF-3	$H_{(HEF1)} = [1/(1.181+0.668+0.151)] * [1.181\ H_{(marg.,c)} + 0.668\ H_{(spec.1,c)} +0.151\ H_{(spec.2,c)}]$



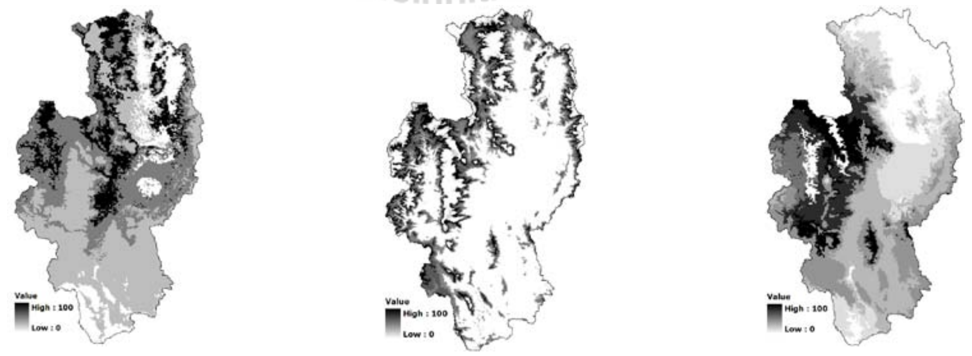
(a) MDF Component 1 (b) MDF Component 2 (c) MDF Component 3

Figure 5.4 Habitat suitability index in each component for mixed deciduous forest.



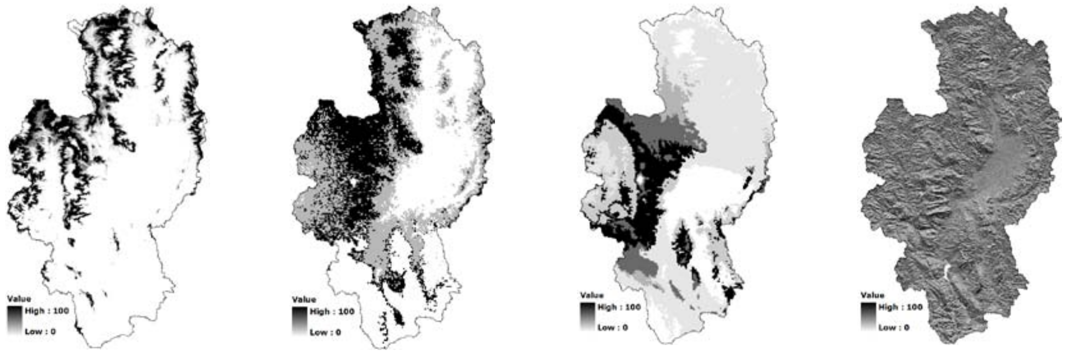
(a) DDF Component 1 (b) DDF Component 2 (c) DDF Component 3

Figure 5.5 Habitat suitability index in each component for dry dipterocarp forest.



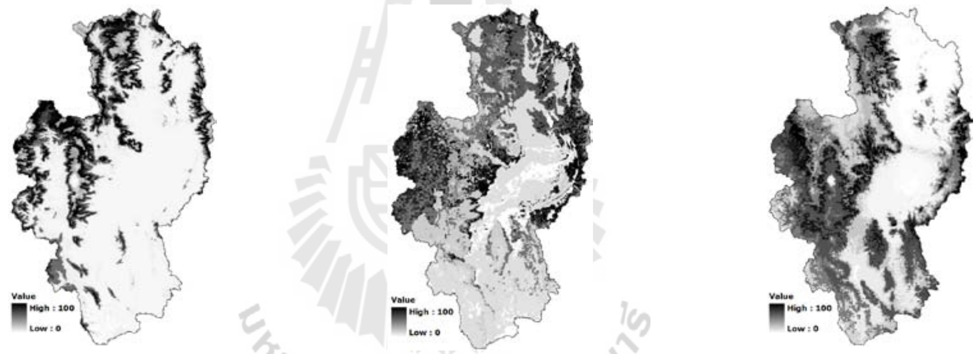
(a) CF Component 1 (b) CF Component 2 (c) CF Component 3

Figure 5.6 Habitat suitability index in each component for coniferous forest.



(a) MDEF Component 1 (b) MDEF Component 2 (c) MDEF Component 3 (d) MDEF Component 4

Figure 5.7 Habitat suitability index in each component for moist and dry evergreen.forest



(a) HEF Component 1 (b) HEF Component 2 (c) HEF Component 3

Figure 5.8 Habitat suitability index in each component for hill evergreen forest.

5.3.2 The best habitat suitability index for each forest type

Absolute Validation Index (AVI), which provides an overall assessment of the model, and Contrast Validation Index (CVI) which is the difference between the AVI of the model and an AVI generated for a completely randomly-distributed species, are here computed for evaluating model validity with forest type datasets for validation to identify the best habitat suitability index for each forest type. The AVI and CVI of each component in each forest type are summarized as shown in Table 5.14. The characteristic of the best habitat suitability index for each forest type are separately described as following.

Table 5.14 The AVI and CVI of each component in each forest type.

Components for each forest type	AVI	CVI
Mixed Deciduous Forest (MDF)		
1. MDF Component 1	**1.00**	**0.15**
2. MDF Component 2	1.00	0.10
3 MDF Component 3	0.95	0.01
Dry Dipterocarp Forest (DDF)		
1. DDF Component 1	0.99	0.07
2. DDF Component 2	**1.00**	**0.09**
3. DDF Component 3	1.00	0.01
Coniferous Forest (CF)		
1. CF Component 1	1.00	0.17
2. CF Component 2	**0.86**	**0.44**
3. CF Component 3	1.00	0.19
Moist and Dry Evergreen Forest (MDEF)		
1. MDEF Component 1	**1.00**	**0.72**
2. MDEF Component 2	1.00	0.44
3. MDEF Component 3	1.00	0.19
4. MDEF Component 4	0.75	-0.22
Hill Evergreen Forest (HEF)		
1. HEF Component 1	**0.95**	**0.39**
2. HEF Component 2	1.00	0.19
3. HEF Component 3	1.00	0.10

5.3.2.1 Mixed deciduous forest

The best habitat suitability index of mixed deciduous forest was derived from Component 1 of MDF which consists of 4 physical variables: elevation, BIO6, BIO1 and BIO5. The proportion of explainable information for this best model composes of 92% of marginality, 6% of the first specialization, 1% of the second specialization and 1% of the third specialization. According to the most marginality preference, mean annually temperature plays an important role as major determinant for prediction of mixed deciduous forest occurrence with correlation coefficient of 0.718. At the same time, specialization 1 accounts for mean monthly minimum temperature with 0.690 and specialization 2 and specialization 3 accounts for mean monthly maximum temperature with 0.708 and -0.748 as minor determinant of forest prediction (Table 5.15). In addition, the habitat suitability index, which is derived from multivariate model for representation of mix deciduous forest distribution, is reclassified into three classes using natural break algorithm (Figure 5.9). Area and percentage of suitability for mixed deciduous forest is shown in Table 5.16.

Table 5.15 The best ecological niche model and habitat suitability model for mixed deciduous forest.

Physical variables	**Marginality**	**Specialization**		
		1	**2**	**3**
1) BIO1: mean annually temperature (°C),	**0.718**	0.244	-0.379	0.643
2) BIO5: mean monthly maximum temperature (°C)	0.620	-0.362	**0.708**	**-0.748**
3) BIO6: mean monthly minimum temperature (°C)	0.243	**0.690**	-0.582	0.111
4) Elevation (m)	-0.204	0.577	0.124	0.123
% of Explanation	92%	6%	1%	1%

Habitat Suitability Model

$$H_{(MDF1)} = [1/(1.725+0.268+0.007+0.001)] * [1.725\ H_{(marg.,c)} + 0.268\ H_{(spec.1,c)} + 0.007\ H_{(spec.2,c)} + 0.001\ H_{(spec.3,c)}]$$

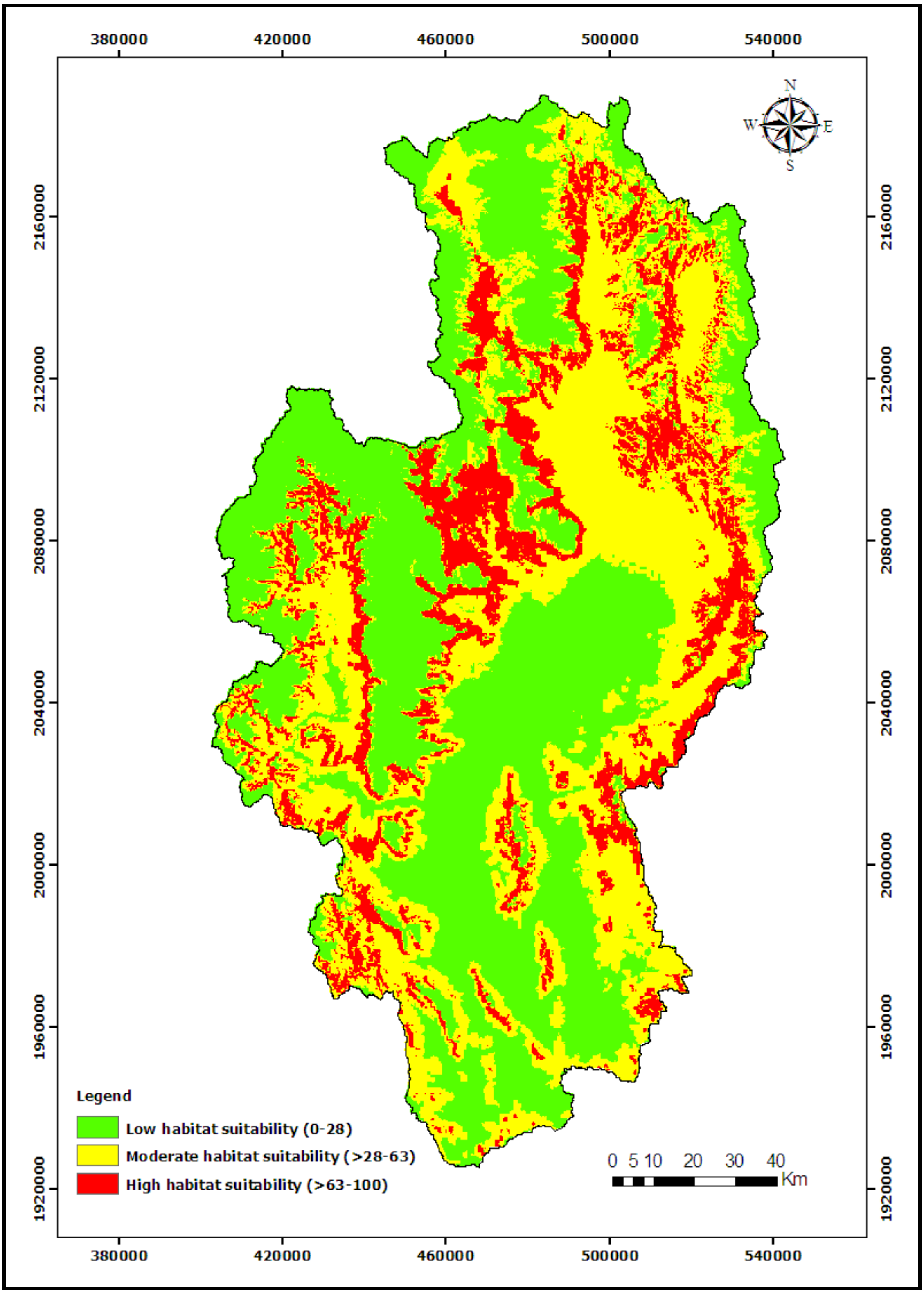


Figure 5.9 Distribution of mixed deciduous forest suitability.

Table 5.16 Area and percentage of suitability for mixed deciduous forest.

Suitability Class (Range indices)	Area (sq. km)	Percent
Low (0-28)	7,031.19	31.28%
Moderate (>28-63)	5,156.39	22.95%
High (>63-100)	10,284.67	45.77%
Total	**22,472.25**	**100.00%**

5.3.2.2 Dry dipterocarp forest

The best habitat suitability index of dry dipterocarp forest was derived from Component 2 of DDF which consists of 4 physical variables: elevation, BIO6, BIO1 and BIO5. The proportion of explainable information for this best model composes of 91% of marginality, 7% of the first specialization and 2% of the second specialization. According to the most marginality preference, mean monthly minimum temperature plays an important role as major determinant for prediction of dry dipterocarp forest occurrence with correlation coefficient of 0.572. While both specialization 1 and 2 accounts for mean monthly maximum temperature with 0.875 and -0.770 as minor determinant of forest prediction (Table 5.17). In addition, the habitat suitability index, which is derived from multivariate model for representation of dry dipterocarp forest distribution, is reclassified into three classes using natural break algorithm (Figure 5.10). Area and percentage of suitability for dry dipterocarp forest is shown in Table 5.18.

Table 5.17 The best ecological niche model and habitat suitability model for dry dipterocarp forest.

Physical variables	Marginality	Specialization	
		1	**2**
1) BIO6: mean monthly minimum temperature (°C)	**0.572**	-0.351	0.209
2) BIO1: mean annually temperature (°C)	0.521	-0.330	0.578
3) Elevation (m)	-0.449	0.042	0.170
4) BIO5: mean monthly maximum temperature (°C)	0.447	**0.875**	**-0.770**
% of Explanation	91%	7%	1%

Habitat Suitability Model

$H_{(MDF2)} = [1/(1.912+0.069+0.011)] * [1.912\ H_{(marg.,c)} + 0.069\ H_{(spec.1,c)} + 0.011\ H_{(spec.2,c)}]$

Table 5.18 Area and percentage of suitability for dry dipterocarp forest.

Suitability Class (Range indices)	Area (sq. km)	Percent
Low (0-25)	4,698.13	20.91%
Moderate (>25-63)	8,256.01	36.74%
High (>63-100)	9,518.11	42.35%
Total	**22,472.25**	**100.00%**

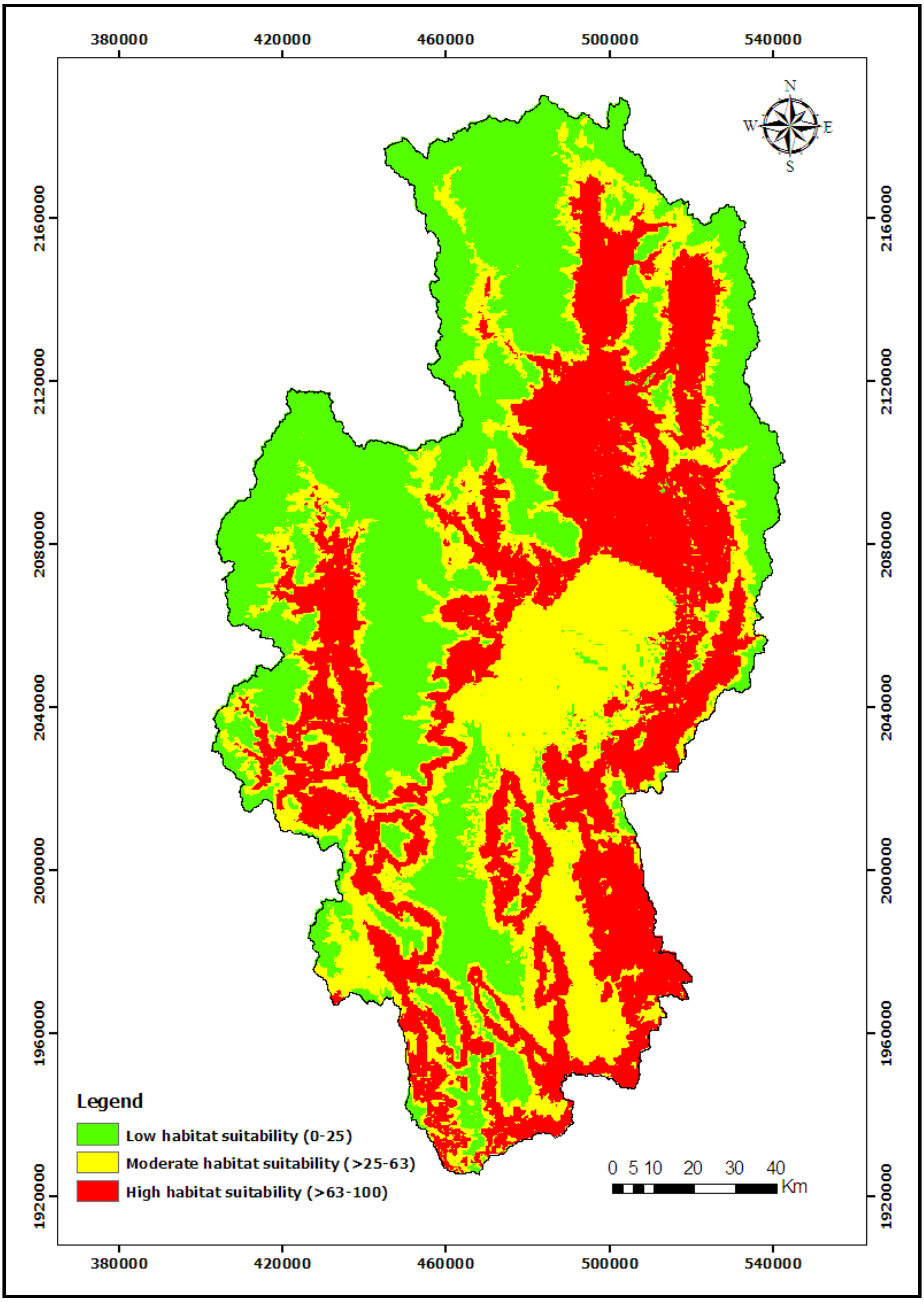


Figure 5.10 Distribution of dry dipterocarp forest suitability.

5.3.2.3 Coniferous forest

The best habitat suitability index of coniferous forest was derived from Component 2 of CF which consists of 4 physical variables: elevation, BIO6, BIO1 and BIO5. The proportion of explainable information for this best model composes of 80% of marginality and 20% of the first specialization. According to the most marginality preference, elevation plays an important role as major determinant for prediction of coniferous forest occurrence with correlation coefficient of 0.903. At the meantime, specialization accounts for mean annually temperature with -0.911 as minor determinant of forest prediction (Table 5.19). In addition, the habitat suitability index, which was derived from multivariate model for representation of coniferous forest distribution, is reclassified into three classes using natural break algorithm as shown in Figure 5.11. Area and percentage of suitability for coniferous forest is shown in Table 5.20

Table 5.19 The best ecological niche model and habitat suitability model for coniferous forest.

Physical variables	**Marginality**	**Specialization**
1) Elevation	**0.903**	-0.027
2) BIO6: mean monthly minimum temperature (°C)	-0.396	0.259
3) BIO1: mean annually temperature (°C)	-0.159	**-0.911**
4) BIO5: mean monthly maximum temperature (°C)	-0.058	0.319
% of Explanation	80%	20%
Habitat Suitability Model		
$H_{(CF2)} = [1/(1.805+0.187)] * [1.805\ H_{(marg.,c)} + 0.187\ H_{(spec.,c)}]$		

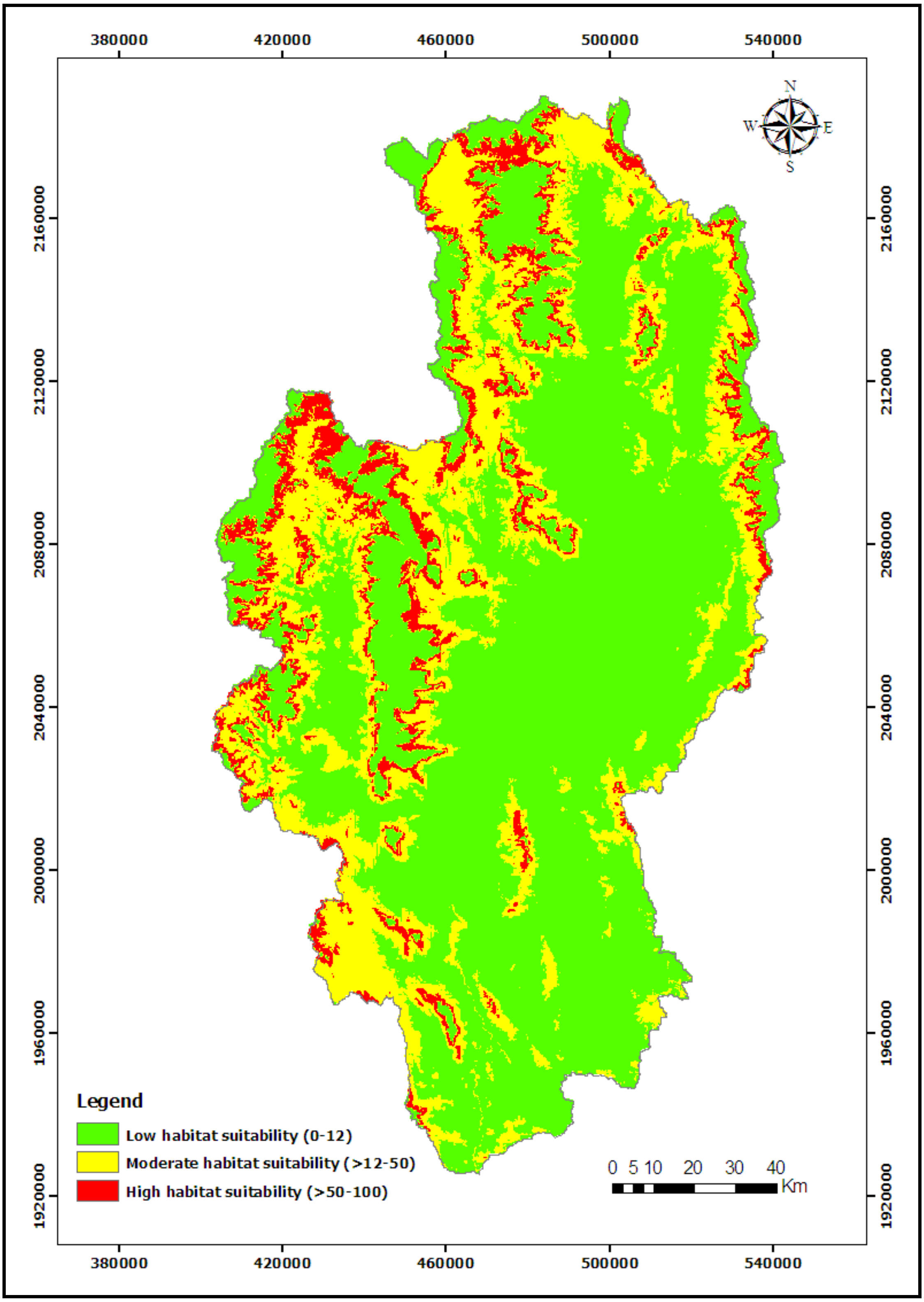


Figure 5.11 Distribution of coniferous forest suitability.

Table 5.20 Area and percentage of suitability for coniferous forest.

Suitability Class (Range indices)	Area (sq. km)	Percent
Low (0-12)	15,574.55	69.30%
Moderate (>12-50)	5,203.88	23.16%
High (>50-100)	1,693.82	7.54%
Total	**22,472.25**	**100.00%**

5.3.2.4 Moist and dry evergreen forest

The best habitat suitability index of moist and dry evergreen forest was derived from Component 1 of MDEF which consists of 4 physical variables: elevation, BIO6, BIO1 and BIO5. The proportion of explainable information for this best model composes of 40% of marginality and 60% of specialization. According to the most specialization preference, mean monthly maximum temperature plays an important role as major determinant for prediction of moist and dry evergreen forest occurrence with correlation coefficient of -0.906. At the same time, marginality accounts for elevation with 0.862 as minor determinant of forest prediction (Table 5.21). In addition, the habitat suitability index, which was derived from multivariate model for representation of moist and dry evergreen forest distribution, is reclassified into three classes using natural break algorithm as shown in Figure 5.12. Area and percentage of suitability for moist and dry evergreen forest is shown in Table 5.22.

Table 5.21 The best ecological niche model and habitat suitability model for moist and dry evergreen forest.

Physical variables	Marginality	Specialization
1) Elevation	**0.862**	0.111
2) BIO6: mean monthly minimum temperature (°C)	-0.444	0.386
3) BIO1: mean annually temperature (°C)	-0.217	0.136
4) BIO5: mean monthly maximum temperature (°C)	-0.115	**-0.906**
% of Explanation	40%	60%

Habitat Suitability Model

$$H_{(MDEF1)} = [1/(1.389+0.606)] * [1.389\ H_{(marg.,c)} + 0.606\ H_{(spec.,c)}]$$

Table 5.22 Area and percentage of suitability for moist and dry evergreen forest.

Suitability Class (Range indices)	Area (sq. km)	Percent
Low (0-9)	16,895.87	75.19%
Moderate (>9-45)	2,678.39	11.92%
High (>45-100)	2,897.99	12.90%
Total	**22,472.25**	**100.00%**

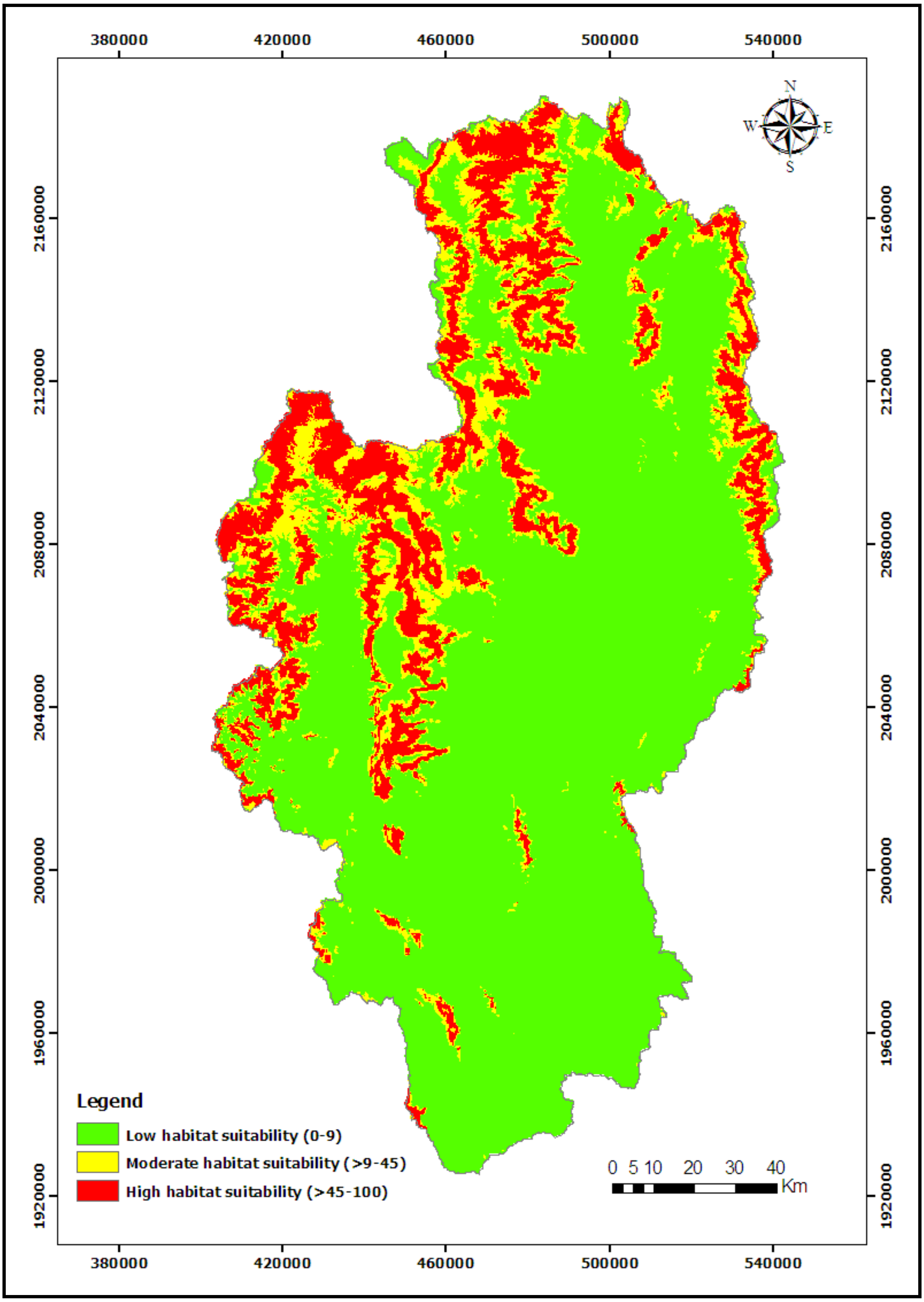


Figure 5.12 Distribution of moist and dry evergreen forest suitability.

5.3.2.5 Hill evergreen forest

The best habitat suitability index of hill evergreen forest was derived from Component 1 of HEF which consists of 4 physical variables: elevation, BIO6, BIO1 and BIO5. The proportion of explainable information for this best model composes of 75% of marginality, 24% of the first specialization and 1% of the second specialization. According to the most marginality preference, elevation plays an important role as major determinant for prediction of hill evergreen forest occurrence with correlation coefficient of 0.805. At the same time, specialization 1 and specialization 2 accounts for mean monthly maximum temperature with -0.819 and -0.694 as minor determinant of forest prediction (Table 5.23). In addition, the habitat suitability index, which was derived from multivariate model for representation of mixed deciduous forest distribution, is reclassified into three classes using natural break algorithm as shown in Figure 5.13. Area and percentage of suitability for hill evergreen forest is shown in Table 5.24.

Table 5.23 The best ecological niche model and habitat suitability model for hill evergreen forest.

Physical variables	Marginality	Specialization	
		1	2
1) Elevation	**0.805**	0.047	-0.296
2) BIO6: mean monthly minimum temperature (°C)	-0.510	0.495	-0.645
3) BIO1: mean annually temperature (°C)	-0.247	-0.287	-0.123
4) BIO5: mean monthly maximum temperature (°C)	-0.175	**-0.819**	**0.694**
% of Explanation	75%	24%	1%

Habitat Suitability Model

$$H_{(HEF1)} = [1/(1.747+0.243+0.006)] * [1.747\ H_{(marg.,c)} + 0.243\ H_{(spec.1,c)} + 0.006\ H_{(spec.2,c)}]$$

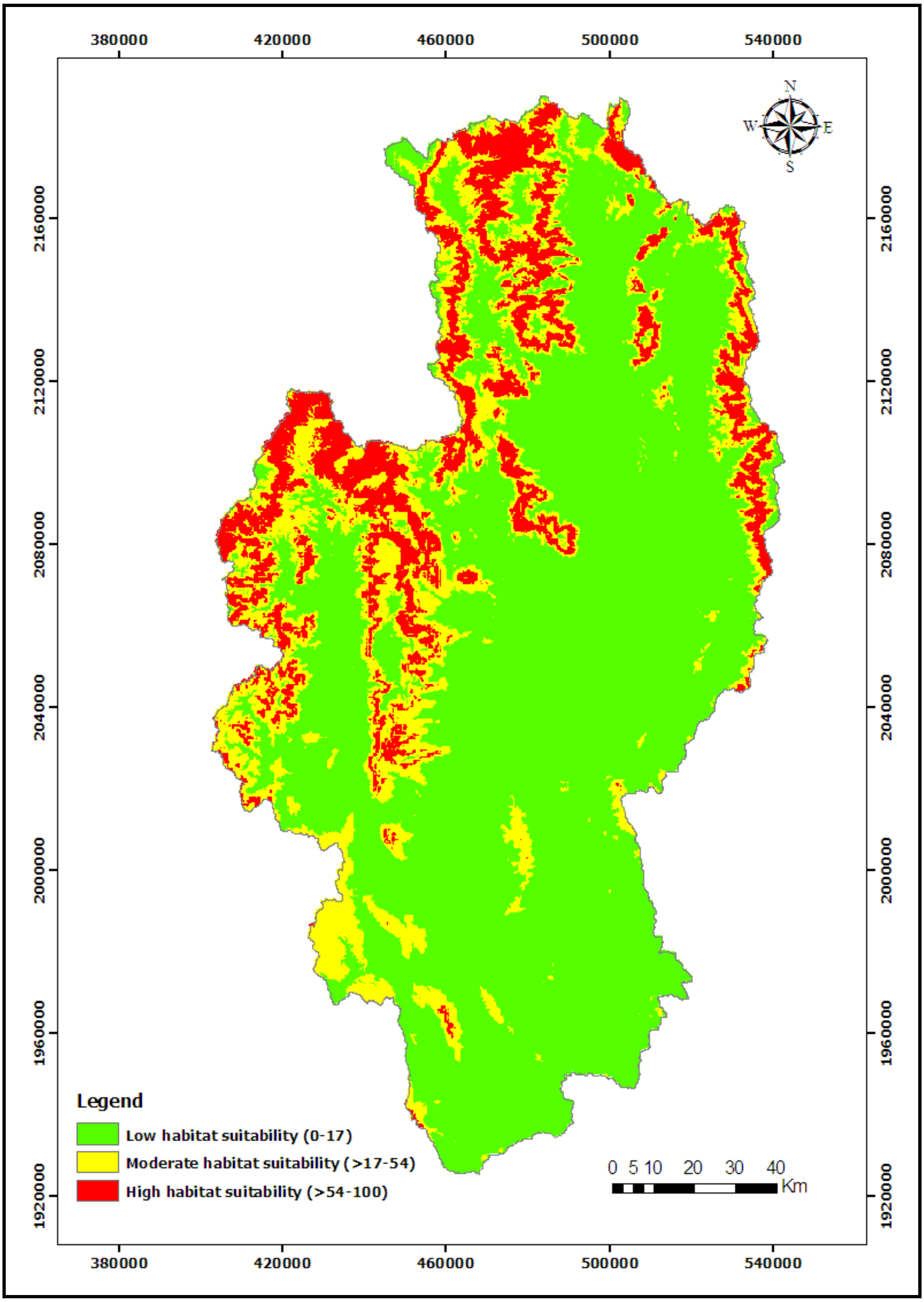


Figure 5.13 Distribution of hill evergreen forest suitability.

