DEVELOPMENT OF ABOVE GROUND BIOMASS ESTIMATION MODEL FOR REFERENCE EMISSION LEVEL CONSTRUCTION UNDER REDD MECHANISM USING GEOINFORMATICS TECHNOLOGY

Tinn Thirakultomorn

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การพัฒนาแบบจำลองการประมาณค่ามวลชีวภาพเหนือพื้นดินสำหรับการสร้างระดับการปลดปล่อยอ้างอิงภายใต้กลไกเรดด์โดยอาศัยเทคโนโลยีภูมิสารสนเทศ

นายติณณ์ ถิรกุลโตมร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต

สาขาวิชาภูมิสารสนเทศ

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.

Thesis Examining Committee

S Dasananda

(Assoc. Prof. Dr. Songkot Dasananda)

Chairperson

Suwit Ong.

(Assoc. Prof. Dr. Suwit Ongsomwang)

Member (Thesis Advisor)

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ติณณ์ ถิรกุลโตมร : การพัฒนาแบบจำลองการประมาณค่ามวลชีวภาพเหนือพื้นดินสำหรับการสร้างระดับการปลดปล่อยอ้างอิงภายใต้กลไกเรดด์โดยอาศัยเทคโนโลยีภูมิสารสนเทศ (DEVELOPMENT OF ABOVE GROUND BIOMASS ESTIMATION MODEL FOR REFERENCE EMISSION LEVEL CONSTRUCTION UNDER REDD MECHANISM USING GEOINFORMATICS TECHNOLOGY) อาจารย์ที่ปรึกษา : รองศาสตราจารย์ ดร.สุวิทย์ อ๋องสมหวัง, 246 หน้า.

เทคโนโลยีภูมิสารสนเทศและแบบจำลองเชิงพื้นที่มีบทบาทสำคัญในการประเมิน การติดตามและการคาดการณ์เกี่ยวกับข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดิน ในการศึกษาครั้งนี้มีวัตถุประสงค์หลักคือ เพื่อจำแนกและคาดการณ์ข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดิน เพื่อพัฒนาแบบจำลองการประมาณค่ามวลชีวภาพเหนือพื้นดินสำหรับประเมินการปลดปล่อยคาร์บอน และเพื่อกำหนดช่วงเวลาการปลดปล่อยอ้างอิงและสร้างเส้นฐานการปลดปล่อยคาร์บอนอ้างอิงสำหรับการดำเนินการภายใต้กลไกเรดด์ วิธีการศึกษา เริ่มจากจำแนกข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดินในระหว่างปี พ.ศ. 2538-2558 จากข้อมูลแลนด์แซท ดัชนีพืชพรรณและปัจจัยทางกายภาพด้วยแบบจำลอง CART ที่เหมาะสม จากนั้น ทำการคาดการณ์ข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดินในระหว่างปี พ.ศ. 2563-2578 โดยแบบจำลอง CA-Markov ในขณะเดียวกัน ทำการพัฒนาแบบจำลองการประมาณค่ามวลชีวภาพเหนือพื้นดินที่เหมาะสมสำหรับชนิดป่าและพื้นที่ปลูกสร้างสวนป่า และสำหรับพื้นที่ป่าไม้โดยรวม โดยใช้การวิเคราะห์การถดถอยเชิงเส้นตรงและแบบไม่ใช่เชิงเส้นตรง หลังจากนั้น ทำการประเมินการปลดปล่อยคาร์บอนจากการตัดไม้ทำลายป่าและความเสื่อมโทรมของป่า ในระหว่างปี พ.ศ. 2538-2558 เพื่อระบุช่วงเวลาการปลดปล่อยคาร์บอนสูงสุด และสร้างเส้นฐานการปลดปล่อยคาร์บอนอ้างอิง

ผลการศึกษาพบว่า แบบจำลอง CART สำหรับการจำแนกข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดินที่เหมาะสม ประกอบด้วยค่าการสะท้อนจากข้อมูลแลนด์แซท (แบนด์ Blue Red NIR SWIR-1 และ SWIR-2) ดัชนีพืชพรรณ (SR NDWI และ Wetness) และปัจจัยทางกายภาพ (ระดับความสูงและความลาดชัน) โดยผลการจำแนกข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดินจากแบบจำลองให้ค่าความถูกต้องโดยรวมคิดเป็นร้อยละ 90.69 และค่าสัมประสิทธิ์แคปปาร้อยละ 88.45 สำหรับผลการจำแนกและคาดการณ์ข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดินในระหว่างปี พ.ศ. 2538-2578 พบว่า พื้นที่ป่าดิบแล้งที่มีความหนาแน่นสูงและความหนาแน่นปานกลาง และป่าปลูกมีแนวโน้มเพิ่มขึ้น ส่วนพื้นที่ป่าเบญจพรรณมีแนวโน้มลดลงในอนาคต พื้นที่ป่าไม้ในระหว่างปี พ.ศ. 2543-2548 พบว่า มีอัตราการเพิ่มขึ้นสูงสุดเท่ากับ 1.798 ตารางกิโลเมตรต่อปี และในระหว่างปี พ.ศ. 2553-2558 พื้นที่ป่ามีอัตรา

การลดลงสูงสุดเท่ากับ 0.254 ตารางกิโลเมตรต่อปี ในขณะเดียวกัน ปริมาณมวลชีวภาพเหนือพื้นดินและคาร์บอนกักเก็บที่ได้จากแบบจำลองการประเมินมวลชีวภาพสำหรับแต่ละชนิดป่า มีเพิ่มขึ้นทั้งหมดเท่ากับ 169,212 ตัน และ 79,530 ตัน ตามลำดับ และปริมาณการปลดปล่อยคาร์บอนเท่ากับ 365,506 ตัน โดยคิดเป็นปริมาณการปลดปล่อยที่เกิดจากการตัดไม้ทำลายป่าและการเสื่อมโทรมของป่าเท่ากับ 139,795 ตัน และ 225,711 ตัน ตามลำดับ ในทำนองเดียวกันปริมาณมวลชีวภาพเหนือพื้นดินและคาร์บอนกักเก็บที่ได้จากแบบจำลองการประเมินมวลชีวภาพสำหรับพื้นที่ป่าไม้โดยรวมมีปริมาณเพิ่มขึ้นเท่ากับ 125,280 ตัน และ 58,882 ตัน ตามลำดับ และปริมาณการปลดปล่อยคาร์บอนเท่ากับ 337,382 ตัน โดยเกิดจากการตัดไม้ทำลายป่าเท่ากับ 130,571 ตัน และการเสื่อมโทรมของป่าเท่ากับ 206,811 ตัน จากนั้น ปริมาณการปลดปล่อยคาร์บอนที่ประเมินได้ถูกนำมาใช้สร้างเส้นฐานการปลดปล่อยอ้างอิงภายใต้กลไกเรดด์ โดยวิธีการคาดการณ์แนวโน้มเชิงเส้นตรงและวิธีคำนวณค่าเฉลี่ยจากข้อมูลในอดีต จากการศึกษาพบว่า การปลดปล่อยคาร์บอนสูงสุดเกิดขึ้นในระหว่างปี พ.ศ. 2543-2548 จึงกำหนดให้เป็นช่วงเวลาการปลดปล่อยอ้างอิง พร้อมกับจัดสร้างเส้นฐานการปลดปล่อยอ้างอิงโดยอาศัยการวิเคราะห์การถดถอยเชิงเส้นตรงภายใต้วิธีการคาดการณ์แนวโน้มเชิงเส้นตรง และอาศัยค่าเฉลี่ยการปลดปล่อยคาร์บอนในระหว่างปี พ.ศ. 2538-2558 ภายใต้วิธีคำนวณค่าเฉลี่ยจากข้อมูลในอดีต

จากผลการศึกษาสามารถสรุปได้ว่า การบูรณาการระหว่างเทคโนโลยีภูมิสารสนเทศกับแบบจำลองเชิงพื้นที่สามารถนำมาใช้เป็นเครื่องมือ สำหรับการจำแนกข้อมูลพื้นที่ป่าไม้และสิ่งปกคลุมดิน การประมาณค่ามวลชีวภาพเหนือพื้นดินและการประเมินคาร์บอนกักเก็บสำหรับสร้างเส้นฐานการปลดปล่อยคาร์บอนอ้างอิงภายใต้การดำเนินการสำหรับกลไกเรดด์ได้อย่างมีประสิทธิภาพ

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา__________

ปีการศึกษา 2559 ลายมือชื่ออาจารย์ที่ปรึกษา__________

TINN THIRAKULTOMORN : DEVELOPMENT OF ABOVE GROUND BIOMASS ESTIMATION MODEL FOR REFERENCE EMISSION LEVEL CONSTRUCTION UNDER REDD MECHANISM USING GEOINFORMATICS TECHNOLOGY. THESIS ADVISOR : ASSOC. PROF. SUWIT ONGSOMWANG, Dr. rer. Nat. 246 PP.

CART/ ABOVE GROUND BIOMASS ESTIMATION/ CARBON EMISSION/ FOREST REFERENCE EMISSION LEVEL/ REDD MECHANISM

Geoinformatics technology and geospatial modelling plays important role in assessing, monitoring, and predicting forest and land cover information. The main objectives of the study were to classify and predict forest and land cover, to develop an optimum AGB estimation model for carbon emission, and to identify reference time period and construct FREL for REDD mechanism implementation. To fulfil the objectives, forest and land cover (1995-2015) was firstly extracted from Landsat data, vegetation indices, and physical factors with an optimum CART model and forest and land cover data (2020-2035) were predicted using CA-Markov model. Meanwhile an optimum AGB estimation model was developed using linear and non-linear regression analysis for forest type and plantation and forest area. Finally, carbon emission value due to forest degradation and deforestation (1995-2015) were calculated to identify the highest carbon emission period and establishment of FREL baseline.

As results, an optimum CART model for forest and land cover classification including Blue, Red, NIR, SWIR-1, SWIR-2, SR, NDWI, Wetness, and Elevation and Slope provided overall accuracy and Kappa hat coefficient of forest and land cover map

in 2015 about 90.69% and 88.45% respectively. According to forest and land cover data (1995-2035), dense and moderate dry evergreen forests and forest plantation tend to increase while mixed deciduous forest tends to decrease in the future. The highest increasing period of forest area occurred during 2000 to 2005 with annual rate of 1.798 km^2. In contrast, the highest decreasing period of forest area occurred between 2010 and 2015 with annual rate of 0.254 km^2. Meanwhile, total gained AGB and carbon stock based on forest type and plantation AGB models were 169,212 ton and 79,530 ton and carbon emission was 365,506 ton, where came from degraded forest (225,711 ton) and deforestation (139,795 ton). Likewise, gain of total AGB and carbon stock using forest AGB model were 125,280 ton and 58,882 ton, respectively while carbon emission was 337,382.37 ton where came from degraded forest (206,811.03 ton) and deforestation (130,571.34 ton). Finally, the derived carbon emission data were applied for FREL construction under REDD mechanism using linear trend extrapolation and historical average methods. In this study, the 2000-2005 period was chosen as reference time period and FREL baseline was constructed using simple linear regression under linear trend extrapolation method and average carbon emission (1995-2015) was applied under historical average method.

In conclusion, it appears that integration of geoinformatics technology with geospatial models can be used as an efficiently tools to classify forest and land cover, to estimate AGB and carbon stock and to assess carbon emission for FREL baseline construction for REDD mechanism implementation.

School of Remote Sensing | Student's Signature____________________

Academic Year 2016 | Advisor's Signature____________________

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LIST OF ABBREVIATIONS

AGB	=	Above ground biomass
AVI	=	Advanced vegetation index
B	=	Brightness
BI	=	Bare soil index
BLA	=	Barren land
BLUE	=	Blue band
BMB	=	Bamboo
C	=	Carbon
CART	=	Classification and regression tree
DDEF	=	Dense dry evergreen forest
DTF	=	Disturbed forest
FCD	=	Forest canopy density
FLC	=	Forest and land cover
FPT	=	Forest plantation
FREL	=	Forest reference emission level
FRL	=	Forest reference level
G	=	Greenness
GHG	=	Greenhouse gases
GREEN	=	Green band
MDEF	=	Moderate dry evergreen forest

LIST OF ABBREVIATIONS (Continued)

MDF	=	Mixed deciduous forest
MLA	=	Miscellaneous land
NDVI	=	Normalized differential vegetation index
NDWI	=	Normalized difference water index
NIR	=	Near-infrared band
NRMSE	=	Normalized root-mean square error
PaF	=	Paddy field and field crops
RED	=	Red band
REDD	=	Reducing emission from deforestation and degradation in developing countries.
REDD+	=	Reducing emission from deforestation and degradation in developing countries, and the role of conservation, sustainable management of forest and the enhancement of forest carbon stocks.
REL	=	Reference emission level
RSR	=	Reduced simple ratio
RVs	=	Reflectance values
SAVI	=	Soil adjusted vegetation index
SI	=	Shadow index
SR	=	Simple ratio
SSI	=	Scaled shadow index

LIST OF ABBREVIATIONS (Continued)

SWIR-1	=	Short-wave infrared band (1)
SWIR-2	=	Short-wave infrared band (2)
TaO	=	Perennial tree and orchard land
TOA	=	Top of atmosphere reflectance
TVI	=	Triangular vegetation index
VD	=	Vegetation density
VIs	=	Vegetation indices
W	=	Wetness

CHAPTER I

INTRODUCTION

1.1 Background problem and significance of the study

Forests play an important role in global carbon cycling, as they are large pools of carbon as well as potential carbon sinks and sources to the atmosphere (Muukkonen and Heiskanen, 2007). Moreover, forests have a critical role to play in addressing climate change. Approximately 17.4 percent of annual global carbon dioxide emissions are caused by deforestation and forest degradation and it will be impossible to solve the climate change problem without addressing these emissions (Virgilio, 2009). At the global level, major sectors which create world greenhouse gases (GHG) included transportation, electricity and heat, other fuel combustion, industry fugitive emission, land use change agriculture and waste. Meanwhile, deforestation from land use change is the main activity causing GHG emission (Figure 1.1).

The role of forests in the carbon cycle trees absorb carbon dioxide gas from the atmosphere during photosynthesis and, in the process of growing, transform the gas to the solid carbon that makes up their bark, wood, leaves and roots. When trees are cut down and burned or left to decompose, the solid carbon chemically changes back to carbon dioxide gas and returns to the atmosphere. Figure 1.2 shows simplistic diagram of trees and the carbon cycle (Virgillo, 2009).

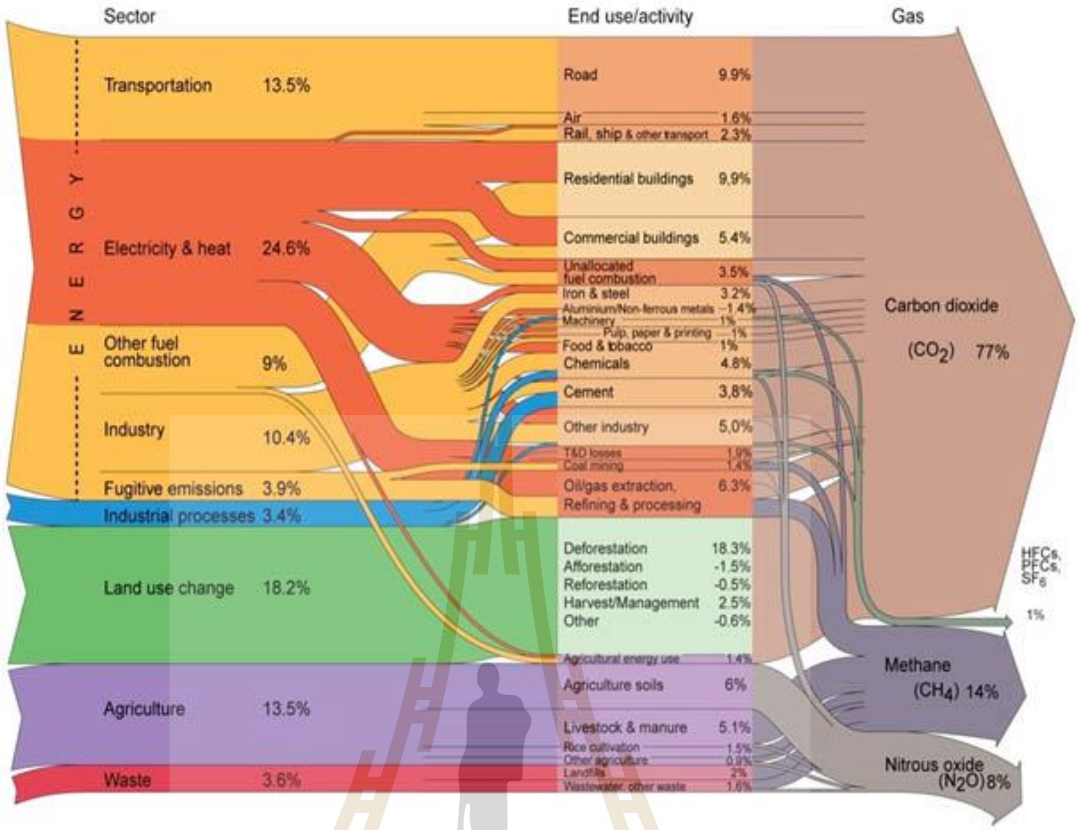


Figure 1.1 The world GHG emissions in 2000 (IPCC, 2005).

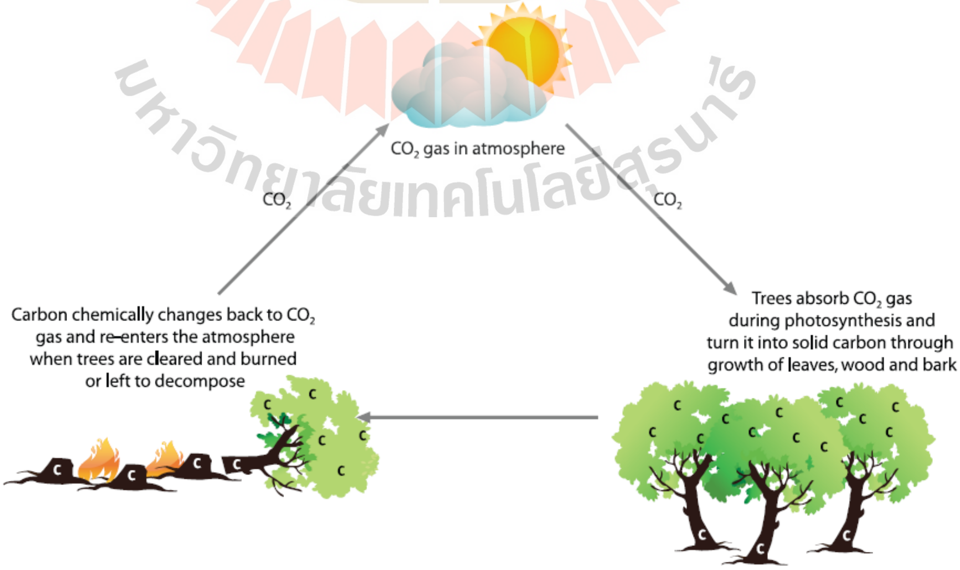


Figure 1.2 Simplistic diagram of trees and the carbon cycle (Virgillo, 2009).

GOFC-GOLD (2012) stated that at current status of negotiation five forest-related activities have been listed to be implemented as mitigation actions by developing countries, namely: reducing emissions from deforestation and reducing emissions from forest degradation, conservation of forest carbon stocks, sustainable management of forest land and enhancement of forest carbon stocks (all relating to carbon stock changes and GHG emissions within managed forest land use). The United Nation Framework Convention on Climate Change (UNFCCC) negotiations and related country submissions on Reducing Emission from Deforestation and Forest Degradation and the Role of Conservation of Forest Carbon Stock, Sustainable Management of Forest and Enhancement of Carbon Stock (REDD+) have advocated that methodologies and tools become available for estimating emissions and removals from deforestation and forest land management with an acceptable level of certainty.

Thailand ratified the UNFCCC on December 28, 1994 and the Convention came into effect in the country three months later in March 1995 and signed the Kyoto Protocol on February 2, 1999 and ratified on August 28, 2002. Later, Thailand's Greenhouse Gas Management Organization (TGO) was established on July 6, 2007. Furthermore, approval of the National Strategy for Climate Change Mitigation by the Cabinet provides the framework for undertaking measure to reduce emission, including those from land use and forest. Based on the national policy on forest conservation and reforestation, it is expected that the carbon sequestration rate in Thailand would increase, resulting in the lower net emission. If the trend for emission between 1990 and 1994 is maintained, CO_2 emission from land use and forest changes could drop from 59 Tg. in 1994 to about 51 Tg. by 2010 and 46 Tg. by 2020 (DNP and RFD, 2009).

However, deforestation has been continuously existed. From the statistics of the Royal Forest Department (RFD) in 2016, it was found that the existing forest cover of Thailand between 1973 and 2015 was continuously decreased (Table 1.1). In 1973 the existing forest area was about 43.21 percent while it dropped to be 31.60 percent in 2015.

Table 1.1 Existing forest area in Thailand during 1973-2015.

Year	Forest area (sq. km)	Percentage	Map Scale
1973	221,707.00	43.21	1:250,000
1976	198,417.00	38.67	1:250,000
1978	175,224.00	34.15	1:250,000
1982	156,600.00	30.52	1:250,000
1985	150,866.00	29.40	1:250,000
1988	143,803.00	28.03	1:250,000
1989	143,417.00	27.95	1:250,000
1991	136,698.00	26.64	1:250,000
1993	133,554.00	26.03	1:250,000
1995	131,485.00	25.62	1:250,000
1998	129,722.00	25.28	1:250,000
2000	170,110.78	33.15	1:50,000
2004	167,590.98	32.66	1:50,000
2005	161,001.30	31.38	1:50,000
2008	171,585.65	33.44	1:50,000
2013	163,391.26	31.57	1:50,000
2014	163,656.64	31.62	1:50,000
2015	163,585.57	31.60	1:50,000

Source: The Royal Forest Department (2016).

Therefore, the study on development of above ground biomass estimation model for reference emission level (REL) construction under REDD mechanism using geoinformatics technology is very important to fulfill the requirement of UNFCCC negotiation. The expected results can provide sufficient information on REDD implementation to various government and non-government agencies.

1.2 Research objectives

The main goal of the study is to development above ground biomass estimation model for Forest Reference Emission Level establishment under REDD mechanism using Geoinformatics Technology. Herein, optimum classification and regression tree (CART) is firstly applied to classify forest and land cover in 1995, 2000, 2005, 2010 and 2015 and CA-Markov model is then applied to predict forest and land cover in 2020, 2025, 2030 and 2035. At the same time, an optimum AGB estimation model is developed to estimate AGB and assess carbon stock of forest areas. Lastly, the extracted carbon emission and deforestation rate in the historical and recent times in the study area are applied to establish FRE baseline for REDD implementation. Specific objectives for the study are as follows:

(1) To classify forest and land cover between 1995 and 2015 using CART and Expert System.

(2) To predict forest and land cover between 2020 and 2035 using CA-Markov model.

(3) To develop an optimum above ground biomass estimation model using linear and non-linear regression analysis for above ground biomass estimation and carbon stock assessment between 1995 and 2035.

(4) To identify reference time period (1995-2015) and construct Reference Emission Level (REL) for REDD mechanism implementation in the study.

1.3 Scope of the study

Scope of the study can be summarized as follows:

(1) Forest and land cover between 1995 and 2015 are extracted from Landsat data, vegetation indices and physical factors with an optimum CART model under SPPS statistical software and Expert System of ERDAS Imagine software. Herein an optimum CART model is justified based on the accuracy assessment of the derived forest and land cover data in 2015 with providing an overall accuracy and Kappa hat coefficient equal or more than 80 percent.

In this study forest and land cover classification system, which included (a) dense dry evergreen forest, (b) moderate dry evergreen forest, (c) mixed deciduous forest, (d) forest plantation, (e) disturbed forest (f) bamboo, (g) perennial trees and orchards (h) paddy field and field crops, (i) bare land and (j) miscellaneous land, is modified from forest type classification system of RFD and land use classification system of LDD.

(2) Forest and land cover between 2020 and 2035 are predicted using CA-Markov model based on the corresponding derived forest and land cover data between 1995 and 2015.

(3) An optimum above ground biomass estimation model is developed using linear and non-linear regression analysis according to the relationship between in situ AGB data in 2015 and influential factors including reflectance value of Landsat data, vegetation indices (SR, NDVI, SAVI, RSR and Greenness) and FCD. Herein, the best candidate equation from linear and non-linear regression analysis, which provide the lowest NRMSE value based on validation dataset, is chosen as an optimum above

ground biomass estimation model for forest type and plantation and forest area in the study area.

(4) For the highest carbon stock/carbon emission period identification, carbon emission value due to forest degradation and deforestation for periods: 1995-2000, 2000-2005, 2005-2010 and 2010-2015 are calculated to identify the highest carbon emission period for establishment of FREL/FRL trend or baseline.

(5) For REDD implementation, the predicted carbon stock/carbon emission between 2020 and 2035 are compared with FREL/FRL trend or baseline to justify for REDD mechanism implementation.

1.4 Limitation of the study

(1) Due to limitation of historical forest cover record in 1995, 2000, 2005 and 2010 only forest and land cover in 2015 is performed accuracy assessment. In addition, results of forest and land use classification in 1995, 2000, 2005 and 2010 which are classified based on the criteria of an optimum CART model may create unexpected outputs. For instance, one forest type become another forest type in 5 years.

(2) Because of limitation of Landsat data availability through the phonological cycle of the forest, one available season of Landsat data is applied in this study.

(3) Because of no Landsat data existing for AGB estimation between 2020 and 2035 using an optimum above ground biomass estimation model, Trend Analysis function of MS Excel and ASCII to Image function of ERDAS Imagine software are here applied for creating the required variables as image data for above ground biomass estimation. The result of AGB estimation between 2020 and 2035 are applied to assess carbon emission for participation under REDD mechanism.

1.5 Definition of technical terms

Important key issues about REDD which are related to monitoring and estimating carbon stock changes and anthropogenic GHG emissions and removals by deforestation, gains and losses of carbon stocks in forests remaining forests and forestation and management of forest land are here reviewed based on a sourcebook of GOFC-GOLD (2012).

1.5.1 Definition and development of REDD

UN-REDD (2013) defined about Reducing Emissions from Deforestation and Forest Degradation (REDD) mechanism is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (Table 1.2). Most of UNFCCC's member states have agreed to implement REDD.

Table 1.2 Chronological development of RED, REDD and REDD+.

Abbreviation	Full Name	Date Start
RED	Reducing Emission from Deforestation in developing countries	UNFCCC: COP11, 2005
REDD	Reducing Emission from Deforestation and Degradation in developing countries	UNFCCC: COP13, 2007
REDD+	Reducing Emission from Deforestation and Degradation in developing countries and the Role of Conservation, Sustainable management of Forest and the Enhancement of Forest Carbon Stocks	UNFCCC: COP14, 2008

1.5.2 Definition of forest land, deforestation and forest degradation

Forest land: For REDD mechanism, the definitions as used in UNFCCC and Kyoto Protocol context are potentially applicable to REDD after a negotiation process (GOFC-GOLD, 2012). Under the UNFCCC, this category includes all lands with woody vegetation consistent with thresholds used to define forest land in the national greenhouse gas inventory.

The FAO uses a minimum cover of 10%, height of 5 m and area of 0.5 ha stating that forest use should be the predominant use (FAO, 2006). However, the FAO approach of a single worldwide value excludes variability in ecological conditions and differing perceptions of forests.

For the purpose of the Kyoto Protocol, parties should select a single value of crown area, tree height and area to define forests within their national boundaries. Selection must be from within the following ranges, with the understanding that young stands that have not yet reached the necessary cover or height are included as forest:

- Minimum forest area 0.05 to 1 ha;
- Potential to reach a minimum height at maturity in situ of 2-5 m;
- Minimum tree crown cover 10 to 30%.

The definition of forest land in Thailand is forest type such as evergreen forest, pine forest, mangrove forest, mixed deciduous forest, dry dipterocarp forest, scrub forest and beach forest which area included in national parks, wildlife sanctuary, national reserved forest and existing forest areas more than 0.5 hectare or 3.125 Rai with a canopy at least 5 meters and covering more than 10 percent of the area (DNP and RFD, 2009).

Deforestation: The most definitions characterize deforestation as the long-term or permanent conversion of land from forest use to other non-forest uses. The UNFCCC defined deforestation as: "the direct, human-induced conversion of forested land to non-forested land." Effectively this definition means a reduction in crown cover from above the threshold for forest definition to below this threshold. Deforestation causes a change in land use and usually in land cover. Common changes include: conversion of forests to annual cropland, conversion to perennial plants (oil palm, shrubs) and conversion to urban lands or other human infrastructure.

The general definition of deforestation refers to land use change permanently from forest area to non-forest area. So the area is covered by canopy to less than that defined in the definition of "forest" due to human activities permanently, thus it was. Thailand's deforestation is defined as the forest area with canopy cover of at least 30 percent, as deforestation occurs when canopy cover is less than specified.

Forest degradation: In areas where there are anthropogenic net emissions during a given time period from forests caused by a decrease in canopy cover/biomass density that does not qualify as deforestation, it is termed as forest degradation.

IPCC (2003) has defined forest degradation that is caused by human activity as long-term changes (over X years) or at least Y% of forest carbon stock in time T, which does not change such as deforestation.

In summary, these definitions directly relate to categories for estimating CO_2 emissions and removals as follows:

- Forest land converted to cropland, forest land converted to grassland, forest land converted to wetlands, forest land converted to settlements and forest land converted to other land, are commonly equated with "deforestation".
- A decrease in carbon stocks of forest land remaining forest land is commonly equated to "forest degradation". An increase in this category would refer to the enhancement of carbon stocks.
- Non-forest land converted to forest land would generally be referred to as forestation and is reflected in new forest area being created.

1.5.3 Reference emission level (REL)

The accounting of emissions and removals from deforestation, forestation and changes in remaining forest areas requires assessing reference levels against which future emissions and removals can be compared. The REL represents expected business-as-usual carbon balance from forest related human activities at national or sub-national level and is based on historical data and national circumstances. Credible reference levels can be established for a REDD+ system using existing scientific and technical tools (GOFC-GOLD, 2012). Basically, the REL used for REDD mechanism, Reference Level (RL) used for REDD+ mechanism and Baseline (BL) used for Clean Development Mechanism (CDM).

The Good Practice Guidance (GPG) suggested two basic inputs for generating inventories of GHG emissions/removals (Angelsen et al., 2011) included (1) activity data and (2) emission factors. The accuracy of REL assessment for REDD mechanism should be at least 80 percent (GOFC-GOLD, 2012). The process of developing REL of REDD mechanisms should be include following steps:

(1) Defined the forest area and its assessment of remote sensing and GIS.

(2) Evaluate the amount of carbon stock in the forest area.

(3) Defined the reference time period.

(4) The calculation of REL.

Reference time period to be used to evaluate REL in REDD mechanism had not yet been resolved by Conference of Parties (COP) 15 in 2009. However, they suggested that after year 2000 the reference time period should not be less than five years due to a situation similar to the present and the map data is adequately supported. But reference time period should not be more than 10 years to get the average value similar to the real circumstances that will occur in the future.

For implementation of the REDD mechanism, it must check the reducing of greenhouse gas emissions as a result of reducing deforestation and forest degradation. REL can be used as a baseline to compare the amount of greenhouse gases can be reduced. The example of REL is shown in Figure 1.3.

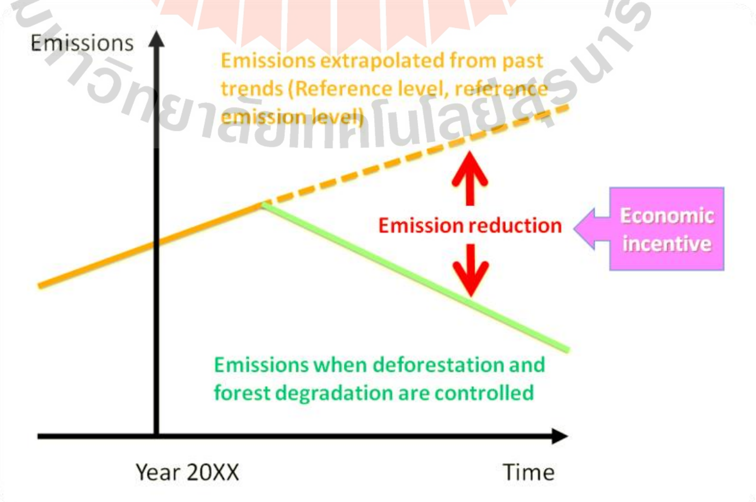


Figure 1.3 Example of Reference Emission Level (REL), (REDD Research and Development Center, 2010).

1.6 Study area

Subwatershed that covers national reserved forest area at Takhob subdistrict of Pakthongchai district, Nakhon Ratchasima province, was ~~is~~ here selected as the study area (Figure 1.4). It is a sub-watershed of Lam Phra Phloeng Watershed and consists of natural forest more than 50%. Furthermore, study area situated in some part of Pha Khoa Phu Luang national reserved forest and Pha Khoa Phu Luang Non-hunting area. The total study area is about 135 sq. km.

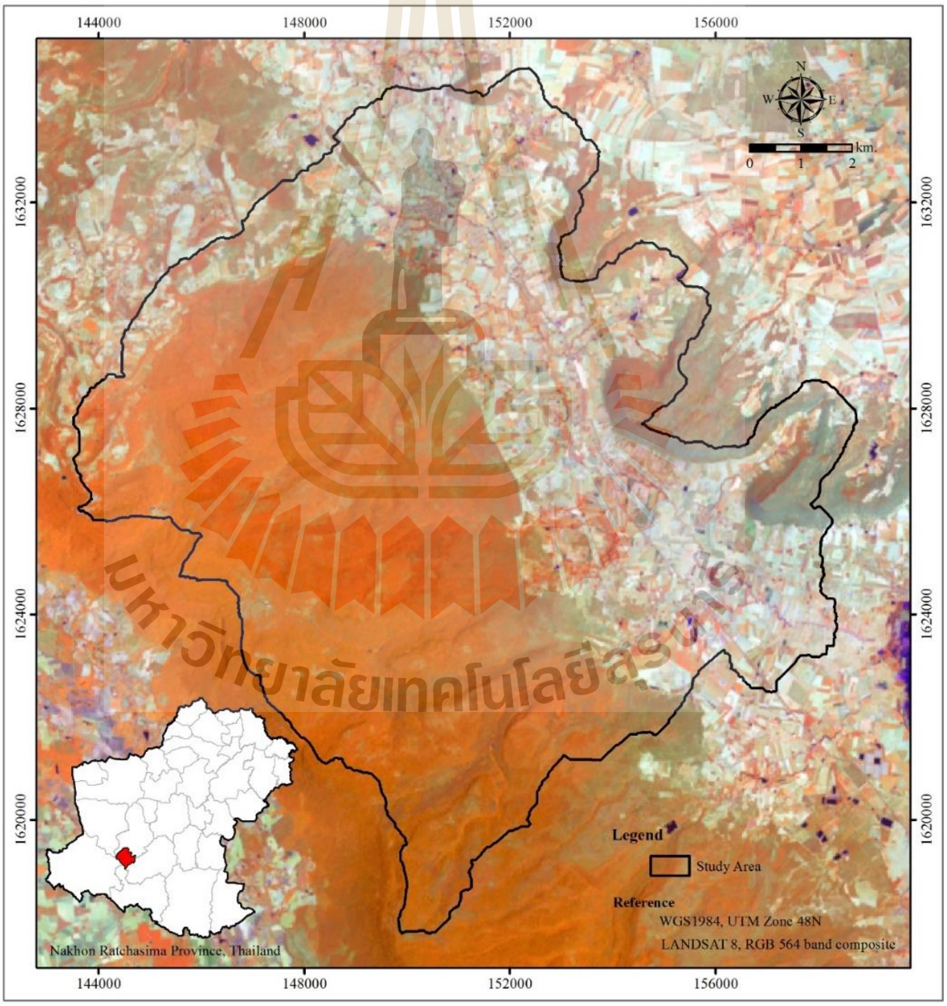


Figure 1.4 Study area with Landsat 8 OLI data 564 band composite.

1.7 Benefit of the study

The specific benefits of the study are presented below:

(1) Optimum CART model for forest and land cover classification;

(2) Classified and predicted forest and land cover status and its change between 1995 and 2035,

(3) An optimum above ground biomass estimation model for forest area;

(4) AGB estimation and carbon stock assessment of forest area between 1995 and 2035 and its change, especially carbon emission;

(5) The FREL/FRL baseline establishment under REDD mechanism implementation in the study area.

(6) Useful information on REDD implementation to various government and non-government agencies.

CHAPTER II

RELATED CONCEPTS AND LITERATURE REVIEWS

2.1 Biomass and carbon stock estimation

IPCC (2006) suggests that carbon stock of forests can be obtained from the biomass. The source of accumulated of carbon consists of five sources of biomass include (1) above ground biomass, (2) underground biomass, (3) dead wood biomass (4) humus biomass and (5) soil biomass (Figure 2.1). An important source of carbon stock is above ground biomass and underground biomass. Especially, above ground biomass is easy to change and biomass of natural forests is highly variable, depending on factors such as forest type, species composition, forest density, topography and environmental factors. The above ground biomass is higher than underground biomass about 2-4 times. Soil carbon is not taken into assess carbon emissions, that course the carbon in the soil is not being emitted at all, although the land use change. Moreover, Thailand is also a lack of information and the coefficient of the greenhouse gas emissions caused by deforestation (Setthasirote, Tavorn, Punangchit and Sunthonwong, 2011).

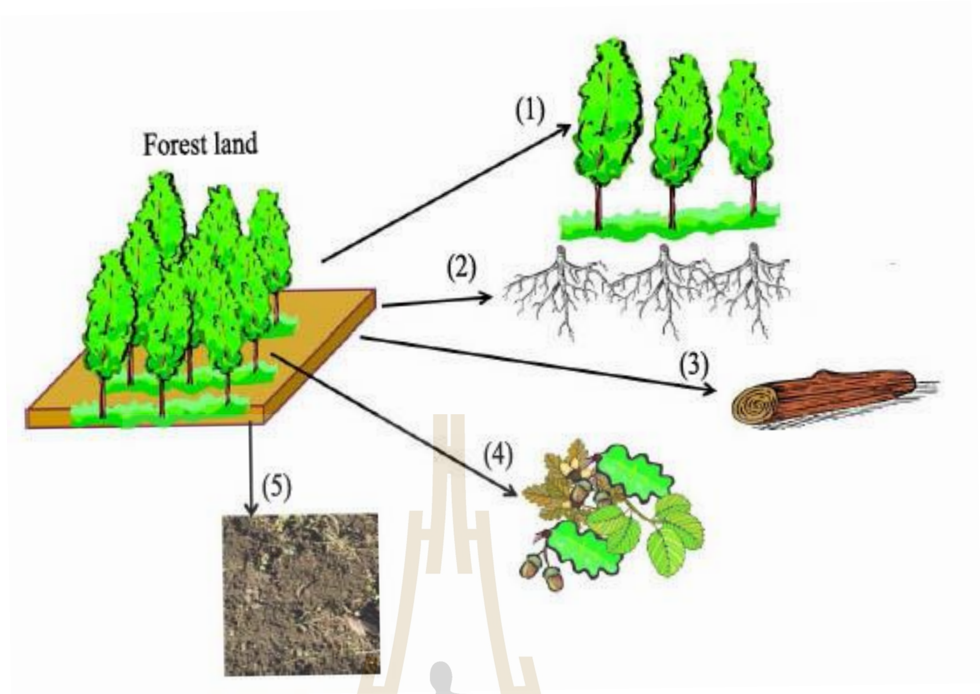


Figure 2.1 Sources of biomass (IPCC, 2006).

In practice, in situ measurement is required to measure the size of each tree in the sample plot. Diameter at breast height (DBH) of tree with size more than 4.5 cm and height of the tree are measured. After that allometry equation of trees or forest type is used to estimate above ground biomass (AGB).

Allometry equations allow aboveground tree biomass and carbon stock to be estimated from tree size (Vieilledent et al., 2012). The allometry scaling theory suggests the existence of a universal power-law relationship between tree biomass and tree diameter with a fixed scaling exponent close to 8/3.

The existing allometry equations of forest types and plantation that were prepared by researchers are applied in this study. They are include:

(1) Dry evergreen forest of Tsutsumi et al. (1983)

$$Stem\ (W_S) = 0.0509(D^2H)^{0.919} \tag{2.1}$$

$$Branch\ (W_B) = 0.00893(D^2H)^{0.997} \tag{2.2}$$

$$Leaf\ (W_L) = 0.0140(D^2H)^{0.669} \tag{2.3}$$

(2) Mixed deciduous forest of Ogawa et al. (1965)

$$Stem\ (W_S) = 0.0396(D^2H)^{0.9326} \tag{2.4}$$

$$Branch\ (W_B) = 0.003487(D^2H)^{1.027} \tag{2.5}$$

$$Leaf\ (W_L) = ((28.0/W_S) + W_B + 0.25) - 1 \tag{2.6}$$

(3) Eucalyptus (*camaldulensis Dehnh.*) plantation of Viriyabuncha et al. (2005)

$$Stem\ (W_S) = 0.0215(D^2H)^{0.9900} \tag{2.7}$$

$$Branch\ (W_B) = 0.0011(D^2H)^{1.1472} \tag{2.8}$$

$$Leaf\ (W_L) = 0.0197(D^2H)^{0.6867} \tag{2.9}$$

Where D is a diameter at breast height (cm)

H is a height of the tree (m)

2.2 Estimation of above ground carbon Stocks

Monitoring the location and areal extent of change in forest cover represents only one of two components involved in assessing emissions and removals from REDD+ related activities. The another component is the emission factors that is, the changes in carbon stocks of the forests undergoing change that are combined with the activity data for estimating the net emissions (GOFC-GOLD, 2012). The focus in this section is on estimating carbon stocks of existing forests that are subject to deforestation and degradation.

2.2.1 Fate of carbon pools as a result of deforestation and degradation

A forest is composed of pools of carbon stored in the living trees above and belowground, in dead matter including standing dead trees, down woody debris and litter, in non-tree understory vegetation and in the soil organic matter. When trees are cut down there are three destinations for the stored carbon, dead wood, wood products or the atmosphere (GOFC-GOLD, 2012).

- In all cases, following deforestation and degradation, the stock in living trees decreases.
- Where degradation has occurred this is often followed by a recovery unless continued anthropogenic pressure or altered ecologic conditions precludes tree regrowth.
- The decreased tree carbon stock can either result in increased dead wood, increased wood products or immediate emissions.
- Dead wood stocks may be allowed to decompose over time or may, after a given period, be burned leading to further emissions.

- Wood products over time decompose, burned, or are retired to land fill.

- Where deforestation occurs, trees can be replaced by non-tree vegetation such as grasses or crops. In this case, the new land-use has consistently lower plant biomass and often lower soil carbon, particularly when converted to annual crops.

- Where a fallow cycle results, then periods of crops are interspersed with periods of forest regrowth that may or may not reach the threshold for definition as forest (GOFC-GOLD, 2012). Figure 2.2 below illustrates potential fates of existing forest carbon stocks after deforestation.

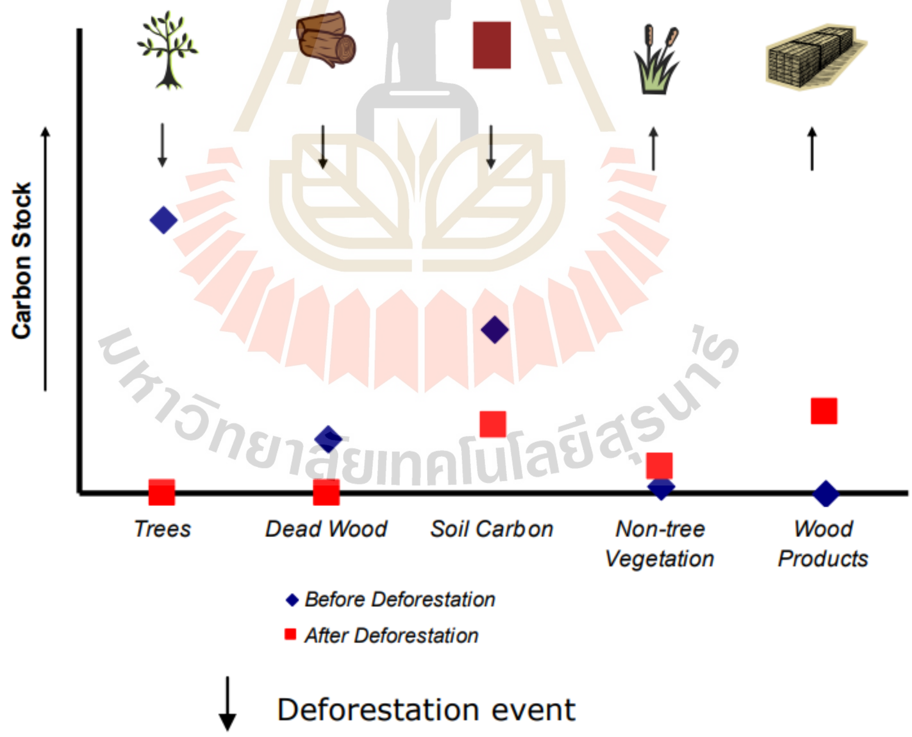


Figure 2.2 Fate of existing forest carbon stocks after deforestation (GOFC-GOLD, 2012).

2.2.2 Stratification by carbon stocks

Carbon stocks vary by forest type, for example tropical pine forests will have a different stock than tropical broadleaf forests which will again have different stock than woodlands or mangrove forests. Even within broadleaf tropical forests, stocks will vary greatly with elevation, rainfall and soil type. Then even within a given forest type in a given location the degree of human disturbance will lead to further differences in stocks. The resolution of most readily and inexpensively available remote sensing imagery is not good enough to differentiate between different forest types or even between disturbed and undisturbed forest and thus cannot differentiate different forest carbon stocks. Therefore stratifying forests can lead to more accurate and cost effective emission estimates associated with a given area of deforestation or degradation (GOFC-GOLD, 2012).

Stratification refers to the division of any heterogeneous landscape into distinct sub-sections (or strata) based on some common grouping factor. In this case, the grouping factor is the stock of carbon in the vegetation. If multiple forest types are present across a country, stratification is the first step in a well-designed sampling scheme for estimating carbon emissions associated with deforestation and degradation over both large and small areas. Stratification is the critical step that will allow the association of a given area of deforestation and degradation with an appropriate vegetation carbon stock for the calculation of net emissions (GOFC-GOLD, 2012).

In general, there are two different approaches for stratifying forests for national carbon accounting, both of which require some spatial information on forest cover within a country (GOFC-GOLD, 2012). In the first approach, all of a country's forests are stratified "up-front" and carbon estimates are made to produce a country wide map of forest carbon stocks. At future monitoring events, only the activity data need to be monitored and combined with the pre-estimated carbon stock values. Such a map would then need to be updated periodically, at least once per commitment period. While, the second approach, a full land cover map of the whole country does not need to be created. Rather, carbon estimates are made at each monitoring event only in those areas that have undergone change. Which approach to use depend on a country's access to relevant and up-to-date data as well as its financial and technological resources.

In this study, forest types and plantation are firstly classified using CART model and in situ forest inventory are then conducted to collect height and DBH of trees for estimating AGB of forest types and plantation using allometry equations. Later, carbon emissions caused by deforestation and degradation are assessed.

2.3 Vegetation index

Basic knowledge of remote sensing of biomass include a unique spectral reflectance characteristics of green plants (Ashraf, Maah and Yusoff, 2011). In the visible part of the spectrum, plants strongly absorb light in the blue (0.45 μm) and red (0.67 μm) regions and reflect strongly in the green portion of the spectrum due to the presence of chlorophyll. In cases where the plant is subjected to stress or to a condition which hinders growth, the chlorophyll production will decrease. And this in turn leads to less absorption in the blue and red bands. In the near infrared portion of the spectrum (0.7-1.3 μm), green plant reflectance increases to 40-50% of incident light. Beyond 1.3μm, there are dips in the reflectance curve due to absorption by water in the leaves.

The differential reflection of green plants in the visible and infrared portion of the spectrum makes possible the detection of green plants from satellites. Normalized

Difference Vegetation Index (NDVI) is commonly used to represent this character. NDVI is determined by the degree of absorption by chlorophyll in the red wavelengths, which is proportional to green leaf density. Therefore, NDVI correlates well with green leaf biomass, leaf area index and other related parameters.

The list of selected vegetation indices that are applied in this study is summarized based on Jensen (2005) and Jensen (2007) in Table 2.1.

Table 2.1 Lists of vegetation indices (Jensen, 2005; Jensen, 2007).

Vegetation index	Equation	Note
Simple Ratio (SR)	$SR = \frac{\rho_{red}}{\rho_{nir}}$	ρ_{red} is red reflectance flux ρ_{nir} is NIR reflectance flux
Normalized Differential Vegetation Index (NDVI)	$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$	ρ_{red} is red reflectance flux ρ_{nir} is NIR reflectance flux
Normalized Difference Water Index (NDWI)	$NDWI = \frac{\rho_{green} - \rho_{nir}}{\rho_{green} + \rho_{nir}}$	ρ_{green} is green reflectance flux ρ_{nir} is NIR reflectance flux
Soil Adjusted Vegetation Index (SAVI)	$SAVI = \frac{(\rho_{nir} - \rho_{red})}{\rho_{nir} + \rho_{red} + L}(1 + L)$	L is a canopy background adjustment factor The best value of L is 0.5
Triangular Vegetation Index (TVI)	$TVI = 0.5\left(120(\rho_{nir} - \rho_{green})\right) - 200(\rho_{red} - \rho_{green})$	ρ_{red} is red reflectance flux ρ_{green} is green reflectance flux ρ_{nir} is NIR reflectance flux
Reduced Simple Ratio (RSR)	$RSR = \frac{\rho_{nir}}{\rho_{red}}\left(1 - \frac{(\rho_{swir} - \rho_{swirmin})}{(\rho_{swirmax} - \rho_{swirmin})}\right)$	ρ_{nir} is NIR reflectance flux ρ_{red} is red reflectance flux ρ_{swir} is SWNIR reflectance flux
Kauth-Thomas Tasseled Cap Transformation: MSS data	$B = 0.2909TM1 + 0.2493TM2 + 0.4806TM3 + 0.5568TM4 + 0.4438TM5 + 0.1706TM7$ $G = 0.2728TM1 - 0.2174TM2 - 0.5508TM3 + 0.7221TM4 + 0.0733TM5 - 0.1648TM7$ $W = 0.1446TM1 + 0.1761TM2 + 0.3322TM3 + 0.3396TM4 - 0.6210TM5 - 0.4186TM7$	B is brightness, G is greenness, W is wetness.

2.4 Forest canopy density (FCD)

Forest canopy density (FCD) is one of the most useful parameters to consider in the planning and implementation of rehabilitation program. This study is development of biophysical analysis model for obtaining of FCD using LANDSAT TM data image analysis. FCD data indicates the degree of degradation, thereby also indicating the intensity of rehabilitation treatment that may be required.

The remote sensing data used in FCD model is LANDSAT TM data. The FCD model comprises biophysical phenomenon modeling and analysis utilizing data derived from four indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI). It determines FCD by modeling operation and obtaining from these indices (Rikimaru, Roy and Miyatake, 2002). The characteristics of four indices for forest condition is displayed in Figure 2.3.

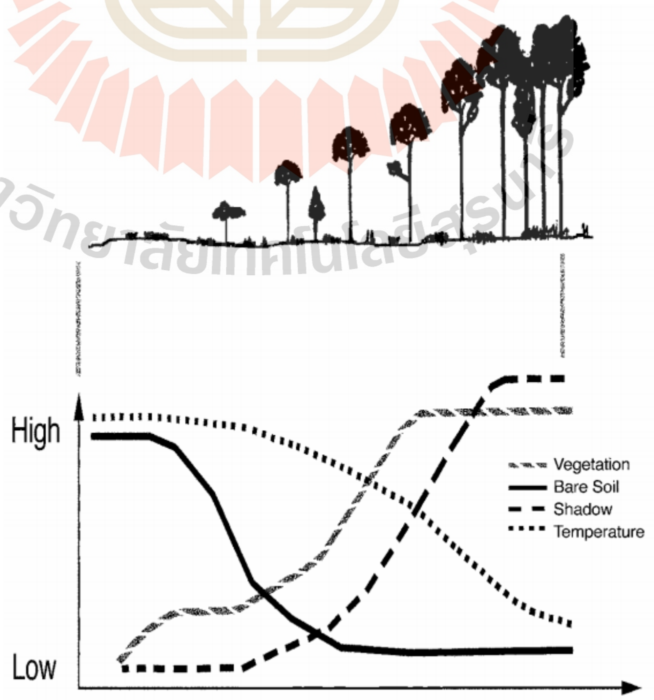


Figure 2.3 Characteristics of four indices for forest condition (Rikimaru et al., 2002).

Rikimaru et al. (2002) had summarized the required four indices as follows:

(1) Advanced vegetation index (AVI) When assessing the vegetation status of forests, the new methods first examine the characteristics of chlorophyll-a using a new Advanced Vegetation Index (AVI) that is calculated with the following conditions:

Case a: $If\ B43 < 0\ then\ AVI = 0$ (2.10)

Case b: $If\ B43 > 0\ then\ AVI = ((B4 + 1) * (256 - B3) * B43)^{1/3}$ (2.11)

Where $B43 = B4 - B3$

(2) Bare soil index (BI) The value of the vegetation index is not so reliable in situations where the vegetation covers less than half of the area. For more reliable estimation of the vegetation status, the new methods include a bare soil index (BI) which is formulated with medium infrared information. The underlying logic of this approach is based on the high reciprocity between bare soil status and vegetation status. By combining both vegetation and bare soil indices in the analysis, one may assess the status of forestlands on a continuum ranging from high vegetation conditions to exposed soil conditions as:

$$BI = \frac{(B5+B3)-(B4+B1)}{(B5+B3)+(B4+B1)} * 100 + 100 \quad (2.12)$$

Where $(0 < BI < 200)$

The range of BI is convert within 8 bits range

(3) Shadow index (SI) One unique characteristic of a forest is its three dimensional structure. To extract information on the forest structure from RS data, the new methods examine the characteristics of shadow by utilizing (a) spectral information on the forest shadow itself and (b) thermal information on the forest influenced by shadow. The shadow index is formulated through extraction of the low radiance of visible bands as:

$$SI = ((256 + B1) * (256 - B2) * (256 - B3))^{1/3} \quad (2.13)$$

(4) Thermal index (TI) Two factors account for the relatively cool temperature inside a forest. One is the shielding effect of the forest canopy, which blocks and absorbs energy from the sun. The other is evaporation from the leaf surface, which mitigates warming. Formulation of the thermal index is based on this phenomenon. The source of thermal information is the thermal infrared band of TM data.

The flowchart of the procedures for FCD mapping model is illustrated in Figure 2.4. Herewith, additional processes are required for FCD extraction included vegetation density (VD), black soil detection, advanced shadow index (ASI) and scaled shadow index (SSI). Summary of each process based on Rikimaru et al. (2002) are as following.

(1) Vegetation density (VD) It is the procedure to synthesize VI and BI. Processing method is using principal component analysis. Because essentially, VI and BI have high correlation of negative. After that, set the scaling of zero percent point and a hundred percent point.

(2) Black soil detection SI data is extracted from the low irradiant area of each visible band. Where the soil is black or appears to be black due to recent slash-and-burn, low irradiant data may confuse shadow phenomenon with black soil conditions. This is because black soil usually has high temperature due to its high absorption rate of sun energy. But shadows lead to a decrease in soil temperature. By overlaying TI data and SI data this confusion can be avoided. Overlays are also useful when evaluating the relative irradiance of different parcels of land characterized by various shades of black soil.

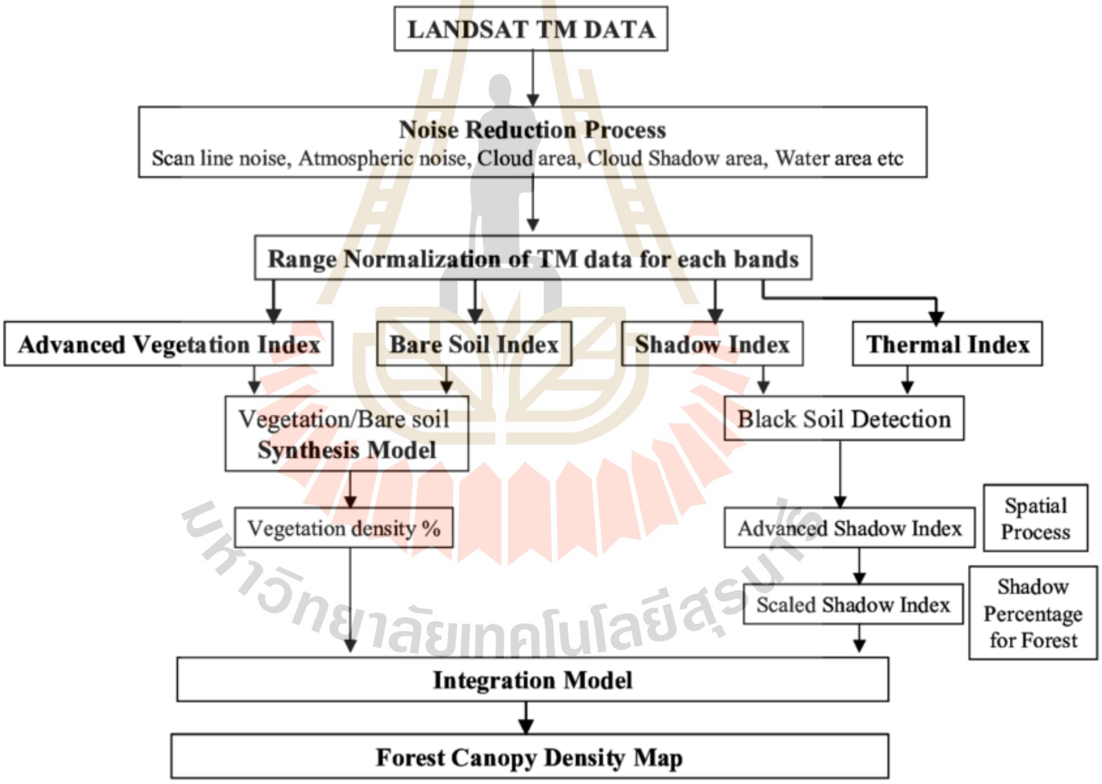


Figure 2.4 Flowchart of FCD mapping model (Rikimaru et al., 2002).

(3) Advanced shadow index (ASI) When the forest canopy is very dense, satellite data is not always be able to indicate the relative intensity of the shadow. Consequently, crown density might be underestimated. To deal with this problem, the new methods include those described below for determining the spatial distribution of shadow information.

(4) Scaled shadow index (SSI) The shadow index (SI) is a relative value. Its normalized value can be utilized for calculation with other parameters. The SSI was developed in order to integrate VI values and SI values. In areas where the SSI value is zero, this corresponds with forests that have the lowest shadow value (i.e. 0%). In areas where the SSI value is 100, this corresponds with forests that have the highest possible shadow value (i.e. 100%). SSI is obtained by linear transformation of SI.

After that VD and SSI are integrated to transform forest canopy density value. Both parameter has no dimension and has percentage scale unit of density. Thus, it is possible to extract FCD as:

$$FCD = (VD * SSI + 1)^{1/2} - 1 \tag{2.14}$$

Image processed results of procedure for FCD mapping model displayed in Figure 2.5.

In this study, derivative equations for FCD as mentioned by Rikimaru et al. (2002) are applied to with Landsat data for creating FCD map under Model Builder module of ERDAS Imagine software.

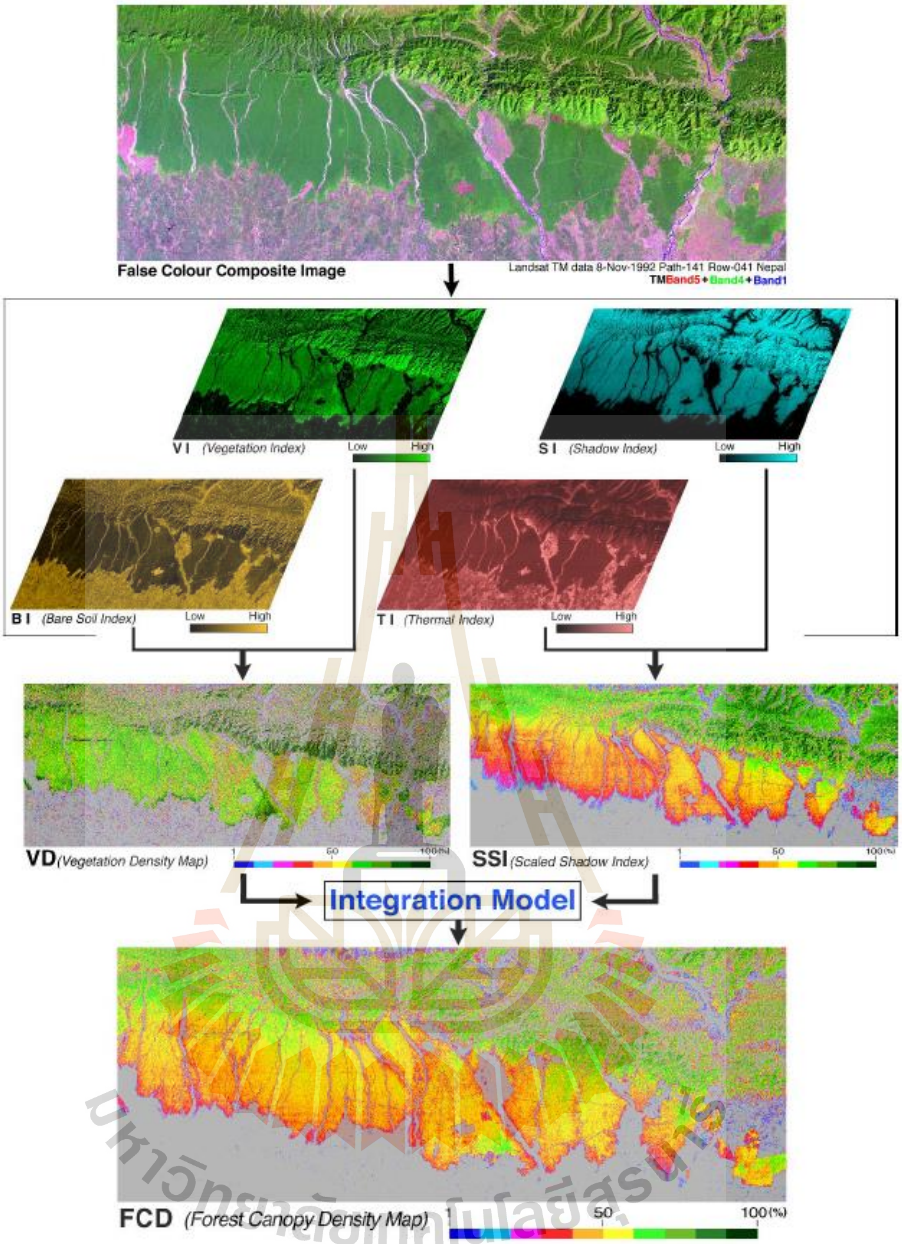


Figure 2.5 Procedure for FCD mapping model (Rikimaru et al., 2002).