Table 5.24 Area and percentage of suitability for hill evergreen forest.

Suitability Class (Range indices)	Area (sq. km)	Percent
Low (0-17)	15,933.08	70.90%
Moderate (>17-54)	4,094.84	18.22%
High (>54-100)	2,444.33	10.88%
Total	**22,472.25**	**100.00%**

Discussion for the results of ENFA

Explanation percent of the best ecological niche model for four forest types (i.e. mixed deciduous forest, dry dipterocarp forest, coniferous forest, and hill evergreen forest) is accounted for marginality preference, whereas moist and dry evergreen forest is accounted for specialization preference. The results of moist and dry evergreen forest is found that is likely the ENFA results of Leverette and Metaxas (2005), revealed the specialization preference for two species (*Paragorgia arborea* and *Primnoa resedaeformis*) of deep-water coral on the Canadian Atlantic continental shelf and slope. Moreover, this result is consistently to summary of evaluation of the physical factors for forest type distribution by factor analysis that is reasoned with the aggregation of two different forest types: Moist Evergreen forest and Dry Evergreen forest as Moist and Dry Evergreen Forest type.

In addition, comparison percent of reclassification of habitat suitability index for forest types (Figure 5.14) were found that deciduous forest (mixed deciduous forest and dry dipterocarp forest) show the greatest percent of suitability in level of high habitat suitability. On opposite, evergreen forest (coniferous forest, moist and dry evergreen forest and hill evergreen forest) show the greatest percent of suitability in level of low habitat suitability. These results come from existing number and distribution of modeled forest inventory data (Figure 5.15) that is used for ENFA and then is used to produce habitat suitability index. The ENFA principle is to compare the distributions of EGVs between the presence dataset and the whole study area (Fulgione et al., 2009).

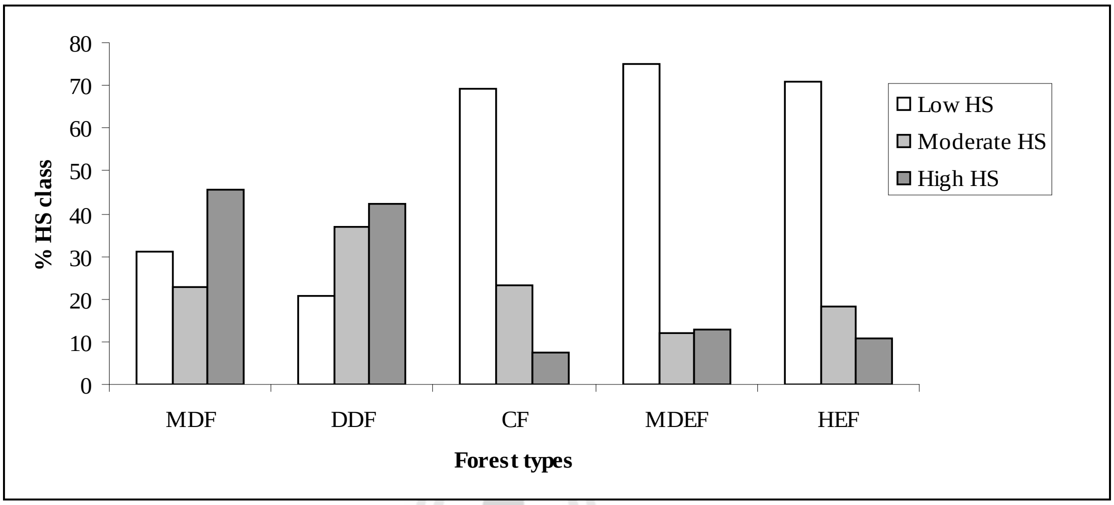
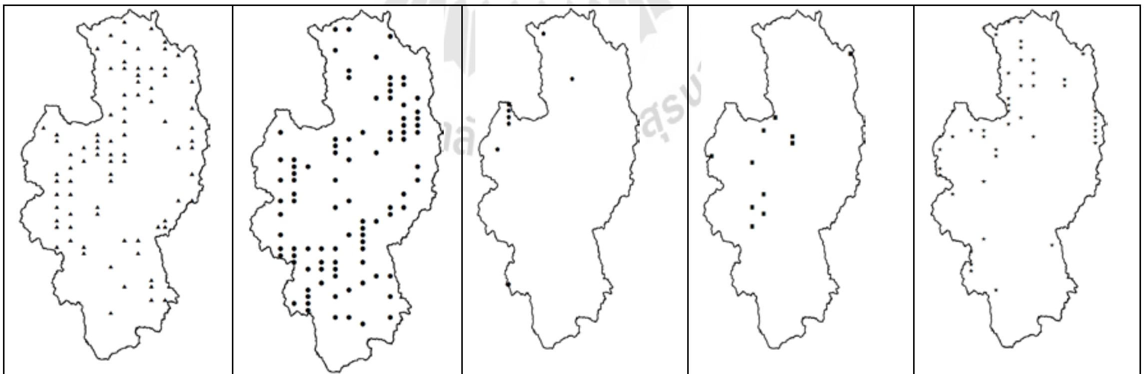


Figure 5.14 Comparison of percent of suitability among forest types.



(a)	(b)	(c)	(d)	(e)
83 forest inventory plots for mixed deciduous forest	**93 forest inventory plots for dry dipterocarp forest**	**8 forest inventory plots for coniferous forest**	**11 forest inventory plots for moist and dry Evergreen Forest**	**46 forest inventory plots for Hill Evergreen Forest**

Figure 5.15 Existing number and distribution of modeled forest inventory data for ENFA.

5.4 Geospatial forest type distribution

To obtain forest type distribution map this study had combined the all 5 reclassified forest type data based on habitat suitability index (from section 5.3) under GIS spatial analysis. In practice, two GIS spatial analysis include reclassification and addition operations are applied to create predictive forest type distribution as described in section 4.3.3.2. In this operation, there are 3 specific outputs as following:

5.4.1 Deciduous forest type distribution

In operational, mixed deciduous forest (MDF) and dry dipterocarp forest (DDF) with theirs suitability classes are firstly assigned the new code (see Table 4.10) and then overlaid together with addition operation to generate deciduous forest type distribution under GIS spatial analysis. As a result, deciduous forests type is composed of mixed deciduous forest, dry dipterocarp forest and deciduous ecotone (Table 5.25). Distribution of deciduous forest in the study area is shown in Figure 5.16. According to Table 5.25, the highest area of deciduous forest type prediction in the study area is deciduous ecotone which covers area of 9,159.47 Sq.km or 40.76% of the study area. Dry dipterocarp forest is the second and covers area of 7,400.20 Sq.km or 32.93% while mixed deciduous forest is the third and cover area of 5,912.58 Sq.km or 26.31%.

Table 5.25 Area and percentage of deciduous forest type distribution.

Deciduous forest types	Area in sq. km	Percent
1. Mixed deciduous forest	5,912.58	26.31
2. Dry dipterocarp forest	7,400.20	32.93
3. Deciduous ecotone	9,159.47	40.76
Total	**22,472.25**	**100.00**

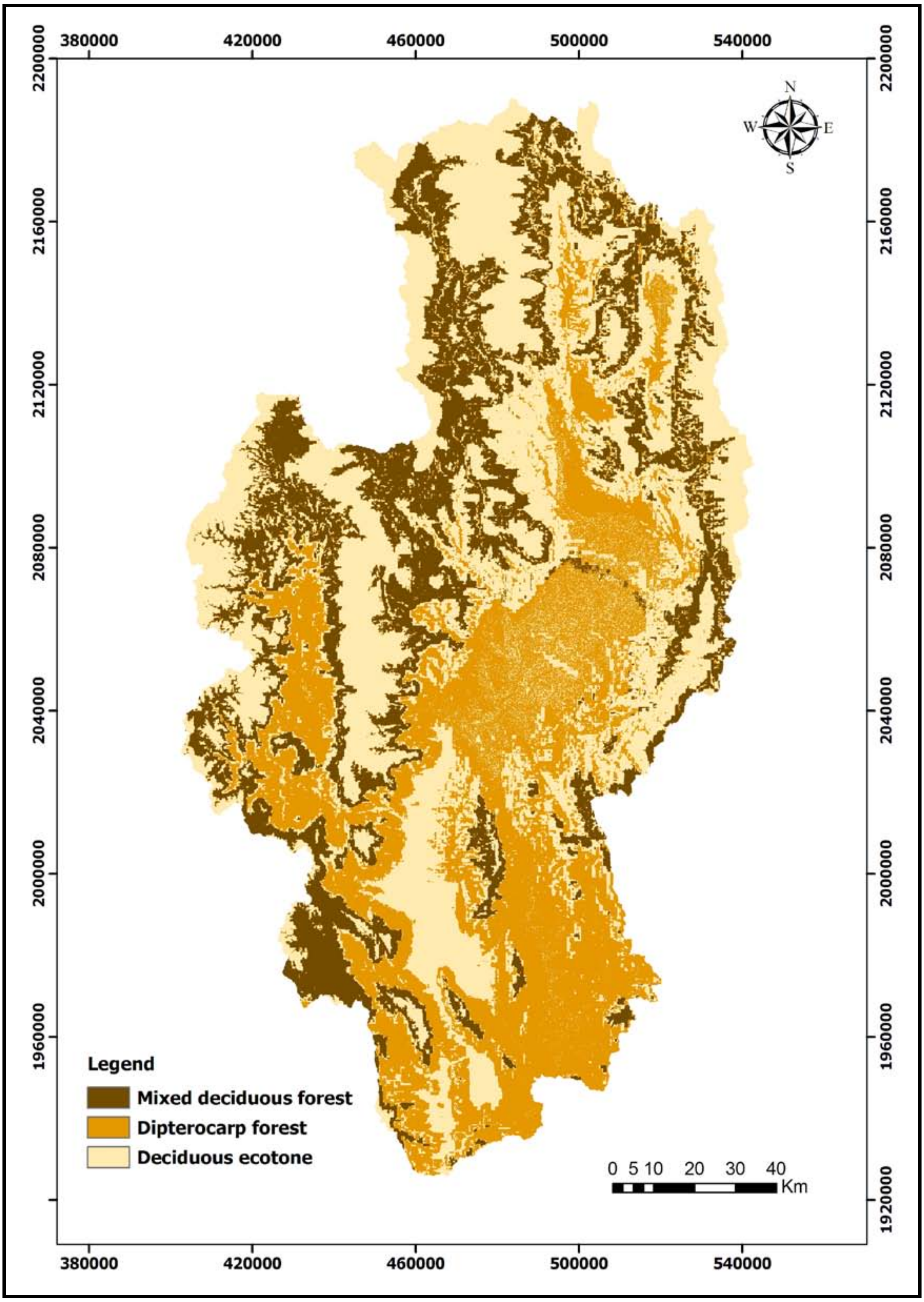
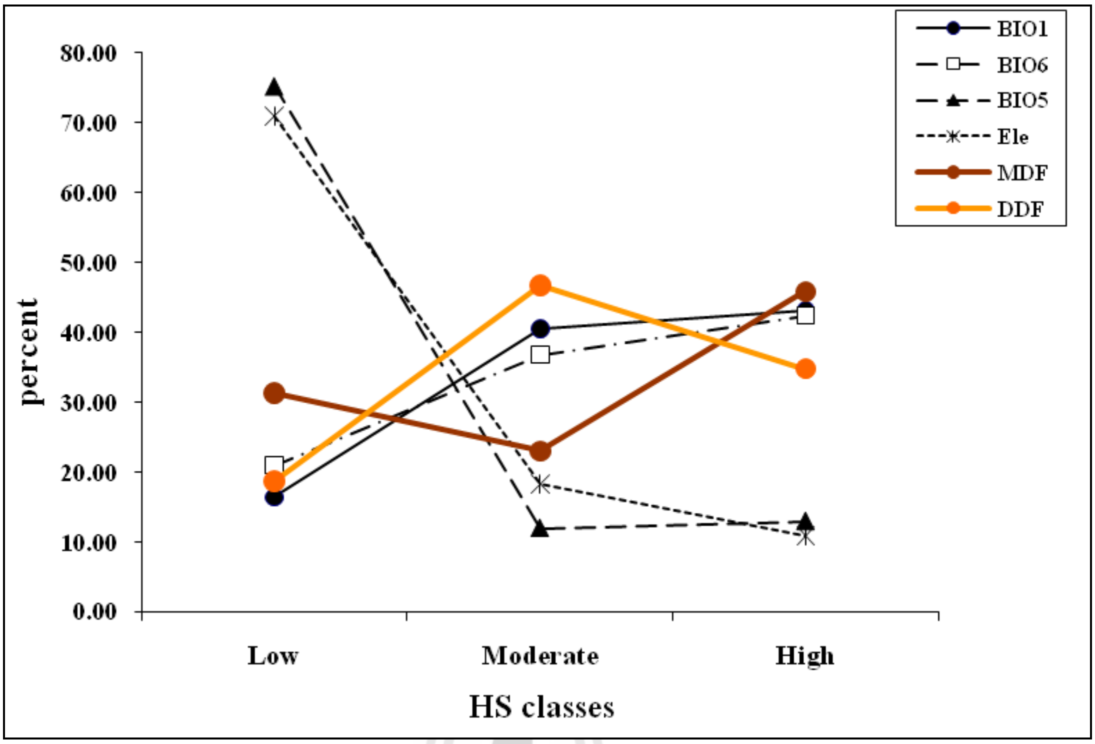


Figure 5.16 Distribution of deciduous forest type in the study area.

Discussion for deciduous forest type distribution

Basically, deciduous forest type distribution in the study area is combined based on the suitability classes from mixed deciduous forest (resulted in section 5.3.2.1) and dry dipterocarp forest (resulted in section 5.3.2.2) that are influenced from four significantly physical variables (mean annually temperature (BIO1), mean monthly minimum temperature (BIO6), mean monthly maximum temperature (BIO5) and Elevation). Herein, BIO1 is major determinant for dry dipterocarp forest while mixed deciduous forest mainly determinants with BIO6. Additionally, these results are summarized based on continuum concept is the average number of limits per interval along the gradient should be equal apart from random effects (Maarel, 2005) can be displayed in Figure 5.17. According to Figure 5.17, it is found that the coincident area between mixed deciduous forest and dry dipterocarp forest, called "deciduous ecotone" as overlapping area between mixed deciduous and dry dipterocarp in each habitat suitability class. In addition, these results can be explained with Gleason's concept for the plant community distribution that the distributional or ecological ranges of any two species coincide precisely, and the degree of association between ground flora and canopy is often weaker than one might assume from casual observation. The "individualistic" model of Gleason in which each species is distributed independently and no clear "communities" are apparent (Figure 2.4b).



Note: BIO1 is mean annually temperature (°C), BIO6 is mean monthly minimum temperature (°C), BIO5 is mean monthly maximum temperature (°C), Ele is Elevation, MDF is mixed deciduous forest, and DDF is dry dipterocarp forest.

Figure 5.17 Deciduous forest distribution based on 4 significantly physical variables.

5.4.2 Evergreen forest type distribution

Under this operation, coniferous forest (CF), moist and dry evergreen forest (MDEF), and hill evergreen forest (HEF)) with theirs suitability classes are firstly assigned the new code (see Table 4.4) and then overlaid together with addition operation to create evergreen forest type distribution under GIS spatial analysis. As a result, evergreen forest type consists of coniferous forest type, moist and dry evergreen, hill evergreen and evergreen ecotone (Table 5.26 and Figure 5.18).

According to Table 5.26, the highest area of evergreen forest type prediction in the study area is evergreen ecotone which covers area of 19,052.70 Sq.km or 84.78% of the study area. Coniferous forest with 2,845.98 Sq.km or 12.67% is the second, moist and dry evergreen forest with 295.04 Sq.km or 1.31% is the third, and hill evergreen forest with 278.53 Sq.km or 1.24% is the fourth.

Table 5.26 Area and percentage of evergreen forest types.

Evergreen forest types	**Area in sq. km**	**Percent**
1. Coniferous forest	2,845.98	12.67
2. Moist and dry evergreen forest	295.04	1.31
3. Hill evergreen forest	278.53	1.24
4. Evergreen ecotone	19,052.70	84.78
Total	**22,472.25**	**100.00**

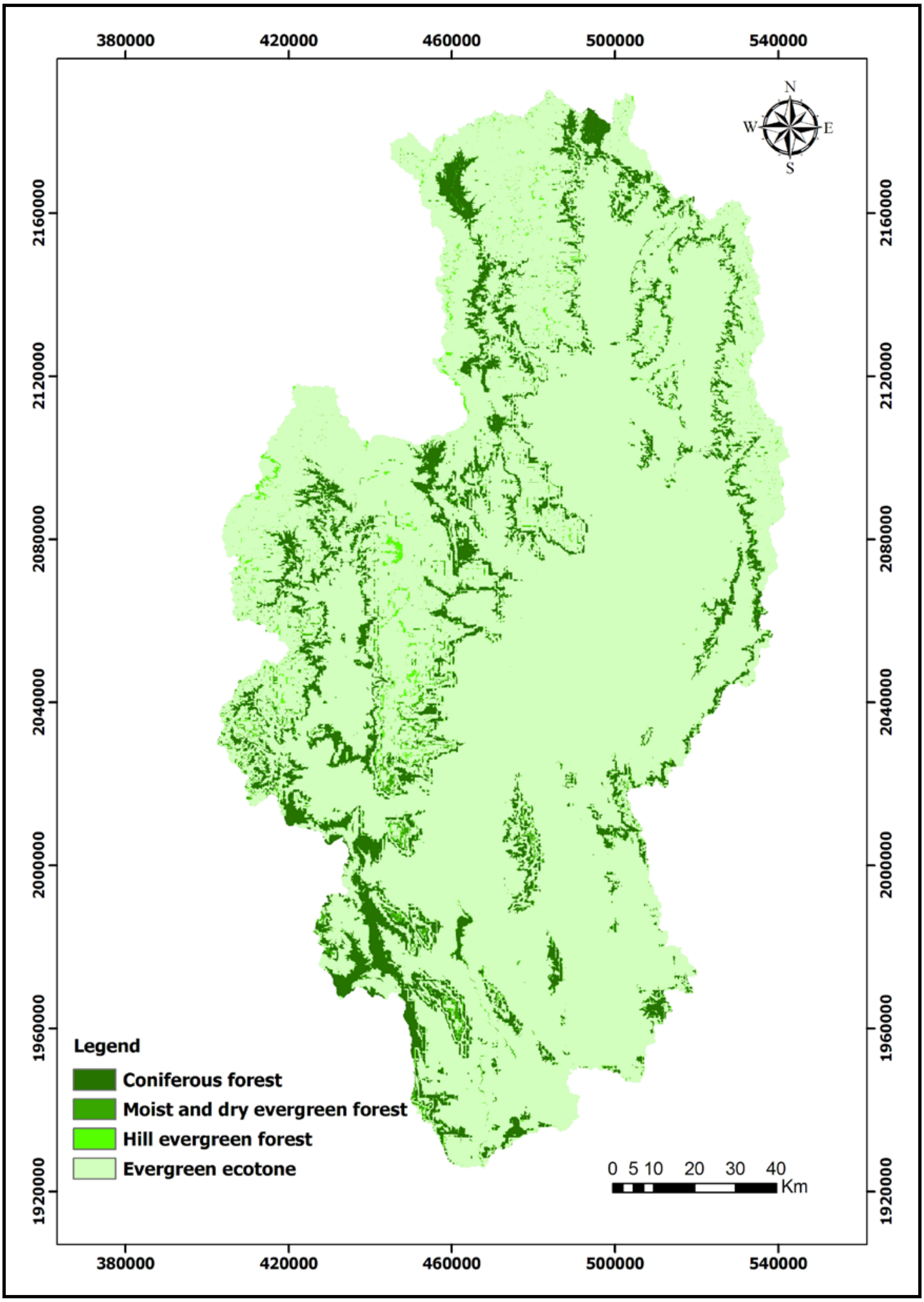
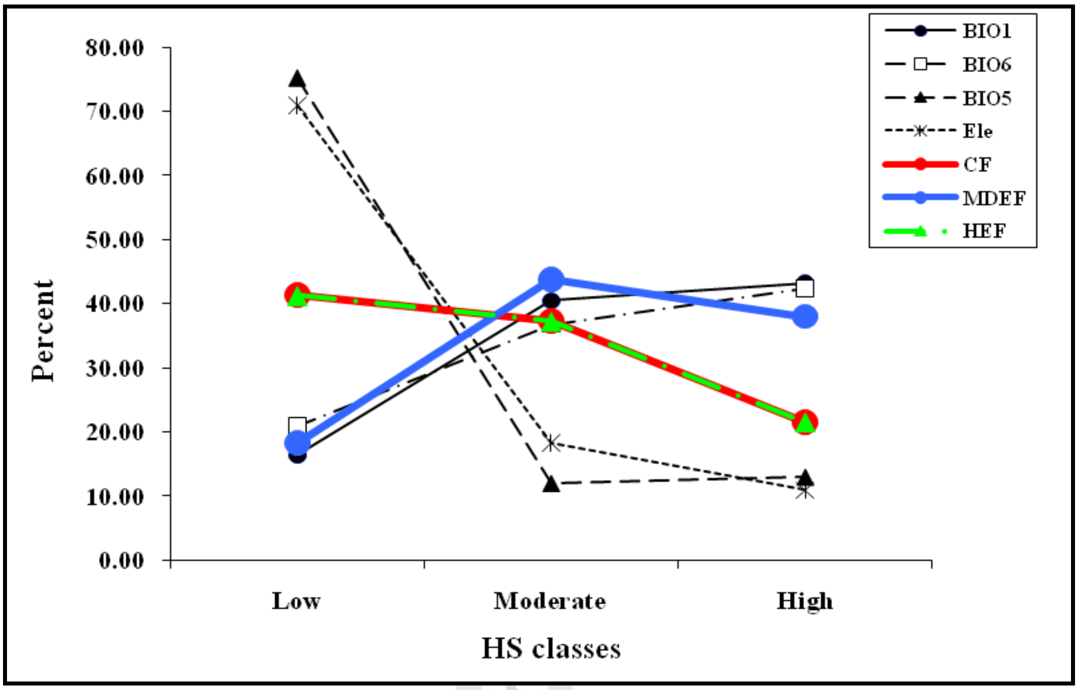


Figure 5.18 Distribution of evergreen forest types in the study area.

Discussion for evergreen forest type distribution

In summary, evergreen forest type distribution in the study area is combined based on the suitability classes from coniferous forest (resulted in section 5.3.2.3), moist and dry evergreen forest (resulted in section 5.3.2.4) and hill evergreen forest (resulted in section 5.3.2.5) that are influenced from four significantly physical variables (BIO1), BIO6), BIO5) and Elevation). Herein, the influence of common topographic factor (elevation) mainly determinants distribution of coniferous forest and hill evergreen forest while BIO5 is mainly determinants distribution of moist and dry evergreen forest. Additionally, these results are summarized based on continuum concept that can be displayed as Figure 5.19. According to Figure 5.19, it is found that the coincident area between coniferous forest, moist and dry evergreen forest and hill evergreen forest, called 'evergreen ecotone' as overlapping area among evergreen forests (coniferous forest, moist and dry evergreen and hill evergreen. In addition, these results can be explained with Gleason's view for the plant community (as same as deciduous forest type distribution) that the distributional or ecological ranges of any two species coincide precisely, and the degree of association between ground flora and canopy is often weaker than one might assume from casual observation (see also Figure 2.4b).



Note: BIO1 is mean annually temperature (°C), BIO6 is mean monthly minimum temperature (°C), BIO5 is mean monthly maximum temperature (°C), Ele is Elevation, CF is coniferous forest, MDEF is moist and dry evergreen forest, and HEF is hill evergreen forest.

Figure 5.19 Evergreen forest distribution based on 4 significantly physical variables.

5.4.3 Forest types distribution

Deciduous forest type data (from 5.4.1) and evergreen forest type data (from 5.4.2) are integrated to create major forest types with ecotone distribution. In practice, deciduous forest types are firstly reassigned the new code by multiplication operation with 1000 (see detail in Appendix C) and then overlaid together with addition operation to generate forest types distribution under GIS spatial analysis. As a result, major forest types are consists of mixed deciduous forest, dry dipterocarp forest, coniferous forest, moist and dry evergreen forest, and hill evergreen forest, and ecotones deciduous ecotone, evergreen ecotone, evergreen and deciduous ecotone (Table 5.27). The distribution of forest type is presented in Figure 5.20.

According to Table 5.27 is summarized in term of 2 main forest types: deciduous forest types (14,040.31 Sq.km or 62.47%) and evergreen forest types (4,592.89 Sq.km or 20.45%). Deciduous forest types comprise of mixed deciduous forest (3,440.79 Sq.km or 15.31%), dry dipterocarp forest (7,373.94 Sq.km or 32.81%) and deciduous ecotone (3,225.58 Sq.km or 14.35%). Evergreen forest types include coniferous forest (365.28 Sq.km or 1.63%), moist and dry dipterocarp forest (290.08 Sq.km or 1.29%), hill evergreen forest (270.56 Sq.km or 1.21%) and evergreen ecotone (3,666.97 Sq.km or 16.32%). In addition, one new ecotone is occurred from deciduous forest type data and evergreen forest type data, called "deciduous and evergreen ecotone".

Table 5.27 Area and percentage of forest types in the study area.

Forest types	**Area (sq.km)**	**% of area**
1. Mixed deciduous forest	3,440.79	15.31
2. Dry dipterocarp forest	7,373.94	32.81
3. Deciduous ecotone	3,225.58	14.35
4. Coniferous forest	365.28	1.63
5. Moist and dry evergreen forest	290.08	1.29
6. Hill evergreen forest	270.56	1.21
7. Evergreen ecotone	3,666.97	16.32
8. Deciduous and evergreen ecotone	2,027.12	9.02
9. Unsuitable forest	1,811.93	8.06
Total	**22,472.25**	**100.00**

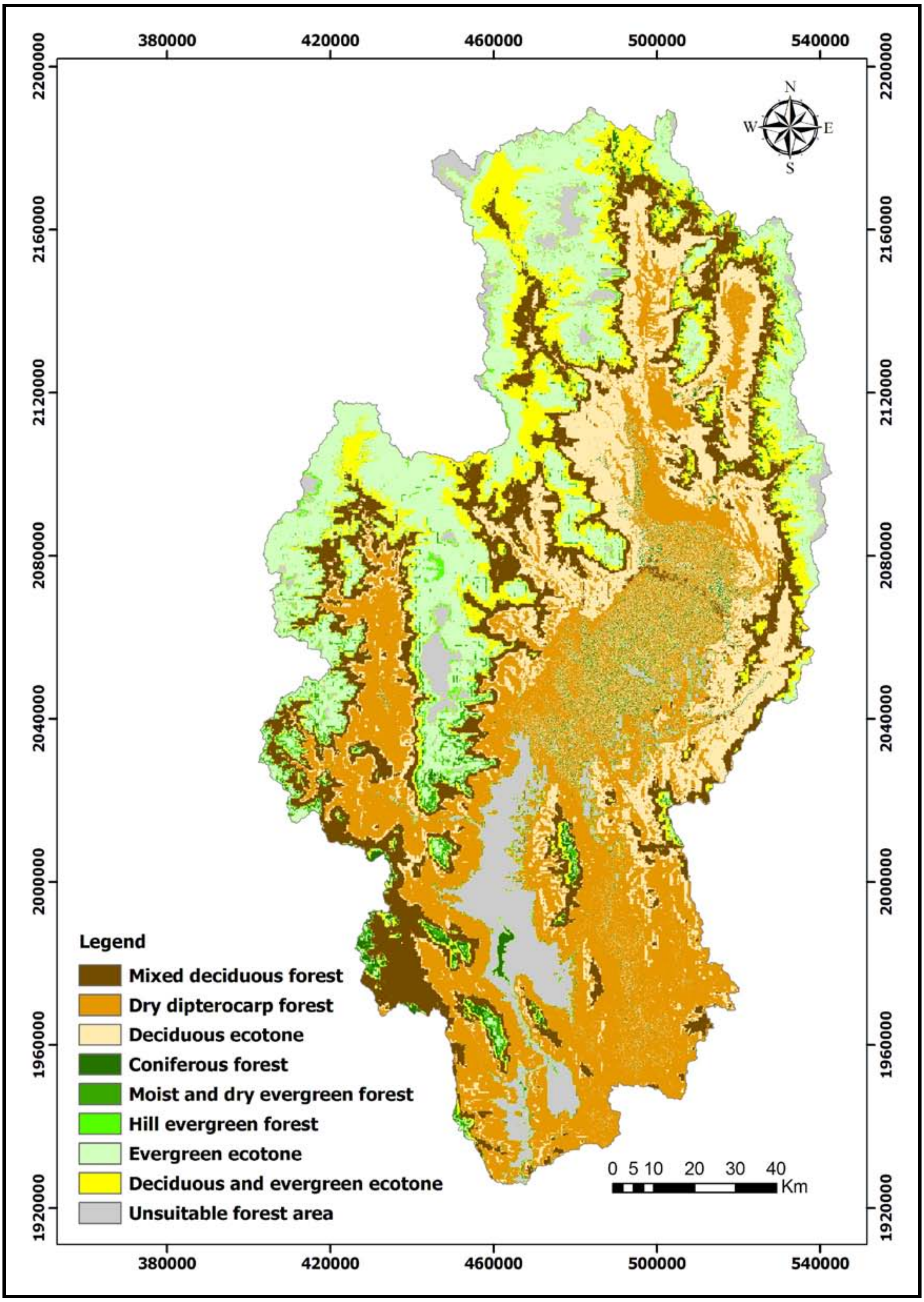
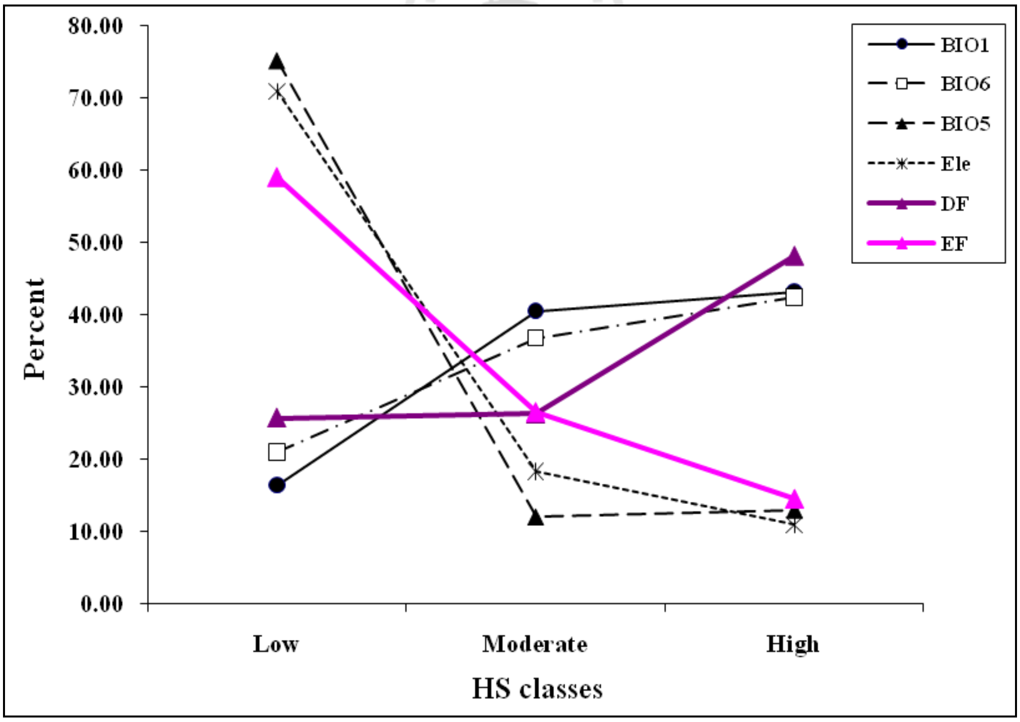


Figure 5.20 Distribution of forest type in the study area.