2.5 Decision trees and classification and regression tree (CART)

(1) Decision trees. Decision trees consist of a number of connected classifiers (called decision nodes in the terminology of trees) none of which is expected to perform the complete segmentation of the image data set. Instead, each component classifier only carries out part of the task as indicated (Richards, 2013). The decision tree classifier in which a pixel is labelled into one of the available classes by a sequence of decisions, each of which narrows down the possibilities for membership (Figure 2.6). The simplest is the binary decision tree in which each component classifier is expected to perform a segmentation of the data into one or two possible classes or groups of classes. The most commonly encountered tree in practice and its topology is shown in Figure 2.7.

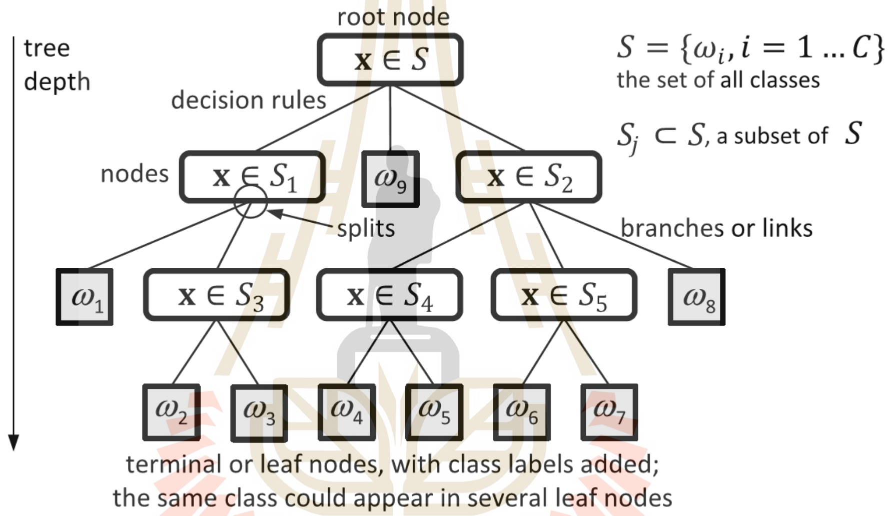


Figure 2.6 The decision tree classifier in which a pixel is labelled into one of the available classes by a sequence of decisions as multistage classifier (Richards, 2013).

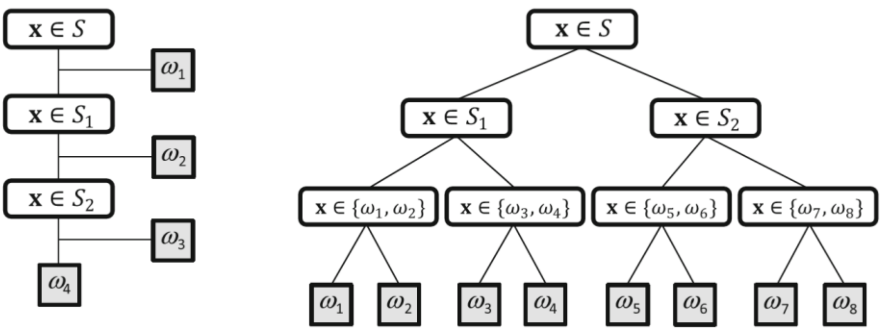


Figure 2.7 Two versions of a binary decision tree (Richards, 2013).

Richards (2013) had summarized the common terminology of decision trees as shown in Table 2.2.

Table 2.2 The common terminology of decision trees (Richards, 2013).

Terminology	Definition
root node	this is where the tree commences
decision node	intermediate node (and the root node)
terminal or leaf node	final node, which usually represents a single class
link or branch	connection between nodes
tree depth	number of layers from the root node to the most distant leaf
antecedent	node immediately above a node of interest; sometimes called a parent node
descendant	node immediately following a node of interest; sometime called a child node
split	the result of a decision to create new descendent nodes

The advantages of the decision tree approach are as follows:

- different sets of features can be used at each decision node;
- simpler segmentations than those needed when a decision has to be made among all available labels for a pixel in a single decision;
- different algorithms can be used at each decision node; and
- different data types can be used at each decision node.

(2) Classification and regression tree (CART) CART is a binary decision tree that can operate on both continuous remote sensing and categorical ancillary data (Lawrence and Wright, 2001). This classifier automatically selects useful spectral and ancillary data from the input data (Breiman, Friedman, Olshen and Stone, 1984). The CART tree is built by recursively dividing the input data until end points or terminal nodes are reached. This supervised algorithm requires training data or learning samples. After analyzing all explanatory variables (i.e., all input spectral bands and auxiliary data), the machine decides which binary splitting of a variable is the best at reducing variance in the land cover classes (Gao, 2009). Among the huge array of potentially useful input and ancillary data, CART is able to differentiate the most-useful from the least useful data in its decision making without any priori knowledge, a characteristic distinguishing decision trees from neural networks and expert systems (Lawrence and Wright, 2001).

At each node in CART, including at the root node, a decision is made to split the training samples into two groups; the aim is to produce sub-groups that are purer class-wise than in the immediately preceding node. All of the training data from all classes is fed to the root node. It then be evaluated all possible binary partitions of the training pixels and choose that partition which minimizes the class mixture in the two groups produced. For example, if there were five separate classes in the training set then it can be expected the sub-groups to have pixels from fewer than five classes and in some cases, one sub-group might have pixels from one class only. It keeps subdividing the groups as it goes down the tree so that ultimately it ends up with groups containing pixels from only one class i.e. “pure” groups. That happens at the leaf nodes. To be able to implement the process just mentioned above, two common metric are used to measure impurity of training classes in a particular group are Gini and Entropy impurity indices (Richards, 2013).

The Gini impurity index is defined at the N^th node as

$$i(N) = \sum_{i \neq j} P(\omega_j)P(\omega_i)$$

$$= 1 - \sum_j P(\omega_j)^2 \qquad (2.15)$$

Where $P(\omega_j)$ is the fraction of the training pixels at node N that are in class ω_j and $P(\omega_i)$ is the proportion not in class ω_j. If all the pixels at the node were from a single class then $P(\omega_j) = 1$ and $P(\omega_i) = 0, for\ i \neq j$ so that $i(N) = 0$, indicating no impurity. If there were N equally distributed classes in the training set then $i(N)$ is a maximum and equal to $1 - 1/N^2$, which is larger for larger N, as would be expected.

Another impurity measure is based on entropy defined as

$$i(N) = -\sum_j P(\omega_j) \log_2 P(\omega_j) \qquad (2.16)$$

Again, this is zero if all the training pixels are from the same class and is large when the group is mixed.

In splitting the training pixels as we go down the tree we are interested in that split which gives the greatest drop in impurity from the antecedent to the descendent nodes-in other words, the split that generates the most pure descendent groups. We can measure the reduction in impurity by subtracting the impurities of the descendent nodes from the impurity of their antecedent node, weighted by the relative proportions of the training pixels in each of the descendent nodes Richards (2013).

Let N refer to a node and N_L and N_R refer to its left and right descendants; let P_L be the proportion of the training pixels from node N that end up in N_L. Then the reduction in impurity in splitting N into N_L and N_R is

$$\Delta i(N) = i(N) - P_L i(N_L) - (1 - P_L) i(N_R) \quad (2.17)$$

Richards (2013) had demonstrated an example of CART derivation based on hypothetical training classes as shown in Figure 2.8. This consists of three classes, each of which is described by two features (bands). The Gini impurity is used. Table 2.3 shows the original impurity for the complete set of data and the subsequent drops in impurity with various candidate splits. Not all possible splits are given because the number of combinations is excessive; only those that are clearly the most favored are shown. The table is segmented by successive layers in the decision tree as it is built, showing splits by layer until the leaf nodes are reached. There are several split options later in the tree; only two are given to demonstrate that trees are often not unique but will still segment the data as required. The resulting segmentations of the training set and the corresponding decision trees are shown in Figure 2.9.

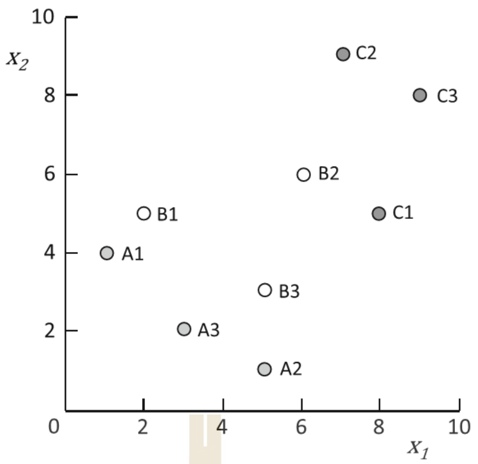


Figure 2.8 Two dimensional data with three classes used for generating a binary decision tree by the CART procedure (Richards, 2013).

Table 2.3 Impurity calculations and splits leading to the decision trees of Figure 2.9.

Original unsplit training set					
A1 A2 A3 B1 B2 B3 C1 C2 C3			$i(N) = 0.667$		
First split candidates					
Left descendent		*Right descendent*	$i(N_L)$	$i(N_R)$	$\Delta i(N)$
A1 A2 A3 B1 B2 B3	(X_1)	C1 C2 C3 (leaf node)	0.500	0	0.334
A2 A3	(X_2)	A1 B1 B2 B3 C1 C2 C3	0	0.612	0.191
C2 C3	(X_2)	C1 A1 A2 A3 B1 B2 B3	0	0.612	0.191
A1	(X_1)	A2 A3 B1 B2 B3 C1 C2 C3	0	0.656	0.084
Second split candidates from A1 A2 A3 B1 B2 B3 | C1 C2 C3 first split					
B1 B2	(X_2)	A1 A2 A3 B3	0	0.375	0.250
A2 A3	(X_2)	A1 B1 B2 B3	0	0.375	0.250
A1	(X_1)	A2 A3 B1 B2 B3	0	0.480	0.100
Third split from B1 B2 | A1 A2 A3 B3 second split					
A1 A3	(X_1)	A2 B3	0	0.500	0.125
Fourth split from A1 A3 | A2 B3 third split					
A2 (leaf node)	(X_2)	B3	0	0	0.500
Third split from A2 A3 | A1 B1 B2 B3 second split					
A1 (leaf node)	(X_1)	B1 B2 B3 (leaf node)	0	0	0.375

Source: Richards, 2013

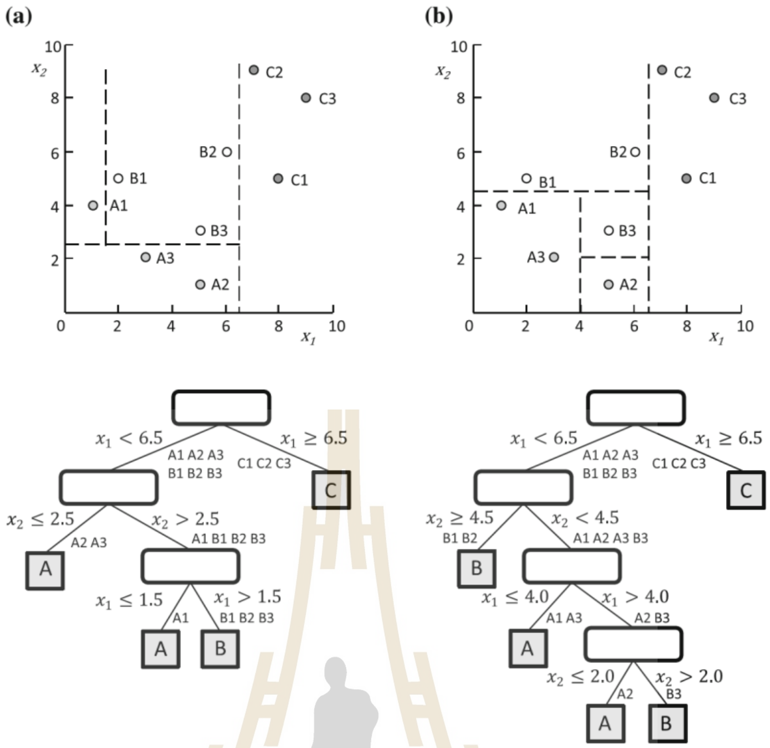


Figure 2.9 Two alternative tree segmentations of the training data in Figure 2.8. (Richards, 2013).

In this study, the selected influential factors on forest and land cover including reflectance value of Landsat data, vegetation indices (SR, NDVI, NDWI, SAVI, TWI, RSR, Brightness, Greenness, Wetness) and physical factor (elevation, slope and aspect) as independent variables and forest and land cover types as dependent are applied to construct the decision tree using CRT growing method under SPSS statistical software.

2.6 CA Markov model

Markov chain model is essentially projection model that describe the probabilistic movements an individual in a system comprised of discrete states (Eastman, 1999). When applied to land use and many other applications, Markov chains often specify both time and a finite set of states as discrete values. Transitions between the states of the system are recorded in the form of a transition matrix that records the probability of moving from one state to another.

Under this operation, two basic processes are required include Markov process and Cellular Automata (CA).

(1) Markov process Markov process is considered in discrete time and characterized by variables that can be in one of *N* states from $S = \{S_1, S_2, \ldots, S_N\}$. The set *T* of transition rules is substituted by a matrix of transition probabilities (P) and this is reflective of the stochastic nature of the process:

$$P = \|P_{ij}\| = \begin{Vmatrix} P_{1,1} & P_{1,2} & \cdots & P_{1,N} \\ P_{2.1} & P_{2,2} & \cdots & P_{2,N} \\ \cdots & \cdots & \cdots & \cdots \\ P_{N,1} & P_{N,2} & \cdots & P_{N,N} \end{Vmatrix} \quad (2.18)$$

$$Prob(S_i \rightarrow S_j) = P_{ij} \quad (2.19)$$

Where P_{ij} is the conditional probability that the state of a cell at moment $t + 1$ will be S_i, given it is S_j at moment t.

The Markov process as a whole is given by a set of status *S* and a transition matrix *P*. By definition, in order to always be "in one of the state" for each *i*, the condition $\sum_j P_{ij} = 1$ should hold (Benenson and Torrens, 2004).

(2) Cellular automata. Cellular automata are dynamic models being discrete in time, space and state. A simple of cellular automata A is defined by a lattice (L), a state space (Q), a neighborhood template (δ) and a local transition function (f):

$$A = (L, Q, \delta, f) \tag{2.20}$$

Each cell of L can be in a discrete state out of Q. The cells can be linked in different ways. Cells can change their states in discrete time-steps. Usually cellular automata are synchronous, i.e. all cells change their states simultaneously. The fate of a cell is dependent on its neighborhood and the corresponding transition function (Balzter, Braun and Kohler, 1998).

Markov chain model are firstly quantified transitional area and probability matrices of forest and land cover change and the prediction of forest and land cover change are allocated by Cellular Auto (CA) model. These operations are implemented under IDRISI software.

2.7 Literature reviews

Recent related literature about above ground biomass/carbon stock estimation and forest monitoring using remotely sensed data and REL establishment development under REDD mechanism were here reviewed and summarized in the following section.

2.7.1 Above ground biomass/carbon stock estimation

Vicharnakorn, Shrestha, Nagai, Salam and Kiratiprayoo (2014) estimated the AGB and carbon stocks (t/ha) of vegetation and soil using standard sampling techniques and allometric equations. Overall, 81 plots, each measuring 1,600 sq. m, were established to represent samples from dry evergreen forest (DEF), mixed deciduous forest (MDF), dry dipterocarp forest (DDF), disturbed forest (DF) and paddy fields (PFi). In each plot, the diameter at breast height (DBH) and height (H) of the over story trees were measured. Soil samples (composite n = 2) were collected at depths of 0-30 cm. Soil carbon was assessed using the soil depth, soil bulk density and carbon content. Remote sensing (RS; Landsat Thematic Mapper (TM) image) was used for land-cover classification and development of the AGB estimation model. The relationships between the AGB and RS data (e.g., single TM band, various vegetation indices (VIs) and elevation) were investigated using a multiple linear regression analysis. The results of the total carbon stock assessments from the ground data showed that the MDF site had the highest value, followed by the DEF, DDF, DF and PFi sites. The RS data showed that the MDF site had the highest area coverage, followed by the DDF, PFi, DF and DEF sites. The results indicated significant relationships between the AGB and RS data. The strongest correlation was found for the PFi site, followed by the MDF, DDF, DEF and DF sites.

Hernandez, Corvalan, Emery, Pena and Donoso (2012) discussed the use of remote sensing data of moderate spatial resolution as input to estimate AGB. In general terms, LANDSAT TM and ETM+ data are the most widely used data of remotely sensed imagery for forest biomass estimation, but data from other moderate spatial resolution sensors have also been used, including ASTER and HYPERION data. Here, they stated that there are a variety of approaches to estimate above ground biomass (AGB), which can be classified according to the data source being used: field measurement, remotely sensed data or ancillary data used in GIS-based modeling. Field measurements are based on destructive sampling or direct measurement and the application of allometric equations. In their research they focused on the use of optical multispectral data such as TM/ETM+ to estimate AGB. Generally, biomass is either estimated via a direct relationship between spectral response and biomass using multiple regression, k-nearest neighbor, neural networks, inverse canopy models or through indirect relationships, whereby attributes estimated from the remotely sensed data, such as leaf area index (LAI), structure (crown closure and height) or shadow fraction are used in equations to estimate biomass.

Poulain, Pea, Schmidt, Schmidt and Schulte (2012) used remotely sensed data for aboveground biomass estimation in intervened and non-intervened Nothofagus pumilio forests. The relationship between satellite-derived multispectral data and forest variables from intervened and non-intervened Nothofagus pumilio forest was examined, in order to quantify the over bark volume (OBV) and aboveground tree biomass (AGTB). Four vegetation parameters - the green normalized difference vegetation index (GNDVI), normalized difference vegetation index (NDVI), simple ratio (SR) and vegetation cover fraction (VCF) - were retrieved from ASTER image. The results indicate that only the VCF presents significant differences among intervened and non-intervened stands. The best OBV and AGTB models were found using the SR index and the VCF as predictors. The result could be transferred to estimate biomass and volume in other Nothofagus pumilio forests with similar conditions. Moreover, it can be used to assess temporal carbon changes.

Lu et al. (2012) presented that demonstrates the forest biomass estimation methods and uncertainty analysis. The results indicated that Landsat TM data can provide adequate biomass estimates for secondary succession but are not suitable for mature forest biomass estimates due to data saturation problems. LiDAR can overcome TM's shortcoming providing better biomass estimation performance but has not been extensively applied in practice due to data availability constraints. The uncertainty analysis indicates that various sources affect the performance of forest biomass/carbon estimation. With that said, the clear dominate sources of uncertainty are the variation of input sample plot data and data saturation problem related to optical sensors. A possible solution to increasing the confidence in forest biomass estimates is to integrate the strengths of multi-sensor data.

Vieilledent et al. (2012) developed a universal approach to estimate biomass and carbon stock in tropical forests using generic allometric models. In theory, allometric equations allow aboveground tree biomass and carbon stock to be estimated from tree size. However, tree allometry depends on environmental and genetic factors which vary from region to region. Consequently, theoretical models that include too few ecological explicative variables or empirical generic models that have been calibrated at particular sites are unlikely to yield accurate tree biomass estimates at other sites. In this study, analysis of biomass was based on a destructive sample of 481 trees in Madagascar spiny dry and moist forests characterized by a high rate of endemism (>95%). They showed that among the available generic allometric models, Chave's model including diameter, height and wood specific gravity as explicative variables for a particular forest type (dry, moist or wet tropical forest) was the only one that gave accurate tree biomass estimates for Madagascar ($R^2 > 83\%$, bias < 6%), with estimates comparable to those obtained with regional allometric models. When biomass allometric models are not available for a given forest site, the result shows that a simple height-diameter allometry is needed to accurately estimate biomass and carbon stock from plot inventories.

Poulain, Pena, Schmidt, Schmidt and Schulte (2011) used along with remotely sensed data to estimate biomass and carbon stocks over large and inaccessible forested areas. The relationship between satellite-derived multispectral data and forest variables from intervened and non-intervened Nothofagus pumilio forest stands located in the Magellan region of Chile was examined, in order to quantify the over bark volume (OBV) and aboveground tree biomass (AGTB). Four vegetation parameters – the green normalised difference vegetation index (GNDVI), normalised difference vegetation index (NDVI), simple ratio (SR) and vegetation cover fraction (VCF) - were retrieved from an Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image of the study area. The results indicate that only the VCF presents significant differences among intervened and non-intervened stands. The best OBV and AGTB models (R^2 = 0.58) were found using the SR index and the VCF as predictors. The result could be transferred to estimate biomass and volume in other Nothofagus pumilio forests with similar conditions. Moreover, it can be used to assess temporal carbon changes.

Gasparri, Parmuchi, Bono, Karszenbaum and Montenegro (2010) assessed correlations between spectral information and ground data to estimate AGB in the Semiarid Chaco, Argentina. Ground data (DBH, height and species of trees) were obtained from 15 samples (0.8 ha each) and AGB was estimated. Multi-temporal Landsat images were used to obtain spectral data (single bands/vegetation indexes) of the samples. Correlation tests between AGB and spectral bands and between AGB and vegetation indexes were performed for all dates. A strong correlation was found between spectral indexes and AGB in the early dry season while poorer results were obtained for summer and winter. A biomass predictive model was fitted using the NDVI of May 12, 2002 and a biomass map was obtained applying this regression. There was a rain-related regional pattern of AGB decrease in an east-west direction and a land-use related local pattern. Our results offer a great potential for increasing the understanding of dry Chaco forest structure and for improving carbon pools estimates.

Zheng, Chen, Tian, Ju and Xia (2007) combined remote sensing imagery and forest age inventory for biomass mapping. Above ground biomass (AGB) of forests is an important component of the global carbon cycle. Landsat ETM+ images and field forest inventory data were used to estimate AGB of forests in Liping County, Guizhou Province, China. Three different vegetation indices, including simple ratio (SR), reduced simple ratio (RSR) and normalized difference vegetation index (NDVI), were calculated from atmospherically corrected ETM+ reflectance images. A leaf area index (LAI) map was produced from the RSR map using a regression model based on measured LAI and RSR. The LAI map was then used to develop an initial AGB map, from which forest stand age was deduced. Vegetation indices, LAI and forest stand age were together used to develop AGB estimation models for different forest types through a stepwise regression analysis. Significant predictors of AGB changed with forest types. LAI and NDVI were significant predictors of AGB for Chinese fir (R^2 = 0.93). The model using LAI and stand age as predictors explained 94% of the AGB variance for coniferous forests. Stand age captured 79% of the AGB variance for broadleaved forests (R^2 = 0.792). AGB of mixed forests was predicted well by LAI and SR (R^2 = 0.931). Without differentiating among forest types, the model with SR and LAI as predictors was able to explain 90% of AGB variances of all forests.

Terakunpisut, Gajaseni and Ruankawe (2007) assessed the potential of carbon sequestration on aboveground biomass in the different forest ecosystems in

Thong Pha Phum National Forest, Thailand. The assessment was based on a total inventory for woody stems at ≥ 4.5 cm diameter at breast height (DBH). Aboveground biomass was estimated using the allometric equation and aboveground carbon stock was calculated by multiplying the biomass with a 0.5 conversion factor. From the results, carbon sequestration among varied different types of forests. Tropical rain forest (Ton Mai Yak station) had higher carbon stock than dry evergreen forest (KP 27 station) and mixed deciduous forest (Pong Phu Ron station) with 137.73 ± 48.07, 70.29 ± 7.38 and 48.14 ± 16.72 ton C/ha, respectively. In the study area, all forest types had a similar pattern of tree size class, with a dominant size class at ≥ 4.5-20 cm. The ≥ 4.5-20 cm trees potentially provided a greater carbon sequestration in tropical rain forest and dry evergreen forest while the size of > 20-40 cm gave potentially high carbon sequestration in mixed deciduous forest. In conclusion, the greatest carbon sequestration potential is in mixed deciduous forest followed by tropical rain forest and dry evergreen forest in Thong Pha Phum National Forest.

Myeong, Nowak and Duggin (2006) presented a method based on the satellite image time series, which can save time and money and greatly speed the process of urban forest carbon storage mapping and possibly of regional forest mapping. Satellite imagery collected in different decades was used to develop a regression equation to predict the urban forest carbon storage from the Normalized Difference Vegetation Index (NDVI) computed from a time sequence (1985-1999) of Landsat image data. This regression was developed from the 1999 field-based model estimates of carbon storage in Syracuse, NY. The total carbon storage estimates based on the NDVI data agree closely with the field-based model estimates. Changes in total carbon storage by trees in Syracuse were estimated using the image data from 1985, 1992 and 1999. Radiometric correction was accomplished by normalizing the imagery to the 1999 image data. After the radiometric image correction, the carbon storage by urban trees in Syracuse was estimated to be 146,800 tons, 149,430 tons and 148,660 tons of carbon for 1985, 1992 and 1999, respectively. The results demonstrate the rapid and cost-effective capability of remote sensing-based quantitative change detection in monitoring the carbon storage change and the impact of urban forest management over wide areas.

Chave et al. (2005) applied tree allometry and improved estimation of carbon stocks and balance in tropical forests. Regression models are used to convert inventory data into an estimate of AGB. Proportional relationships between AGB and the product of wood density, trunk cross-sectional area and total height are constructed. They develop a regression model involving wood density and stem diameter only. Our models were tested for secondary and old growth forests, for dry, moist and wet forests, for lowland and montane forests and for mangrove forests. Overestimates prevailed, giving a bias of 0.5-6.5% when errors were averaged across all stands. Our regression models can be used reliably to predict aboveground tree biomass across a broad range of tropical forests. Because they are based on an unprecedented dataset, these models should improve the quality of tropical biomass estimates and bring consensus about the contribution of the tropical forest biome and tropical deforestation to the global carbon cycle.

Lu (2005) explored AGB estimation using Landsat Thematic Mapper (TM) data in the eastern and western Brazilian Amazon. Estimating AGB is still a challenging task, especially for the sites with complicated biophysical environments. The TM spectral responses are more suitable for AGB estimation in the sites with relatively simple forest stand structure than for the sites with complicated forest stand structure. Conversely, textures appear more important than spectral responses in AGB estimation in the sites with complicated forest stand structure. A combination of spectral responses and textures improves AGB estimation performance. Different study areas having various biophysical conditions affect AGB estimation performance. The summary of aboveground biomass estimation models using Landsat TM derived variable shown in table, it imply that Landsat TM image is more successful for AGB estimation in successional forests than in mature forests.

Zheng et al. (2004) bridged the application of remote sensing techniques with various forest management practices in Chequamegon National Forest, USA by producing a high-resolution stand age map and a spatially explicit AGB map. They coupled AGB values, calculated from field measurements of tree DBH, with various vegetation indices derived from Landsat 7 ETM+ data through multiple regression analyses to produce an initial biomass map. They founded that AGB estimates for hardwood forests were strongly related to stand age and near-infrared reflectance (R^2 = 0.95) while the AGB for pine forests was strongly related to the corrected NDVI (R^2 = 0.86). Separating hardwoods from pine forests improved the AGB estimates in the area substantially, compared to overall regression (R^2 = 0.82). Estimated AGB was validated using independent field measurements (R^2 = 0.67). The AGB and age maps can be used as baseline information for future landscape level studies such as quantifying the regional carbon budget or monitoring management practices.

Stenberg, Rautiainen, Manninen, Voipio and Smolander (2004) estimated of leaf area index (LAI) using spectral vegetation indices (SVIs) was studied based on data from 683 plots on two Scots pine and Norway spruce dominated sites in

Finland. The SVIs studied included the normalized difference vegetation index (NDVI), the simple ratio (SR) and the reduced simple ratio (RSR) and were calculated from Landsat ETM images of the two sites. Regular grids of size 1 km^2 with grid points placed at 50 m intervals were established at the sites and measurements of LAI using the LAI-2000 instrument were taken at the grid points. SVI-LAI relationships were examined at plot scale, where the plots were defined as circular areas of radius 70 m around each grid point. Plot wise mean LAI was computed as a weighted average of LAI readings taken around the grid points belonging to the plot. Mean LAI for the plots ranged from 0.36 to 3.72 (hemi surface area). All of the studied SVIs showed fair positive correlation with LAI but RSR responded more dynamically to LAI than did SR or NDVI. Especially NDVI showed poor sensitivity to changes in LAI. RSR explained 63% of the variation in LAI when all plots were included (n = 683) and the coefficient of determination rose to 75% when data was restricted to homogeneous plots (n = 381). Maps of estimated LAI using RSR showed good agreement with maps of measured LAI for the two sites.

2.7.2 Forest monitoring using remotely sensed data

Vorovencii and Muntean (2014) presented five relative radiometric normalization methods (RRN) from the specialized literature and a case study using two Landsat 5 Thematic Mapper (TM) satellite images, acquired in 2007 and 2011. These methods are histogram matching (HM), simple regression (SR), pseudo-invariant features (PIF), dark and bright set (DB) and no-change set determined from scattergrams (NC). The results indicate that, for the studied area, the best methods are HM, SR and NC. The DB and PIF methods fail to produce good results because of the lack of invariant details in the two images, of the high spectral variability specific to agricultural land in the studied area and of the low number of pixels selected to calculate the RRN coefficients.

Ghose, Pradhan and Ghose (2010) developed a decision tree classification algorithm for remotely sensed satellite data using the separability matrix of the spectral distributions of probable classes in respective bands. The spectral distance between any two classes is calculated from the difference between the minimum spectral value of a class and maximum spectral value of its preceding class for a particular band. The decision tree is then constructed by recursively partitioning the spectral distribution in a Top-Down manner. Using the separability matrix, a threshold and a band will be chosen in order to partition the training set in an optimal manner. The classified image of forest and land cover is compared with the image classified by using classical method Maximum Likelihood Classifier (MLC). The overall accuracy was found to be 98% using the Decision Tree method and 95% using the Maximum Likelihood method with kappa values 97% and 94% respectively.

Azizi, Najafi and Sohrabi (2008) used satellite image to estimate forest canopy density, it's a major factor in evaluation of forest status and is an important indicator of possible management interventions. Forest canopy cover, also known as canopy coverage or crown cover, is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns. Estimation of forest canopy cover has recently become an important part of forest inventories. Using satellite imagery to estimate crown coverage has a long history. Conventional remote sensing methods assess the forest status based on qualitative data analysis derived from "training areas". That has certain disadvantages in terms of time and cost requirements for training area establishment. Forest Canopy Density Model is one of the useful methods to detect and estimate the canopy density over large area in a time and cost effective manner. The overall accuracy for IRS image was 84.4% and Kappa Coefficient was 78.3%

Baynes (2007) utilized Landsat imagery, forest canopy density (FCD) estimated with the FCD Mapper software for 20 field plots measured in native forest at Noosa Heads, Australia. A corresponding image was used to calculate FCD in Leyte Island, the Philippines and was validated on the ground for accuracy. The FCD Mapper was produced for the International Tropical Timber Organization and estimates FCD as an index of canopy density using reflectance characteristics of Landsat ETM images. At Noosa, a positive strong nonlinear relationship ($R^2 = 0.86$) was found between FCD and predominant height (PDH) for 15 field plots with variable PDH but complete canopy closure. An additional five field plots were measured in forest with a broken canopy and the software assessed these plots as having a much lower FCD than forest with canopy closure. FCD estimates for forest and agricultural land in the island of Leyte and subsequent field validation showed that at appropriate settings, the FCD Mapper differentiated between tropical rainforest and banana or coconut plantation. These findings suggest that in forests with a closed canopy this remote sensing technique has promise for forest inventory and productivity assessment. The findings also suggest that the software has promise for discriminating between native forest with a complete canopy and forest which has a broken canopy, such as coconut or banana plantation.

Herold, Koeln and Cunnigham (2003) utilized EarthSat software and CART technology in order to map sub-pixel impervious surface and forest canopy surfaces at a 30 meter resolution. The complex interactions that exist between various input data sets, as they relate to the target impervious and canopy features, are learned and modeled through exhaustive examination. CART technology, or machine learning, can provide a low-cost, high quality alternative, without such difficulties. Results for estimating percent impervious surface and canopy cover, per ETM+, pixel were found to be very effective. The average error in percent estimation was within 8.4 percent and had a correlation coefficient of 0.90 to 0.93.

Rogan et al. (2003) monitored land-cover change in San Diego County (1990-1996) using multitemporal Landsat TM data. Change vectors of Kauth Thomas features were combined with stable multitemporal Kauth Thomas features and a suite of ancillary variables within a classification tree classifier. A combination of aerial photointerpretation and field measurements yielded training and validation data. Maps of land-cover change were generated for three hierarchical levels of change classification of increasing detail: change vs. no-change; four classes representing broad increase and decrease classes; and nine classes distinguishing increases or decreases in tree canopy cover, shrub cover and urban change. The multitemporal Kauth Thomas (both stable and change features representing brightness, greenness and wetness) provided information for magnitude and direction of land-cover change. Overall accuracies of the land-cover change maps were high (72 to 92 percent). Ancillary variables representing elevation, fire history and slope were most significant in mapping the most complicated level of land-cover change, contributing 15 percent to overall accuracy. Classification trees have not previously been used operationally with remotely sensed and ancillary data to map land-cover change at this level of thematic detail. The results confirm the value of classification tree algorithms for mapping land-cover change. Spectral and ancillary variables were readily integrated and their contribution to map accuracy was revealed in the hierarchical structure of the tree and in the increase in accuracy when ancillary data were included in the classification.

Lawrence and Wright (2001) incorporated ancillary data into image classification can increase classification accuracy and precision. Rule-based classification systems using expert systems or machine learning are a particularly useful means of incorporating ancillary data, but have been difficult to implement. They developed a means for creating a rule-based classification using classification and regression tree analysis (CART), a commonly available statistical method. The CART classification does not require expert knowledge, automatically selects useful spectral and ancillary data from data supplied by the analyst and can be used with continuous and categorical ancillary data. They demonstrated the use of the CART classification at three increasingly detailed classification levels for a portion of the Greater Yellowstone Ecosystem. Overall accuracies ranged from 96 percent at level 1, to 79 percent at level 2 and 65 percent at level 3.

2.7.3 REL establishment development under REDD mechanism

Puangchit et al. (2010) reviewed the development of a REL for the mechanism of REDD. The simplest forms of REL can be divided in to seven forms;

(1) Simple Historical Approach is propose from Brazil in 2006. This is the simplest way to REL using the average deforestation rate of the past 10 years.

(2) Compensated Reduction Approach (Coalition for Rainforest Nations, 2005). Defines a REL in relation to the rate of deforestation in the past, evaluate the amount of carbon stock by the IPCC method which should not be less than five years. The REL should be adjusted to the time period. For some countries that have

the average of deforestation rate less than 0.1% per year, should use the average of the past 10 years plus another 10% as the base line.

(3) Joint Research Center (JRC) Approach (Mollicone et al., 2007) the base lines have separated in to two cases; (a) If the rate of deforestation is more than half of the world average, the REL to the rate of deforestation in the past is not less than five years, (b) If the rate of deforestation is less than half of the world average, the base line is equal to half of the world average.

(4) Terrestrial Carbon Group Approach (Terrestrial Carbon Group, 2008) these focus on carbon emissions from forests in the past which are divided into two groups, the first group has protected for conservation groups and no risk of deforestation. The rest area is an area that can generate carbon credits called “tradable terrestrial carbon”. Carbon trading has annual fixed at 1/50 of all carbon trading or equal to the emission rate of 2% per year.

(5) Corridor Approach (Griscom, 2009) is determined REL implied by the significance of the variation between years. The minimum and maximum level of emissions in the past will be set. In the case of greenhouse gas emissions below the minimum level reference, it shall be deemed to have released the credit. In the case of greenhouse gas emissions higher than the highest level of the reference, then the excess will be deducted from the cost of debt for the year to come.

(6) Combined Incentives (Strassburg, Turner, Fisher, Schaeffer and Lovett, 2008). The REL has been calculated from greenhouse emission rate in the past to adjust the REL of the world, calculate the annual credit from the following formula;

$$C_a = \Big((E_n * alpha) + \big(E_g * (1 - alpha)\big)\Big) - E_a \qquad (2.21)$$

Where C_a is the year credit

E_n is greenhouse gas emissions of the country.

E_g is greenhouse gas emissions of the world.

E_a is actual annual emissions.

$alpha$ is constant (0.9). It can be changed over time.

(7) The Stock-Flow Approach (Griscom, 2009). This approach is similar to Combined Incentives however, the alpha constant is 0.5. The formula is as follows;

$$C_a = (E_n - E_a) * 0.5 + (E_g * 0.5) \quad (2.22)$$

The COP 15 meeting in Copenhagen, Denmark, has agreed to set reference emission levels (REL) according to the format of the data in the past. However, there is no explicit reference time period.

CHAPTER III

RESEARCH METHODOLOGY

To serve the research objectives of the study, overall research framework were divided into one basic task and four components as presented in Figure 3.1. It consisted of one common task for data collection and preparation and four distinctive research components as follows:

(1) Forest and land cover classification and prediction;

(2) Above ground biomass estimation model development;

(3) AGB estimation and carbon stock assessment;

(4) Carbon emission assessment and REDD mechanism implementation.

Details of each component are separately described in the following sections.

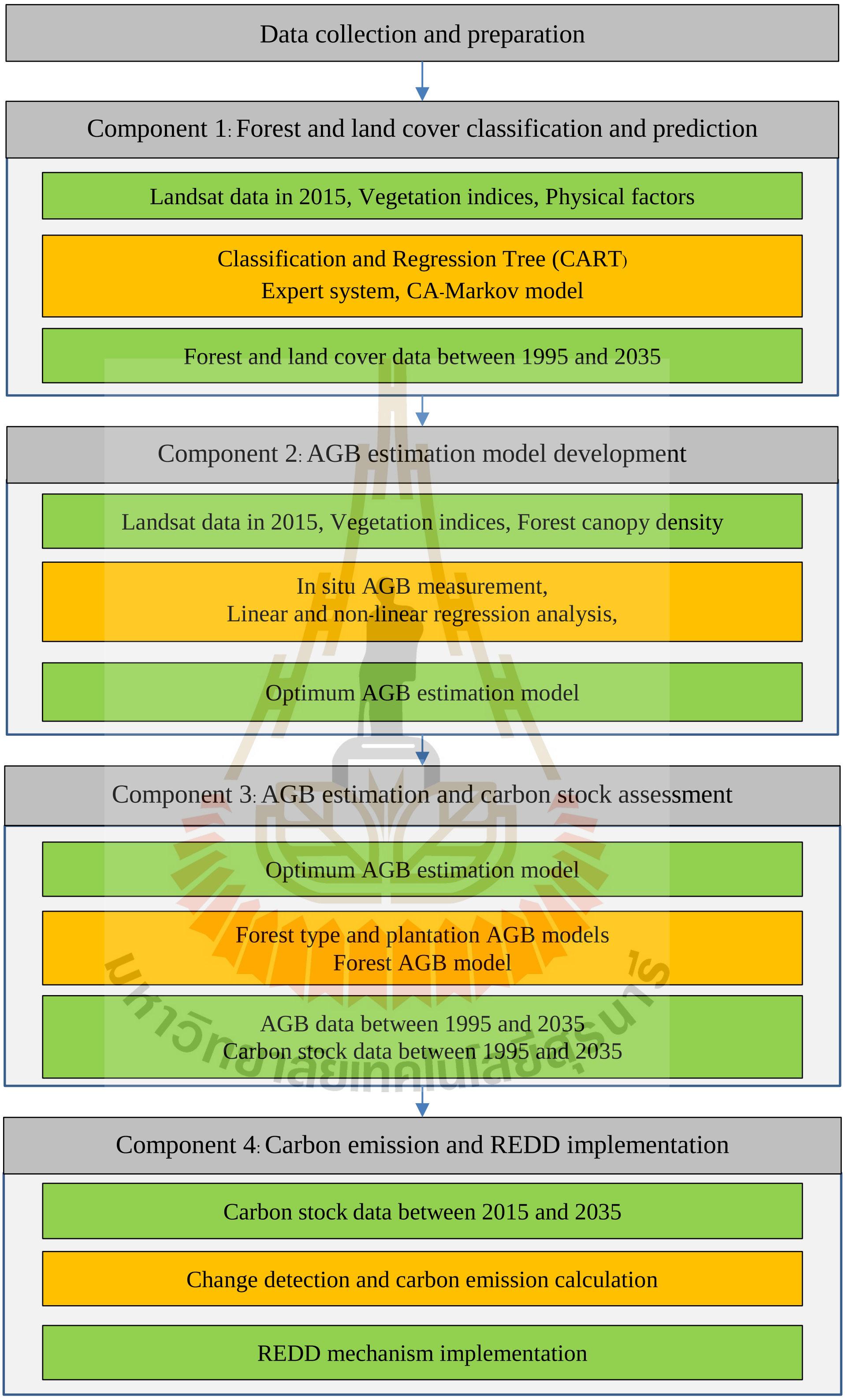


Figure 3.1 Overview of research methodology.

3.1 Data collection and preparation

Basic remotely sensed data which were collected in this research is summarized in Table 3.1. For data analysis, a common name of selected spectral band of Landsat 5-TM and Landsat-8 OLI bands was here applied for an optimum CART model for forest and land cover classification and an optimum AGB estimation model development as summary in Table 3.2. While GIS data and physical used in this study is summarized in Table 3.3.

Table 3.1 Basic data of Landsat data.

No	Landsat series	Path	Row	Acquired date	Source	Selected band
1	Landsat 5 TM	128	50	7 February 1995	USGS	Band 1, 2, 3, 4, 5 and 7
2	Landsat 5 TM	128	50	4 January 2000	USGS	Band 1, 2, 3, 4, 5 and 7
3	Landsat 5 TM	128	50	6 March 2005	USGS	Band 1, 2, 3, 4, 5 and 7
4	Landsat 5 TM	128	50	21 April 2010	USGS	Band 1, 2, 3, 4, 5 and 7
5	Landsat 8 OLI	128	50	18 March 2015	USGS	Band 2, 3, 4, 5, 5 and 7

Note: USGS: The United States Geological Survey.

Table 3.2 A common used name of Landsat data in the study.

Original band		Common name
Landsat 5 - TM	Landsat 8 - OLI	
1	2	Blue
2	3	Green
3	4	Red
4	5	NIR
5	6	SWIR-1
7	7	SWIR-2

Table 3.3 Basic data of GIS.

No	Data collection	Source	Data Preparation
1	Administrative boundary	DEQP	-
2	DEM	LDD	To Extract elevation (m), slope (%) and aspect (degree)

Note: DEQP: Department of Environmental Quality Promotion; LDD: Land Development Department.

For remotely sensed data, the downloaded Landsat data were firstly converted to Top of Atmosphere (ToA) reflectance before forest and land cover classification using CART.

To convert DN values of Landsat 5 TM data to ToA reflectance, it required two-steps according to suggestion in Landsat Users Handbook. The first step was to convert the DNs to radiance values using the bias and gain values specific to the individual scene. The second step converted the radiance data to ToA reflectance.

The equation to convert DN values to radiance using gain and bias values is:

$$L_{\lambda} = gain * DN + bias \tag{3.1}$$

Where L_{λ} = the cell value as radiance

DN = the cell value digital number

$gain$ = the gain value for a specific band

$bias$ = the bias value for a specific band

The equation to convert Radiance to ToA reflectance is as follow:

$$\rho_\lambda = \frac{\pi * L_\lambda * d^2}{ESUN_\lambda * \cos\theta} \tag{3.2}$$

Where ρ_λ = Unitless planetary reflectance

L_λ = spectral radiance (from earlier step)

d = Earth-Sun distance in astronmoical units

$ESUN_\lambda$ = mean solar exoatmospheric irradiances

θ = solar zenith angle

Similarly, to convert DN of Landsat 8 OLI data to TOA reflectance, it applies reflectance rescaling coefficients that provide in the product metadata file (MTL file). The equation to convert DN values of Landsat 8 OLI data to TOA reflectance is as follows:

$$\rho\lambda' = M_\rho * Q_{cal} + A_\rho \tag{3.3}$$

Where $\rho\lambda'$ = TOA planetary reflectance, without correction for solar angle

M_ρ = Band-specific multiplicative rescaling factor from the metadata

A_ρ = Band-specific additive rescaling factor from the metadata

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

TOA reflectance with a correction for the sun angle is:

$$\rho\lambda = \frac{\rho\lambda\prime}{\cos(\theta_{SZ})} = \frac{\rho\lambda\prime}{\sin(\theta_{SE})} \tag{3.4}$$

Where $\rho\lambda$ = TOA planetary reflectance

θ_{SE} = Local sun elevation angle.

θ_{SZ} = Local solar zenith angle; θ_{SZ} = 90° - θ_{SE}

The required data were prepared in advance for an optimum CART model for forest and land cover classification and an optimum AGB estimation model development. Herein, they were remotely sensed data and its derivation and physical factors. Figure 3.2 displays a composite image of Landsat data in 1995, 2000, 2005, 2010 and 2015 while derivative data from Landsat 8-OLI include (1) SR, (2) NDVI (3) NDWI (4) SAVI, (5) TVI, (6) RSR, (7) Brightness, (8) Greenness, (9) Wetness, (10) FCD which are assumed as dynamic data are displayed in Figure 3.3. Meanwhile, physical factors that dictate forest and land cover distribution including (1) elevation, (2) slope and (3) aspect are displayed in Figure 3.4. In this study, all physical factors were assumed as static data.

In case of FCD data, it was prepared using relevance equations including advanced vegetation index (AVI), bare soil index (BI), shadow index (SI), thermal index (TI), vegetation density (VD), scaled shadow index (SSI) as shown Figure 3.5. (See detail of equation in Section 2.3 of Chapter II)

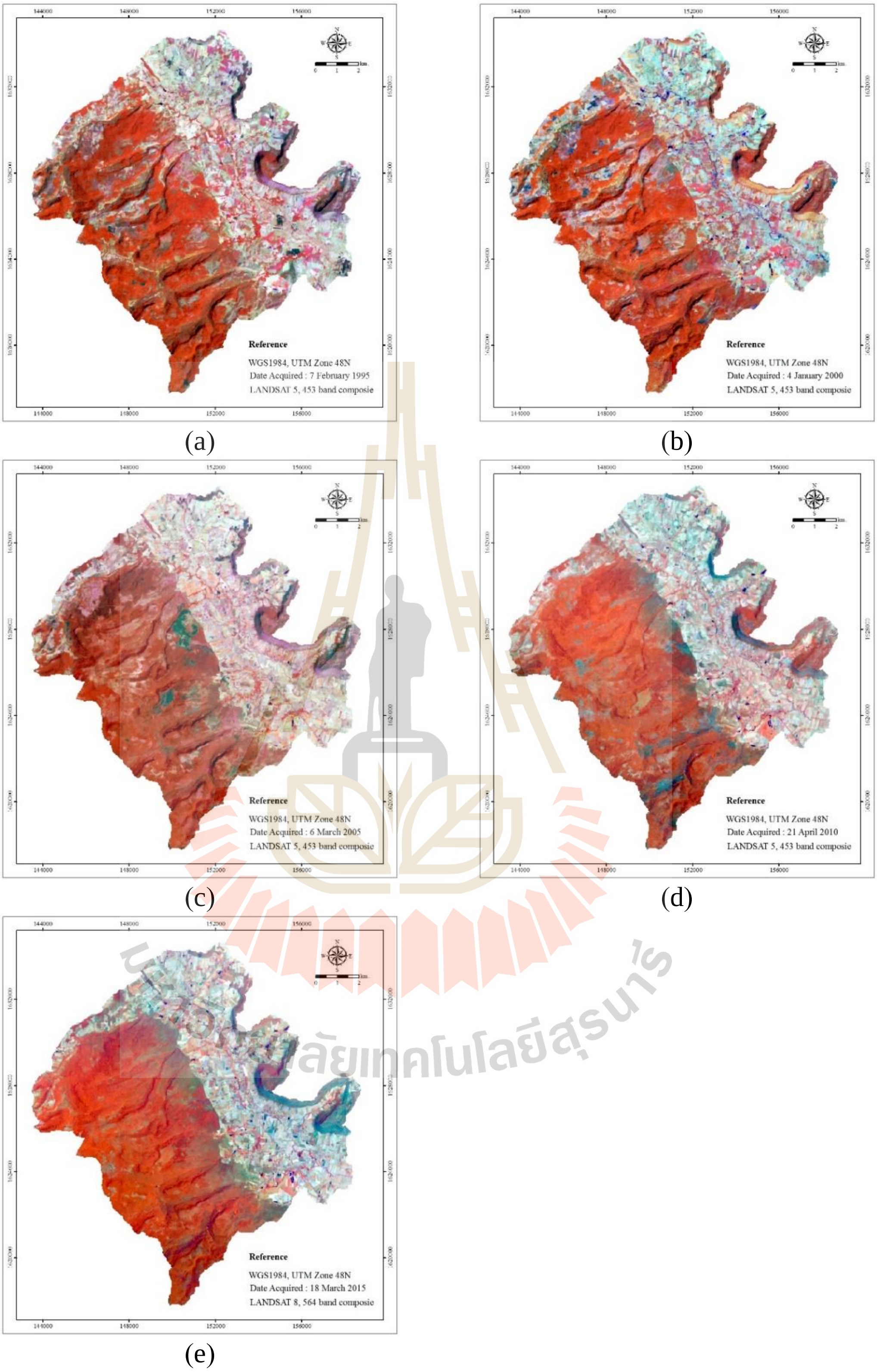
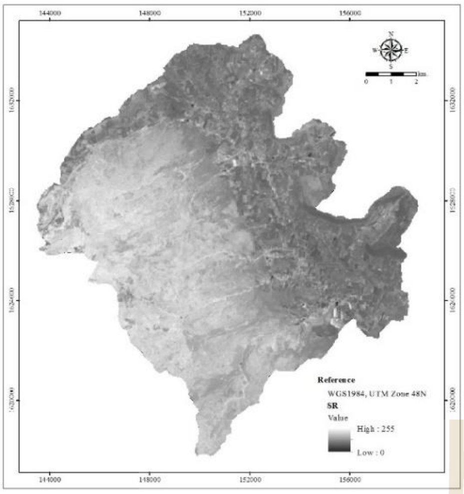
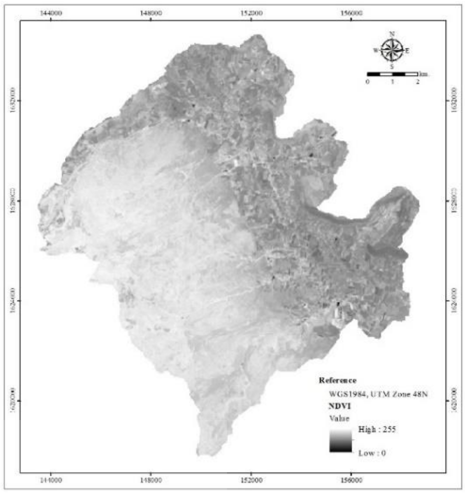


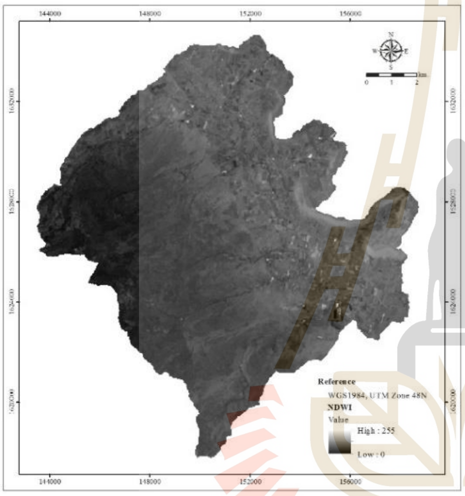
Figure 3.2 Landsat data as composite image of NIR, SWIR-1 and RED (RGB): (a) in 1995, (b) in 2000, (c) in 2005, (d) in 2010 and (e) in 2015.



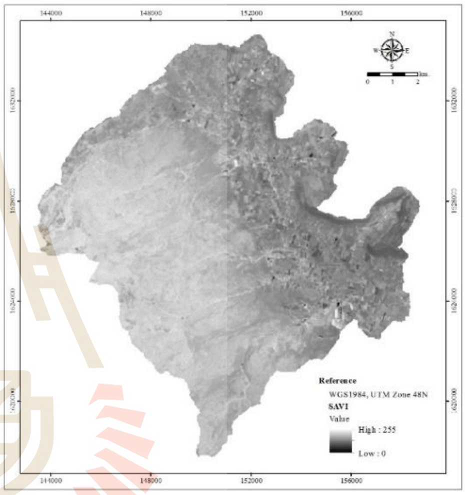
(a)



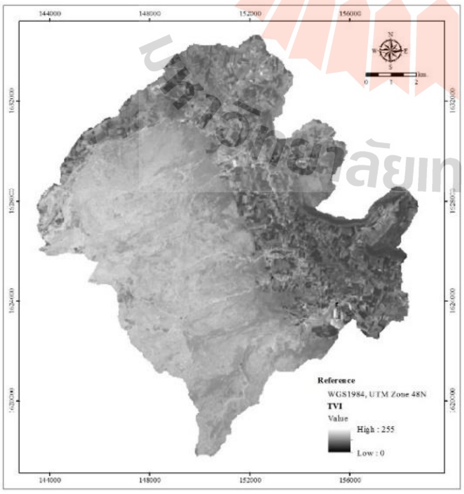
(b)



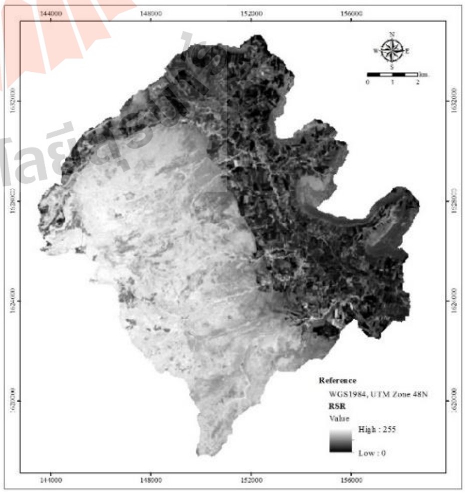
(c)



(d)

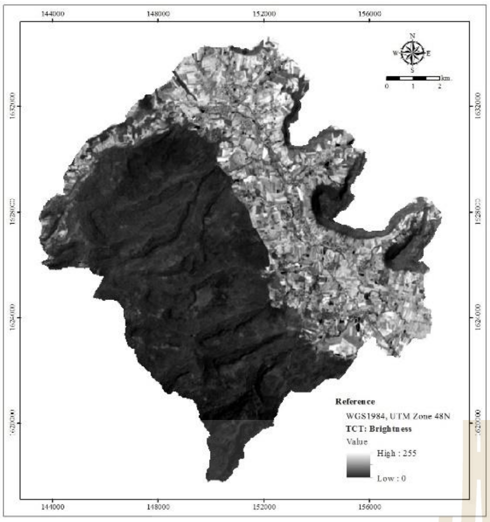


(e)

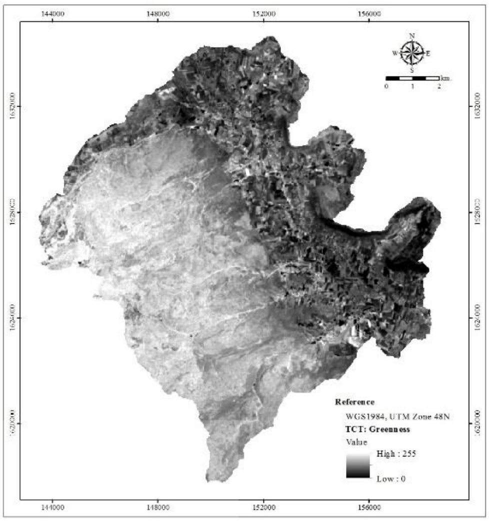


(f)

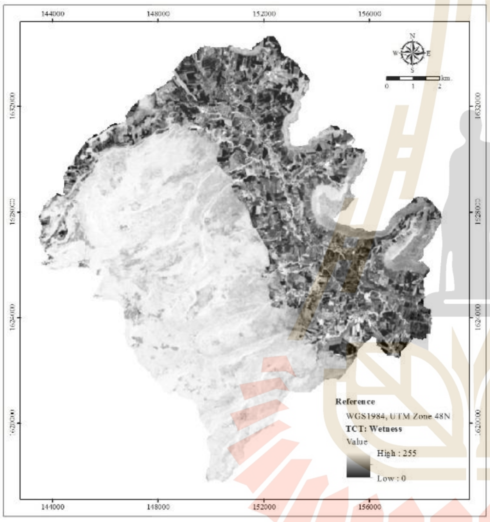
Figure 3.3 Derived vegetation indices of Landsat-8 OLI: (a) SR, (b) NDVI (c) NDWI (d) SAVI, (e) TVI, (f) RSR, (g) Brightness, (h) Greenness, (i) Wetness and (j) FCD.



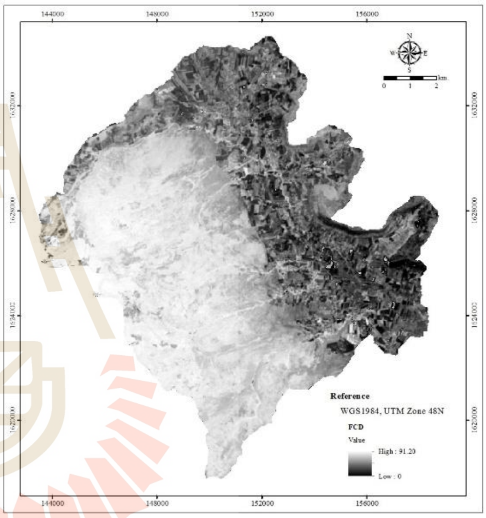
(g)



(h)



(i)



(j)

Figure 3.3 Derived vegetation indices of Landsat-8 OLI: (a) SR, (b) NDVI (c) NDWI (d) SAVI, (e) TVI, (f) RSR, (g) Brightness, (h) Greenness, (i) Wetness and (j) FCD. (Continued).

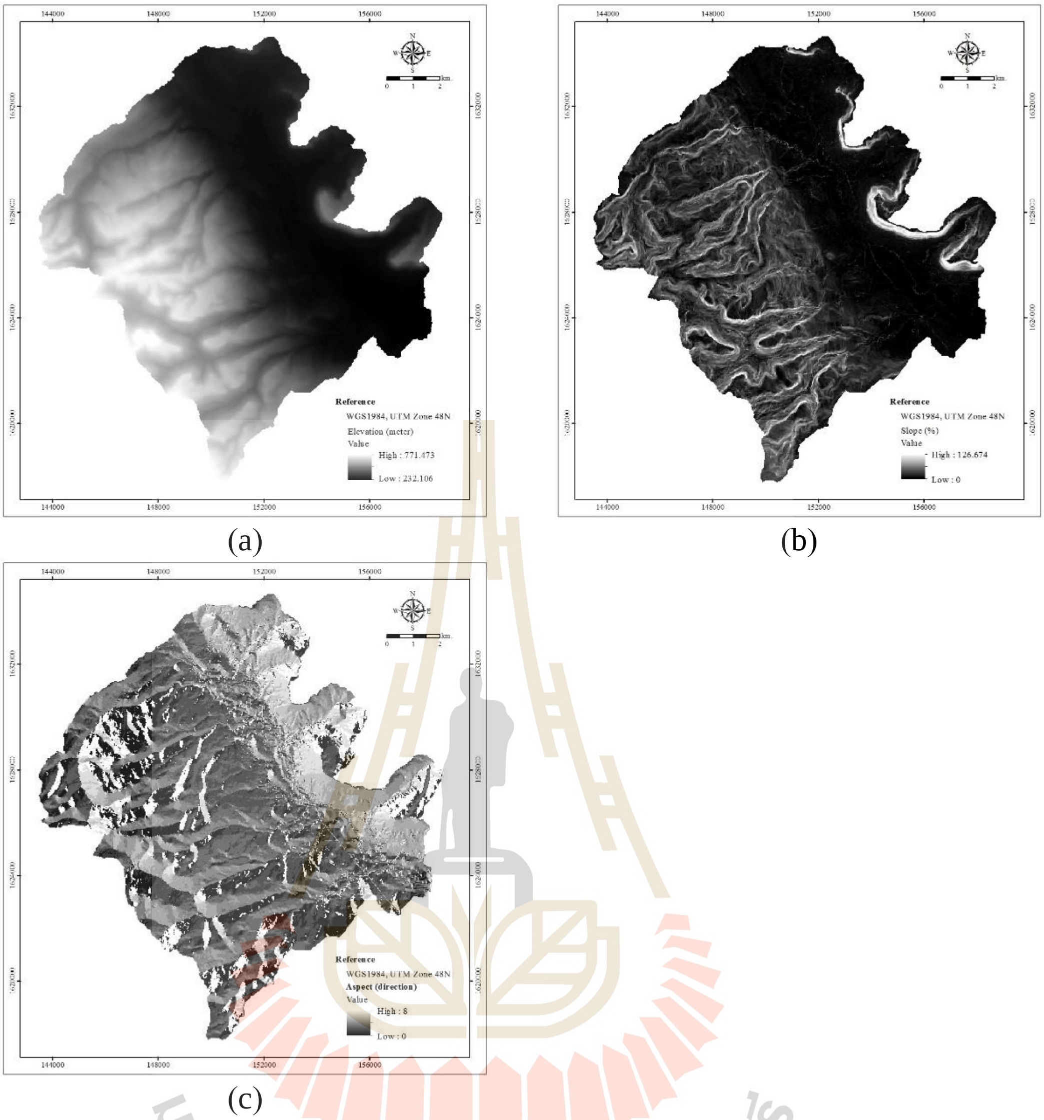


Figure 3.4 Physical factor: (a) elevation, (b) slope and (c) aspect.

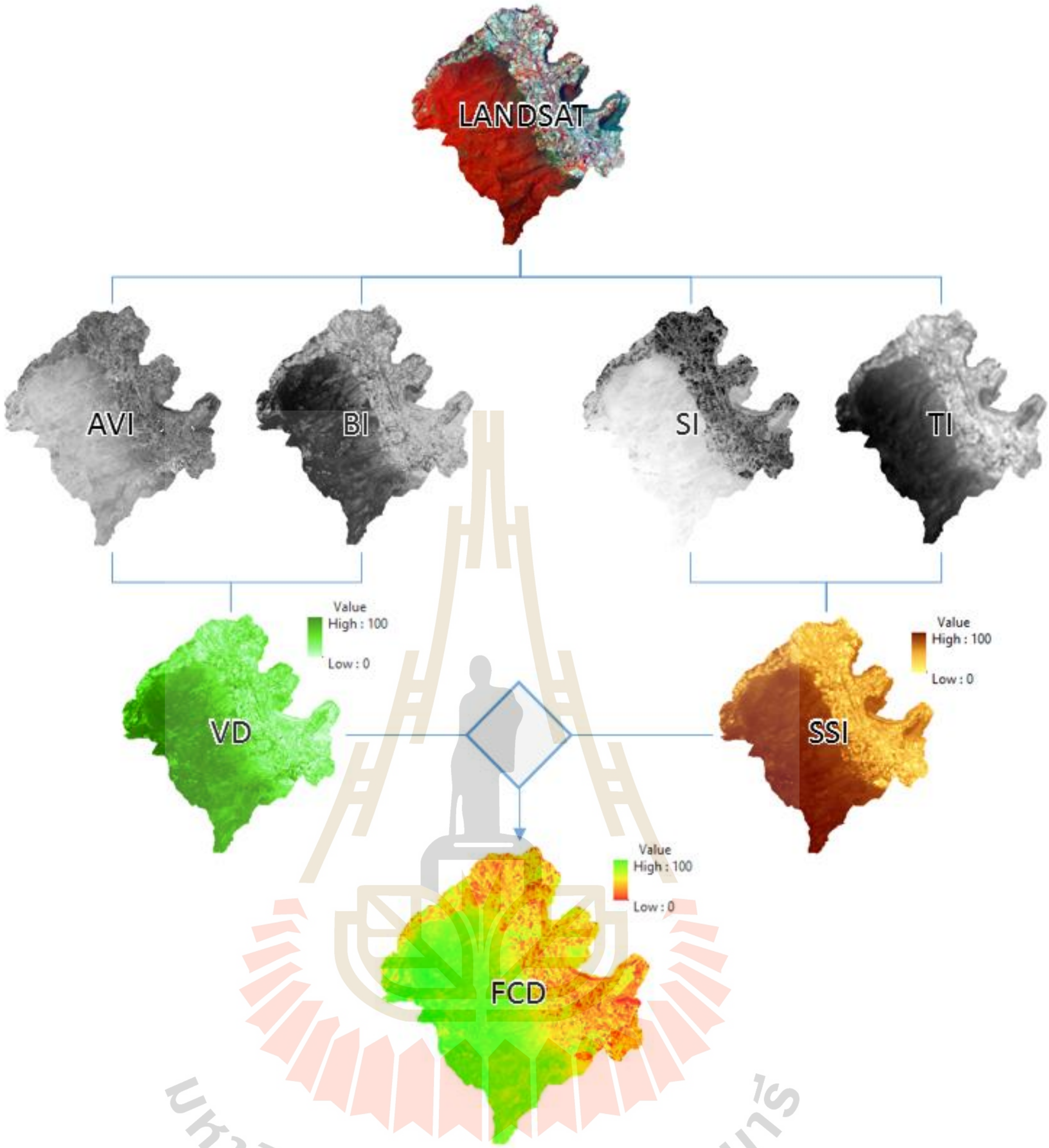


Figure 3.5 Derivative products for FCD data extraction.

3.2 Forest and land cover classification and prediction

This component consists of two major tasks included (1) forest and land cover classification using CART for years 1995, 2000, 2005, 2010 and 2015 and (2) forest and land cover prediction by CA-Markov model for years 2020, 2025, 2030 and 2035 as shown in Figure 3.6.

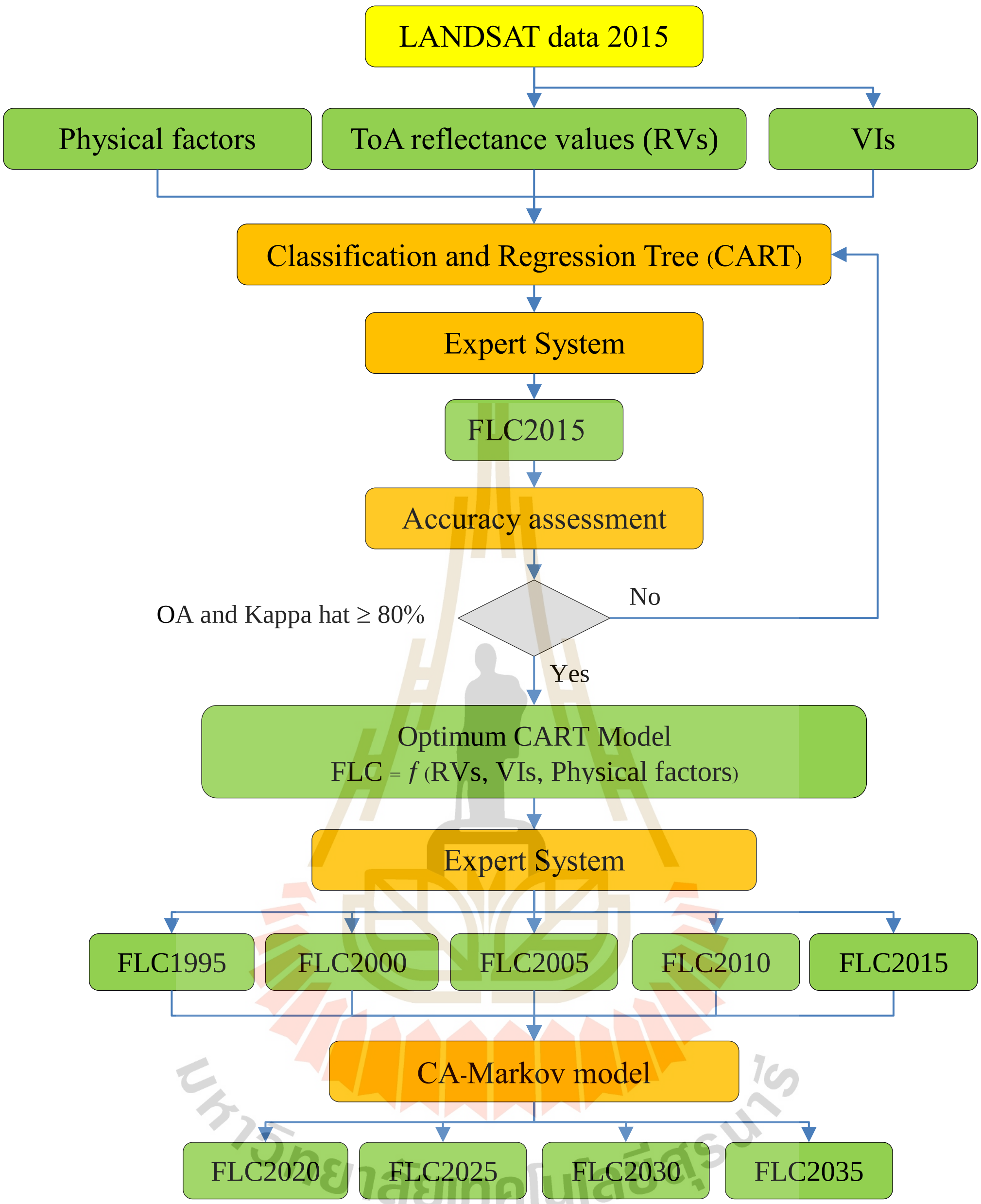


Figure 3.6 Schematic workflow of forest and land cover classification and prediction.

3.2.1 Forest and land cover classification between 1995 and 2015

Landsat data acquired in 2015 (BLUE, GREEN, RED, NIR, SWIR-1, SWIR-2) and its derived vegetation indices (SR, NDVI, NDWI, SAVI, TVI, RSR, Brightness, Greenness and Wetness) and physical factors (elevation, slope, aspect) were firstly discriminated by CART model for Decision Tree construction under

Decision Tree module of SPSS statistical software and the derived decision tree was further transferred to Expert System of ERDAS Imagine to classify forest and land cover.

The classified forest and land cover map was further used to assess its accuracy using overall accuracy and Kappa hat coefficient to identify an optimum CART model for forest and land cover classification. If both accuracy values were equal or greater than 80 percent, the derived decision tree was chosen as optimum CART model for forest and land cover classification, else the process was reiteration until achieve the threshold values. For accuracy assessment, number of samples size were derived based on binomial distribution with expected accuracy of 85% at the allowable error of 5% and the stratified random sampling technique was selected for observing points allocation. In this study, 204 points were required in field survey for accuracy assessment.

After that the optimum CART model were directly applied to other Landsat data acquiring in 1995, 2000, 2005, 2010 and 2015 to classify forest and land covers in the corresponding year. Herein histogram matching technique for relative radiometric normalization was applied to those Landsat dataset before forest and land cover classification under Expert System of ERDAS Imagine. Based on the comparison test of five relative radiometric normalization methods including histogram matching (HM), simple regression (SR, pseudo-invariant features (PIF), dark and bright set (DB) and no-change set determined from scattergrams (NC) by Vorovencii and Muntean (2014) with two Landsat data acquired in 2007 and 2011, the best method were HM, SR and NC. So, histogram matching was here applied in this study.

3.2.2 Forest and land cover prediction between 2020 and 2035

CA-Markov model was here used to predict forest and land cover data in 2020, 2025, 2030 and 2035 based on the derived forest and land cover data in 1995, 2000, 2005, 2010 and 2015. In practice, forest and land cover data from 2010 and 2015 were used to predict forest and land cover in 2020, forest and land cover data from 2005 and 2015 were used to predict forest and land cover in 2025, forest and land cover data from 2000 and 2015 were used to predict forest and land cover in 2030 and forest and land cover data from 1995 and 2015 were used to predict forest and land cover in 2035.

Additional, the derived historical forest and land cover data in 2005 and 2010 were applied to validate CA-Markov model. Herein the predicted forest and land cover data in 2015 by CA-Markov model were compared with the classified forest and land cover data in 2015 using optimum CART model.

Finally, all classified and predicted forest and land covers between 1995 and 2035 were used to assess forest and land cover areas and their changes using post-classification change detection algorithm. All derived forest type areas of these periods were used as basic data to estimate AGB in the next component.

3.3 Above ground biomass estimation model development

Two major tasks include in situ AGB data collection and AGB estimation model development using linear and non-linear regression analysis were integrated under this component as shown in Figure 3.7.

3.3.1 In situ above ground biomass data collection

The random sampling technique was here applied to allocate for sample plots for above ground biomass data collection in each forest type and forest plantation.

In this study, a square plot with size of 20x20 m. was used to measure trees data in each stratum of forest type and plantation. At least 8 plots are applied for each stratum. All trees with size more than 4.5 cm and their heights were measured for AGB estimation using the existing allometry equations (See section 2.1 of Chapter II). The calculated AGB data at sampling plots area were further converted to be pixel size 30x30 m.

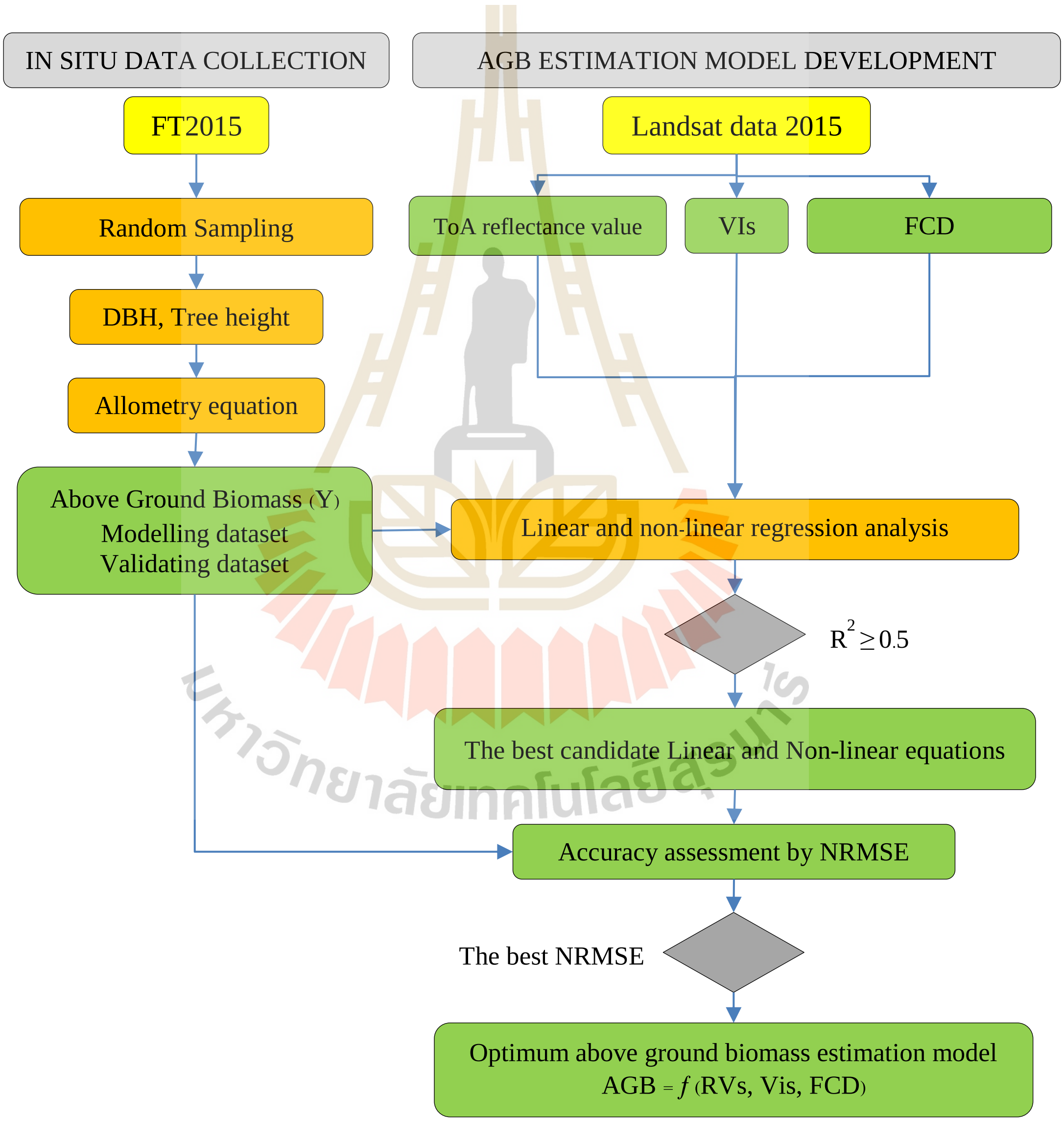


Figure 3.7 Schematic workflow of above ground biomass estimation model development.

In this study, AGB data were dived into two datasets: one set for modeling and another set for validating with ratio of 75:25 percent. The modeling dataset was used to construct above ground biomass estimation model using linear and non-linear regression analysis while validation dataset was used to assess accuracy and identify an optimum linear or non-linear equation for above ground biomass estimation of forest area using NRMSE.

3.3.2 Above ground biomass estimation model development

Linear and non-linear regression analysis were here applied to identify the relationship between AGB of forest area and its relevant factors [Reflectance value of Landsat data in 2015 (BLUE, GREEN, RED, NIR, SWIR-1, SWIR-2), vegetation indices (SR, NDVI, SAVI, TVI, RSR and Greenness) and forest canopy density (FCD)]. In practice, the derived linear or non-linear equations for above ground biomass estimation which provided the highest R^2 value (it must has value equal or greater than 0.5) were firstly selected as the best candidate of linear and non-linear equations. Then, the best candidate of linear or non-linear equations which provides the lowest NRMSE value based on validation dataset was chosen as an optimum above ground biomass estimation model.

The equations of RMSE and NRMSE for accuracy measurement are as follows:

$$NRMSE = \frac{RMSE}{\text{Maximum observed value} - \text{Minimum observed value}} \quad (3.5)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}[Estimated\ value - Observed\ value]^2} \quad (3.6)$$

Where n is number of observation (plots) *RMSE* is Root Mean Square Error

In this study, two approaches for optimum AGB estimation model were developed based on forest type and plantation and forest as mentioned by GOFC-GOLD (2012) on stratification in Section 2.2 under Chapter II. Under the first approach, optimum AGB estimation model (equation) of each forest type and plantation was generated one by one. In contrast, under the second approach, all sample plots from forest type and plantation were aggregated and then use to generate one equation for forest AGB estimation.

3.4 AGB estimation and carbon stock assessment

Under this component, two main tasks include (1) AGB estimation and its change and (2) carbon stock assessment and its change (Figure 3.8).

In practice, the optimum AGB estimation model of forest type and plantation are then directly applied to estimate AGB of each forest type and plantation for years 1995, 2000, 2005, 2010 and 2015. Meanwhile they were also applied to estimate AGB of each forest type and forest plantation for years 2020, 2025, 2030 and 2035. Herein, the Trend Analysis function of MS Excel and ASCII to image of ERDAS Imagine software were applied for creating variables as image data accordance with selected variables by optimum AGB estimation model. Likewise, optimum forest AGB estimation model, which was aggregate sampling plots of forest type and plantation, was directly and indirectly applied to estimate AGB for forest area between 1995 and 2035. After that, the derived AGB between 1995 and 2035 from two approaches: forest type and plantation AGB models and forest AGB model were further used to access carbon stock by multiply with carbon conversion factor (0.47).

The derived output of this component was quantity of AGB and carbon stock and its change between 1995 and 2035. These information is further used to estimate carbon emission for REDD mechanism implementation in the next component.

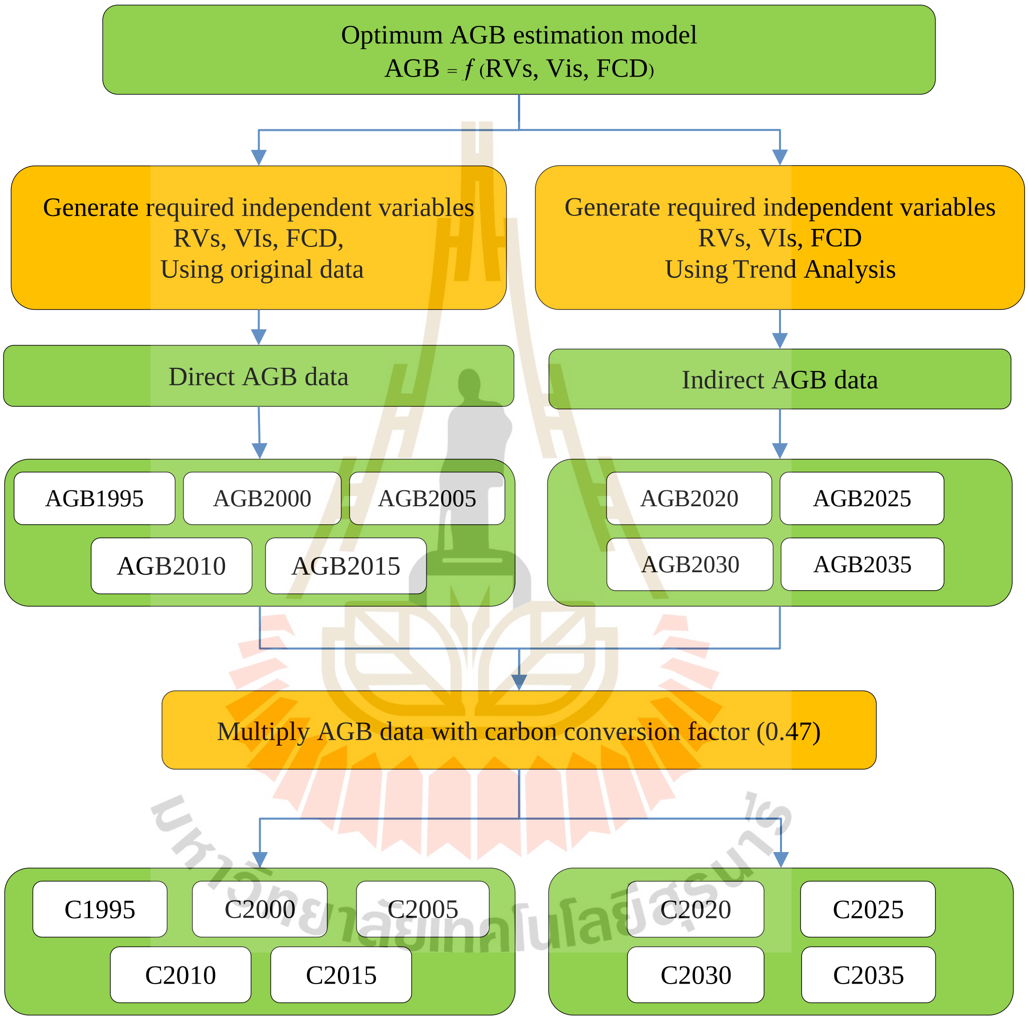


Figure 3.8 Schematic workflow of AGB estimation and carbon stock assessment.

3.5 Carbon emission assessment and REDD mechanism implementation

Under this component, the derived carbon stock that was derived from of forest type and plantation AGB models and forest AGB model in 1995, 2000, 2005, 2010 and 2015 were used to identify change due to forest degradation and deforestation for carbon emission in 4 periods: 1995-2000, 2000-2005, 2005-2010 and 2010-2015 to identify the highest period of carbon emission (Figure 3.9).

In practice, individual pixel of carbon stock in 1995, 2000, 2005, 2010 and 2015 was firstly identified change, which included carbon sink (forest upgradation and regrowth) and carbon emission (forest degradation and deforestation), to extract carbon emission using Matrix Operation for change detection under ERDAS imagine software. The derived carbon emission of forest area in each period (1995-2000, 2000-2005, 2005-2010, 2010-2015) was compared to identify the highest carbon emission period for FREL baseline establishment for REDD mechanism implementation.

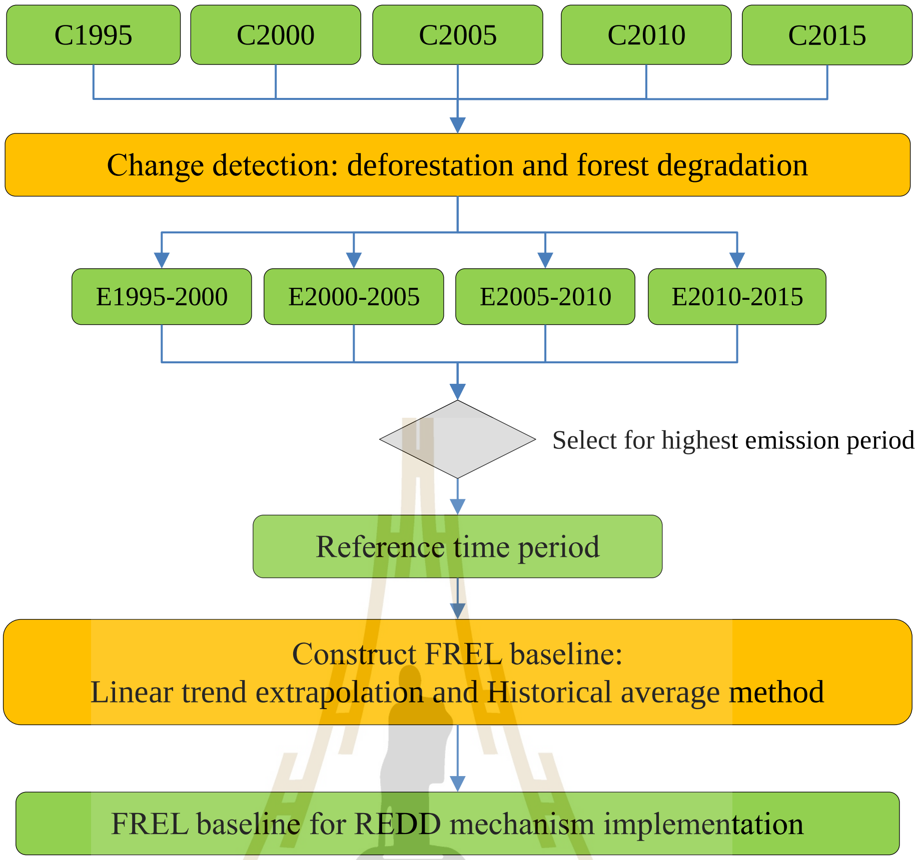


Figure 3.9 Highest carbon emission period identification and REL construction.

In this study, two common methods of FREL/FRL construction, which are suggested by REDD including linear trend extrapolation and historical average were here implemented as shown an example in Figure 3.10. In addition, Combined Incentive (CI) reference level method, which is a new emerging approach and applied by Guyana was also examined as shown as example in Figure 3.11.

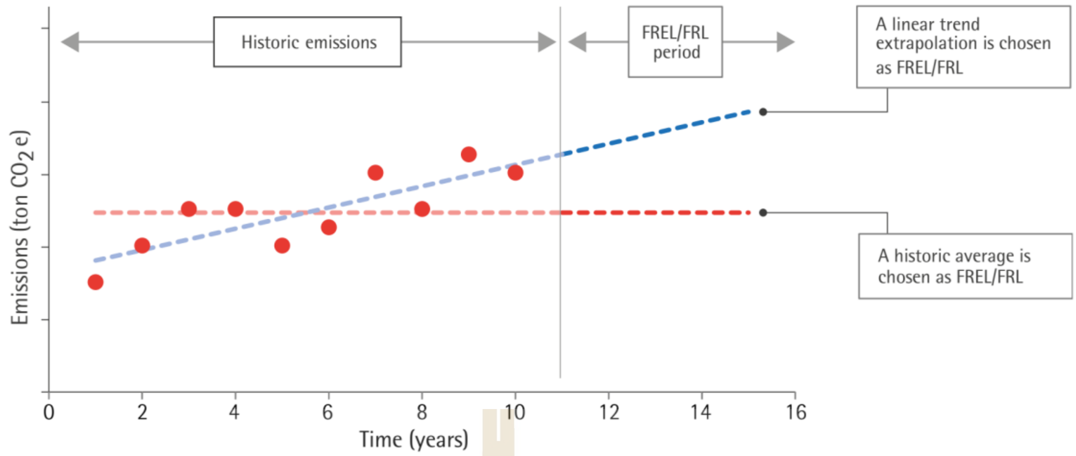


Figure 3.10 An example of two FREL/FRL construction methods.

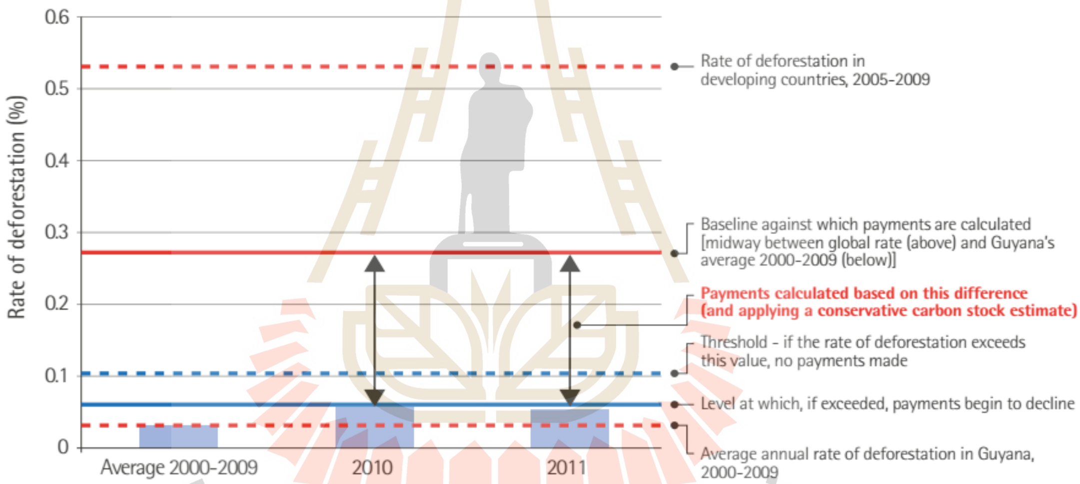


Figure 3.11 Guyana's Combined Incentives reference level (FAO, 2014).

In case of CI reference level method, deforestation rate in the study area was used as primary dataset for reference level establishment. In addition, deforestation rate of the country was also complied to calculate average deforestation rate. At the same time, a benchmark level of carbon emissions was set up according to deforestation rate during 1995 to 2015 and optimum threshold value was proposed for limiting the payment.

CHAPTER IV

FOREST AND LAND COVER CLASSIFICATION AND PREDICTION

Major results of the first and second objectives of the study included (1) to classify forest and land cover between 1995 and 2015 using CART and Expert System and (2) to predict forest and land cover between 2020 and 2035 using CA-Markov model are here reported. They consist of (1) an optimum CART model for forest and land cover classification; (2) forest and land cover classification between 1995 and 2015; (3) forest and land cover prediction between 2020 and 2035 and (4) forest area change. Details of each result are described and discussed in following sections.

4.1 An optimum CART model for forest and land cover classification

For optimum CART model of forest and land cover classification, the original Landsat-8 data in 2015 and their vegetation indices and selected physical factors as independent variables are here firstly extracted values from training areas of each forest and land cover class as dependent variable and exported as ASCII file (Table 4.1). Figure 4.1 shows an example of image data and ground photograph of each forest and land cover classes in this study. The prepared independent and dependent variables as ASCII file are further applied to construct decision tree construction with CRT growing method under SPSS statistical software.

Table 4.1 Example of ASCII file format from training area for decision tree construction.

FLC	Blue	Green	Red	NIR	SWIR1	SWIR2	SR	NDVI	NDWI	SAVI	TVI	RSR	Brightness	Greenness	Wetness	Elevation	Slope	Aspect
DDEF	26	21	17	136	50	10	187	217	50	186	175	194.57	111.48	181.40	231.09	495.42	1.57	7
DDEF	25	20	16	146	50	9	196	223	44	194	184	204.31	113.30	188.98	232.29	496.42	3.49	4
DDEF	25	21	16	155	52	10	203	227	38	200	190	209.15	116.11	195.13	232.22	496.06	4.68	5
DDEF	25	20	16	147	50	10	197	224	43	195	185	204.77	113.91	189.81	231.92	495.63	2.96	4
DDEF	25	20	15	141	50	9	192	221	47	190	180	200.53	112.14	185.40	231.76	495.08	2.22	2
DDEF	25	20	15	141	50	9	192	221	47	190	180	200.53	112.14	185.40	231.76	494.34	2.22	2
DDEF	24	20	15	146	48	9	197	224	43	194	185	206.77	112.61	189.25	232.95	493.87	5.44	2
DDEF	23	19	14	142	49	9	194	222	46	191	181	202.96	111.90	186.44	232.04	492.76	7.83	2
DDEF	23	19	14	142	50	10	195	222	46	192	182	202.35	112.56	186.59	231.27	491.24	10.36	1
DDEF	26	22	16	146	51	10	195	223	45	193	184	201.74	114.03	188.25	231.48	496.11	4.58	7
DDEF	24	22	15	146	48	9	197	224	44	195	186	207.25	112.49	189.20	233.44	496.69	7.57	2
DDEF	25	21	16	151	51	9	200	226	41	198	188	207.88	114.76	192.55	232.42	495.65	10.47	1
DDEF	25	20	14	144	48	9	196	223	45	193	184	206.08	111.99	187.84	232.72	495.42	10.05	1
DDEF	24	19	14	146	51	10	198	224	43	195	185	204.68	113.67	189.47	231.46	496.11	7.62	1
DDEF	24	19	14	146	51	10	198	224	43	195	185	204.68	113.67	189.47	231.46	496.43	7.62	1
DDEF	23	20	15	150	50	9	201	226	41	198	188	208.77	114.21	192.29	232.32	496.22	7.33	1
DDEF	24	19	14	148	50	9	199	225	42	196	186	207.52	113.41	190.53	232.41	495.48	9.89	1
DDEF	23	19	15	142	51	10	194	221	45	191	181	200.64	112.72	186.30	231.00	494.53	11.68	1

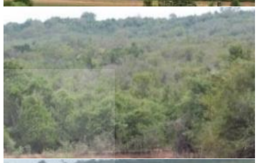
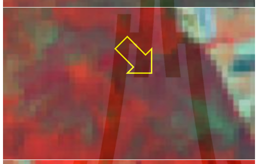
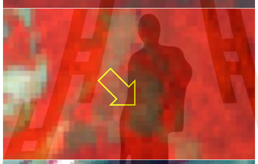
FLC	Landsat	Land photograph
Dense dry evergreen forest		
Moderate dry evergreen forest		
Mixed deciduous forest		
Forest plantation		
Disturbed forest		
Bamboo		
Perennial trees and Orchards		
Paddy field and Field crops		
Bare land		
Miscellaneous land		

Figure 4.1 Example of training area as color composite of Landsat 8 (SWIR-1, NIR, Red: RGB) and its photograph.

The result of the optimum CART model for forest and land cover classification as decision tree structure is displayed in Figure 4.2. It reveals that the final criteria of optimum CART model for forest and land cover classification applies only 10 independent variables including BLUE, RED, NIR, SWIR-1, SWIR-2, SR, NDWI, Wetness and Elevation and Slope. Meanwhile, other independent variable including GREEN, NDVI, SAVI, TVI, RSR, Brightness, Greenness and Aspect are dropped from the model. The decision tree consists of 42 nodes that includes 22 terminal nodes of various forest and land use classes.

According to accuracy assessment of the model based on training data as model-based inference statistics, the derived decision tree provides overall accuracy of 96.60% (Table 4.2). Basically, model-based inference statistic is not concerned with the accuracy of the thematic map. It is concerned with estimating the error of model that generates the thematic map. Model-based inference can provide the user with a quantitative assessment of each classification decision (Stehman, 2000, 2001). The accuracy of the derived optimum model for forest and land cover classification varies between 88.00% for miscellaneous land (MLA) and 100% for bamboo (BMB).

4.2 Forest and land use classification between 1995 and 2015

The decision tree structure of the CART model was transferred to Expert System of ERDAS imagine software as table form for forest and land cover classification including hypothesis, rule and conditions displays in Table 4.3. Distribution of final forest and land cover classification in 2015 after regrouping classes displays in Figure 4.3. While, the classified forest and land cover map was further performed accuracy assessment using 204 sample point with stratified random sampling in 2015. Error matrix form for forest and land cover accuracy assessment is displayed in Table 4.4.

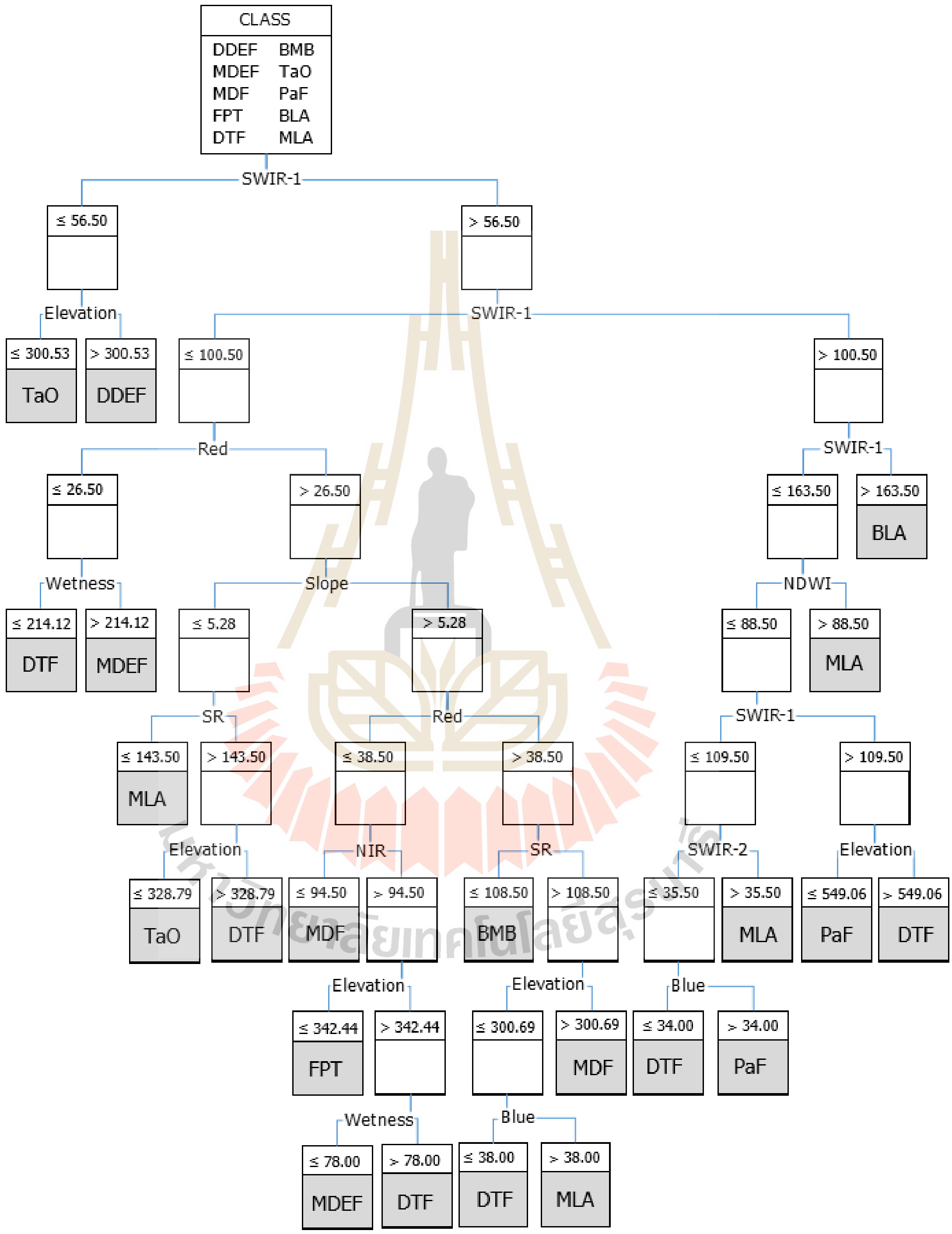


Figure 4.2 Decision tree structure for forest and land cover classification.

Table 4.2 Accuracy assessment of decision tree classification based training dataset.

Observed	Predicted										
	DDEF	**MDEF**	**MDF**	**FPT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Percent Correct**
DDEF	**423**	2	0	3	0	0	0	0	0	0	98.80%
MDEF	3	**360**	0	0	2	0	0	0	0	0	98.60%
MDF	0	5	**168**	1	1	0	0	0	0	2	94.90%
FPT	0	2	1	**116**	0	0	5	0	0	1	92.80%
DTF	0	4	2	2	**82**	0	0	0	0	1	90.10%
BMB	0	0	0	0	0	**54**	0	0	0	0	100.00%
TaO	0	3	0	1	0	0	**91**	4	0	0	91.90%
PaF	0	0	0	0	0	0	3	**561**	0	3	98.90%
BLA	0	0	0	0	0	0	0	7	**201**	0	96.60%
MLA	0	0	0	0	0	0	1	15	2	**132**	88.00%
Overall Percentage	18.80%	16.60%	7.60%	5.40%	3.80%	2.40%	4.40%	25.90%	9.00%	6.10%	**96.60%**

Table 4.3 Hypothesis, rules and conditions of forest and land cover classification.

Hypotheses	**Rules (Variables)**	**Conditions**
Dense dry evergreen forest (DDEF)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 ≤ 56.5
	Elevation	Elevation > 300.53 m
Moderate dry evergreen forest (MDEF) (1)	Multispectral (8 bits)	Remote sensing reflectance Red ≤ 26.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	Wetness > 214.12
Moderate dry evergreen forest (MDEF) (2)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 to 38.5 NIR > 94.5 SWIR-1 > 56.5 to 78
	Elevation	Elevation > 342.44 m
	Slope	Slope > 5.28%
Mixed deciduous forest (MDF) (1)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 to 38.5 NIR ≤ 94.5OLI SWIR-1 > 56.5 to 100.5
	Slope	Slope > 5.28%

Table 4.3 Hypothesis, rules and conditions of forest and land cover classification. (Continued).

Hypotheses	**Rules (Variables)**	**Conditions**
Mixed deciduous forest (MDF) (2)	Multispectral (8 bits)	Remote sensing reflectance Red > 38.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	SR > 108.5
	Elevation	Elevation > 300.69 m
	Slope	Slope > 5.28%
Forest plantation (FPT)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 to 38.5 NIR > 94.5 SWIR-1 > 56.5 to 100.5
	Elevation	Elevation ≤ 342.44 m
	Slope	Slope > 5.28%
Disturbed forest (DTF) (1)	Multispectral (8 bits)	Remote sensing reflectance Red ≤ 26.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	Wetness ≤ 214.12
Disturbed forest (DTF) (2)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	SR > 143.5
	Elevation	Elevation > 328.79 m
	Slope	Slope ≤ 5.28%
Disturbed forest (DTF) (3)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 to 38.5 NIR > 94.5 SWIR-1 > 78 to 100.5
	Elevation	Elevation > 342.44 m
	Slope	Slope > 5.28%
Disturbed forest (DTF) (4)	Multispectral (8 bits)	Remote sensing reflectance Blue ≤ 38 Red > 38.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	SR > 108.5
	Elevation	Elevation ≤ 300.69 m
	Slope	Slope > 5.28%

Table 4.3 Hypothesis, rules and conditions of forest and land cover classification. (Continued).

Hypotheses	**Rules (Variables)**	**Conditions**
Disturbed forest (DTF) (5)	Multispectral (8 bits)	Remote sensing reflectance Blue ≤ 34 SWIR-1 > 100.5 to 109.5 SWIR-2 ≤ 35.5
	Vegetation index (8 bits)	NDWI ≤ 88.5
	Elevation	Elevation ≤ 300.69 m
Disturbed forest (DTF) (6)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 > 109.5 to 163.5
	Vegetation index (8 bits)	NDWI ≤ 88.5
	Elevation	Elevation > 549.06 m
Bamboo (BMB)	Multispectral (8 bits)	Remote sensing reflectance Red > 38.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	SR ≤ 108.5
	Slope	Slope > 5.28%
Perennial trees and orchards (TaO (1)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 ≤ 56.5
	Elevation	Elevation ≤ 300.53 m
Perennial trees and Orchards (TaO) (2)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	SR > 143.5
	Elevation	Elevation ≤ 328.79 m
	Slope	Slope ≤ 5.28%
Paddy field and field crops (PaF) (1)	Multispectral (8 bits)	Remote sensing reflectance Blue > 34 SWIR-1 > 100.5 to 109.5 SWIR-2 ≤ 35.5
	Vegetation index (8 bits)	NDWI ≤ 88.5
	Elevation	Elevation ≤ 300.69 m
Paddy field and field crops (PaF) (2)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 > 109.5 to 163.5
	Vegetation index (8 bits)	NDWI ≤ 88.5
	Elevation	Elevation ≤ 549.06 m
Bare land (BLA)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 > 163.5

Table 4.3 Hypothesis, rules and conditions of forest and land cover classification. (Continued).

Hypotheses	**Rules (Variables)**	**Conditions**
Miscellaneous land (MLA) (1)	Multispectral (8 bits)	Remote sensing reflectance Red > 26.5 SWIR-1 > 56.5 to 100.5
	Vegetation index (8 bits)	SR ≤ 143.5
	Slope	Slope ≤ 5.28%
Miscellaneous land (MLA) (2)	Multispectral (8 bits)	Remote sensing reflectance Blue > 38 Red > 38.5 SWIR-1 > 56.5 to 100.5
	Vegetation Index (8 bits)	SR > 108.5
	Elevation	Elevation ≤ 300.69 m
	Slope	Slope > 5.28%
Miscellaneous land (MLA) (3)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 > 109.5 to 163.5
	Vegetation index (8 bits)	NDWI > 88.5
Miscellaneous land (MLA) (4)	Multispectral (8 bits)	Remote sensing reflectance SWIR-1 > 100.5 to ≤ 109.5 SWIR-2 > 35.5
	Vegetation index (8 bits)	NDWI ≤ 88.5

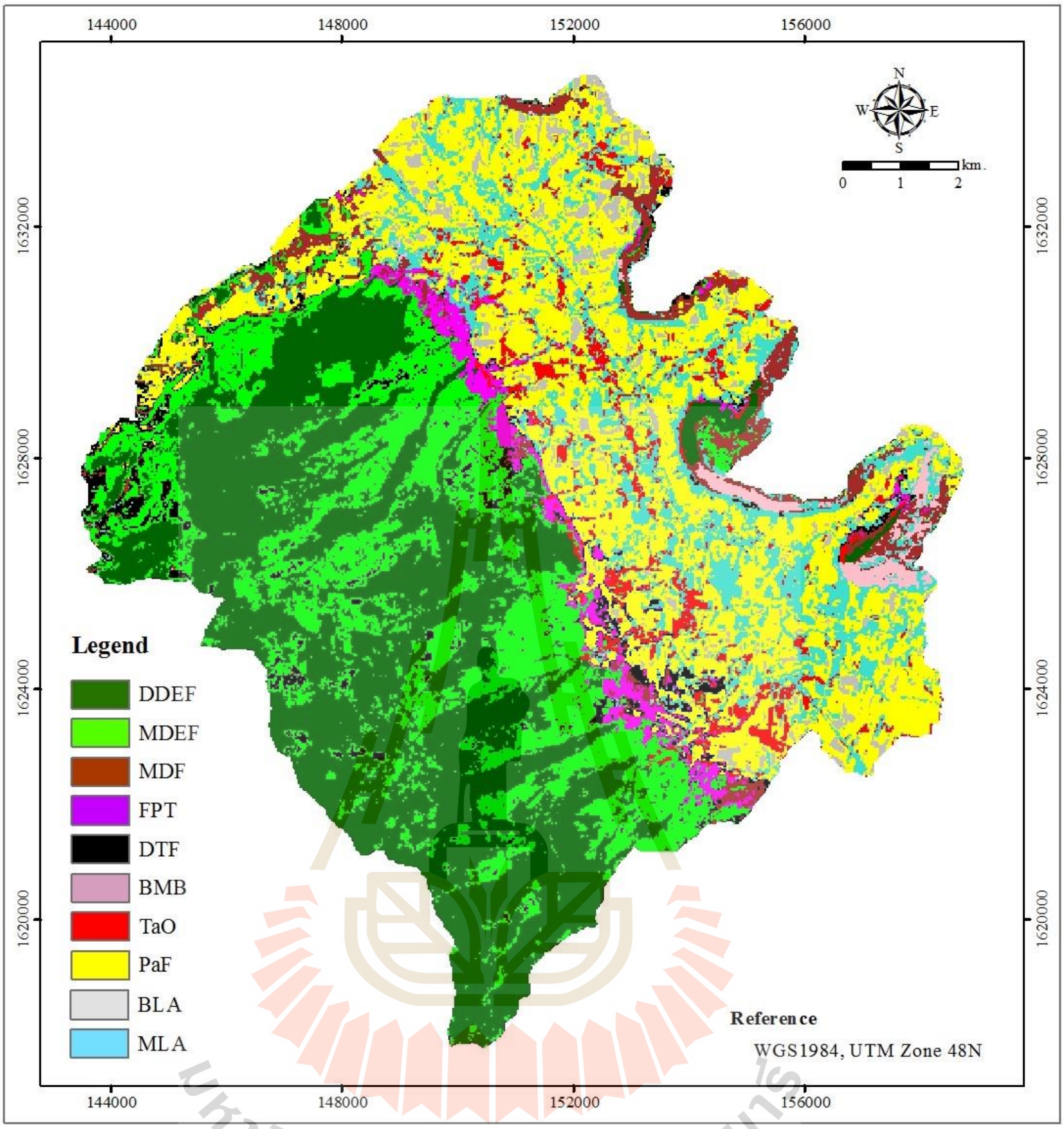


Figure 4.3 Distribution of forest and land cover classification in 2015.

Table 4.4 Error matrixes and accuracy assessment of forest and land cover in 2015.

(Unit: point)

	Ground truth data											
CART	**DDEF**	**MDEF**	**MDF**	**PFT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Total**	**UA (%)**
DDEF	**57**	5	0	0	0	0	0	0	0	0	62	**91.94**
MDEF	0	**37**	1	0	0	0	1	0	0	0	39	**94.87**
MDF	0	0	**7**	1	0	0	0	0	0	0	8	**87.50**
PFT	0	0	0	**5**	0	0	0	0	0	0	5	**100.00**
DTF	0	0	0	0	**6**	0	0	0	0	0	6	**100.00**
BMB	0	0	0	0	0	**3**	0	0	0	0	3	**100.00**
TaO	0	0	0	0	0	0	**6**	1	0	0	7	**80.00**
PaF	0	0	0	0	0	0	1	**42**	1	3	47	**86.36**
BLA	0	0	0	0	0	0	0	1	**4**	0	5	**85.71**
MLA	0	0	1	0	0	0	0	2	0	**19**	22	**89.36**
Total	57	42	9	6	6	3	8	46	5	22	**204**	
PA (%)	**100.00**	**88.10**	**77.78**	**83.33**	**100.00**	**100.00**	**75.00**	**91.30**	**80.00**	**86.36**		
OA (%)	**91.18**											
KC (%)	**89.06**											

Note: PA, producer's accuracy; UA, user's accuracy; OA, overall accuracy and KC, Kappa coefficient

As results, it reveals that overall accuracy was 91.18% and Kappa hat coefficient was 89.06%. Meanwhile producer's accuracy varied between 75.00%-100.00% and user's accuracy varied between 80.00%–100.00%. Based on Fitzpatrick-Lins (1981), Kappa hat coefficient more than 80 percent represents strong agreement or accuracy between the predicted map and the reference map. In addition, the derived accuracy assessment of CART model in this study is similar with the previous work of Ghose, Pradhan and Ghose (2010), who applied CART for forest and land cover classification with overall accuracy of 98% and Kappa hat coefficient of 97%.

In the study area, most of main natural forest areas in the study area including dense and moderate dry evergreen forest situated in Non-hunting area in mountainous area. While mixed deciduous forest distributes over hilly areas in eastern part of the study area and forest plantation (Eucalyptus *camaldulensis* Dehnhn.) situates in buffer zone between natural forest and other land use classes that locates over undulate area between mountain and hilly areas.

The derived optimum CART model of forest and land cover classification in 2015 from Landsat 8-OLI was further applied to extract forest and land cover data in 1995, 2000, 2005 and 2010 from Landsat 5-TM. Herein, the historical Landsat data in 1995, 2000, 2005 and 2010 were firstly applied multiple-date image normalization using Histogram Matching method. At the same time, additional required spectral band of independent variables include SR, NDWI and Wetness were prepared for historical forest and land cover classification with the optimum CART model.

Distribution of final forest and land cover classification in 1995, 2000, 2005 and 2010 displays in Figure 4.4. Meanwhile, area and percentage of forest and land cover classes between 1995 and 2015 is summarized as shown in Table 4.5. Dynamic change of percentage of forest and land cover classes between 1995 and 2015 are compared as shown in Figure 4.5.

As results, the most dominant forest cover classes in 2015 are dense and moderate dry evergreen forest, which are mostly located in Non-hunting area and cover area about 31% and 19% of the total area. Meanwhile the most dominant land use and land cover classes are paddy field and field crop and miscellaneous land which cover area about 23% and 11% of the total area.

In term of temporal change between 1995 and 2015, it reveals that area of dense and moderate dry evergreen forest increase from 41.81 sq. km and 15.18 sq. km in 1995 to 42.27 sq. km and 25.39 sq. km in 2015, respectively. These areas tend to increase in the future. In contrast, area of mixed deciduous forest is about 7.62 sq. km in 1995 and is about 5.42 sq. km in 2015. This class tends to decrease in the future. Meanwhile forest plantation in 1995 is about 2.03 sq. km and 3.22 sq. km in 2015. At the same time non-forest areas include disturbed forest, bamboo, perennial trees and orchards, paddy field and field crops and miscellaneous land are fluctuate through the time. In addition, it can be observed that an expected results of forest and land use changes occur between 5 years period. For example disturbed forest in 2005 becomes moderate dry evergreen forest in 2010 or paddy field and field crops in 1995 become miscellaneous land in 2000. These unexpected results cannot be avoid because the classified forest and land use data in 1995, 2000, 2005 and 2010 were derived based on hypothesis, rules and conditions of optimum CART model. This is a limitation of historical forest and land use classification in this study due to limitation of historical forest cover record in 1995, 2000, 2005 and 2010.

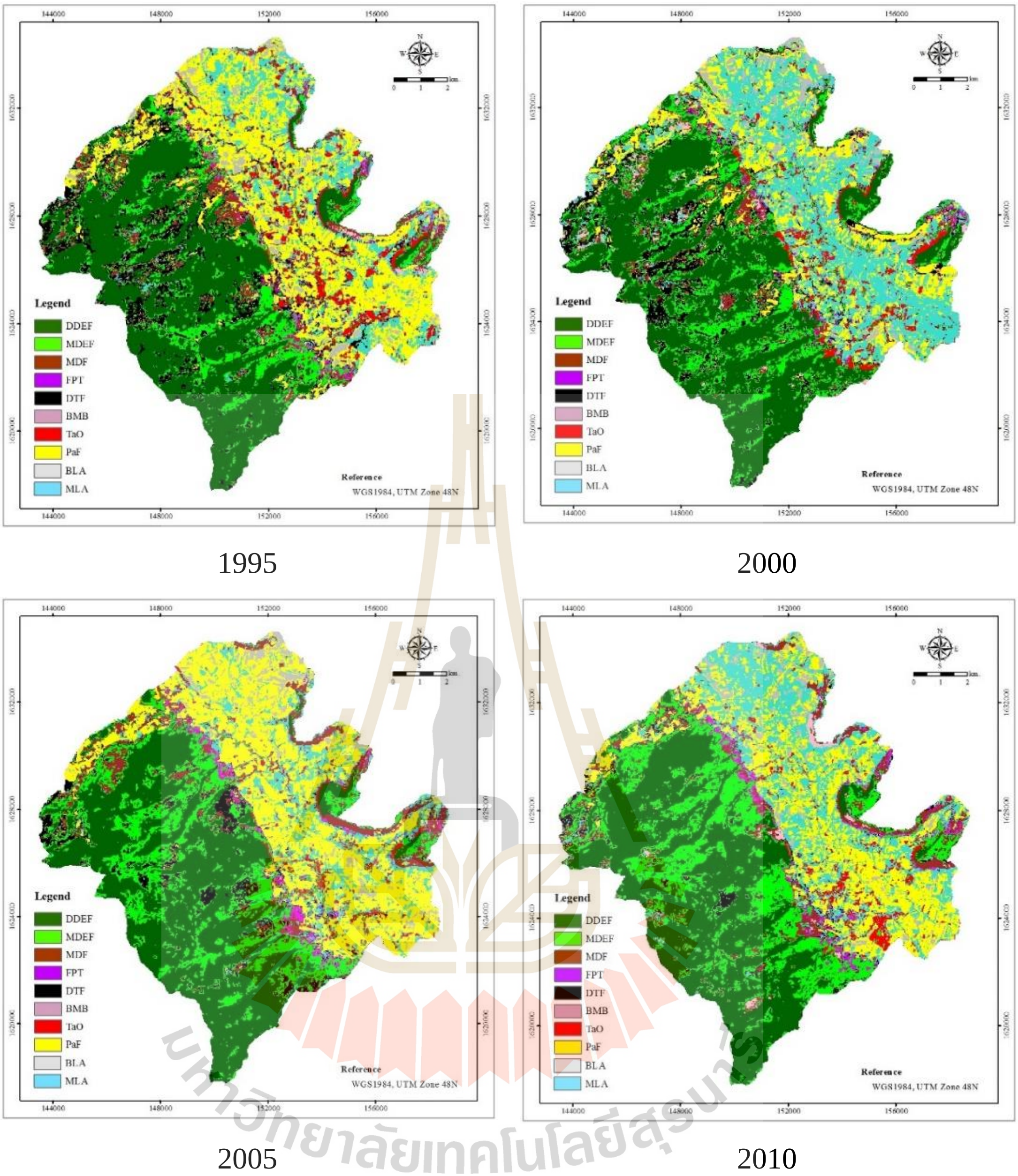


Figure 4.4 Distribution of forest and land cover classification in 1995, 2000, 2005 and 2010.

Table 4.5 Area and percentage for forest and land cover in 1995, 2000, 2005, 2010 and 2015.

Forest and land cover	1995		2000		2005		2010		2015	
	sq. km	%	sq. km	%	sq. km	%	sq. km	%	sq. km	%
DDEF	41.81	30.74	41.05	30.19	42.87	31.52	43.19	31.76	42.27	31.08
MDEF	15.18	11.16	18.31	13.47	22.10	16.25	24.59	18.08	25.39	18.67
MDF	7.62	5.60	5.46	4.02	8.34	6.13	7.42	5.45	5.42	3.98
PFT	2.03	1.49	1.96	1.44	2.46	1.81	2.37	1.74	3.22	2.37
DTF	12.89	9.48	11.76	8.65	5.82	4.28	3.03	2.23	3.95	2.91
BMB	0.56	0.41	1.85	1.36	0.19	0.14	1.20	0.88	1.43	1.05
TaO	5.57	4.09	4.47	3.28	3.10	2.28	3.43	2.52	4.81	3.53
PaF	30.85	22.69	17.91	13.17	34.83	25.61	24.70	18.16	31.25	22.98
BLA	3.55	2.61	3.51	2.58	3.38	2.48	3.53	2.59	3.48	2.56
MLA	15.94	11.72	29.70	21.84	12.91	9.49	22.53	16.57	14.77	10.86
Total	**135.99**	**100.00**	**135.99**	**100.00**	**135.99**	**100.00**	**135.99**	**100.00**	**135.99**	**100.00**

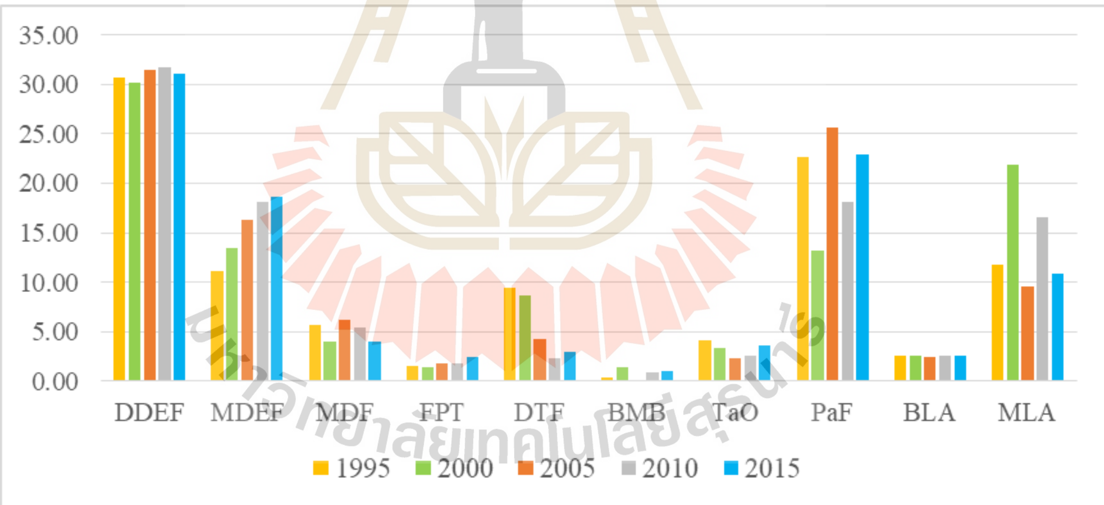


Figure 4.5 Dynamic change of forest and land cover classes between 1995 and 2015 by percentage.

4.3 Forest and land cover prediction between 2020 and 2035

CA-Markov model were here applied to predict forest and land cover data in 2020, 2025, 2030 and 2035 based on the derived forest and land cover data in 1995, 2000, 2005, 2010 and 2015. In practice, one pair of historical forest and land cover data is used to predict forest and land cover data. For example, forest and land cover data from 2010 and 2015 were used to predict forest and land cover in 2020 based on transition area and transition probability matrices between 2010 and 2015 as Markov Chain to determine the quantity of change and allocate its change in 2020 by Cellular Automata (CA). Details of transition area and probability matrices for forest and land cover prediction are shown in Appendix A.

Distribution of predictive forest and land cover classification in 2020, 2025, 2030 and 2035 displays in Figure 4.6. Meanwhile area and percentage of forest and land cover classes between 2020 and 2035 are summarized as shown in Table 4.6 and percentage of forest and land cover between 2020 and 2035 were compared as shown in Figure 4.7.

As a result, it reveals that area of dense dry evergreen forest, mixed deciduous forest, forest plantation increase between 2020 and 2035 while area of moderate dry evergreen forest and disturbed forest decrease in the same period. In fact, area of dense dry evergreen forest, mixed deciduous forest, forest plantation in 2020 are about 41.53, 5.09 and 3.41 sq. km and are about 44.15, 5.69 and 3.60 sq. km in 2035, respectively. While area of moderate dry evergreen forest and disturbed forest are about 25.92 and 3.89 sq. km in 2020 and are about 24.78 and 3.28 sq. km in 2035, respectively.

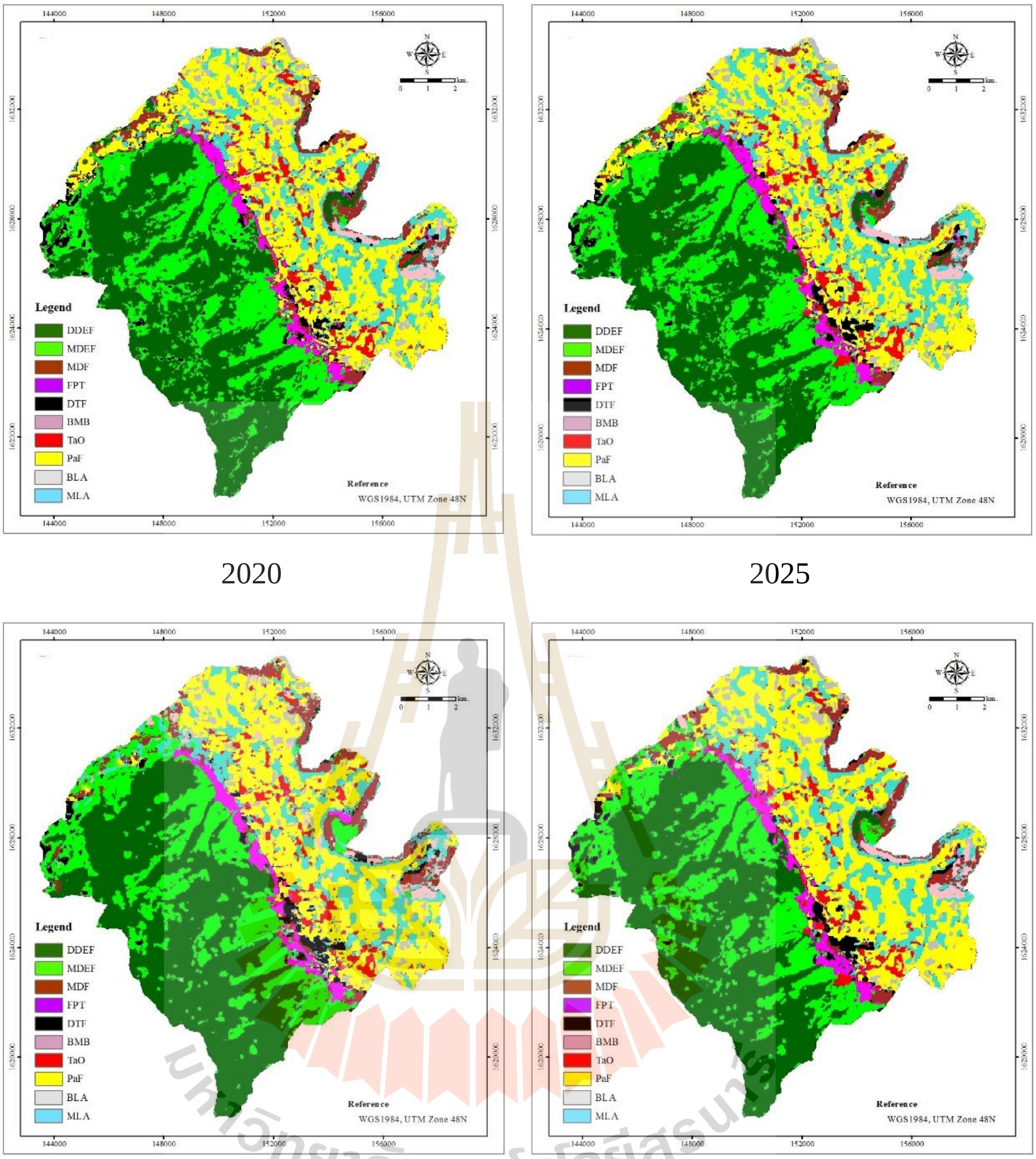


Figure 4.6 Distribution of forest and land cover classification in 2020, 2025, 2030 and 2035.

Table 4.6 Area and percentage for forest and land cover in 2020, 2025, 2030 and 2015.