Discussion for forest types distribution

In summary, forest type distribution in the study area is combined based on the suitability classes from deciduous forest types (resulted in section 5.4.1) and evergreen forest types (resulted in section 5.4.2) that are influenced from such 4 significantly physical variables (BIO1, BIO6, BIO5 and elevation). Additionally, these results are summarized based on continuum concept (see section 2.2.2) that can be displayed as Figure 5.21. It is found that the coincident area between deciduous forest types and evergreen forest types, called 'deciduous and evergreen ecotone' as overlapping area between deciduous forest and evergreen forest as shown in Figure 5.21. These results can be also explained with Gleason's view for the plant community as same as deciduous and evergreen forest type distribution.



Note: BIO1 is mean annually temperature (°C), BIO6 is mean monthly minimum temperature (°C), BIO5 is mean monthly maximum temperature (°C), Ele is Elevation, DF is deciduous forest types, and EF is evergreen forest types.

Figure 5.21 Forest type distribution based on 4 significantly physical variables.

5.5 Accuracy assessment

Basically, the accuracy assessment of predictive forest type by ENFA was conducted using simple descriptive statistics, Kappa analysis and fuzzy accuracy assessment with Fuzzy logical rule with field survey data in April 2011. Number of sampling points was calculated based on multinomial distribution theory (Eq. 4.8) with desired level of confident 90 percent and a precision of 10 percent was 141 points and sampling method was stratified random sampling. The proportion of sampling points in each forest type and ecotone are presented in Table 5.28. Distribution of sample points over predictive forest types was shown in Figure 5.22. Due to limitation of road accessibility (6 points) and non-forest area (7 points), only 128 of 141 points can be visited and collected concerned information (as Appendix D) and can be summarized representation of forest type conditions in the study area (Figure 5.23).

Table 5.28 The number of samples in each forest type area for ground checking.

	Forest types	**Area (sq.km)**	**Percent**	**Points**
1.	Mixed Deciduous Forest (MDF)	3,440.79	15.31	23.00
2.	Dry Dipterocarp Forest (DDF)	7,373.94	32.81	50.00
3.	Deciduous Ecotone (DE)	3,225.58	14.35	22.00
4.	Coniferous Forest (CF)	365.28	1.63	3.00
5.	Moist and Dry Evergreen Forest (MDEF)	290.08	1.29	2.00
6.	Hill Evergreen Forest (HEF)	270.55	1.21	2.00
7.	Evergreen Ecotone (EE)	3,666.97	16.32	25.00
8	Deciduous and Evergreen Ecotone (DEE)	2,027.12	9.02	14.00
9	Unsuitable forest area	1,811.93	8.06	-
	Total	**22,472.25**	**100.00**	**141.00**

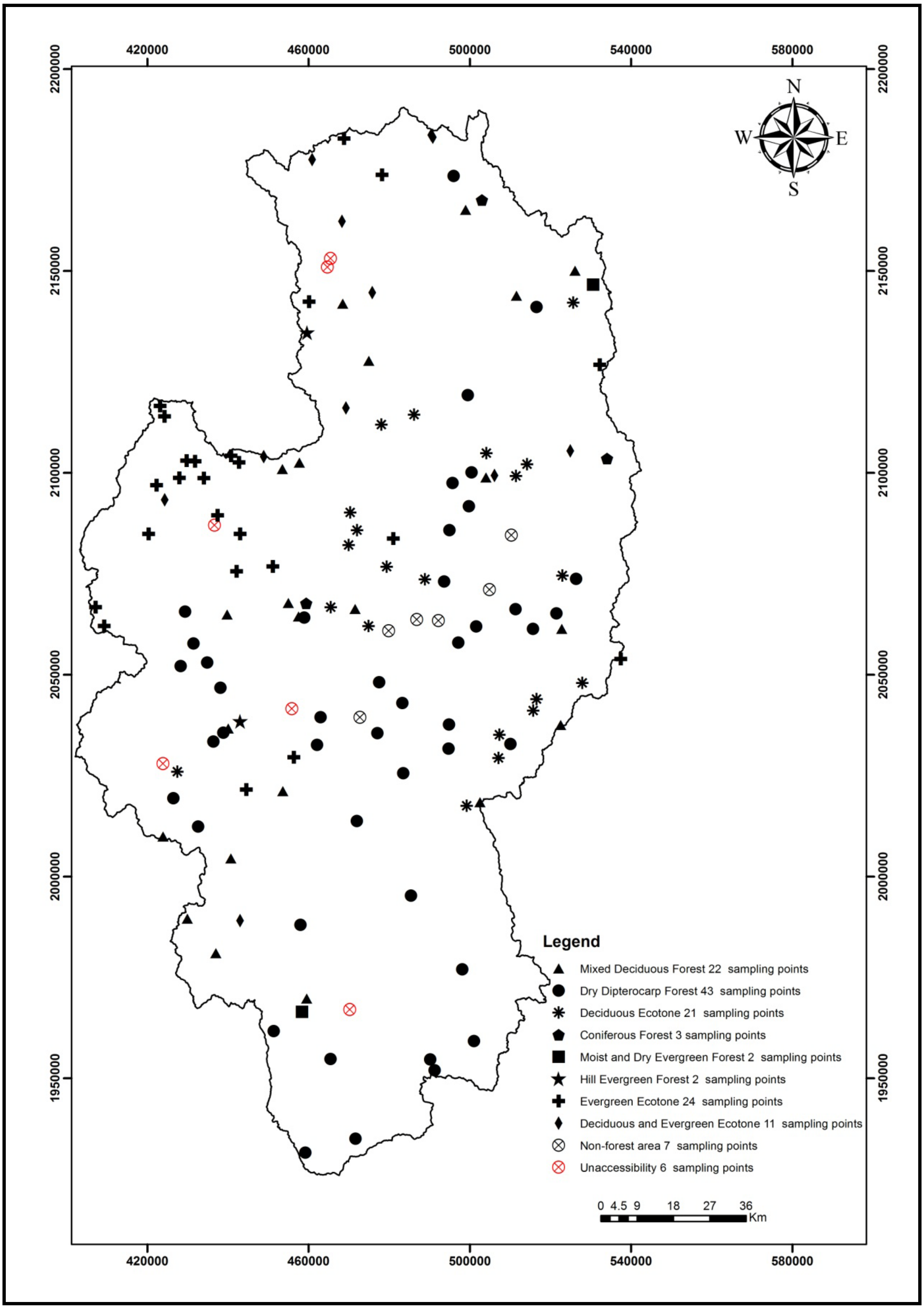


Figure 5.22 Distribution of sampling points for accuracy assessment.

1. Mixed deciduous forest

(a) This location appears s dominant tree species of *Afzelia xylocarpa, Cassia fistula, Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus, Xylia xylocarpa* var. *kerrii* and bamboos (*i.e., Bambusa bambos, Dendrocalamus strictus* and *Gigantochloa albociliata*) and shallow and sandy soil at elevations between 600-900 m.

(b) This location appears dominant tree species of *Cassia fistula, Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and bamboos (*i.e. Bambusa bambos* and *Gigantochloa albociliata*), ground site with laterit rock and elevations between 500-700 m.

2. Dry dipterocarp forest

(a) This location appears dominant tree species of *Dipterocarpus obtusifolius* and *D. tuberculatus*, highly sandy and shallow soil, elevations between 200-400 m. and ground site with fire disturbance.

(b) This location appears dominant tree species of *Shorea obtusa* and *S. siamensis*, highly shallow and sandy soil and elevations between 200-600 m.

(c) This location appears dominant tree species of Dipterocarpaceae and *Pinus* spp. (slight appearance) in characteristics of a small forest community, sandy shallow soil and outcrop, and elevations between 600-700 m.

3. Deciduous ecotone

(a) This location appears mixture of dry dipterocarp forest and mixed deciduous forest. Environmental conditions include moderate slope with elevations between 700-800 m.

(b) This location appears mixture of dry dipterocarp forest and mixed deciduous forest. Environmental conditions include slope from moderate to high with at elevations between 800-900 m.

Figure 5.23 Characteristics of all forest types in the study area from ground truthing.

4. Coniferous forest

(a) This location appears dominant tree species of *Pinus* spp. (outstanding) with environmental conditions; elevations between 1,000-1,100 m and high slope.

(b) This location appears dominant tree species of *Pinus* spp. (outstanding) and *Dipterocarpus obtusifolius*, *D. tuberculatus* (some evenly and sparsely). Environmental conditions include a moderate slope between 600-700 m. and sandy and shallow soil.

5. Moist and dry evergreen forest

- This location appears dominant tree species of Dipterocarpus spp. with environmental conditions; elevations between 900-1,000 m where includes mountainously complex topography with high slope.

6. Hill evergreen forest

- This location appears dominant tree species of *Castanopsis* spp. *Lithocarpus* spp. and *Quercus* spp. Environmental conditions include elevations between 1,100-1,200 m where locates the series of complex mountains with very highly slope.

7. Evergreen ecotone

(a) This location appears mixture of hill evergreen forest and coniferous forest on a hillside. Environmental conditions include very highly slope between 1,300-1,400 m where soil characteristics are sandy and calcifuge soil.

(b) This location appears mixture of hill evergreen forest and coniferous forest on a hillside. Environmental conditions include very highly slope where elevation is between 1,300-1,400 m. and sandy and calcifuge soil.

8. Deciduous and evergreen ecotone

(a) This location appears mixture of coniferous forest and deciduous forest with characteristics of a small forest community. Environmental conditions include elevations between 900-1,000 m and a high slope, shallow and outcrop soil.

(b) This location appears mixture of moist and dry evergreen forest and mixed deciduous forest. Environmental conditions include elevations between 800-900 m where includes from moderate to high slope.

Figure 5.23 (Continued).

5.5.1 Simple descriptive statistics

Based on error matrix, overall accuracy of predictive forest type data was 75.78%. Producer's accuracy varies from 25.00% of hill evergreen forest to 100.00% of deciduous ecotone, coniferous forest, and evergreen ecotone. At the same time, user's accuracy diverges from 42.86% of deciduous ecotone to 100.00% of moist and dry evergreen forest and hill evergreen forest (Table 5.29).

5.5.2 Kappa analysis

Additionally, kappa hat coefficient of agreement of predictive forest type data was 68.76%. For conditional kappa hat coefficient of agreement as producer's accuracy varies from 23.81% of hill evergreen forest to 100.00% of deciduous ecotone, coniferous forest and evergreen ecotone. At the same time, conditional kappa hat coefficient of agreement as user's accuracy varies from 38.54% of deciduous ecotone to 100.00% of coniferous forest, moist and dry evergreen forest, and hill evergreen forest. According to Landis and Koch (1977), kappa hat coefficient of agreement represented moderate accuracy between the predictive forest type data by ENFA and the ground reference information for this study (see also Table 5.29).

Table 5.29 Error matrix of accuracy assessment with simple description statistics and Kappa analysis.

		Data of ground reference									User accuracy (%)	User's conditional K_{hat}(%)
Predicted data	**Forest types**	**MDF**	**DDF**	**D-Ecotone**	**CF**	**MDEF**	**HEF**	**E_Ecotone**	**D-E_Ecotone**	**Row total**		
	MDF	18	2	0	0	0	0	0	2	22	81.82	76.96
	DDF	1	42	0	0	0	0	0	0	43	97.67	95.92
	D-Ecotone	6	6	9	0	0	0	0	0	21	42.86	38.54
	CF	0	2	0	1	0	0	0	0	3	33.33	100.00
	MDEF	0	0	0	0	2	0	0	0	2	100.00	100.00
	HEF	0	0	0	0	0	2	0	0	2	100.00	100.00
	E_Ecotone	0	1	0	0	0	5	18	0	24	75.00	70.91
	D-E_Ecotone	2	2	0	0	1	1	0	5	11	45.45	42.30
	Column total	27	55	9	1	3	8	18	7	**128**		
Producer's accuracy (%)		66.67	76.36	100.00	100.00	66.67	25.00	100.00	71.43			
Producer's conditional K_{hat}(%)		59.75	64.41	100.00	100.00	66.14	23.81	100.00	68.74			
Overall accuracy = 75.78%												
Kappa accuracy = 68.76%												

Note: MDF is Mixed Deciduous Forest, DDF is Dry Dipterocarp Forest, DE is Deciduous Ecotone, CF is Coniferous Forest, MDEF is Moist and Dry Evergreen Forest, HEF is Hill Evergreen Forest, EE is Evergreen Ecotone, DEE is Deciduous and Evergreen Ecotone, and Other are urban, paddy field and abandon land

5.5.3 Fuzzy accuracy assessment

In this part, 128 sample points from the field data had been firstly reviewed using fuzzy logical rule as pre-defined according to habitat suitability classes of deciduous and evergreen forest and theirs ecotones and then was evaluated using simple descriptive statistic. Herewith, overall accuracy for fuzzy assessment of predictive forest type data was 97.66%. In the meantime, producer's accuracy varies from 93.48% of dry dipterocarp forest to 100.00% of mixed deciduous forest, deciduous ecotone, coniferous forest, moist and dry evergreen forest, hill evergreen forest, evergreen ecotone, and deciduous and evergreen ecotone. For user's accuracy diverges from 33.33% of coniferous forest to 100.00% of mixed deciduous forest, dry dipterocarp forest, deciduous ecotone, moist and dry evergreen forest, hill evergreen forest, and deciduous and evergreen ecotone.

Discussion

As a result, fuzzy accuracy assessment provides higher value of overall accuracy, producer's accuracy and user's accuracy than simple descriptive statistics. Because simple descriptive statistics ignores any variation in the interpretation of reference data and the inherent fuzziness at class boundaries.

Table 5.30 Error matrix of their accuracy assessment with Fuzzy logic rule.

	Data of ground reference										User's row total fuzzy (%)
	Forest types	**MDF**	**DDF**	**D_Ecotone**	**CF**	**MDEF**	**HEF**	**E_Ecotone**	**D-E_Ecotone**	**Row total fuzzy**	
Predicted data	**MDF**	18	2/0	0/0	0/0	0/0	0/0	0/0	2/0	22	100.00
	DDF	1/0	42	0/0	0/0	0/0	0/0	0/0	0/0	43	100.00
	D-Ecotone	6/0	6/0	9	0/0	0/0	0/0	0/0	0/0	21	100.00
	CF	0/0	0/2	0/0	1	0/0	0/0	0/0	0/0	3	33.33
	MDEF	0/0	0/0	0/0	0/0	2	0/0	0/0	0/0	2	100.00
	HEF	0/0	0/0	0/0	0/0	0/0	2	0/0	0/0	2	100.00
	E_Ecotone	0/0	0/1	0/0	0/0	0/0	5/0	18	0/0	24	95.83
	D-E_Ecotone	2/0	2/0	0/0	0/0	1/0	1/0	0/0	5	11	100.00
	Column total fuzzy	22	46	21	1	2	2	23	11	**128**	
Producer's column total fuzzy (%)		100.00	93.48	100.00	100.00	100.00	100.00	100.00	100.00		
Overall fuzzy accuracy = 97.66%											

Note: MDF is Mixed Deciduous Forest, DDF is Dry Dipterocarp Forest, DE is Deciduous Ecotone, CF is Coniferous Forest, MDEF is Moist and Dry Evergreen Forest, HEF is Hill Evergreen Forest, EE is Evergreen Ecotone, DEE is Deciduous and Evergreen Ecotone, and Other are urban, paddy field and abandon land

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Prediction of forest type distribution in Ping Basin of Thailand had been modeled based on ENFA. This forest ecological modeling had used the physical factors that were based on the identified physical factors of forest types from Kutintara (1999). Results can be summarized in specific objectives and significant findings as following.

6.1.1 Identification and evaluation of physical factors for forest type distribution by Factor Analysis

In this study, the significant physical factors including climate, topography and soil were composed of 10 climatic variables, 3 topographic variables, and 1 soil variable had been identified for five forest types (mixed deciduous forest, dry dipterocarp forest, coniferous forest, moist and dry evergreen forest, and hill evergreen forest) from forest inventory data of DNP in 2007. Then, 14 the identified physical variables were evaluated for each forest type distribution using factor analysis. The results of factor analysis showed the cumulative variance with eigenvalues greater than 1 of dry dipterocarp forest (95.35%) provided the highest percent of variation whereas the cumulative variance of moist and dry evergreen forest (90.18%) provided the lowest percentage of variation. This result comes from the aggregation of two different forest types: moist evergreen forest and dry evergreen forest as moist and dry evergreen forest type. In addition, the important physical factors for all forest types in this study which relevant to the identified physical factors of Kutintara (1999) are climate (mean annually temperature, mean monthly minimum temperature, and mean monthly maximum temperature), and topography (elevation).

6.1.2 Development of forest ecological modeling for prediction of forest type distribution by ENFA

The significant variables in each component of each forest type from factor analysis were used as EGVs to generate 16 ENFA models included 3 components of mixed deciduous forest (MDF1, MDF2, and MDF3), 3 components of dry dipterocarp forest (DDF1, DDF2, and DDF3), 3 components of coniferous forest (CF1, CF2, and CF3), 4 components of moist and dry evergreen forest (MDEF1, MDEF2, MDEF3, and MDEF4), and 3 components of hill evergreen forest (HEF1, HEF2, and HEF3). Then they were used to generate habitat suitability for each component of each forest type under ENFA. The best forest habitat suitability of each forest type was evaluated and validated by AVI and CVI. The result of evaluation showed that the best forest habitat suitability of each forest type composed of the same physical variables: (1) mean annually temperature (BIO1), (2) mean monthly maximum temperature (BIO5), (3) mean monthly minimum temperature (BIO6), and (4) elevation (Elevation). Results showed that the best forest ecological model as habitat suitability of four forest types (mixed deciduous forest, dry dipterocarp forest, coniferous forest, and hill evergreen forest) had been accounted for marginality preference that indicated the high relationship between forest type’s niche and the mean environmental conditions of the study area. In opposite, moist and dry evergreen forest had been accounted for specialization preference that indicated the high relationship between forest type's niche and the variation of environmental conditions in the study area. In addition, major determinant for coniferous forest and hill evergreen forest distribution is elevation, while determinant factor for mixed deciduous forest, dry dipterocarp forest and moist and dry evergreen forest is mean annually temperature; mean monthly minimum temperature and mean monthly maximum temperature, respectively.

The best habitat suitability index for distribution of each forest type which was derived from multivariate model is as follows:

(1) Mixed deciduous forest:

$H_{(MDF1)} = [1/(1.725+0.268+0.007+0.001)] * [1.725\ H_{(marg.,c)} + 0.268\ H_{(spec.1,c)} + 0.007\ H_{(spec.2,c)} + 0.001\ H_{(spec.3,c)}]$

(2) Dry dipterocarp forest:

$H_{(MDF2)} = [1/(1.912+0.069+0.011)] * [1.912\ H_{(marg.,c)} + 0.069\ H_{(spec.1,c)} + 0.011\ H_{(spec.2,c)}]$

(3) Coniferous forest:

$H_{(CF2)} = [1/(1.805+0.187)] * [1.805\ H_{(marg.,c)} + 0.187\ H_{(spec.,c)}]$

(4) Moist and dry evergreen forest:

$H_{(MDEF1)} = [1/(1.389+0.606)] * [1.389\ H_{(marg.,c)} + 0.606\ H_{(spec.,c)}]$

(5) Hill evergreen forest:

$H_{(HEF1)} = [1/(1.747+0.243+0.006)] * [1.747\ H_{(marg.,c)} + 0.243\ H_{(spec.1,c)} + 0.006\ H_{(spec.2,c)}]$

These habitat suitability indices for each forest type had been then reclassified into three classes (low, moderate and high) using natural break algorithm. It was found that the highest proportion of coverage of deciduous forest distribution (mixed deciduous forest and dry dipterocarp forest) situate in high habitat suitability class. In contrary, evergreen forest (coniferous forest, moist and dry evergreen forest and hill evergreen forest) was situated in low habitat suitability class. These results come from existing number and distribution of modeled forest inventory data.

6.1.3 Geospatial forest type distribution

To obtain forest type distribution map this study had combined all 5 reclassified forest type data based on habitat suitability index under GIS spatial analysis. In this analysis, there are three specific outputs: (1) deciduous forest distribution, (2) evergreen forest distribution, and (3) forest type distribution that they were influenced from four significantly physical variables (mean annually temperature, mean monthly minimum temperature, mean monthly maximum temperature and elevation). As a result, three outputs can be here summarized by area coverage in the study area as following.

(1) Deciduous forest distribution is composed of mixed deciduous forest (26.31%), dry dipterocarp forest (32.93%) and deciduous ecotone (40.76%).

(2) Evergreen forest distribution is consisted of coniferous forest (12.67%), moist and dry evergreen forest (1.31%), hill evergreen forest (1.24%), and evergreen ecotone (84.78%).

(3) Forest type distribution is composed of mixed deciduous forest (15.31%), dry dipterocarp forest (32.81%) and deciduous ecotone (14.35%), coniferous forest (1.63%), moist and dry evergreen forest (1.29%), hill evergreen

forest (1.21%), evergreen ecotone (16.32%), deciduous and evergreen ecotone (9.02%), and unsuitable forest (8.06%).

Forest ecotones (deciduous ecotone, evergreen ecotone and deciduous and evergreen ecotone) were specially assigned in this study according to habitat suitability classes of forest types. These results can be explained with Gleason's view for the plant community that the distributional or ecological ranges of any two species coincide precisely, and the degree of association between ground flora and canopy is often weaker than one might assume from casual observation.

6.1.4 Accuracy assessment

Accuracy assessment of predictive forest type by ENFA was conducted using simple descriptive statistics, Kappa analysis and fuzzification based on field survey data in April 2011. The error matrices were generated between predictive forest types and reference data from field survey with 128 sampling points. It was found that traditional accuracy assessment based on deterministic error matrix, overall accuracy and kappa hat coefficient of agreement for predictive forest type distribution was 75.78% and 68.76%, respectively. These results represented moderate accuracy between the predictive forest type data by ENFA and the ground reference information according to Landis and Koch (1977). In the meantime, overall accuracy of fuzzy accuracy assessment based on fuzzy logical rule was 97.66%. This method provides higher value of overall accuracy than traditional accuracy assessment because simple descriptive statistics ignores any variation in the interpretation of reference data and the inherent fuzziness at class boundaries. In this study, fuzzy logical rule was applied based on habitat suitability classes of deciduous and evergreen forest and theirs ecotones.

Finally, it may be concluded that physical factors include mean annually temperature, mean monthly maximum temperature, mean monthly minimum temperature, and elevation can be used to create forest type distribution map using ENFA. The obtained output can be used for rehabilitation of forest resource, especially in national reserved forest area to fit with climate and terrain of forest.

6.2 Recommendations and future improvements

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

(1) Soil data is one important factor for forest ecological modeling. However, the result of this study revealed that soil group data of slope complex area with geological information has not influenced to forest type distribution. This comes from geological map scale 1:250,000 that is more coarse data than soil map scale 1:100,000. Thus, forest soil should be investigated and applied for the further study.

(2) Results of accuracy assessment for forest types distribution map reveals over accuracy with 75.78% and kappa hat coefficient of agreement with 68.76% (as moderate accuracy between the predictive forest type data by ENFA and the ground reference information for this study). In the meantime, overall accuracy of fuzzy accuracy assessment based on fuzzy logical rule was 97.66%. Therefore, forest type distribution mapping should be considered for alternative technique besides remote sensing data is not available. Furthermore forest type distribution map can be used effectively as a basic data for forest rehabilitation based on ecological suitability.

(3) Due to the limitation of sample points from forest inventory data for prediction of forest distribution in this study, distinctly moist evergreen forest and dry

evergreen forest were combined as moist and dry evergreen forest and provided specialization preference which was different from other forest types. So, it should identify other test sites with enough sample points to predict both moist evergreen forest and dry evergreen forest distributions separately.

(4) Prediction of forest distribution map with physical data using ENFA model should be tested in another area or region for verification and validation of the model.

APPENDIX

APPENDIX A

DATA PREPARATION

A.1 Attribute tables for monthly mean rainfall.

St.	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ele (m)	Lat. (dd)	Long. (dd)
1	X = 377073.27 Y = 2134437.20	7.70	5.00	16.60	59.00	168.30	168.00	184.00	217.00	254.00	205.00	107.00	45.00	800.00	97.83	19.30
2	X = 86830.70 Y = 2009323.40	7.00	7.00	11.30	47.00	162.80	163.00	178.00	188.00	225.00	177.00	107.00	21.00	208.00	97.93	18.17
3	X = 497892.25 Y = 2076485.34	7.70	9.00	17.30	54.00	155.40	155.00	119.00	158.00	224.00	202.00	117.00	51.00	308.00	98.98	18.78
4	X = 503165.52 Y = 2053250.26	2.40	6.00	13.10	43.00	146.40	146.00	123.00	118.00	153.00	191.00	111.00	48.00	292.00	99.03	18.57
5	X = 512781.30 Y = 1866284.00	4.20	8.00	13.40	42.00	161.20	161.00	124.00	94.00	128.00	209.00	204.00	61.00	123.00	99.12	16.88
6	X = 452017.09 Y = 1843103.43	2.30	8.00	8.70	39.00	168.80	169.00	235.00	312.00	333.00	160.00	99.00	25.00	238.00	98.55	16.67
7	X = 505315.63 Y = 1904999.76	4.40	7.00	18.10	60.00	182.90	183.00	88.00	80.00	114.00	219.00	206.00	50.00	149.00	99.05	17.23
8	X = 486092.47 Y = 1771152.02	7.50	14.00	32.40	91.00	186.30	186.00	191.00	216.00	253.00	248.00	159.00	27.00	528.00	98.87	16.02
9	X = 592072.82 Y = 2208403.01	11.20	12.00	20.90	95.00	194.70	195.00	195.00	319.00	378.00	271.00	131.00	57.00	387.00	99.88	19.97
10	X = 594654.18 Y = 2115455.41	5.00	11.00	22.60	94.00	168.70	169.00	102.00	140.00	190.00	194.00	117.00	41.00	394.00	99.90	19.13
11	X = 687613.73 Y = 2077423.65	7.30	13.00	31.60	96.00	167.80	168.00	133.00	215.00	271.00	197.00	79.00	21.00	205.00	100.78	18.78
12	X =689361.00 Y = 2112865.82	9.10	12.00	35.60	104.00	190.50	191.00	188.00	262.00	296.00	183.00	82.00	25.00	228.00	100.80	19.10
13	X = 623747.02 Y = 2009387.89	6.30	10.00	24.60	77.00	174.00	174.00	121.00	153.00	212.00	185.00	90.00	22.00	163.00	100.17	18.17
14	X = 616701.65 Y = 1948483.77	7.40	15.00	25.40	79.00	233.20	233.00	186.00	187.00	264.00	264.00	116.00	30.00	69.00	100.10	17.62

A.1 (Continue).

St.	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ele (m)	Lat. (dd)	Long. (dd)
15.	X= 556568.86 Y = 1822105.72	1.80	14.00	30.40	30.00	198.20	198.00	150.00	152.00	174.00	269.00	191.00	50.00	82.00	99.53	16.48
16	X = 635348.94 Y = 1855650.91	5.10	13.00	30.50	55.00	178.40	178.00	180.00	188.00	257.00	231.00	159.00	33.00	47.00	100.27	16.78
17	X = 729579.04 Y = 1817719.28	5.60	19.00	38.40	68.00	155.80	156.00	144.00	154.00	189.00	201.00	87.00	11.00	122.00	101.15	16.43
18	X = 739839.22 Y = 1855470.83	4.40	23.00	43.00	63.00	159.30	159.00	137.00	137.00	191.00	188.00	79.00	15.00	149.00	101.25	16.77
19	X = 727257.38 Y = 1731355.5	6.90	14.00	37.90	90.00	167.70	168.00	137.00	160.00	207.00	244.00	118.00	17.00	77.00	101.12	15.65
20	X = 554961.64 Y = 2021242.33	5.60	8.00	20.50	65.00	148.50	149.00	115.00	146.00	193.00	210.00	106.00	34.00	255.00	99.52	18.28
21	X = 625311.37 Y = 1747161.10	5.40	13.00	33.40	58.00	153.10	153.00	110.00	133.00	185.00	218.00	133.00	31.00	28.00	100.17	15.80

Note: St.1 = Mae Hong Son, St2. = Mae Sariang, St.3 = Chaing Mai, St.4 = Lumphun, St.5 = Tak, St.6 = Mae Sot, St.7 = Bhumibol Dam, St.8 = Umphang, St.9 = Chaing Rai, St.10 = Phayao, St.11 = Nan, St.12 = Tha Wang Pha, St.13 = Phrae, St.14 = Uttradit, St.15 = Kamphaeng Phet, St.16 = Phitsanulok, St.17 = Phetchabun, St.18 = Lom Sak, St.19 = Wichian Buri, St.20 = Lampang, and St.21 = Nakhon Sawan

A.2 Attribute tables for monthly mean maximum temperature.

St	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ele (m)	Lat. (dd)	Long. (dd)
1	X = 377073.27 Y = 2134437.20	29.90	33.20	36.60	38.20	35.70	32.90	32.00	31.70	32.60	32.60	30.90	29.10	800.00	97.83	19.30
2	X = 86830.70 Y = 2009323.40	30.80	33.60	36.40	37.60	34.90	31.50	30.50	30.50	31.80	32.50	31.60	30.20	208.00	97.93	18.17
3	X = 497892.25 Y = 2076485.34	29.30	32.20	34.90	36.00	34.10	32.60	31.80	31.30	31.50	31.20	29.80	28.30	308.00	98.98	18.78
4	X = 503165.52 Y = 2053250.26	30.60	33.60	36.80	37.70	35.30	33.30	32.80	32.30	32.00	31.30	30.20	28.90	292.00	99.03	18.57
5	X = 512781.30 Y = 1866284.00	32.00	35.00	37.50	38.40	35.40	32.90	32.40	32.10	32.30	31.50	30.50	30.20	123.00	99.12	16.88
6	X = 452017.09 Y = 1843103.43	31.00	33.40	35.60	36.50	33.90	31.10	30.10	29.80	31.20	31.80	30.90	30.00	238.00	98.55	16.67
7	X = 505315.63 Y = 1904999.76	31.40	34.50	37.00	37.80	35.10	33.10	32.80	32.60	32.60	31.70	30.60	29.80	149.00	99.05	17.23
8	X = 486092.47 Y = 1771152.02	30.60	32.80	34.80	34.90	32.30	29.60	28.90	28.40	29.60	29.90	29.30	28.70	528.00	98.87	16.02
9	X = 592072.82 Y = 2208403.01	28.10	31.00	33.80	34.80	33.10	31.90	30.90	30.70	30.80	30.00	28.30	26.60	387.00	99.88	19.97
10	X = 594654.18 Y = 2115455.41	29.20	32.10	35.20	35.90	33.60	32.30	31.40	31.20	31.20	30.40	28.90	27.40	394.00	99.90	19.13
11	X = 687613.73 Y = 2077423.65	30.20	32.90	35.70	36.70	34.80	33.20	32.10	31.70	32.40	32.10	30.70	29.10	205.00	100.78	18.78
12	X =689361.00 Y = 2112865.82	29.30	32.10	35.00	35.90	33.90	32.20	31.10	30.80	31.70	31.40	29.90	28.10	228.00	100.80	19.10
14	X = 616701.65 Y = 1948483.77	30.90	33.40	36.10	37.30	35.20	33.50	32.50	32.10	32.20	32.00	31.00	29.80	69.00	100.10	17.62
13	X = 623747.02 Y = 2009387.89	32.10	34.50	36.70	38.00	35.90	34.00	33.20	32.70	33.10	33.00	32.10	31.10	163.00	100.17	18.17

A.2 (Continued).