Forest and land cover	2020		2025		2030		2035	
	sq. km	%	sq. km	%	sq. km	%	sq. km	%
DDEF	41.53	30.54	42.32	31.12	44.32	32.59	44.15	**32.47**
MDEF	25.92	19.06	25.44	18.71	25.07	18.44	24.78	**18.22**
MDF	5.09	3.74	5.28	3.88	6.20	4.56	5.69	**4.19**
FPT	3.41	2.51	3.54	2.60	3.65	2.69	3.60	**2.65**
DTF	3.89	2.86	3.75	2.76	3.52	2.59	3.28	**2.41**
BMB	1.26	0.93	1.25	0.92	1.85	1.36	1.81	**1.33**
TaO	5.34	3.92	5.58	4.10	4.48	3.29	4.50	**3.31**
PaF	32.48	23.89	29.95	22.02	30.12	22.15	30.40	**22.35**
BLA	3.47	2.55	3.32	2.44	3.45	2.53	3.40	**2.50**
MLA	13.59	9.99	15.56	11.44	13.33	9.80	14.38	**10.57**
Total	**135.99**	**100.00**	**135.99**	**100.00**	**135.99**	**100.00**	**135.99**	**100.00**

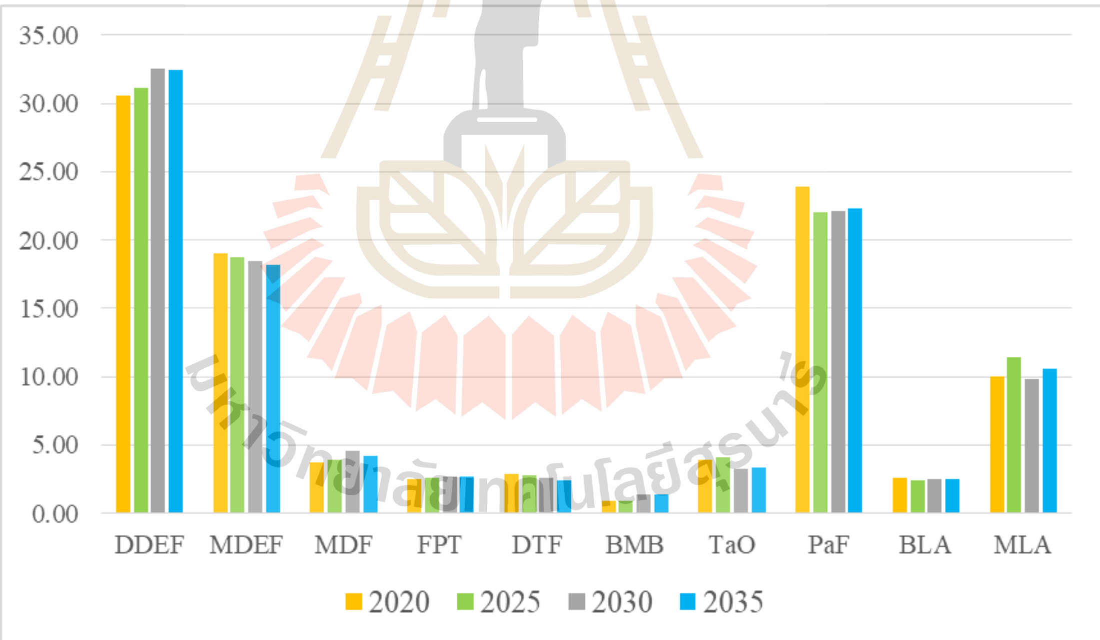


Figure 4.7 Predictive change of forest and land cover classes between 2020 and 2035 by percentage.

In addition, validation of CA-Markov model for forest and land cover prediction was here conducted based on accuracy assessment of predicted forest and land cover data in 2015 (Figure 4.8) with 204 sampling points from ground survey data in 2015. It was found that overall accuracy was 67.65% and Kappa hat coefficient was 60.09% (Table 4.7). Based on Fitzpatrick-Lins (1981), Kappa hat coefficient between 40 and 80 percent represents moderate agreement or accuracy between the predicted map and the reference map.

Table 4.7 Error matrixes and accuracy assessment for CA-Markov model validation in 2015.

(Unit: point)

	Ground truth data											
CART	**DDEF**	**MDEF**	**MDF**	**FPT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Total**	**UA (%)**
DDEF	**51**	10	0	0	0	0	0	0	0	0	61	**83.61**
MDEF	5	**28**	3	2	3	1	0	0	0	0	42	**66.67**
MDF	1	2	**4**	0	1	2	0	0	0	0	10	**40.00**
FPT	0	0	0	**3**	0	0	0	0	0	0	3	**100.00**
DTF	0	0	0	0	**1**	0	1	0	0	0	2	**50.00**
BMB	0	2	1	1	0	**0**	0	0	0	0	4	**0.00**
TaO	0	0	0	0	0	0	**4**	1	0	1	6	**66.67**
PaF	0	0	0	0	0	0	3	**28**	1	3	35	**80.00**
BLA	0	0	0	0	0	0	0	2	**1**	0	3	**33.33**
MLA	0	0	1	0	1	0	0	15	3	**18**	38	**47.37**
Total	57	42	9	6	6	3	8	46	5	22	**204**	
PA (%)	**89.47**	**66.67**	**44.44**	**50.00**	**16.67**	**0.00**	**50.00**	**60.87**	**20.00**	**81.82**		
OA (%)	**67.65**											
KC (%)	**60.09**											

Note: PA, producer's accuracy; UA, user's accuracy; OA, overall accuracy and KC, Kappa coefficient.

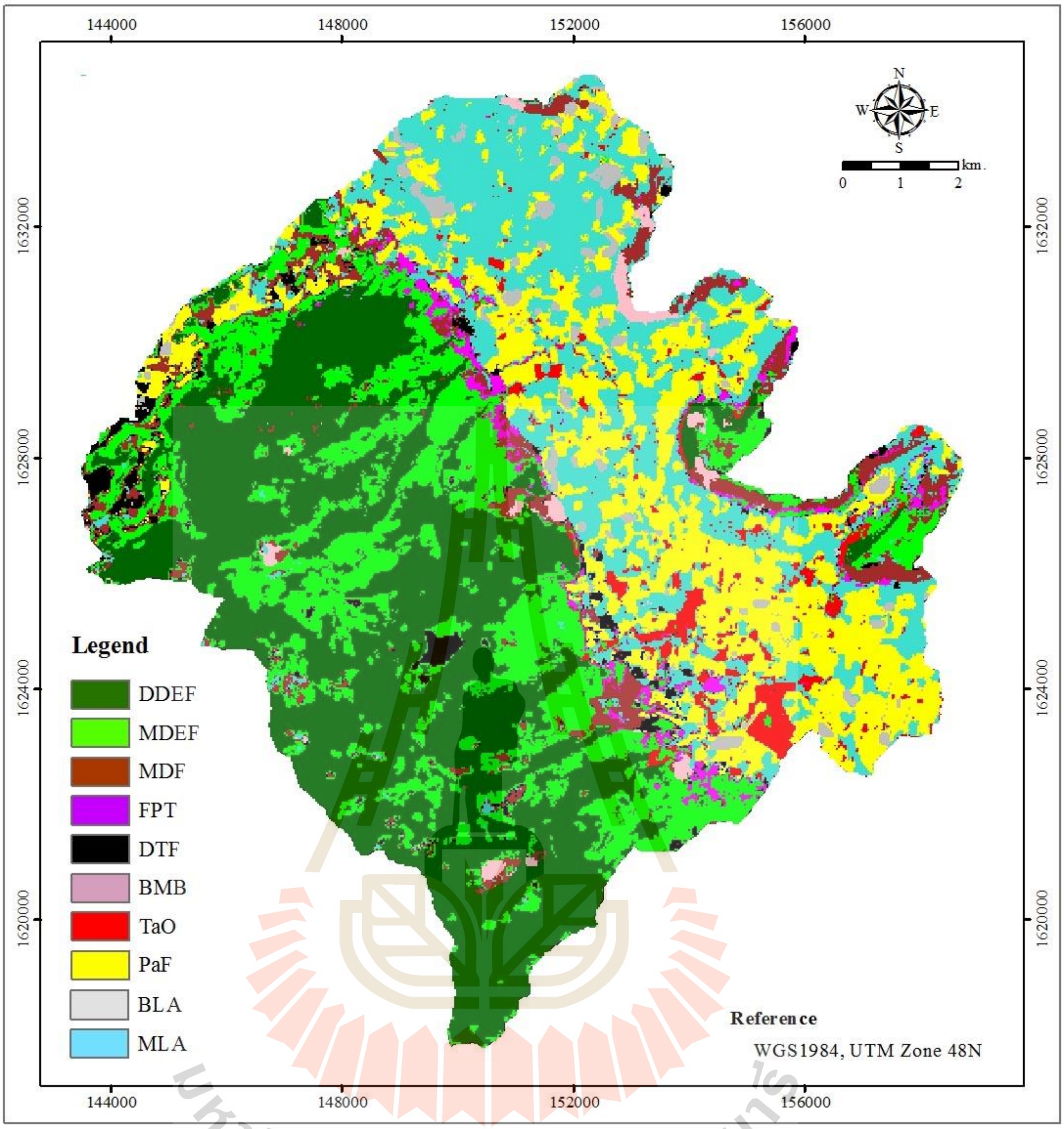


Figure 4.8 Predictive forest and land cover map in 2015 using CA-Markov model.

4.4 Forest area change

The classified forest and land cover data in 1995, 2000, 2005, 2010 and 2015 and the predicted forest and land cover data in 2020, 2025, 2030 and 2035 were regrouped into two classes: forest area and non-forest area (Table 4.8). Area of forest change, annual change and percent of change is summarized in Table 4.9 and Figure 4.9 displays change of forest area in term of gain (increase) and loss (decrease) in 8 periods.

Table 4.8 Reclassification of forest and land cover for forest and non-forest area.

Forest and Non-forest	**Forest and land cover data**
Forest area	Dense dry evergreen forest (DDEF)
	Moderate dry evergreen forest (MDEF)
	Mixed deciduous forest (MDF)
	Forest plantation (FPT)
Non-forest area	Disturbed forest (DTF)
	Bamboo (BMB)
	Tree and orchard land (TaO)
	Paddy field and field crops (PaF)
	Barren land (BLA)
	Miscellaneous land (MLA)

Table 4.9 Forest area change between 1995 and 2035.

Year	**Forest area (sq. km)**	**Change area (sq. km)**	**Annual change (sq.km)**	**% of change**
1995	66.64			
2000	66.78	0.14	0.028	0.0420
2005	75.77	8.99	1.798	2.6924
2010	77.57	1.8	0.36	0.4751
2015	76.3	-1.27	-0.254	-0.3274
2020	75.95	-0.35	-0.07	-0.0917
2025	76.58	0.63	0.126	0.1659
2030	79.24	2.66	0.532	0.6947
2035	78.22	-1.02	-0.204	-0.2574

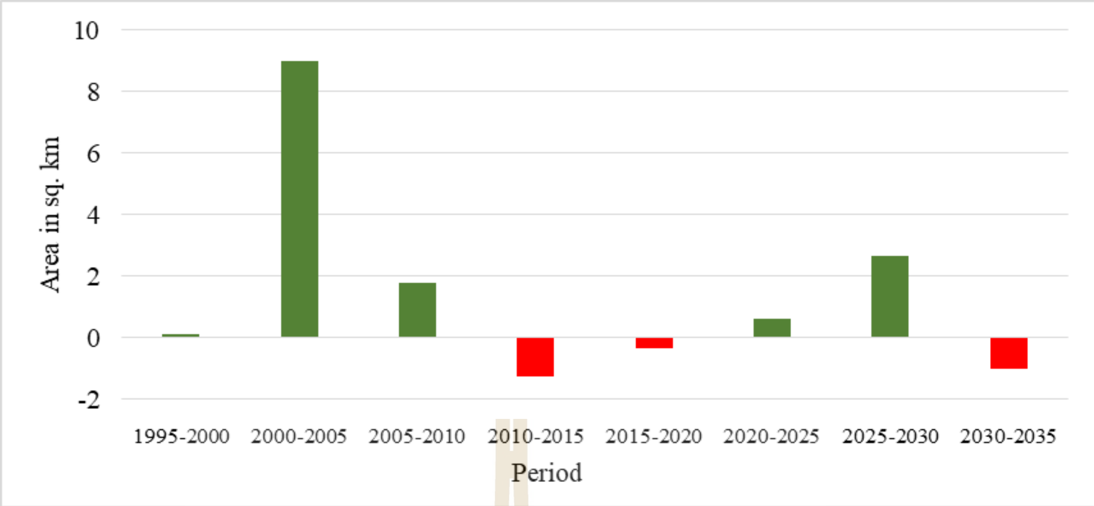


Figure 4.9 Gain and loss of forest area change in 8 periods.

As a result, it reveals that the highest increasing of forest area occurs between 2000 and 2005 and it covers area of 8.99 sq. km or 6.6108 percent of the study area with annual increasing rate of 1.798 sq.km. In contrast, the highest decreasing of forest area occurs between 2010 and 2015 and it covers area of 1.27 sq. km or 0.9339 percent of the study area with annual decreasing rate of 0.254 sq.km. In addition, it can be observed that forest area increase about 9.66 sq. km during 1995 and 2015 (25 years) meanwhile forest area increase only 1.92 sq. km during 2020 to 2035 (20 years).

Furthermore, distribution of forest area change and its component in 8 periods including forest, deforestation, regrowth and non-forest areas are displayed in Figures 4.10 and 4.11. Area of each component in forest change map is summarized in Table 4.10 and comparatively displayed in Figure 4.12. Basically, this information was extracted using post classification comparison change detection algorithm under Matrix operation of ERDAS Imagine software. Details of transitional area of forest change are presented in Appendix B. Most important components that relates with carbon emission is forest and deforestation areas. In fact, forest area component in each period consists of upgradation and degradation forest. Degraded forest and deforestation are directly concern with forest carbon emission. This information will be quantify more detail in Chapter VII: Carbon emission assessment and REDD implementation.

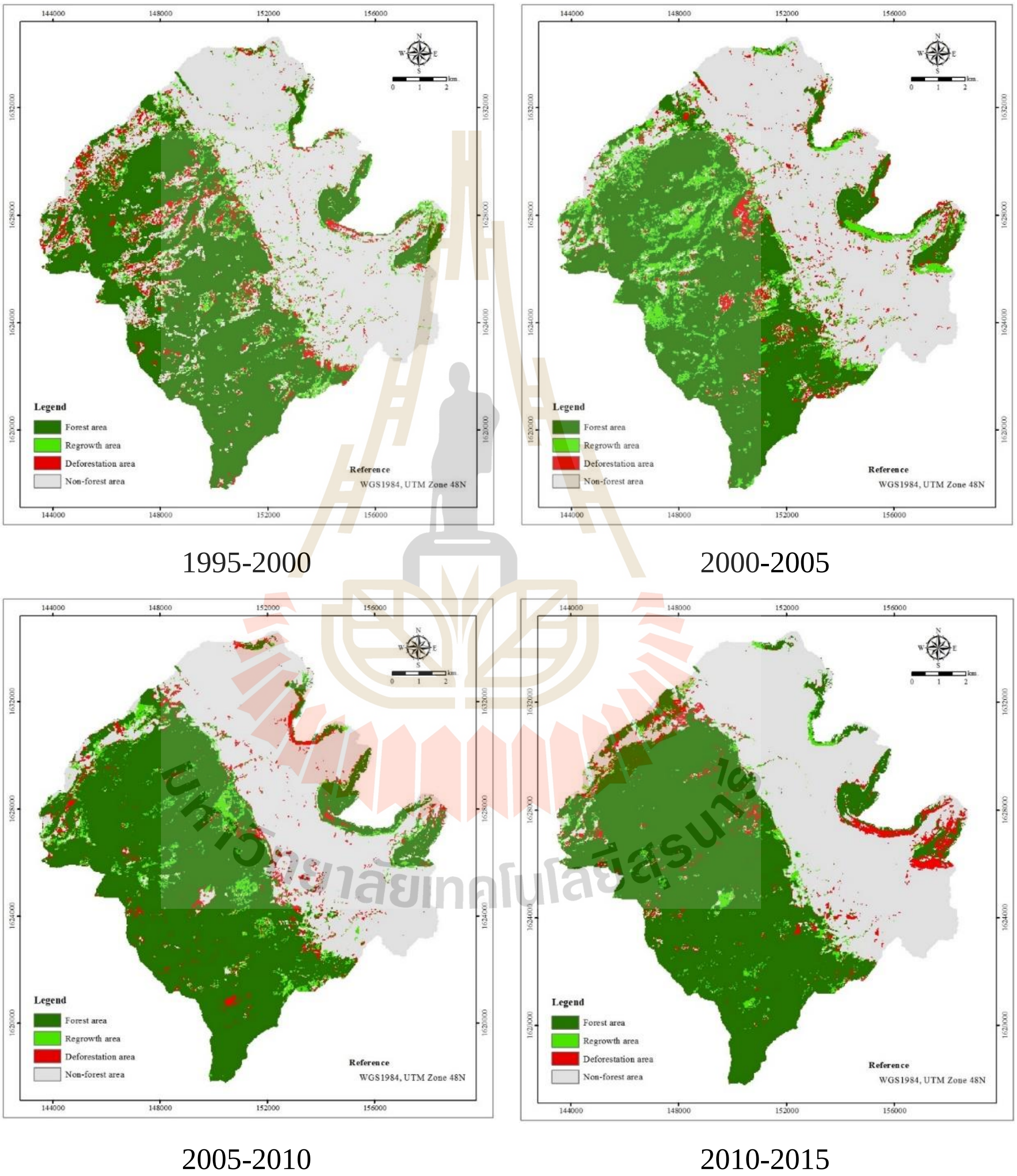


Figure 4.10 Change of forest area between 1995 and 2015.

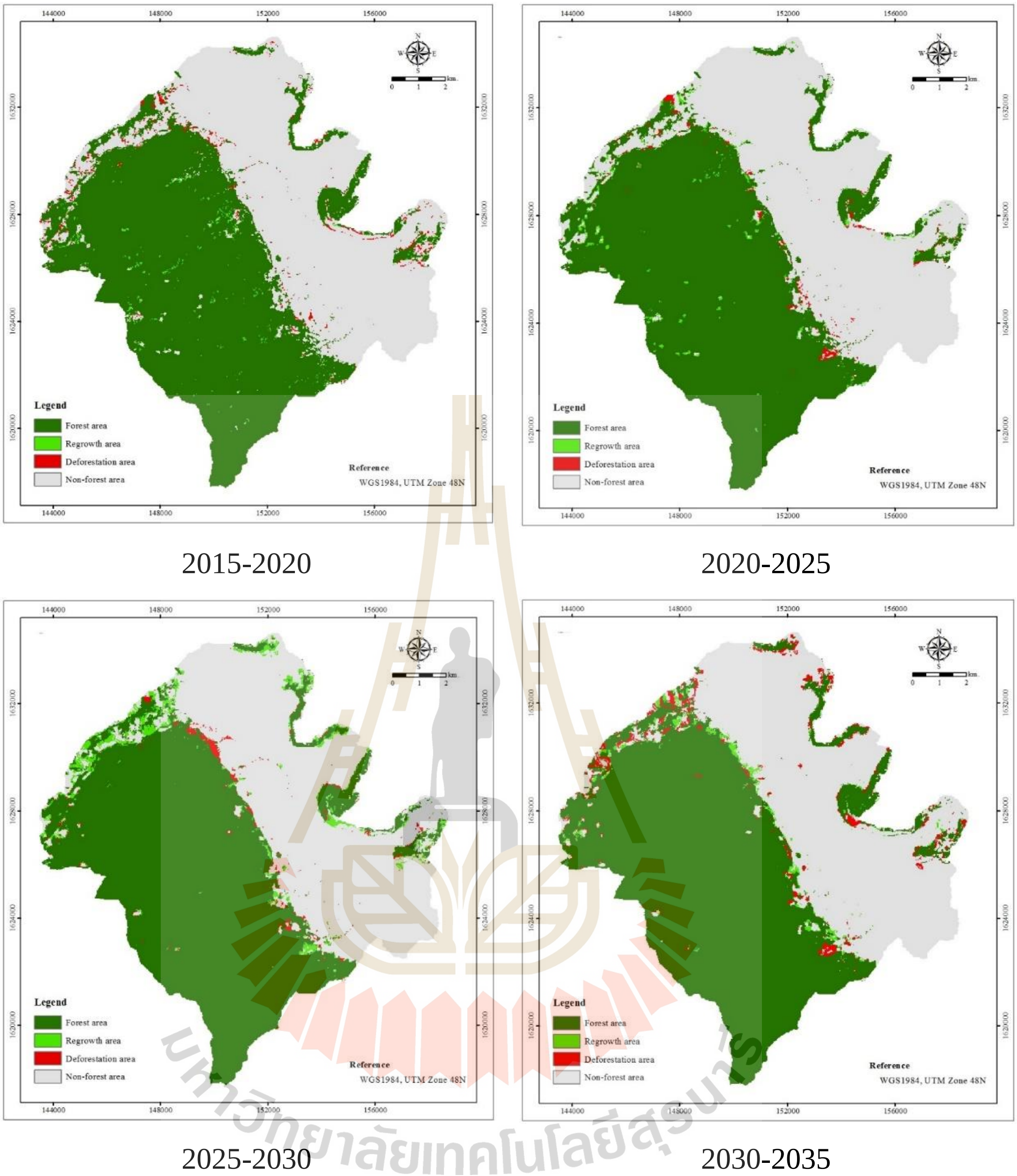


Figure 4.11 Change of forest area between 2015 and 2035.

Table 4.10 Forest change and its component between 1995 and 2035.

Period	Component of forest change (in sq.km)			
	Forest area	Deforestation area	Regrowth area	Non-forest area
1995-2000	59.38	7.26	7.41	61.94
2000-2005	61.52	5.27	14.24	54.96
2005-2010	71.42	4.34	6.15	54.07
2010-2015	72.68	4.90	3.62	54.80
2015-2020	74.99	1.31	0.97	58.72
2020-2025	74.97	1.00	1.62	58.41
2025-2030	75.41	1.17	3.84	55.57
2030-2035	76.46	2.78	1.76	54.99

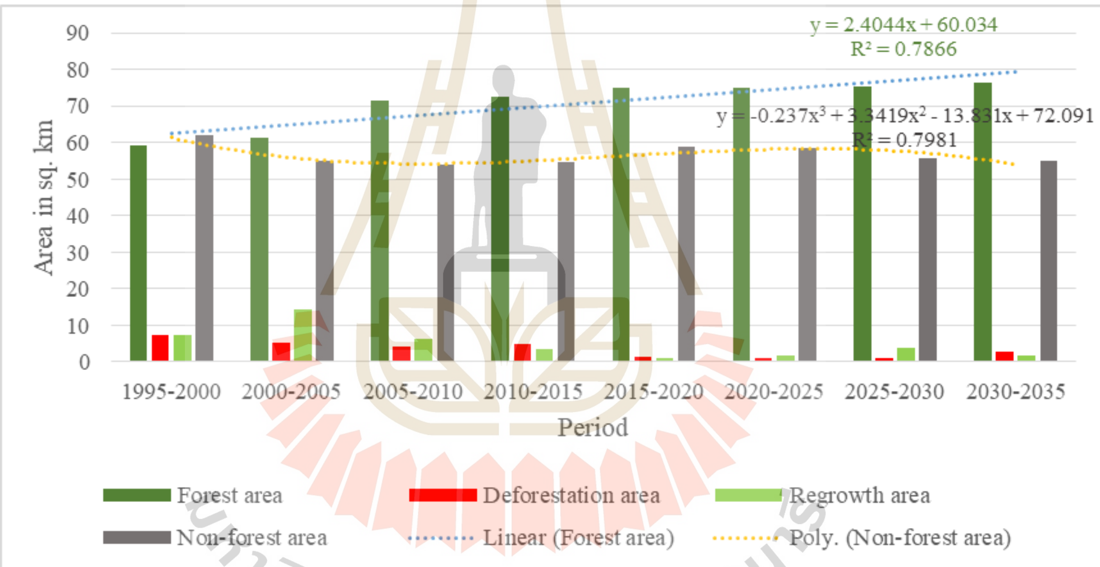


Figure 4.12 Comparison of area of each component in forest change map.

As a result, forest area tends to increase in the future while non-forest area is fluctuates and tends to decrease. Likewise, deforestation and regrowth are fluctuate and seem to decrease in the future. Because most of forest area situates in Non-hunting area where is carefully controlled with strictly patrolling. The coefficient of the determination (R^2) of simple linear equation of trend line for forest area is 78.66% while R^2 of polynomial equation with order 3 of trend line for non-forest area is 79.81%.

CHAPTER V

OPTIMUM ABOVE GROUND BIOMASS ESTIMATION MODEL DEVELOPMENT

Main result of the third object on optimum above ground biomass estimation model development are here separately reported include (1) in situ AGB data, (2) influential factors on AGB, (3) AGB estimation model development for forest type and plantation and (4) AGB estimation model development for forest area. Details of each result are separately described and discussed in following sections.

5.1 In situ AGB data

ABG data are here calculated using allometry equations (Equations 2.1 to 2.9) based on ground measurement data in 2015 of each forest type and plantation. They are dense and moderate dry evergreen forest, mixed deciduous forest and forest plantation. Plant profile which represents horizontal and vertical structure of forest type and plantation and details of scientific name (DNP, 2017 and SERS, 2017) are displayed in Figures 5.1 to 5.4. Dominant species of dense dry evergreen forest are *Hopea odorata* Roxb., Pean (local name), *Dipterocarpus tuberculatus* Roxb. and *Walsura trichostemon* Miq. While *Hopea odorata* Roxb., *Walsura trichostemon* Miq., *Atalantia monophylla* (DC.) Correa *and Dipterocarpus tuberculatus* Roxb. are dominant species of moderate dry evergreen forest. For mixed deciduous forest, the dominant species are

Indora siamensis Teijsm. & Miq., *Rothmannia wittii* (Craib) Bremek., *Suregada multiflorum* (A. Jus.) Baill. and *Microcos paniculata* L. Meanwhile, main specie in forest plantation is *Eucalyptus camaldulensis* Dehnhn. Details of forest inventory data for optimum AGB estimation model development including local name, scientific name, GBH (cm), DBH (cm) and total height (m) are presented in Appendix C.

The AGB data of each forest type and plantation as dependent variable is summarized in Table 5.1. The average AGB of dense and moderate dry evergreen forest from ground sampling plot (20 x 20 m) are 5,230.92 and 4,690.46 kg/plot, respectively while mixed deciduous forest and forest plantation are 3,176.31 and 2,740.78 kg/plot, respectively.

The derived average AGB data of dense and moderate dry evergreen forest in the study are similar with the previous study of Terakunpisut (2003) who found average AGB data of dry evergreen forest was about 5,624 kg. In contrast, they are rather low when they compare with the previous study of Diloksumpun et al (2005) who found that average AGB data of dry evergreen forest in Sakaerat Environmental Research Station was about 13,072 kg. Likewise, Kantirach (2002) who found that average AGB data of dry evergreen forest in Huai Tuptun-Huai Samran Wildlife Sanctuary was about 10,700 kg. While Nuanurai (2005) who found that average AGB data of dry evergreen forest in Kaeng Krachan National Park was about 8,308 kg., respectively.

The derived average AGB data of mixed deciduous forest in the study area is higher than the previous study of Nuanurai (2005) who found that average AGB data of mixed deciduous forest in Kaeng Krachan National Park was 2,741 kg. Meanwhile, it is rather low when it compares with the previous study of Kantirach (2002) who found that average AGB data of mixed deciduous forest in Huai Tuptun-Huai Samran Wildlife Sanctuary was about 7,488 kg.

The derived average AGB data of *Eucalyptus camaldulensis* plantation in the study is lower than the previous study of Trephattanasuwan et al. (2010) who found that average AGB data of *Eucalyptus camaldulensis* plantation in the Pu Parn Royal Development Study Centre was about 3,289 kg.

The AGB at plot level (20 x 20 m) are further proportional converted by area at pixel level (30x30) for regression analysis. The distribution of modeling and validation datasets of each forest type and plantation is displayed in Figure 5.5.

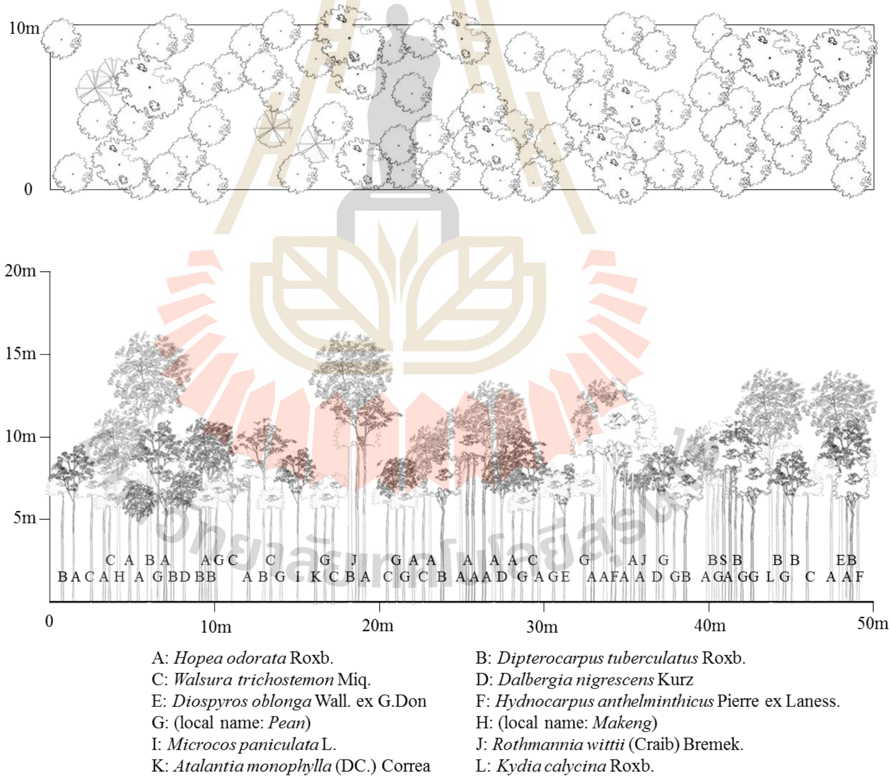


Figure 5.1 Plant profile of dense dry evergreen forest.

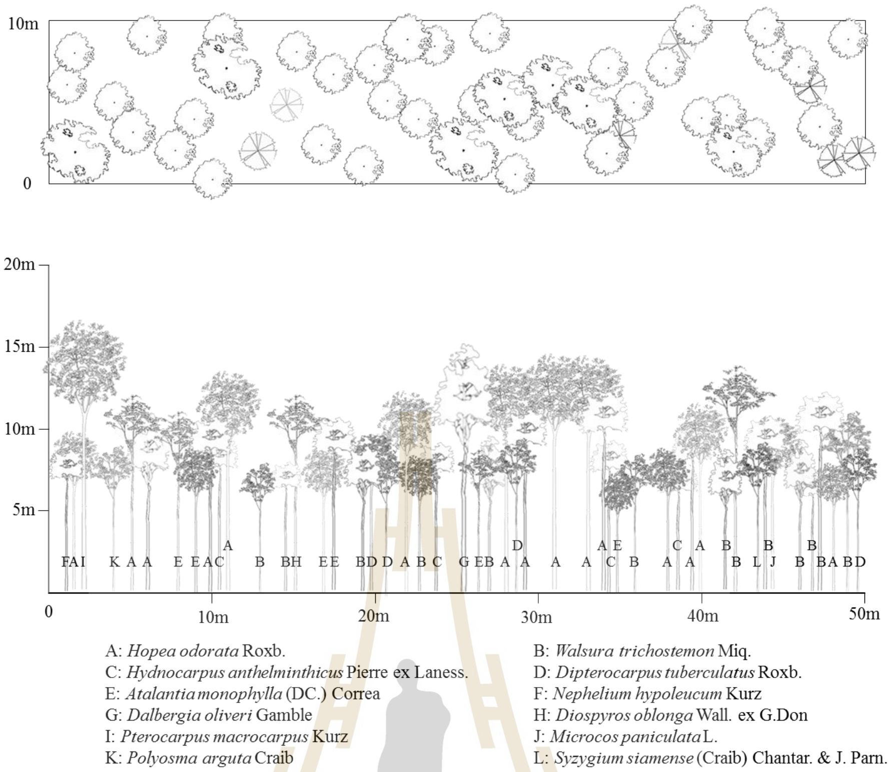


Figure 5.2 Plant profile of moderate dry evergreen forest.

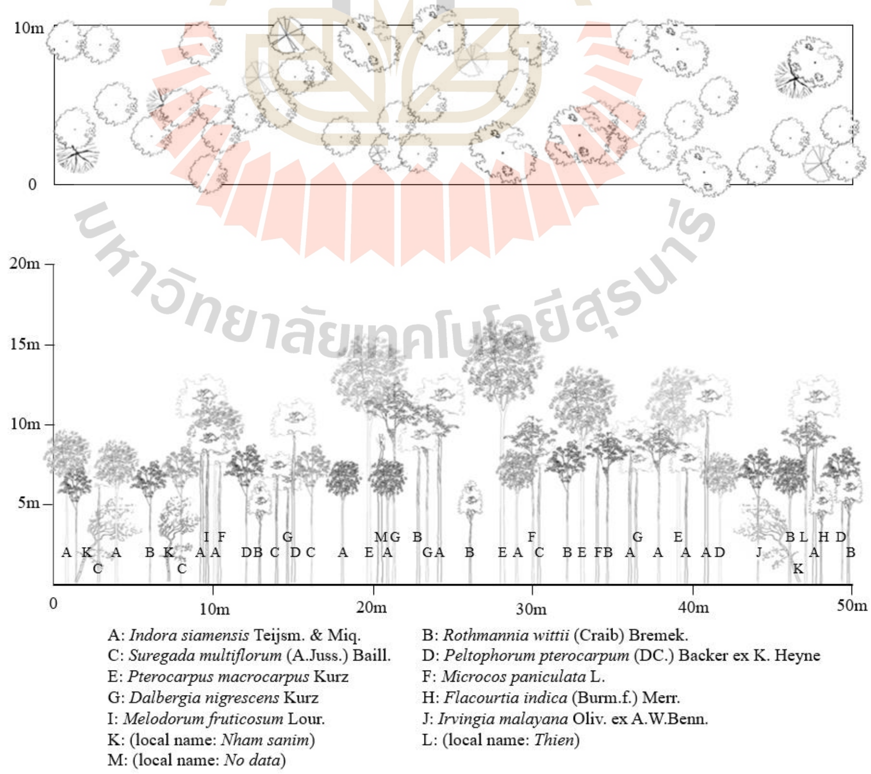


Figure 5.3 Plant profile of mixed deciduous forest.

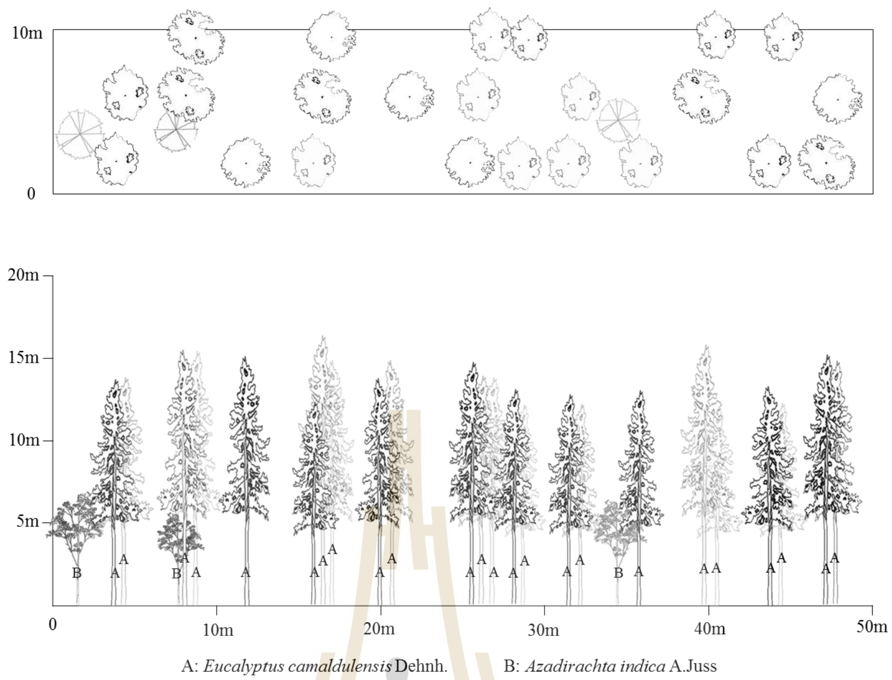


Figure 5.4 Plant profile of forest plantation.

Table 5.1 In situ AGB data of natural forest and forest plantation.

Plot No.	Natural forest and forest plantation	Above ground biomass (kg/sq. m)	
		At sample plot (20 x 20 m)	At pixel size (30x30m)
1*	Dense dry evergreen forest	6,016.29	13,536.66
2	Dense dry evergreen forest	4,956.92	11,153.08
3	Dense dry evergreen forest	5,555.26	12,499.34
4	Dense dry evergreen forest	4,498.52	10,121.67
5	Dense dry evergreen forest	4,455.58	10,025.05
6	Dense dry evergreen forest	6,066.11	13,648.75
7	Dense dry evergreen forest	5,280.60	11,881.35
8*	Dense dry evergreen forest	5,018.11	11,290.74
	Minimum value	**4,455.58**	**10,025.05**
	Maximum value	**6,066.11**	**13,648.75**
	Average	**5,230.92**	**11,769.58**
	Standard deviation	**618.75**	**1,392.18**

Table 5.1 In situ AGB data of natural forest and forest plantation. (Continued).

No	Natural forest and forest plantation	Above ground biomass (kg/sq. m)	
		At sample plot (20 x 20 m)	At pixel size (30x30m)
1*	Moderate dry evergreen forest	4,967.38	11,176.61
2	Moderate dry evergreen forest	4,717.76	10,614.95
3	Moderate dry evergreen forest	4,806.77	10,815.24
4	Moderate dry evergreen forest	4,556.24	10,251.55
5	Moderate dry evergreen forest	4,676.27	10,521.60
6	Moderate dry evergreen forest	4,546.43	10,229.46
7	Moderate dry evergreen forest	5,555.31	12,499.44
8*	Moderate dry evergreen forest	3,697.52	8,319.42
	Minimum value	**3,697.52**	**8,319.42**
	Maximum value	**5,555.31**	**12,499.44**
	Average	**4,690.46**	**10,553.53**
	Standard deviation	**516.00**	**1,161.01**
1*	Mixed deciduous forest	3,065.59	6,897.58
2	Mixed deciduous forest	2,993.98	6,736.45
3	Mixed deciduous forest	2,574.90	5,793.51
4	Mixed deciduous forest	3,560.20	8,010.46
5	Mixed deciduous forest	2,694.90	6,063.51
6	Mixed deciduous forest	3,883.78	8,738.50
7	Mixed deciduous forest	3,099.30	6,973.43
8*	Mixed deciduous forest	3,537.79	7,960.03
	Minimum value	**2,574.90**	**5,793.51**
	Maximum value	**3,883.78**	**8,738.50**
	Average	**3,176.31**	**7,146.68**
	Standard deviation	**450.94**	**1,014.62**
1*	Forest plantation	2,717.33	6,114.00
2	Forest plantation	2,359.32	5,308.48
3	Forest plantation	2,756.29	6,201.66
4	Forest plantation	2,107.30	4,741.41
5	Forest plantation	2,683.17	6,037.14
6	Forest plantation	3,429.04	7,715.34
7	Forest plantation	2,827.63	6,362.17
8*	Forest plantation*	3,046.15	6,853.84
	Minimum value	**2,107.30**	**4,741.41**
	Maximum value	**3,429.04**	**7,715.34**
	Average	**2,740.78**	**6,166.76**
	Standard deviation	**400.97**	**902.17**

Note: * Sample plots that are applied for model validation using NRMSE.

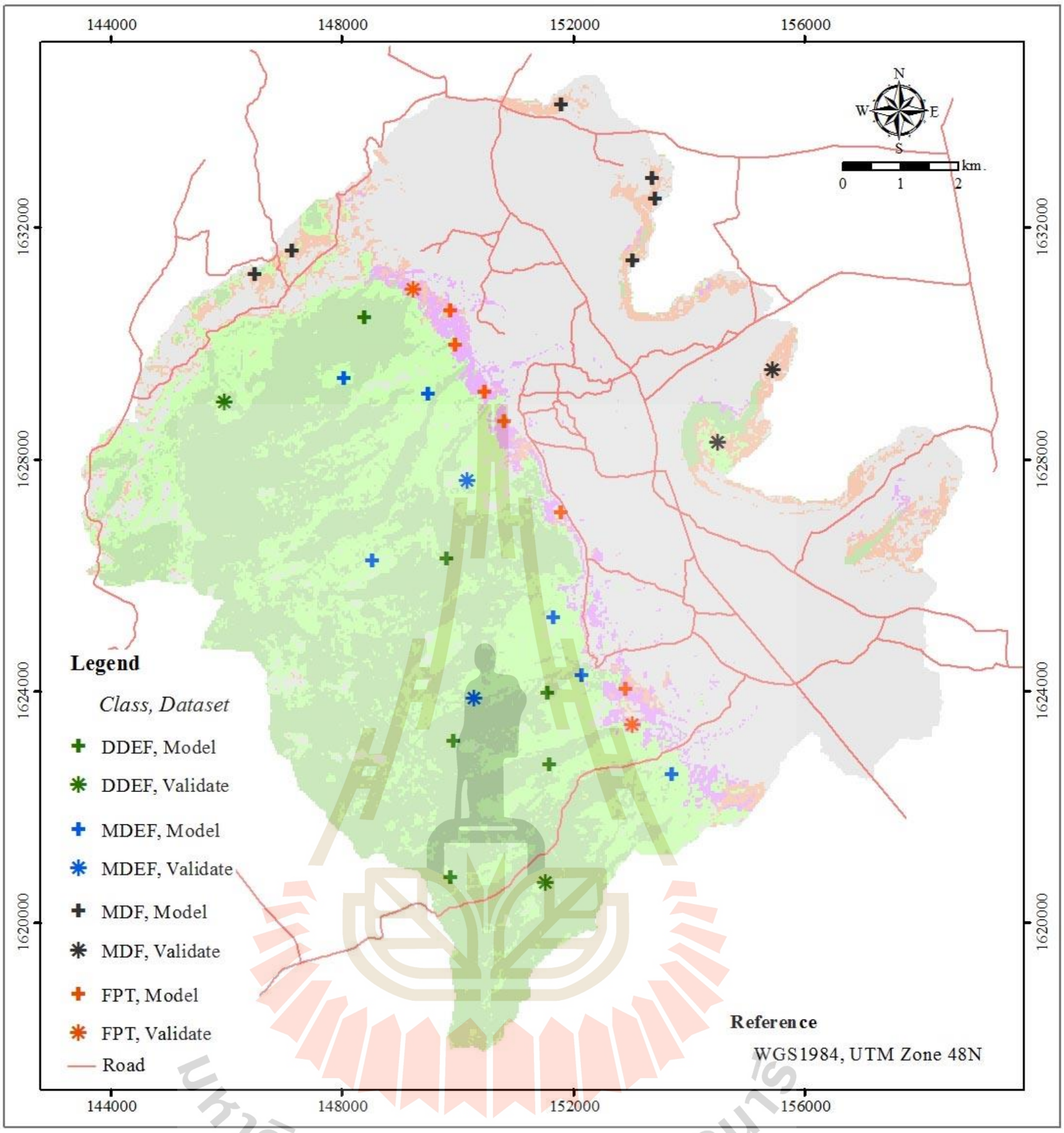


Figure 5.5 Distribution of modeling and validation datasets of each forest type and forest plantation for an optimum AGB estimation development.

5.2 Influential factors on above ground biomass

In the study, the selected influential factors on AGB include reflectance value of Landsat data (BLUE, GREEN, RED, NIR, SWIR-1 and SWIR-2) and vegetation indices (SR, NDVI, SAVI, RSR and GREENNESS) and Forest Canopy Density (FCD). See example of influential factor map in Chapter III. These factors as independent variables of regression analysis are here directly extracted from each factor map in each location of sampling plots. Independent variables and its value for each sampling plot of each forest type and plantation are summarized in Tables 5.2 to 5.5. These data is further applied to identify relationship with AGB data using linear and non-linear regression analysis.

Table 5.2 Independent variables of dense dry evergreen forest.

No	Independent Variables	Samples number							
		1*	2	3	4	5	6	7	8*
1	BLUE	14.661	14.405	14.34	14.207	14.345	14.135	14.468	14.147
2	GREEN	11.927	11.579	11.519	11.333	11.377	11.423	11.701	11.228
3	RED	9.385	9.171	8.924	9.024	8.896	8.796	9.411	8.705
4	NIR	29.281	24.557	27.082	24.597	23.954	28.864	26.341	26.572
5	SWIR-1	15.57	12.446	11.894	14.03	11.477	14.817	14.715	13.459
6	SWIR-2	6.587	5.357	4.624	6.233	4.624	6.014	6.203	5.269
7	SR	3.119	2.677	3.034	2.725	2.692	3.281	2.799	3.052
8	NDVI	0.514	0.456	0.504	0.463	0.458	0.532	0.473	0.506
9	SAVI	0.336	0.275	0.316	0.279	0.272	0.343	0.296	0.314
10	RSR	2.441	2.235	2.561	2.203	2.291	2.609	2.23	2.496
11	GREENNESS	0.09	0.058	0.079	0.06	0.056	0.093	0.07	0.078
12	FCD	81.011	77.019	83.704	77.011	79.26	85.316	75.896	83.142

Note * Validation dataset.

Table 5.3 Independent variables of moderate dry evergreen forest.

No	Independent Variables	Samples number							
		1*	**2**	**3**	**4**	**5**	**6**	**7**	**8***
1	BLUE	14.296	14.582	14.463	14.557	14.559	14.41	14.519	14.615
2	GREEN	11.561	11.766	11.985	11.831	11.787	11.859	11.943	11.943
3	RED	9.036	9.686	9.762	9.727	9.546	9.788	9.525	9.821
4	NIR	28.641	24.974	28	24.923	26.644	26.314	28.897	26.011
5	SWIR-1	16.196	16.716	19.183	16.662	16.078	17.238	16.509	17.757
6	SWIR-2	7.158	8.018	9.35	7.95	7.163	8.011	7.172	8.77
7	SR	3.169	2.578	2.868	2.562	2.791	2.688	3.033	2.648
8	NDVI	0.52	0.441	0.482	0.438	0.472	0.457	0.504	0.451
9	SAVI	0.335	0.27	0.311	0.269	0.297	0.287	0.328	0.282
10	RSR	2.447	1.968	2.072	1.958	2.16	2.029	2.327	1.976
11	GREENNESS	0.089	0.056	0.077	0.056	0.07	0.066	0.087	0.062
12	FCD	82.44	74.195	75.23	70.751	75.721	72.854	79.73	72.014

Note * Validation dataset.

Table 5.4 Independent variables of mixed deciduous forest.

No	Independent Variables	Samples number							
		1*	**2**	**3**	**4**	**5**	**6**	**7**	**8***
1	BLUE	14.906	15.099	15.029	15.183	15.218	15.097	15.332	15.067
2	GREEN	12.309	12.462	12.705	12.914	12.84	12.8	12.993	12.604
3	RED	10.99	11.011	11.328	11.535	11.593	11.447	11.947	11.244
4	NIR	23.069	23.686	23.651	25.174	24.776	25.344	25.4	23.977
5	SWIR-1	17.804	20.618	18.829	18.687	22.267	20.182	22.975	19.763
6	SWIR-2	10.459	11.489	11.272	10.75	12.544	11.766	12.639	11.353
7	SR	2.098	2.151	2.087	2.182	2.137	2.214	2.125	2.132
8	NDVI	0.354	0.365	0.352	0.371	0.362	0.377	0.36	0.361
9	SAVI	0.215	0.224	0.217	0.235	0.228	0.24	0.231	0.224
10	RSR	1.564	1.502	1.52	1.594	1.434	1.562	1.401	1.519
11	GREENNESS	0.03	0.034	0.03	0.04	0.037	0.042	0.039	0.034
12	FCD	58.766	57.73	57.79	60.376	57.56	60.425	56.611	58.728

Note * Validation dataset.

Table 5.5 Independent variables of forest plantation.

No	Independent Variables	Samples number							
		1	2	3	4	5	6	7	8
1	BLUE	14.897	14.682	14.927	14.829	14.752	14.806	14.766	14.619
2	GREEN	12.204	12.111	12.239	12.22	12.059	12.222	12.038	12.104
3	RED	10.382	10.643	10.452	10.687	10.361	10.629	10.482	10.62
4	NIR	23.059	23.371	22.353	23.176	22.593	24.459	23.409	25.349
5	SWIR-1	17.934	19.796	16.788	19.162	17.571	21.263	17.843	21.151
6	SWIR-2	9.273	10.925	8.486	10.226	9.304	11.593	9.418	11.13
7	SR	2.221	2.195	2.138	2.168	2.18	2.301	2.233	2.386
8	NDVI	0.379	0.374	0.362	0.368	0.371	0.394	0.381	0.409
9	SAVI	0.227	0.227	0.215	0.223	0.221	0.243	0.231	0.256
10	RSR	1.65	1.564	1.63	1.567	1.633	1.582	1.663	1.646
11	GREENNESS	0.035	0.036	0.03	0.034	0.033	0.043	0.038	0.051
12	FCD	62.117	59.801	59.899	59.755	61.242	63.846	62.686	64.232

Note * Validation dataset.

5.3 AGB estimation model development for forest type and plantation

Data input for linear regression analysis include dependent and independent variables as mentioned in Sections 5.1 and 5.2 are here applied to develop AGB estimation model for each forest type and plantation using linear and non-linear regression analysis under SPSS software. The derived equations from both analyses which provide the highest coefficient of determination (R^2) is chosen as the best candidate equation for identifying an optimum AGB estimation model using NRMSE value.

Furthermore, all dependent and independents variable are aggregated to develop AGB estimation model for forest area using linear and non-linear regression analysis again. This approach can provide more number of samples for modeling and validation dataset more than the previous approach which has number samples for modeling and validating only 6 and 2 for each forest type and plantation due to the limitation of accessibility in the study area and expenditure.

5.3.1 Linear regression analysis of forest type and plantation AGB model

Simple linear and multiple linear regression analysis were here applied to identify the best candidate equation to compare with non-linear regression analysis using NRMSE value.

(1) Candidate equations of simple linear regression analysis

All equations of simple linear regression analysis of forest type and plantation that provide R^2 equal or greater than 0.5 and its NRMSE is presented in Table 5.6. It was found that most of selected vegetation indices include SR, NDVI, SAVI and GREENNESS except RSR show high positively correlation ($R^2 \geq 0.8$) with AGB of dense evergreen forest while FCD shows moderate positively correlation with AGB of dense evergreen forest with R^2 of 0.520. This is an unexpected result since dense dry evergreen forest has high canopy density as shown in Figure 5.1, where crown cover of trees is more than 80%. In contrast, FCD shows high correlation with moderate dry evergreen forest with R^2 of 0.806 and those vegetation indices show moderate correlation with R^2 between 0.644 and 0.747.

Similar to dense dry evergreen forest, SR, NDVI and SAVI show high correlation ($R^2 \geq 0.8$) with AGB of mixed deciduous forest while FCD shows moderate correlation with this forest type with R^2 of 0.643. This is not unexpected result because canopy of mixed deciduous forest in the study area that mostly locates on eroded hilly areas has moderate canopy density as shown in Figure 5.3 wherein crown cover of trees is less than 60%. Likewise, FCD shows moderate correlation with R^2 of 0.75 for forest plantation.

According to a result of simple linear regression analysis, the derived equation from NIR of Landsat data is chosen as the best candidate equation to compare with the best candidate equation of non-linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.941 and provides the highest accuracy for AGB estimation with NRMSE of 0.2449.

For moderate dry evergreen forest, the derived equation from FCD data is chosen as the best candidate equation to compare with the best candidate equation of non-linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.806 and it provides moderate accuracy for AGB estimation with NRMSE of 0.5963. Although NIR equation provides the highest accuracy for AGB estimation with NRMSE of 0.5689 but NIR model shows the moderate correlation with AGB with R^2 of 0.605. The efficiency of NIR model is rather low when it compares with FCD model and accuracy of both models are not much different.

Similar to moderate dry evergreen forest, for mixed deciduous forest, the derived equation from NDVI of Landsat data is chosen as the best candidate equation of linear regression analysis to compare with the best candidate equation of non-linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.852 and it provides the moderate accuracy for AGB estimation with NRMSE of 1.0853. Although FCD equation provides the highest accuracy for AGB estimation with NRMSE of 0.5400 but it shows the moderate correlation with AGB with R^2 of 0.643. The efficiency of the FCD model is rather low when it compares with NDVI model.

For forest plantation, the derived equation from FCD is chosen as the best candidate equation to compare with the best candidate equation of non-linear regression analysis for identify an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.941 and it provides the highest accuracy for AGB estimation with NRMSE of 0.8143.

(2) Candidate equations of multiple linear regression analysis

According to multiple linear regression analysis with available five methods include (1) Enter, (2) Stepwise, (3) Remove, (4) Backward and (5) Forward under SPSS software, it was found that only stepwise method can perform analysis and create equations same as the result of simple linear regression analysis.

For dense dry evergreen forest, Stepwise method uses NIR as independent variable to create equation same as simple linear regression analysis. Likewise, moderate dry evergreen forest, it applies RSR to create equations same as simple linear regression analysis. In addition, there is no derived multiple linear equation for mixed deciduous forest and forest plantation. Therefore, there is no the best candidate equation to compare with the best candidate equation of non-linear regression analysis for identify an optimum equation for AGB estimation model.

Table 5.6 List of candidate equations of simple linear regression analysis.

Independent	variable	Equation	R^2	NRMSE
Dense dry evergreen forest	NIR	-7285.594 + (727.455 * X)	0.941	0.2449
	SR	-3731.979 + (5330.144 * X)	0.831	0.4814
	NDVI	-8719.484 + (42150.430 * X)	0.835	0.4905
	SAVI	-2624.756 + (47769.664 * X)	0.898	0.3620
	RSR	-3499.325 + (6392.893 * X)	0.675	0.6141
	GREENNESS	5118.237 + (92836.092 * X)	0.908	0.3597
	FCD	-9139.415 + (259.649 * X)	0.520	0.6320
Moderate dry evergreen forest	NIR	-212.200 + (414.426 * X)	0.605	0.5689
	SR	83.381 + (3900.239 * X)	0.690	0.6059
	NDVI	-1928.566 + (27381.400 * X)	0.667	0.5968
	SAVI	2197.222 + (29369.411 * X)	0.644	0.5827
	RSR	-180.864 + (5275.485 * X)	0.747	0.6127
	GREENNESS	6925.715 + (56742.597 * X)	0.653	0.5702
	FCD	-8050.142 + (252.482 * X)	0.806	0.5963
Mixed deciduous forest	SR	-43496.199 + (23518.382 * X)	0.850	1.1067
	NDVI	-36619.832 + (119814.747 * X)	0.852	1.0853
	SAVI	-21910.688 + (126385.447 * X)	0.822	1.4654
	GREENNESS	-1005.176 + (217778.896 * X)	0.708	1.3078
	FCD	-26247.727 + (570.048 * X)	0.643	0.5400
Forest plantation	SR	-22528.979 + (12980.710 * X)	0.541	1.5408
	NDVI	-18560.810 + (65658.250 * X)	0.528	1.4218
	FCD	-25057.352 + (508.430 * X)	0.750	0.8143

5.3.2 Non-linear regression analysis of forest type and plantation AGB model

In this study, frequently used non-linear equations for biomass studies are here selected include:

(1) Logarithmic model $Y = \beta_0 + (\beta_1 * ln(X))$ (5.1)

(2) Power model $Y = \beta_0 * X^{\beta}{}_1$ (5.2)

(3) S curve model $Y = exp(\beta_0 + (\beta_1/X))$ (5.3)

(4) Exponential model $Y = \beta_0 * exp(\beta_1 * X)$ (5.4)

Where *Y* and *X* is dependent and independent variable, respectively.

Similar to linear regression analysis, equations of non-linear regression analysis of forest type and plantation that provide R^2 equal or greater than 0.5 and its NRMSE value were extracted to identify the best candidate equation of non-linear regression analysis to compare with the best candidate equation of linear equation for an optimum equation for AGB estimation model. The derived equations of non-linear regression of forest type and plantation is separately summarized as shown in Tables 5.7 to 5.10. It was found that influence degree of independent variables on AGB in each forest type and plantation are similar with simple linear analysis. The R^2 value of four different models of simple non-linear equation of each variable are very slight different.

As a result, for dense dry evergreen forest, the derived NIR equation of Landsat data from the Logarithmic model is chosen as the best candidate equation to compare with the best candidate equation of linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.942 and NRMSE of 0.2549. Even though Power model of NIR provides NRMSE of 0.2331 but it provides correlation with AGB with R^2 of 0.925 less than Logarithmic model of NIR.

For moderate dry evergreen forest, the derived FCD equation from the Logarithmic model is chosen as the best candidate equation to compare with the best candidate equation of linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.816 and it provides the highest accuracy with NRMSE of 0.5097.

For mixed deciduous forest, the derived NDVI equation from the Exponential model is chosen as the best candidate equation to compare with the best candidate equation of linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.850 and it provides the accuracy with NRMSE of 1.0940. Though Logarithmic model of FCD provides NRMSE of 0.5369 but it provides correlation with AGB with R^2 of 0.637 less than Exponential model of NDVI.

For forest plantation, the derived FCD equation from the Logarithmic model is chosen as the best candidate equation to compare with the best candidate equation of linear regression analysis for identifying an optimum equation for AGB estimation model. Because it shows the highest correlation with AGB with R^2 of 0.748 and it provides the highest accuracy with NRMSE of 0.8039.

Table 5.7 Candidate equations of dense dry evergreen forest.

Independent	Model	Equation	R^2	NRMSE
NIR	Logarithm.	-50643.25 + (19125.773 * Ln(X))	0.942	0.2549
	Power	56.949 * (Power(X,1.632))	0.928	0.2444
	S curve	Exp(11.008 + (-42.788 / X))	0.930	0.2495
	Exponential.	2305.441 * Exp(0.062 * X)	0.925	0.2331
SR	Logarithm.	-5060.736 + (15812.487 * Ln(X))	0.835	0.4860
	Power	2828.878 * (Power(X,1.333))	0.804	0.4796
	S curve	Exp(10.731 + (-3.942 / X))	0.807	0.4846
	Exponential.	3167.535 * Exp(0.449 * X)	0.799	0.4761
NDVI	Logarithm.	26779.023 + (20754.887 * Ln(X))	0.837	0.4946
	Power	41513.418 * (Power(X,1.752))	0.807	0.4875
	S curve	Exp(11.145 + (-0.861 / X))	0.809	0.4923
	Exponential.	2076.372 * Exp(3.556 * X)	0.805	0.4839
SAVI	Logarithm	29341.204 + (14601.072 * Ln(X))	0.902	0.3770
	Power	51940.093 * (Power(X,1.239))	0.879	0.3580
	S curve	Exp(10.627 + (-0.377 / X))	0.884	0.3718
	Exponential.	3453.1 * Exp(4.048 * X)	0.873	0.3425
RSR	Logarithm	-1513.061 + (15300.788 * Ln(X))	0.669	0.6094
	Power	3817.127 * (Power(X,1.29))	0.644	0.6165
	S curve	Exp(10.663 + (-3.08 / X))	0.638	0.6117
	Exponential	3228.816 * Exp(0.539 * X)	0.649	0.6215
GREENNESS	Logarithm	29646.177 + (6735.47 * Ln(X))	0.913	0.3909
	Power	53521.117 * (Power(X,0.573))	0.894	0.3733
	S curve	Exp(9.953 + (-0.041 / X))	0.895	0.386
	Exponential	6651.205 * Exp(7.877 * X)	0.885	0.3400
FCD	Logarithm	-79038.281 + (20696.168 * Ln(X))	0.509	0.6282
	Power	6.100 * (Power(X, 1.723))	0.477	0.6341
	S curve	Exp(11.071 + (-137.033 / X))	0.466	0.6319
	Exponential	2049.670 * Exp(0.022 * X)	0.488	0.6307

Table 5.8 Candidate equations of moderate dry evergreen forest.

Independent	Model	Equation	R^2	NMRSE
NIR	Logarithm	-25003.658 + (10921.229 * Ln(X))	0.587	0.5717
	Power	455.615 * (Power(X,0.965))	0.593	0.5678
	S curve	Exp(10.242 + (-25.366 / X))	0.575	0.5682
	Exponential	4073.227 * Exp(0.037 * X)	0.612	0.5975
SR	Logarithm	45.16 + (10659.331 * Ln(X))	0.668	0.5961
	Power	4168.82 * (Power(X,0.941))	0.674	0.5957
	S curve	Exp(10.222 + (-2.564 / X))	0.651	0.5891
	Exponential	4184.192 * Exp(0.344 * X)	0.696	0.6049
NDVI	Logarithm	20503.893 + (12647.516 * Ln(X))	0.649	0.5908
	Power	25389.019 * (Power(X,1.117))	0.655	0.5899
	S curve	Exp(10.395 + (-0.515 / X))	0.636	0.5819
	Exponential	3501.834 * Exp(2.418 * X)	0.674	0.5970
SAVI	Logarithm	21267.764 + (8507.009 * Ln(X))	0.617	0.5810
	Power	27163.847 * (Power(X,0.751))	0.623	0.5791
	S curve	Exp(10.029 + (-0.217 / X))	0.597	0.5737
	Exponential	5040.652 * Exp(2.594 * X)	0.650	0.5799
RSR	Logarithm	2666.063 + (11122.578 * Ln(X))	0.730	0.5957
	Power	5274.603 * (Power(X,0.977))	0.728	0.6032
	S curve	Exp(10.275 + (-2.052 / X))	0.710	0.5885
	Exponential	4108.939 * Exp(0.463 * X)	0.746	0.6201
GREENNESS	Logarithm	20875.976 + (3735.68 * Ln(X))	0.591	0.5698
	Power	26216.868 * (Power(X,0.33))	0.595	0.5628
	S curve	Exp(9.604 + (-0.021 / X))	0.533	0.5790
	Exponential	7656.345 * Exp(5.004 * X)	0.658	0.5671
FCD	Logarithm	-70320.148 + (18811.536 * Ln(X))	0.791	0.5828
	Power	8.226 * (Power(X,1.664))	0.801	0.5862
	S curve	Exp(10.946 + (-123.811 / X))	0.786	0.5820
	Exponential	2034.169 * Exp(0.022 * X)	0.816	0.5097

Table 5.9 Candidate equations of mixed deciduous forest.

Independent	Model	Equation	R^2	NRMSE
SR	Logarithm	-31572.484 + (50491.705 * Ln(X))	0.847	1.1041
	Power	32.217 * (Power(X,7.03))	0.843	1.1137
	S curve	Exp(15.876 + (-15.095 / X))	0.840	1.1107
	Exponential	6.147 * Exp(3.273 * X)	0.845	1.1136
NDVI	Logarithm	51039.581 + (43574.378 * Ln(X))	0.848	1.0816
	Power	3221176.492 * (Power(X,6.077))	0.846	1.0908
	S curve	Exp(14.917 + (-2.21 / X))	0.843	1.0855
	Exponential	15.857 * Exp(16.7 * X)	0.850	1.0940
SAVI	Logarithm	49361.233 + (28706.494 * Ln(X))	0.814	1.4697
	Power	2611443.3 * (Power(X,4.02))	0.819	1.4124
	S curve	Exp(12.838 + (-0.913 / X))	0.812	1.4193
	Exponential	121.298 * Exp(17.683 * X)	0.826	1.4100
GREENNESS	Logarithm	32100.965 + (7583.528 * Ln(X))	0.678	1.2811
	Power	240251.942 * (Power(X,1.071))	0.695	1.2611
	S curve	Exp(9.862 + (-0.037 / X))	0.667	1.2497
	Exponential	2242.658 * Exp(30.681 * X)	0.722	1.2929
FCD	Logarithm	-128472.404 + (33320.677 * Ln(X))	0.637	0.5369
	Power	7.328E-05 * (Power(X,4.517))	0.601	0.5652
	S curve	Exp(13.369 + (-263.793 / X))	0.594	0.5621
	Exponential	76.305 * Exp(0.077 * X)	0.607	0.6317

Table 5.10 Candidate equations of forest plantation.