St	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ele (m)	Lat. (dd)	Long. (dd)
15	X= 556568.86 Y = 1822105.72	32.20	34.50	36.30	37.40	35.50	33.60	33.10	32.60	32.70	32.10	31.40	30.60	82.00	99.53	16.48
16	X = 635348.94 Y = 1855650.91	31.70	33.90	35.90	37.30	35.70	33.90	33.10	32.40	32.50	32.30	31.50	30.70	47.00	100.27	16.78
17	X = 729579.04 Y = 1817719.28	32.20	34.60	36.50	37.20	35.20	33.30	32.60	32.00	32.20	32.10	31.50	30.90	122.00	101.15	16.43
18	X = 739839.22 Y = 1855470.83	31.90	33.80	35.60	36.30	34.80	33.10	32.20	31.60	32.10	32.10	31.40	30.60	149.00	101.25	16.77
19	X = 727257.38 Y = 1731355.5	32.30	34.40	36.40	37.00	35.10	33.80	33.10	32.50	32.20	32.20	31.70	31.20	77.00	101.12	15.65
20	X = 554961.64 Y = 2021242.33	30.70	33.70	36.60	37.80	35.30	33.70	32.90	32.50	32.30	31.80	30.60	29.40	255.00	99.52	18.28
21	X = 625311.37 Y = 1747161.10	32.70	35.10	36.90	38.00	36.00	34.80	34.20	33.40	32.80	32.30	31.70	31.20	28.00	100.17	15.80

Note: St.1 = Mae Hong Son, St2. = Mae Sariang, St.3 = Chaing Mai, St.4 = Lumphun, St.5 = Tak, St.6 = Mae Sot, St.7 = Bhumibol Dam, St.8 = Umphang, St.9 = Chaing Rai, St.10 = Phayao, St.11 = Nan, St.12 = Tha Wang Pha, St.13 = Phrae, St.14 = Uttradit, St.15 = Kamphaeng Phet, St.16 = Phitsanulok, St.17 = Phetchabun, St.18 = Lom Sak, St.19 = Wichian Buri, St.20 = Lampang, and St.21 = Nakhon Sawan

A.3 Attribute tables for monthly mean minimum temperature.

St.	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ele (m)	Lat. (dd)	Long. (dd)
1	X = 377073.27 Y = 2134437.20	13.50	33.20	17.60	22.30	23.50	23.70	23.40	23.30	23.00	21.90	19.00	15.30	800.00	97.83	19.30
2	X = 86830.70 Y = 2009323.40	13.10	33.60	17.40	22.20	23.80	23.50	23.10	23.10	23.00	22.20	19.10	14.90	208.00	97.93	18.17
3	X = 497892.25 Y = 2076485.34	14.10	32.20	19.00	22.30	23.60	23.90	23.70	23.50	23.10	22.00	19.10	15.20	308.00	98.98	18.78
4	X = 503165.52 Y = 2053250.26	14.00	33.60	19.20	22.90	23.80	24.20	23.90	23.70	23.30	22.20	19.00	14.70	292.00	99.03	18.57
5	X = 512781.30 Y = 1866284.00	16.30	35.00	23.60	26.00	25.50	25.10	24.90	24.50	23.90	22.70	20.00	16.40	123.00	99.12	16.88
6	X = 452017.09 Y = 1843103.43	14.60	33.40	19.60	22.90	23.90	23.50	23.10	23.00	23.10	22.20	19.00	15.10	238.00	98.55	16.67
7	X = 505315.63 Y = 1904999.76	17.20	34.50	22.80	25.00	24.90	24.70	24.60	24.30	23.60	22.50	20.00	16.90	149.00	99.05	17.23
8	X = 486092.47 Y = 1771152.02	12.10	32.80	15.20	19.20	21.20	21.70	21.30	21.40	21.00	19.80	16.40	12.50	528.00	98.87	16.02
9	X = 592072.82 Y = 2208403.01	12.10	31.00	16.40	20.10	22.30	23.20	23.10	22.90	22.30	20.60	17.00	12.90	387.00	99.88	19.97
10	X = 594654.18 Y = 2115455.41	13.40	32.10	19.50	22.80	23.60	24.00	23.60	23.40	22.90	21.60	18.10	13.60	394.00	99.90	19.13
11	X = 687613.73 Y = 2077423.65	13.80	32.90	18.70	22.30	23.70	24.30	24.00	23.80	23.40	21.90	18.50	14.20	205.00	100.78	18.78
12	X =689361.00 Y = 2112865.82	12.80	32.10	18.00	21.70	23.40	24.10	23.70	23.50	23.10	21.30	17.70	13.30	228.00	100.80	19.10
13	X = 616701.65 Y = 1948483.77	15.10	33.40	20.70	23.90	24.40	24.40	24.10	24.00	23.80	22.60	19.30	15.40	69.00	100.10	17.62
14	X = 623747.02 Y = 2009387.89	17.00	34.50	21.50	24.10	24.70	24.70	24.40	24.20	24.00	23.10	20.40	17.40	163.00	100.17	18.17

A.3 (Continue).

St.	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ele (m)	Lat. (dd)	Long. (dd)
15	X= 556568.86 Y = 1822105.72	18.20	34.50	22.40	24.70	25.10	25.00	24.70	24.60	24.30	23.60	21.40	18.00	82.00	99.53	16.48
16	X = 635348.94 Y = 1855650.91	18.40	33.90	23.70	25.50	25.30	25.00	24.80	24.60	24.70	24.10	21.60	18.40	47.00	100.27	16.78
17	X = 729579.04 Y = 1817719.28	16.90	34.60	22.20	24.40	24.60	24.50	24.10	24.00	23.90	22.80	19.80	16.70	122.00	101.15	16.43
18	X = 739839.22 Y = 1855470.83	16.90	33.80	21.40	23.60	24.30	24.40	24.10	24.00	23.80	22.60	19.70	16.70	149.00	101.25	16.77
19	X = 727257.38 Y = 1731355.5	17.40	34.40	22.90	24.60	24.90	24.60	24.30	24.10	24.10	23.30	20.30	17.20	77.00	101.12	15.65
20	X = 554961.64 Y = 2021242.33	14.40	33.70	19.60	22.90	24.00	24.20	24.00	23.70	23.30	22.10	18.80	14.80	255.00	99.52	18.28
21	X = 625311.37 Y = 1747161.10	18.80	35.10	24.50	25.90	25.60	25.30	24.90	24.60	24.30	23.80	21.40	18.40	28.00	100.17	15.80

Note: St.1 = Mae Hong Son, St2. = Mae Sariang, St.3 = Chaing Mai, St.4 = Lumphun, St.5 = Tak, St.6 = Mae Sot, St.7 = Bhumibol Dam, St.8 = Umphang, St.9 = Chaing Rai, St.10 = Phayao, St.11 = Nan, St.12 = Tha Wang Pha, St.13 = Phrae, St.14 = Uttradit, St.15 = Kamphaeng Phet, St.16 = Phitsanulok, St.17 = Phetchabun, St.18 = Lom Sak, St.19 = Wichian Buri, St.20 = Lampang, and St.21 = Nakhon Sawan

A.4 The best results for monthly mean rainfall with cokriging.

Rainfall						
Month	**Cokriging Type**	**Semivariogram Models**				**RMSE**
		Type	**Partial sill**	**Range**	**Nugget**	
Jan	SCK	RQ	2.08	330040	3.94	1.90
Feb	SCK	J-B	16.19	451280	3.66	2.36
Mar	SCK	RQ	88.18	451280	15.82	4.86
Apr	SCK	RQ	567.38	325050	0.57	16.02
May	DCK	RQ	0.32	329920	0.74	19.09
Jun	SCK	RQ	767.06	323490	847.99	37.24
Jul	SCK	RQ	3730.70	320260	864.86	55.62
Aug	SCK	RQ	3514.50	321160	1240.90	57.80
Sep	SCK	HE	142.59	471210	869.82	30.31
Oct	SCK	RQ	1870.50	323420	1.87	25.66
Nov	SCK	RQ	253.82	322570	0.25	9.77
Dec	SCK	HE	10.68	471210	10.78	1.90

A.5 The best results for monthly mean maximum temperature and monthly mean minimum temperature with cokriging.

Maximum temperature						
Month	**Cokriging Type**	**Semivariogram Models**				**RMSE**
		Type	**Partial sill**	**Range**	**Nugget**	
Jan	DCK	K-B	0.99	271820	0.08	0.52
Feb	DCK	Stab	0.84	271820	0.29	0.62
Mar	DCK	Exp	0.74	249560	0.38	0.75
Apr	DCK	Exp	1.052	249440	0.078	0.85
May	DCK	Exp	1.14	249470	0.10	0.76
Jun	DCK	RQ	1.11	329730	0.06	0.80
Jul	DCK	Gau	1.10	329150	0.07	0.87
Aug	DCK	RQ	1.05	327040	0.13	0.85
Sep	DCK	RQ	1.07	324670	0.12	0.64
Oct	DCK	Exp	1.12	249370	0.10	0.62
Nov	DCK	Exp	1.08	251030	0.10	0.58
Dec	DCK	Sph	1.08	304590	0.10	0.61
Minimum temperature						
Month	**Cokriging Type**	**Semivariogram Models**				**RMSE**
		Type	**Partial sill**	**Range**	**Nugget**	
Jan	DCK	Exp	1.08	253350	0.10	1.07
Feb	SCK	Gau	10.165	254870	0.01	1.20
Mar	DCK	Exp	1.10	252340	0.10	1.38
Apr	DCK	RQ	1.12	330380	0.07	1.26
May	DCK	Exp	1.13	251570	0.10	0.63
Jun	DCK	Exp	1.13	250370	0.10	0.50
Jul	DCK	Exp	1.10	249760	0.10	0.51
Aug	DCK	Exp	1.08	250200	0.10	0.45
Sep	DCK	Exp	1.11	251250	0.10	0.49
Oct	DCK	Exp	1.12	251620	0.10	0.56
Nov	DCK	Exp	1.13	250710	0.10	0.66
Dec	DCK	Exp	1.10	251260	0.10	0.84

A.6 The comparative results of error with MAE, MRE and RMSE for mean monthly rainfall using various interpolation methods.

Month	Cokriging			IDW			GPI			LPI			RBF			Kriging		
	MAE	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**
Jan	1.54	28.38	1.90 (SCK_RQ)	1.87	36.28	2.44	1.82	34.77	2.24	1.79	36.72	2.40	1.78	31.11	2.22 (IMQ)	1.68	29.67	2.20 (DK_Gau)
Feb	1.93	18.26	2.36 (SCK_J-B)	2.07	19.45	2.49	2.42	22.46	2.86	2.00	18.70	2.38	1.96	18.81	2.39 (IMQ)	2.13	19.71	2.52 (UK_Sph)
Mar	14.29	8.26	4.86 (SCK_RQ)	3.85	17.09	40.05	4.20	28.78	32.34	4.07	19.91	34.26	4.01	18.63	31.43 (IMQ)	4.00	18.48	5.18 (SK_Cir)
Apr	10.19	0.20	16.02 (SCK_RQ)	12.19	20.78	16.35	13.78	24.79	18.78	14.45	26.98	19.58	11.47	19.97	15.82 (IMQ)	11.39	20.27	16.23 (SK_RQ)
May	14.29	8.26	19.09 (DCK_RQ)	14.51	0.08	19.81	17.03	9.90	21.87	17.36	10.39	22.16	14.66	8.47	19.73 (SWT)	14.82	8.40	19.57 (DK_Tsph)
Jun	29.08	0.21	37.24 (SCK_RQ)	32.49	22.96	40.99	35.22	23.86	42.44	31.69	21.39	40.14	22.14	14.58	29.72 (MQ)	29.06	19.75	37.41 (SK_J-B)
Jul	38.47	23.17	55.62 (SK_RQ)	44.74	28.19	61.63	52.67	30.70	68.71	45.20	25.07	60.56	42.54	25.42	55.89 (MQ)	32.14	19.04	55.75 (SK_J-B)
Aug	43.18	20.66	57.80 (SCK_RQ)	47.65	23.76	63.66	53.16	24.98	68.41	47.67	22.07	63.86	42.66	20.77	58.79 (CRS)	44.76	21.48	60.66 (SK_HE)
Sep	23.41	11.03	30.31 (SCK_HE)	24.47	11.62.	32.21	27.61	13.14	35.58	27.53	13.64	36.58	24.49	11.52	31.60 (IMQ)	24.00	11.97	39.76 (DK_HE)
Oct	17.60	0.13	25.66 (SCK_RQ)	19.71	14.79	25.85	29.43	23.68	37.18	22.75	17.67	30.51	14.60	11.01	21.58 (CRS)	12.54	9.70	28.91 (SK_Gau)
Nov	6.18	0.16	9.77 ((SCK_RQ)	8.48	23.82	11.00	8.48	23.82	14.12	7.09	26.11	9.32	5.03	18.62	6.57 (SWT)	0.53	2.14	10.72 (SK_Gau)
Dec	2.11	27.87	1.90 (SCK_HE)	44.74	28.19	3.81	2.53	38.69	3.17	3.81	28.70	2.60	2.12	25.54	3.13 (MQ)	3.14	39.29	3.24 (SK_K-B)

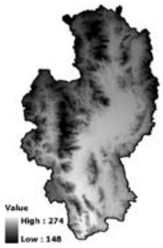
A.7 The comparative results of error with MAE, MRE and RMSE for monthly mean maximum temperature using various interpolation methods**.**

Month	Cokriging			IDW			GPI			LPI			RBF			Kriging		
	MAE	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**
Jan	0.01	3.03	0.52 (DCK_K-B)	0.09	2.06	0.74	0.02	4.01	0.72	0.11	3.72	0.53	0.01	3.49	0.56 (MQ)	0.77	3.40	0.99 (DK_K-B)
Feb	0.08	3.03	0.62 (DCK_Stab)	1.12	4.51	0.80	0.03	4.74	0.82	0.12	4.08	0.66	0.02	3.67	0.67 (MQ)	1.08	4.35	1.29 (DK_Stab)
Mar	0.02	3.01	0.75 (DCK_Exp)	0.13	3.64	0.90	0.03	4.02	0.93	0.10	3.36	0.76	0.02	3.69	0.83 (MQ)	0.84	3.06	1.20 (DK_Exp)
Apr	0.01	2.62	0.85 (DCK_Exp)	0.12	2.83	1.02	0.03	3.49	1.15	0.16	2.85	0.90	0.02	2.77	0.97 (MQ)	0.79	3.03	1.14 (DK_Exp)
May	0.29	1.26	0.76 (DCK_Exp)	0.10	2.23	0.93	0.03	2.90	1.12	0.18	1.98	0.84	0.04	1.91	0.84 (SWT)	0.51	2.02	0.80 (DK_Exp)
Jun	0.48	1.74	0.80 (DCK_RQ)	0.13	2.27	1.04	0.04	2.78	1.21	0.23	1.78	0.96	0.02	1.66	0.88 (CRS)	0.51	1.82	0.75 (DK_RQ)
Jul	0.49	1.83	0.87 (DCK_Gau)	0.17	2.48	1.14	0.05	3.09	1.32	0.25	2.48	1.00	0.05	1.72	0.95 (CRS)	0.53	1.92	0.80 (DK_Gau)
Aug	0.46	1.73	0.85 (DCK_RQ)	0.16	2.22	1.09	0.04	2.22	1.26	0.24	1.71	0.92	0.04	1.56	0.88 (CRS)	0.53	1.97	0.76 (DK_RQ)
Sep	0.33	1.25	0.64 (DCK_RQ)	0.08	1.89	0.77	0.02	1.89	0.92	0.14	1.65	0.72	0.03	1.35	0.72 (CRS)	0.38	1.42	0.61 (DK_RQ)
Oct	0.32	1.26	0.62 (DCK_Exp)	0.00	1.99	0.74	0.01	1.99	0.93	0.08	1.91	0.65	0.02	1.65	0.67 (MQ)	0.41	2.02	0.65 (DK_Exp)
Nov	0.33	1.25	0.58 (DCK_Exp)	0.01	2.48	0.78	0.01	2.48	0.97	0.09	2.42	0.64	0.02	2.19	0.65 (MQ)	0.53	2.14	0.85 (DK_Exp)
Dec	0.41	1.75	0.61 (DCK_Sph)	0.04	3.24	0.81	0.02	4.09	0.93	0.12	3.39	0.62	0.00	2.87	0.60 (SWT)	0.52	1.73	0.95 (DK_Sph)

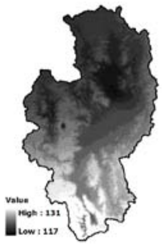
A.8 The comparative results of error with MAE, MRE and RMSE for monthly mean minimum temperature using various interpolation methods**.**

	Cokriging			IDW			GPI			LPI			RBF			Kriging		
	MAE	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**	**MAE**	**MRE**	**RMSE**
Jan	0.08	0.03	1.07 (DCK_Exp)	0.20	4.01	1.42	0.06	4.01	1.68	0.28	3.72	1.33	0.02	3.49	1.20 (MQ)	0.13	3.40	1.25 (SK_RQ)
Feb	0.15	0.03	1.20 (SCK_Gau)	0.32	4.51	1.93	0.08	4.74	2.21	0.30	4.08	1.77	0.09	3.67	1.06 (IMQ)	1.08	4.35	1.25 (SK_RQ)
Mar	0.13	3.01	1.38 (DCK_Exp)	0.37	3.64	1.98	0.09	4.02	2.25	0.25	3.36	1.77	0.22	3.69	1.49 (IMQ)	0.84	3.06	1.36 (DK_Exp)
Apr	0.16	2.62	1.26 (DCK_RQ)	0.27	2.83	1.51	0.06	3.49	1.74	0.17	2.85	1.39	0.18	2.77	1.32 (CRS)	0.79	3.03	1.14 (DK_Exp)
May	0.04	8.26	0.63 (DCK_Exp)	0.15	2.23	0.94	0.04	2.90	1.09	0.11	1.98	0.86	0.10	1.91	0.76 (CRS)	0.51	2.02	0.80 (DK_Exp)
Jun	0.03	1.74	0.50 (DCK_Exp)	0.14	2.27	0.76	0.03	2.78	0.84	0.10	1.78	0.66	0.08	1.66	0.62 (CRS)	0.51	1.82	0.75 (DK_RQ)
Jul	0.04	1.83	0.51 (DCK_Exp)	0.15	2.48	0.78	0.03	3.09	0.88	0.13	2.48	0.63	0.04	1.72	0.53 (CRS)	0.53	1.92	0.80 (DK_Gau)
Aug	0.03	1.73	0.45 (DCK_Exp)	0.13	2.22	0.70	0.03	2.22	0.79	0.12	1.71	0.57	0.02	1.56	0.53 (IMQ)	0.53	1.97	0.76 (DK_RQ)
Sep	0.02	1.25	0.49 (DCK_Exp)	0.10	1.89	0.72	0.03	1.89	0.82	0.12	1.65	0.70	0.03	1.35	0.63 (IMQ)	0.38	1.42	0.61 (DK_RQ)
Oct	0.02	1.26	0.56 (DCK-Exp)	0.09	1.99	0.87	0.03	1.99	1.02	0.14	1.91	0.87	0.04	1.65	0.79 (CRS)	0.41	2.02	0.65 (DK_Exp)
Nov	0.03	1.25	0.66 (DCK_Exp)	0.12	2.48	1.10	0.04	2.48	1.33	0.19	2.42	1.06	0.01	2.19	0.96 (SWT)	0.53	2.14	0.85 (DK_Exp)
Dec	0.01	2.75	0.84 (DCK_Exp)	0.12	3.24	1.27	0.04	4.09	1.60	0.26	3.39	1.21	0.01	2.87	1.05 (SWT)	0.52	1.73	0.95 (DK_Sph)

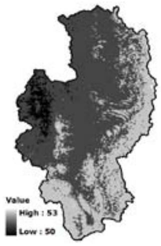
A.9 The spatial output of 19 bio-climatic variables from BIOCLIM model.



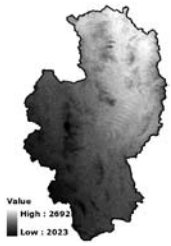
BIO1:Mean Annually Temperature



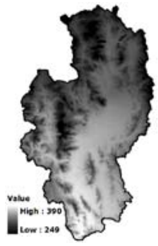
BIO2: Mean Diurnal Range



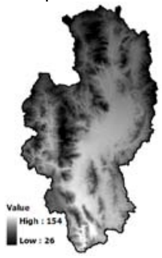
BIO3: Isothermality



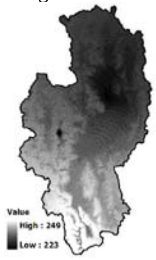
BIO4: Temperature Seasonality



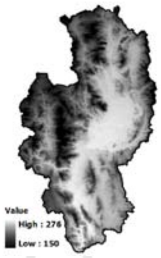
BIO5: Annually Maximum Temperature



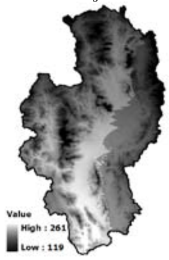
BIO6: Annually Minimum Temperature



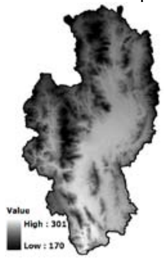
BIO7: Annually Temperature Range



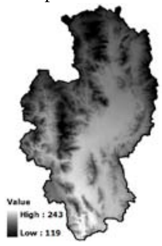
BIO8: Mean Temperature of Wettest Quarter



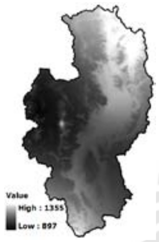
BIO9: Mean Temperature of Driest Quarter



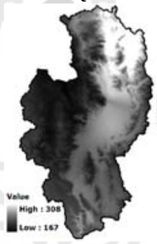
BIO10: Mean Temperature of Warmest Quarter



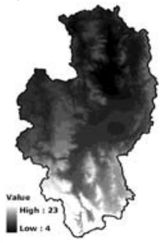
BIO11: Mean Temperature of Coldest Quarter



BIO12: Mean Annually Precipitation



BIO13: Annually Maximum Precipitation



BIO14: Annually Minimum Precipitation

BIO15: Precipitation Seasonality

BIO16: Precipitation of Wettest Quarter

BIO17: Precipitation of Driest Quarter

BIO18: Precipitation of Warmest Quarter

BIO19: Precipitation of Coldest Quarter

A.10 Correlation of 19 bioclimate variables

Bio. Var.	BIO1	BIO2	BIO3	BIO4	BIO5	BIO6	BIO7	BIO8	BIO9	BIO10	BIO11	BIO12	BIO13	BIO14	BIO15	BIO16	BIO17	BIO18	BIO19
BIO1	1	0.26	**-0.98**	-0.39	0.47	0.43	0.34	**0.93**	**0.99**	**1.00**	**0.98**	-0.58	0.54	0.50	0.43	**-0.84**	**0.87**	**-0.82**	**0.87**
BIO2		1	**0.94**	-0.40	0.43	0.28	0.31	**0.87**	**0.97**	**0.95**	**0.79**	-0.35	-0.41	0.39	-0.42	**-0.86**	**0.86**	**-0.89**	**0.88**
BIO3			1	0.21	-0.28	-0.22	0.22	**-0.97**	**-0.95**	**-0.99**	**-0.98**	0.38	0.32	0.47	-0.37	**0.92**	**0.96**	**0.95**	**0.97**
BIO4				1	-0.32	-0.27	-0.45	**0.92**	**-0.93**	**-0.98**	**-0.96**	0.33	0.64	-0.66	0.66	**0.86**	**-0.73**	**0.77**	**-0.74**
BIO5					1	0.48	0.56	**0.83**	**0.80**	**0.78**	**0.76**	-0.35	-0.44	0.29	0.44	**-0.84**	**0.88**	**-0.78**	**0.98**
BIO6						1	0.39	**0.90**	**0.92**	**0.91**	**0.86**	-0.26	0.06	0.13	0.20	**-0.82**	**0.87**	**-0.89**	**0.88**
BIO7							1	**0.97**	**0.89**	**0.94**	**0.96**	-0.09	-0.48	0.53	-0.13	**-0.78**	**0.76**	**-0.75**	**0.74**
BIO8								1	**0.76**	**0.95**	**0.88**	0.09	0.39	-0.11	0.43	**0.94**	**-0.91**	**-0.83**	**-0.98**
BIO9									1	**0.89**	**0.92**	-0.36	-0.10	0.16	0.09	**-0.91**	**0.87**	**-0.91**	**0.92**
BIO10										1	**0.98**	-0.48	0.45	0.59	0.44	**-0.82**	**0.96**	**-0.80**	**0.93**
BIO11											1	-0.31	0.41	0.42	0.41	**-0.82**	**0.99**	**-0.80**	**0.97**
BIO12												1	0.47	-0.57	0.54	**0.88**	**0.89**	**0.87**	**0.87**
BIO13													1	-0.53	0.49	**0.85**	**0.89**	**0.80**	**0.81**
BIO14														1	-0.44	**-0.82**	**0.78**	**-0.80**	**0.75**
BIO15															1	**0.84**	**-0.88**	**0.91**	**-0.81**
BIO16																1	**0.82**	**0.75**	**-0.77**
BIO17																	1	**0.82**	**0.84**
BIO18																		1	**-0.86**
BIO19																			1

Note: 1. Correlation is significant at the 0.05 level
2. Bold coefficients are highly correlated that are higher than 0.70.
3. Thin coefficients are slightly correlated that are lower than 0.

APPENDIX B

FACTOR ANALYSIS

B.1 Mixed deciduous forest with 164 forest inventory plots.

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
1	263.00	127.00	2313.00	380.00	137.00	243.00	1138.00	221.00	15.00	73.00	354.00	23.93	215.07	62-O
2	255.00	128.00	2302.00	373.00	127.00	246.00	1121.00	207.00	17.00	71.00	295.00	20.00	180.00	62-O
3	243.00	128.00	2204.00	360.00	116.00	244.00	1146.00	204.00	16.00	71.00	856.00	25.58	232.94	62-Trgr
4	258.00	125.00	2360.00	373.00	132.00	241.00	1052.00	217.00	13.00	76.00	631.00	56.29	2.12	48
5	250.00	126.00	2367.00	364.00	123.00	241.00	1034.00	208.00	15.00	74.00	775.00	42.35	13.08	62-Qt
6	265.00	124.00	2314.00	380.00	141.00	239.00	1090.00	225.00	10.00	78.00	331.00	6.35	246.80	RL
7	260.00	126.00	2345.00	375.00	134.00	241.00	1067.00	216.00	12.00	76.00	464.00	50.75	299.51	52
8	249.00	126.00	2360.00	364.00	122.00	242.00	1029.00	205.00	14.00	74.00	695.00	6.72	330.26	29
9	260.00	125.00	2332.00	375.00	135.00	240.00	1053.00	218.00	11.00	77.00	499.00	10.62	115.56	48
10	246.00	127.00	2356.00	360.00	119.00	241.00	1022.00	201.00	14.00	73.00	803.00	41.14	263.02	62-SD
11	231.00	127.00	2291.00	346.00	103.00	243.00	1037.00	191.00	16.00	72.00	734.00	54.04	289.83	62-SD
12	261.00	125.00	2296.00	376.00	135.00	241.00	1079.00	203.00	10.00	77.00	460.00	4.17	90.00	62-Tmm
13	263.00	124.00	2307.00	377.00	138.00	239.00	1064.00	217.00	10.00	78.00	324.00	7.93	273.01	29
14	261.00	124.00	2334.00	375.00	136.00	239.00	1043.00	219.00	10.00	78.00	435.00	1.67	270.00	48
15	246.00	126.00	2301.00	361.00	118.00	243.00	1012.00	186.00	12.00	75.00	811.00	8.33	90.00	62-Trm
16	261.00	124.00	2374.00	373.00	135.00	238.00	1036.00	223.00	9.00	79.00	391.00	10.67	141.34	GrSC
17	248.00	125.00	2401.00	360.00	119.00	241.00	1006.00	205.00	12.00	76.00	705.00	32.45	15.64	62-SD
18	247.00	125.00	2235.00	362.00	121.00	241.00	1014.00	190.00	11.00	77.00	814.00	25.93	23.68	62-Trm
19	245.00	126.00	2270.00	360.00	118.00	242.00	1003.00	185.00	12.00	75.00	810.00	26.78	275.36	62Trm
20	263.00	123.00	2335.00	376.00	138.00	238.00	1056.00	209.00	9.00	78.00	448.00	26.58	131.19	62-Trm
21	263.00	123.00	2297.00	376.00	137.00	239.00	1053.00	198.00	8.00	79.00	352.00	5.59	26.57	62-Trgr
22	256.00	124.00	2370.00	368.00	129.00	239.00	1015.00	212.00	10.00	78.00	441.00	8.70	16.70	62-CPk
23	254.00	124.00	2382.00	365.00	127.00	238.00	1008.00	213.00	10.00	78.00	488.00	46.29	13.54	62-O
24	252.00	124.00	2404.00	362.00	124.00	238.00	1004.00	213.00	10.00	79.00	572.00	11.32	353.66	44
25	254.00	123.00	2205.00	369.00	129.00	240.00	982.00	185.00	8.00	81.00	799.00	72.49	117.01	62-E
26	237.00	124.00	2257.00	351.00	110.00	241.00	982.00	194.00	10.00	78.00	656.00	10.82	344.36	62-O
27	246.00	124.00	2280.00	359.00	119.00	240.00	970.00	186.00	10.00	78.00	859.00	34.81	101.04	62-Trm
28	242.00	124.00	2279.00	356.00	115.00	241.00	974.00	187.00	11.00	77.00	878.00	2.43	120.96	62-Trgr
29	265.00	122.00	2354.00	375.00	140.00	235.00	1059.00	220.00	7.00	81.00	287.00	16.76	124.88	62-Qa
30	264.00	122.00	2373.00	375.00	139.00	236.00	1052.00	222.00	7.00	82.00	297.00	3.33	270.00	48

B.1 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
31	253.00	124.00	2450.00	363.00	125.00	238.00	1016.00	221.00	9.00	80.00	553.00	17.16	209.05	62-Trgr
32	250.00	124.00	2439.00	360.00	122.00	238.00	1015.00	216.00	9.00	79.00	631.00	26.28	87.27	62-Trgr
33	239.00	124.00	2282.00	354.00	113.00	241.00	968.00	194.00	9.00	79.00	705.00	38.81	266.92	62-Trm
34	243.00	124.00	2278.00	357.00	117.00	240.00	963.00	190.00	10.00	78.00	755.00	2.64	108.43	62-O
35	262.00	122.00	2365.00	373.00	137.00	236.00	1037.00	215.00	7.00	81.00	423.00	50.34	96.65	62-Qa
36	258.00	123.00	2444.00	368.00	132.00	236.00	1037.00	232.00	8.00	83.00	379.00	4.60	354.81	48
37	252.00	124.00	2434.00	361.00	124.00	237.00	1017.00	220.00	8.00	80.00	542.00	54.84	126.35	62-SD
38	245.00	124.00	2435.00	354.00	116.00	238.00	1011.00	209.00	10.00	77.00	611.00	38.37	87.51	62-SD
39	248.00	124.00	2421.00	357.00	120.00	237.00	1019.00	214.00	9.00	79.00	546.00	7.17	234.46	GrSC
40	260.00	121.00	2308.00	373.00	135.00	238.00	982.00	172.00	7.00	81.00	620.00	15.92	222.88	62-Trgr
41	247.00	123.00	2314.00	361.00	121.00	240.00	954.00	180.00	9.00	79.00	751.00	16.21	205.91	62-Trgr
42	255.00	122.00	2321.00	366.00	129.00	237.00	992.00	196.00	8.00	79.00	635.00	34.81	47.91	62-PE
43	248.00	124.00	2424.00	356.00	120.00	236.00	1026.00	217.00	9.00	79.00	513.00	26.70	112.96	62-SD
44	247.00	122.00	2273.00	361.00	122.00	239.00	939.00	184.00	8.00	80.00	664.00	8.76	177.27	62-Trgr
45	259.00	121.00	2348.00	369.00	134.00	235.00	1013.00	204.00	7.00	81.00	436.00	19.04	113.20	62-PE
46	214.00	124.00	2258.00	325.00	88.00	237.00	1007.00	192.00	10.00	76.00	1197.00	74.28	226.82	62-PE
47	246.00	123.00	2459.00	353.00	117.00	236.00	1048.00	217.00	8.00	79.00	536.00	20.92	35.27	62-C
48	251.00	123.00	2518.00	358.00	122.00	236.00	1066.00	224.00	8.00	82.00	474.00	12.50	306.87	62-Trgr
49	241.00	124.00	2433.00	347.00	111.00	236.00	1049.00	208.00	9.00	77.00	735.00	30.31	18.43	62-Trgr
50	257.00	120.00	2308.00	369.00	133.00	236.00	942.00	173.00	7.00	81.00	588.00	27.04	118.54	62-Trgr
51	238.00	122.00	2298.00	350.00	112.00	238.00	944.00	183.00	9.00	79.00	797.00	18.41	264.81	62-Trgr
52	250.00	122.00	2377.00	359.00	123.00	236.00	987.00	194.00	8.00	79.00	488.00	39.33	36.38	62-SDCtp
53	248.00	123.00	2501.00	355.00	119.00	236.00	1057.00	223.00	8.00	80.00	499.00	46.10	229.40	62-C
54	248.00	123.00	2490.00	354.00	119.00	235.00	1070.00	220.00	8.00	80.00	534.00	41.25	44.18	62-C
55	233.00	122.00	2262.00	345.00	107.00	238.00	946.00	192.00	8.00	80.00	1088.00	19.18	177.51	62-Trgr
56	237.00	124.00	2450.00	344.00	108.00	236.00	1057.00	207.00	9.00	77.00	775.00	28.09	35.34	62-C
57	238.00	124.00	2477.00	344.00	108.00	236.00	1073.00	208.00	9.00	77.00	553.00	13.46	338.20	62-SD
58	216.00	122.00	2229.00	327.00	91.00	236.00	991.00	196.00	8.00	78.00	1133.00	30.76	261.43	62-Trgr
59	251.00	120.00	2302.00	362.00	127.00	235.00	918.00	179.00	7.00	82.00	668.00	44.07	164.65	62-Trgr
60	254.00	119.00	2341.00	365.00	130.00	235.00	932.00	173.00	6.00	82.00	545.00	35.87	210.74	62-SDCtp
61	245.00	121.00	2331.00	356.00	119.00	237.00	936.00	177.00	8.00	79.00	777.00	18.83	114.86	62-Trgr
62	250.00	121.00	2390.00	359.00	124.00	235.00	996.00	194.00	7.00	79.00	524.00	41.40	20.62	62-O
63	243.00	122.00	2398.00	352.00	116.00	236.00	990.00	189.00	8.00	78.00	507.00	25.44	328.39	62-SDCtp
64	232.00	123.00	2455.00	338.00	102.00	236.00	1062.00	201.00	10.00	76.00	827.00	33.75	237.09	62-Trgr
65	236.00	123.00	2472.00	341.00	106.00	235.00	1081.00	206.00	9.00	77.00	819.00	14.55	346.76	62-SD
66	254.00	119.00	2316.00	365.00	131.00	234.00	922.00	175.00	6.00	82.00	611.00	8.27	130.91	62-Qt

B.1 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
67	207.00	122.00	2277.00	316.00	80.00	236.00	1022.00	189.00	9.00	75.00	1416.00	27.72	317.44	62-Trgr
68	243.00	121.00	2388.00	351.00	116.00	235.00	996.00	189.00	8.00	78.00	573.00	28.24	338.36	62-SDCtp
69	255.00	121.00	2458.00	362.00	128.00	234.00	1095.00	232.00	6.00	83.00	431.00	19.59	51.91	48
70	243.00	123.00	2465.00	348.00	114.00	234.00	1103.00	216.00	8.00	80.00	594.00	11.84	219.29	62-Trgr
71	236.00	123.00	2499.00	342.00	106.00	236.00	1094.00	208.00	9.00	78.00	746.00	48.24	340.31	62-SD
72	240.00	120.00	2324.00	352.00	115.00	237.00	917.00	185.00	7.00	82.00	1041.00	44.46	79.74	62-C
73	236.00	121.00	2345.00	346.00	109.00	237.00	943.00	179.00	8.00	79.00	914.00	31.96	219.71	62-Trgr
74	252.00	120.00	2433.00	358.00	126.00	232.00	1059.00	212.00	6.00	81.00	759.00	13.91	98.62	62-Trm
75	231.00	123.00	2455.00	335.00	101.00	234.00	1098.00	202.00	10.00	77.00	699.00	16.68	192.99	62-SD
76	227.00	122.00	2332.00	336.00	100.00	236.00	974.00	177.00	8.00	77.00	1204.00	11.84	140.71	62-Trgr
77	242.00	121.00	2375.00	350.00	115.00	235.00	994.00	183.00	7.00	79.00	811.00	31.28	221.76	62-Trm
78	248.00	120.00	2449.00	355.00	121.00	234.00	1027.00	197.00	6.00	80.00	632.00	32.20	280.44	62-Trm
79	240.00	121.00	2425.00	346.00	112.00	234.00	1025.00	193.00	7.00	78.00	694.00	40.07	207.90	62-O
80	251.00	120.00	2475.00	356.00	123.00	233.00	1100.00	221.00	6.00	82.00	471.00	26.63	200.14	62-Trm
81	236.00	120.00	2315.00	348.00	111.00	237.00	922.00	190.00	6.00	83.00	1015.00	54.04	287.04	62-O
82	239.00	120.00	2362.00	349.00	113.00	236.00	943.00	174.00	7.00	80.00	942.00	40.81	152.65	62-O
83	246.00	119.00	2386.00	353.00	120.00	233.00	998.00	182.00	6.00	79.00	835.00	15.56	290.38	62-Trm
84	247.00	120.00	2410.00	354.00	121.00	233.00	1022.00	191.00	6.00	79.00	729.00	37.65	5.08	62-Trm
85	248.00	120.00	2427.00	353.00	121.00	232.00	1040.00	197.00	6.00	80.00	566.00	28.17	7.65	62-SDCtp
86	237.00	121.00	2449.00	343.00	109.00	234.00	1030.00	190.00	8.00	78.00	810.00	18.15	328.13	62-Trgr
87	221.00	122.00	2374.00	328.00	93.00	235.00	1031.00	179.00	9.00	75.00	922.00	52.82	276.34	62-Trgr
88	224.00	123.00	2446.00	329.00	94.00	235.00	1112.00	198.00	10.00	76.00	931.00	45.43	348.90	62-Trgr
89	235.00	120.00	2323.00	345.00	110.00	235.00	936.00	183.00	7.00	81.00	997.00	39.73	347.28	62-C
90	215.00	122.00	2327.00	324.00	88.00	236.00	1003.00	181.00	8.00	77.00	1035.00	41.80	246.50	62-Trgr
91	216.00	121.00	2360.00	325.00	89.00	236.00	1002.00	178.00	8.00	77.00	1438.00	40.59	5.30	62-Trgr
92	235.00	120.00	2371.00	343.00	109.00	234.00	983.00	170.00	7.00	78.00	874.00	32.28	113.59	62-Trgr
93	243.00	120.00	2392.00	350.00	117.00	233.00	1000.00	180.00	6.00	79.00	716.00	29.59	270.81	62-Trm
94	233.00	121.00	2391.00	340.00	106.00	234.00	1026.00	184.00	8.00	77.00	714.00	44.36	331.99	62-O
95	248.00	120.00	2541.00	349.00	118.00	231.00	1177.00	240.00	6.00	83.00	378.00	7.75	216.25	62-C
96	247.00	121.00	2528.00	348.00	117.00	231.00	1175.00	239.00	6.00	83.00	522.00	5.92	129.29	62-PTrv
97	238.00	122.00	2527.00	341.00	108.00	233.00	1149.00	223.00	8.00	80.00	553.00	25.93	23.68	62-Trgr
98	239.00	119.00	2377.00	349.00	114.00	235.00	940.00	176.00	6.00	81.00	769.00	44.54	297.28	62-E
99	243.00	119.00	2411.00	350.00	117.00	233.00	998.00	177.00	6.00	79.00	702.00	15.42	91.55	62-Trm
100	238.00	120.00	2422.00	345.00	111.00	234.00	1001.00	176.00	7.00	78.00	812.00	42.70	197.02	62-SDCtp
101	247.00	119.00	2449.00	352.00	120.00	232.00	1060.00	196.00	6.00	80.00	592.00	5.80	201.04	62-SDCtp
102	236.00	121.00	2507.00	339.00	106.00	233.00	1158.00	225.00	8.00	80.00	755.00	32.67	174.14	62-Trgr

B.1 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
103	230.00	120.00	2331.00	339.00	104.00	235.00	961.00	178.00	7.00	79.00	1033.00	31.19	67.20	62-O
104	236.00	120.00	2409.00	343.00	109.00	234.00	1011.00	176.00	7.00	78.00	936.00	11.44	123.11	62-Trgr
105	230.00	121.00	2437.00	336.00	102.00	234.00	1050.00	185.00	8.00	77.00	912.00	34.49	25.02	62-Trgr
106	228.00	120.00	2334.00	338.00	103.00	235.00	960.00	182.00	6.00	80.00	1133.00	37.29	309.56	62-E
107	241.00	121.00	2543.00	341.00	111.00	230.00	1205.00	250.00	7.00	82.00	633.00	16.03	261.03	62-C
108	243.00	119.00	2510.00	345.00	114.00	231.00	1105.00	206.00	5.00	80.00	688.00	29.78	287.93	62-Trm
109	245.00	119.00	2551.00	345.00	115.00	230.00	1191.00	247.00	5.00	83.00	446.00	42.66	12.41	62-C
110	243.00	120.00	2553.00	343.00	113.00	230.00	1192.00	246.00	6.00	83.00	539.00	10.29	58.24	47
111	235.00	120.00	2476.00	340.00	107.00	233.00	1069.00	186.00	6.00	78.00	893.00	25.31	237.09	62-Trm
112	240.00	119.00	2480.00	344.00	112.00	232.00	1098.00	201.00	5.00	80.00	827.00	15.50	36.25	62-PE
113	250.00	118.00	2590.00	349.00	119.00	230.00	1233.00	268.00	4.00	85.00	463.00	18.04	263.37	48
114	227.00	120.00	2465.00	332.00	98.00	234.00	1083.00	185.00	7.00	77.00	929.00	55.08	280.46	62-Cgr
115	225.00	121.00	2446.00	330.00	96.00	234.00	1089.00	186.00	7.00	77.00	832.00	32.83	203.96	62-Cgr
116	240.00	120.00	2578.00	341.00	110.00	231.00	1221.00	257.00	6.00	83.00	971.00	53.55	20.97	62-C
117	227.00	121.00	2547.00	330.00	96.00	234.00	1206.00	239.00	8.00	80.00	1116.00	50.35	335.56	62-Trgr
118	211.00	121.00	2414.00	316.00	83.00	233.00	1091.00	180.00	9.00	76.00	1096.00	37.94	271.89	62-Trgr
119	247.00	118.00	2539.00	349.00	119.00	230.00	1183.00	243.00	4.00	83.00	518.00	33.18	244.72	29
120	252.00	118.00	2593.00	352.00	123.00	229.00	1253.00	277.00	4.00	86.00	353.00	6.51	140.19	59
121	246.00	119.00	2607.00	346.00	116.00	230.00	1237.00	267.00	5.00	84.00	523.00	49.26	308.13	62-C
122	236.00	121.00	2542.00	337.00	105.00	232.00	1235.00	258.00	7.00	82.00	686.00	23.72	239.38	62-SD
123	243.00	119.00	2523.00	345.00	115.00	230.00	1163.00	231.00	5.00	82.00	630.00	36.68	358.70	62-Trgr
124	237.00	119.00	2543.00	340.00	108.00	232.00	1151.00	222.00	5.00	81.00	753.00	21.22	226.59	62-O
125	237.00	120.00	2517.00	339.00	107.00	232.00	1165.00	227.00	6.00	80.00	769.00	60.15	102.40	62-CP
126	247.00	119.00	2578.00	347.00	117.00	230.00	1276.00	283.00	5.00	85.00	513.00	13.29	147.80	48
127	248.00	119.00	2605.00	349.00	119.00	230.00	1247.00	270.00	4.00	85.00	450.00	2.12	11.31	62-CP
128	246.00	119.00	2582.00	347.00	117.00	230.00	1250.00	270.00	5.00	84.00	490.00	39.64	93.01	62-CP
129	242.00	120.00	2589.00	342.00	112.00	230.00	1296.00	286.00	6.00	84.00	526.00	24.52	80.22	62-C
130	229.00	120.00	2503.00	335.00	101.00	234.00	1112.00	198.00	6.00	79.00	858.00	28.29	223.81	62-SD
131	238.00	119.00	2589.00	341.00	109.00	232.00	1197.00	242.00	5.00	82.00	708.00	31.90	33.27	62-Trgr
132	244.00	120.00	2602.00	345.00	114.00	231.00	1318.00	297.00	5.00	86.00	476.00	15.42	321.58	48
133	227.00	121.00	2545.00	329.00	97.00	232.00	1263.00	262.00	8.00	81.00	843.00	33.59	246.61	62-Trgr
134	234.00	120.00	2540.00	337.00	105.00	232.00	1198.00	239.00	5.00	81.00	813.00	26.35	145.30	62-C
135	230.00	121.00	2557.00	331.00	100.00	231.00	1238.00	253.00	7.00	81.00	693.00	26.31	349.05	62-CPk
136	240.00	119.00	2529.00	344.00	112.00	232.00	1177.00	233.00	4.00	81.00	705.00	25.85	20.77	62-C
137	225.00	120.00	2492.00	329.00	97.00	232.00	1163.00	218.00	6.00	80.00	894.00	35.63	169.22	62-C
138	236.00	120.00	2593.00	339.00	107.00	232.00	1218.00	249.00	5.00	82.00	702.00	46.48	354.34	62-C

B.1 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
139	249.00	119.00	2582.00	350.00	120.00	230.00	1296.00	289.00	4.00	86.00	451.00	21.12	75.14	62-C
140	232.00	120.00	2565.00	334.00	103.00	231.00	1242.00	256.00	6.00	82.00	756.00	92.08	338.78	62-Png2
141	241.00	120.00	2608.00	342.00	111.00	231.00	1294.00	283.00	5.00	85.00	596.00	19.52	343.89	62-CP
142	240.00	120.00	2618.00	341.00	110.00	231.00	1302.00	286.00	5.00	85.00	727.00	44.85	234.83	62-C
143	222.00	120.00	2528.00	326.00	93.00	233.00	1169.00	218.00	6.00	79.00	934.00	31.38	190.71	62-C
144	232.00	121.00	2576.00	333.00	102.00	231.00	1285.00	273.00	6.00	82.00	608.00	29.74	281.31	62-Cb
145	239.00	120.00	2606.00	340.00	109.00	231.00	1338.00	298.00	6.00	85.00	613.00	16.75	84.29	62-C
146	240.00	120.00	2658.00	342.00	110.00	232.00	1331.00	296.00	5.00	85.00	688.00	48.45	148.36	62-C
147	231.00	121.00	2597.00	333.00	102.00	231.00	1311.00	283.00	6.00	83.00	792.00	39.02	6.75	62-C
148	233.00	119.00	2531.00	337.00	105.00	232.00	1175.00	225.00	5.00	81.00	828.00	8.70	106.70	62-C
149	238.00	120.00	2612.00	341.00	110.00	231.00	1262.00	266.00	5.00	83.00	782.00	34.32	60.95	62-C
150	230.00	120.00	2583.00	332.00	101.00	231.00	1275.00	266.00	6.00	82.00	817.00	68.53	162.67	62-Png2
151	238.00	120.00	2624.00	339.00	108.00	231.00	1314.00	287.00	5.00	84.00	693.00	33.81	67.54	62-C
152	239.00	120.00	2621.00	340.00	109.00	231.00	1336.00	296.00	5.00	85.00	639.00	20.58	68.63	62-C
153	203.00	120.00	2511.00	306.00	74.00	232.00	1195.00	212.00	8.00	77.00	1277.00	51.44	144.89	62-C
154	246.00	120.00	2645.00	348.00	117.00	231.00	1313.00	291.00	4.00	86.00	549.00	34.66	189.69	62-Png2
155	235.00	120.00	2643.00	338.00	105.00	233.00	1318.00	286.00	6.00	84.00	637.00	24.56	194.74	62-C
156	225.00	120.00	2558.00	329.00	96.00	233.00	1194.00	227.00	5.00	80.00	895.00	23.37	281.31	48
157	218.00	120.00	2579.00	322.00	88.00	234.00	1198.00	223.00	6.00	79.00	1144.00	44.27	54.96	62-C
158	213.00	120.00	2513.00	317.00	84.00	233.00	1202.00	222.00	7.00	78.00	1133.00	45.38	224.26	62-C
159	240.00	120.00	2643.00	342.00	111.00	231.00	1306.00	283.00	5.00	85.00	601.00	39.73	102.72	62-Png2
160	231.00	120.00	2602.00	334.00	102.00	232.00	1288.00	270.00	6.00	83.00	824.00	21.25	191.31	62-Png2
161	226.00	121.00	2617.00	328.00	96.00	232.00	1285.00	265.00	6.00	82.00	928.00	39.00	220.67	62-Png2
162	213.00	121.00	2576.00	316.00	84.00	232.00	1267.00	250.00	8.00	80.00	1160.00	26.17	76.18	62-Png2
163	212.00	120.00	2564.00	315.00	82.00	233.00	1230.00	231.00	7.00	79.00	1140.00	21.06	242.93	62-C
164	225.00	120.00	2620.00	329.00	96.00	233.00	1257.00	253.00	6.00	82.00	983.00	23.19	107.78	62-C

Note: BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (standard deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (standard deviation), elevation (m), slope (%), aspect (direction), and soil (modified soil group)

B.2 Dry dipterocarp forest with 179 forest inventory plots.

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
1	244.00	129.00	2186.00	362.00	117.00	245.00	1165.00	208.00	19.00	69.00	979.00	8.99	13.39	30
2	264.00	125.00	2325.00	381.00	140.00	241.00	1114.00	224.00	13.00	75.00	552.00	21.42	52.91	48
3	260.00	126.00	2362.00	377.00	134.00	243.00	1097.00	218.00	14.00	74.00	514.00	22.92	207.03	48
4	262.00	127.00	2287.00	379.00	136.00	243.00	1132.00	217.00	14.00	73.00	552.00	29.36	145.41	62-Trgr
5	259.00	127.00	2296.00	376.00	133.00	243.00	1108.00	215.00	15.00	73.00	745.00	30.08	10.38	62-C2
6	255.00	125.00	2400.00	371.00	130.00	241.00	1052.00	215.00	14.00	75.00	726.00	24.04	351.03	62-Qt
7	239.00	127.00	2173.00	355.00	112.00	243.00	1130.00	205.00	17.00	71.00	1014.00	14.39	79.99	62-Trgr
8	237.00	128.00	2210.00	354.00	110.00	244.00	1119.00	205.00	17.00	71.00	1011.00	11.33	162.90	30
9	249.00	128.00	2234.00	366.00	122.00	244.00	1121.00	201.00	16.00	71.00	790.00	8.37	5.71	62-Trgr
10	238.00	127.00	2185.00	354.00	111.00	243.00	1128.00	205.00	16.00	71.00	1019.00	17.96	266.01	62-Trgr
11	242.00	128.00	2218.00	359.00	115.00	244.00	1117.00	202.00	16.00	71.00	998.00	6.01	236.31	62-Trgr
12	250.00	128.00	2236.00	367.00	122.00	245.00	1112.00	198.00	15.00	72.00	815.00	9.81	102.26	62-Trgr
13	255.00	125.00	2358.00	369.00	130.00	239.00	1033.00	215.00	13.00	75.00	589.00	18.89	221.42	62-SD
14	236.00	127.00	2179.00	351.00	109.00	242.00	1115.00	205.00	16.00	73.00	1042.00	14.87	101.31	62-Trgr
15	252.00	127.00	2220.00	369.00	125.00	244.00	1096.00	194.00	14.00	73.00	704.00	24.22	26.57	62-Trgr
16	269.00	123.00	2325.00	383.00	145.00	238.00	1132.00	230.00	9.00	78.00	274.00	5.59	116.57	48
17	256.00	125.00	2354.00	369.00	130.00	239.00	1031.00	214.00	12.00	76.00	564.00	8.19	345.26	35
18	243.00	127.00	2208.00	360.00	117.00	243.00	1082.00	198.00	15.00	72.00	934.00	10.62	311.82	62-Trgr
19	237.00	127.00	2203.00	352.00	110.00	242.00	1077.00	200.00	16.00	72.00	1004.00	47.70	252.20	62-Trgr
20	262.00	125.00	2344.00	377.00	136.00	241.00	1068.00	218.00	11.00	76.00	526.00	40.04	192.01	62-Trgr
21	263.00	125.00	2358.00	377.00	136.00	241.00	1066.00	220.00	11.00	77.00	422.00	5.80	111.04	62-Trgr
22	242.00	127.00	2343.00	355.00	114.00	241.00	1018.00	199.00	15.00	73.00	787.00	45.33	251.23	62-SD
23	248.00	127.00	2249.00	364.00	121.00	243.00	1058.00	192.00	14.00	73.00	748.00	23.39	4.09	62-PE
24	264.00	124.00	2298.00	379.00	139.00	240.00	1099.00	215.00	10.00	77.00	471.00	44.02	17.06	62-PE
25	261.00	125.00	2352.00	375.00	134.00	241.00	1047.00	218.00	11.00	77.00	444.00	7.93	86.99	48
26	246.00	126.00	2355.00	359.00	118.00	241.00	1013.00	203.00	14.00	74.00	717.00	20.70	229.90	48
27	252.00	126.00	2230.00	367.00	126.00	241.00	1057.00	187.00	12.00	74.00	726.00	32.20	280.44	62-Trgr
28	261.00	125.00	2276.00	376.00	136.00	240.00	1077.00	206.00	10.00	77.00	457.00	20.62	104.04	62-O
29	266.00	123.00	2301.00	379.00	141.00	238.00	1085.00	221.00	9.00	78.00	336.00	3.77	186.34	48
30	261.00	124.00	2381.00	373.00	134.00	239.00	1040.00	220.00	10.00	78.00	427.00	2.43	149.04	48
31	255.00	125.00	2378.00	368.00	128.00	240.00	1022.00	212.00	12.00	76.00	632.00	16.38	172.69	62-SD
32	252.00	125.00	2391.00	365.00	124.00	241.00	1015.00	209.00	12.00	76.00	630.00	6.90	295.02	48
33	244.00	126.00	2244.00	359.00	116.00	243.00	1032.00	192.00	13.00	74.00	767.00	23.47	286.50	62-Trgr
34	259.00	125.00	2297.00	374.00	133.00	241.00	1056.00	198.00	10.00	76.00	427.00	21.87	107.74	62-Trm
35	266.00	123.00	2303.00	379.00	141.00	238.00	1091.00	216.00	9.00	79.00	289.00	14.17	118.07	62-Qt
36	263.00	124.00	2339.00	377.00	138.00	239.00	1063.00	216.00	9.00	78.00	365.00	5.34	218.66	48

B.2 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
37	260.00	124.00	2338.00	373.00	133.00	240.00	1040.00	211.00	10.00	77.00	540.00	11.21	138.01	62-Qt
38	252.00	125.00	2387.00	364.00	124.00	240.00	1012.00	209.00	12.00	76.00	665.00	23.24	14.53	48
39	237.00	126.00	2231.00	352.00	111.00	241.00	1027.00	196.00	13.00	75.00	1037.00	14.92	144.09	62-Trgr
40	256.00	125.00	2320.00	371.00	129.00	242.00	1026.00	197.00	11.00	77.00	601.00	39.64	176.99	62-Trm
41	264.00	123.00	2337.00	377.00	139.00	238.00	1063.00	217.00	9.00	79.00	318.00	8.27	319.09	48
42	256.00	125.00	2311.00	369.00	129.00	240.00	1023.00	205.00	11.00	76.00	515.00	12.02	213.69	62-Qt
43	260.00	124.00	2357.00	372.00	134.00	238.00	1030.00	218.00	10.00	79.00	535.00	36.12	163.24	62-CPk
44	240.00	125.00	2223.00	355.00	113.00	242.00	1021.00	197.00	12.00	76.00	991.00	29.75	307.03	62-Tmm
45	235.00	125.00	2214.00	350.00	109.00	241.00	1018.00	196.00	12.00	76.00	887.00	12.72	58.39	62-Tmm
46	254.00	125.00	2261.00	368.00	127.00	241.00	1016.00	183.00	10.00	77.00	630.00	33.33	90.00	62-Trm
47	252.00	125.00	2346.00	366.00	125.00	241.00	1008.00	200.00	11.00	76.00	478.00	29.66	155.96	62-SD
48	242.00	125.00	2247.00	357.00	116.00	241.00	1009.00	196.00	11.00	77.00	820.00	25.19	235.78	62-Trm
49	250.00	124.00	2248.00	365.00	124.00	241.00	1002.00	186.00	10.00	78.00	940.00	31.55	12.20	62-Trm
50	251.00	124.00	2270.00	367.00	125.00	242.00	999.00	183.00	10.00	77.00	669.00	16.59	308.88	62-Trm
51	254.00	124.00	2287.00	368.00	127.00	241.00	1004.00	179.00	10.00	78.00	589.00	13.24	335.85	62-Trm
52	242.00	125.00	2295.00	357.00	115.00	242.00	994.00	188.00	12.00	76.00	863.00	40.86	168.23	62-Trm
53	265.00	123.00	2301.00	377.00	140.00	237.00	1062.00	208.00	8.00	80.00	375.00	16.30	122.47	62-Trm
54	260.00	123.00	2305.00	372.00	134.00	238.00	1029.00	202.00	9.00	79.00	488.00	24.17	133.60	62-PE
55	264.00	122.00	2350.00	376.00	138.00	238.00	1053.00	217.00	8.00	80.00	321.00	10.87	237.53	48
56	260.00	123.00	2376.00	372.00	134.00	238.00	1030.00	213.00	9.00	79.00	414.00	15.86	356.99	35
57	262.00	123.00	2414.00	373.00	136.00	237.00	1038.00	225.00	8.00	81.00	352.00	9.15	300.07	48
58	241.00	124.00	2214.00	356.00	115.00	241.00	996.00	196.00	10.00	78.00	1057.00	32.47	146.51	62-Trm
59	260.00	123.00	2304.00	374.00	134.00	240.00	1020.00	183.00	8.00	78.00	423.00	12.60	145.78	62-Trm
60	252.00	124.00	2268.00	366.00	126.00	240.00	989.00	179.00	10.00	77.00	610.00	39.31	265.14	62-Trm
61	243.00	125.00	2308.00	358.00	116.00	242.00	982.00	183.00	11.00	77.00	846.00	7.12	20.56	62-EO
62	257.00	123.00	2379.00	368.00	131.00	237.00	1019.00	219.00	9.00	80.00	390.00	3.58	305.54	62-SD
63	260.00	122.00	2303.00	374.00	134.00	240.00	1004.00	176.00	7.00	80.00	543.00	31.87	64.44	62-Trm
64	255.00	123.00	2381.00	368.00	128.00	240.00	997.00	196.00	9.00	78.00	531.00	19.59	128.09	62-PE
65	263.00	122.00	2374.00	373.00	137.00	236.00	1045.00	224.00	8.00	81.00	371.00	34.22	47.96	62-SD
66	254.00	123.00	2387.00	365.00	128.00	237.00	1008.00	215.00	9.00	79.00	609.00	59.51	33.58	62-SD
67	249.00	124.00	2400.00	359.00	121.00	238.00	1008.00	212.00	10.00	77.00	779.00	59.84	102.88	62-SD
68	242.00	124.00	2287.00	355.00	115.00	240.00	964.00	186.00	10.00	78.00	863.00	69.57	198.87	62-Trm
69	257.00	123.00	2422.00	368.00	131.00	237.00	1026.00	224.00	8.00	82.00	373.00	8.50	258.69	48
70	259.00	123.00	2429.00	368.00	132.00	236.00	1035.00	229.00	8.00	82.00	390.00	2.43	30.96	44
71	256.00	123.00	2425.00	365.00	129.00	236.00	1030.00	229.00	8.00	82.00	526.00	35.60	147.43	62-SD
72	255.00	122.00	2295.00	368.00	130.00	238.00	961.00	176.00	8.00	79.00	627.00	44.54	17.42	62-Trgr