Independent	Model	Equation	R^2	NRMSE
SR	Logarithm	-16537.502 + (28630.672 * Ln(X))	0.533	1.4622
	Power	R^2 value is less than 0.5.		
	S curve	R^2 value is less than 0.5.		
	Exponential	R^2 value is less than 0.5.		
NDVI	Logarithm	30216.601 + (24618.409 * Ln(X))	0.519	1.3384
	Power	R^2 value is less than 0.5.		
	S curve	R^2 value is less than 0.5.		
	Exponential	R^2 value is less than 0.5.		
FCD	Logarithm	-122691.980 + (31297.094 * Ln(X))	0.748	0.8039
	Power	6.132E-06 * (Power(X, 5.032))	0.721	0.8429
	S curve	Exp(13.763 + (-309.791 / X))	0.720	0.8195
	Exponential	40.369 * Exp(0.082 * X)	0.722	1.0294

5.3.3 Optimum AGB estimation model for forest type and plantation

Using efficiency of simple linear and non-linear model (R^2) and its accuracy (NRMSE), an optimum model for AGB estimation for natural forest and forest plantation are justified as summary in Table 5.11. The optimum model is further used to estimate AGB and carbon stock data between 1995 and 2035.

Table 5.11 An optimum model for AGB estimation of forest type and plantation.

Natural forest /Plantation	Model	Equation	Independent variable	R^2	NRMSE
Dense dry evergreen forest	Linear model	Y= -7285.594 + (727.455 * X)	NIR	0.94	0.2449
Moderate Dry evergreen forest	Non-linear model (Exponential)	Y =2034.169 * Exp(0.022 * X)	FCD	0.82	0.5097
Mixed deciduous forest	Linear model	Y = -36619.832 + (119814.747 * X)	NDVI	0.85	1.0853
Forest plantation	Non-linear model (Logarithm)	Y= -122691.980 + (31297.094 * Ln(X))	FCD	0.75	0.8039

5.4 AGB estimation model development for forest area

As mentioned earlier in Section 5.3 due to the limitation of accessibility in the study area and cost of forest inventory, numbers of sampling plots apply for each forest type and plantation is rather low, so sampling plots from each forest type and plantation are combined for forest AGB estimation model development again. Table 5.12 summarized dependent and independent variables for forest AGB estimation model development using linear and non-linear regression analysis.

5.4.1 Linear regression analysis of forest AGB model

Simple linear and multiple linear regression analysis were here applied to identify the best candidate equation to compare with non-linear regression analysis using NRMSE value.

(1) Candidate equations of simple linear regression analysis

All equations of simple linear regression analysis of forest area that provide R^2 equal or greater than 0.5 and its NRMSE is presented in Table 5.13. It was found that 10 of 12 independent variables influencing AGB including BLUE, RED, NIR, SWIR-2, SR, NDVI, SAVI, RSR, GREENNESS and FCD provide R^2 equal or greater than 0.5. The R^2 value varies between 0.550 (BLUE) and 0.902 (SAVI) and NRMSE varies between 0.1552 (RSR) and 0.2660 (BLUE). As a result, simple linear equation of SAVI is chosen as the best candidate equation to consider as optimum forest AGB estimation model by comparing NRMSE with the best candidate equation of multiple linear and simple non-linear equations. Because it shows the highest correlation with AGB and provides the high accuracy for AGB estimation with NRMSE of 0.1971.

Table 5.12 Dependent and independent variables for forest AGB estimation model development.

No	FT/FPT	AGB	BLUE	GREEN	RED	NIR	SWIR1	SWIR2	SR	NDVI	SAVI	RSR	GREENNESS	FCD
1*	DDEF	13,536.66	14.661	11.927	9.385	29.281	15.57	6.587	3.119	0.514	0.336	2.441	0.09	81.011
2	DDEF	11,153.08	14.405	11.579	9.171	24.557	12.446	5.357	2.677	0.456	0.275	2.235	0.058	77.019
3	DDEF	12,499.34	14.34	11.519	8.924	27.082	11.894	4.624	3.034	0.504	0.316	2.561	0.079	83.704
4	DDEF	10,121.67	14.207	11.333	9.024	24.597	14.03	6.233	2.725	0.463	0.279	2.203	0.06	77.011
5	DDEF	10,025.05	14.345	11.377	8.896	23.954	11.477	4.624	2.692	0.458	0.272	2.291	0.056	79.26
6	DDEF	13,648.75	14.135	11.423	8.796	28.864	14.817	6.014	3.281	0.532	0.343	2.609	0.093	85.316
7	DDEF	11,881.35	14.468	11.701	9.411	26.341	14.715	6.203	2.799	0.473	0.296	2.23	0.07	75.896
8*	DDEF	11,290.74	14.147	11.228	8.705	26.572	13.459	5.269	3.052	0.506	0.314	2.496	0.078	83.142
9*	MDEF	11,176.61	14.296	11.561	9.036	28.641	16.196	7.158	3.169	0.52	0.335	2.447	0.089	82.44
10	MDEF	10,614.95	14.582	11.766	9.686	24.974	16.716	8.018	2.578	0.441	0.27	1.968	0.056	74.195
11	MDEF	10,815.24	14.463	11.985	9.762	28	19.183	9.35	2.868	0.482	0.311	2.072	0.077	75.23
12	MDEF	10,251.55	14.557	11.831	9.727	24.923	16.662	7.95	2.562	0.438	0.269	1.958	0.056	70.751
13	MDEF	10,521.60	14.559	11.787	9.546	26.644	16.078	7.163	2.791	0.472	0.297	2.16	0.07	75.721
14	MDEF	10,229.46	14.41	11.859	9.788	26.314	17.238	8.011	2.688	0.457	0.287	2.029	0.066	72.854
15	MDEF	12,499.44	14.519	11.943	9.525	28.897	16.509	7.172	3.033	0.504	0.328	2.327	0.087	79.73
16*	MDF	6,897.58	14.615	11.943	9.821	26.011	17.757	8.77	2.648	0.451	0.282	1.976	0.062	72.014
17*	MDF	6,897.58	14.906	12.309	10.99	23.069	17.804	10.459	2.098	0.354	0.215	1.564	0.03	58.766
18	MDF	6,736.45	15.099	12.462	11.011	23.686	20.618	11.489	2.151	0.365	0.224	1.502	0.034	57.73
19	MDF	5,793.51	15.029	12.705	11.328	23.651	18.829	11.272	2.087	0.352	0.217	1.52	0.03	57.79
20	MDF	8,010.46	15.183	12.914	11.535	25.174	18.687	10.75	2.182	0.371	0.235	1.594	0.04	60.376
21	MDF	6,063.51	15.218	12.84	11.593	24.776	22.267	12.544	2.137	0.362	0.228	1.434	0.037	57.56
22	MDF	8,738.50	15.097	12.8	11.447	25.344	20.182	11.766	2.214	0.377	0.24	1.562	0.042	60.425
23	MDF	6,973.43	15.332	12.993	11.947	25.4	22.975	12.639	2.125	0.36	0.231	1.401	0.039	56.611
24*	MDF	7,960.03	15.067	12.604	11.244	23.977	19.763	11.353	2.132	0.361	0.224	1.519	0.034	58.728
25	FPT	6,114.00	14.897	12.204	10.382	23.059	17.934	9.273	2.221	0.379	0.227	1.65	0.035	62.117
26	FPT	5,308.48	14.682	12.111	10.643	23.371	19.796	10.925	2.195	0.374	0.227	1.564	0.036	59.801
27	FPT	6,201.66	14.927	12.239	10.452	22.353	16.788	8.486	2.138	0.362	0.215	1.63	0.03	59.899
28	FPT	4,741.41	14.829	12.22	10.687	23.176	19.162	10.226	2.168	0.368	0.223	1.567	0.034	59.755
29	FPT	6,037.14	14.752	12.059	10.361	22.593	17.571	9.304	2.18	0.371	0.221	1.633	0.033	61.242
30	FPT	7,715.34	14.806	12.222	10.629	24.459	21.263	11.593	2.301	0.394	0.243	1.582	0.043	63.846
31	FPT	6,362.17	14.766	12.038	10.482	23.409	17.843	9.418	2.233	0.381	0.231	1.663	0.038	62.686
32*	FPT	6,853.84	14.619	12.104	10.62	25.349	21.151	11.13	2.386	0.409	0.256	1.646	0.051	64.232

Note * Validation dataset.

Table 5.13 List of candidate equations of simple linear regression analysis for forest AGB estimation model development.

No	Variable	Equation	R^2	NRMSE
1	BULE	93969.583 + (-5790.384 * X)	0.550	0.2660
2	RED	30642.822 + (-2138.078 * X)	0.610	0.2117
3	NIR	-20747.988 + (1179.833 * X)	0.671	0.1679
4	SWIR-2	15861.869 + (-794.489 * X)	0.579	0.1973
5	SR	-8362.837 + (6912.743 * X)	0.889	0.1921
6	NDVI	-9580.002 + (43774.200 * X)	0.899	0.1957
7	SAVI	-7917.9063 + (64188.162 * X)	0.902	0.1971
8	RSR	-3279.685 + (6439.032 * X)	0.840	0.1552
9	GREENNESS	2047.781 + (129586.076 * X)	0.889	0.1965
10	FCD	-8793.799 + (257.840 * X)	0.867	0.1693

(2) Candidate equations of multiple linear regression analysis

Candidate equations of multiple linear regression analysis deriving from five available methods of SPSS software that provide R^2 equal or greater than 0.5 and its NRMSE is presented in Table 5.14. As a result, the derived equation from Backward method is chosen as the best candidate equation to consider as optimum forest AGB estimation model by comparing NRMSE with the best candidate equation of simple linear and non-linear equations. Because it provides the highest R^2 of 0.959 and the lowest NRMSE of 0.1919. The multiple linear equation includes eight influential factors on forest AGB: NIR, SWIR-1, BLUE, SWIR-2, RED, RSR, NDVI and SR. It reveals that NDVI shows the highest positively correlation with AGB. This finding is true because NDVI applies the inverse relationship between chlorophyll absorption of red radiant energy and increased reflectance of near-infrared energy for healthy plant canopies (Cohen, 1991). In contrast, RSR provides the highest negatively correlation with AGB. This correlation is unexpected result because RSR is similar with SR.

Table 5.14 List of candidate equations of multiple linear regression analysis for forest AGB estimation model development.

Method	Equation	R^2	NRMSE
ENTER	Y= -132141.204 + (4096.94 * X_1) + (453.71 * X_2) + (6653.216 * X_3) + (-3007.195 * X_4) + (-1365.825 * X_5) + (439.7 * X_6) + (27006.081 * X_7) + (195615.795 * X_8) + (-24650.527 * X_{10}) + (-4.15 * X_{12})	0.959	0.1928
STEPWISE	Y= -40411.411 + (274596.308 * X_9) + (-428084.024 * X_{11})	0.919	0.1961
BACKWARD	Y= -130984.984 + (4317.749 * X_1) + (6763.098 * X_3) + (-2939.615 * X_4) + (-1419.518 * X_5) + (457.167 * X_6) + (27641.683 * X_7) + (192522.941 * X_8) + (-25458.255 * X_{10})	0.959	0.1919

Note X_1: BLUE, X_2: GREEN, X_3: RED, X_4: NIR, X_5: SWIR-1, X_6: SWIR-2, X_7: SR, X_8: NDVI, X_9: SAVI, X_{10}: RSR, X_{11}: GREENNESS and X_{12}: FCD

5.4.2 Non-linear regression analysis of forest AGB model

All derived equations of non-linear regression of forest AGB that provide R^2 equal or greater than 0.5 is summarized in Tables 5.15. It was found that the derived equation from Algorithm model with SAVI provides the highest R^2 of 0.916 with NRMSE of 0.2021. Hence, it is chosen as the best candidate equation to consider as optimum forest AGB estimation model by comparing NRMSE with the best candidate equation of simple and multiple linear equations.

5.4.3 Optimum AGB estimation model for forest area

An optimum model of AGB estimation for forest area among three best candidate equations is the derived equation of multiple linear equation from Backward method as summary in Table 5.16. Because it can provide the highest efficiency with R^2 of 0.959 and deliver the highest accuracy with the lowest NRMSE of 0.1919. The optimum model is also used to estimate AGB and carbon stock data between 1995 and 2035.

Table 5.15 List of candidate equations of non-linear regression analysis for forest AGB estimation model development.

Independent	Model	Equation	R^2	NRMSE
Blue	Logarithm.	239064.748 + (-85657.892 * Ln(X))	0.554	0.2663
	Power	R^2 value is less than 0.5	-	-
	S curve	Exp(-0.669 + (142.705 / X))	0.507	0.2692
	Exponential.	R^2 value is less than 0.5	-	-
Red	Logarithm.	60238.162 + (-22174.587 * Ln(X))	0.627	0.2096
	Power	2930315.669 * (Power(X,-2.523))	0.580	0.2067
	S curve	Exp(6.478 + (25.932 / X))	0.593	0.2091
	Exponential.	100897.282 * Exp(-0.243 * X)	0.563	0.2063
NIR	Logarithm.	-88536.213 + (30245.257 * Ln(X))	0.676	0.1695
	Power	0.113 * (Power(X,3.484))	0.641	0.1728
	S curve	Exp(12.61 + (-89.03 / X))	0.648	0.1699
	Exponential.	283.22 * Exp(0.135 * X)	0.631	0.1762
SWIR-2	Logarithm.	22510.587 + (-6399.307 * Ln(X))	0.568	0.1985
	Power	40383.003 * (Power(X,-0.732))	0.531	0.2070
	S curve	R^2 value is less than 0.5	-	-
	Exponential.	18859.859 * Exp(-0.091 * X)	0.540	0.1994
SR	Logarithm.	-7142.625 + (17715.472 * Ln(X))	0.897	0.1938
	Power	1357.865 * (Power(X,2.027))	0.839	0.2061
	S curve	Exp(11.144 + (-5.132 / X))	0.849	0.1995
	Exponential.	1192.243 * Exp(0.787 * X)	0.823	0.2145
NDVI	Logarithm.	25152.313 + (18660.232 * Ln(X))	0.900	0.1994
	Power	55267.24 * (Power(X,2.148))	0.851	0.1994
	S curve	Exp(11.236 + (-0.908 / X))	0.855	0.1970
	Exponential.	1022.86 * Exp(5.019 * X)	0.844	0.2045
SAVI	Logarithm.	32283.451 + (17325.603 * Ln(X))	0.916	0.2021
	Power	125721.642 * (Power(X,1.995))	0.867	0.2137
	S curve	Exp(11.119 + (-0.531 / X))	0.884	0.2099
	Exponential.	1240.984 * Exp(7.349 * X)	0.844	0.2194
RSR	Logarithm.	1274.139 + (12320.074 * Ln(X))	0.837	0.1579
	Power	3557.436 * (Power(X,1.409))	0.783	0.1552
	S curve	Exp(10.489 + (-2.625 / X))	0.777	0.1531
	Exponential.	2126.39 * Exp(0.733 * X)	0.778	0.1607
GREENNESS	Logarithm.	30085.412 + (7058.968 * Ln(X))	0.916	0.2125
	Power	99074.426 * (Power(X,0.818))	0.878	0.2107
	S curve	Exp(9.911 + (-0.04 / X))	0.888	0.2142
	Exponential.	3889.411 * Exp(14.812 * X)	0.830	0.2183
FCD	Logarithm.	-65899.866 + (17727.126 * Ln(X))	0.864	0.1726
	Power	1.516 * (Power(X,2.046))	0.822	0.1679
	S curve	Exp(11.116 + (-139.3 / X))	0.821	0.1675
	Exponential.	1111.338 * Exp(0.03 * X)	0.820	0.1705

Table 5.16 Candidate equations for considering as an optimum model for forest AGB estimation.

Linear model	Variable	Equation	R^2	NRMSE
Simple linear	SAVI	-7917.9063 + (64188.162 * X)	0.902	0.1971
Multiple linear with backward method	Blue Red NIR SWIR-1 SWIR-2 SR NDVI RSR	$-130984.984 + (4317.749 * X_1) + (6763.098 * X_3) + (-2939.615 * X_4) + (-1419.518 * X_5) + (457.167 * X_6) + (27641.683 * X_7) + (192522.941 * X_8) + (-25458.255 * X_{10})$	0.959	0.1919
Non-linear with Logarithm model	SAVI	32283.451 + (17325.603 * Ln(X))	0.916	0.2021

CHAPTER VI

ESTIMATION OF ABOVE GROUND BIOMASS AND CARBON STOCK ASSESSMENT

Main results of this chapter include (1) AGB estimation and its change between 1995 and 2035 using an optimum AGB estimation model based on two approaches: forest type and plantation AGB models and forest AGB model and (2) assessment of carbon stock and its change between 1995 and 2035 are here explained and discussed.

6.1 Estimation of AGB using forest type and plantation AGB models

To estimate ABG of forest type and plantation between 1995 and 2015 as historical and recent information, the derived forest type and plantation AGB models were directly applied to estimate AGB of the classified forest type and plantation in 1995, 2000, 2005, 2010 and 2015 using Model Builder under ERDAS Imagine software. Meanwhile, to estimation of forest type and plantation AGB between 2020 and 2035 as future information, it firstly require to construct the relevant variables of optimum AGB estimation models with Trend Analysis function of MS Excel software and Data preparation function of ERDAS Imagine software and then use an optimum AGB estimation models to estimate AGB of the predicted forest type and plantation in 2020, 2025, 2030 and 2035.

6.1.1 AGB estimation between 1995 and 2015

Results of AGB estimation between 1995 and 2015 as historical and recent information based on optimum AGB estimate model of each forest type and plantation is summarized in Table 6.1 while temporal change of AGB in each forest type and plantation and its total AGB in this period is demonstrated in Figures 6.1 and 6.2, respectively. The distribution of AGB in 1995, 2000, 2005, 2010 as historical year and in 2015 as recent year is displayed in Figures 6.3 to 6.4 and summary of basic statistical value of AGB at pixel level between 1995 and 2015 of each forest type and forest plantation is reported in Tables 6.2 to 6.5.

Table 6.1 Estimation of AGB of forest type and plantation between 1995 and 2015 using forest type and plantation AGB models.

Year	Forest type and plantation	AGB (ton)
1995	Dense Dry evergreen forest	539,976.12
	Moderate Dry evergreen forest	166,677.52
	Mixed deciduous forest	73,611.75
	Forest plantation	18,823.53
	Total	799,088.93
2000	Dense Dry evergreen forest	545,449.95
	Moderate Dry evergreen forest	222,906.49
	Mixed deciduous forest	53,686.80
	Forest plantation	20,310.16
	Total	842,353.40
2005	Dense Dry evergreen forest	519,876.84
	Moderate Dry evergreen forest	250,958.08
	Mixed deciduous forest	83,193.18
	Forest plantation	26,450.15
	Total	880,478.25
2010	Dense Dry evergreen forest	586,691.14
	Moderate Dry evergreen forest	293,619.32
	Mixed deciduous forest	57,589.72
	Forest plantation	23,626.05
	Total	961,526.24
2015	Dense Dry evergreen forest	597,813.58
	Moderate Dry evergreen forest	306,006.47
	Mixed deciduous forest	29,067.29
	Forest plantation	24,390.79
	Total	957,278.13

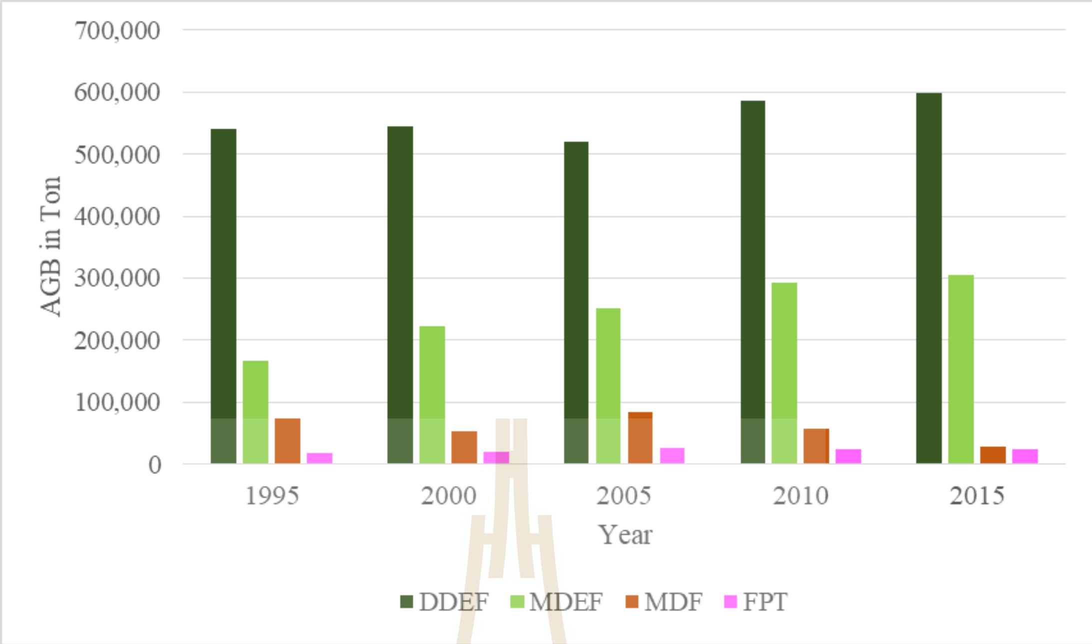


Figure 6.1 Temporal change of AGB in each forest type and plantation between 1995 and 2015.

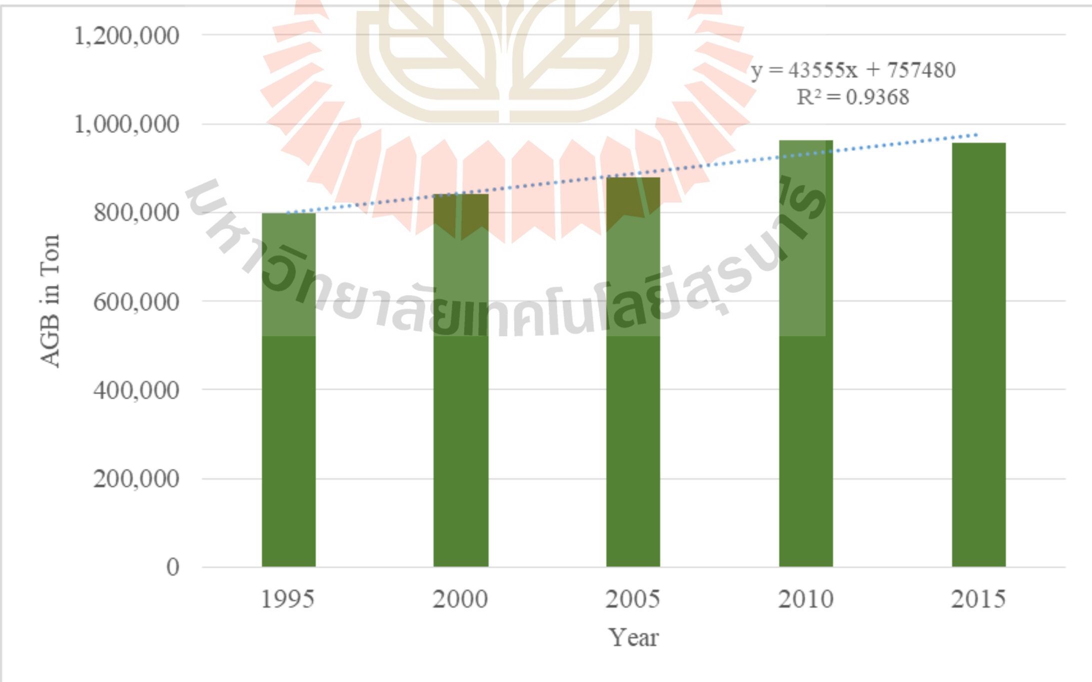


Figure 6.2 Temporal change of total AGB between 1995 and 2015 using forest type and plantation AGB models.

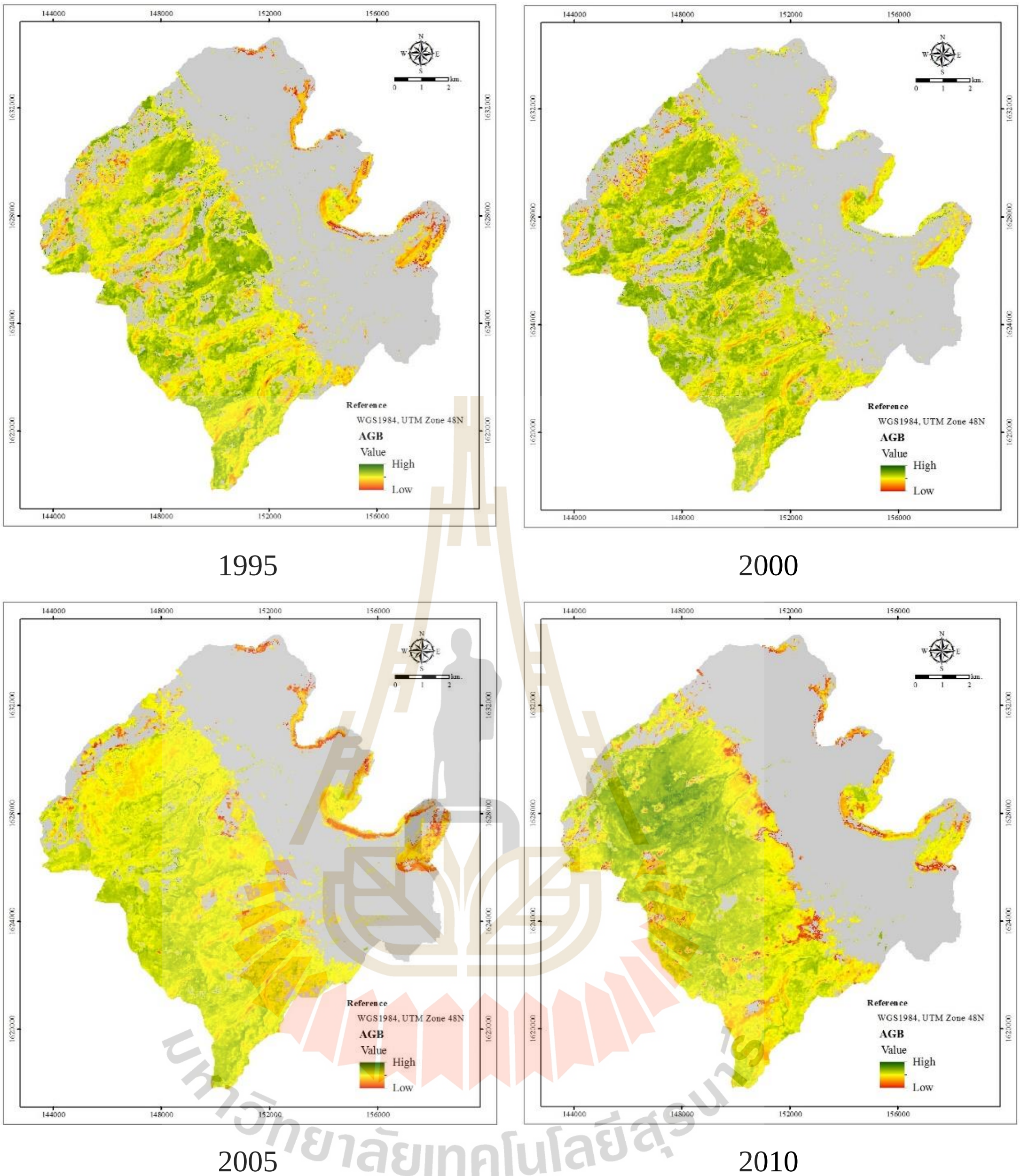


Figure 6.3 Distribution of AGB in 1995, 2000, 2005 and 2010 as historical data using forest type and plantation AGB models.

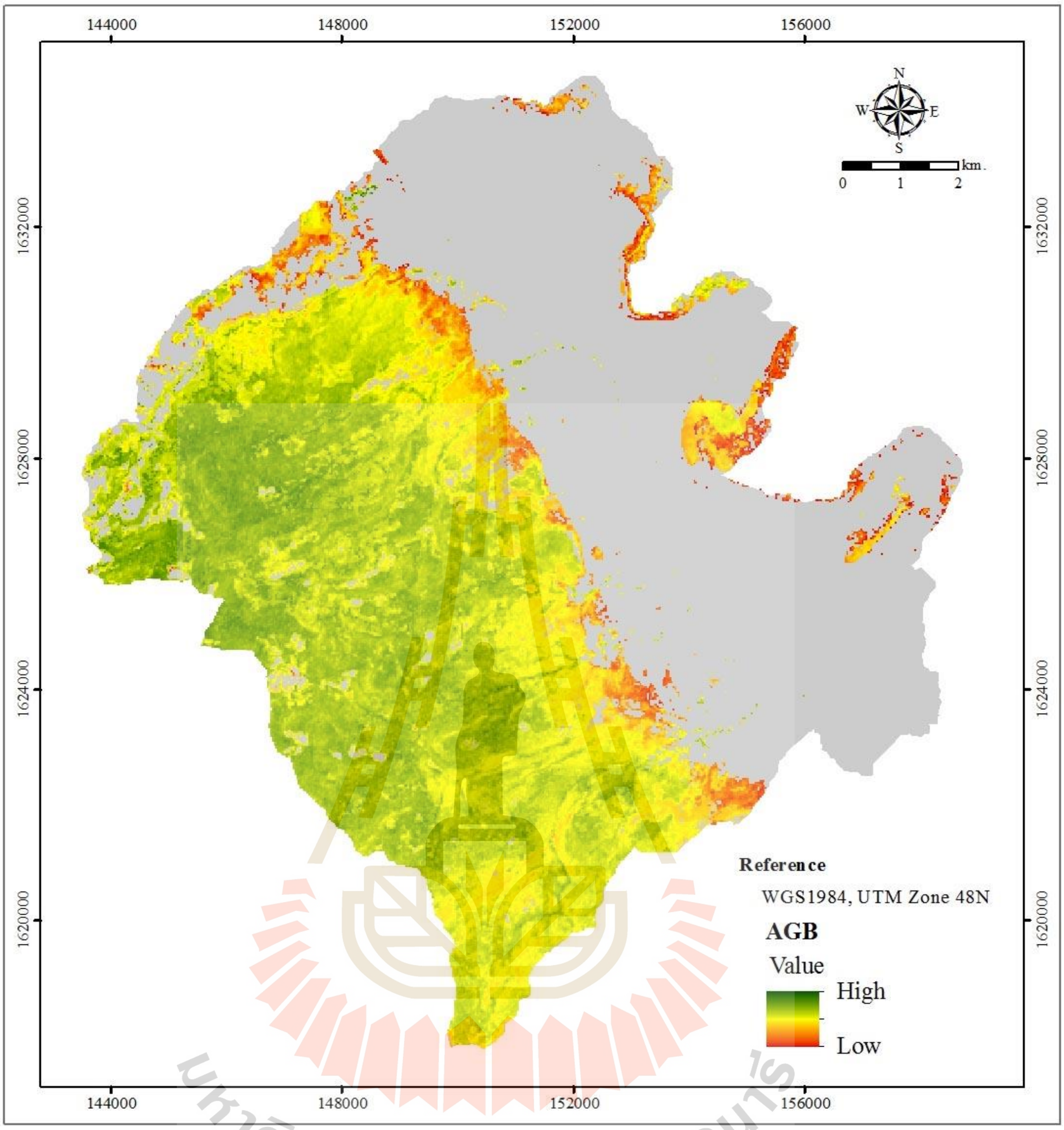


Figure 6.4 Distribution of AGB in 2015 using forest type and plantation AGB models.

Table 6.2 Basic statistical of AGB of dense dry evergreen forest.

Year	Basic statistical of AGB			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
1995	506.78	19,751.58	11,676.42	2,127.88
2000	3,104.24	17,508.32	12,012.20	2,110.78
2005	1,097.11	15,619.26	10,962.32	1,426.10
2010	4,284.90	18,216.72	12,277.21	1,912.67
2015	4,635.95	17,440.38	12,785.27	1,602.07

Table 6.3 Basic statistical of AGB of moderate dry evergreen forest.

Year	Basic statistical of AGB			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
1995	6,730.38	14,268.14	9,881.29	1,147.66
2000	7,170.77	15,493.10	10,954.17	1,287.12
2005	6,877.60	14,525.83	10,218.58	813.36
2010	6,148.40	15,304.40	10,746.23	1,343.65
2015	6,807.79	14,955.84	10,846.29	1,450.82

Table 6.4 Basic statistical of AGB of mixed deciduous forest.

Year	Basic statistical of AGB			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
1995	19.55	22,157.05	8,880.66	4,093.83
2000	279.07	21,828.52	8,946.31	4,122.13
2005	58.05	20,710.84	9,120.06	4,241.76
2010	29.58	23,689.28	7,833.20	4,441.38
2015	0.71	23,606.77	6,257.76	4,239.34

Table 6.5 Basic statistical of AGB of forest plantation.

Year	Basic statistical of AGB			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
1995	844.65	14287.17	8354.875	2169.62
2000	3,948.82	14,134.91	9,308.05	1,537.15
2005	5,167.87	14,538.52	9,692.25	1,362.74
2010	4,115.82	13,725.19	8,962.84	1,712.37
2015	414.53	16,354.42	6,816.88	2,254.77

As a result, it reveals that AGB of dense and moderate dry evergreen forests tend to continuously increase in the future while AGB of mixed deciduous forest is fluctuate and tends to decrease in the future. Meanwhile, AGB of forest plantation is rather stable between 1995 and 2015. In addition, total AGB of natural forest and forest plantation had been continuously increased from 1995 to 2010 and slightly decreased in 2015. The extrapolation of total AGB in the future by simple linear regression provides R^2 of 0.9368.

6.1.2 AGB estimation between 2020 and 2035

As mentioned earlier AGB estimation in 2020, 2025, 2030 and 2035 requires to prepare the corresponding variables accordance with the derived optimum equation in each forest type and plantation using the Trend Analysis function of MS Excel software and Data preparation function of ERDAS Imagine software as results shown in Figures 6.5 to 6.7. These results are generated predicted data between 2020 and 2035 based on variations of historical and recent data in 1995, 2000, 2005, 2010 and 2015 from each pixel by simple linear fitting. The derived data is here simulated to estimate additional ABG and carbon stock for decision makers.

Results of AGB estimation between 2020 and 2035 is summarized in Table 6.6. The temporal change of AGB in each forest type and plantation and total AGB is displayed in Figures 6.8 to 6.9, respectively. Meanwhile distribution of AGB is displayed in Figure 6.10 and summary of basic statistical value of AGB between 2020 and 2035 of each forest type and forest plantation is reported in Tables 6.7 to 6.10.

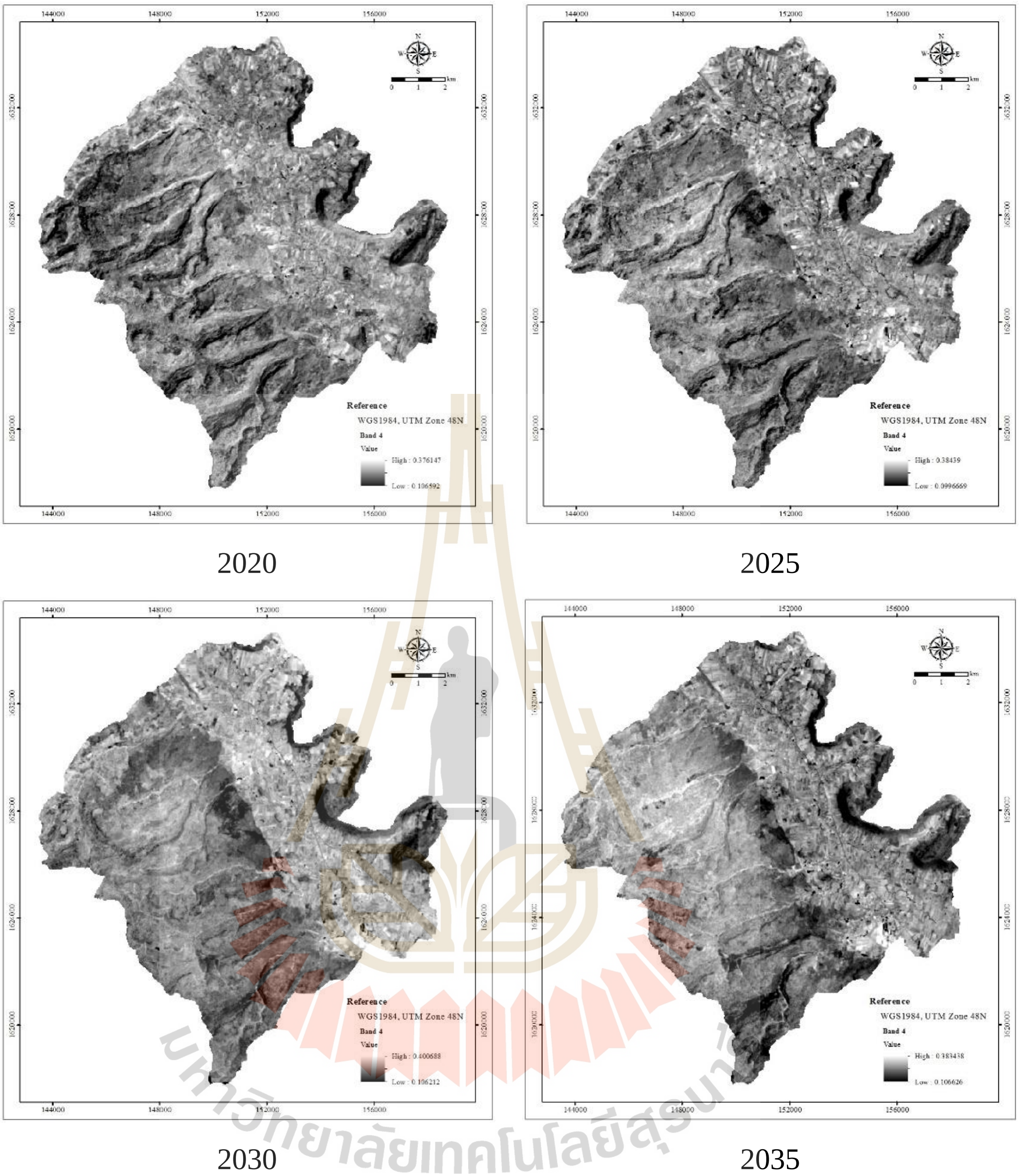
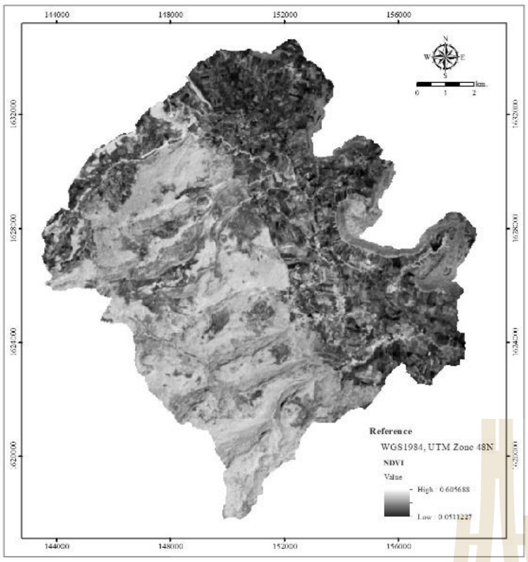
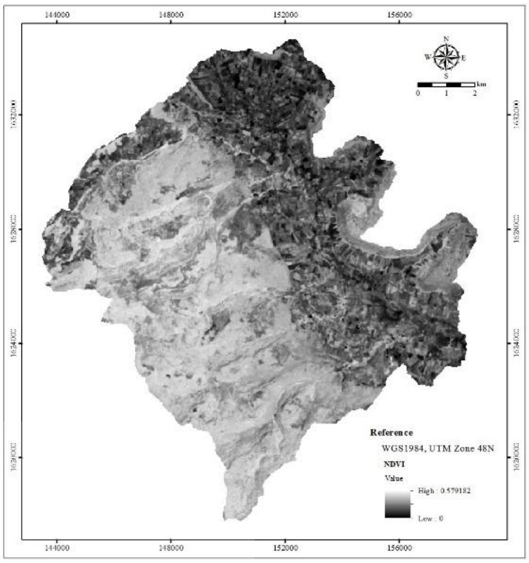


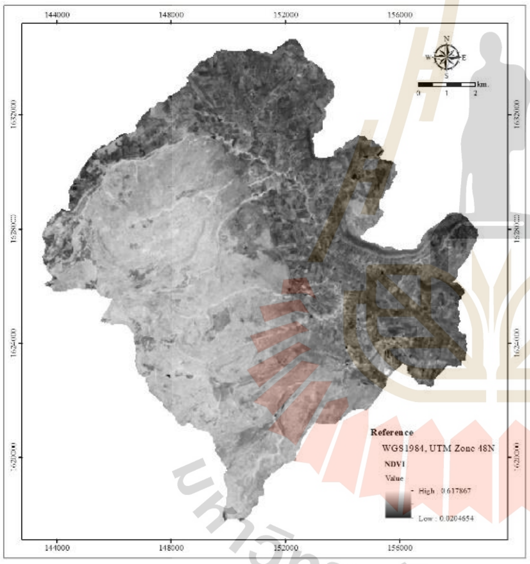
Figure 6.5 NIR data in 2020, 2025, 2030 and 2035 from Trend analysis**.**



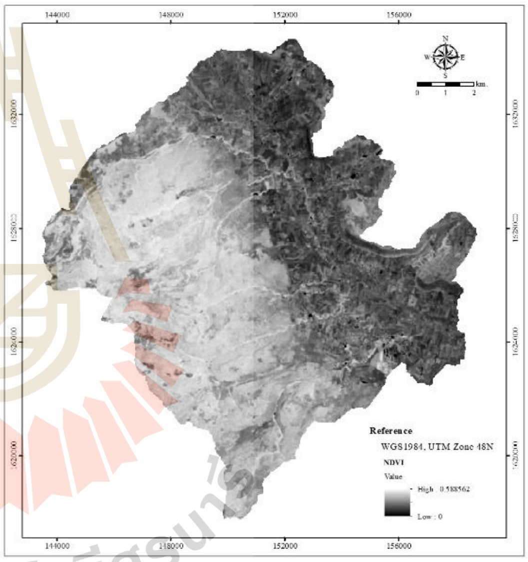
2020



2025



2030



2035

Figure 6.6 NDVI data in 2020, 2025, 2030 and 2035 from Trend analysis.

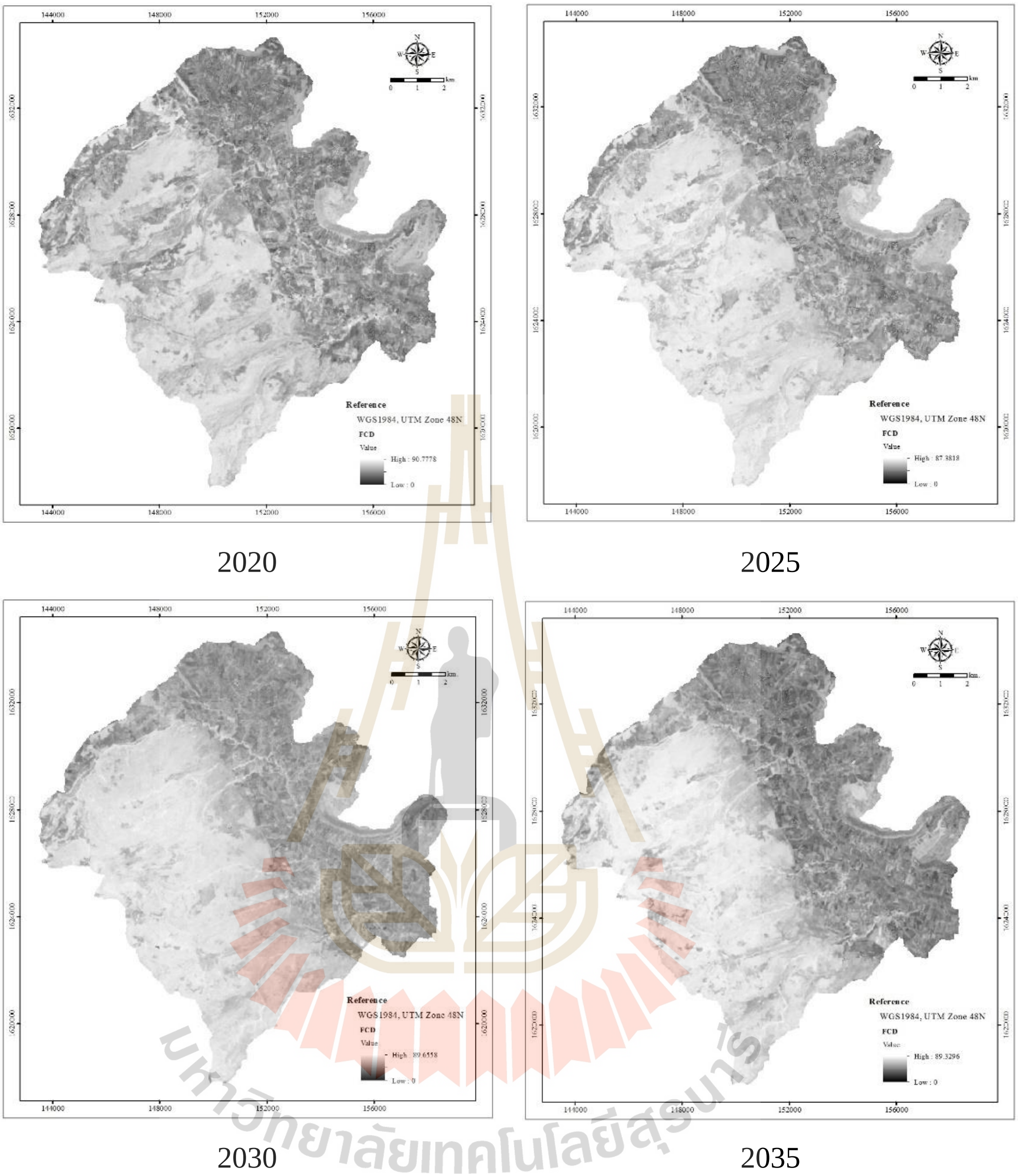


Figure 6.7 FCD data in 2020, 2025, 2030 and 2035 from Trend analysis.

As a result, it reveals that predicted AGB of dense dry evergreen forest tends to continuously increase between 2020 and 2035 while AGB of mixed deciduous forest tends to decrease in the future. Meanwhile, AGB of moderate dry evergreen forest and forest plantation are rather stable between 2020 and 2035. In addition, total AGB of natural forest and forest plantation had been gradually increased from 2020 to 2035. The predicted linear equation provides R^2 of 0.8399.

Table 6.6 Estimation of AGB between 2020 and 2035.

Year	Forest type and plantation	AGB (ton)
2020	Dense dry evergreen forest	531,316.70
	Moderate dry evergreen forest	267,668.19
	Mixed deciduous forest	71,672.54
	Forest plantation	34,757.37
	Total	**905,414.80**
2025	Dense dry evergreen forest	558,116.01
	Moderate dry evergreen forest	279,248.61
	Mixed deciduous forest	69,698.44
	Forest plantation	38,344.64
	Total	**945,407.69**
2030	Dense dry evergreen forest	578,953.41
	Moderate dry evergreen forest	277,011.03
	Mixed deciduous forest	49,358.77
	Forest plantation	35,993.05
	Total	**941,316.26**
2035	Dense dry evergreen forest	608,772.78
	Moderate dry evergreen forest	279,596.87
	Mixed deciduous forest	50,322.15
	Forest plantation	29,609.07
	Total	**968,300.87**

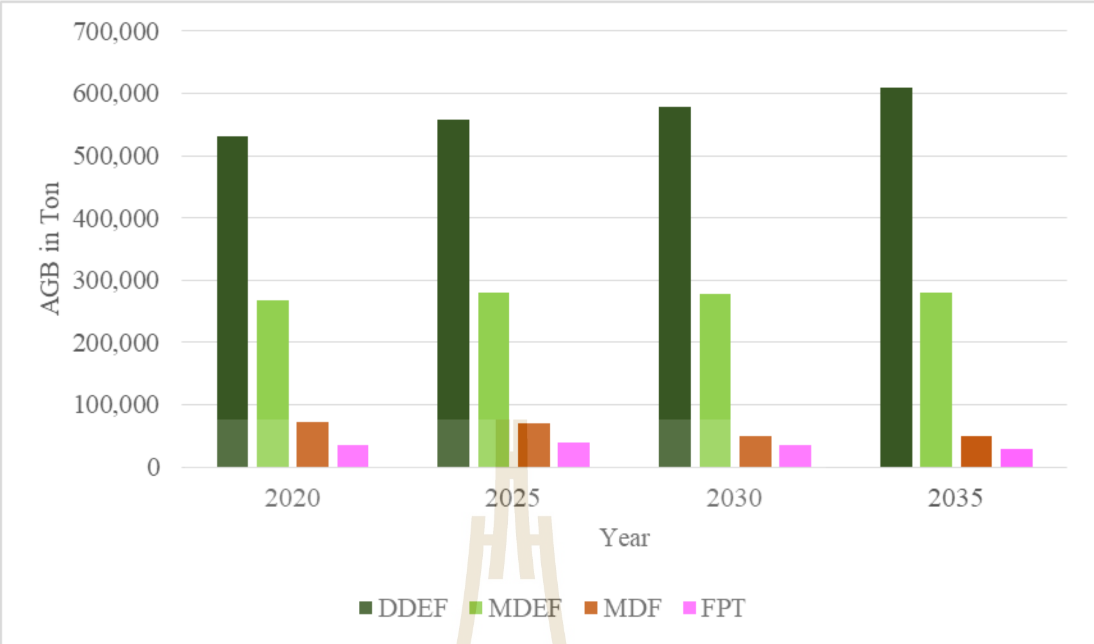


Figure 6.8 Dynamic change of AGB in each forest type and plantation between 2020 and 2035.

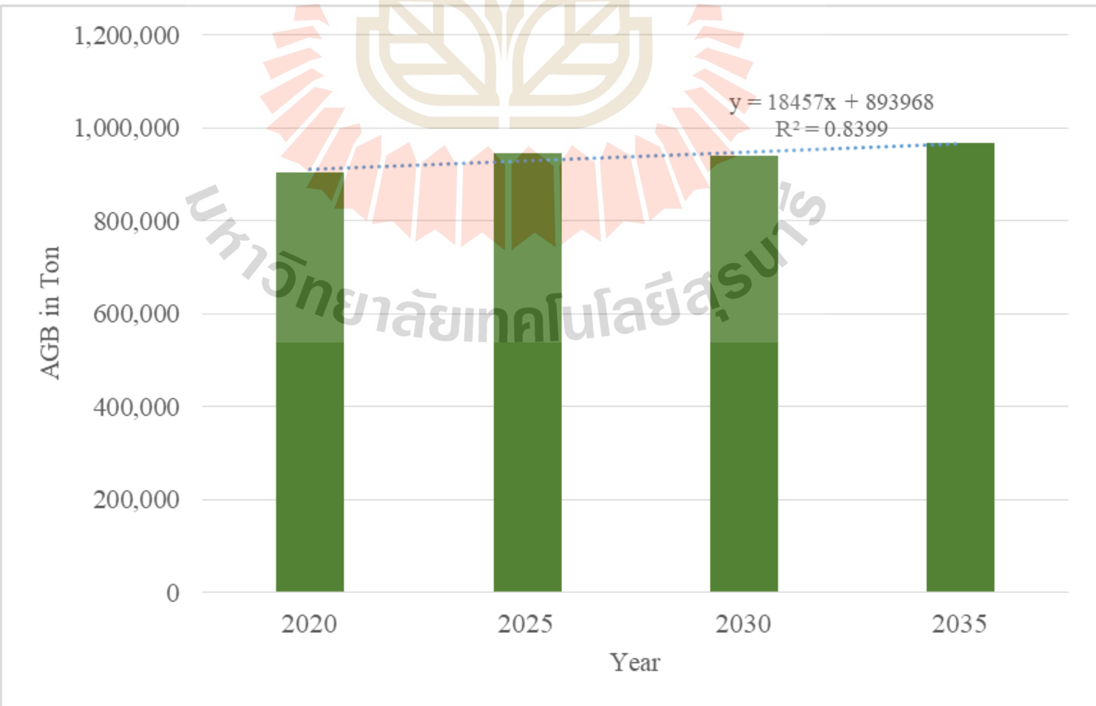
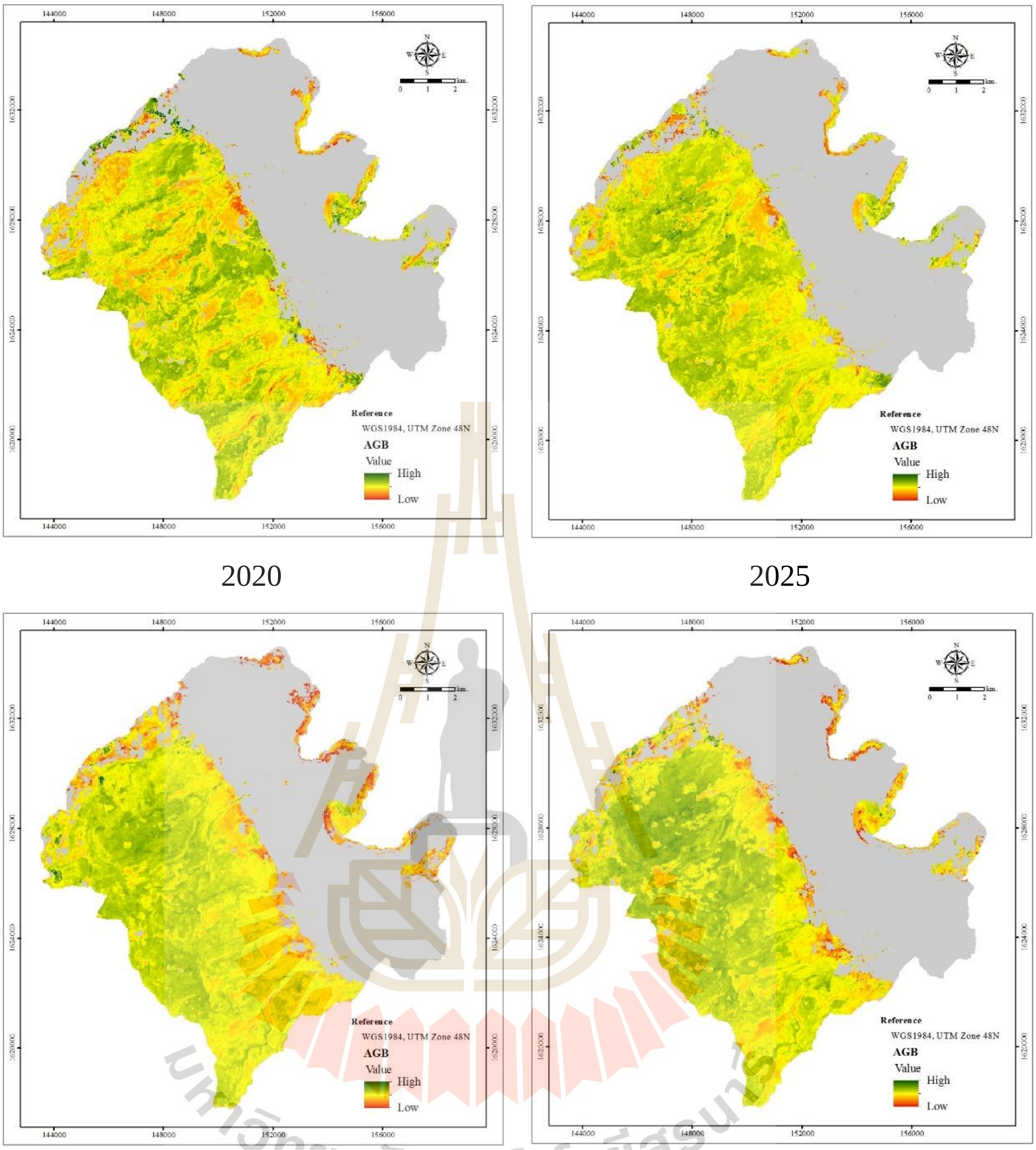


Figure 6.9 Dynamic change of total AGB between 2020 and 2035 using forest type and plantation AGB models.



2020 2025

2030 2035

Figure 6.10 Distribution of AGB in 2020, 2025, 2030 and 2035 as future data.

Table 6.7 Basic statistical of AGB of dense dry evergreen forest.

Year	Basic statistical of AGB			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
2020	468.48	18,728.86	11,564.94	1,975.11
2025	3,985.59	18,200.27	11,916.13	1,407.63
2030	4,230.65	16,086.41	11,780.99	1,228.22
2035	6,062.21	17,878.46	12,444.76	1,545.06

Table 6.8 Basic statistical of AGB of moderate dry evergreen forest.

Year	Basic statistical of AGB			
	Minimum	Maximum	Mean	Standard deviation
2020	4,894.84	14,483.74	9,294.03	1,651.49
2025	4,785.63	13,459.33	9,877.21	1,384.65
2030	4,312.75	13,785.62	9,944.39	1,385.73
2035	4,599.58	14,127.92	10,151.29	1,455.81

Table 6.9 Basic statistical of AGB of mixed deciduous forest.

Year	Basic statistical of AGB			
	Minimum	Maximum	Mean	Standard deviation
2020	24.12	31,591.56	12,932.61	6,016.57
2025	7.68	31,132.01	12,138.36	5,077.04
2030	2.89	26,605.20	8,120.89	4,793.55
2035	0.91	27,464.31	8,665.77	4,096.37

Table 6.10 Basic statistical of AGB of forest plantation.

Year	Basic statistical of AGB			
	Minimum	Maximum	Mean	Standard deviation
2020	16.73	16,497.15	9,333.34	3,336.53
2025	98.86	16,383.28	9,769.33	2,483.99
2030	91.92	15,881.42	8,871.84	2,295.53
2035	218.52	15,093.24	7,594.02	2,673.36

6.2 Estimation of AGB using forest AGB model

Likewise estimation of AGB using forest type and plantation models, the derived forest AGB model is directly applied to estimate AGB of forest area in 1995, 2000, 2005, 2010 and 2015 using Model Builder under ERDAS Imagine software. Meanwhile, to estimation of forest AGB between 2020 and 2035 as future information, it firstly requires to construct the relevant variables of optimum AGB estimation models with Trend Analysis function of MS Excel software and Data preparation function of

ERDAS Imagine software and then uses an optimum AGB estimation models to estimate AGB of forest area in 2020, 2025, 2030 and 2035.

6.2.1 AGB estimation between 1995 and 2015

Results of AGB estimation between 1995 and 2015 based on forest AGB model is summarized in Table 6.11 while temporal change of total AGB of forest area in this period is demonstrated in Figure 6.11. The distribution of AGB in 1995, 2000, 2015, 2015 as historical year and in 2015 as recent year is displayed in Figures 6.12 to 6.13, respectively and summary of basic statistical value of AGB at pixel level between 1995 and 2015 in forest area is reported in Table 6.12.

Table 6.11 Estimation of AGB of forest area between 1995 and 2015 using forest AGB model.

Year	AGB (ton)
1995	787,351.84
2000	829,152.39
2005	871,151.98
2010	932,723.82
2015	950,164.04

Figure 6.11 Temporal change of total AGB between 1995 and 2015 using forest AGB model.

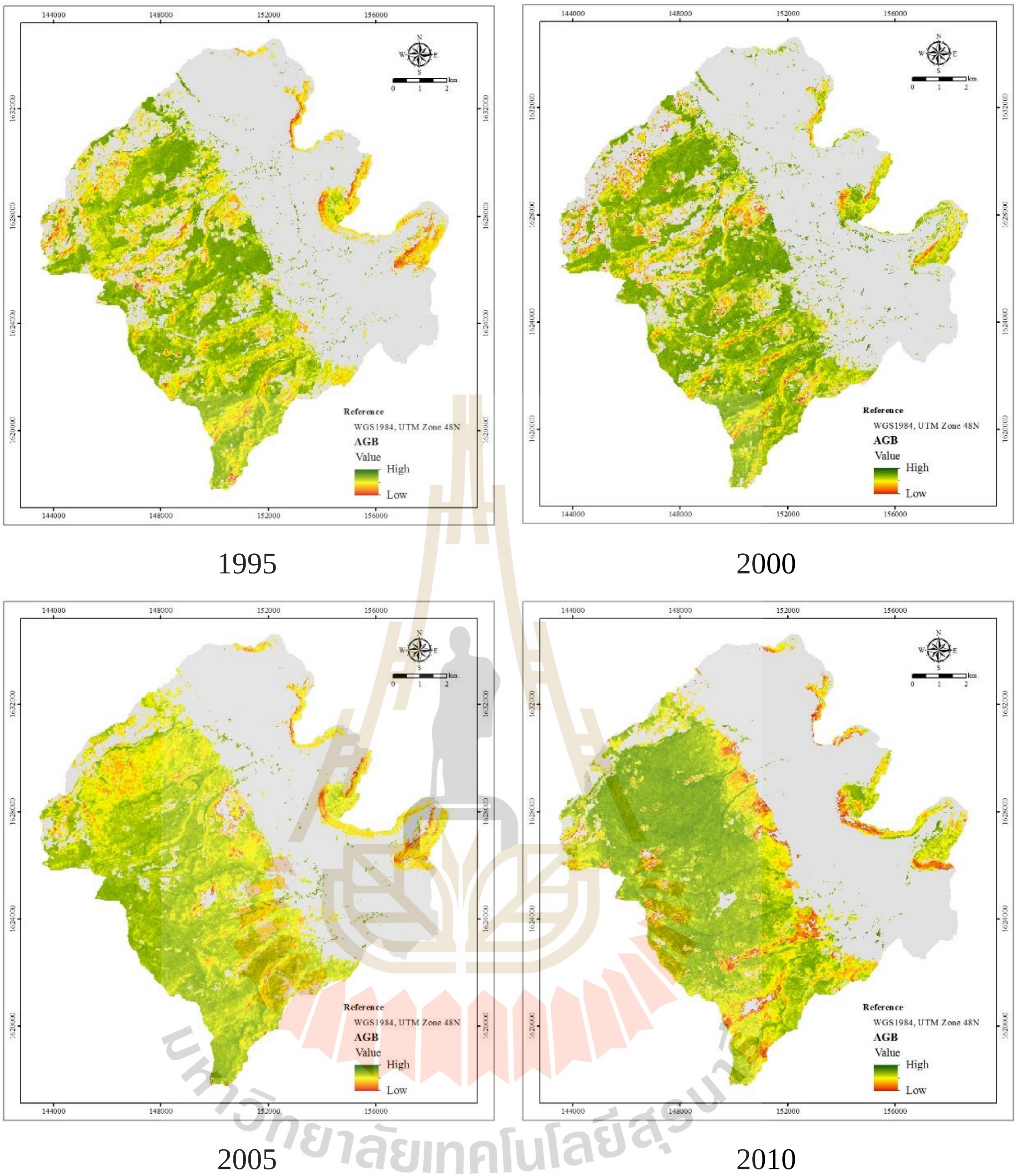


Figure 6.12 Distribution of AGB in 1995, 2000, 2005 and 2010 as historical data using forest AGB model.