B.2 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
73	261.00	122.00	2420.00	370.00	135.00	235.00	1051.00	233.00	7.00	83.00	329.00	3.95	341.57	35
74	260.00	122.00	2453.00	369.00	133.00	236.00	1052.00	237.00	7.00	84.00	364.00	8.98	68.20	48
75	255.00	123.00	2448.00	362.00	127.00	235.00	1038.00	228.00	8.00	81.00	482.00	38.56	173.80	48
76	244.00	124.00	2429.00	352.00	115.00	237.00	1025.00	210.00	9.00	77.00	632.00	14.19	356.63	62-Trgr
77	253.00	122.00	2279.00	366.00	128.00	238.00	940.00	182.00	8.00	81.00	859.00	33.48	73.37	62-Trgr
78	253.00	123.00	2442.00	362.00	125.00	237.00	1033.00	228.00	7.00	82.00	339.00	8.01	278.97	48
79	257.00	122.00	2470.00	365.00	130.00	235.00	1055.00	239.00	7.00	85.00	385.00	16.41	66.04	48
80	253.00	122.00	2382.00	363.00	127.00	236.00	993.00	198.00	8.00	80.00	502.00	45.46	182.63	62-O
81	258.00	121.00	2377.00	367.00	132.00	235.00	1029.00	215.00	7.00	82.00	376.00	10.02	135.00	48
82	259.00	122.00	2487.00	366.00	131.00	235.00	1073.00	245.00	6.00	86.00	468.00	16.64	22.07	62-C
83	255.00	123.00	2484.00	362.00	127.00	235.00	1069.00	234.00	7.00	83.00	525.00	34.98	102.38	62-Png1
84	243.00	122.00	2296.00	356.00	118.00	238.00	923.00	188.00	8.00	82.00	883.00	36.12	163.24	62-Trgr
85	249.00	121.00	2293.00	361.00	124.00	237.00	931.00	179.00	8.00	81.00	740.00	57.86	78.37	62-O
86	254.00	121.00	2383.00	364.00	128.00	236.00	1014.00	208.00	7.00	81.00	447.00	23.24	284.53	48
87	259.00	121.00	2410.00	368.00	134.00	234.00	1058.00	226.00	7.00	83.00	362.00	5.56	102.99	35
88	232.00	124.00	2425.00	339.00	103.00	236.00	1039.00	198.00	10.00	75.00	759.00	68.58	355.12	62-C
89	249.00	123.00	2497.00	355.00	120.00	235.00	1076.00	220.00	8.00	81.00	706.00	15.95	40.76	62-Qa
90	252.00	120.00	2351.00	364.00	127.00	237.00	923.00	178.00	7.00	82.00	921.00	50.62	57.09	62-Trgr
91	250.00	120.00	2320.00	361.00	125.00	236.00	929.00	178.00	7.00	81.00	688.00	4.71	135.00	62-Trgr
92	256.00	122.00	2512.00	361.00	127.00	234.00	1104.00	239.00	7.00	84.00	381.00	31.00	143.75	62-C
93	247.00	123.00	2503.00	353.00	118.00	235.00	1070.00	221.00	8.00	80.00	471.00	34.85	116.26	62-C
94	236.00	121.00	2287.00	348.00	111.00	237.00	925.00	191.00	7.00	81.00	954.00	54.33	327.53	62-SDCtp
95	253.00	118.00	2319.00	365.00	130.00	235.00	910.00	180.00	6.00	84.00	658.00	23.75	52.13	62-Trgr
96	256.00	118.00	2320.00	366.00	133.00	233.00	942.00	170.00	6.00	81.00	548.00	32.73	328.54	62-SDCtp
97	232.00	122.00	2304.00	343.00	106.00	237.00	947.00	182.00	8.00	79.00	985.00	60.52	218.29	62-Trgr
98	241.00	121.00	2352.00	349.00	115.00	234.00	970.00	176.00	8.00	78.00	829.00	24.59	90.97	62-PE
99	251.00	120.00	2418.00	359.00	124.00	235.00	1008.00	195.00	7.00	79.00	625.00	10.17	124.99	62-O
100	252.00	122.00	2505.00	356.00	123.00	233.00	1123.00	231.00	7.00	83.00	536.00	53.28	257.81	56
101	249.00	122.00	2500.00	353.00	120.00	233.00	1114.00	225.00	7.00	82.00	583.00	22.92	1.04	62-Trgr
102	247.00	119.00	2321.00	359.00	123.00	236.00	900.00	186.00	6.00	83.00	789.00	14.34	215.54	62-C
103	248.00	119.00	2349.00	359.00	124.00	235.00	918.00	178.00	6.00	82.00	791.00	35.40	206.57	62-SDCtp
104	252.00	119.00	2356.00	362.00	128.00	234.00	931.00	172.00	6.00	82.00	733.00	25.34	350.54	62-SDCtp
105	236.00	122.00	2392.00	345.00	109.00	236.00	973.00	173.00	8.00	77.00	977.00	10.54	341.57	62-Trgr
106	239.00	122.00	2475.00	343.00	110.00	233.00	1107.00	212.00	9.00	79.00	836.00	45.34	197.10	62-SD
107	247.00	119.00	2333.00	359.00	124.00	235.00	903.00	185.00	6.00	84.00	873.00	47.28	22.27	62-C
108	246.00	119.00	2334.00	357.00	122.00	235.00	919.00	178.00	6.00	82.00	819.00	17.21	186.95	62-C

B.2 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
109	248.00	119.00	2330.00	359.00	124.00	235.00	929.00	173.00	6.00	81.00	610.00	4.29	330.95	62-C
110	212.00	122.00	2297.00	321.00	84.00	237.00	1009.00	185.00	9.00	76.00	1377.00	23.24	14.53	62-Trgr
111	250.00	121.00	2574.00	353.00	120.00	233.00	1158.00	230.00	7.00	83.00	494.00	4.17	216.87	62-PTrv
112	236.00	122.00	2476.00	339.00	105.00	234.00	1109.00	208.00	9.00	78.00	629.00	57.67	236.20	47
113	225.00	121.00	2303.00	336.00	99.00	237.00	957.00	188.00	7.00	80.00	1155.00	31.58	239.04	62-SDCtp
114	245.00	119.00	2358.00	355.00	120.00	235.00	932.00	174.00	6.00	81.00	754.00	29.59	99.73	62-C
115	238.00	121.00	2446.00	345.00	110.00	235.00	1021.00	188.00	7.00	77.00	829.00	32.43	20.30	62-O
116	243.00	122.00	2560.00	346.00	112.00	234.00	1147.00	224.00	7.00	81.00	676.00	28.29	46.19	62-C
117	234.00	120.00	2306.00	344.00	109.00	235.00	933.00	185.00	7.00	82.00	1043.00	28.89	213.23	62-C
118	242.00	119.00	2351.00	352.00	117.00	235.00	932.00	177.00	6.00	81.00	732.00	32.75	36.72	62-SDCtp
119	242.00	120.00	2419.00	348.00	115.00	233.00	1013.00	184.00	6.00	79.00	703.00	43.46	355.60	62-O
120	251.00	119.00	2452.00	356.00	124.00	232.00	1067.00	201.00	5.00	81.00	767.00	9.81	347.74	62-SDCtp
121	253.00	118.00	2539.00	353.00	124.00	229.00	1187.00	243.00	5.00	84.00	349.00	4.71	225.00	48
122	238.00	120.00	2438.00	345.00	111.00	234.00	1014.00	180.00	7.00	78.00	720.00	38.77	115.46	62-SDCtp
123	252.00	119.00	2599.00	351.00	122.00	229.00	1210.00	258.00	5.00	85.00	359.00	3.95	198.43	48
124	230.00	120.00	2385.00	338.00	104.00	234.00	991.00	167.00	7.00	78.00	1144.00	8.84	351.87	62-PE
125	240.00	120.00	2447.00	346.00	113.00	233.00	1029.00	183.00	6.00	79.00	755.00	8.33	270.00	62-PE
126	246.00	119.00	2424.00	350.00	119.00	231.00	1066.00	194.00	5.00	80.00	668.00	10.00	180.00	62-SDCtp
127	230.00	121.00	2446.00	336.00	102.00	234.00	1043.00	183.00	7.00	77.00	820.00	27.94	182.56	62-Trm
128	244.00	120.00	2537.00	345.00	114.00	231.00	1161.00	231.00	6.00	82.00	487.00	17.77	320.71	62-C
129	249.00	119.00	2550.00	348.00	119.00	229.00	1201.00	253.00	5.00	84.00	467.00	45.75	142.40	62-C
130	249.00	119.00	2569.00	348.00	119.00	229.00	1210.00	257.00	5.00	84.00	371.00	5.27	108.43	W
131	243.00	120.00	2550.00	344.00	113.00	231.00	1185.00	242.00	6.00	83.00	535.00	7.66	67.62	62-C
132	232.00	120.00	2340.00	341.00	106.00	235.00	958.00	178.00	6.00	81.00	1050.00	39.80	107.68	62-Trgr
133	247.00	119.00	2507.00	349.00	118.00	231.00	1139.00	223.00	5.00	82.00	527.00	22.00	232.70	62-Trm
134	247.00	119.00	2548.00	346.00	117.00	229.00	1193.00	250.00	5.00	84.00	506.00	48.87	348.69	62-C
135	239.00	120.00	2530.00	342.00	109.00	233.00	1160.00	229.00	6.00	81.00	828.00	45.60	102.13	62-C
136	235.00	121.00	2478.00	338.00	106.00	232.00	1155.00	224.00	7.00	80.00	580.00	10.87	265.60	29
137	238.00	121.00	2543.00	340.00	108.00	232.00	1179.00	236.00	7.00	81.00	671.00	32.41	223.96	62-C
138	238.00	121.00	2520.00	340.00	108.00	232.00	1184.00	239.00	7.00	81.00	730.00	16.03	332.10	62-C
139	252.00	118.00	2514.00	351.00	123.00	228.00	1191.00	250.00	4.00	84.00	398.00	11.26	128.99	48
140	241.00	120.00	2549.00	342.00	111.00	231.00	1196.00	246.00	6.00	82.00	613.00	21.22	46.59	48
141	245.00	120.00	2590.00	345.00	114.00	231.00	1224.00	261.00	6.00	83.00	524.00	12.50	36.87	62-C
142	228.00	122.00	2523.00	332.00	98.00	234.00	1167.00	224.00	8.00	79.00	804.00	27.13	259.38	62-C
143	239.00	120.00	2548.00	340.00	109.00	231.00	1199.00	246.00	6.00	82.00	639.00	8.27	229.09	47

B.2 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
144	235.00	121.00	2554.00	337.00	105.00	232.00	1202.00	245.00	7.00	81.00	660.00	34.20	133.03	62-C
145	249.00	118.00	2564.00	349.00	120.00	229.00	1197.00	252.00	4.00	84.00	475.00	18.87	136.79	48
146	242.00	120.00	2534.00	342.00	112.00	230.00	1215.00	256.00	5.00	83.00	631.00	34.95	39.19	62-C
147	229.00	121.00	2530.00	331.00	98.00	233.00	1200.00	238.00	8.00	79.00	662.00	33.27	157.93	62-SD
148	233.00	120.00	2486.00	337.00	105.00	232.00	1113.00	203.00	6.00	79.00	759.00	35.58	71.57	62-Trgr
149	249.00	118.00	2581.00	350.00	120.00	230.00	1209.00	256.00	4.00	85.00	437.00	32.87	30.47	62-CP
150	234.00	120.00	2557.00	336.00	104.00	232.00	1206.00	245.00	7.00	81.00	912.00	46.02	5.19	62-C
151	243.00	119.00	2571.00	344.00	113.00	231.00	1206.00	251.00	5.00	83.00	656.00	36.31	211.87	62-CP
152	238.00	120.00	2559.00	339.00	108.00	231.00	1208.00	249.00	6.00	82.00	593.00	14.06	348.02	62-C
153	235.00	120.00	2589.00	337.00	105.00	232.00	1250.00	264.00	7.00	82.00	733.00	37.58	183.81	62-SD
154	235.00	120.00	2569.00	337.00	106.00	231.00	1213.00	248.00	6.00	81.00	701.00	32.54	177.06	62-CP
155	236.00	119.00	2482.00	340.00	108.00	232.00	1139.00	215.00	5.00	81.00	728.00	18.28	226.85	62-C
156	238.00	120.00	2586.00	339.00	108.00	231.00	1236.00	259.00	5.00	82.00	622.00	35.17	126.33	62-CP
157	243.00	120.00	2618.00	344.00	113.00	231.00	1288.00	284.00	5.00	85.00	619.00	48.23	260.05	62-C
158	226.00	120.00	2502.00	331.00	98.00	233.00	1143.00	210.00	6.00	79.00	946.00	43.06	331.70	62-C
159	247.00	119.00	2594.00	348.00	118.00	230.00	1277.00	281.00	4.00	85.00	495.00	14.25	232.13	48
160	228.00	120.00	2554.00	330.00	98.00	232.00	1217.00	243.00	7.00	80.00	887.00	24.86	129.56	62-Png2
161	246.00	120.00	2627.00	346.00	117.00	229.00	1313.00	295.00	5.00	86.00	638.00	55.92	74.00	62-C
162	227.00	121.00	2561.00	328.00	97.00	231.00	1283.00	269.00	8.00	82.00	740.00	34.59	180.69	62-Trgr
163	232.00	120.00	2525.00	336.00	104.00	232.00	1168.00	225.00	5.00	80.00	849.00	33.05	103.86	62-C
164	244.00	120.00	2637.00	346.00	114.00	232.00	1318.00	294.00	5.00	86.00	700.00	73.74	137.75	62-Png2
165	239.00	120.00	2625.00	340.00	109.00	231.00	1328.00	295.00	6.00	85.00	614.00	25.67	166.87	62-CP
166	223.00	121.00	2571.00	325.00	93.00	232.00	1293.00	269.00	8.00	81.00	918.00	47.82	202.54	62-Trgr
167	246.00	119.00	2629.00	349.00	117.00	232.00	1295.00	285.00	4.00	86.00	479.00	14.77	286.39	62-Qt
168	241.00	120.00	2611.00	343.00	112.00	231.00	1291.00	281.00	5.00	85.00	500.00	23.15	300.26	62-C
169	240.00	120.00	2646.00	342.00	110.00	232.00	1315.00	290.00	5.00	85.00	727.00	44.60	299.68	62-Png2
170	232.00	119.00	2557.00	337.00	103.00	234.00	1182.00	228.00	5.00	81.00	810.00	3.95	108.43	62-Tmm
171	230.00	121.00	2601.00	331.00	100.00	231.00	1317.00	283.00	7.00	83.00	951.00	23.15	210.26	62-C
172	236.00	119.00	2585.00	341.00	108.00	233.00	1195.00	235.00	4.00	82.00	750.00	4.60	354.81	48
173	234.00	120.00	2614.00	338.00	105.00	233.00	1259.00	262.00	5.00	83.00	710.00	53.65	316.89	62-C
174	226.00	121.00	2588.00	328.00	97.00	231.00	1262.00	257.00	6.00	81.00	650.00	40.02	211.37	62-C
175	237.00	120.00	2623.00	339.00	107.00	232.00	1308.00	283.00	5.00	84.00	634.00	10.54	251.57	56
176	227.00	121.00	2609.00	329.00	97.00	232.00	1288.00	268.00	6.00	82.00	833.00	55.18	205.02	62-Png2
177	220.00	120.00	2558.00	324.00	90.00	234.00	1199.00	225.00	6.00	80.00	970.00	46.92	250.28	62-C
178	221.00	120.00	2567.00	325.00	93.00	232.00	1221.00	235.00	6.00	80.00	1052.00	27.50	90.00	62-C
179	230.00	120.00	2583.00	333.00	101.00	232.00	1270.00	263.00	5.00	83.00	838.00	20.63	316.64	62-C

Note: BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (standard deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (standard deviation), elevation (m), slope (%), aspect (direction), and soil (modified soil group)

B.3 Coniferous forest with 15 forest inventory plots.

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
1	238.00	127.00	2183.00	354.00	111.00	243.00	1135.00	205.00	16.00	72.00	1021.00	10.96	188.75	30
2	240.00	127.00	2210.00	357.00	113.00	244.00	1107.00	202.00	15.00	72.00	987.00	16.77	26.57	62-Trgr
3	242.00	121.00	2448.00	346.00	113.00	233.00	1056.00	204.00	7.00	78.00	654.00	45.11	205.14	62-Trm
4	227.00	121.00	2322.00	339.00	102.00	237.00	948.00	196.00	7.00	82.00	1227.00	26.46	123.44	62-SDCtp
5	240.00	120.00	2362.00	352.00	115.00	237.00	921.00	186.00	7.00	82.00	922.00	23.70	280.12	62-C
6	225.00	120.00	2394.00	335.00	98.00	237.00	979.00	179.00	7.00	79.00	1040.00	29.78	17.93	62-Trgr
7	233.00	120.00	2367.00	342.00	107.00	235.00	964.00	175.00	6.00	80.00	994.00	9.88	62.35	62-Tmm
8	229.00	120.00	2386.00	338.00	103.00	235.00	976.00	175.00	6.00	79.00	1058.00	25.00	270.00	62-Trgr
9	228.00	120.00	2404.00	336.00	101.00	235.00	985.00	174.00	7.00	79.00	1100.00	24.34	218.05	62-Trgr
10	227.00	119.00	2387.00	336.00	101.00	235.00	983.00	176.00	6.00	80.00	1113.00	21.93	231.17	62-Tmm
11	229.00	120.00	2387.00	338.00	103.00	235.00	987.00	173.00	6.00	79.00	1087.00	9.59	55.62	62-Trgr
12	228.00	120.00	2401.00	336.00	101.00	235.00	996.00	171.00	6.00	79.00	1066.00	2.43	239.04	62-Trgr
13	216.00	121.00	2477.00	320.00	87.00	233.00	1138.00	200.00	8.00	77.00	1193.00	30.33	142.82	62-Trgr
14	223.00	120.00	2539.00	328.00	95.00	233.00	1177.00	220.00	6.00	79.00	1044.00	29.46	61.26	62-Trgr
15	233.00	120.00	2602.00	338.00	104.00	234.00	1201.00	235.00	4.00	81.00	803.00	8.19	284.74	48

Note: BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (standard deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (standard deviation), elevation (m), slope (%), aspect (direction), and soil (modified soil group)

B.4 Moist and dry evergreen forest with 19 forest inventory plots.

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
1	223.00	125.00	2234.00	336.00	96.00	240.00	1013.00	195.00	12.00	75.00	1294.00	42.54	278.45	62-Trgr
2	238.00	124.00	2269.00	350.00	112.00	238.00	972.00	181.00	11.00	76.00	1024.00	39.92	13.89	62-Trm
3	218.00	124.00	2240.00	330.00	92.00	238.00	1005.00	193.00	10.00	76.00	1232.00	9.66	277.43	62-Trgr
4	238.00	123.00	2363.00	350.00	111.00	239.00	962.00	176.00	9.00	77.00	1122.00	34.42	38.12	62Trgr
5	223.00	123.00	2288.00	333.00	97.00	236.00	978.00	183.00	9.00	77.00	1158.00	10.07	335.56	62-Qa
6	215.00	122.00	2317.00	324.00	87.00	237.00	996.00	185.00	9.00	76.00	1316.00	39.76	141.81	62-PE
7	210.00	121.00	2226.00	320.00	85.00	235.00	1012.00	199.00	8.00	78.00	1361.00	13.57	137.49	62-SDCtp
8	220.00	121.00	2263.00	331.00	95.00	236.00	977.00	195.00	7.00	80.00	1345.00	35.84	144.46	62-Trgr
9	233.00	121.00	2433.00	339.00	105.00	234.00	1035.00	186.00	8.00	77.00	914.00	34.89	139.84	62-Trgr
10	221.00	122.00	2363.00	328.00	93.00	235.00	1040.00	181.00	9.00	76.00	988.00	7.68	130.60	62-Trgr
11	228.00	121.00	2407.00	334.00	100.00	234.00	1037.00	183.00	8.00	76.00	1038.00	20.35	247.11	30
12	237.00	120.00	2426.00	345.00	111.00	234.00	1001.00	174.00	6.00	78.00	831.00	13.91	351.38	62-PE
13	232.00	120.00	2427.00	340.00	105.00	235.00	998.00	169.00	7.00	78.00	958.00	13.44	330.26	62-Trm
14	217.00	121.00	2440.00	324.00	88.00	236.00	1052.00	177.00	9.00	76.00	1318.00	44.29	4.32	62-PE
15	222.00	120.00	2360.00	332.00	95.00	237.00	986.00	183.00	7.00	79.00	1125.00	23.24	284.53	62-SDCtp
16	222.00	121.00	2396.00	328.00	94.00	234.00	1040.00	175.00	8.00	76.00	1228.00	19.94	169.16	62-PE
17	210.00	121.00	2405.00	316.00	82.00	234.00	1082.00	177.00	8.00	76.00	1353.00	24.67	4.84	62-Trgr
18	236.00	119.00	2498.00	339.00	107.00	232.00	1121.00	209.00	5.00	80.00	782.00	29.47	33.47	62-SD
19	214.00	121.00	2582.00	316.00	83.00	233.00	1280.00	258.00	9.00	80.00	1044.00	25.03	161.57	62-Trgr

Note: BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (standard deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (standard deviation), elevation (m), slope (%), aspect (direction), and soil (modified soil group)

B.5 Hill evergreen forest with 83 forest inventory plots.

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
1	236.00	128.00	2223.00	353.00	109.00	244.00	1104.00	203.00	18.00	70.00	1001.00	28.50	344.74	62-Trgr
2	236.00	127.00	2185.00	352.00	110.00	242.00	1090.00	203.00	15.00	73.00	1028.00	10.62	318.18	30
3	237.00	126.00	2230.00	353.00	110.00	243.00	1076.00	201.00	15.00	74.00	1060.00	18.28	136.85	30
4	233.00	126.00	2210.00	348.00	107.00	241.00	1046.00	200.00	13.00	74.00	1055.00	15.56	200.38	62-Trm
5	248.00	125.00	2407.00	360.00	120.00	240.00	1006.00	205.00	12.00	76.00	711.00	35.32	162.85	62-Qt
6	228.00	125.00	2228.00	342.00	102.00	240.00	1023.00	196.00	13.00	74.00	1067.00	33.30	328.30	62-PE
7	232.00	124.00	2216.00	347.00	107.00	240.00	1003.00	205.00	8.00	80.00	1118.00	51.16	20.50	62-Trgr
8	228.00	124.00	2277.00	340.00	101.00	239.00	982.00	188.00	11.00	76.00	1125.00	18.73	339.15	62-Trgr
9	211.00	123.00	2227.00	322.00	85.00	237.00	1029.00	202.00	9.00	77.00	1496.00	94.01	337.87	62-Trgr
10	206.00	123.00	2212.00	315.00	80.00	235.00	1030.00	192.00	10.00	75.00	1545.00	23.46	236.59	62-Trgr
11	237.00	122.00	2303.00	349.00	112.00	237.00	942.00	183.00	8.00	79.00	955.00	22.55	295.14	62-Trgr
12	158.00	119.00	2052.00	261.00	35.00	226.00	1178.00	202.00	9.00	72.00	2339.00	41.94	310.97	62-PE
13	205.00	123.00	2236.00	314.00	79.00	235.00	1028.00	190.00	10.00	75.00	1608.00	19.76	304.70	62-PE
14	227.00	123.00	2332.00	337.00	99.00	238.00	977.00	177.00	9.00	76.00	1163.00	56.05	327.14	62-Trgr
15	222.00	122.00	2266.00	335.00	96.00	239.00	978.00	200.00	8.00	80.00	1252.00	74.20	349.32	62-SDCtp
16	220.00	122.00	2255.00	332.00	94.00	238.00	982.00	199.00	7.00	80.00	1142.00	26.52	188.13	62-SDCtp
17	234.00	121.00	2321.00	348.00	109.00	239.00	929.00	194.00	7.00	82.00	1044.00	29.42	102.26	62-SDCtp
18	224.00	122.00	2285.00	335.00	98.00	237.00	960.00	195.00	7.00	80.00	1225.00	46.60	77.08	62-SDCtp
19	222.00	121.00	2296.00	333.00	96.00	237.00	966.00	195.00	7.00	80.00	1164.00	30.20	332.02	62-SDCtp
20	228.00	122.00	2351.00	337.00	101.00	236.00	979.00	173.00	9.00	77.00	1320.00	45.84	152.97	62-Trgr
21	239.00	121.00	2356.00	347.00	113.00	234.00	977.00	175.00	8.00	78.00	853.00	3.33	270.00	62-Trgr
22	225.00	121.00	2303.00	336.00	99.00	237.00	957.00	194.00	7.00	81.00	1274.00	37.97	266.86	62-O
23	226.00	122.00	2388.00	335.00	98.00	237.00	984.00	172.00	8.00	77.00	1059.00	16.18	101.89	62-Qa
24	220.00	121.00	2326.00	331.00	93.00	238.00	974.00	192.00	7.00	80.00	1382.00	53.00	286.44	62-SDCtp
25	226.00	123.00	2477.00	330.00	96.00	234.00	1128.00	205.00	10.00	77.00	812.00	37.65	174.92	62-Trgr
26	195.00	123.00	2360.00	298.00	66.00	232.00	1134.00	185.00	10.00	73.00	1644.00	6.59	251.57	62-Trgr
27	206.00	121.00	2301.00	315.00	80.00	235.00	1027.00	196.00	7.00	78.00	1579.00	20.28	279.46	62-Trgr
28	213.00	121.00	2312.00	323.00	87.00	236.00	999.00	192.00	7.00	79.00	1496.00	45.86	2.08	62-O
29	235.00	119.00	2371.00	346.00	110.00	236.00	933.00	183.00	6.00	82.00	1005.00	35.37	105.02	62-O
30	219.00	121.00	2342.00	328.00	92.00	236.00	996.00	178.00	8.00	77.00	1261.00	15.37	130.60	62-Trgr
31	230.00	121.00	2368.00	338.00	103.00	235.00	982.00	169.00	7.00	78.00	1104.00	24.73	327.38	62-Trm
32	231.00	121.00	2434.00	336.00	102.00	234.00	1049.00	187.00	8.00	77.00	963.00	19.02	151.19	62-Trgr
33	247.00	120.00	2564.00	348.00	117.00	231.00	1191.00	247.00	6.00	83.00	471.00	10.67	38.66	62-Png1
34	216.00	123.00	2410.00	320.00	87.00	233.00	1128.00	198.00	10.00	75.00	1141.00	55.15	261.75	62-Trgr
35	202.00	123.00	2378.00	306.00	73.00	233.00	1137.00	191.00	10.00	74.00	1464.00	29.61	230.71	62-Trgr
36	238.00	119.00	2364.00	348.00	113.00	235.00	940.00	177.00	6.00	81.00	1079.00	62.19	57.59	62-O

B.5 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
37	221.00	121.00	2336.00	329.00	94.00	235.00	988.00	180.00	8.00	78.00	1194.00	9.43	315.00	62-E
38	220.00	121.00	2345.00	328.00	93.00	235.00	994.00	178.00	8.00	78.00	1240.00	25.34	313.67	62-Trgr
39	214.00	121.00	2338.00	321.00	86.00	235.00	1015.00	179.00	8.00	77.00	1417.00	5.34	141.34	62-Trgr
40	230.00	122.00	2519.00	334.00	100.00	234.00	1157.00	220.00	9.00	78.00	745.00	73.66	224.54	62-Trgr
41	218.00	123.00	2459.00	322.00	88.00	234.00	1144.00	206.00	10.00	76.00	1033.00	35.48	326.50	62-Trgr
42	223.00	121.00	2389.00	329.00	95.00	234.00	1022.00	172.00	8.00	76.00	1087.00	50.34	199.33	62-Trgr
43	239.00	119.00	2450.00	344.00	111.00	233.00	1037.00	183.00	6.00	79.00	977.00	27.80	192.99	62-PE
44	228.00	122.00	2491.00	330.00	98.00	232.00	1173.00	227.00	9.00	79.00	1022.00	40.85	341.57	62-Trgr
45	202.00	123.00	2405.00	305.00	72.00	233.00	1157.00	200.00	10.00	74.00	1238.00	37.66	245.14	62-Trgr
46	216.00	121.00	2379.00	323.00	88.00	235.00	1037.00	172.00	8.00	76.00	1191.00	50.37	321.04	62-Trgr
47	233.00	120.00	2452.00	339.00	105.00	234.00	1052.00	183.00	7.00	78.00	911.00	18.15	189.25	62-PE
48	236.00	119.00	2463.00	341.00	108.00	233.00	1071.00	189.00	6.00	78.00	1010.00	24.04	81.03	62-Trgr
49	224.00	122.00	2475.00	327.00	95.00	232.00	1168.00	222.00	9.00	78.00	912.00	52.61	229.50	62-C
50	230.00	122.00	2528.00	333.00	100.00	233.00	1195.00	238.00	8.00	80.00	967.00	32.73	201.67	62-Trgr
51	207.00	123.00	2427.00	310.00	78.00	232.00	1167.00	209.00	10.00	75.00	1198.00	48.83	207.44	62-Trgr
52	221.00	120.00	2384.00	330.00	94.00	236.00	994.00	181.00	7.00	79.00	1204.00	30.84	128.42	62-SDCtp
53	219.00	121.00	2401.00	325.00	91.00	234.00	1053.00	176.00	8.00	76.00	1279.00	43.56	158.10	62-Trgr
54	223.00	122.00	2508.00	326.00	93.00	233.00	1181.00	227.00	9.00	78.00	1014.00	33.59	133.99	62-C
55	187.00	122.00	2334.00	289.00	59.00	230.00	1177.00	197.00	9.00	73.00	1407.00	40.84	271.17	62-C
56	221.00	120.00	2444.00	327.00	93.00	234.00	1061.00	178.00	7.00	77.00	1113.00	23.31	294.27	62-Trm
57	246.00	120.00	2570.00	346.00	116.00	230.00	1258.00	276.00	5.00	85.00	564.00	10.02	253.07	62-C
58	216.00	120.00	2429.00	322.00	88.00	234.00	1065.00	175.00	8.00	76.00	1280.00	32.60	321.23	62-Trgr
59	231.00	120.00	2467.00	337.00	104.00	233.00	1072.00	183.00	6.00	78.00	861.00	15.02	19.44	62-Trgr
60	226.00	120.00	2454.00	332.00	98.00	234.00	1079.00	183.00	7.00	78.00	934.00	20.03	225.00	62-Trgr
61	220.00	122.00	2518.00	323.00	91.00	232.00	1201.00	232.00	9.00	78.00	1037.00	30.10	265.24	62-Trgr
62	211.00	120.00	2410.00	317.00	83.00	234.00	1091.00	178.00	8.00	77.00	1268.00	17.52	115.35	62-Trgr
63	237.00	120.00	2517.00	340.00	108.00	232.00	1140.00	217.00	5.00	80.00	786.00	44.04	57.36	62-Trgr
64	205.00	121.00	2421.00	310.00	77.00	233.00	1126.00	185.00	9.00	76.00	1356.00	47.73	225.00	62-Trgr
65	218.00	121.00	2464.00	322.00	89.00	233.00	1129.00	198.00	8.00	77.00	1271.00	61.15	107.45	62-Trgr
66	222.00	121.00	2479.00	326.00	93.00	233.00	1142.00	208.00	7.00	78.00	1123.00	43.98	62.95	62-Trgr
67	202.00	122.00	2445.00	305.00	73.00	232.00	1172.00	205.00	9.00	76.00	1356.00	36.44	112.17	62-CP
68	214.00	120.00	2442.00	318.00	86.00	232.00	1131.00	195.00	8.00	76.00	1112.00	70.64	256.70	62-Trgr
69	225.00	121.00	2537.00	328.00	95.00	233.00	1207.00	237.00	7.00	80.00	1044.00	37.31	66.30	62-C
70	233.00	119.00	2521.00	338.00	105.00	233.00	1134.00	210.00	5.00	80.00	753.00	22.18	151.99	62-C
71	220.00	121.00	2504.00	324.00	91.00	233.00	1156.00	211.00	7.00	78.00	1287.00	62.92	23.00	62-C
72	222.00	120.00	2511.00	325.00	94.00	231.00	1162.00	214.00	6.00	79.00	1143.00	29.80	290.46	62-C

B.5 (Continued).

Plot	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Elevation	Slope	Aspect	Soil
73	216.00	120.00	2521.00	320.00	87.00	233.00	1173.00	215.00	7.00	78.00	1093.00	11.80	312.14	62-C
74	220.00	121.00	2583.00	322.00	90.00	232.00	1286.00	265.00	8.00	81.00	1073.00	20.83	73.74	62-C
75	208.00	120.00	2508.00	312.00	79.00	233.00	1179.00	209.00	8.00	77.00	1137.00	22.42	221.99	62-Trgr
76	194.00	120.00	2447.00	296.00	65.00	231.00	1192.00	203.00	8.00	76.00	1562.00	22.46	220.49	62-Trgr
77	204.00	120.00	2504.00	307.00	75.00	232.00	1190.00	210.00	8.00	77.00	1437.00	61.42	343.04	62-C
78	222.00	119.00	2547.00	326.00	94.00	232.00	1175.00	216.00	5.00	80.00	1183.00	30.84	141.58	62-Trgr
79	210.00	120.00	2526.00	313.00	80.00	233.00	1207.00	221.00	7.00	78.00	1279.00	43.31	281.09	62-C
80	192.00	119.00	2442.00	294.00	64.00	230.00	1197.00	197.00	7.00	77.00	1648.00	25.89	123.18	62-Trgr
81	208.00	120.00	2546.00	312.00	79.00	233.00	1210.00	218.00	7.00	78.00	1237.00	46.16	239.04	62-C
82	210.00	120.00	2554.00	313.00	80.00	233.00	1214.00	223.00	7.00	78.00	1218.00	47.96	50.64	62-C
83	216.00	120.00	2569.00	319.00	86.00	233.00	1227.00	232.00	6.00	79.00	1092.00	10.87	122.47	62-C

Note: BIO1 = Mean annually temperature (°C), BIO2= Mean monthly temperature range (°C), BIO4 = Mean annually temperature seasonality (standard deviation), BIO5 = Mean monthly maximum temperature (°C), BIO6 = Mean monthly minimum temperature (°C), BIO7 = Mean annually temperature range (°C), BIO12 = Mean annually precipitation (mm), BIO13 = Mean monthly maximum precipitation (mm), BIO14 = Mean monthly minimum precipitation (mm), BIO15 = Mean precipitation seasonality (standard deviation), elevation (m), slope (%), aspect (direction), and soil (modified soil group)

B.6 Correlation matrix of 14 physical variables on mixed deciduous forest.