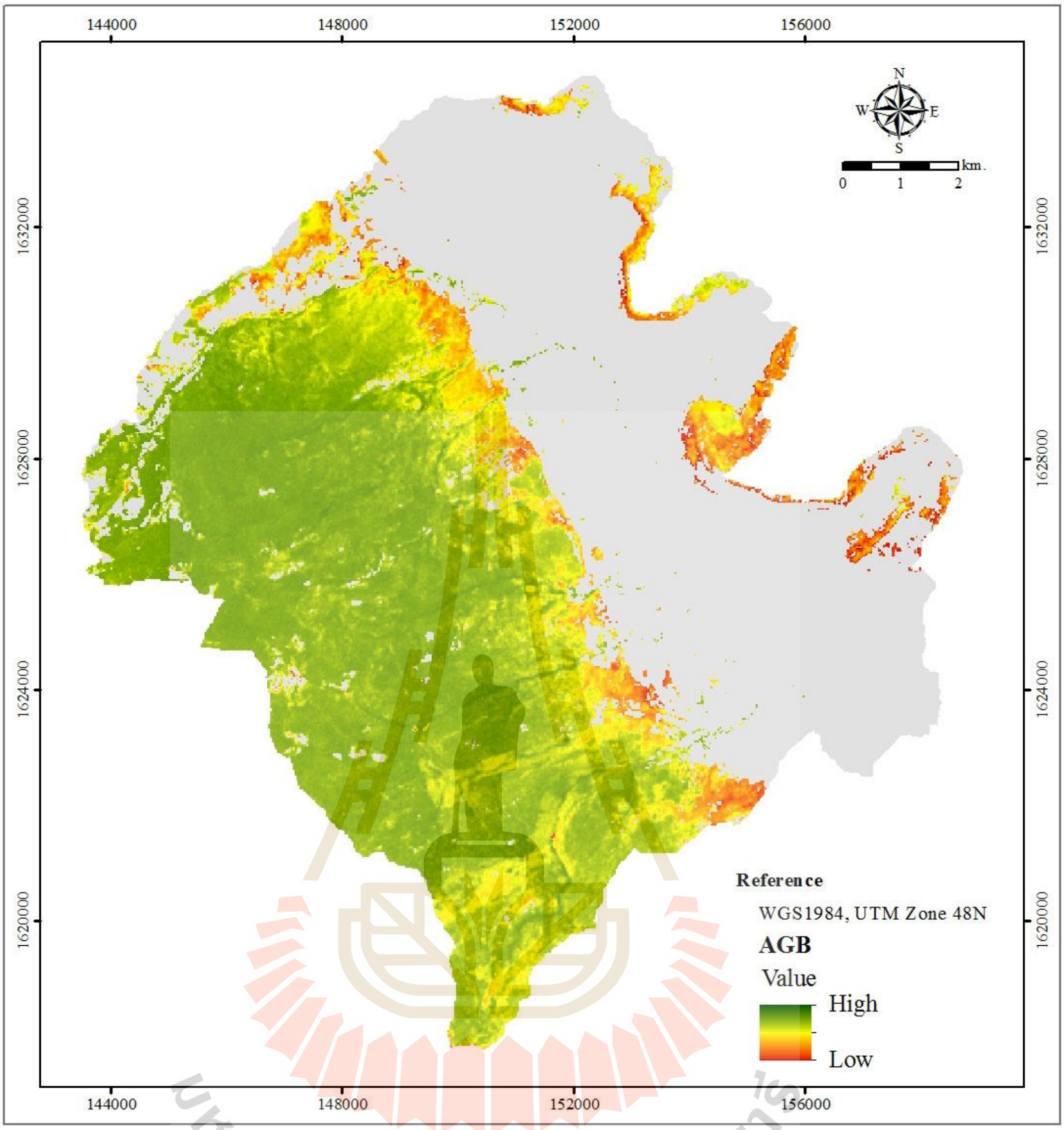


Figure 6.13 Distribution of AGB in 2015 using forest AGB model.

Table 6.12 Basic statistical of AGB in forest area.

Year	Basic statistical of AGB			
	Minimum	Maximum	Mean	Standard deviation
1995	2.77	17,836.10	10,684.21	2,580.94
2000	1.31	17,629.59	11,254.34	2,719.78
2005	11.20	17,089.20	10,383.34	2,031.29
2010	0.05	16,222.88	10,906.12	2,791.17
2015	4.12	14,787.79	11,320.64	2,691.24

As a result, it reveals that total AGB of forest area that consists of natural forest and plantation had been continuously increased from 1995 to 2015. The trend of total AGB based on forest AGB model is different from forest type and plantation AGB model, whereby total AGB in 2015 using forest type and plantation AGB models slightly decrease after 2010 (See Figure 6.2).

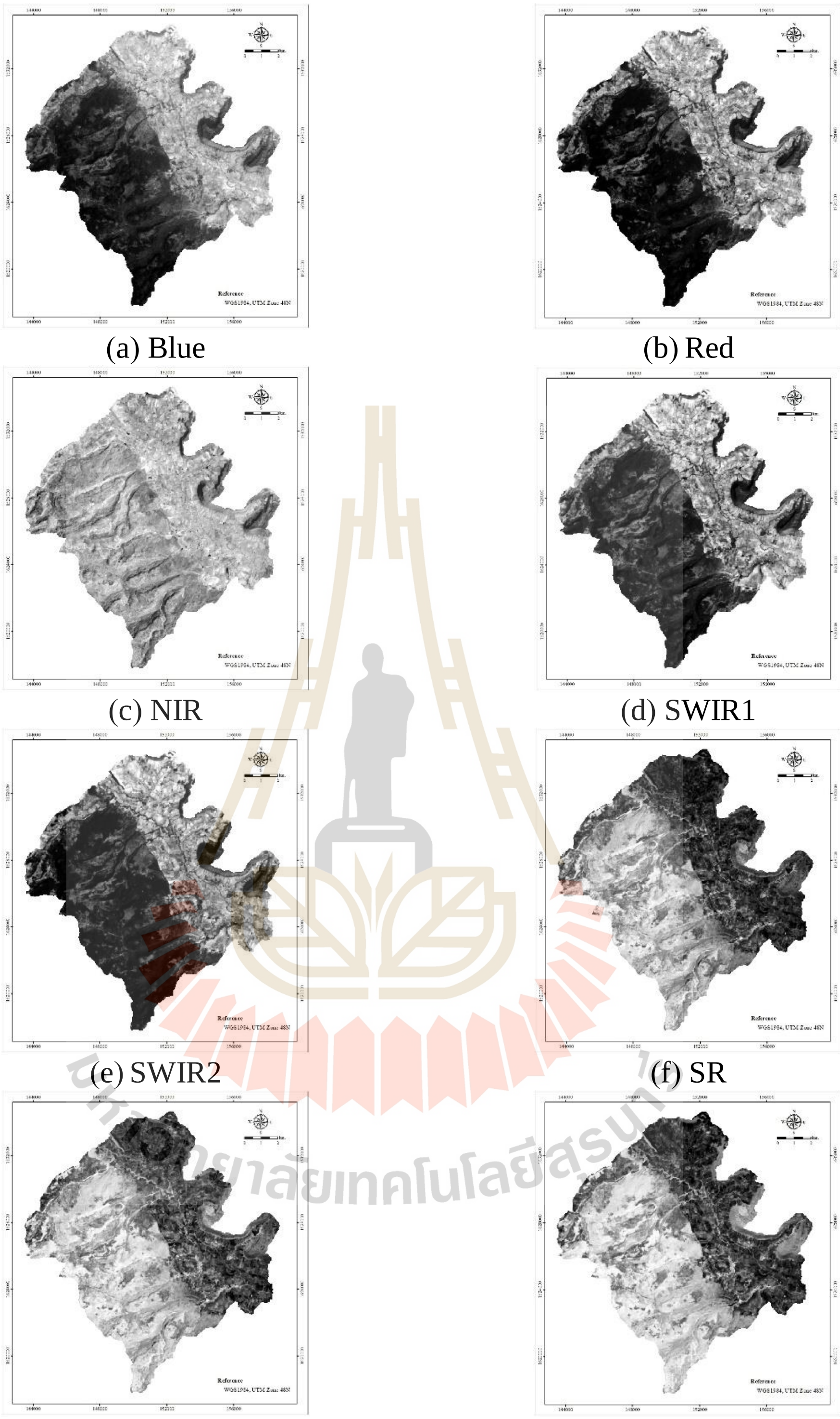
6.2.2 AGB estimation between 2020 and 2035

Likewise AGB estimation based on forest type and plantation AGB model, the corresponding variables accordance with the derived optimum equation of forest must be prepared using the Trend Analysis function of MS Excel software and Data preparation function of ERDAS Imagine as an example shown in Figure 6.14.

Results of AGB estimation between 2020 and 2035 is summarized in Table 6.13. The temporal change of total AGB in forest area is displayed in Figure 6.15. Meanwhile distribution of AGB between 2020 and 2025 is displayed in Figure 6.16 and summary of basic statistical value of AGB in this period is reported in Table 6.14.

As a result, it reveals that total AGB of natural forest and forest plantation sharply increase from 2020 to 2030 and then decrease from 2030 to 2035. The predicted linear equation provides R^2 of 0.785.

It can be observed that efficiency of simple linear model for predicting forest area using forest AGB model is lower than forest type and plantation models as mentioned above. Because total AGB of forest area using forest type and plantation AGB models is firstly generated by a specific model of each forest type and plantation and its result is then combined as total AGB of forest area. This implies that optimum AGB estimation model from forest type and plantation is more reliable than optimum AGB estimation model form forest area.



(a) Blue (b) Red
(c) NIR (d) SWIR1
(e) SWIR2 (f) SR
(g) NDVI (h) RSR

Figure 6.14 Example of various predicted variable in 2035 from Trend analysis**.**

Table 6.13 Estimation of AGB between 2020 and 2035 based on forest AGB model.

Year	AGB (ton)
2020	875,961.00
2025	893,186.24
2030	920,427.67
2035	912,632.15

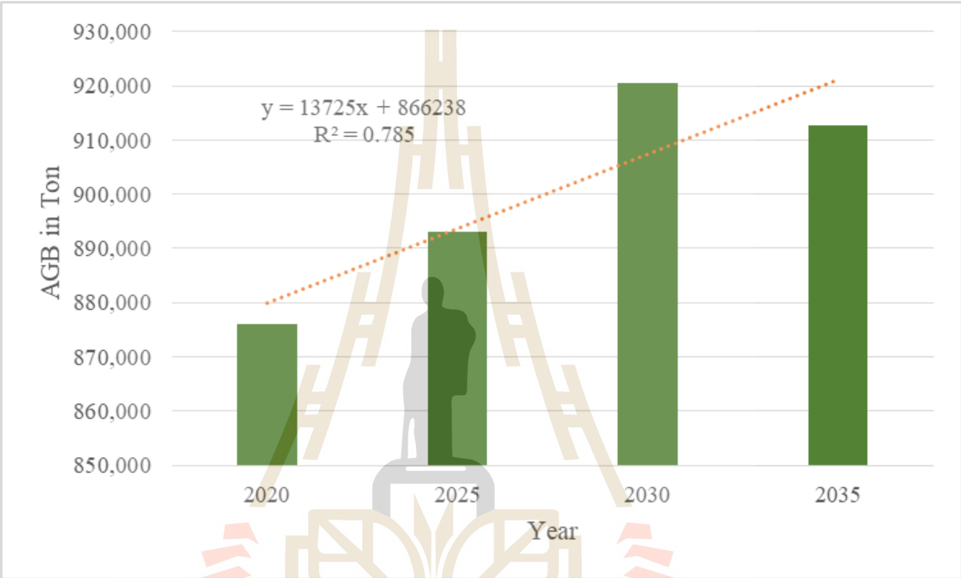


Figure 6.15 Dynamic change of total AGB between 2020 and 2035 using forest AGB model.

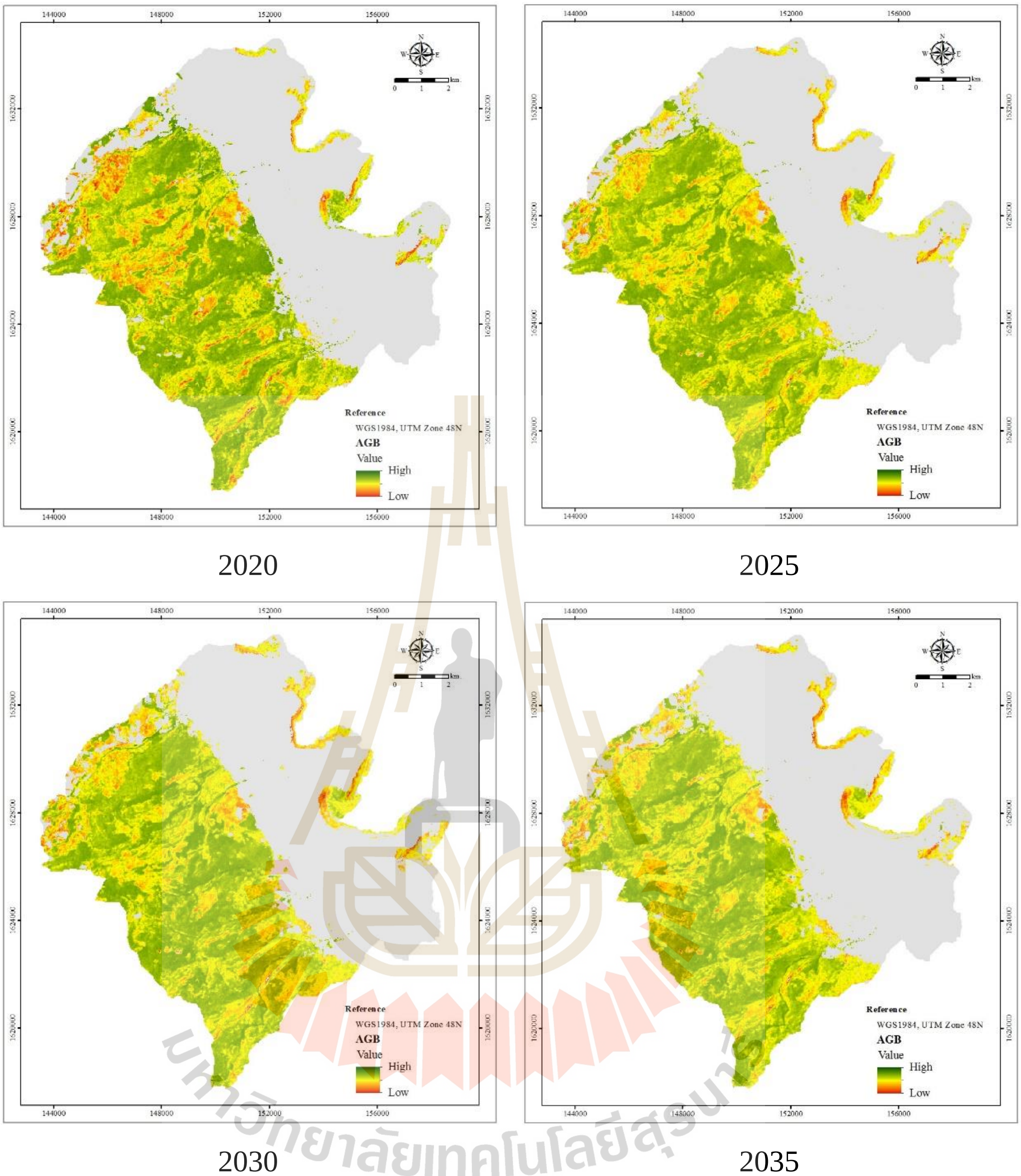


Figure 6.16 Distribution of AGB in 2020, 2025, 2030 and 2035 as future data based on forest AGB model.

Table 6.14 Basic statistical of AGB of forest area between 2020 and 2035.

Year	Basic statistical of AGB			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
2020	36.32	18,951.77	10,416.95	2,640.82
2025	185.09	17,899.60	10,526.40	2,182.20
2030	36.48	18,095.63	10,479.53	2,138.65
2035	79.82	17,429.87	10,528.39	2,088.50

6.3 Change of above ground biomass

Results of AGB estimation which are estimated based on two approaches: (1) forest type and plantation AGB models and (2) forest AGB model are here separately described and discussed in details in the following sections.

6.3.1 Change of AGB using forest type and plantation AGB models

Change of AGB between 1995 and 2035 in term of gain (increase) and loss (decrease) and annual rate and percent of change in each natural forest and forest plantation and total AGB is separately summarized in Tables 6.15 to 6.19. Herein AGB between 1995 and 2015 which are directly related with classified forest type and plantation from CART model, represents historical and present data. While AGB between 2020 and 2035, which are directly related with predicted forest type and plantation from CA-Markov model, represents future data.

Table 6.15 Change of AGB in dense dry evergreen forest between 1995 and 2035.

Year	Forest area (sq.km)	AGB (ton)			
		DDEF	Change	Annual rate	% of Change
1995	41.81	539,976.12			
2000	41.05	545,449.95	5,473.83	1,094.77	0.2027
2005	42.87	519,876.84	-25,573.11	-5,114.62	-0.9377
2010	43.19	586,691.14	66,814.30	13,362.86	2.5704
2015	42.27	597,813.58	11,122.44	2,224.49	0.3792
2020	41.53	531,316.70	-66,496.88	-13,299.38	-2.2247
2025	42.32	558,116.01	26,799.31	5,359.86	1.0088
2030	44.32	578,953.41	20,837.40	4,167.48	0.7467
2035	44.15	608,772.78	29,819.37	5,963.87	1.0301
		Total	**68,796.66**		

Table 6.16 Change of AGB in moderate dry evergreen forest between 1995 and 2035.

Year	Forest area (sq.km)	AGB (ton)			
		MDEF	Change	Annual rate	% of Change
1995	15.18	166,677.52			
2000	18.31	222,906.49	56,228.97	11,245.79	6.7470
2005	22.1	250,958.08	28,051.59	5,610.32	2.5169
2010	24.59	293,619.32	42,661.24	8,532.25	3.3999
2015	25.39	306,006.47	12,387.15	2,477.43	0.8438
2020	25.92	267,668.19	-38,338.28	-7,667.66	-2.5057
2025	25.44	279,248.61	11,580.42	2,316.08	0.8653
2030	25.07	277,011.03	-2,237.58	-447.52	-0.1603
2035	24.78	279,596.87	2,585.84	517.17	0.1867
		Total	112,919.35		

Table 6.17 Change of AGB in mixed deciduous forest between 1995 and 2035.

Year	Forest area (sq.km)	AGB (ton)			
		MDF	Change	Annual rate	% of Change
1995	7.62	73,611.75			
2000	5.46	53,686.80	-19,924.95	-3,984.99	-5.4135
2005	8.34	83,193.18	29,506.38	5,901.28	10.9920
2010	7.42	57,589.72	-25,603.46	-5,120.69	-6.1552
2015	5.42	29,067.29	-28,522.43	-5,704.49	-9.9054
2020	5.09	71,672.54	42,605.25	8,521.05	29.3149
2025	5.28	69,698.44	-1,974.10	-394.82	-0.5509
2030	6.2	49,358.77	-20,339.67	-4,067.93	-5.8365
2035	5.69	50,322.15	963.38	192.68	0.3904
		Total	**- 23,289.60**		

Table 6.18 Change of AGB in forest plantation between 1995 and 2035.

Year	Forest area (sq.km)	AGB (ton)			
		FTP	Change	Annual rate	% of Change
1995	2.03	18,823.53			
2000	1.96	20,310.16	1,486.63	297.33	1.5795
2005	2.46	26,450.15	6,139.99	1,228.00	6.0462
2010	2.37	23,626.05	-2,824.10	-564.82	-2.1354
2015	3.22	24,390.79	764.74	152.95	0.6474
2020	3.41	34,757.37	10,366.58	2,073.32	8.5004
2025	3.54	38,344.64	3,587.27	717.45	2.0642
2030	3.65	35,993.05	-2,351.59	-470.32	-1.2266
2035	3.6	29,609.07	-6,383.98	-1,276.80	-3.5473
		Total	**10,785.54**		

Table 6.19 Change of total AGB in the study area between 1995 and 2035 based on forest type and plantation AGB models.

Year	Forest area (sq.km)	AGB (ton)			
		Total AGB	Change	Annual rate	% of Change
1995	66.64	799,088.93			
2000	66.78	842,353.40	43,264.47	8,652.89	1.08
2005	75.77	880,478.25	38,124.85	7,624.97	0.91
2010	77.57	961,526.24	81,047.99	16,209.60	1.84
2015	76.3	957,278.13	-4,248.11	-849.62	-0.09
2020	75.95	905,414.80	-51,863.33	-10,372.67	-1.08
2025	76.58	945,407.69	39,992.89	7,998.58	0.88
2030	79.24	941,316.26	-4,091.43	-818.29	-0.09
2035	78.22	968,300.87	26,984.61	5,396.92	0.57
		Total	**169,211.94**		

According to results of AGB change, AGB of dense and moderate dry evergreen forest during 1995 and 2035 gain about 68,797 and 112,919 ton, respectively while AGB of mixed deciduous forest losses about 23,289 ton. In the same period AGB of forest plantation gains about 10,786 ton while AGB in the study area totally gains about 169,212 ton.

Annual increasing rate of AGB in dense dry evergreen forest is highest between 2005 and 2010 with annual rate of 13,362.86 ton while annual highest decreasing rate of AGB in dense dry evergreen forest is occurred between 2015 and 2020 with annual rate of 13,299.38 ton. Meanwhile, annual increasing rate of AGB in moderate dry evergreen forest is highest between 1995 and 2000 with annual rate of 11,245.79 ton while annual decreasing rate of AGB in moderate dry evergreen forest is highest between 2015 and 2020 with annual rate of 7,667.66 ton. In the same period, annual increasing rate of AGB in mixed deciduous forest is highest between 2015 and 2020 with annual rate of 8,521.05 ton while annual decreasing rate of AGB in mixed deciduous forest is highest between 2010 and 2015 with annual rate of 5,704.49 ton. Meanwhile, annual increasing rate of AGB in plantation forest is highest between 2015 and 2020 with annual rate of 2,073.32 ton while annual decreasing rate of AGB in plantation forest is highest between 2030 and 2035 with annual rate of 1,276.80 ton. In addition, annual increasing rate of total AGB in the study area is highest between 2005 and 2010 with annual rate of 16,209.60 ton while annual decreasing rate of total AGB in the study area is highest between 2015 and 2020 with annual rate of 10,372.67 ton.

The annual change of total AGB between 1995 and 2035 is presented in Figure 6.17. It was found that total AGB in 3 periods: 2010-2015, 2015-2020 and 2030-2035 decrease while 5 periods: 1995-2000, 2000-2005, 2005-2010, 2020-2030 and 2030-2035 increase.

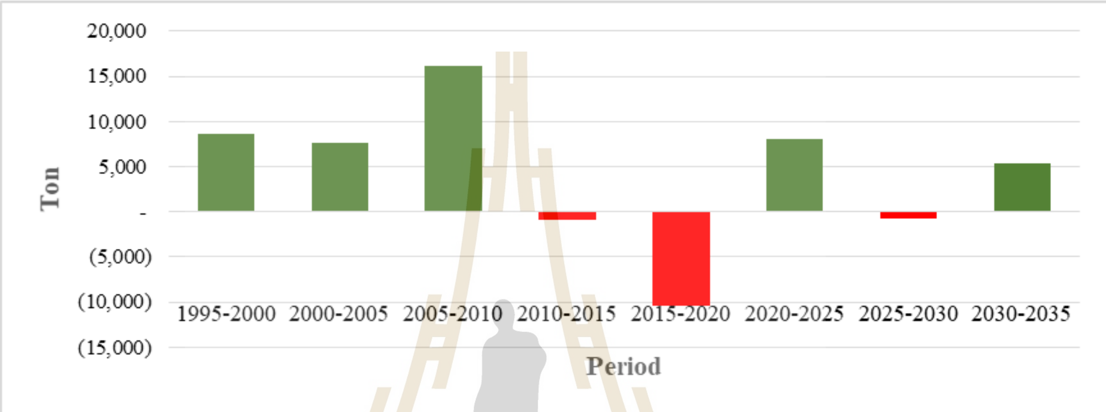


Figure 6.17 Temporal change of total AGB between 1995 and 2035 using forest type and plantation AGB models.

6.3.2 Change of AGB based on forest AGB model

Change of AGB between 1995 and 2035 based on forest AGB model in term of gain (increase) and loss (decrease) and annual rate and percent of change of total AGB is summarized in Table 6.20.

Table 6.20 Change of total AGB in the study area between 1995 and 2035 based on forest AGB model.

Year	Forest area (sq.km)	AGB (ton)			
		Total AGB	Change	Annual rate	% of Change
1995	66.64	787,351.84			
2000	66.78	829,152.39	41,800.55	8,360.11	1.06
2005	75.77	871,151.98	41,999.59	8,399.92	1.01
2010	77.57	932,723.82	61,571.84	12,314.37	1.41
2015	76.3	950,164.04	17,440.22	3,488.04	0.37
2020	75.95	875,961.00	-74,203.04	-14,840.61	-1.56
2025	76.58	893,186.24	17,225.24	3,445.05	0.39
2030	79.24	920,427.67	27,241.43	5,448.29	0.61
2035	78.22	912,632.15	-7,795.52	-1,559.10	-0.17
		Total	**125,280.31**		

According to results of total AGB change, total AGB of forest area gains about 125,280 ton. Annual increasing rate of total AGB in the study area is highest between 2005 and 2010 with annual rate of 12,314.37 ton while annual decreasing rate of total AGB in the study area is lowest between 2015 and 2020 with annual rate of 14,840.61 ton.

The annual change of total AGB between 1995 and 2035 is presented in Figure 6.18. It was found that total AGB in 2 periods: 2015-2020 and 2030-2035 decrease while 6 periods: 1995-2000, 2000-2005, 2005-2010, 2010-2015, 2020-2030 and 2030-2035 increase. Total AGB of forest area using forest AGB model gains about 125,280.31 ton.

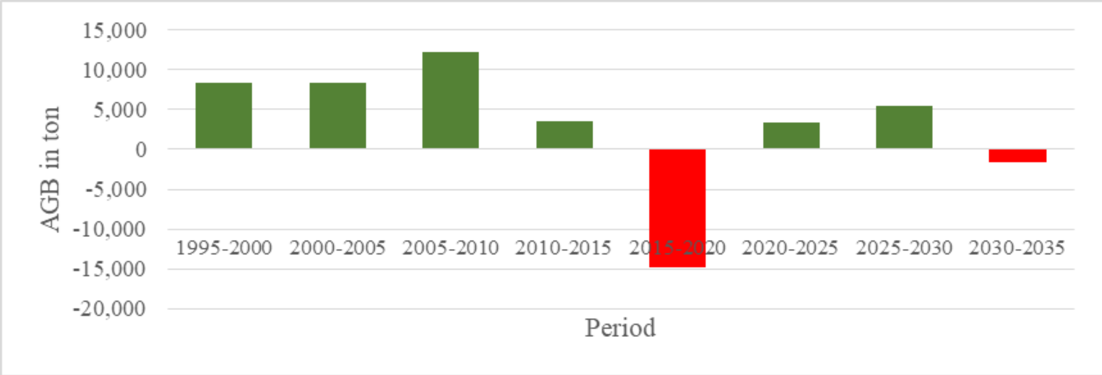


Figure 6.18 Temporal change of total AGB between 1995 and 2035.

Furthermore, it can be observed that total gain AGB between 1995 and 2035 that was derived from forest AGB model provides total AGB lower than forest type and plantation AGB models about 43,932 ton. Total AGB of forest type and plantation models is higher than forest AGB model in every year between 1995 and 2035. However, temporal change patterns of total AGB from both models are rather similar (Figure 6.19).

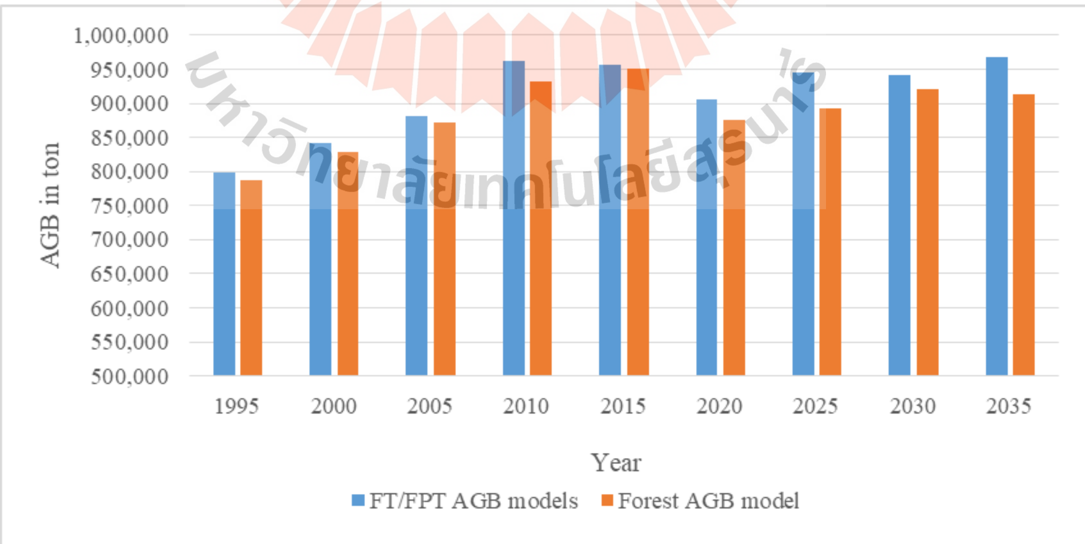


Figure 6.19 Comparison of total derived AGB using forest type AGB models and forest AGB model.

6.4 Carbon stock assessment and its change

Results of AGB estimation which are estimated based on two approaches: (1) forest type and plantation AGB models and (2) forest AGB model are here applied to assess carbon stock by multiply carbon conversion factor of 0.47 with AGB. Results of carbon stock assessment and its change is separately described and discussed in details in the following section.

6.4.1 Carbon stock assessment using forest type and plantation AGB models

Carbon stock of natural forest and forest plantation and its total during 1995 to 2035 are here assessed based on estimated AGB using forest type and plantation AGB models. Results of carbon stock assessment is summarized in Table 6.21. Meanwhile temporal of carbon stock in each forest type and forest plantation and total carbon stock is presented in Figures 6.20 and 6.21.

Table 6.21 Carbon stock assessment of forest type and plantation (1995-2035).

Year	Forest type and plantation	Carton stock (Ton)
1995	Dense Dry evergreen forest	253,788.78
	Moderate Dry evergreen forest	78,338.44
	Mixed deciduous forest	34,597.52
	Forest plantation	8,847.06
	Total	375,571.80
2000	Dense Dry evergreen forest	256,361.48
	Moderate Dry evergreen forest	104,766.05
	Mixed deciduous forest	25,232.80
	Forest plantation	9,545.77
	Total	395,906.10

Table 6.21 Carbon stock assessment of forest type and plantation (1995-2035).

(Continued).

Year	**Forest type and plantation**	**Carton stock (Ton)**
2005	Dense Dry evergreen forest	244,342.11
	Moderate Dry evergreen forest	117,950.30
	Mixed deciduous forest	39,100.80
	Forest plantation	12,431.57
	Total	413,824.78
2010	Dense Dry evergreen forest	275,744.84
	Moderate Dry evergreen forest	138,001.08
	Mixed deciduous forest	27,067.17
	Forest plantation	11,104.25
	Total	451,917.33
2015	Dense Dry evergreen forest	280,972.38
	Moderate Dry evergreen forest	143,823.04
	Mixed deciduous forest	13,661.63
	Forest plantation	11,463.67
	Total	449,920.72
2020	Dense Dry evergreen forest	249,718.85
	Moderate Dry evergreen forest	125,804.05
	Mixed deciduous forest	33,686.10
	Forest plantation	16,335.96
	Total	425,544.95
2025	Dense Dry evergreen forest	262,314.52
	Moderate Dry evergreen forest	131,246.85
	Mixed deciduous forest	32,758.27
	Forest plantation	18,021.98
	Total	444,341.62
2030	Dense Dry evergreen forest	272,108.10
	Moderate Dry evergreen forest	130,195.18
	Mixed deciduous forest	23,198.62
	Forest plantation	16,916.73
	Total	442,418.64
2035	Dense Dry evergreen forest	286,123.21
	Moderate Dry evergreen forest	131,410.53
	Mixed deciduous forest	23,651.41
	Forest plantation	13,916.26
	Total	455,101.41

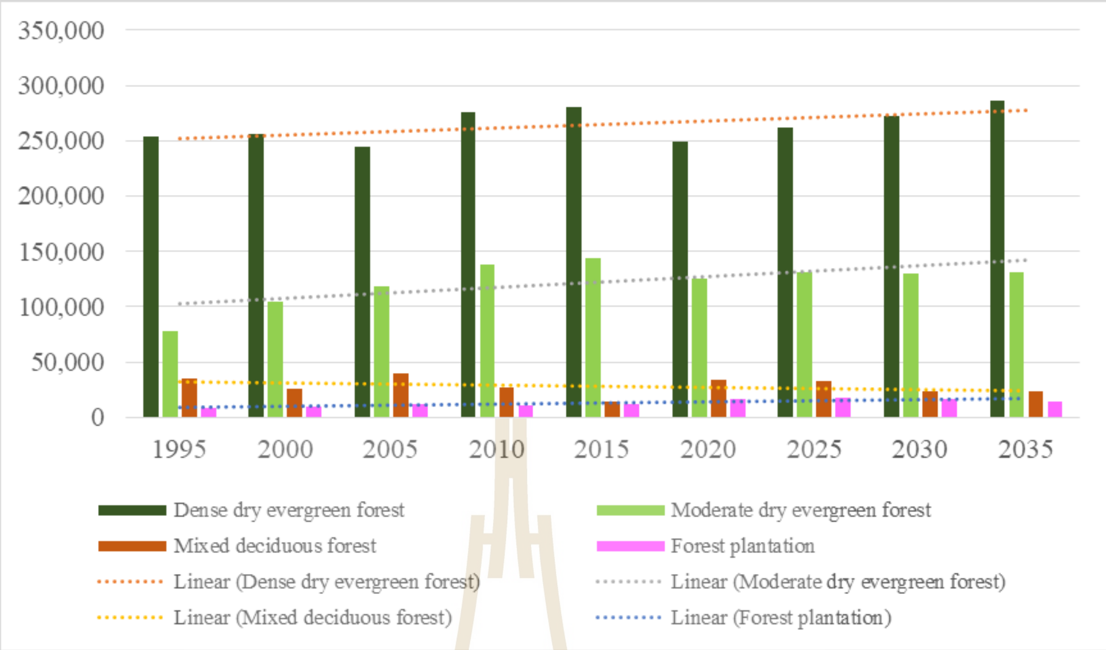


Figure 6.20 Temporal change of carbon stock in each forest type and plantation between 1995 and 2035.

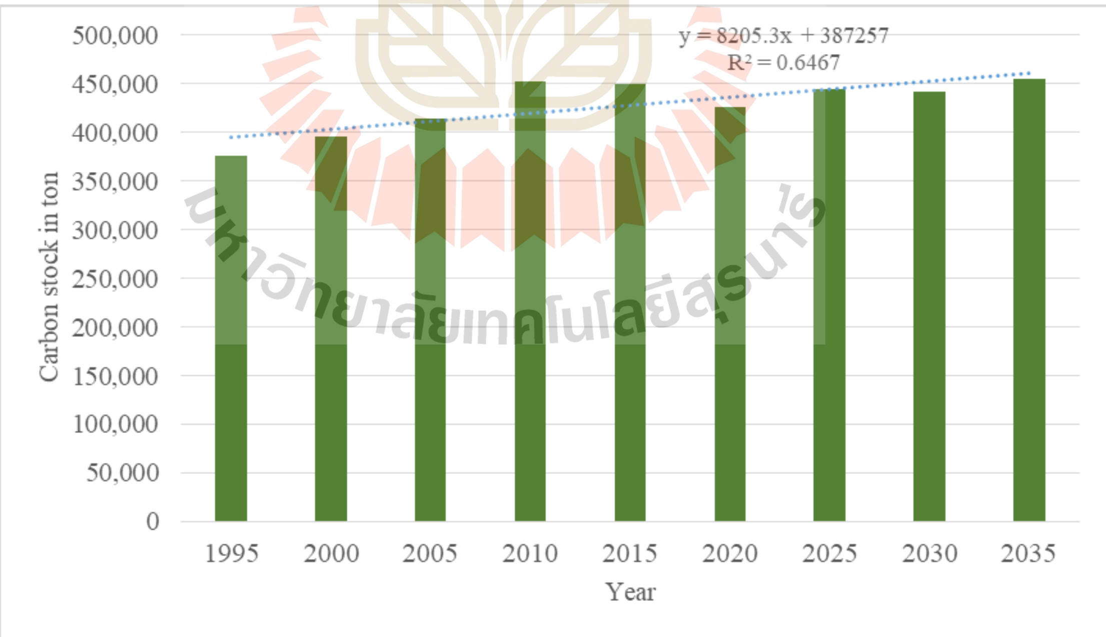


Figure 6.21 Temporal change of total carbon stock between 1995 and 2035 using forest type and plantation AGB models.

As a result, characteristic of carbon stock shows similar pattern as AGB. During 1995 to 2015, carbon stock of dense and moderate dry evergreen forests tend to continuously increase in the future while carbon stock of mixed deciduous forest is fluctuate and tends to decrease in the future. Meanwhile, carbon stock of forest plantation is rather stable between 1995 and 2015. In addition, total carbon stock of natural forest and forest plantation has been continuously increased from 1995 to 2010 and it has been slightly decreased in 2015.

Likewise, it reveals that predicted carbon stock of dense and moderate dry evergreen forests tends to continuously increase between 2020 and 2035 while carbon stock of mixed deciduous forest tends to decrease in the future. Meanwhile, carbon stock of forest plantation is rather stable between 2020 and 2035.

Furthermore, the derived carbon stock between 1995 and 2035 is here applied to calculate change in term of gain (increase) and loss (decrease) in each 5 years period and its annual rate. Change of carbon stock between 1995 and 2035 is presented in Table 6.22 and Figure 6.22.

As a result, carbon stock is loosen in three periods: 2010–2015, 2015-2020 and 2025-2030 but carbon stock is gained in other five periods. Overall carbon stock gain about 79,530 ton between 1995 and 2035 due to increasing of natural forest in this period. The simple linear regression analysis between natural forest and forest plantation areas and carbon stock show high positively correlation with R^2 of 0.8193 (Figure 6.23)

Table 6.22 Change of carbon stock between 1995 and 2035 using forest type and plantation AGB models.

Year	Forest area (sq.km)	Carbon stock	Change	Annual change	Gain/Loss
1995	66.64	375,571.80			
2000	66.78	395,906.10	20,334.30	4,066.86	Gain
2005	75.77	413,824.78	17,918.68	3,583.74	Gain
2010	77.57	451,917.33	38,092.55	7,618.51	Gain
2015	76.3	449,920.72	-1,996.61	-399.32	Loss
2020	75.95	425,544.96	-24,375.76	-4,875.15	Loss
2025	76.58	444,341.61	18,796.65	3,759.33	Gain
2030	79.24	442,418.64	-1,922.97	-384.59	Loss
2035	78.22	455,101.41	12,682.77	2,536.55	Gain
		Total	**79,529.61**		

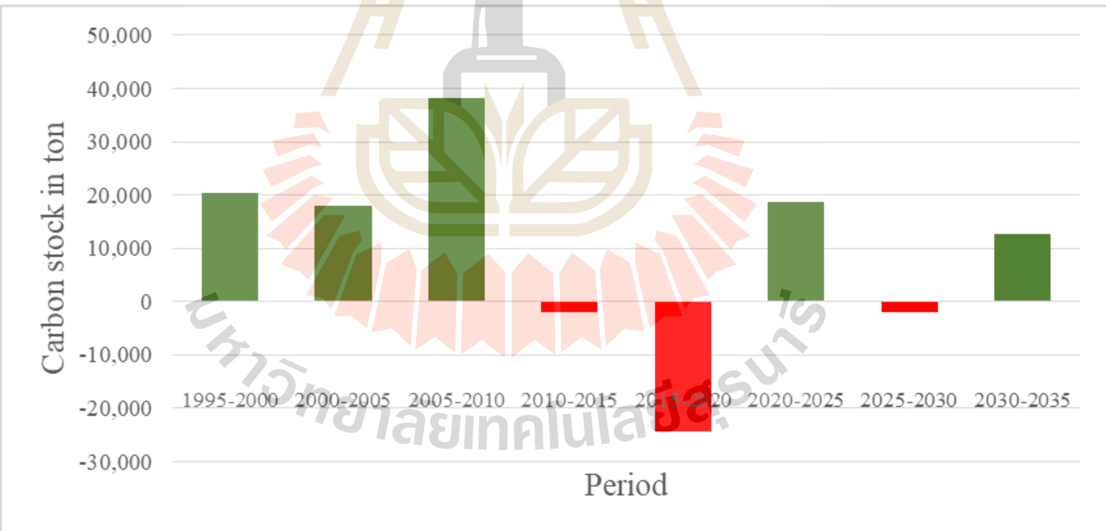


Figure 6.22 Temporal change of carbon stock in each 5 years period between 1995 and 2035.

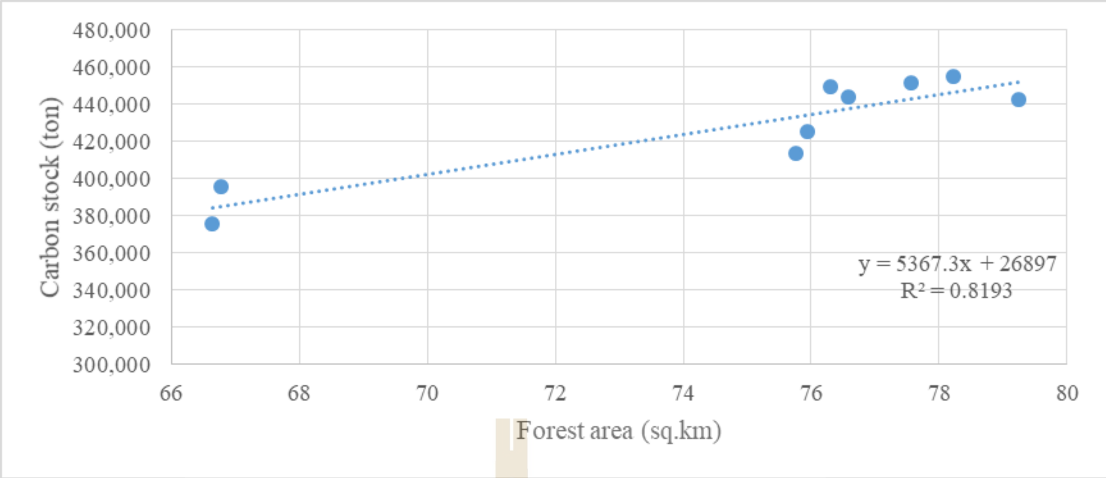


Figure 6.23 Simple linear regression analysis between forest area and carbon stock.

6.4.2 Carbon stock assessment based on forest AGB model.

Carbon stock of forest and its change during 1995 to 2035 are here assessed based on estimated AGB using forest AGB model. Results of carbon stock assessment is summarized in Table 6.23. Meanwhile temporal change of total carbon stock is presented in Figure 6.24. As a result, characteristic of carbon stock shows similar pattern as AGB.

Table 6.23 Carbon stock assessment (1995-2015) based on forest AGB model.

Year	Carbon stock (ton)
1995	370,055.36
2000	389,701.62
2005	409,441.43
2010	438,380.20
2015	446,577.10
2020	411,701.67
2025	419,797.53
2030	432,601.01
2035	428,937.11

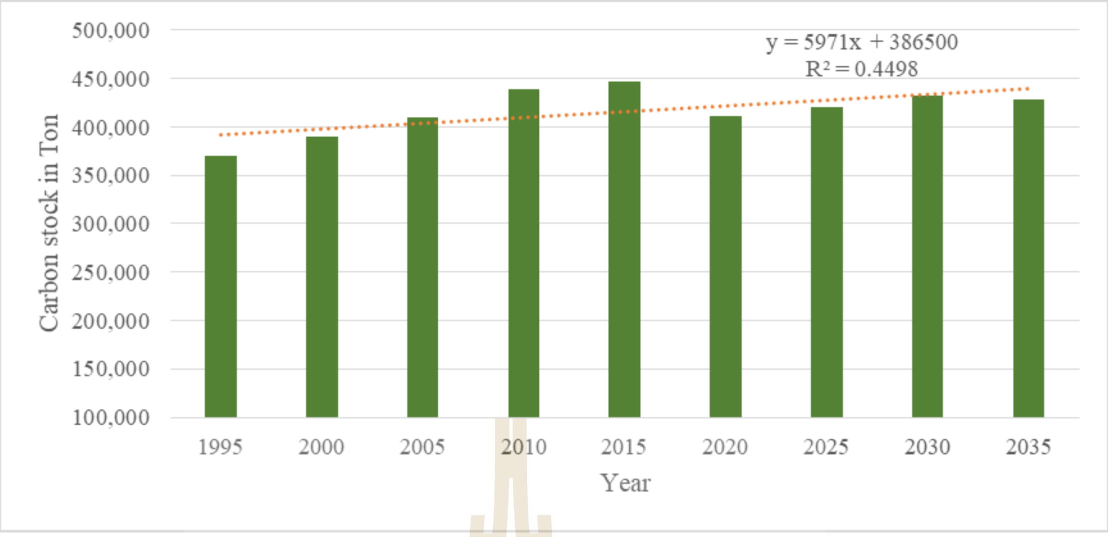


Figure 6.24 Temporal change of total carbon stock between 1995 and 2035 based on forest AGB model.

Furthermore, the derived carbon stock between 1995 and 2035 based on forest AGB model are here used to calculate change in term of gain (increase) and loss (decrease) in each 5 years period and its annual rate. Change of carbon stock between 1995 and 2035 is presented in Table 6.24 and Figure 6.25.

Table 6.24 Change of carbon stock between 1995 and 2035 using forest AGB model.

Year	Forest area (sq.km)	Carbon stock	Change	Annual change	Gain/Loss
1995	66.64	370,055.36			
2000	66.78	389,701.62	19,646.26	3,929.25	Gain
2005	75.77	409,441.43	19,739.81	3,947.96	Gain
2010	77.57	438,380.20	28,938.77	5,787.75	Gain
2015	76.3	446,577.10	8,196.90	1,639.38	Gain
2020	75.95	411,701.67	-34,875.43	-6,975.09	Loss
2025	76.58	419,797.53	8,095.86	1,619.17	Gain
2030	79.24	432,601.01	12,803.48	2,560.70	Gain
2035	78.22	428,937.11	-3,663.90	-732.78	Loss
		Total	**58,881.75**		

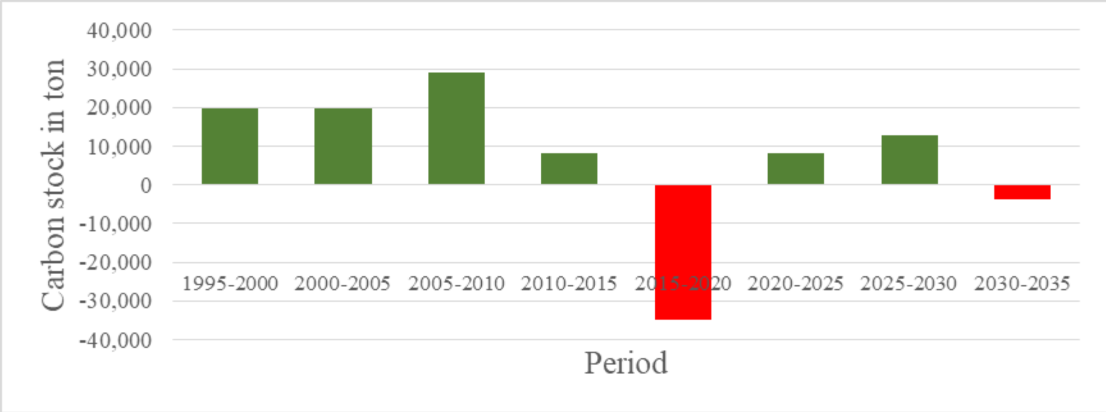


Figure 6.25 Temporal change of carbon stock in each 5 years period between 1995 and 2035.

As a result, during 1995 to 2015 as historical and current data, no carbon stock is loosen between 2010 and 2015 but in the future carbon stock is loosen between 2015 and 2020 and 2030 and 2035. In summary, carbon stock is gained between 1995 and 2035 about 58,882 tons.

Furthermore, it can be here observed that total gain of carbon stock between 1995 and 2035 that was derived from forest AGB model provides total carbon stock lower than forest type and plantation AGB models about 20,648 ton. This finding is similar with total AGB.

CHAPTER VII

CARBON EMISSION ASSESSMENT AND REDD IMPLEMENTATION

Main results of the fourth object regarding reference time period (1995 -2015) identification and Reference Emission Level (REL) construction for REDD mechanism implementation in the study is here reported. They are included (1) carbon emission assessment and (2) FREL baseline for REDD mechanism implementation: trend line extrapolation and historical average methods. Additional, combined incentive (CI) reference level method, which is a new emerging approach under REDD program is also examined in this study.

7.1 Carbon emission assessment

Based on quantitative carbon stock change analysis using post-classification comparison algorithm (pixel by pixel) in each 5 year, three main component of forest areas include (1) carbon upgrade or degrade in forest area (2) carbon stock loss due to deforestation and (3) carbon stock gain due to regrowth as mentioned in Table 4.10 of Section 4.4 in Chapter IV is here extract to evaluate carbon sink and emission according to two approaches of AGB estimation: forest type and plantation AGB models and forest AGB model.

Results of carbon stock assessment which are assessed based on two mentioned approaches are here separately described and discussed in details in the following section.

7.1.1 Carbon emission assessment using forest type and plantation AGB models

The quantity of carbon change in three components is summarized in Table 7.1 and distribution of carbon change in each 5 years period is presented in Figures 7.1 to 7.2.

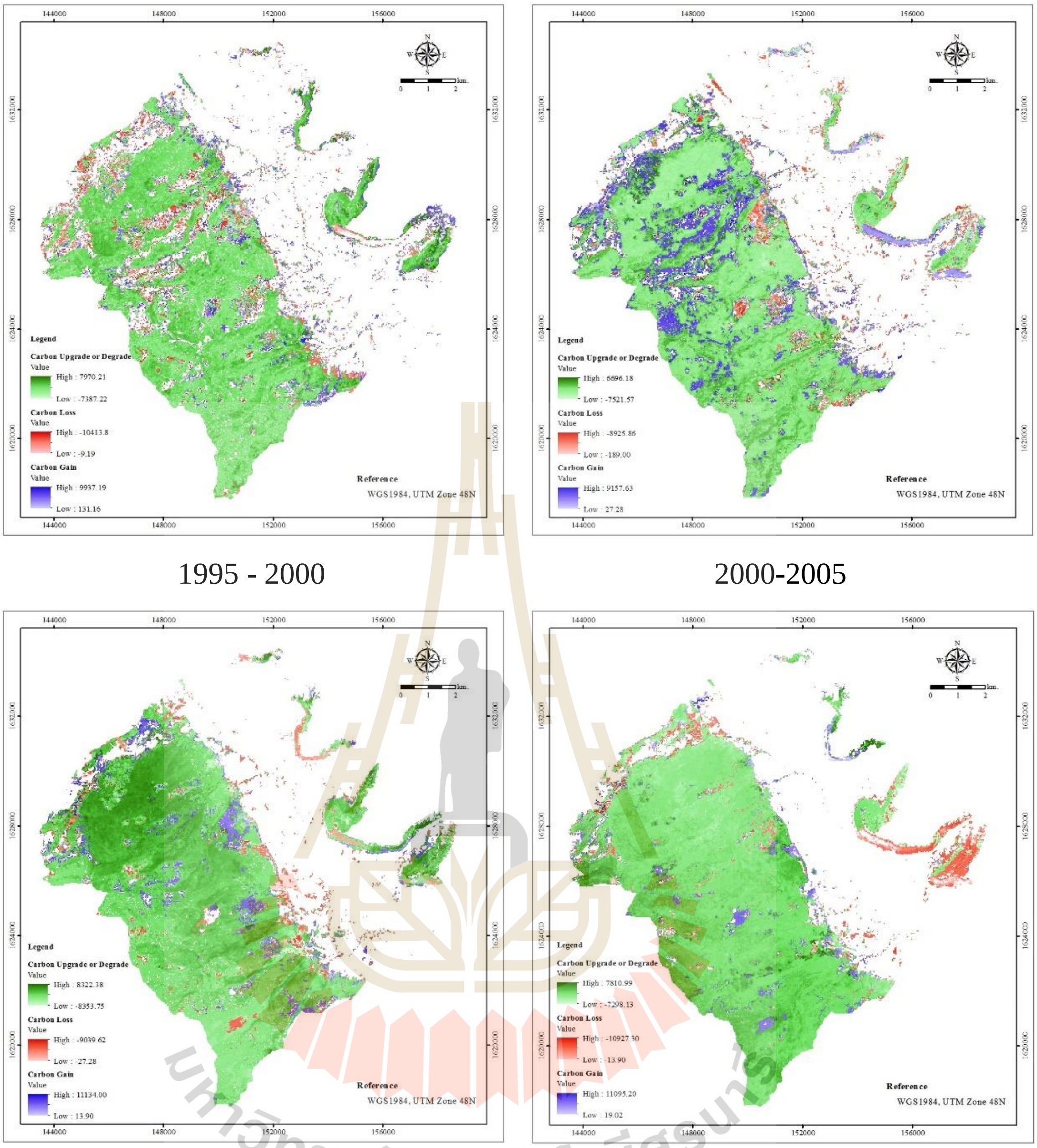
As a result, it can be observed that the summation of three components equals carbon stock change as report in Table 6.22 of Section 6.4.1 in Chapter VI. Additional summation of three components: upgrade or degrade carbon, carbon loss by deforestation, and carbon gain, equal carbon stock change. Likewise, distribution of carbon change map provides degree of carbon change in each components as quantitative information. In case of carbon upgrade or degrade, the high value (+ sign) shows the maximum carbon upgrade at pixel level but the low value (- sign) shows the maximum carbon degrade at pixel level. If pixel value equal zero, it means no carbon upgrade or degrade at that pixel. Likewise, in case of carbon loss, it shows degree of deforestation within minimum and maximum range (- sign). On contrary, in case of carbon gain, it show degree of regrowth within minimum and maximum range (+ sign). From this interpretation of distribution of carbon change map, it can be observed that degree of carbon change in three components in each period is directly related with transitional change matrix between forest area (dense and moderate dry evergreen forest, mixed deciduous forest and Eucalyptus plantation) and non-forest area of two dates with carbon stock value at pixel level. The difference image value between date

1 (e.g. 1995) and date 2 (e.g. 2000) in both forest areas with plus sign (+) is upgraded carbon stock while the difference image value between date 2 (e.g. 2000) and date 1 (e.g. 1995) in forest area with minus sign (-) is degraded carbon stock. Meanwhile, if the forest area of date 1 (e.g. 1995) is converted to non-forest area in date 2 (e.g. 2000), the difference image value show minus sign (-). This is deforestation area. In opposite, if the non-forest area of date 1 (e.g. 1995) is regenerated to forest area in date 2 (e.g. 2000), the difference image value show plus sign (+).This is regrowth area.

Table 7.1 Quantity of carbon stock change in three major components.

Year	**Carbon stock change**	**Component of carbon stock change (in tons)**		
		Upgrade or Degrade carbon	**Carbon loss by deforestation**	**Carbon gain by regrowth**
1995-2000	20,334.30	17,934.62	-34,806.94	37,206.62
2000-2005	17,918.68	-29,990.20	-26,080.64	73,989.52
2005-2010	38,092.55	28,903.79	-23,258.98	32,447.74
2010-2015	-1,996.60	6,542.41	-26,995.90	18,456.89
2015-2020	-24,375.77	-29,170.01	-5,381.59	10,175.83
2020-2025	18,796.66	16,755.50	-5,846.84	7,888.00
2025-2030	-1,922.97	-8,215.23	-7,508.65	13,800.91
2030-2035	12,682.76	15,920.75	-9,915.78	6,677.79
Balance	**79,529.61**	**18,681.63**	**-139,795.30**	**200,643.30**

These information directly relates with carbon sink and emission in each period. In case of the degraded forest and deforestation areas, they will release carbon while in case of the upgraded forest and regrowth areas, they will enhance carbon sink. So, this interpretation can be quantified in term of carbon sink and emission as summary in Table 7.2 and Figure 7.3.



1995 - 2000 2000-2005

2005-2010 2010-2015

Figure 7.1 Carbon stock change between 1995 and 2015 using forest type and plantation AGB models.

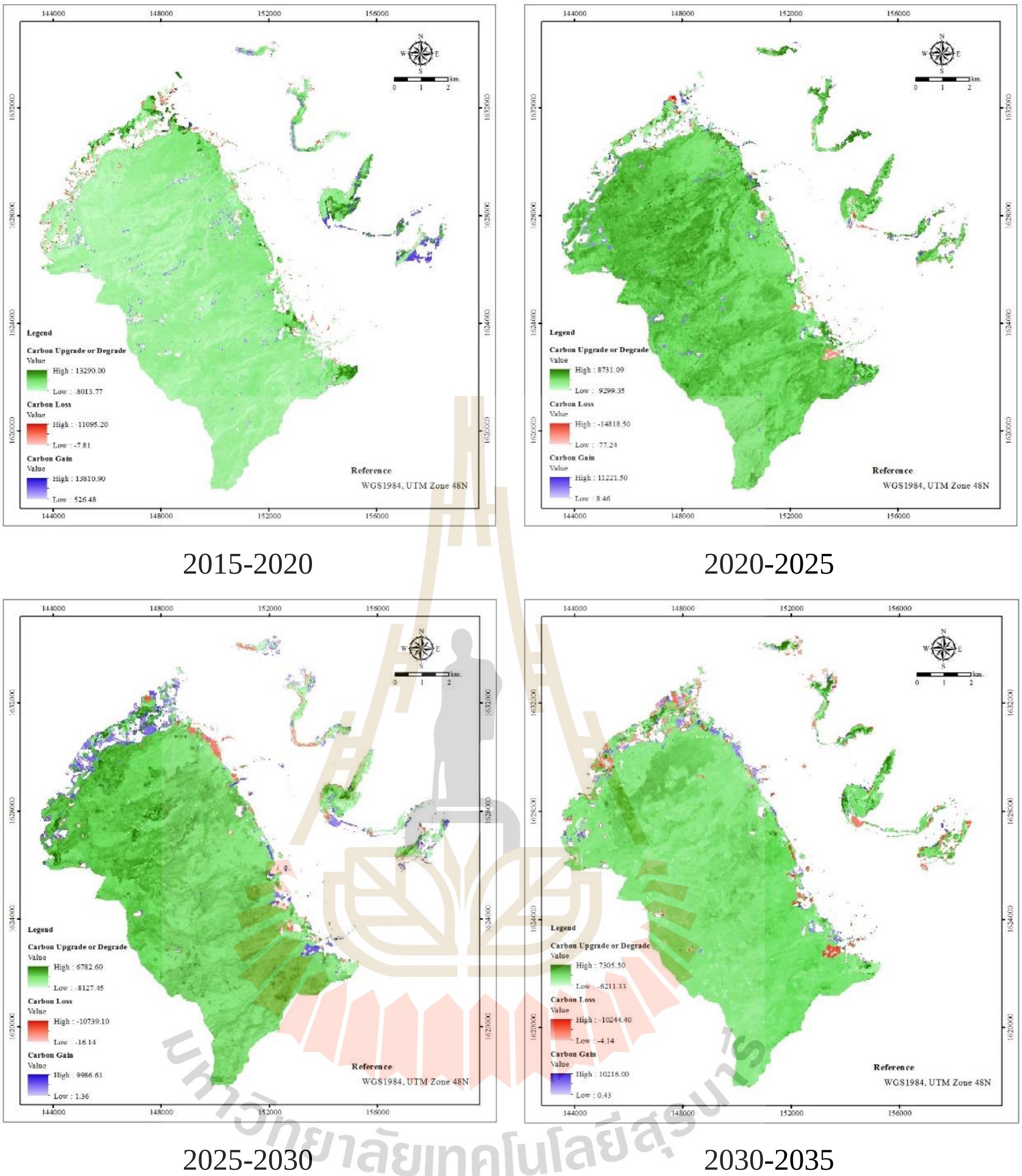


Figure 7.2 Carbon stock change between 2015 and 2035 using forest type and plantation AGB model.

Table 7.2 Carbon sink and emission in three major components using forest type and plantation AGB models.

Periods	Carbon stock change	Carbon stock in Ton			
		Carbon sink		Carbon emission	
		Upgrade forest area	Regrowth area	Degraded forest area	Deforestation area
1995-2000	20,334.30	31,035.25	37,206.62	-13,100.63	-34,806.94
2000-2005	17,918.68	15,992.21	73,989.52	-45,982.40	-26,080.65
2005-2010	38,092.55	52,077.93	32,447.74	-23,174.15	-23,258.97
2010-2015	-1,996.60	31,736.20	18,456.89	-25,193.78	-26,995.91
2015-2020	-24,375.77	33,235.29	10,175.83	-62,405.30	-5,381.59
2020-2025	18,796.66	32,246.10	7,888.00	-15,490.60	-5,846.84
2025-2030	-1,922.97	21,417.80	13,800.91	-29,633.03	-7,508.65
2030-2035	12,682.76	26,651.52	6,677.79	-10,730.78	-9,915.77
Balance	**79,529.71**	**244,392.30**	**200,643.30**	**-225,710.67**	**-139,795.32**

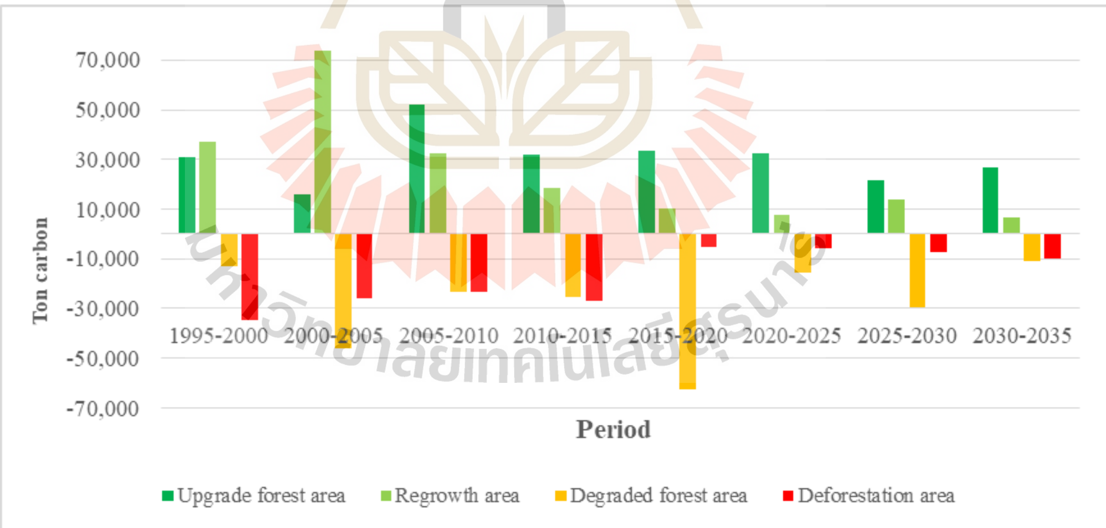


Figure 7.3 Carbon sink and carbon emission in 5 years period between 1995 using forest type and plantation AGB model.

As a result, it reveals that during 1995 and 2035 total stock in natural forest and plantation increases (gain) about 79,529.61 ton. In fact this gained carbon stock was derived by compare between total carbon sink and emission. Herein, carbon sink in these period is 445,035.60 ton that consists of upgraded forest carbon (244,392.30 ton) and carbon from regrowth (200,643.30 ton). In opposite, carbon emission in these period is 365,505.99 ton that consists of emission carbon from degraded forest (225,710.67 ton) and emission carbon from deforestation (139,795.32 ton). There balancing of carbon sink and emission as gained carbon stock in in natural forest and plantation between 1995 and 2035 is 79,529.61 ton. The balancing of carbon sink and emission in each period is summarized in Table 7.2 and displayed in Figure 7.3.

The derived carbon emission from degraded forest area and deforestation are applied for FREL baseline for REDD mechanism implementation.

7.1.2 Carbon emission assessment based on forest AGB model

The quantity of carbon change in three components based on forest AGB model is summarized in Table 7.3 and distribution of carbon change in each 5 years period is presented in Figures 7.4 to 7.5. As a result, it can be observed that the summation of three components equals carbon stock change as report in Table 6.24 of Section 6.4.2 in Chapter VI. The distribution of carbon change map provides degree of carbon change in three components in each period is also directly related with transitional change matrix between forest area and non-forest area of two dates with carbon stock value at pixel level as explained in details in the previous section.

Table 7.3 Quantity of carbon stock change in three major components based on forest AGB model.

Year	Carbon stock change	Component of carbon stock change (in tons)		
		Upgrade or Degrade carbon	Carbon loss by deforestation	Carbon gain by regrowth
1995-2000	19,646.26	17,641.41	-33,611.81	35,616.66
2000-2005	19,739.81	-29,071.68	-25,913.86	74,725.35
2005-2010	28,938.77	18,260.48	-20,973.47	31,651.76
2010-2015	8,196.90	12,007.81	-22,685.76	18,874.85
2015-2020	-34,875.43	-34,588.22	-4,227.46	3,940.25
2020-2025	8,095.86	6,307.79	-5,189.47	6,977.54
2025-2030	12,803.47	2,109.50	-5,748.99	16,442.96
2030-2035	-3,663.90	815.21	-12,220.54	7,741.43
Balance	**58,881.74**	**-6,517.70**	**-130,571.36**	**195,970.80**

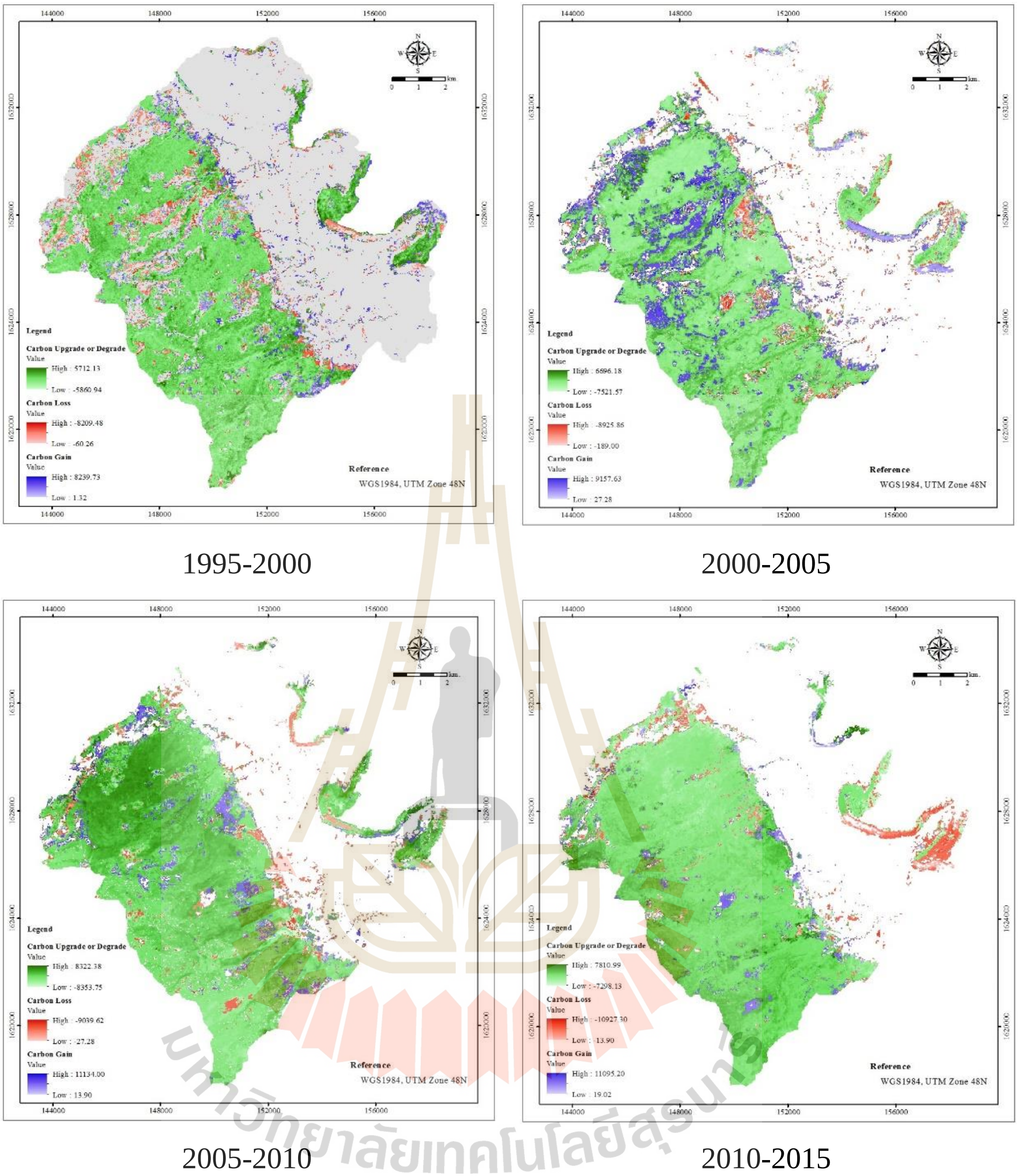


Figure 7.4 Carbon stock change between 1995 and 2015 based on forest AGB model.

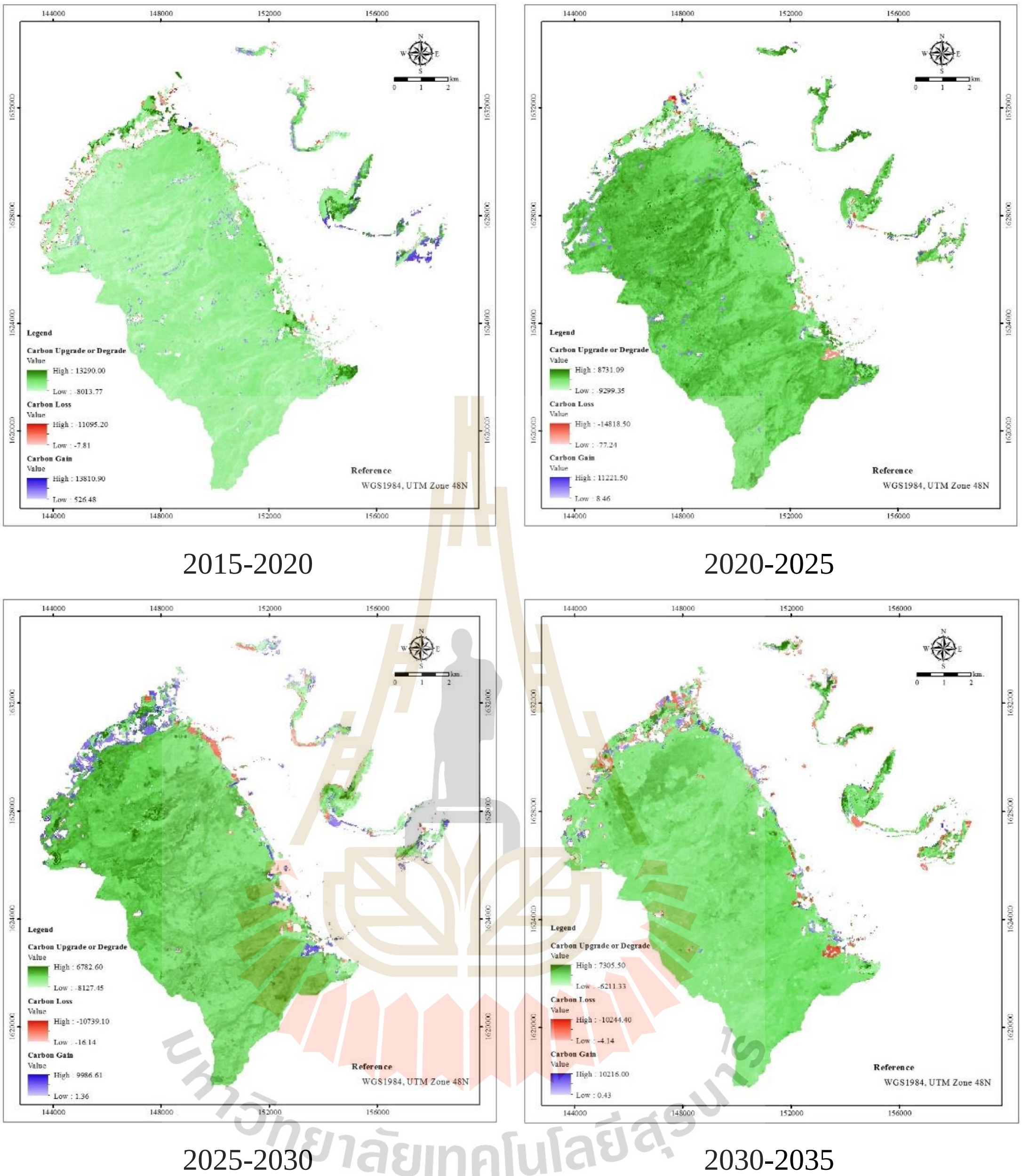


Figure 7.5 Carbon stock change between 2015 and 2035 based on forest AGB model.

These information directly relates with carbon sink and emission in each period. In case of the degraded forest and deforestation areas, they will release carbon while in case of the upgraded forest and regrowth areas, they will enhance carbon sink. So, this interpretation can be quantified in term of carbon sink and emission in detail as summary in Table 7.4 and Figure 7.6.

As a result, it reveals that during 1995 and 2035 total stock in forest area increases (gain) about 58,881.74 ton. In fact this gained carbon stock was derived by compare between total carbon sink and emission. Herein, carbon sink in these period is 396,264.11 ton that consists of upgraded forest carbon (200,293.31 ton) and carbon from regrowth (195,970.80 ton). In opposite, carbon emission in these period is 337,382.37 ton that consists of emission carbon from degraded forest (206,811.03 ton) and emission carbon from deforestation (130,571.34 ton). There balancing of carbon sink and emission as gained carbon stock in forest area between 1995 and 2035 is 58,881.74 ton. The balancing of carbon sink and emission in each period is summarized in Table 7.4 and displayed in Figure 7.6.

Similar to the previous section, the derived carbon emission from degraded forest area and deforestation are applied for FREL baseline for REDD mechanism implementation.

Table 7.4 Carbon sink and emission in three major components using forest AGB model.

Periods	Carbon stock change	Carbon stock in Ton			
		Carbon sink		Carbon emission	
		Upgrade forest area	Regrowth area	Degraded forest area	Deforestation area
1995-2000	19,646.26	31,318.60	35,616.66	-13,677.19	-33,611.81
2000-2005	19,739.81	20,459.48	74,725.35	-49,531.16	-25,913.86
2005-2010	28,938.77	51,757.32	31,651.76	-33,496.84	-20,973.47
2010-2015	8,196.90	37,856.17	18,874.85	-25,848.35	-22,685.77
2015-2020	-34,875.43	35,646.31	3,940.25	-70,234.54	-4,227.45
2020-2025	8,095.86	15,989.50	6,977.54	-9,681.72	-5,189.46
2025-2030	12,803.47	5,213.26	16,442.96	-3,103.76	-5,748.99
2030-2035	-3,663.90	2,052.67	7,741.43	-1,237.47	-12,220.53
Balance	**58,881.74**	**200,293.31**	**195,970.80**	**-206,811.03**	**-130,571.34**

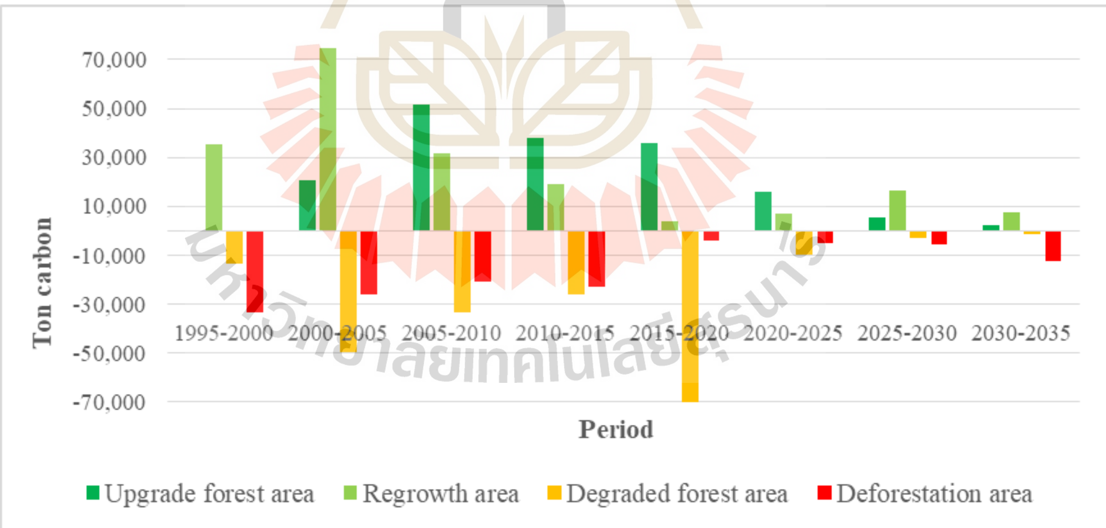


Figure 7.6 Carbon sink and carbon emission in 5 years period between 1995 using forest AGB model.

7.2 FREL baseline for REDD mechanism implementation

Results of FREL baseline for REDD mechanism implementation are here separately described and discussed according to the derived carbon emission based on forest type and plantation AGB models and forest AGB model.

In practice, FREL baseline for REDD mechanism implementation involves four main steps: (1) Reference time period identification (2) FREL baseline establishment (3) Carbon emission trend REDD mechanism implementation and (4) Recommendation for REDD participation. Herein, two methods of FREL construction including linear trend extrapolation and historical average method are explained and discussed.

7.2.1 FREL establishment for REDD implementation based on forest type and plantation AGB models

7.2.1.1 Reference time period identification

Under linear trend extrapolation and historical average methods, carbon emission from historical and recent data from four period between 1995 and 2015 is compared to select reference time period that represents the highest period of carbon emission (Figure 7.7). As a result, the 2000-2005 period is chosen as reference time period of the study area. Carbon emission in this period is 72,063.05 ton.

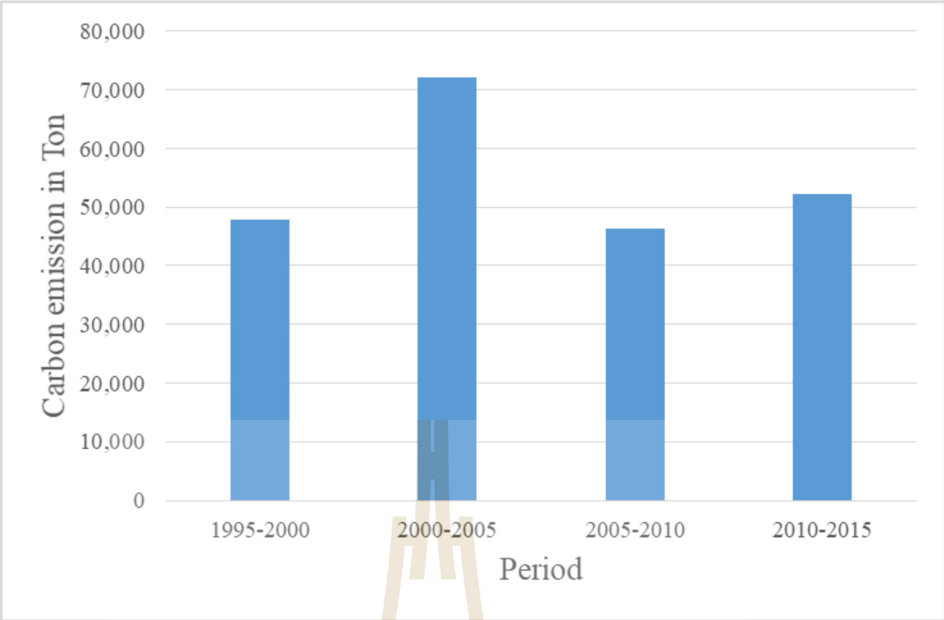


Figure 7.7 Comparison of carbon emission for highest period identification.

7.2.1.2 FREL baseline establishment

To establishment FREL baseline, linear trend extrapolation method applies simple linear analysis to construct linear trend and chosen as FREL baseline as shown in Figure 7.8. The constructed linear trend line provides R^2 of 0.0194. The simple linear equation of trend line is:

$$Y = -1278.4(X) + 5784 \tag{7.1}$$

Where *Y* is carbon emission in Ton and *X* is period of time.

Meanwhile, historical average method, carbon emission in 4 periods between 1995 and 2015 are averaged and plotted as FREL baseline (Figure 7.9). Average value of carbon emission is 54,648.36 ton.

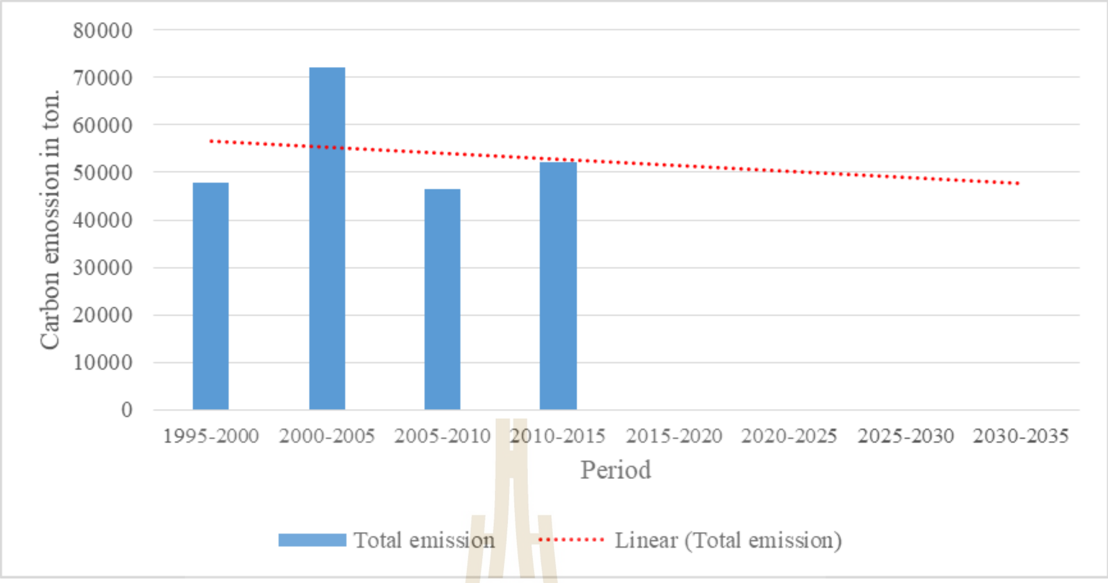


Figure 7.8 FREL baseline using linear trend extrapolation method.

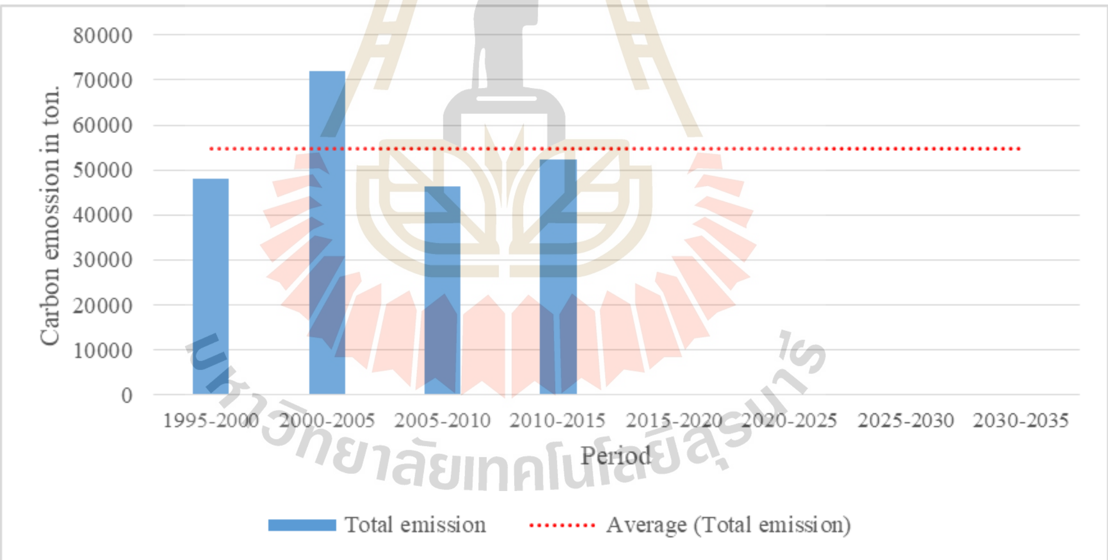


Figure 7.9 FREL baseline using historical average method.

7.2.1.3 Carbon emission trend for REDD mechanism implementation

Under linear trend extrapolation method, predicted carbon emission during 2015 to 2035, which is simulated based on predicted forest types and forest plantation using CA-Markov and optimum AGB of forest type and plantation, are plotted over FREL baseline for REDD implementation (Figure 7.10). The predicted carbon emission during 2020 and 2035 is an additional support information for decision maker to participate in REDD program. In principle, if the predicted carbon emission is higher trend line, the implementation of REDD mechanism is not recommended.

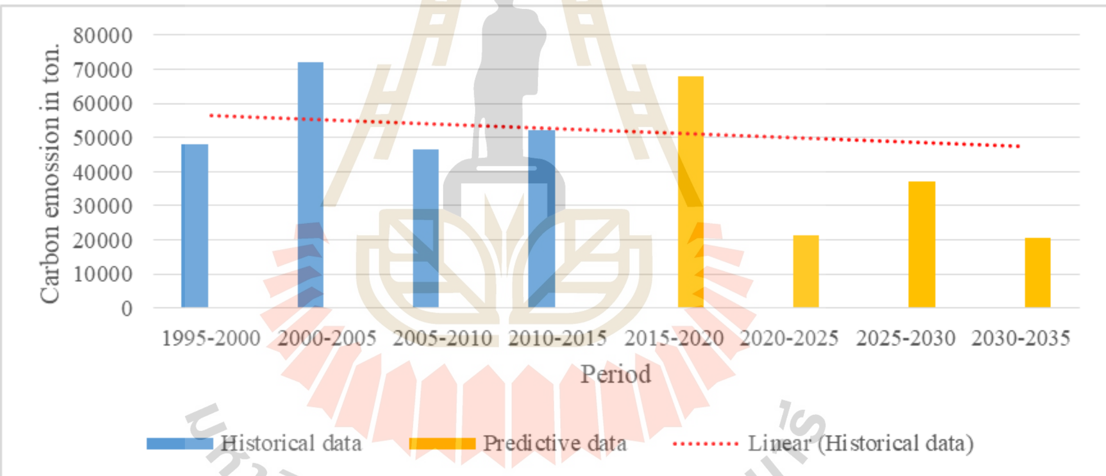


Figure 7.10 Predicted carbon emission between 2020 and 2035 and FRL baseline for REDD implementation under linear trend extrapolation method.

Likewise, predicted carbon emission during 2020 to 2035 are also plotted over FREL baseline under historical average method as a result shown in Figure 7.11. The predicted carbon emission during 2020 and 2035 is an additional support information for decision maker to participate in REDD program as same as linear trend extrapolation method.

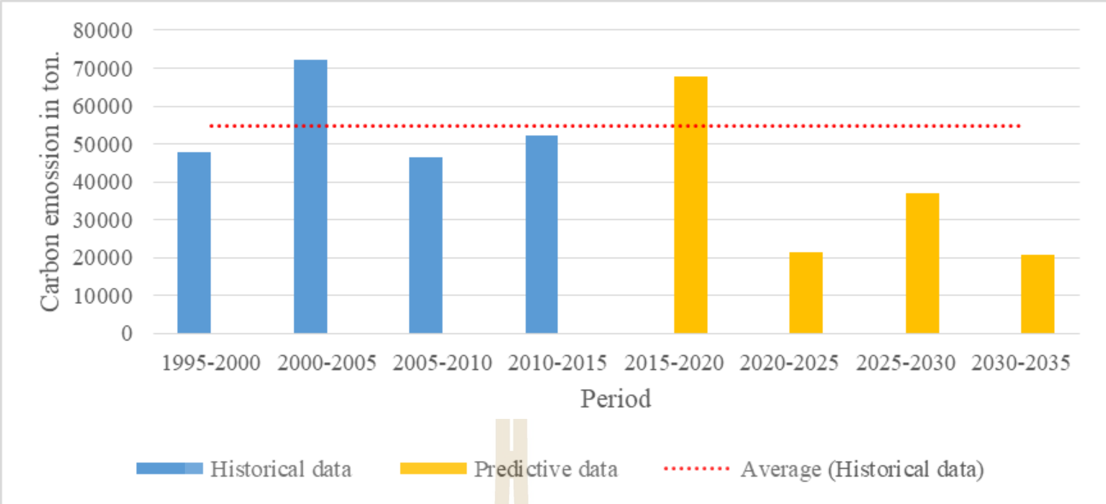


Figure 7.11 Predicted carbon emission between 2020 and 2035 and FRL baseline for REDD implementation under historical average method.

7.2.1.4 Recommendation for REDD participation

Based on the results of linear trend extrapolation and historical average methods, Government may propose the study area as one of candidate area under REDD mechanism. Because carbon emission after 2020 tends to decrease. In addition, it was found that carbon emission in the study during 2020-2035 tends to decrease according to the extrapolation of trend line by simple linear analysis (Equation 7.1) as summary in Table 7.5. However, basic information of forest classification in the study should be revised.

Table 7.5 Predicted carbon emission based on the extrapolation of trend line.

Period	Predict carbon emission by trend line (Eq. 7.1) in Ton
2015-2020	51,454
2020-2025	50,176
2025-2030	48,898
2030-2035	47,620

7.2.2 FRL establishment for REDD implementation based on forest AGB model

Like section 7.2.1, results of FREL baseline for REDD mechanism implementation based on forest AGB model are here divided into 4 parts include (1) Reference time period identification (2) FREL baseline establishment (3) Carbon emission trend REDD mechanism implementation and (4) Recommendation for REDD participation.

7.2.2.1 Reference time period identification

The highest period of carbon emission between 1995 and 2015 that is chosen as reference time period under linear trend extrapolation and historical average methods is 2000-2005 period (Figure 7.12). Carbon which is emitted from degraded forest and deforestation in the study is 75,445.02 ton.

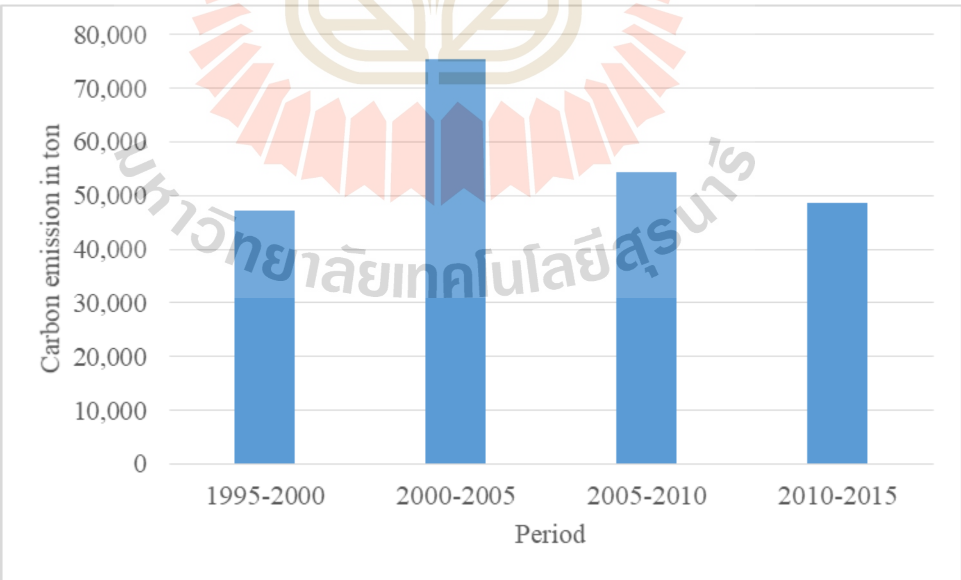


Figure 7.12 Comparison of carbon emission for highest period identification.

7.2.2.2 FREL baseline establishment

Under linear trend extrapolation method, simple linear analysis is applied to extrapolate trend line and chosen as FREL baseline as shown in Figure 7.13. The constructed linear trend line provide R^2 of 0.0291. The simple linear equation of trend line is:

$$Y = -1723.9(X) + 60744 \quad (7.2)$$

Where Y is carbon emission in Ton and X is period of time.

At the same time, average carbon emission with value of 56,434.60 ton in 4 periods between 1995 and 2015 is plotted as FREL baseline as shown in Figure 7.14.

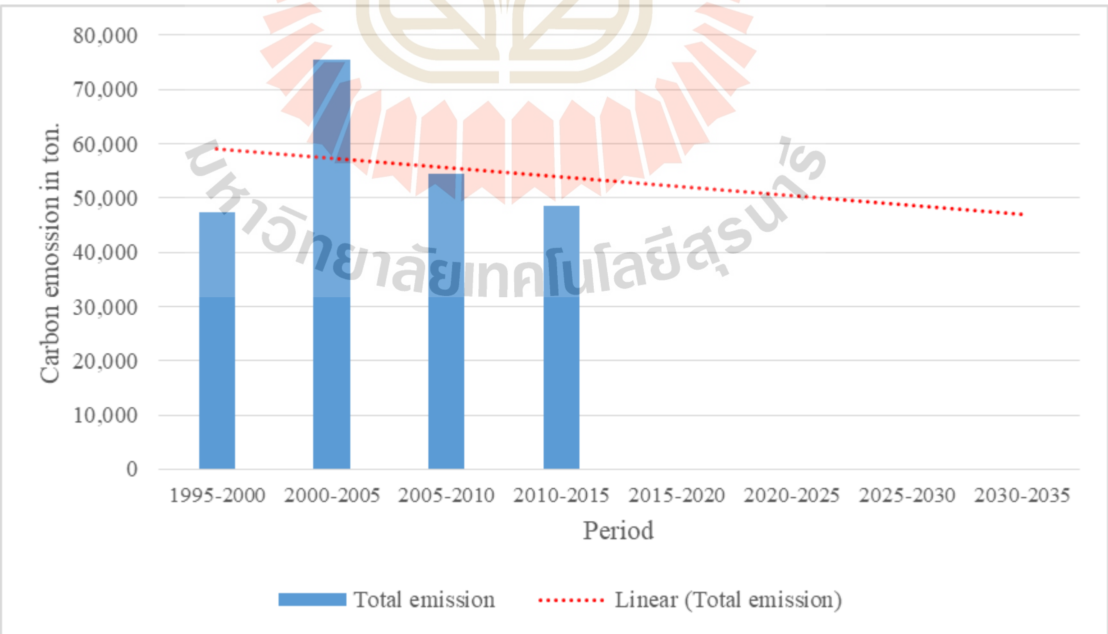


Figure 7.13 FREL baseline under linear trend extrapolation method.

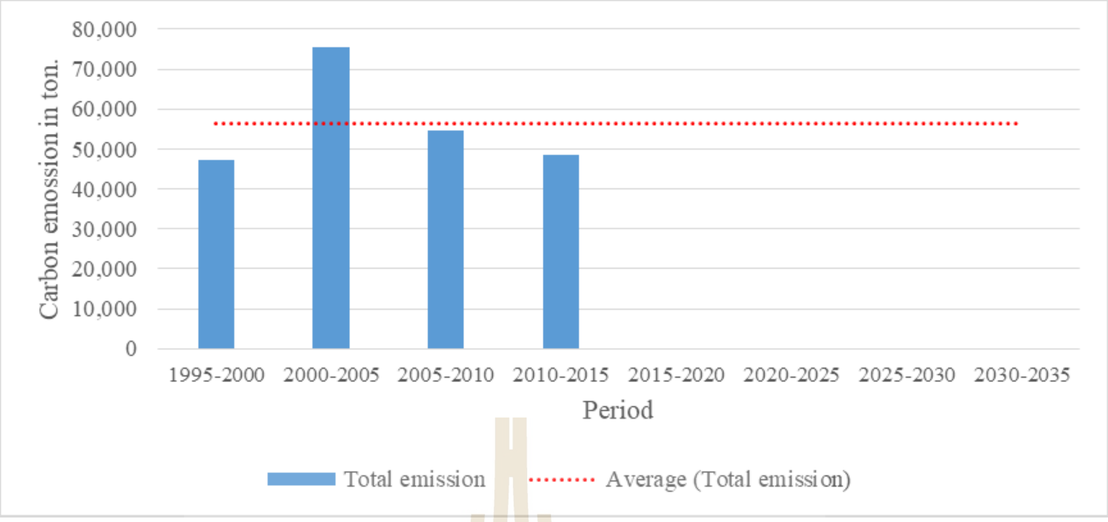


Figure 7.14 FREL baseline under historical average method.

7.2.2.3 Carbon emission trend for REDD mechanism implementation

The predicted carbon emission during 2015 to 2035, which is simulated based on predicted forest types and forest plantation using CA-Markov and optimum AGB of forest area, are plotted with FREL baseline of linear trend extrapolation and historical average methods as result shown in Figures 7.15 and 7.16, respectively. The predicted carbon emission during 2020 and 2035 is an additional support information for decision maker to participate in REDD program.

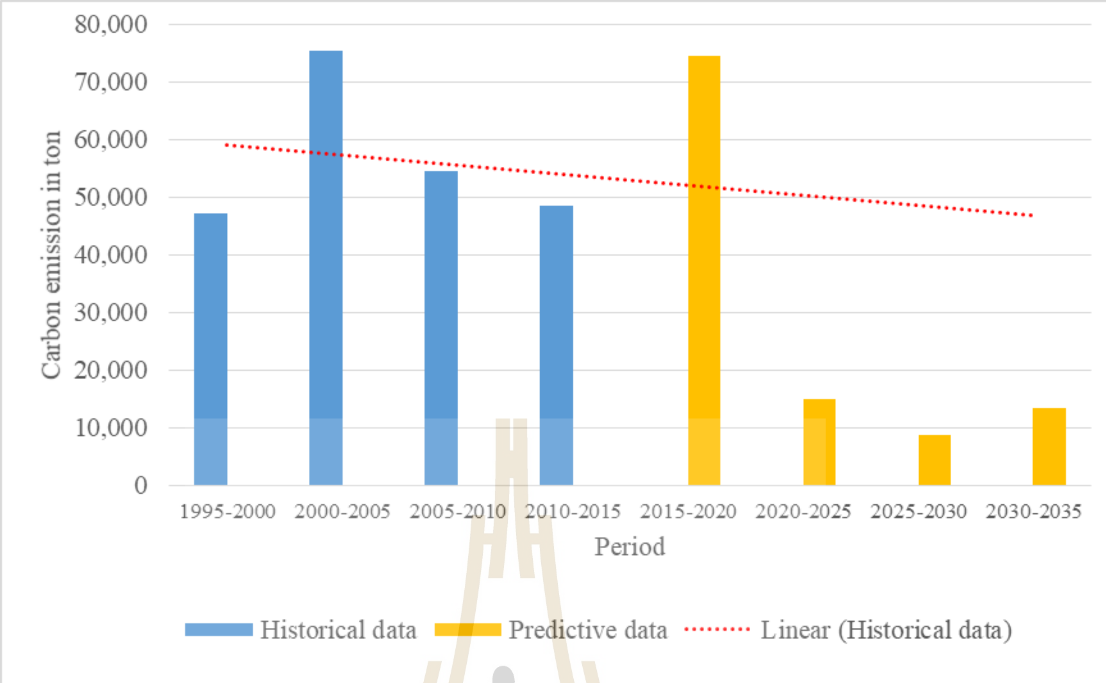


Figure 7.15 Predicted carbon emission between 2020 and 2035 and FRL baseline for REDD implementation under linear trend extrapolation method.

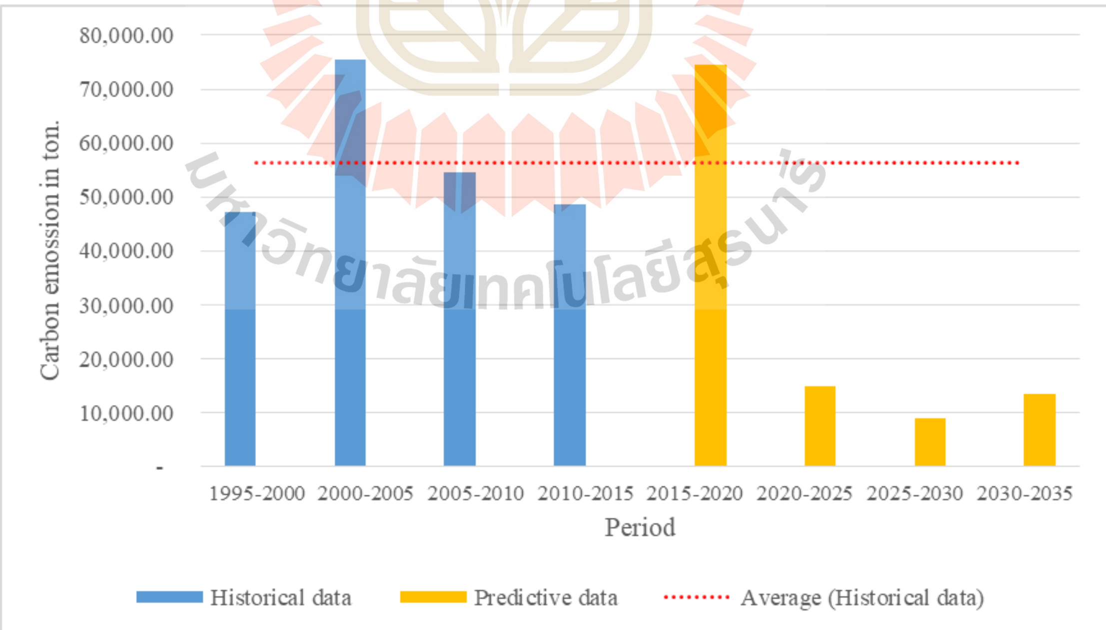


Figure 7.16 Predicted carbon emission between 2020 and 2035 and FRL baseline for REDD implementation under historical average method.

7.2.2.4 Recommendation for REDD participation

According to results of linear trend extrapolation and historical average methods, Government may propose the study area as one of candidate area for REDD participation since carbon emission after 2020 tends to decrease.

7.3 REDD implementation using CI reference level method

In case of CI reference level method for REDD implementation, two required datasets about deforestation are deforestation rate in the study area as primary dataset for reference level establishment and deforestation rate of the country (Tables 7.6 and 7.7) The average of percent of deforestation rate in the study area between 1995 and 2035 (0.2255%) and the country between 2000 and 2005 (2.1512%) is here applied to calculate a midway for establishment a payment calculation baseline. In this exercise, a payment calculation baseline of study area is 1.1883%. Meanwhile, a benchmark level of carbon emissions that is set up according to the highest deforestation rate in 2015 is 0.4093% and the maximum deforestation rate of 0.50% as threshold value is here set up for testing the CI reference level method. The range between benchmark level and threshold value is applied for payment using a sliding scale between midway point at level of 1.1883% and benchmark level of 0.4093%.

If deforestation rate exceeds the benchmark level in any given year, payments are reduced on a sliding scale, up to a maximum deforestation rate as threshold value (0.5%), at this point, there are no payments made.

Table 7.6 Basic data of forest area in the study area and deforestation rate.

Year	Area in sq. km			
	Forest area	**Deforestation area**	**Deforestation rate**	**% of deforestation rate***
1995	66.64			
2000	66.78	0.1400	0.0350	0.0525
2005	75.77	8.9900	2.2475	3.3655
2010	77.57	1.8000	0.4500	0.5939
2015	76.3	-1.2700	-0.3175	-0.4093
2020	75.95	-0.3500	-0.0875	-0.1147
2025	76.58	0.6300	0.1575	0.2074
2030	79.24	2.6600	0.6650	0.8684
2035	78.22	-1.0200	-0.2550	-0.3218
Average of percent of deforestation rate				**0.2255**

Note * Percent of deforestation rate is deforestation rate divide by forest area in the previous year.

Table 7.7 Basic data of existing forest area of Thailand and deforestation rate.

Year	Area in sq. km			
	Forest area	**Deforestation area**	**Deforestation rate**	**% of deforestation rate***
2000	170,110.78			
2004	167,590.98	-2,519.8000	-629.9500	-0.3703
2005	161,001.30	-6,589.6800	-6,589.6800	-3.9320
Average of percent of deforestation rate				**-2.1512**

Note *Percent of deforestation rate is deforestation rate divide by forest area in the previous year.

Figure 7.17 displays CI's component include benchmark level or FREL baseline, a maximum deforestation rate (threshold value), and payment calculation baseline with its range.

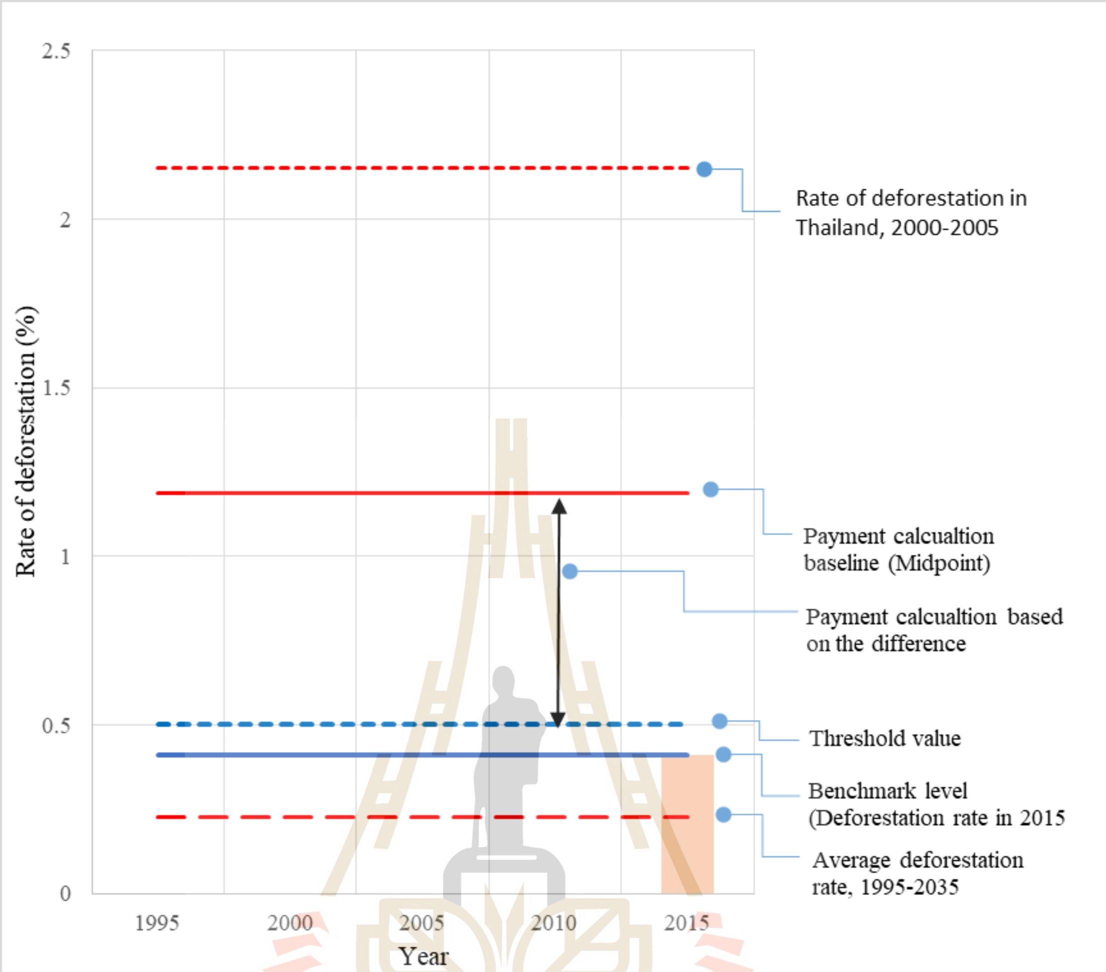


Figure 7.17 Combined incentive component.

In conclusion, CI reference level method as the new emerging approach is suitable for conservation area. However, the implementation of CI requires international fund for supporting the program. The threshold value is here set up for testing the CI reference level approach as an example of Guyana.

CHAPTER VIII

CONCLUSION AND RECOMENDATION

Under this chapter, major results according to objectives of the study, which were reported in Chapters IV to VII, are here separately concluded and recommendations for future research and development are suggested.

8.1 Conclusion

8.1.1 Optimum CART model for forest and land cover classification

An optimum CART model for forest and land cover classification, which applies Blue, Red, NIR, SWIR-1, SWIR-2, SR, NDWI, Wetness and Elevation and Slope to construct a decision tree for forest and land cover classification, can provide overall accuracy of model-based inference statistic at 96.60%. The overall accuracy and Kappa hat coefficient of forest and land cover map in 2015, which was classified using the optimum CART, were 90.69% and 88.45% respectively.

8.1.2 Assessment of forest area and its change

By using optimum CART model and CA-Markov model, dense and moderate dry evergreen forest, where situated in Non-hunting area in mountainous area, tend to increase in the future. Likewise, forest plantation, where locates in buffer zone between natural forest and other land use classes, tends to increase in the future. On contrary, mixed deciduous forest, where distribute over hilly areas in eastern part of the study area, tends to decrease in the future.

Based on change detection analysis between 1995 and 2035, the highest increasing period of forest area occured between 2000 and 2005 and covers area of 8.99 sq. km with annual increasing rate of 1.798 sq.km. In contrast, the highest decreasing period of forest area occurs between 2010 and 2015 and covers area of 1.27 sq. km with annual decreasing rate of 0.254 sq.km.

8.1.3 Optimum AGB estimation model

An optimum AGB estimate model was here developed using linear and non-liner regression analysis based in situ AGB data in 2015 and its influential factors including reflectance value of Landsat data (BLUE, GREEN, RED, NIR, SWIR-1 and SWIR-2) and vegetation indices (SR, NDVI, SAVI, RSR and GREENNESS) and Forest Canopy Density (FCD). The derived optimum AGB estimation model including forest type and plantation models and forest AGB model are as follows:

1. Dense dry evergreen forest: AGB = -7285.594 + (727.455 * NIR)
2. Moderate dry evergreen forest: AGB =2034.169 * Exp(0.022 * FCD)
3. Mixed deciduous forest: AGB = -36619.832 + (119814.747 * NDVI)
4. Eucalyptus plantation: AGB = -122691.980 + (31297.094 * Ln(FCD))
5. Forest area: AGB = -130984.984 + (4317.749 * BLUE) + (6763.098 * RED) + (-2939.615 * NIR) + (-1419.518 * SWIR-1) + (457.167 * SWIR-2) + (27641.683 * SR) + (192522.941 * NDVI) + (-25458.255 * FCD)

8.1.4 AGB estimation and its change

According to results of AGB estimation (1995-2035) using forest type and plantation AGB models, AGB of dense dry evergreen forest gains about 68,797 ton with annual highest increasing rate at 13,362.86 ton during 2005-2010. Likewise, AGB of moderate dry evergreen forest gains about 112,919 ton with annual highest increasing rate at 11,245.79 ton during 1995-2000. In contrast, AGB of mixed deciduous forest losses about 23,289 ton with annual highest decreasing rate at 5,704.49 ton during 2010-2015. In opposite, AGB of Eucalyptus plantation gains about 10,786 ton with annual highest increasing rate at 2,073.32 ton during 2015-2020.

Similarly, according to results of AGB estimation (1995-2035) using forest AGB model, total AGB of forest area gains about 125,280 ton with annual highest increasing rate at 12,314.37 ton during 2005-2010.

8.1.5 Carbon stock assessment and its change

According to results of carbon stock assessment (1995-2035) using forest type and plantation AGB models, carbon stock of dense and moderate dry evergreen forests and Eucalyptus tend to continuously increase in the future while carbon stock of mixed deciduous forest is fluctuate and tends to decrease in the future. However, total gain of carbon stock between 1995 and 2035 is about 79,530 ton.

Likewise, according to results of carbon stock assessment (1995-2035) using forest AGB model, carbon stock gains over forest area between 2010 and 2015 but carbon stock will loss in the future at two periods: 2015-2020 and 2030-2035. However, total carbon stock is gained during whole periods about 58,881.75 tons.

8.1.6 Carbon emission and REDD implementation

Based on AGB estimation forest type and plantation AGB models, it was found that during 1995 and 2035 total stock in natural forest and plantation increases (gain) about 79,529.61 ton. In fact, carbon sink is 445,035.60 ton that consist of upgraded forest carbon (244,392.30 ton) and carbon from regrowth (200,643.30 ton). In opposite, carbon emission is 365,505.99 ton that consist of emission carbon from degraded forest (225,710.67 ton) and emission carbon from deforestation (139,795.32 ton).

Likewise, based on AGB estimation forest AGB model, it reveals that during 1995 and 2035 total stock in forest area increases (gain) about 58,881.74 ton. In detail, carbon sink is 396,264.11 ton that consists of upgraded forest carbon (200,293.31 ton) and carbon from regrowth (195,970.80 ton). In opposite, carbon emission is 337,382.37 ton that is composed of emission carbon from degraded forest (206,811.03 ton) and emission carbon from deforestation (130,571.34 ton).

These derived carbon emission from degraded forest area and deforestation based on two mentioned approaches are here applied for REDD mechanism implementation using linear trend extrapolation and historical average methods. Based on AGB estimation forest type and plantation AGB models and forest AGB model, 2000-2005 period is chosen as reference time period for both methods with carbon emission of 72,063.05 ton and 75,445.02 ton, respectively. To establishment FREL baseline, linear trend extrapolation method applies simple linear analysis to construct linear trend while historical average method applies average carbon emission during 1995 to 2015. Average carbon emission based on AGB estimation forest type and plantation AGB models and forest AGB model is 54,648.36 ton and 56,434.60 ton, respectively.

By comparison predicted carbon emission between 2020 and 2035 based on AGB estimation forest type and plantation AGB models and forest AGB model as an additional support information for decision maker with FREL baseline of both methods, it suggests that Government may propose the study area as one of candidate area under REDD mechanism. Because carbon emission after 2020 tends to decrease. However, basic information of forest classification in the study should be revised.

In conclusion, it appears that integration of geoinformatics technology with geospatial models can be used as an efficiently tools to extract forest and land cover, to estimate AGB and carbon stock and to assess carbon emission for FREL baseline establishment for REDD mechanism implementation.

8.2 Recommendation

Many objectives were here investigated and implemented, the possibly expected recommendations could be made for further studies as following:

1. It is a time consume to identify an optimum CART model for forest and land cover at acceptance model with overall accuracy and Kappa hat coefficient equal or greater 80 percent. Therefore, a relatively new algorithm such as random forest can be examined for forest and land cover classification. Classification accuracy using random forests is higher than using a single tree approach such as CART (Gislason, Benediktsson and Sveinsson, 2006).

2. Due to the limitation of accessibility in the study area, number of sampling plot for optimum AGB estimation model is limited, so selection of the study area should be carefully considered before the implementation of the project.

3. In this study, Trend Analysis function of MS Excel are applied for creating the future image of Landsat data based on simple linear equation. In fact, the derived output do not necessarily represent a linear relationship with positive or negative trend. Therefore, new approach for simulation/prediction of future image should be more investigated.

4. Nowadays, there are new emerging approaches to FREL/FRL development were adopted in different contexts, including for demonstration activities by countries seeking to take actions to reduce GHG emissions (FAO, 2014). Therefore, researchers who are interest in REDD/REDD+ should be monitor and update the new release of agreement from the UNFCCC Conference of the Parties (COP).

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APPENDICES

APPENDIX A

TRANSITION AREA AND PROBABILITY MATRICES

FOR FOREST AND LAND COVER PREDICTION

Table A.1 Transition area matrix for forest and land cover change between 2010 and 2015.

FLC 2010	FLC 2015										
	DDEF	MDEF	MDF	FPT	DTF	BMB	TaO	PaF	BLA	MLA	Total
DDEF	44650	5415	145	44	20	18	0	12	0	2	**50306**
MDEF	4355	21193	1892	854	1022	306	172	212	2	247	**30255**
MDF	249	1361	2053	637	647	601	21	501	4	427	**6501**
FPT	12	295	797	1652	320	199	43	155	1	422	**3896**
DTF	48	2044	217	320	1255	31	12	251	1	521	**4700**
BMB	95	258	476	158	111	187	27	51	0	314	**1677**
TaO	0	107	58	34	44	6	2996	1429	75	998	**5747**
PaF	0	59	312	139	474	14	1853	25290	2198	6832	**37171**
BLA	0	0	12	1	16	0	103	2675	953	348	**4108**
MLA	14	126	170	284	709	131	1177	7980	872	6099	**17562**
Total	**49423**	**30858**	**6132**	**4123**	**4618**	**1493**	**6404**	**38556**	**4106**	**16210**	**161923**

Table A.2 Transition probability matrix for forest and land cover change between 2010 and 2015.

FLC 2010	FLC 2015										
	DDEF	MDEF	MDF	FPT	DTF	BMB	TaO	PaF	BLA	MLA	Total
DDEF	0.888	0.108	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	**1.00**
MDEF	0.144	0.701	0.063	0.028	0.034	0.010	0.006	0.007	0.000	0.008	**1.00**
MDF	0.038	0.209	0.316	0.098	0.100	0.092	0.003	0.077	0.001	0.066	**1.00**
FPT	0.003	0.076	0.204	0.424	0.082	0.051	0.011	0.040	0.000	0.108	**1.00**
DTF	0.010	0.435	0.046	0.068	0.267	0.007	0.003	0.054	0.000	0.111	**1.00**
BMB	0.056	0.154	0.284	0.094	0.066	0.111	0.016	0.030	0.000	0.188	**1.00**
TaO	0.000	0.019	0.010	0.006	0.008	0.001	0.521	0.249	0.013	0.174	**1.00**
PaF	0.000	0.002	0.008	0.004	0.013	0.000	0.050	0.680	0.059	0.184	**1.00**
BLA	0.000	0.000	0.003	0.000	0.004	0.000	0.025	0.651	0.232	0.085	**1.00**
MLA	0.001	0.007	0.010	0.016	0.040	0.007	0.067	0.454	0.050	0.347	**1.00**
Total	**1.14**	**1.71**	**0.95**	**0.74**	**0.61**	**0.28**	**0.70**	**2.24**	**0.36**	**1.27**	**10.00**

Table A.3 Transition area matrix for forest and land cover change between 2005 and 2015.

FLC 2005	FLC 2015										
	DDEF	MDEF	MDF	FPT	DTF	BMB	TaO	PaF	BLA	MLA	Total
DDEF	44298	5358	388	93	68	67	0	15	0	19	**50306**
MDEF	5880	19042	1712	1160	1056	208	502	287	3	402	**30252**
MDF	67	1937	1914	345	503	711	0	586	18	419	**6500**
FPT	25	381	578	1562	509	31	29	233	3	546	**3897**
DTF	69	3034	145	227	836	14	30	165	1	178	**4699**
BMB	0	7	681	0	67	135	15	165	37	569	**1676**
TaO	0	170	137	200	86	25	2521	1268	59	1281	**5747**
PaF	6	216	640	197	523	57	1909	23817	2575	7230	**37170**
BLA	0	1	12	1	5	0	198	2516	914	460	**4107**
MLA	7	190	157	466	769	229	1471	6566	304	7405	**17564**
Total	**50352**	**30336**	**6364**	**4251**	**4422**	**1477**	**6675**	**35618**	**3914**	**18509**	**161918**

Table A.4 Transition probability matrix for forest and land cover change between 2005 and 2015.

FLC 2005	FLC 2015										
	DDEF	MDEF	MDF	FPT	DTF	BMB	TaO	PaF	BLA	MLA	Total
DDEF	0.881	0.107	0.008	0.002	0.001	0.001	0.000	0.000	0.000	0.000	**1.00**
MDEF	0.194	0.629	0.057	0.038	0.035	0.007	0.017	0.010	0.000	0.013	**1.00**
MDF	0.010	0.298	0.294	0.053	0.077	0.109	0.000	0.090	0.003	0.064	**1.00**
FPT	0.007	0.098	0.148	0.401	0.131	0.008	0.008	0.060	0.001	0.140	**1.00**
DTF	0.015	0.646	0.031	0.048	0.178	0.003	0.006	0.035	0.000	0.038	**1.00**
BMB	0.000	0.005	0.406	0.000	0.040	0.080	0.009	0.098	0.022	0.339	**1.00**
TaO	0.000	0.030	0.024	0.035	0.015	0.004	0.439	0.221	0.010	0.223	**1.00**
PaF	0.000	0.006	0.017	0.005	0.014	0.002	0.051	0.641	0.069	0.195	**1.00**
BLA	0.000	0.000	0.003	0.000	0.001	0.000	0.048	0.613	0.222	0.112	**1.00**
MLA	0.000	0.011	0.009	0.027	0.044	0.013	0.084	0.374	0.017	0.422	**1.00**
Total	**1.11**	**1.83**	**1.00**	**0.61**	**0.54**	**0.23**	**0.66**	**2.14**	**0.35**	**1.55**	**10.00**

Table A.5 Transition area matrix for forest and land cover change between 2000 and 2015.

FLC 2000	FLC 2015										
	DDEF	**MDEF**	**MDF**	**FPT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Total**
DDEF	42019	4819	1863	713	136	333	10	109	24	279	**50305**
MDEF	9111	14358	1851	1145	785	259	444	962	31	1309	**30255**
MDF	732	3673	587	320	593	42	2	385	12	153	**6499**
FPT	10	210	554	802	365	139	17	734	31	1035	**3897**
DTF	597	2639	241	131	411	81	70	255	6	268	**4699**
BMB	102	521	156	69	211	5	11	314	17	271	**1677**
TaO	0	322	243	526	209	59	1571	1449	136	1233	**5748**
PaF	56	2866	1804	509	1087	1237	1818	19441	1989	6365	**37172**
BLA	0	1	20	6	18	1	185	2535	986	357	**4109**
MLA	89	463	115	153	422	14	1242	9603	857	4605	**17563**
Total	**52716**	**29872**	**7434**	**4374**	**4237**	**2170**	**5370**	**35787**	**4089**	**15875**	**161924**

Table A.6 Transition probability matrix for forest and land cover change between 2000 and 2015.

FLC 2000	FLC 2015										
	DDEF	**MDEF**	**MDF**	**FPT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Total**
DDEF	0.835	0.096	0.037	0.014	0.003	0.007	0.000	0.002	0.001	0.006	**1.00**
MDEF	0.301	0.475	0.061	0.038	0.026	0.009	0.015	0.032	0.001	0.043	**1.00**
MDF	0.113	0.565	0.090	0.049	0.091	0.006	0.000	0.059	0.002	0.024	**1.00**
FPT	0.003	0.054	0.142	0.206	0.094	0.036	0.004	0.188	0.008	0.266	**1.00**
DTF	0.127	0.562	0.051	0.028	0.088	0.017	0.015	0.054	0.001	0.057	**1.00**
BMB	0.061	0.311	0.093	0.041	0.126	0.003	0.006	0.187	0.010	0.162	**1.00**
TaO	0.000	0.056	0.042	0.092	0.036	0.010	0.273	0.252	0.024	0.215	**1.00**
PaF	0.002	0.077	0.049	0.014	0.029	0.033	0.049	0.523	0.054	0.171	**1.00**
BLA	0.000	0.000	0.005	0.001	0.004	0.000	0.045	0.617	0.240	0.087	**1.00**
MLA	0.005	0.026	0.007	0.009	0.024	0.001	0.071	0.547	0.049	0.262	**1.00**
Total	**1.45**	**2.22**	**0.58**	**0.49**	**0.52**	**0.12**	**0.48**	**2.46**	**0.39**	**1.29**	**10.00**

Table A.7 Transition area matrix for forest and land cover change between 1995 and 2015.

FLC 1995	FLC 2015										
	DDEF	**MDEF**	**MDF**	**FPT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Total**
DDEF	43422	5405	807	164	186	175	0	60	0	87	**50306**
MDEF	8014	15510	2186	1292	877	253	10	852	636	624	**30254**
MDF	316	2963	1340	415	470	301	29	234	3	429	**6500**
FPT	24	474	772	1037	284	114	21	706	24	441	**3897**
DTF	598	2616	161	139	451	5	11	277	131	311	**4700**
BMB	0	5	185	0	5	789	32	419	7	235	**1677**
TaO	0	14	37	41	60	0	581	437	232	2707	**4109**
PaF	88	831	270	267	521	237	955	5010	1313	8071	**17563**
BLA	0	89	75	161	104	45	160	1582	1482	2049	**5747**
MLA	51	1632	1034	775	945	222	2216	7577	1567	21153	**37172**
Total	**52513**	**29539**	**6867**	**4291**	**3903**	**2141**	**4015**	**17154**	**5395**	**36107**	**161925**

Table A.8 Transition probability matrix for forest and land cover change between 1995 and 2015.

FLC 1995	FLC 2015										
	DDEF	**MDEF**	**MDF**	**FPT**	**DTF**	**BMB**	**TaO**	**PaF**	**BLA**	**MLA**	**Total**
DDEF	0.863	0.107	0.016	0.003	0.004	0.004	0.000	0.002	0.000	0.001	**1.00**
MDEF	0.265	0.513	0.072	0.043	0.029	0.008	0.021	0.021	0.000	0.028	**1.00**
MDF	0.049	0.456	0.206	0.064	0.072	0.046	0.000	0.066	0.005	0.036	**1.00**
FPT	0.006	0.122	0.198	0.266	0.073	0.029	0.006	0.113	0.005	0.181	**1.00**
DTF	0.127	0.557	0.034	0.030	0.096	0.001	0.028	0.066	0.002	0.059	**1.00**
BMB	0.000	0.003	0.110	0.000	0.003	0.470	0.005	0.140	0.019	0.250	**1.00**
TaO	0.000	0.016	0.013	0.028	0.018	0.008	0.258	0.357	0.028	0.275	**1.00**
PaF	0.001	0.044	0.028	0.021	0.025	0.006	0.042	0.569	0.060	0.204	**1.00**
BLA	0.000	0.003	0.009	0.010	0.015	0.000	0.056	0.659	0.142	0.106	**1.00**
MLA	0.005	0.047	0.015	0.015	0.030	0.014	0.075	0.460	0.054	0.285	**1.00**
Total	**1.32**	**1.87**	**0.70**	**0.48**	**0.36**	**0.59**	**0.49**	**2.45**	**0.32**	**1.43**	**10.00**

APPENDIX B

TRANSITIONAL AREA OF FOREST CHANGE

Table B.1 Transitional forest area change matrix between 1995 and 2000.