	Elevation	Slope	Aspect	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Soil
Elevation	1.00	0.36	0.08	-0.85	-0.15	-0.09	-0.72	-0.80	-0.04	-0.10	-0.30	-0.01	-0.27	0.30
Slope		1.00	0.03	-0.35	-0.09	0.08	-0.32	-0.34	-0.09	0.05	-0.01	-0.03	-0.06	0.28
Aspect			1.00	-0.18	0.03	-0.04	-0.15	-0.18	0.02	-0.04	-0.08	0.07	-0.09	-0.05
BIO1				1.00	0.28	-0.25	0.96	0.99	0.32	-0.23	0.01	0.16	0.11	-0.34
BIO2					1.00	-0.57	0.47	0.29	0.88	-0.37	-0.29	0.93	-0.72	-0.15
BIO4						1.00	-0.50	-0.35	-0.81	0.87	0.82	-0.63	0.66	0.11
BIO5							1.00	0.98	0.57	-0.43	-0.21	0.37	-0.12	-0.33
BIO6								1.00	0.37	-0.32	-0.08	0.19	0.07	-0.34
BIO7									1.00	-0.64	-0.57	0.88	-0.74	-0.14
BIO12										1.00	0.92	-0.43	0.55	0.09
BIO13											1.00	-0.41	0.68	0.02
BIO14												1.00	-0.84	-0.09
BIO15													1.00	0.06
Soil														1.00

Note: Correlations significant at $p<0.05$

B.7 Correlation matrix of 14 physical variables on dry dipterocarp forest.

	Elevation	**Slope**	**Aspect**	**BIO1**	**BIO2**	**BIO4**	**BIO5**	**BIO6**	**BIO7**	**BIO12**	**BIO13**	**BIO14**	**BIO15**	**Soil**
Elevation	1.00	0.29	0.00	-0.76	0.10	-0.23	-0.54	-0.69	0.16	-0.10	-0.32	0.24	-0.34	0.46
Slope		1.00	-0.07	-0.30	-0.12	0.14	-0.29	-0.30	-0.14	0.04	0.04	-0.12	0.11	0.23
Aspect			1.00	-0.14	-0.10	0.11	-0.14	-0.13	-0.11	0.04	0.03	-0.10	0.04	0.02
BIO1				1.00	0.28	-0.33	0.94	0.99	0.35	-0.33	-0.13	0.19	-0.04	-0.41
BIO2					1.00	-0.69	0.52	0.30	0.90	-0.24	-0.31	0.95	-0.85	-0.22
BIO4						1.00	-0.61	-0.42	-0.87	0.73	0.80	-0.74	0.74	0.10
BIO5							1.00	0.96	0.64	-0.51	-0.36	0.45	-0.32	-0.38
BIO6								1.00	0.41	-0.43	-0.23	0.22	-0.09	-0.39
BIO7									1.00	-0.52	-0.58	0.89	-0.84	-0.17
BIO12										1.00	0.90	-0.27	0.32	0.06
BIO13											1.00	-0.38	0.54	-0.03
BIO14												1.00	-0.91	-0.12
BIO15													1.00	0.05
Soil														1.00

Note: Correlations significant at $p<0.05$

B.8 Correlation matrix of 14 physical variables on coniferous forest.

	Elevation	Slope	Aspect	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Soil
Elevation	1.00	-0.17	-0.27	-0.72	-0.06	-0.24	-0.45	-0.61	0.08	-0.26	-0.41	0.05	0.03	0.68
Slope		1.00	-0.06	-0.08	-0.16	0.20	-0.20	-0.12	-0.30	-0.03	0.14	-0.09	0.10	0.01
Aspect			1.00	0.20	-0.25	0.23	0.06	0.19	-0.24	-0.06	0.04	-0.26	0.30	-0.36
BIO1				1.00	0.47	-0.43	0.93	0.99	0.50	-0.06	0.14	0.40	-0.27	-0.50
BIO2					1.00	-0.72	0.64	0.43	0.88	0.40	0.31	0.97	-0.89	-0.35
BIO4						1.00	-0.69	-0.51	-0.87	0.32	0.35	-0.80	0.58	-0.09
BIO5							1.00	0.96	0.76	-0.14	0.03	0.61	-0.40	-0.34
BIO6								1.00	0.53	-0.20	0.03	0.39	-0.20	-0.39
BIO7									1.00	0.05	0.04	0.89	-0.69	-0.11
BIO12										1.00	0.85	0.28	-0.48	-0.55
BIO13											1.00	0.16	-0.18	-0.63
BIO14												1.00	-0.90	-0.23
BIO15													1.00	0.27
Soil														1.00

Note: Correlations significant at $p<0.05$

B.9 Correlation matrix of 14 physical variables on moist and dry evergreen forest.

	Elevation	**Slope**	**Aspect**	**BIO1**	**BIO2**	**BIO4**	**BIO5**	**BIO6**	**BIO7**	**BIO12**	**BIO13**	**BIO14**	**BIO15**	**Soil**
Elevation	1.00	0.23	-0.17	-0.76	0.37	-0.55	-0.57	-0.71	0.45	-0.20	-0.06	0.43	-0.32	0.67
Slope		1.00	-0.54	0.12	0.19	0.00	0.15	0.08	0.34	-0.01	0.06	0.29	-0.10	0.07
Aspect			1.00	0.07	0.03	-0.17	0.13	0.12	0.09	-0.23	-0.08	-0.07	0.05	0.11
BIO1				1.00	-0.04	0.17	0.95	0.99	0.04	-0.30	-0.30	-0.20	0.08	-0.54
BIO2					1.00	-0.65	0.18	0.01	0.80	-0.33	-0.05	0.92	-0.63	0.18
BIO4						1.00	-0.12	0.04	-0.71	0.74	0.34	-0.48	0.39	-0.25
BIO5							1.00	0.98	0.32	-0.52	-0.41	-0.03	-0.03	-0.41
BIO6								1.00	0.11	-0.41	-0.36	-0.18	0.07	-0.50
BIO7									1.00	-0.61	-0.28	0.71	-0.46	0.32
BIO12										1.00	0.80	-0.12	0.36	-0.03
BIO13											1.00	0.05	0.54	0.13
BIO14												1.00	-0.67	0.16
BIO15													1.00	0.03
Soil														1.00

Note: Correlations significant at $p<0.05$

B.10 Correlation matrix of 14 physical variables on hill evergreen forest.

	Elevation	Slope	Aspect	BIO1	BIO2	BIO4	BIO5	BIO6	BIO7	BIO12	BIO13	BIO14	BIO15	Soil
Elevation	1.00	0.16	0.20	-0.87	-0.07	-0.46	-0.77	-0.82	-0.19	-0.02	-0.30	0.08	-0.44	0.10
Slope		1.00	0.04	-0.15	0.00	-0.01	-0.14	-0.15	-0.03	0.01	0.03	-0.04	0.01	0.11
Aspect			1.00	-0.21	0.26	-0.30	-0.15	-0.19	0.11	-0.08	-0.14	0.35	-0.37	-0.31
BIO1				1.00	0.17	0.15	0.97	0.99	0.49	-0.33	0.07	-0.02	0.47	-0.24
BIO2					1.00	-0.51	0.29	0.19	0.69	-0.15	-0.01	0.90	-0.55	-0.47
BIO4						1.00	-0.06	0.06	-0.59	0.65	0.52	-0.51	0.43	0.36
BIO5							1.00	0.99	0.66	-0.49	-0.05	0.10	0.38	-0.32
BIO6								1.00	0.53	-0.41	0.01	0.00	0.46	-0.26
BIO7									1.00	-0.65	-0.31	0.55	-0.14	-0.48
BIO12										1.00	0.75	-0.04	-0.07	0.25
BIO13											1.00	-0.08	0.36	0.30
BIO14												1.00	-0.76	-0.51
BIO15													1.00	0.41
Soil														1.00

Note: Correlations significant at p<0.05

B.11 KMO and Bartlett’s test of sphericity**.**

1. Mixed deciduous Forest		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.70
Bartlett's Test of Sphericity	Approx. Chi-Square	3668.201
	df	78
	Sig	.000
2. Dry deciduous forest		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.70
Bartlett's Test of Sphericity	Approx. Chi-Square	3977.629
	df	78
	Sig	.000
3. Coniferous forest		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.62
Bartlett's Test of Sphericity	Approx. Chi-Square	238.39
	df	36
	Sig	.000
4. Moist and dry evergreen forest		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.60
Bartlett's Test of Sphericity	Approx. Chi-Square	297.62
	df	45
	Sig	.000
5. Hill evergreen forest		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.60
Bartlett's Test of Sphericity	Approx. Chi-Square	1622.15
	df	45
	Sig	.000

APPENDIX C

CODING

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		**Evergreen forest**		**Possibly forest types**	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
11000	Deciduous ecotone	111	Evergreen ecotone	11111	Unsuitable forest area
		112	CF-MHS	11112	CF
		113	CF-HHS	11113	CF
		121	MDEF-MHS	11121	MDEF
		122	Evergreen ecotone-MHS	11122	Evergreen ecotone
		123	CF-HHS	11123	CF
		131	MDEF-HHS	11131	MDEF
		132	MDEF-HHS	11132	MDEF
		133	Evergreen ecotone-HHS	11133	Evergreen ecotone
		211	HEF-MHS	11211	HEF
		212	Evergreen ecotone-MHS	11212	Evergreen ecotone
		213	CF-HHS	11213	CF
		221	Evergreen ecotone-MHS	11221	Evergreen ecotone
		222	Evergreen ecotone-MHS	11222	Evergreen ecotone
		223	CF-HHS	11223	CF
		231	MDEF-HHS	11231	MDEF
		232	MDEF-HHS	11232	MDEF
		233	Evergreen ecotone-HHS	11233	Evergreen ecotone
		311	HEF-HHS	11311	HEF
		312	HEF-HHS	11312	HEF
		313	Evergreen ecotone-HHS	11313	Evergreen ecotone
		321	HEF-HHS	11321	HEF
		322	HEF-HHS	11322	HEF
		323	Evergreen ecotone-HHS	11323	Evergreen ecotone
		331	Evergreen ecotone-HHS	11331	Evergreen ecotone
		332	Evergreen ecotone-HHS	11332	Evergreen ecotone
		333	Evergreen ecotone-HHS	11333	Evergreen ecotone
12000	MDF-MHS	111	Evergreen ecotone-LHS	12111	MDF
		112	CF-MHS	12112	Deciduous and Evergreen ecotone
		113	CF-MHS	12113	CF
		121	MDEF-MHS	12121	Deciduous and evergreen ecotone
		122	Evergreen ecotone- MHS	12122	Deciduous and evergreen ecotone
		123	CF- HHS	12123	CF
		131	MDEF-HHS	12131	MDEF
		132	MDEF-HHS	12132	MDEF
		133	Evergreen ecotone-HHS	12133	Evergreen ecotone
		211	HEF-MHS	12211	Deciduous and evergreen ecotone
		212	Evergreen ecotone-MHS	12212	Deciduous and evergreen ecotone

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		Evergreen forest		Possibly forest types	
Code	Name	Code	Name	Code	Name
		213	CF-HHS	12213	CF
		221	Evergreen ecotone-MHS	12221	Deciduous and evergreen ecotone
		222	Evergreen ecotone-MHS	12222	Deciduous and evergreen ecotone
		223	CF-HHS	12223	CF
		231	MDEF-HHS	12231	MDEF
		232	MDEF-HHS	12232	MDEF
		233	Evergreen ecotone-HHS	12233	Evergreen ecotone
		311	HEF-HHS	12311	HEF
		312	HEF-HHS	12312	HEF
		313	Evergreen ecotone-HHS	12313	Evergreen ecotone
		321	HEF-HHS	12321	HEF
		322	HEF-HHS	12322	HEF
		323	Evergreen ecotone-HHS	12323	Evergreen ecotone
		331	Evergreen ecotone-HHS	12331	Evergreen ecotone
		332	Evergreen ecotone-HHS	12332	Evergreen ecotone
		333	Evergreen ecotone-HHS	12333	Evergreen ecotone
13000	MDF-HHS	111	Evergreen ecotone-HHS	13111	MDF
		112	CF-MHS	13112	MDF
		113	CF-HHS	13113	Deciduous and evergreen ecotone
		121	MDEF-MHS	13121	MDF
		122	Evergreen ecotone-MHS	13122	MDF
		123	CF-HHS	13123	Deciduous and evergreen ecotone
		131	MDEF-HHS	13131	Deciduous and evergreen ecotone
		132	MDEF-HHS	13132	Deciduous and evergreen ecotone
		133	Evergreen ecotone-HHS	13133	Deciduous and evergreen ecotone
		211	HEF-MHS	13211	MDF
		212	Evergreen ecotone-MHS	13212	MDF
		213	CF-HHS	13213	Deciduous and evergreen ecotone
		221	Evergreen ecotone-MHS	13221	MDF
		222	Evergreen ecotone-MHS	13222	MDF
		223	CF-HHS	13223	Deciduous and evergreen ecotone
		231	MDEF-HHS	13231	Deciduous and evergreen ecotone
		232	MDEF-HHS	13232	Deciduous and evergreen ecotone
		233	Evergreen ecotone-HHS	13233	Deciduous and evergreen ecotone
		311	HEF-HHS	13311	Deciduous and evergreen ecotone
		312	HEF-HHS	13312	Deciduous and evergreen ecotone

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		Evergreen forest		Possibly forest types	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
		313	Evergreen ecotone-HHS	13313	Deciduous and evergreen ecotone
		321	HEF-HHS	13321	Deciduous and evergreen ecotone
		322	HEF-HHS	13322	Deciduous and evergreen ecotone
		323	Evergreen ecotone-HHS	13323	Deciduous and evergreen ecotone
		331	Evergreen ecotone-HHS	13331	Deciduous and evergreen ecotone
		332	Evergreen ecotone-HHS	13332	Deciduous and evergreen ecotone
		333	Evergreen ecotone-HHS	13333	Deciduous and evergreen ecotone
21000	DDF-MHS	111	Evergreen ecotone-LHS	21111	DDF
		112	CF-MHS	21112	Deciduous and evergreen ecotone
		113	CF-HHS	21113	CF
		121	MDEF-MHS	21121	Deciduous and evergreen ecotone
		122	Evergreen ecotone-MHS	21122	Deciduous and evergreen ecotone
		123	CF-HHS	21123	CF
		131	MDEF-HHS	21131	MDEF
		132	MDEF-HHS	21132	MDEF
		133	Evergreen ecotone-HHS	21133	Evergreen ecotone
		211	HEF-MHS	21211	Deciduous and evergreen ecotone
		212	Evergreen ecotone-MHS	21212	Deciduous and evergreen ecotone
		213	CF-HHS	21213	CF
		221	Evergreen ecotone-MHS	21221	Deciduous and evergreen ecotone
		222	Evergreen ecotone-MHS	21222	Deciduous and evergreen ecotone
		223	CF-HHS	21223	CF
		231	MDEF-HHS	21231	MDEF
		232	MDEF-HHS	21232	MDEF
		233	Evergreen ecotone-HHS	21233	Evergreen ecotone
		311	HEF-HHS	21311	HEF
		312	HEF-HHS	21312	HEF
		313	Evergreen ecotone-HHS	21313	Evergreen ecotone
		321	HEF-HHS	21321	HEF
		322	HEF-HHS	21322	HEF
		323	Evergreen ecotone	21323	Evergreen ecotone
		331	Evergreen ecotone	21331	Evergreen ecotone
		332	Evergreen ecotone	21332	Evergreen ecotone
		333	Evergreen ecotone	21333	Evergreen ecotone
22000	Deciduous ecotone	111	Evergreen ecotone	22111	Deciduous ecotone
		112	CF-MHS	22112	Deciduous and evergreen ecotone
		113	CF-HHS	22113	CF

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		Evergreen forest		Possibly forest types	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
		121	MDEF-MHS	22121	Deciduous and evergreen ecotone
		122	Evergreen ecotone-MHS	22122	Deciduous and evergreen ecotone
		123	CF-HHS	22123	CF
		131	MDEF-HHS	22131	MDEF
		132	MDEF-HHS	22132	MDEF
		133	Evergreen ecotone-HHS	22133	Evergreen ecotone
		211	HEF-MHS	22211	Deciduous and evergreen ecotone
		212	Evergreen ecotone-MHS	22212	Deciduous and evergreen ecotone
		213	CF-HHS	22213	CF
		221	Evergreen ecotone-MHS	22221	Deciduous and evergreen ecotone
		222	Evergreen ecotone-MHS	22222	Deciduous and evergreen ecotone
		223	CF-HHS	22223	CF
		231	MDEF-HHS	22231	MDEF
		232	MDEF-HHS	22232	MDEF
		233	Evergreen ecotone-HHS	22233	Evergreen ecotone
		311	HEF-HHS	22311	HEF
		312	HEF-HHS	22312	HEF
		313	Evergreen ecotone-HHS	22313	Evergreen ecotone
		321	HEF-HHS	22321	HEF
		322	HEF-HHS	22322	HEF
		323	Evergreen ecotone-HHS	22323	Evergreen ecotone
		331	Evergreen ecotone-HHS	22331	Evergreen ecotone
		332	Evergreen ecotone-HHS	22332	Evergreen ecotone
		333	Evergreen ecotone-HHS	22333	Evergreen ecotone
23000	MDF-HHS	111	Evergreen ecotone-LHS	23111	MDF
		112	CF-MHS	23112	MDF
		113	CF-HHS	23113	Deciduous and evergreen ecotone
		121	MDEF-MHS	23121	MDF
		122	Evergreen ecotone-MHS	23122	MDF
		123	CF-HHS	23123	Deciduous and evergreen ecotone
		131	MDEF-HHS	23131	Deciduous and evergreen ecotone
		132	MDEF-HHS	23132	Deciduous and evergreen ecotone
		133	Evergreen ecotone-HHS	23133	Deciduous and evergreen ecotone
		211	HEF-MHS	23211	MDF
		212	Evergreen ecotone-MHS	23212	MDF
		213	CF-HHS	23213	Deciduous and evergreen ecotone
		221	Evergreen ecotone-MHS	23221	MDF
		222	Evergreen ecotone-MHS	23222	MDF
		223	CF-HHS	23223	Deciduous and evergreen ecotone

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		Evergreen forest		Possibly forest types	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
		231	MDEF-HHS	23231	Deciduous and evergreen ecotone
		232	MDEF-HHS	23232	Deciduous and evergreen ecotone
		233	Evergreen ecotone-HHS	23233	Deciduous and evergreen ecotone
		311	HEF-HHS	23311	Deciduous and evergreen ecotone
		312	HEF-HHS	23312	Deciduous and evergreen ecotone
		313	Evergreen ecotone-HHS	23313	Deciduous and evergreen ecotone
		321	HEF-HHS	23321	Deciduous and evergreen ecotone
		322	HEF-HHS	23322	Deciduous and evergreen ecotone
		323	Evergreen ecotone-HHS	23323	Deciduous and evergreen ecotone
		331	Evergreen ecotone-HHS	23331	Deciduous and evergreen ecotone
		332	Evergreen ecotone-HHS	23332	Deciduous and evergreen ecotone
		333	Evergreen ecotone-HHS	23333	Deciduous and evergreen ecotone
31000	DDF-HHS	111	Evergreen ecotone-LHS	31111	DDF
		112	CF-MHS	31112	DDF
		113	CF-HHS	31113	Deciduous and evergreen ecotone
		121	MDEF-MHS	31121	DDF
		122	Evergreen ecotone-MHF	31122	DDF
		123	CF-HHS	31123	Deciduous and evergreen ecotone
		131	MDEF-HHS	31131	Deciduous and evergreen ecotone
		132	MDEF-HHS	31132	Deciduous and evergreen ecotone
		133	Evergreen ecotone-HHS	31133	Deciduous and evergreen ecotone
		211	HEF-MHS	31211	DDF
		212	Evergreen ecotone-MHS	31212	DDF
		213	CF-HHS	31213	Deciduous and evergreen ecotone
		221	Evergreen ecotone-MHS	31221	DDF
		222	Evergreen ecotone-MHS	31222	DDF
		223	CF-HHS	31223	Deciduous and evergreen ecotone
		231	MDEF-HHS	31231	Deciduous and evergreen ecotone
		232	MDEF-HHS	31232	Deciduous and evergreen ecotone
		233	Evergreen ecotone-HHS	31233	Deciduous and evergreen ecotone
		311	HEF-HHS	31311	Deciduous and evergreen ecotone

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		**Evergreen forest**		**Possibly forest types**	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
		312	HEF-HHS	31312	Deciduous and evergreen ecotone
		313	Evergreen ecotone-HHS	31313	Deciduous and evergreen ecotone
		321	HEF-HHS	31321	Deciduous and evergreen ecotone
		322	HEF-HHS	31322	Deciduous and evergreen ecotone
		323	Evergreen ecotone-HHS	31323	Deciduous and evergreen ecotone
		331	Evergreen ecotone-HHS	31331	Deciduous and evergreen ecotone
		332	Evergreen ecotone-HHS	31332	Deciduous and evergreen ecotone
		333	Evergreen ecotone-HHS	31333	Deciduous and evergreen ecotone
32000	DDF-HHS	111	Evergreen ecotone-LHS	32111	DDF
		112	CF-MHS	32112	DDF
		113	CF-HHS	32113	Deciduous and evergreen ecotone
		121	MDEF-MHS	32121	DDF
		122	Evergreen ecotone-MHS	32122	DDF
		123	CF-HHS	32123	Deciduous and evergreen ecotone
		131	MDEF-HHS	32131	Deciduous and evergreen ecotone
		132	MDEF-HHS	32132	Deciduous and evergreen ecotone
		133	Evergreen ecotone-HHS	32133	Deciduous and evergreen ecotone
		211	HEF-MHS	32211	DDF
		212	Evergreen ecotone-MHS	32212	DDF
		213	CF-HHS	32213	Deciduous and evergreen ecotone
		221	Evergreen ecotone-MHS	32221	DDF
		222	Evergreen ecotone-MHS	32222	DDF
		223	CF-HHS	32223	Deciduous and evergreen ecotone
		231	MDEF-HHS	32231	Deciduous and evergreen ecotone
		232	MDEF-HHS	32232	Deciduous and evergreen ecotone
		233	Evergreen ecotone-HHS	32233	Deciduous and evergreen ecotone
		311	HEF-HHS	32311	Deciduous and evergreen ecotone
		312	HEF-HHS	32312	Deciduous and evergreen ecotone
		313	Evergreen ecotone-HHS	32313	Deciduous and evergreen ecotone
		321	HEF-HHS	32321	Deciduous and evergreen ecotone
		322	HEF-HHS	32322	Deciduous and evergreen ecotone

C.1 Coding for combining between deciduous forest and evergreen forest.

Deciduous forest		Evergreen forest		Possibly forest types	
Code	**Name**	**Code**	**Name**	**Code**	**Name**
		323	Evergreen ecotone-HHS	32323	Deciduous and evergreen ecotone
		331	Evergreen ecotone-HHS	32331	Deciduous and evergreen ecotone
		332	Evergreen ecotone-HHS	32332	Deciduous and evergreen ecotone
		333	Evergreen ecotone-HHS	32333	Deciduous and evergreen ecotone
33000	Deciduous ecotone	111	Evergreen ecotone-LHS	33111	Deciduous ecotone
		112	CF-MHS	33112	Deciduous ecotone
		113	CF-HHS	33113	Deciduous and evergreen ecotone
		121	MDEF-MHS	33121	Deciduous ecotone
		122	Evergreen ecotone-MHS	33122	Deciduous ecotone
		123	CF-HHS	33123	Deciduous and evergreen ecotone
		131	MDEF-HHS	33131	Deciduous and evergreen ecotone
		132	MDEF-HHS	33132	Deciduous and evergreen ecotone
		133	Evergreen ecotone-HHS	33133	Deciduous and evergreen ecotone
		211	HEF-MHS	33211	Deciduous ecotone
		212	Evergreen ecotone-MHS	33212	Deciduous ecotone
		213	CF-HHS	33213	Deciduous and evergreen ecotone
		221	Evergreen ecotone-MHS	33221	Deciduous ecotone
		222	Evergreen ecotone-MHS	33222	Deciduous ecotone
		223	CF-HHS	33223	Deciduous and evergreen ecotone
		231	MDEF-HHS	33231	Deciduous and evergreen ecotone
		232	MDEF-HHS	33232	Deciduous and evergreen ecotone
		233	Evergreen ecotone-HHS	33233	Deciduous and evergreen ecotone
		311	HEF-HHS	33311	Deciduous and evergreen ecotone
		312	HEF-HHS	33312	Deciduous and evergreen ecotone
		313	Evergreen ecotone-HHS	33313	Deciduous and evergreen ecotone
		321	HEF-HHS	33321	Deciduous and evergreen ecotone
		322	HEF-HHS	33322	Deciduous and evergreen ecotone
		323	Evergreen ecotone-HHS	33323	Deciduous and evergreen ecotone
		331	Evergreen ecotone-HHS	33331	Deciduous and evergreen ecotone
		332	Evergreen ecotone-HHS	33332	Deciduous and evergreen ecotone
		333	Evergreen ecotone-HHS	33333	Deciduous and evergreen ecotone

APPENDIX D

THE FIELD DATA

D.1 Field data on April 9, 2011 – April 18 2011.

No.	Easting (X)	Northing (Y)	Class	Ground reference
1	462104	2032614	DDF	- **Forest type**: DDF - **Location**: Urban at Chom Thong district, Chaing Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* and *Shorea obtusa* - **Environmental condition**: Low slope, elevation between 400-500 m., and shallow and highly sandy soil
2	495764	2097474	DDF	- **Forest type**: DDF - **Location**: Ban Dong Neon at Mar Rim district, Chaing Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius*, *D. tuberculatus*, *Shorea obtusa* and *S. siamensis* - **Environmental condition**: Low slope, elevation between 300-400 m, and shallow and highly sandy soil
3	499784	2091684	DDF	- **Forest type**: DDF - **Location**: Urban at San Sai district, Chaing Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* and *D. tuberculatus* - **Environmental condition**: Low slope, elevation between 300-400 m., and shallow and highly sandy soil
4[1]	444554	2021514	EE	- **Forest type**: EE - **Location**: Op Luang National Park at Chom Thong district, Chaing Mai province - **Tree species dominance**: *Castanopsis tribuloides*, *C. acuminatissima*, *Pinus kesiya* and *P. merkusii* - **Environmental conditions**: Very highly slope, elevation between 1,300-1,400 m., and sandy and calcifuge soil
5	439784	2064894	MDF	- **Forest type**: MDF - **Location**: Urban of Mae Cham district, Chaing Mai province - **Tree species dominance**: *Afzelia xylocarpa*, *Cassia fistula*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* - **Environmental condition**s: A moderate slope, elevation between 800-900 m., and shallow, sandy and calcifuge soil.
6	465494	2153064	DEE	- This location was not accessed.
7[1]	423164	2116554	EE	- **Forest type**: EE - **Location**: Ban Huai Nam Dang at Pai district, Mae Hong Son province - **Tree species dominance**: *Castanopsis tribuloides*, *C. acuminatissima*, and *Pinus* spp. - **Environmental conditions**: Very highly slope, elevation between 1,200-1,300 m., sandy and calcifuge soil
8	470234	1967004	DEE	- This location is not accessed.
9	526124	2150034	MDF	- **Forest type**: MDF - **Location**: Wiang Pa Pao district, Chaing Rai province - **Tree species dominance**: *Afzelia xylocarpa*, *Cassia fistula*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, and *Xylia xylocarpa* var. *kerrii* - **Environmental condition**: A moderate slope, elevation between 600-700 m, and shallow and sandy soil
10[1]	460124	2142384	EE	- **Forest type**: EE - **Location**: Huai Nam Dang National Park at Chiang Dao district, Chaing Mai province - **Tree species dominance**: *Castanopsis tribuloides*, *C. acuminatissima*, and *Pinus* spp. - **Environmental conditions**: Very high slope and elevation between 1,100-1,200 m
11[1]	451154	2076774	EE	- **Forest type**: EE - **Location**: Su Thep-Pui National Park in Muang district, Chaing Rai province - **Tree species dominance**: *Castanopsis tribuloides, C. acuminatissima*, and *Pinus* spp. - **Environmental conditions**: Very high slope, elevation between 1,100-1,200 m, and sandy and calcifuge soil

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
12	468494	2141904	MDF	- **Forest type**: MDF - **Location**: Huai Nam Dang National Park and Chaing Dao Wildlife Sanctuary at Chiang Dao district, Chaing Mai province - **Tree species dominance**: *Afzelia xylocarpa*, *Cassia fistula*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *Bambusa bambos*, *Dendrocalamus strictus* and *Gigantochloa albociliata* - **Environmental condition**s: Low slope, elevation between 700-800 m. and shallow and sandy soil
13	457724	2102514	MDF	- **Forest type**: MDF - **Location**: Sameng Wildlife Sanctuary at Sameng district, Chaing Mai province - **Tree species dominance**: *Afzelia xylocarpa*, *Cassia fistula*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *Bambusa bambos*, *Dendrocalamus strictus* and *Gigantochloa albociliata* - **Environmental conditions**: Low slope and elevation between 800-900 m
14	496004	2173524	DDF	- **Forest type**: MDF - **Location**: Chiang Dao National Park at Chiang Dao district, Chaing Mai province - **Tree species dominance**: *Afzelia xylocarpa*, *Cassia fistula*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *Bambusa bambos* and *Gigantochloa albociliata* - **Environmental condition**s: Low slope and elevation between 600-700 m
15[2]	503054	2167614	CF	- **Forest type**: DDF - **Location**: Chiang Dao National Park at Chiang Dao district, Chaing Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *Shorea siamensis*, and *Pinus* spp. - **Environmental conditions**: A moderate slope, elevation between 600-700 m., and sandy and shallow soil
16	506144	2099304	DEE	- **Forest type**: DDF - **Location**: urban at Doi Sakret district, Chaing Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* and *D. tuberculatus*. - **Environmental conditions**: A moderate slope, elevation between 600-700 m, highly sandy and shallow soil and fire disturbance on ground
17	463004	2039454	DDF	- **Forest type**: DDF - **Location**: Chiang Dao National Park at Chom Thong district, Chaing Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis* and *Dipterocarpus tuberculatus* - **Environmental conditions**: Low slope, elevation between 200-300 m, and highly sandy and shallow soil
18	516584	2141034	DDF	- **Forest type**: DDF - **Location**: Buffer zone of Chiang Dao National Park at Phrao district, Chaing Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius*, *D. tuberculatus*, *Anneslea fragrans*, *Syzygium cumini*, *and Phyllanthus emblica*, - **Environmental conditions**: Low slope, elevation between 200-300 m, and highly sandy and shallow soil. Moreover, fire disturbance on ground.
19	522554	2037534	MDF	- **Forest type**: MDF - **Location**: Route from Lumphun to Lampang or Highway 11 - **Tree species dominance**: *Cassia fistula*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *Bambusa bambos* and *Gigantochloa albociliata* - **Environmental conditions**: Low slope, elevation between 600-700 m, and laterit rock

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
20	432644	2012364	DDF	- **Forest type**: DDF - **Location**: Ban Boa Luang at Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* - **Environmental conditions**: A moderate slope, elevation between 700-800 m, highly sandy, shallow and laterite soil
21	474884	2062044	DE	- **Forest type**: DDF - **Location**: San Pa Tong district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis* and *Dipterocarpus tuberculatus* - **Environmental condition**s: Elevation between 400-500 m, low slope and sandy and shallow soil
22	479894	2060814	DDF	- This location is not DDF but it is urban of San Pa Tong district, Chiang Mai province
23	423914	2009874	MDF	- **Forest type**: MDF - **Location**: Ban Mai Thung Son at Mae Sa Raing district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: Low slope and elevation between 1,000-2,000 m.
24	426464	2019354	DDF	- **Forest type**: DDF - **Location**: Ban Boa Luang in Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* and Theaceae - **Environmental condition**s: Low slope, elevation between 400-500 m, and highly sandy and shallow soil
25	507374	2035104	DE	- **Forest type**: DE - **Location**: Nearly Highway 11 (Lamphun-Lampang) - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: A moderate slope, elevation between 500-600 m, sandy and shallow soil
26	504044	2098824	MDF	- **Forest type**: DDF - **Location**: San Sai district , Chiang Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* - **Environmental condition**s: A moderate slope, elevation between 700-800 m, and highly sandy and shallow soil. Moreover, fire disturbance on ground
27	494954	2085804	DDF	- **Forest type**: DDF - **Location**: Mae Rim district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis* and *Dipterocarpus tuberculatus* - **Environmental condition**s: Low slope, elevation between 300-400 m, and highly sandy and shallow soil
28	511454	2099214	DE	- **Forest type**: DDF - **Location**: Urban of Wiang Pa Pao district, Chiang Rai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Albizia lebbek*, *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and *Bambusa* spp. - **Environmental condition**s: A moderate slope, elevation between 600-700 m, and sandy and shallow soil
29	440054	2036634	MDF	- **Forest type**: MDF - **Location**: Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: Low slope, elevation between 800-900 m., and sandy and shallow soil
30	488894	2073624	EDF	- **Forest type**: MDF - **Location**: nearly Doi Suthep (southern), Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: Low slope, elevation between 400-500 m, and sandy and shallow soil

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
31	498974	2165124	MDF	- **Forest type**: DDF - **Location**: Muang Chiang Mai district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa, S. siamensis* and *Dipterocarpus tuberculatus* - **Environmental condition**s: Low slope, elevation between 700-800 m, and sandy and shallow soil
32	486854	2063634	DDF	- This location is not DDF but it is urban of San Pa Tong district Chiang Mai province
33[1]	532274	2126754	EE	- **Forest type**: EE - **Location**: Chiang Dao National Park at Phrao district, Chiang Mai province - **Tree species dominance**: Fagaceae, Theaceae and *Pinus* spp. - **Environmental conditions**: Very highly slope, elevation between 1,300-1,400 m, and sandy and calcifuge soil.
34	453644	2021154	MDF	- **Forest type**: MDF - **Location**: Op Luang National Park at Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: A moderate slope and elevation between 800-900 m.
35	434894	2053014	DDF	- **Forest type**: DDF - **Location**: Nearly Mae Cham district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis* and *Dipterocarpus tuberculatus* - **Environmental condition**s: A moderate slope, elevation between 500-600 m, and shallow soil
36	497144	2057904	DDF	- **Forest type**: DDF - **Location**: Urban at Saraphi district, Chiang Mai province - **Tree species dominance**: Dipterocarpaceae and *Shorea roxburghii* - **Environmental condition**s: Low slope, elevation between 200-300 m, and sandy and shallow soil
37	515684	2061324	DDF	- **Forest type**: DDF - **Location**: Saraphi district, Chiang Mai province - **Tree species dominance**: Dipterocarpaceae and *Shorea roxburghii* - **Environmental condition**s: Low slope, elevation between 300-400 m, and sandy and shallow soil
38	429944	1989534	MDF	- **Forest type**: MDF - **Location**: Op Luang National Park, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *Tectona grandis* and Bamboos - **Environmental condition**s: this site is highly slope between 1,000-1,100 m.
39	437024	1981014	MDF	- **Forest type**: Mixed Deciduous Forest (MDF) - **Location**: this site is closely Ban Thung Jam Reon, Omkoi district where is accessed on Highway 1099. - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, and Bamboos - **Environmental conditions**: High slope and elevation between 900-1,000 m.
40	436664	2086974	DEE	- This location is not accessed
41	499244	2017524	DE	- **Forest type**: DE - **Location**: Thung Hua Chang district, Lamphun province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental conditions**: A moderate slope and elevation between 700-800 m

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
42	500474	2100084	DDF	- **Forest type**: DDF - **Location**: Urban at Doi Sa Kret district, Chiang Mai province - **Tree species dominance**: Dipterocarpaceae - **Environmental conditions**: Low slope, elevation between 300-400 m, and sandy and shallow soil.
43	438134	2046744	DDF	- **Forest type**: DDF - **Location**: Mae Cham district, Chiang Mai province - **Tree species dominance**: Dipterocarpaceae and *Cratoxylum* spp. - **Environmental condition**s: A moderate slope, elevation between 600-700 m, sandy and shallow soil. Moreover, characteristic of DDF is a small forest community
44[2]	475844	2144634	DEE	- **Forest type**: DEE - **Location**: Chiang Dao wildlife sanctuary (eastern), Chiang Mai province - **Tree species dominance**: *Pinus* spp., *Bauhinia malabarica*, *Dalbergia* spp. *Millettia* spp. and *Cratoxylum* spp. - **Environmental condition**s: High slope, elevation between 900-1,000 m, shallow soil. Moreover, characteristic of DDF is a small forest community
45	459524	1969764	MDF	- **Forest type**: MDF - **Location**: Ban Doi Kaew at Omkoi district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, and Bamboos - **Environmental condition**s: Highly slope and elevation between 900-1,000 m.
46	443054	2084844	EE	- **Forest type**: EE - **Location**: Sameng district, Chiang Mai province - **Tree species dominance**: Fagaceae and Theaceae and *Pinus* spp. - **Environmental conditions**: High slope, elevation between 1,000-1,100 m, and sandy and shallow soil.
47	490184	1954644	DDF	- **Forest type**: DDF - **Location**: Nearly Mae Ping National Park (southern east) at Dao Tao district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Very highly slope, elevation between 1,000-1,100 m, and sandy and hallow soil
48[1]	424274	2113974	EE	- **Forest type**: EE - **Location**: Ban Huai Hom at Mar Hong Son province - **Tree species dominance**: Fagaceae, Theaceae and *Pinus* spp. - **Environmental conditions**: Very highly slope, elevation between 1,100-1,200 m, and sandy and shallow soil
49	431474	2057694	DDF	- **Forest type**: DDF - **Location**: Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae), and *Gardenia* spp. - **Environmental condition**s: A moderate slope, elevation between 700-800 m, and sandy and shallow soil
50[1]	440804	2104224	EE	- **Forest type**: EE - **Location**: Nearly Sameng wildlife sanctuary or locally called 'Wat Chan' - **Tree species dominance:** Fagaceae and Theaceae. CF includes *Pinus* spp. - **Environmental conditions**: Very highly slope, elevation between 1,100-1,200 m, and sandy and shallow soil
51	459194	1931604	DDF	- **Forest type**: DDF - **Location**: Omkoi wildlife sanctuary (southern), Chiang Mai province - **Tree species dominance**: Dipterocarpaceae and *Pinus* spp. (slightly scattered appearance) and *Cratoxylum* spp. - **Environmental condition**s: A moderate slope, elevation between 700-800 m, and highly sandy and shallow soil. Moreover, characteristic of DDF is a small forest community

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
52	511394	2066214	DDF	- **Forest type**: DDF - **Location**: Nearly urban of San Kam Phang district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius*, and Theaceae - **Environmental condition**s: A moderate slope, elevation between 300-400 m, highly sandy and shallow soil and fire disturbance on ground
53	524984	2105424	DEE	- **Forest type**: DEE - **Tree species dominance**: *Tectona grandis*, *Bauhinia malabarica*, *Dalbergia* spp. *Millettia* spp, *Diptercarpus alatus*, *Erythina subumbrans*, and *Toona ciliate*. - **Environmental conditions**: A moderate slope, elevation between 800-900 m, and moisture soil. Moreover, this forest community is closely stream
54	457994	1988034	DDF	- **Forest type**: DDF - **Location**: Nearly Ban Bua Kom at Doi Tao district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae). - **Environmental conditions**: Low slope, elevation between 600-700 m, and sandy and shallow soil.
55	492224	2063364	DDF	- This location is not DDF but it is paddy of urban in San Pa Tong district, Chiang Mai province
56	458924	2064114	DDF	- **Forest type**: DDF - **Location**: Ban Yang Tong at San Pa Tong district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae). and *Gardenia* spp. - **Environmental conditions**: A moderate slope, elevation between 700-800 m, and sandy and shallow soil
57	521504	2065164	DDF	- **Forest type**: DDF - **Location**: Urban of Ban Thi district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus obtusifolius* - **Environmental condition**s: Low slope, elevation between 400-500 m, and sandy and shallow soil
58	494864	2037624	DDF	- **Forest type**: DDF - **Location**: Nearly route of Mae Tha district (Highway 11) - **Tree species dominance**: *Shorea obtusa, S. Siamensis, Dipterocarpus tuberculatus* and *Cratoxylum spp*. - **Environmental condition**s: Low slope, elevation between 300-400 m, and sandy and shallow soil
59	464684	2150934	EEF	- This location is not accessed
60[3]	407174	2066694	EE	- **Forest type**: HEF - **Location**: Khun Yuam district, Mae Hong Son province - **Tree species dominance**: *Castanopsis acuminatissima*, *C. calathiformis*, *C. fissa*. *Lagerstroemia tomentosa*, *L. balansae*, *Gmelina arborea*, *Hopea* spp., *Irvingia* spp., and *Lagerstroemia* spp. - **Environmental condition**s: Very high slope and elevation between 1,200-1,300 m
61	501074	1959234	DDF	- **Forest type**: DDF - **Location**: Li district (Highway 11), Lamphun province - **Tree species dominance**: *Shorea obtusa, S. Siamensis, Dipterocarpus tuberculatus* and *Cratoxylum spp*. - **Environmental condition**s: A moderate slope and elevation between 400-600 m.
62	474944	2127744	MDF	- **Forest type**: MDF - **Location**: Huai Nam Dang National Park (southern this national park and close to Mae Loa-Mae Sae Wildlife Sanctuary), Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, and Bamboos. - **Environmental condition**s: High slope and elevation between 800-900 m.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
63	472004	2013744	DDF	- **Forest type**: DDF - **Location**: Ban Hong district, Lamphun province - **Tree species dominance**: *Shorea obtusa, S. Siamensis, Dipterocarpus tuberculatus* and *Cratoxylum* spp. - **Environmental condition**s: A moderate slope, elevation between 600-700 m, and sandy and shallow soil
64	494744	2031654	DDF	- **Forest type**: DDF - **Location**: Thung Hua Chang district, Lamphun province - **Tree species dominance**: *Shorea obtusa, S. Siamensis,* and *Dipterocarpus tuberculatus* - **Environmental condition**s: Low slope and elevation between 300-400 m.
65	465494	1954764	DDF	- **Forest type**: DDF - **Location**: Omkoi wildlife sanctuary - **Tree species dominance**: *S. Siamensis* and *Dipterocarpus* spp. - **Environmental condition**s: Low slope, elevation between 300-400 m, sandy and shallow soil. Characteristic of DDF is a small forest community.
66	453494	2100894	MDF	- **Forest type**: MDF - **Location**: Sameng wildlife sanctuary, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, and Bamboos - **Environmental condition**s: A moderate slope, elevation between 800-900 m, and sandy and shallow soil
67	522854	2061324	MDF	- **Forest type**: MDF - **Location**: Mae On district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, and Bamboos - **Environmental condition**s: A moderate slope, elevation between 700-800 m, and sandy and shallow soil
68[1]	427964	2098734	EE	- **Forest type**: EE - **Location**: Ban Huai Ya or locally called 'Wat Chan' , Chiang Mai province - **Tree species dominance**: Fagaceae and Theaceae and Pinus spp. - **Environmental conditions**: Very highly slope and elevation between 1,000-1,100 m.
69	514244	2102124	DE	- **Forest type**: DDF - **Location**: Nearly Sri Lanna national park (southern west) at Wiang Pa Pao district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa, S. Siamensis, Dipterocarpus tuberculatus* and *Cratoxylum* spp. - **Environmental condition**s: A moderate slope and elevation between 500-600 m, and sandy and shallow soil.
70	428294	2052114	DDF	- **Forest type**: DDF - **Location**: Mae Cham district, Chiang Mai province - **Tree species dominance**: Dipterocarpaceae and *Cratoxylum* spp. - **Environmental conditions**: A moderate slope, elevation between 600-700 m, and sandy and shallow soil. Characteristic of DDF is small forest community
71[2]	420344	2084874	EEF	- **Forest type**: DDF - **Location**: Ban Huai Pha or locally called 'Wat Chan' , Chiang Mai province - **Tree species dominance**: Dipterocarpaceae and *Pinus* spp. (mostly appearance) and *Cratoxylum* spp. - **Environmental condition**s: this site is highly slope between 1,000-1,100 m where soil characteristics are sandy and shallow. DDF characterized as a small forest community.
72	499544	2119224	DDF	- **Forest type**: DDF - **Location**: Urban at Mae Taeng district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus, D. obtusifolius, D. tuberculatus, Shorea obtusa, S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Low slope, elevation between 300-400 m, and sandy and shallow soil

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
73	511574	2143884	MDF	- **Forest type**: MDF - **Location**: Phrao district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, and Bamboos (highly standing) such as *D. strictus* and *Thyrsostachys siamensis* - **Environmental condition**s: A moderately slope, elevation between 600-700 m, and sandy and shallow soil
74	469304	2116074	DEE	- **Forest type**: DEE - **Location**: Ban Pa Pae at Mae Taeng district, Chiang Mai province - **Tree species dominance**: *Bauhinia malabarica*, *Dalbergia* spp. *Millettia* spp., *Diptercarpus alatus*, *Erythina subumbrans*, and *Toona ciliate*. - **Environmental condition**s: Moderate slope, elevation between 800-900 m, and sandy soil.
75	471554	2066274	MDF	- **Forest type**: MDF - **Location**: Nearly local road at Ban Huai Yuak, San Pa Tong district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *D. strictus* and *Thyrsostachys siamensis*. *Pinus* spp. - **Environmental condition**s: Moderate slope, elevation between 700-800 m, and sandy and shallow soil.
76	468824	2182794	EE	- **Forest type**: EE - **Location**: Nearly the north of Chiang Dao National Park, Chiang Dao district, Chiang Mai province - **Tree species dominance**: Fagaceae, Theaceae and *Pinus* spp. - **Environmental conditions**: Low slope, elevation between 1,200-1,300 m, and shallow soil.
77	502544	2018364	MDF	- **Forest type**: DEE - **Location**: Mae Tha district and Thung Hua Chang district, Lampang province and Lamphun province - **Tree species dominance**: *Bauhinia malabarica*, *Dalbergia* spp. *Millettia* spp., Bamboos, *Diptercarpus alatus*, *Erythina subumbrans*. - **Environmental condition**s: High slope, elevation between 900-1,000 m, and sandy soil.
78	457514	2064414	MDF	- **Forest type**: DEE - **Location**: Ban Yang Tong at Mae Wang district, Chiang Mai province - **Tree species dominance**: *Hopea* spp., *Dipterocarpus oliveri*, *Bauhinia malabarica*, *Dalbergia* spp. *Millettia* spp. and Bamboos. - **Environmental conditions**: High slope and elevation between 900-1,000 m.
79	515744	2041074	DE	- **Forest type**: DE - **Location**: Ban Sala Mae Tha, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos. - **Environmental condition**s: Low slope, elevation between 300-400 m, and sandy soil
80	491324	1951974	DDF	- **Forest type**: DDF - **Location**: Urban at Mae Taeng district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Low slope, elevation between 300-400 m, and sandy and shallow soil
81	434024	2098674	EE	- **Forest type**: EE - **Location**: Wat Chan and nearly the west of Sameng Wildlife Sanctuary, Sameng district, Chiang Mai province - **Tree species dominance**: Fagaceae, Theaceae and *Pinus* spp. - **Environmental conditions**: elevation between 1,300-1,400 m and very high slope.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
82	440744	2004474	MDF	- **Forest type**: MDF - **Location**: Near to Op Luang National Park at Mae Sa Riang District, Chiang Rai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus* and *Thyrsostachys siamensis*, - **Environmental condition**s: Moderate slope, elevation between 800-900 m, and sandy and shallow soil
83	455894	2041554	MDF	- This location is not accessed
84	477524	2048094	DDF	- **Forest type**: DDF - **Location**: Urban at Doi Lo district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Low slope, elevation between 300-400 m, and sandy and shallow soil
85[3]	459674	2134704	HEF	- **Forest type**: HEF - **Location**: Huai Nam Dang National Park, Mae Taeng district, Chiang Mai province - **Tree species dominance**: *Pinus* spp. mixed some shrub - **Environmental condition**s: Very highly slope and elevation between 1,500-1,600 m.
86	451364	1961664	DDF	- **Forest type**: DDF - **Location**: Omkoi Wildlife Sanctuary, Omkoi district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Moderate slope and elevation between 800-900 m.
87	510344	2084514	DDF	- This location is not DDF but it is urban of Doi Sakret district , Chiang Mai province
88	442184	2075604	EE	- **Forest type**: HEF - **Location**: Ban Sa Gae at Sameng district, Chiang Mai province - **Tree species dominance**: Castanopsis spp., *Pinus* spp., *Tetrameles* spp., *Gmelina* spp. and *Lagerstroemia* spp. - **Environmental condition**s: High slope and elevation between 1,100-1,200 m.
89	472754	2039394	DDF	- This location is not DDF but it is urban of Doi Lo district, Chiang Mai province
90	438884	2035614	DDF	- **Forest type**: DDF - **Location**: Near to local road in Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Moderate slope and elevation between 700-800 m.
91	454994	2067744	MDF	- **Forest type**: MDF - **Location**: Near to local road at Sameng District, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus* and *Thyrsostachys siamensis*. - **Environmental condition**s: Moderate slope, elevation between 900-1,000 m, and sandy and shallow soil
92	481034	2083704	EE	- **Forest type**: EEF - **Location**: Doi Suthep-Pui National Park at Mae Taeng district, Chiang Mai province - **Tree species dominance**: Fagaceae, Theaceae, *Hopea* ferra, *Dipterocarpus* spp. and *Irvingia malayana* and *Pinus* spp. - **Environmental conditions**: elevation between 1,000-1,100 m and very highly slope.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
93	507164	2029374	DE	- **Forest type**: DE - **Location**: Ban Pha Daeng and is nearly The west of Doi Pha Muang Wildlife Sanctuary, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: Elevation between 800-900 m and moderate slope.
94*	498134	1976994	DDF	- **Forest type**: DDF - **Location**: Li district, Lamphun province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Elevation between 600-700 m and moderate slope.
95	504104	2104854	DE	- **Forest type**: MDF - **Location**: San Sai District, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus* and *Thyrsostachys siamensis*. - **Environmental condition**s: Moderate slope between 400-500 m and sandy and shallow soil.
96	525704	2142144	DE	- **Forest type**: DDF - **Location**: Li district, Lamphun province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. MDF species are *Acacia* spp., *Albizia* spp., Dalbergia spp., *Xylia xylocarpa*, and *Bambusa* spp. - **Environmental condition**s: Elevation between 600-700 m and moderate slope.
97	478274	2173824	EE	- **Forest type**: EEF - **Location**: Chiang Dao National Park, Chiang Rai province - **Tree species dominance**: Fagaceae and Theaceae, *Hopea ferra*, *Dipterocarpus* spp., *Irvingia malayana* and *Pinus* spp. - **Environmental conditions**: elevation between 1,000-1,100 m and very highly slope.
98*	471644	1935024	DDF	- **Forest type**: DDF - **Location**: Mae Ping National Park, Tak province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Gardenia* spp. - **Environmental condition**s: Elevation between 800-900 m and moderate slope.
99	493664	2073084	DDF	- This location is not DDF but it is paddy field in Ban Ubosod, Doi Suthep district, Chiang Mai province
100	429404	2065584	DDF	- **Forest type**: DDF - **Location**: Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) and *Pinus* spp. (evenly) - **Environmental condition**s: Elevation between 500-600 m and moderate slope.
101	427454	2025954	DE	- **Forest type**: DE - **Location**: Near to Ob Luang National Park, Mae Cham district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: Elevation between 500-600 m and moderate slope.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
102	485414	1995234	DDF	- **Forest type**: DDF - **Location**: Li district, Lamphun province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae). - **Environmental condition**s: Elevation between 500-600 m and moderate slope.
103	443024	2038404	HEF	- **Forest type**: HEF - **Location**: Near to Ban Kong Kaeg and Ban Hlu at Mae Cham district, Chiang Mai province - **Tree species dominance**: *Castanopsis* spp. *Lithocarpus* spp. and *Quercus* spp. - **Environmental condition**s: Elevation between 1,100-1,200 m and very highly slope.
104	460904	2177574	DDE	- **Forest type**: MDEF - **Location**: Vieng Hae district, Chiang Rai province - **Tree species dominance**: *Dipterocarpus* spp., Dalbergia spp., *Milletia* spp. and bamboos (*Bambusa bambos*, *Dendrocalamus strictus*, and *Gigantochloa albociliata*) - **Environmental condition**s: Elevation between 900-1,000 m and high slope.
105	483314	2042964	DDF	- **Forest type**: DDF - **Location**: Near to urban of Doi Lo district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae). - **Environmental condition**s: Elevation between 200-300 m and low slope.
106	477104	2035524	DDF	- **Forest type**: DDF - **Location**: Near to urban of Pa Sang district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae). - **Environmental condition**s: Elevation between 200-300 m and low slope.
107	501584	2061954	DDF	- **Forest type**: DDF - **Location**: Near to urban of Saraphi district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* (Dipterocarpaceae) - **Environmental condition**s: Elevation between 200-300 m and low slope
108	472034	2085804	DE	- **Forest type**: MDF - **Location**: Sameng district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus*, *Thyrsostachys siamensis* and bamboos. - **Environmental condition**s: Moderate slope, elevation between 500-600 m, and sandy and shallow soil.
109	478094	2111964	DE	- **Forest type**: DE - **Location**: Doi Suthep-Pui National Park, Mae Taeng district, Chiang Mai province - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental condition**s: Elevation between 500-600 m and moderate slope.
110	504914	2071014	DDF	- This location is not DDF but it is paddy field in urban of Saraphi district, Chiang Mai province

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
111	483494	2025594	DDF	- **Forest type**: DDF - **Location**: Urban of Wiang Nong Long district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* or Dipterocarpaceae. - **Environmental condition**s: Elevation between 300-400 m and low slope.
112	431834	2102844	EE	- **Forest type**: EE - **Location**: Ban Cham Noi (nearly Ban Wat Chan), Chiang Mai province - **Tree species dominance**: Fagaceae, Theaceae and *Pinus* spp - **Environmental conditions**: elevation between 1,000-1,100 m and very highly slope.
113	526394	2073744	DDF	- **Forest type**: DDF - **Location**: urban of San Kam Phang district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* or Dipterocarpaceae. - **Environmental condition**s: Elevation between 300-400 m and low slope.
114	436394	2033394	DDF	- **Forest type**: DDF - **Location**: Urban of Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* or Dipterocarpaceae. - **Environmental condition**s: Elevation between 700-800 m and moderate slope.
115	510104	2032824	DDF	- **Forest type**: DDF - **Location**: Urban of Mae Cham district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* or Dipterocarpaceae. - **Environmental condition**s: Elevation between 700-800 m and moderate slope.
116	465524	2066694	EDF	- **Forest type**: DDF - **Location**: Urban of San Pa Tong district, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis* or Dipterocarpaceae. MDF species include *Dalbergia* spp., *Acacia tomentosa*, and *Bauhinia malabarica*. - **Environmental condition**s: Elevation between 500-600 m and moderate slope.
117	468344	2162274	DEE	- **Forest type**: DEE - **Location**: Ban Mae Tae at Vieng Hae district, Chiang Mai province - **Tree species dominance**: *Hopea* spp., *Dipterocarpus oliveri, Bauhinia malabarica, Dalbergia* spp. *Millettia* spp. and Bamboos. - **Environmental condition**s: Elevation between 800-900 m and moderate slope.
118	442754	2102544	EE	- **Forest type**: EE - **Location**: Ban Wat Chan and Sameng Wildlife Sanctuary, Chiang Mai province - **Tree species dominance**: HEF includes Fagaceae and Theaceae. CF includes *Pinus* spp. - **Environmental conditions**: elevation between 1,000-1,100 m and very highly slope.
119	422324	2096934	EEF	- **Forest type**: HEF - **Location**: Near to Ban Huai Ya at Sameng district, Chaing Mai province - **Tree species dominance**: *Castanopsis* spp. *Lithocarpus* spp., *Quercus* spp. and *Pinus* spp. - **Environmental condition**s: Elevation between 1,000-1,100 m and very highly slope.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
120	456374	2029494	EE	- **Forest type**: HEF - **Location**: Ob Luang National Park, Chom Thong district, Chiang Mai province - **Tree species dominance**: *Castanopsis* spp. *Lithocarpus* spp. and *Quercus* spp. - **Environmental conditions**: Elevation between 1,300-1,400 m and very highly slope.
121	429764	2103024	EE	- **Forest type**: EE - **Location**: Ban Cham Noi (nearly Ban Wat Chan) and is not so far Sameng Wild life sanctuary, Sameng district, Chiang Mai province - **Tree species dominance**: HEF species include *Castanopsis* spp. *Lithocarpus* spp. and *Quercus* spp. and CF species include *Pinus* spp. - **Environmental conditions**: Elevation between 1,000-1,100 m and very highly slope.
122	479384	2076744	DE	- **Forest type**: MDF - **Location**: Near to Doi Suthep-Pui, Chaing Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus*, *Thyrsostachys siamensis* and bamboos. - **Environmental conditions**: Moderate slope, elevation between 700-800 m, and sandy and shallow soil.
123	409304	2062014	EE	- **Forest type**: HEF - **Location**: Near to stream in Ban Khun Mae at Mae Cham district, Chiang Mai province - **Tree species dominance**: *Castanopsis* spp. *Lithocarpus* spp. and *Quercus* spp., *Baccaurea ramiflora*, *Lagerstroemia* spp., *Afzelia* spp. and *Cotylelobium* spp. - **Environmental conditions**: Elevation between 1,100-1,200 m and very highly slope.
124	470354	2090184	DE	- **Forest type**: MDF - **Location**: Urban of Sameng district, Chiang Mai province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus*, *Thyrsostachys siamensis* and bamboos. - **Environmental conditions**: Moderate slope, elevation between 500-600 m, and sandy and shallow soil.
125	537494	2053854	EE	- **Forest type**: EE - **Location**: Jae Son National Park, Chae Hom district of Lampang province. - **Tree species dominance**: *Castanopsis* spp. *Lithocarpus* spp., *Quercus* spp. and *Pinus* spp. - **Environmental conditions**: Elevation between 1,100-1,200 m and very highly slope.
126[4]	448904	2103984	DEE	- **Forest type**: HEF - **Location**: Sameng Wildlife Sanctuary - **Tree species dominance**: *Castanopsis* spp., *Lithocarpus* spp., *Quercus* spp. and *Pinus* spp. - **Environmental conditions**: Elevation between 900-1,000 m and very highly slope.
127	516554	2043954	DE	- **Forest type**: DDF - **Location**: Ban Pha Luk, Chiang Mai province - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis*, *Dalbergia* spp. and bamboos. - **Environmental conditions**: Elevation between 700-800 m and moderate slope.
128	486194	2114424	DE	- **Forest type**: DE - **Location**: Mae Taeng district and near to Doi Suthep-Pui National Park - **Tree species dominance**: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus tuberculatus*, *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii* and Bamboos - **Environmental conditions**: Elevation between 400-500 m and moderate slope.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
129	437444	2089464	EE	- **Forest type**: EE - **Location**: Near to Sameng Wildlife Sanctuary - **Tree species dominance**: *Castanopsis* spp., *Lithocarpus* spp., *Quercus* spp. and *Pinus* spp. - **Environmental condition**s: Elevation between 1,000-1,100 m and very highly slope.
130	423884	2027934	EDF	- This location is not accessed
131	527954	2047974	DE	- **Forest type**: MDF - **Location**: Ban Khun Tarn in Doi Khun Tarn National Park, Lamphun province - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos such as *D. strictus*, *Thyrsostachys siamensis* and bamboos. - **Environmental condition**s: Moderate slope between 400-500 m and sandy and shallow soil.
132	469964	2082084	DE	- **Forest type**: MDF - **Location**: Sameng district - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos *(D. strictus*, *Thyrsostachys siamensis*), *Shorea siamensis*, and *Dipterocarpus obtusifolius*. - **Environmental condition**s: this site is moderate slope between 500-600 m where includes outcrop and shallow soil.
133	522974	2074554	DE	- **Forest type**: DDF - **Location**: Near to urban of San Kam Phang district - **Tree species dominance**: *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa*, *S. siamensis*, *Pterocarpus macrocarpus*, *Sindora siamensis* var. *maritime*, *Xylia xylocarpa* var. *kerri* and bamboos. - **Environmental conditions**: Elevation between 400-500 m and moderate slope.
134	490874	2183094	DEE	- **Forest type**: MDF - **Location**: Chiang Dao National Park - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos *(D. strictus*, *Thyrsostachys siamensis*), *Anisoptera curtisii*, *Intsia* spp. and *Artocarpus* spp. - **Environmental conditions**: Moderate slope, elevation between 800-900 m, and sandy and shallow soil.
135	424364	2093304	DEE	- **Forest type**: DEE - **Location**: Ban Sub Mae Ruam at Sameng district - **Tree species dominance**: *Hopea* spp., *Dipterocarpus oliveri*, *Bauhinia malabarica*, *Dalbergia* spp. *Millettia* spp. and Bamboos. - **Environmental condition**s: Elevation between 900-1,000 m and high slope.
136[2]	443054	1989054	DEE	- **Forest type**: DDF - **Location**: Near to local road of Omkoi district - **Tree species dominance**: *Dipterocarpus obtusifolius*, *Shorea* spp., *Schima wallichii*, and *Pinus* spp. - **Environmental condition**s: Elevation between 1,000-1,100 m and very high slope.
137[2]	534074	2103534	CF	- **Forest type**: DDF - **Location**: Near to local road of Doi Sakret district - **Tree species dominance**: *Dipterocarpus obtusifolius*, *Shorea* spp., *Schima wallichii*, and *Pinus* spp. - **Environmental condition**s: Elevation between 700-800 m and moderate slope.
138	490484	2183694	DEE	- **Forest type**: MDF - **Location**: Chiang Dao National Park - **Tree species dominance**: *Dalbergia* spp., *Millettia* spp., *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, bamboos *(D. strictus*, *Thyrsostachys siamensis)*, *Anisoptera curtisii*, *Intsia* spp. and *Artocarpus* spp. - **Environmental condition**s: Moderate slope, elevation between 800-900 m, and sandy and shallow soil.

D.1 (Continue).

No.	Easting (X)	Northing (Y)	Class	Ground reference
139	459464	2067714	CF	- **Forest type**: CF - **Location**: Ban Sa Pok at San Pa Tong district - **Tree species dominance**: *Pinus* spp. - **Environmental condition**s: Elevation between 1,000-1,100 m and very high slope.
140	458414	1966464	MDEF	- **Forest type**: HEF - **Location**: Omkoi Wildlife Sanctuary - **Tree species dominance**: *Castanopsis* spp. *Lithocarpus* spp., *Quercus* spp. and *Pinus* spp. - **Environmental condition**s: Elevation between 900-1,000 m and very highly slope.
141	530594	2146614	MDEF	- **Forest type**: MDEF - **Location**: Sri Lan Na National Park at Phroa district - **Tree species dominance**: Dipterocarpus spp. - **Environmental condition**s: Elevation between 900-1,000 m and very high slope.

Note: - 1 is called 'lower montane pine-oak forest' by Santisuk (2006).
- 2 is called 'pine-deciduous forest' by Santisuk (2006).
- 3 is called 'lower montane rain forest' by Santisuk (2006).
- 4 is called 'lower montane oak forest' by Santisuk (2006).
- MDF = Mixed deciduous forest, DDF = Dry dipterocarp forest, DE = Deciduous ecotone, CF = Coniferous forest, MDEF = Moist and dry evergreen forest, HEF = Hill evergreen forest, EE = Evergreen ecotone, and DEE = Deciduous and evergreen ecotone

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