(Unit: sq. km)

Forest and Land cover	**2000**		
1995	Forest area	Non forest area	**Grand Total**
Forest area	59.38	7.26	**66.64**
Non forest area	7.41	61.94	**69.35**
Grand Total	**66.79**	**69.20**	**135.99**
Area of change (sq. km)	7.41	7.26	
Percent of change (%)	12.48	11.72	
Annual change rate (sq. km)	1.48	1.45	

Table B.2 Transitional forest area change matrix between 2000 and 2005.

(Unit: sq. km)

Forest and Land cover	**2005**		
2000	Forest area	Non forest area	**Grand Total**
Forest area	61.52	5.27	**66.79**
Non forest area	14.24	54.96	**69.20**
Grand Total	**75.76**	**60.22**	**135.99**
Area of change (sq. km)	14.24	5.27	
Percent of change (%)	23.15	9.59	
Annual change rate (sq. km)	2.85	1.05	

Table B.3 Transitional forest area change matrix between 2005 and 2010.

(Unit: sq. km)

Forest and Land cover	**2010**		
2005	Forest area	Non forest area	**Grand Total**
Forest area	71.42	4.34	**75.76**
Non forest area	6.15	54.07	**60.22**
Grand Total	**77.57**	**58.41**	**135.99**
Area of change (sq. km)	6.15	4.34	
Percent of change (%)	8.61	8.03	
Annual change rate (sq. km)	1.23	0.87	

Table B.4 Transitional forest area change matrix between 2010 and 2015.

(Unit: sq. km)

Forest and Land cover	2015		
2010	Forest area	Non forest area	**Grand Total**
Forest area	72.68	4.90	**77.57**
Non forest area	3.62	54.80	**58.41**
Grand Total	**76.30**	**59.69**	**135.99**
Area of change (sq. km)	3.62	4.90	
Percent of change (%)	4.98	8.93	
Annual change rate (sq. km)	0.72	0.98	

Table B.5 Transitional forest area change matrix between 2015 and 2020.

(Unit: sq. km)

Forest and Land cover	2020		
2015	Forest area	Non forest area	**Grand Total**
Forest area	74.99	1.31	**76.30**
Non forest area	0.97	58.72	**59.69**
Grand Total	**75.96**	**60.03**	**135.99**
Area of change (sq. km)	0.97	1.31	
Percent of change (%)	1.29	2.23	
Annual change rate (sq. km)	0.19	0.26	

Table B.6 Transitional forest area change matrix between 2020 and 2025.

(Unit: sq. km)

Forest and Land cover	2025		
2020	Forest area	Non forest area	**Grand Total**
Forest area	74.97	1.00	**75.96**
Non forest area	1.62	58.41	**60.03**
Grand Total	**76.58**	**59.41**	**135.99**
Area of change (sq. km)	1.62	1.00	
Percent of change (%)	2.15	1.70	
Annual change rate (sq. km)	0.32	0.20	

Table B.7 Transitional forest area change matrix between 2025 and 2030.

(Unit: sq. km)

Forest and Land cover	**2030**		
2025	Forest area	Non forest area	**Grand Total**
Forest area	75.41	1.17	**76.58**
Non forest area	3.84	55.57	**59.41**
Grand Total	**79.25**	**56.75**	**135.99**
Area of change (sq. km)	3.84	1.17	
Percent of change (%)	5.09	2.11	
Annual change rate (sq. km)	0.77	0.23	

Table B.8 Transitional forest area change matrix between 2030 and 2035.

(Unit: sq. km)

Forest and Land cover	**2035**		
2030	Forest area	Non forest area	**Grand Total**
Forest area	76.46	2.78	**79.24**
Non forest area	1.76	54.99	**56.75**
Grand Total	**78.22**	**57.77**	**135.99**
Area of change (sq. km)	1.76	2.78	
Percent of change (%)	2.31	5.06	
Annual change rate (sq. km)	0.35	0.56	

APPENDIX C

DETAILS OF FOREST INVENTORY DATA FOR OPTIMUM AGB ESTIMATION MODEL DEVELOPMENT

Table C.1 Detail of DDEF Plot 1. (X: 149806 Y: 1626275, AGB 6,016.29 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	พลอง	*Dipterocarpus tuberculatus* Roxb.	54	17.19	7.60
2	หยอง	-	34	10.82	7.30
3	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	35	11.14	7.30
4	ปีน (ฟีน)	-	34	10.82	6.80
5	พลอง	*Dipterocarpus tuberculatus* Roxb.	67	21.33	9.90
6	พลอง	*Dipterocarpus tuberculatus* Roxb.	48	15.28	8.70
7	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	34	10.82	7.30
8	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	11.30
9	พลอง	*Dipterocarpus tuberculatus* Roxb.	37	11.78	6.30
10	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	49	15.60	7.80
11	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	10.70
12	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.80
13	ปีน (ฟีน)	-	34	10.82	7.30
14	ตะเคียน	*Hopea odorata* Roxb.	72	22.92	9.20
15	ตะเคียน	*Hopea odorata* Roxb.	43	13.69	8.80
16	ตะเคียน	*Hopea odorata* Roxb.	42	13.37	8.80
17	ปีน (ฟีน)	-	45	14.33	8.50
18	ปีน (ฟีน)	-	42	13.37	8.80
19	ตะเคียน	*Hopea odorata* Roxb.	44	14.01	9.30
20	ปีน (ฟีน)	-	39	12.42	7.30
21	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	55	17.51	9.30
22	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	46	14.65	8.90
23	หยอง	-	34	10.82	8.70
24	พลอง	*Dipterocarpus tuberculatus* Roxb.	54	17.19	8.90
25	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	38	12.10	7.30
26	พลอง	*Dipterocarpus tuberculatus* Roxb.	69	21.97	9.80
27	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	49	15.60	8.90
28	พลอง	*Dipterocarpus tuberculatus* Roxb.	53	16.87	9.70
29	พะวา (ส้มโมงป่า)	*Garcinia speciosa* Wall.	42	13.37	7.30
30	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	49	15.60	8.00
31	ตะเคียน	*Hopea odorata* Roxb.	59	18.78	11.30
32	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	8.30
33	ปีน (ฟีน)	-	61	19.42	8.70
34	พลับพลา	*Microcos paniculata* L.	84	26.74	12.70
35	พะวา (ส้มโมงป่า)	*Garcinia speciosa* Wall.	54	17.19	8.30
36	ปีน (ฟีน)	-	44	14.01	9.30
37	พลอง	*Dipterocarpus tuberculatus* Roxb.	63	20.06	8.70
38	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.30
39	ตะเคียน	*Hopea odorata* Roxb.	47	14.96	8.30
40	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	48	15.28	10.30
41	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	69	21.97	9.30
42	หยอง	-	52	16.56	8.30
43	พลอง	*Dipterocarpus tuberculatus* Roxb.	36	11.46	8.30

Table C.1 Detail of DDEF Plot 1. (X: 149806 Y: 1626275, AGB 6,016.29 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
44	-	-	35	11.14	7.30
45	ไก๋แดง (ไก๋นก ขี้นก สารภีดง)	Ternstroemia gymnanthera (Wight & Arn.) Bedd.	90	28.65	12.90
46	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	10.10
47	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	44	14.01	7.30
48	ตะเคียน	*Hopea odorata* Roxb.	40	12.73	9.80
49	ปีน (ฟีน)	-	36	11.46	8.30
50	ตะเคียน	*Hopea odorata* Roxb.	37	11.78	9.60
51	ไก๋แดง (ไก๋นก ขี้นก สารภีดง)	Ternstroemia gymnanthera (Wight & Arn.) Bedd.	83	26.42	9.60
52	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	10.90
53	พลอง	*Dipterocarpus tuberculatus* Roxb.	52	16.56	8.60
54	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	39	12.42	7.30
55	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	8.30
56	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	38	12.10	6.30
57	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	116	36.93	12.90
58	พลอง	*Dipterocarpus tuberculatus* Roxb.	42	13.37	7.30
59	ปีน (ฟีน)	-	64	20.38	7.30
60	ตะเคียน	*Hopea odorata* Roxb.	58	18.47	13.80
61	ตะเคียน	*Hopea odorata* Roxb.	64	20.37	13.90
62	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	13.60

Table C.2 Detail of DDEF Plot 2. (X: 151546 Y: 1623965, AGB 4,956.92 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	มะกอก (กอกเขา)	*Spondias pinnata* (L.f.) Kurz	80	25.47	17.70
2	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	31	9.87	9.40
3	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	7.80
4	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	47	14.96	13.00
5	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	98	31.20	14.20
6	พลับพลา	*Microcos paniculata* L.	36	11.46	11.70
7	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	49	15.60	6.60
8	มะไฟแรด (นมวัว)	*Scleropyrum wallichianum* (Wight & Arn.) Arn.	38	12.10	12.00
9	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	31	9.87	10.80
10	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	45	14.33	11.20
11	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	59	18.78	11.40
12	มะไฟแรด (นมวัว)	*Scleropyrum wallichianum* (Wight & Arn.) Arn.	40	12.73	6.90
13	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	33	10.51	12.50
14	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	60	19.10	10.90
15	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	39	12.42	10.00
16	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	35	11.14	6.60
17	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	21	6.56	13.40
18	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	37	11.78	8.60
19	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	55	17.51	13.40

Table C.2 Detail of DDEF Plot 2. (X: 151546 Y: 1623965, AGB 4,956.92 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
20	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	43	13.69	9.50
21	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	26	8.28	7.30
22	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	31	9.87	6.10
23	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	37	11.78	6.30
24	พะยูง	*Dalbergia cochinchinensis* Pierre	25	7.96	6.10
25	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	27	8.60	5.20
26	พลับพลา	*Microcos paniculata* L.	51	16.24	8.50
27	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	35	11.14	8.20
28	หนามกราย	*Terminalia triptera* Stapf.	30	9.55	5.60
29	ตะไกล้	-	44	14.01	7.50
30	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	46	14.65	13.00
31	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	47	14.96	10.90
32	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	98	31.20	17.90
33	พลับพลา	*Microcos paniculata* L.	134	42.66	11.00
34	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	36	11.46	12.50
35	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	60	19.10	14.50
36	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	57	18.15	16.60
37	หนามกราย	*Terminalia triptera* Stapf.	34	10.82	12.50
38	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	20	6.37	6.80
39	พลับพลา	*Microcos paniculata* L.	78	24.87	10.20
40	พะยูง	*Dalbergia cochinchinensis* Pierre	28	8.91	7.60
41	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	104	33.17	15.00
42	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	47	14.96	9.80

Table C.3 Detail of DDEF Plot 3. (X: 145961 Y: 1628980, AGB 5,555.26 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ตะเคียน	*Hopea odorata* Roxb.	31	9.87	8.30
2	พลอง	*Dipterocarpus tuberculatus* Roxb.	54	17.19	9.40
3	ปีน (ฟีน)	-	34	10.82	9.30
4	ตะเคียน	*Hopea odorata* Roxb.	61	19.42	11.30
5	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	37	11.78	9.20
6	พลอง	*Dipterocarpus tuberculatus* Roxb.	62	19.74	9.70
7	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	55	17.51	7.30
8	พลับพลา	*Microcos paniculata* L.	95	30.25	8.70
9	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	7.50
10	ปีน (ฟีน)	-	33	10.51	7.50
11	พลับพลา	*Microcos paniculata* L.	53	16.87	12.10
12	ปีน (ฟีน)	-	37	11.78	8.50
13	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	34	10.82	7.40
14	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.90
15	ตะเคียน	*Hopea odorata* Roxb.	34	10.82	5.60

Table C.3 Detail of DDEF Plot 3. (X: 145961 Y: 1628980, AGB 5,555.26 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
16	หยอง	-	34	10.82	6.30
17	ตะเคียน	*Hopea odorata* Roxb.	44	14.01	9.20
18	ปีน (ฟีน)	-	40	12.73	6.30
19	ตะเคียน	*Hopea odorata* Roxb.	54	17.19	11.10
20	ปีน (ฟีน)	-	44	14.01	8.80
21	ตะเคียน	*Hopea odorata* Roxb.	65	20.69	11.30
22	ตะเคียน	*Hopea odorata* Roxb.	37	11.78	9.20
23	ปีน (ฟีน)	-	51	16.24	8.20
24	พลอง	*Dipterocarpus tuberculatus* Roxb.	39	12.42	7.30
25	ปีน (ฟีน)	-	34	10.82	7.30
26	หยอง	-	36	11.46	5.30
27	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	9.50
28	ปีน (ฟีน)	-	45	14.33	9.10
29	ตะเคียน	*Hopea odorata* Roxb.	83	26.42	11.50
30	ปีน (ฟีน)	-	38	12.10	7.30
31	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	9.30
32	พลับพลา	*Microcos paniculata* L.	47	14.96	9.80
33	ปีน (ฟีน)	-	40	12.73	7.70
34	ตะเคียน	*Hopea odorata* Roxb.	34	10.82	7.30
35	ตะเคียน	*Hopea odorata* Roxb.	60	19.10	9.30
36	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	69	21.97	10.80
37	หยอง	-	40	12.73	6.30
38	ตะเคียน	*Hopea odorata* Roxb.	42	13.37	8.80
39	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	44	14.01	11.30
40	ตะเคียน	*Hopea odorata* Roxb.	33	10.51	7.30
41	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	9.30
42	พลับพลา	*Microcos paniculata* L.	55	17.51	8.30
43	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	9.80
44	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	68	21.65	9.00
45	พลับพลา	*Microcos paniculata* L.	53	16.87	9.90
46	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.30
47	ตะเคียน	*Hopea odorata* Roxb.	46	14.65	9.30
48	พลอง	*Dipterocarpus tuberculatus* Roxb.	51	16.24	8.30
49	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	50	15.92	8.10
50	ตาทิพย์	*Neolitsea siamensis* Kosterm	73	23.24	10.10
51	ตะเคียน	*Hopea odorata* Roxb.	38	12.10	9.10
52	ตะใกล้	-	36	11.46	8.30
53	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	42	13.37	9.50
54	-	-	69	21.97	12.80
55	ตะเคียน	*Hopea odorata* Roxb.	56	17.83	8.70
56	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	7.30
57	ตะเคียน	*Hopea odorata* Roxb.	44	14.01	7.30
58	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	7.30

Table C.3 Detail of DDEF Plot 3. (X: 145961 Y: 1628980, AGB 5,555.26 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
59	พลอง	*Dipterocarpus tuberculatus* Roxb.	54	17.19	8.30
60	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	74	23.56	8.30
61	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	50	15.92	9.90
62	ปืน (ฟืน)	-	54	17.19	9.20
63	ตะเคียน	*Hopea odorata* Roxb.	51	16.24	10.10
64	ตะเคียน	*Hopea odorata* Roxb.	54	17.15	11.20
65	ตะเคียน	*Hopea odorata* Roxb.	48	15.28	9.70
66	ปืน (ฟืน)	-	52	16.56	8.80
67	ปืน (ฟืน)	-	44	14.01	8.30
68	พลอง	*Dipterocarpus tuberculatus* Roxb.	40	12.73	8.50
69	มะเคง	-	38	12.10	11.30
70	ตะเคียน	*Hopea odorata* Roxb.	33	10.51	7.30
71	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	9.30

Table C.4 Detail of DDEF Plot 4. (X: 149871 Y: 1620787, AGB 4,498.52 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	20	6.21	7.90
2	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	38	12.10	14.20
3	พลับพลา	*Microcos paniculata* L.	45	14.33	9.30
4	-	-	33	10.51	9.80
5	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	11.00
6	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	9.80
7	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	60	19.10	14.40
8	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	32	10.19	11.80
9	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	56	17.83	12.90
10	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	68	21.65	12.90
11	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	32	10.19	10.50
12	พะยูง	*Dalbergia cochinchinensis* Pierre	31	9.87	7.80
13	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	83	26.42	12.90
14	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	68	21.65	12.90
15	พลับพลา	*Microcos paniculata* L.	44	14.01	9.70
16	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	56	17.83	9.80
17	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	46	14.65	13.40
18	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	8.80
19	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	68	21.65	12.10
20	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	66	21.01	13.60
21	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	65	20.69	6.70
22	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	43	13.69	10.00
23	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	50	15.92	10.20
24	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	47	14.96	10.30
25	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	67	21.33	10.90
26	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	55	17.51	9.90
27	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	61	19.42	15.40

Table C.4 Detail of DDEF Plot 4. (X: 149871 Y: 1620787, AGB 4,498.52 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
28	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	30	9.55	10.80
29	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	26	8.28	9.20
30	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	41	13.05	11.20
31	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	39	12.42	7.80
32	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	124	39.48	15.00
33	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	34	10.82	7.40
34	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	45	14.33	5.60
35	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	23	7.32	4.90
36	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	30	9.55	5.40
37	-	-	34	10.82	7.50
38	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	29	9.23	6.60
39	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	28	8.91	6.30
40	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	23	7.32	4.80
41	พลับพลา	*Microcos paniculata* L.	57	18.15	9.20
42	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	28	8.91	6.20
43	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	39	12.42	9.20
44	สะแก	*Combretum quadrangulare* Kurz	24	7.64	6.80
45	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	40	12.73	11.00
46	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	34	10.82	9.80
47	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	44	14.28	11.80
48	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	32	10.19	12.00

Table C.5 Detail of DDEF Plot 5. (X: 151581 Y: 1622719, AGB 4,455.58 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	พลับพลา	*Microcos paniculata* L.	23	7.32	9.30
2	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	41	13.05	8.10
3	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	99	31.52	10.00
4	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	39	12.42	7.00
5	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	11.20
6	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	81	25.79	16.30
7	พลับพลา	*Microcos paniculata* L.	51	16.24	9.00
8	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	59	18.78	16.30
9	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	63	20.06	16.30
10	กระเชา (มหาเหนียว)	*Holoptelea integrifolia* Planch.	39	12.42	36.80
11	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	7.50
12	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	47	14.96	9.80
13	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	33	10.51	9.80
14	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	63	20.06	10.50
15	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	82	26.11	13.60
16	พะยูง	*Dalbergia cochinchinensis* Pierre	28	8.91	10.40
17	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	32	10.19	12.30
18	เทียน	-	39	12.42	10.80

Table C.5 Detail of DDEF Plot 5. (X: 151581 Y: 1622719, AGB 4,455.58 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
19	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	41	13.05	13.90
20	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	62	19.74	13.90
21	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	7.90
22	พะยูง	*Dalbergia cochinchinensis* Pierre	33	10.51	8.20
23	พะยูง	*Dalbergia cochinchinensis* Pierre	38	12.10	8.30
24	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	23	7.32	4.90
25	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	47	14.96	10.40
26	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	26	8.28	4.90
27	พะยูง	*Dalbergia cochinchinensis* Pierre	33	10.51	5.90
28	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	23	7.32	7.10
29	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	31	9.87	4.80
30	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	29	9.23	8.60
31	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	46	14.65	11.90
32	พลับพลา	*Microcos paniculata* L.	60	19.10	10.60
33	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	62	19.74	12.50
34	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	87	27.70	17.00
35	พลับพลา	*Microcos paniculata* L.	34	10.82	11.30
36	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	74	23.56	13.10
37	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	6.80
38	พะยูง	*Dalbergia cochinchinensis* Pierre	20	6.37	6.80
39	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	34	10.82	9.60
40	พลับพลา	*Microcos paniculata* L.	60	19.10	9.70
41	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	36	11.46	8.60
42	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	20	6.37	6.80
43	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	75	23.88	16.90
44	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	27	8.60	6.80

Table C.6 Detail of DDEF Plot 6. (X: 149926 Y: 1623125, AGB 6,066.11 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	7.90
2	ตะเคียน	*Hopea odorata* Roxb.	35	11.14	7.90
3	ตะเคียน	*Hopea odorata* Roxb.	76	24.20	10.10
4	ตะเคียน	*Hopea odorata* Roxb.	49	15.60	10.00
5	แคขาว (แคป่า)	*Dolichandrone serrulata* (DC.) Seem.	49	15.60	9.60
6	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	48	15.28	9.00
7	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	9.20
8	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	8.20
9	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	50	15.92	9.30
10	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	63	20.06	11.30
11	ตะเคียน	*Hopea odorata* Roxb.	67	21.33	11.80
12	ปีน (ฟีน)	-	40	12.73	7.30

Table C.6 Detail of DDEF Plot 6. (X: 149926 Y: 1623125, AGB 6,066.11 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
13	ปีน (ฟีน)	-	65	20.69	9.80
14	ตะเคียน	*Hopea odorata* Roxb.	58	18.47	9.50
15	มะไฟแรด (นมวัว)	*Scleropyrum wallichianum* (Wight & Arn.) Arn.	36	11.46	8.30
16	ตะเคียน	*Hopea odorata* Roxb.	42	13.37	9.50
17	พลับพลา	*Microcos paniculata* L.	36	11.46	7.30
18	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	8.10
19	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	8.10
20	ตะเคียน	*Hopea odorata* Roxb.	34	10.82	7.30
21	พลับพลา	*Microcos paniculata* L.	47	14.96	11.30
22	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	34	10.82	7.30
23	ตะเคียน	*Hopea odorata* Roxb.	41	13.05	7.30
24	ตะเคียน	*Hopea odorata* Roxb.	50	15.92	9.10
25	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	58	18.47	8.30
26	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.30
27	ปีน (ฟีน)	-	63	20.06	9.30
28	หยอง	-	40	12.73	6.30
29	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	71	22.60	8.30
30	ปีน (ฟีน)	-	51	16.24	8.70
31	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	36	11.46	8.50
32	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	58	18.47	7.80
33	พลอง	*Dipterocarpus tuberculatus* Roxb.	37	11.78	7.30
34	พลอง	*Dipterocarpus tuberculatus* Roxb.	41	13.05	8.80
35	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	38	12.10	8.80
36	เตียว	-	43	13.69	8.30
37	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	33	10.51	9.80
38	พลอง	*Dipterocarpus tuberculatus* Roxb.	49	15.60	8.90
39	ปีน (ฟีน)	-	39	12.42	7.80
40	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	74	23.56	12.10
41	พลับพลา	*Microcos paniculata* L.	57	18.15	10.10
42	ปีน (ฟีน)	-	36	11.46	8.10
43	พลับพลา	*Microcos paniculata* L.	48	15.28	8.90
44	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	64	20.38	9.30
45	ตะเคียน	*Hopea odorata* Roxb.	50	15.92	12.00
46	ตะเคียน	*Hopea odorata* Roxb.	34	10.82	7.90
47	ตะเคียน	*Hopea odorata* Roxb.	46	14.65	9.00
48	ตะเคียน	*Hopea odorata* Roxb.	59	18.78	10.10
49	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	40	12.73	6.30
50	ตะเคียน	*Hopea odorata* Roxb.	99	31.52	9.30
51	พลับพลา	*Microcos paniculata* L.	47	14.96	9.90
52	ปีน (ฟีน)	-	60	19.10	9.40
53	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	9.80
54	ปีน (ฟีน)	-	77	24.51	8.80
55	พลับพลา	*Microcos paniculata* L.	70	22.29	10.30

Table C.6 Detail of DDEF Plot 6. (X: 149926 Y: 1623125, AGB 6,066.11 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
56	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	9.60
57	-	-	70	22.29	9.80
58	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	49	15.60	9.30
59	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	58	18.47	11.10
60	ตะเคียน	*Hopea odorata* Roxb.	50	15.92	10.10
61	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	41	13.05	8.30
62	ตะเคียน	*Hopea odorata* Roxb.	52	16.56	10.00
63	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	44	14.01	7.30
64	ปีน (ฟีน)	-	83	26.42	11.90
65	ตะเคียน	*Hopea odorata* Roxb.	43	13.69	9.10
66	ปีน (ฟีน)	-	41	13.05	9.30
67	พลอง	*Dipterocarpus tuberculatus* Roxb.	53	16.87	9.80
68	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	50	15.92	10.10

Table C.7 Detail of DDEF Plot 7. (X: 148386 Y: 1630440, AGB 5,280.60 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	พลับพลา	*Microcos paniculata* L.	21	6.69	7.70
2	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	32	10.25	11.50
3	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	19	6.05	5.80
4	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	57	18.15	17.60
5	พลับพลา	*Microcos paniculata* L.	49	15.60	11.30
6	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	47	14.96	11.00
7	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	45	14.33	7.80
8	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	56	17.83	10.80
9	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	37	11.78	8.60
10	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	34	10.82	12.90
11	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	58	18.47	12.90
12	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	35	11.14	12.90
13	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	65	20.69	13.10
14	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	66	21.01	16.40
15	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	83	26.42	16.30
16	พลับพลา	*Microcos paniculata* L.	31	9.87	7.90
17	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	31	9.87	11.40
18	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	47	14.96	11.40
19	งิ้วป่า	*Bombax anceps* Pierre var. anceps	60	19.10	11.60
20	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	39	12.42	11.60
21	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	36	11.46	9.50
22	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	104	33.11	17.40
23	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	32	10.19	10.50
24	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	46	14.65	10.10
25	พลับพลา	*Microcos paniculata* L.	37	11.78	10.00

Table C.7 Detail of DDEF Plot 7. (X: 148386 Y: 1630440, AGB 5,280.60 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
26	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	58	18.47	13.60
27	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	67	21.33	13.90
28	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	33	10.51	8.80
29	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	124	39.55	14.70
30	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	26	8.28	7.50
31	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	24	7.64	6.30
32	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	29	9.23	5.40
33	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	30	9.55	3.80
34	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	48	15.28	7.80
35	พลับพลา	*Microcos paniculata* L.	35	11.14	6.20
36	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	29	9.23	7.00
37	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	31	9.87	7.20
38	มะค่า	*Afzelia xylocarpa* (Kurz) Craib	102	32.47	16.50
39	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	24	7.64	7.40
40	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	34	10.82	11.30
41	เลียงฝ้าย (ปอ)	*Kydia calycina* Roxb.	38	12.10	14.80
42	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	34	10.82	11.80
43	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	42	13.37	9.20
44	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	20	6.37	6.80
45	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	31	9.87	6.10
46	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	44	14.01	7.10
47	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	25	7.96	6.10
48	พลับพลา	*Microcos paniculata* L.	34	10.82	6.80
49	พลับพลา	*Microcos paniculata* L.	51	16.24	8.50
50	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	46	14.65	8.80

Table C.8 Detail of DDEF Plot 8. (X: 151516 Y: 1620695, AGB 5,018.11 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	35	11.14	7.30
2	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	9.30
3	พลอง	*Dipterocarpus tuberculatus* Roxb.	54	17.19	8.80
4	ตะเคียน	*Hopea odorata* Roxb.	38	12.10	8.30
5	ตะเคียน	*Hopea odorata* Roxb.	54	17.19	10.90
6	พลอง	*Dipterocarpus tuberculatus* Roxb.	48	15.28	11.00
7	หยอง	-	33	10.51	5.80
8	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	58	18.47	10.50
9	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	36	11.46	6.60
10	พลอง	*Dipterocarpus tuberculatus* Roxb.	45	14.33	10.70
11	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	57	18.15	10.70
12	ปีน (ฟีน)	-	42	13.37	10.70
13	พลอง	*Dipterocarpus tuberculatus* Roxb.	48	15.28	8.50

Table C.8 Detail of DDEF Plot 8. (X: 151516 Y: 1620695, AGB 5,018.11 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
14	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	8.50
15	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	49	15.60	9.20
16	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	73	23.24	5.30
17	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	40	12.73	8.80
18	ปีน (ฟีน)	-	35	11.14	6.30
19	ตะเคียน	*Hopea odorata* Roxb.	53	16.87	9.30
20	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.33	7.30
21	ตะเคียน	*Hopea odorata* Roxb.	53	16.87	8.10
22	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	43	13.69	8.30
23	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	9.50
24	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	7.30
25	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	8.10
26	ตะเคียน	*Hopea odorata* Roxb.	69	21.97	10.30
27	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	8.70
28	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	9.30
29	พลอง	*Dipterocarpus tuberculatus* Roxb.	42	13.37	7.30
30	พลอง	*Dipterocarpus tuberculatus* Roxb.	40	12.73	8.70
31	ปีน (ฟีน)	-	44	14.01	7.30
32	ตะเคียน	*Hopea odorata* Roxb.	61	19.42	9.80
33	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	47	14.96	9.30
34	ตะเคียน	*Hopea odorata* Roxb.	83	26.42	9.30
35	ตะเคียน	*Hopea odorata* Roxb.	42	13.37	9.80
36	ปีน (ฟีน)	-	48	15.28	7.80
37	หยอง	-	37	11.78	8.30
38	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	12.60
39	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	41	13.05	8.30
40	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	36	11.46	7.30
41	ปีน (ฟีน)	-	47	14.96	8.30
42	พลอง	*Dipterocarpus tuberculatus* Roxb.	36	11.46	7.30
43	กัดลิ้น (ขี้ มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	43	13.69	7.30
44	พลอง	*Dipterocarpus tuberculatus* Roxb.	49	15.60	7.30
45	ตะเคียน	*Hopea odorata* Roxb.	33	10.51	9.30
46	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.33	8.30
47	ตะเคียน	*Hopea odorata* Roxb.	48	15.28	8.90
48	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	9.10
49	ตะเคียน	*Hopea odorata* Roxb.	54	17.19	9.30
50	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	76	24.19	13.10
51	ตะเคียน	*Hopea odorata* Roxb.	51	16.24	10.90
52	ตะเคียน	*Hopea odorata* Roxb.	40	12.73	9.10
53	ตะเคียน	*Hopea odorata* Roxb.	39	12.42	9.30
54	ตะเคียน	*Hopea odorata* Roxb.	48	15.28	7.30
55	ปีน (ฟีน)	-	35	11.14	7.30
56	ตะเคียน	*Hopea odorata* Roxb.	52	16.56	9.60

Table C.8 Detail of DDEF Plot 8. (X: 151516 Y: 1620695, AGB 5,018.11 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
57	อีแปะ	*Vitex quinata* (Lour.) F.N.Williams	49	15.60	8.80
58	พลับพลา	*Microcos paniculata* L.	40	12.73	7.30
59	ตะเคียน	*Hopea odorata* Roxb.	78	24.83	13.80
60	ปีน (ฟีน)	-	41	13.05	7.50
61	ปีน (ฟีน)	-	36	11.46	7.30
62	ไก่แดง (ไก่นก ขี้นก สารภีดง)	*Ternstroemia gymnanthera* (Wight & Arn.) Bedd.	49	15.60	9.30
63	พลอง	*Dipterocarpus tuberculatus* Roxb.	45	14.33	8.70
64	ไก่แดง (ไก่นก ขี้นก สารภีดง)	*Ternstroemia gymnanthera* (Wight & Arn.) Bedd.	55	17.51	9.30

Table C.9 Detail of MDEF Plot 1. (X: 148516 Y: 1626245, AGB 4,967.38 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ปีน (ฟีน)	-	35	11.14	7.30
2	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	65	20.69	8.20
3	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	80	25.47	8.10
4	แปะ	*Vitex canescens* Kurz	35	11.14	10.10
5	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	40	12.73	7.90
6	-	-	63	20.06	11.90
7	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	30	9.55	8.10
8	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	105	33.43	6.90
9	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	60	19.10	7.10
10	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	105	33.43	7.60
11	-	-	30	9.55	9.00
12	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	45	14.33	10.50
13	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	95	30.25	8.30
14	ปีน (ฟีน)	-	40	12.73	7.30
15	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	75	23.88	8.30
16	พลอง	*Dipterocarpus tuberculatus* Roxb.	40	12.73	7.30
17	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	10.10
18	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	165	52.53	7.90
19	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	65	20.69	7.30
20	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	35	11.14	8.10
21	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	25	7.96	14.50
22	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	41	13.05	13.90
23	ปีน (ฟีน)	-	72	22.92	9.30
24	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	82	26.11	9.30
25	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	47	14.96	10.10
26	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	37	11.78	9.50
27	พลอง	*Dipterocarpus tuberculatus* Roxb.	45	14.33	7.30
28	ปีน (ฟีน)	-	29	9.23	7.30
29	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	74	23.56	8.30
30	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	40	12.73	9.30
31	พลอง	*Dipterocarpus tuberculatus* Roxb.	27	8.60	9.30

Table C.9 Detail of MDEF Plot 1. (X: 148516 Y: 1626245, AGB 4,967.38 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
32	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	35	11.14	7.30
33	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	41	13.05	9.50
34	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	64	20.38	7.10
35	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	25	7.96	7.90
36	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	8.10
37	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	65	20.69	7.30
38	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	57	18.15	8.30
39	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	53	16.87	14.70
40	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	37	11.78	7.30
41	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	57	18.15	7.30
42	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	54	17.19	7.30
43	พลอง	*Dipterocarpus tuberculatus* Roxb.	44	13.82	7.30
44	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	48	15.28	9.00
45	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	80	25.47	10.80
46	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	54	17.19	10.60

Table C.10 Detail of MDEF Plot 2. (X: 150166 Y: 1627625, AGB 4,717.76 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.33	7.90
2	ตะเคียน	*Hopea odorata* Roxb.	80	25.47	10.50
3	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	35	11.14	8.10
4	ปีน (ฟีน)	-	58	18.47	8.50
5	พะยูง	*Dalbergia cochinchinensis* Pierre	78	24.83	15.30
6	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	46	14.65	8.30
7	ตะเคียน	*Hopea odorata* Roxb.	50	15.92	9.70
8	ตะเคียน	*Hopea odorata* Roxb.	55	17.51	10.10
9	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	80	25.47	8.10
10	-	-	109	34.70	13.60
11	ตะเคียน	*Hopea odorata* Roxb.	42	13.37	9.10
12	ปีน (ฟีน)	-	53	16.87	13.90
13	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	39	12.42	7.30
14	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	41	13.05	9.30
15	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	43	13.69	9.30
16	-	-	94	29.93	10.10
17	พลอง	*Dipterocarpus tuberculatus* Roxb.	55	17.51	7.30
18	ตะเคียน	*Hopea odorata* Roxb.	62	19.74	13.50
19	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	38	12.10	8.10
20	หว้าปลอก	*Syzygium siamense* (Craib) Chantar. & J. Parn.	52	16.56	9.30
21	ตะเคียน	*Hopea odorata* Roxb.	59	18.78	11.30
22	ตะเคียน	*Hopea odorata* Roxb.	40	12.73	7.30
23	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	33	10.51	7.30

Table C.10 Detail of MDEF Plot 2. (X: 150166 Y: 1627625, AGB 4,717.76 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
24	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	43	13.69	7.30
25	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	30	9.55	7.30
26	คอแลน (มะแงว ลิ้นจี่ป่า)	*Nephelium hypoleucum* Kurz	83	26.42	9.50
27	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	32	10.19	7.30
28	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	58	18.47	10.10
29	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	52	16.56	7.10
30	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	46	14.65	7.30
31	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	50	15.92	8.30
32	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	57	18.15	8.30
33	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	43	13.69	7.50
34	ตะเคียน	*Hopea odorata* Roxb.	36	11.46	13.30
35	ตะเคียน	*Hopea odorata* Roxb.	57	18.15	14.30
36	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	57	18.15	7.30
37	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	76	24.20	12.30
38	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	34	10.82	7.50
39	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	43	13.69	7.50
40	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	49	15.60	8.70
41	-	-	44	14.01	7.90
42	ตะเคียน	*Hopea odorata* Roxb.	78	24.83	11.30

Table C.11 Detail of MDEF Plot 3. (X: 148036 Y: 1629394, AGB 4,806.77 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	38	12.10	7.80
2	ตะเคียน	*Hopea odorata* Roxb.	57	18.15	8.10
3	พลอง	*Dipterocarpus tuberculatus* Roxb.	59	18.78	9.70
4	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	53	16.87	8.90
5	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	53	16.87	8.90
6	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	39	12.42	7.10
7	ตะเคียน	*Hopea odorata* Roxb.	44	14.01	10.00
8	ตะเคียน	*Hopea odorata* Roxb.	57	18.15	9.20
9	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	44	14.01	9.00
10	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	38	12.10	7.30
11	เลือดแรด (สมิง)	*Knema globularia* (Lam.) Warb	46	14.65	8.30
12	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	44	14.01	9.30
13	สนิม	-	58	18.47	7.30
14	สนิม	-	43	13.69	7.30
15	ปีน (ฟีน)	-	32	10.19	7.30
16	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	44	14.01	7.30
17	ปีน (ฟีน)	-	44	14.01	7.30
18	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	38	12.10	7.90
19	ตะเคียน	*Hopea odorata* Roxb.	47	14.96	9.30

Table C.11 Detail of MDEF Plot 3. (X: 148036 Y: 1629394, AGB 4,806.77 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
20	ปีน (ฟีน)	-	36	11.46	8.10
21	ตะเคียน	*Hopea odorata* Roxb.	67	21.33	13.30
22	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	38	12.10	7.70
23	ตะเคียน	*Hopea odorata* Roxb.	49	15.60	13.90
24	ตะเคียน	*Hopea odorata* Roxb.	75	23.88	13.00
25	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.34	10.60
26	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	98	31.20	11.80
27	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	43	13.69	7.30
28	ตะเคียน	*Hopea odorata* Roxb.	59	18.78	9.50
29	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	69	21.97	10.60
30	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.33	9.30
31	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	40	12.73	9.30
32	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.33	7.30
33	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.70
34	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	54	17.19	7.90
35	ชิงชัน (ประดู่ชิงชัน)	*Dalbergia oliveri* Gamble	94	29.93	13.70
36	ตะเคียน	*Hopea odorata* Roxb.	76	24.20	13.30
37	ตะเคียน	*Hopea odorata* Roxb.	75	23.88	10.00
38	ตะเคียน	*Hopea odorata* Roxb.	30	9.55	9.70
39	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	39	12.42	7.30
40	พลอง	*Dipterocarpus tuberculatus* Roxb.	56	17.83	7.30
41	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	68	21.65	8.70
42	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	65	20.69	8.70
43	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	57	18.15	6.30
44	พลอง	*Dipterocarpus tuberculatus* Roxb.	63	20.06	13.90
45	ตะเคียน	*Hopea odorata* Roxb.	41	13.05	11.90
46	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	39	12.42	9.20
47	พลอง	*Dipterocarpus tuberculatus* Roxb.	45	14.33	9.60
48	พลอง	*Dipterocarpus tuberculatus* Roxb.	42	13.37	9.80

Table C.12 Detail of MDEF Plot 4. (X: 151652 Y: 1625258, AGB 4,556.24 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ตะเคียน	*Hopea odorata* Roxb.	48	15.28	10.50
2	พลอง	*Dipterocarpus tuberculatus* Roxb.	44	14.01	8.20
3	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	42	13.37	8.20
4	ปีน (ฟีน)	-	55	17.51	7.90
5	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	52	16.56	6.90
6	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	49	15.60	7.60
7	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	57	18.15	6.30
8	พลอง	*Dipterocarpus tuberculatus* Roxb.	83	26.42	13.90
9	ตะเคียน	*Hopea odorata* Roxb.	41	13.05	11.90
10	สนิม	-	39	12.42	9.80
11	พลอง	*Dipterocarpus tuberculatus* Roxb.	60	19.10	9.80
12	พลอง	*Dipterocarpus tuberculatus* Roxb.	62	19.74	9.80
13	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	64	20.38	11.50
14	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	55	17.51	10.40
15	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	46	14.65	10.00
16	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	36	11.46	9.30
17	พลอง	*Dipterocarpus tuberculatus* Roxb.	42	13.37	9.30
18	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	52	16.56	7.30
19	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	40	12.73	9.30
20	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	40	12.73	8.60
21	ปีน (ฟีน)	-	55	17.51	7.30
22	ตะเคียน	*Hopea odorata* Roxb.	87	27.70	13.80
23	ตะเคียน	*Hopea odorata* Roxb.	65	20.69	9.50
24	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.30
25	ตะเคียน	*Hopea odorata* Roxb.	115	36.60	17.20
26	พลับพลา	*Microcos paniculata* L.	93	29.61	10.10
27	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	42	13.37	7.30
28	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	49	15.60	9.30
29	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	36	11.46	8.30
30	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	34	10.82	11.90
31	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	29	9.23	7.40
32	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	49	15.60	9.00
33	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	59	18.78	8.70
34	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	47	14.96	7.50
35	ตะเคียน	*Hopea odorata* Roxb.	86	27.38	11.70
36	ตะเคียน	*Hopea odorata* Roxb.	69	21.97	15.30
37	พลอง	*Dipterocarpus tuberculatus* Roxb.	59	18.78	9.80

Table C.13 Detail of MDEF Plot 5. (X: 149478 Y: 1629126, AGB 4,676.27 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	36	11.46	7.30
2	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	55	17.51	10.10
3	ตะเคียน	*Hopea odorata* Roxb.	94	29.93	11.90
4	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	45	14.33	7.70
5	พลอง	*Dipterocarpus tuberculatus* Roxb.	59	18.78	9.30
6	แจง	-	105	33.66	15.00
7	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	55	17.51	6.70
8	ตะเคียน	*Hopea odorata* Roxb.	38	12.10	9.70
9	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	46	14.65	7.30
10	ตะเคียน	*Hopea odorata* Roxb.	48	15.28	8.50
11	ตะเคียน	*Hopea odorata* Roxb.	46	14.65	7.30
12	สนิม	-	35	11.14	7.30
13	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	50	15.92	8.90
14	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	43	13.69	7.30
15	ตะเคียน	*Hopea odorata* Roxb.	46	14.65	10.80
16	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	50	15.92	7.70
17	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	106	33.72	14.50
18	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	42	13.37	8.60
19	สนิม	-	78	24.83	15.20
20	ตะเคียน	*Hopea odorata* Roxb.	60	19.10	11.30
21	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	52	16.56	11.30
22	พลอง	*Dipterocarpus tuberculatus* Roxb.	62	19.74	9.10
23	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	42	13.37	7.30
24	ตะเคียน	*Hopea odorata* Roxb.	122	38.84	10.60
25	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	8.10
26	ตะเคียน	*Hopea odorata* Roxb.	37	11.78	8.30
27	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	35	11.14	7.30
28	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	38	12.10	7.30
29	พลอง	*Dipterocarpus tuberculatus* Roxb.	46	14.65	7.30
30	พลอง	*Dipterocarpus tuberculatus* Roxb.	46	14.65	7.30
31	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	27	8.60	7.50
32	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	35	11.14	7.60
33	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	35	11.14	8.10
34	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	51	16.24	11.90
35	คอแลน (มะแงว ลิ้นจี่ป่า)	*Nephelium hypoleucum* Kurz	70	22.29	13.30
36	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	33	10.51	7.30
37	ตะเคียน	*Hopea odorata* Roxb.	55	17.51	10.00
38	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	14.30

Table C.14 Detail of MDEF Plot 6. (X: 153703 Y: 1622560, AGB 4,546.43 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	7.70
2	ปีน (ฟีน)	-	25	7.96	9.70
3	-	-	75	23.88	9.30
4	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	55	17.51	8.90
5	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	32	10.19	9.70
6	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	11.70
7	พลอง	*Dipterocarpus tuberculatus* Roxb.	45	14.33	8.50
8	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	58	18.47	7.30
9	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	95	30.25	8.90
10	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	30	9.55	7.30
11	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	50	15.92	7.30
12	ตะเคียน	*Hopea odorata* Roxb.	48	15.28	11.60
13	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	13.30
14	พลอง	*Dipterocarpus tuberculatus* Roxb.	25	7.96	7.70
15	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	32	10.19	14.00
16	หยอง	-	29	9.23	11.50
17	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	25	7.96	10.40
18	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	190	60.49	8.00
19	ปีน (ฟีน)	-	40	12.73	10.60
20	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	35	11.14	10.10
21	ประดู่ป่า (ประดู่เสน)	*Pterocarpus macrocarpus* Kurz	25	7.96	13.50
22	ตะเคียน	*Hopea odorata* Roxb.	80	25.47	13.80
23	ตะเคียน	*Hopea odorata* Roxb.	68	21.65	13.60
24	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	48	15.28	9.80
25	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	45	14.33	7.30
26	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	49	15.60	11.90
27	พลอง	*Dipterocarpus tuberculatus* Roxb.	33	10.51	7.30
28	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	49	15.60	9.00
29	พลอง	*Dipterocarpus tuberculatus* Roxb.	65	20.69	11.70
30	เหมือดคนดง (เข็ม)	*Helicia formosana* Hemsl. var. oblanceolata Sleumer	41	13.05	7.50
31	ตะเคียน	*Hopea odorata* Roxb.	45	14.33	14.30
32	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	56	17.83	14.30
33	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	39	12.42	11.70
34	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	56	17.83	8.30
35	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	42	13.37	10.60
36	ตะขบป่า (ตะขบหนาม)	*Flacourtia indica* (Burm.f.) Merr.	45	14.33	7.50
37	กร่าง (ไทรทอง)	*Ficus altissima* Blume	47	15.15	8.70
38	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	39	12.42	8.10
39	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	65	20.69	11.30
40	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	35	11.14	11.50
41	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	43	13.69	10.40
42	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	62	19.64	9.90
43	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	39	12.42	10.60

Table C.15 Detail of MDEF Plot 7. (X: 150286 Y: 1623875, AGB 5,555.31 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ประดู่ป่า (ประดู่เสน)	*Pterocarpus macrocarpus* Kurz	34	10.82	10.10
2	ไม้ใหญ่ (ยอดด้วน)	-	105	33.43	9.20
3	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	27	8.60	6.70
4	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	115	36.61	7.30
5	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	70	22.29	7.90
6	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	45	14.33	15.30
7	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	35	11.14	9.30
8	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	65	20.69	8.10
9	พลอง	*Dipterocarpus tuberculatus* Roxb.	31	9.87	9.80
10	-	-	45	14.33	14.50
11	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	25	7.96	11.30
12	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	45	14.33	11.30
13	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	10.40
14	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	9.10
15	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	9.30
16	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	165	52.53	7.30
17	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	35	11.14	9.50
18	พลอง	*Dipterocarpus tuberculatus* Roxb.	32	10.19	8.10
19	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	31	9.87	11.70
20	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	65	20.69	9.30
21	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	80	25.47	10.10
22	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	44	14.01	7.30
23	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	40	12.73	7.30
24	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	82	26.11	7.30
25	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	49	15.60	7.30
26	ตะเคียน	*Hopea odorata* Roxb.	40	12.73	7.30
27	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	40	12.73	7.50
28	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	60	19.10	7.30
29	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	63	20.06	10.10
30	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	35	11.14	7.70
31	พลอง	*Dipterocarpus tuberculatus* Roxb.	43	13.69	8.30
32	กร่าง (ไทรทอง)	*Ficus altissima* Blume	54	17.19	7.50
33	พลอง	*Dipterocarpus tuberculatus* Roxb.	36	11.46	7.50
34	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	70	22.29	13.30
35	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	35	11.14	13.30
36	ตะเคียน	*Hopea odorata* Roxb.	41	13.05	12.50
37	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	7.50
38	ตะขบป่า (ตะขบหนาม)	*Flacourtia indica* (Burm.f.) Merr.	39	12.42	12.30
39	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	48	15.28	7.50
40	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	58	18.47	8.70
41	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	53	16.87	9.30
42	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	35	11.14	11.30
43	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	30	9.55	10.10

Table C.15 Detail of MDEF Plot 7. (X: 150286 Y: 1623875, AGB 5,555.31 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
44	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	49	15.60	7.30
45	พลอง	*Dipterocarpus tuberculatus* Roxb.	43	13.69	13.50
46	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	59	18.78	8.10
47	พลอง	*Dipterocarpus tuberculatus* Roxb.	47	14.96	9.30
48	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	114	36.28	14.00
49	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	39	12.42	7.30
50	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	43	13.69	11.30
51	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	66	21.01	10.80

Table C.16 Detail of MDEF Plot 8. (X: 152146 Y: 1624265, AGB 3,697.52 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	8.50
2	ประดู่ป่า (ประดู่เสน)	*Pterocarpus macrocarpus* Kurz	35	11.14	8.20
3	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	45	14.33	8.90
4	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	10.00
5	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	60	19.10	6.30
6	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	8.10
7	ตะเคียน	*Hopea odorata* Roxb.	92	29.54	15.80
8	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	68	21.65	7.30
9	พลอง	*Dipterocarpus tuberculatus* Roxb.	58	18.47	9.30
10	พลอง	*Dipterocarpus tuberculatus* Roxb.	48	15.28	9.70
11	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	45	14.33	7.30
12	พลอง	*Dipterocarpus tuberculatus* Roxb.	55	17.51	7.30
13	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	55	17.51	9.80
14	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	59	18.78	9.80
15	พลอง	*Dipterocarpus tuberculatus* Roxb.	50	15.92	13.60
16	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	53	16.87	10.80
17	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	44	14.01	7.70
18	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	47	14.96	9.10
19	กัดลิ้น (มะค่าลิ้น ลำไยป่า)	*Walsura trichostemon* Miq.	58	18.47	13.90
20	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	58	18.47	7.30
21	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	53	16.87	9.30
22	ตะเคียน	*Hopea odorata* Roxb.	74	23.56	11.80
23	หยอง	-	35	11.14	7.30
24	ตะเคียน	*Hopea odorata* Roxb.	58	18.47	10.60
25	ปีน (ฟีน)	-	55	17.51	13.10
26	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	7.30
27	ตะเคียน	*Hopea odorata* Roxb.	50	15.92	7.30
28	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	58	18.47	13.30
29	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	50	15.92	7.30
30	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	51	16.24	7.30

Table C.16 Detail of MDEF Plot 8. (X: 152146 Y: 1624265, AGB 3,697.52 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
31	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	84	26.74	7.60
32	ปีน (ฟีน)	-	53	16.87	9.30
33	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	58	18.47	11.90
34	พลอง	*Dipterocarpus tuberculatus* Roxb.	48	15.28	13.30

Table C.17 Detail of MDF Plot 1. (X: 154489 Y: 1628296, AGB 3,065.59 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	99	31.52	10.00
2	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	60	19.10	14.80
3	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	35	11.14	12.90
4	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	45	14.33	11.20
5	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	59	18.78	16.30
6	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	63	20.06	16.30
7	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	47	14.96	11.40
8	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	39	12.42	11.60
9	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	36	11.46	9.50
10	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	104	33.11	17.40
11	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	48	15.28	12.10
12	พลับพลา	*Microcos paniculata* L.	40	12.73	15.80
13	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	50	15.92	12.00
14	พลับพลา	*Microcos paniculata* L.	37	11.78	10.00
15	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	67	21.33	13.90
16	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	33	10.51	8.80
17	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	26	8.28	9.20
18	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	35	11.14	6.60
19	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	38	12.10	9.80
20	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	40	12.73	6.80
21	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	30	9.55	7.80
22	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	48	15.28	7.80
23	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	28	8.91	6.30
24	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	58	18.47	14.80
25	พลับพลา	*Microcos paniculata* L.	57	18.15	9.20
26	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	39	12.42	9.20
27	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	62	19.74	12.50
28	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	74	23.56	13.10
29	หนามกราย	*Terminalia triptera* Stapf.	34	10.82	12.50
30	ต้นปอ	*Kydia calycina* Roxb.	38	12.10	14.80
31	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	34	10.82	11.80
32	พลับพลา	*Microcos paniculata* L.	80	25.47	14.80
33	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	34	10.82	9.60
34	พลับพลา	*Microcos paniculata* L.	60	19.10	9.70

Table C.18 Detail of MDF Plot 2. (X: 146491 Y: 1631190, AGB 2,993.98 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	40	12.73	7.50
2	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	30	9.55	9.10
3	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	35	11.14	6.90
4	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	30	9.55	7.90
5	พลอง	*Dipterocarpus tuberculatus* Roxb.	100	31.84	6.60
6	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	40	12.73	9.00
7	-	-	25	7.96	8.00
8	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	110	35.02	6.30
9	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	65	20.69	6.90
10	พลอง	*Dipterocarpus tuberculatus* Roxb.	40	12.73	7.50
11	-	-	53	16.87	6.30
12	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	53	16.87	6.30
13	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	40	12.73	14.30
14	-	-	38	12.10	9.80
15	พลอง	*Dipterocarpus tuberculatus* Roxb.	20	6.37	6.70
16	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	43	13.69	12.90
17	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	27	8.60	13.00
18	-	-	43	13.69	6.30
19	ปีน (ฟีน)	-	67	21.33	8.30
20	พลอง	*Dipterocarpus tuberculatus* Roxb.	77	24.51	8.30
21	พลับพลา	*Microcos paniculata* L.	65	20.69	6.30
22	ปีน (ฟีน)	-	35	11.14	9.60
23	พลอง	*Dipterocarpus tuberculatus* Roxb.	32	10.19	8.50
24	พลอง	*Dipterocarpus tuberculatus* Roxb.	40	12.73	6.30
25	ประดู่ป่า (ประดู่แสน)	*Pterocarpus macrocarpus* Kurz	20	6.37	12.50
26	พลับพลา	*Microcos paniculata* L.	60	19.10	8.30
27	พลอง	*Dipterocarpus tuberculatus* Roxb.	22	7.00	8.30
28	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	39	12.42	6.30
29	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	55	17.51	6.30
30	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	6.70
31	พลอง	*Dipterocarpus tuberculatus* Roxb.	38	12.10	7.30
32	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	44	14.01	10.90
33	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	43	13.69	10.90
34	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	12.30
35	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	44	14.01	8.00
36	พลอง	*Dipterocarpus tuberculatus* Roxb.	45	14.33	9.80
37	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	30	9.55	12.30
38	กร่าง (ไทรทอง)	*Ficus altissima* Blume	28	8.91	11.80
39	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	60	19.14	12.60
40	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	54	17.19	10.30
41	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	40	12.73	10.30
42	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	60	19.10	11.80

Table C.19 Detail of MDF Plot 3. (X: 153013 Y: 1631428, AGB 2,574.90 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ประดู่ป่า (ประดู่เสน)	*Pterocarpus macrocarpus* Kurz	20	6.37	7.20
2	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	60	19.10	7.20
3	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	22	7.00	5.70
4	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	27	8.60	8.70
5	-	-	45	14.33	5.30
6	พลอง	*Dipterocarpus tuberculatus* Roxb.	90	28.65	7.30
7	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	6.30
8	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	25	7.96	6.30
9	พลับพลา	*Microcos paniculata* L.	45	14.33	6.30
10	พลับพลา	*Microcos paniculata* L.	50	15.92	9.10
11	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	60	19.10	6.30
12	พลอง	*Dipterocarpus tuberculatus* Roxb.	35	11.14	12.60
13	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	20	6.37	13.50
14	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	40	12.73	13.50
15	หยอง	-	24	7.64	10.50
16	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	20	6.37	6.30
17	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	25	7.96	8.30
18	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	42	13.37	9.10
19	งิ้วป่า	*Bombax anceps* Pierre var. anceps	26	8.28	10.70
20	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	43	13.69	12.30
21	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	35	11.14	8.30
22	พลอง	*Dipterocarpus tuberculatus* Roxb.	75	23.88	9.10
23	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	35	11.14	6.30
24	ปีน (ฟีน)	-	36	11.46	6.30
25	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	6.30
26	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	36	11.46	8.50
27	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	35	11.14	6.50
28	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	59	18.78	6.10
29	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	52	16.56	7.30
30	พลอง	*Dipterocarpus tuberculatus* Roxb.	33	10.51	12.30
31	พลอง	*Dipterocarpus tuberculatus* Roxb.	28	8.91	6.30
32	พลอง	*Dipterocarpus tuberculatus* Roxb.	43	13.69	6.40
33	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	41	13.05	9.00
34	พลอง	*Dipterocarpus tuberculatus* Roxb.	60	19.10	8.70
35	พลับพลา	*Microcos paniculata* L.	24	7.64	6.30
36	-	*Streblus ilicifolius* (Vidal) Corner	43	13.69	6.50
37	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	60	19.10	10.30
38	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	57	18.15	10.30
39	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	25	7.96	10.30
40	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	37	11.78	10.30
41	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	34	10.82	10.30
42	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	59	18.78	10.30
43	พลอง	*Dipterocarpus tuberculatus* Roxb.	26	8.28	10.30
44	พลอง	*Dipterocarpus tuberculatus* Roxb.	38	12.10	10.30

Table C.19 Detail of MDF Plot 3. (X: 153013 Y: 1631428, AGB 2,574.90 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
45	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	38	12.10	10.30
46	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	34	10.82	10.30

Table C.20 Detail of MDF Plot 4. (X: 153357 Y: 1632846, AGB 3,560.20 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	39	12.42	7.00
2	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	47	14.96	11.00
3	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	11.00
4	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	47	14.96	13.00
5	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	71	22.60	13.00
6	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	68	21.65	12.90
7	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	32	10.19	10.50
8	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	83	26.42	12.90
9	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	68	21.65	12.90
10	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	31	9.87	10.80
11	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	59	18.78	11.40
12	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	72	22.92	13.60
13	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	33	10.51	12.50
14	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	41	13.05	13.90
15	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	60	19.10	10.90
16	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	7.90
17	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	39	12.42	12.00
18	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	124	39.48	16.50
19	พลับพลา	*Microcos paniculata* L.	51	16.24	8.50
20	พลับพลา	*Microcos paniculata* L.	33	10.51	5.90
21	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	23	7.32	7.10
22	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	31	9.87	4.80
23	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	28	8.91	6.20
24	พลับพลา	*Microcos paniculata* L.	60	19.10	10.60
25	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	111	35.34	17.50
26	ลำดวน (หอมนวล)	*Melodorum fruticosum* Lour.	24	7.64	7.40
27	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	47	14.96	10.90
28	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	87	27.70	17.00
29	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	6.80
30	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	42	13.37	9.20
31	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	20	6.37	6.80
32	พลับพลา	*Microcos paniculata* L.	51	16.24	8.90
33	พลับพลา	*Microcos paniculata* L.	39	12.32	7.60
34	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	52	16.56	10.60
35	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	58	18.47	11.00

Table C.21 Detail of MDF Plot 5. (X: 147128 Y: 1631600, AGB 2,694.90 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	พลับพลา	*Microcos paniculata* L.	45	14.33	9.30
2	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	31	9.87	9.40
3	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	41	13.05	7.80
4	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	45	14.33	7.80
5	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	98	31.20	14.20
6	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	28	8.91	11.20
7	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	58	18.47	12.90
8	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	56	17.83	12.90
9	พลับพลา	*Microcos paniculata* L.	44	14.01	9.70
10	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	66	21.01	16.40
11	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	83	26.42	16.30
12	งิ้วป่า	*Bombax anceps* Pierre var. anceps	60	19.10	11.60
13	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	41	13.05	8.80
14	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	46	14.65	10.10
15	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	66	21.01	13.60
16	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	43	13.69	10.00
17	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	58	18.47	13.60
18	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	47	14.96	10.30
19	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	67	21.33	10.90
20	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	61	19.42	15.40
21	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	30	9.55	10.80
22	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	39	12.42	10.00
23	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	26	8.28	7.50
24	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	26	8.28	7.30
25	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	47	14.96	10.40
26	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	26	8.28	4.90
27	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	29	9.23	6.60
28	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	31	9.87	6.10
29	พลับพลา	*Microcos paniculata* L.	25	7.96	6.10
30	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	35	11.14	8.20
31	เถาวัลย์	-	30	9.55	5.60
32	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	29	9.23	8.60
33	ตะไกล้	-	44	14.01	7.50
34	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	20	6.37	6.80
35	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	75	23.88	16.90
36	แข้งกวาง (กวาว)	*Wendlandia tinctoria* (Roxb.) DC.	27	8.60	6.80
37	ตะไกล้	-	20	6.37	5.80

Table C.22 Detail of MDF Plot 6. (X: 153406 Y: 1632485, AGB 3,883.78 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ประดู่ป่า (ประดู่เสน)	*Pterocarpus macrocarpus* Kurz	29	9.23	9.10
2	พลอง	*Dipterocarpus tuberculatus* Roxb.	75	23.88	7.10
3	กร่าง (ไทรทอง)	*Ficus altissima* Blume	58	18.47	10.90
4	พลับพลา	*Microcos paniculata* L.	70	22.29	8.30
5	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	25	7.96	7.10
6	พลับพลา	*Microcos paniculata* L.	100	31.85	11.20
7	พลอง	*Dipterocarpus tuberculatus* Roxb.	30	9.55	10.70
8	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	40	12.73	7.10
9	ปีน (ฟีน)	-	35	11.14	6.30
10	พลอง	*Dipterocarpus tuberculatus* Roxb.	43	13.69	8.30
11	พลอง	*Dipterocarpus tuberculatus* Roxb.	33	10.51	8.70
12	พลอง	*Dipterocarpus tuberculatus* Roxb.	90	28.65	7.90
13	พลอง	*Dipterocarpus tuberculatus* Roxb.	80	25.47	9.80
14	พลอง	*Dipterocarpus tuberculatus* Roxb.	26	8.28	8.80
15	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	40	12.73	8.80
16	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	44	14.01	8.80
17	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	32	10.19	8.10
18	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	40	12.73	10.30
19	พลอง	*Dipterocarpus tuberculatus* Roxb.	50	15.92	9.40
20	พลับพลา	*Microcos paniculata* L.	50	15.92	8.10
21	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	185	58.90	7.00
22	ปีน (ฟีน)	-	40	12.73	12.10
23	พลอง	*Dipterocarpus tuberculatus* Roxb.	30	9.55	9.10
24	ปีน (ฟีน)	-	24	7.64	6.30
25	ปีน (ฟีน)	-	77	24.51	6.30
26	พลับพลา	*Microcos paniculata* L.	44	14.01	6.30
27	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	58	18.47	9.10
28	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	69	21.97	6.60
29	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	40	12.73	11.80
30	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	25	7.96	7.10
31	-	-	60	19.10	6.30
32	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	48	15.28	13.70
33	พลอง	*Dipterocarpus tuberculatus* Roxb.	37	11.78	7.30
34	พลอง	*Dipterocarpus tuberculatus* Roxb.	47	14.96	7.70
35	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	65	20.69	12.30
36	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	51	16.24	13.30
37	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	34	10.82	10.70
38	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	50	15.92	7.90

Table C.23 Detail of MDF Plot 7. (X: 151793 Y: 1634121, AGB 3,099.30 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ปีน (ฟีน)	-	30	9.55	6.30
2	ปีน (ฟีน)	-	20	6.37	8.70
3	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	50	15.92	7.90
4	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	55	17.51	6.10
5	ไม้ใหญ่ (ยอดด้วน)	-	100	31.84	8.20
6	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	40	12.73	9.50
7	ปีน (ฟีน)	-	70	22.29	7.30
8	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	6.30
9	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	60	19.10	10.80
10	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	50	15.92	8.80
11	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	43	13.54	6.90
12	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	60	19.10	9.80
13	พลอง	*Dipterocarpus tuberculatus* Roxb.	30	9.55	8.30
14	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	60	19.10	7.10
15	ข่อย (ข่อยหนาม)	Streblus ilicifolius (Vidal) Corner	30	9.55	7.10
16	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	50	15.92	12.30
17	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	29	9.23	6.70
18	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	36	11.46	12.90
19	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	40	12.73	10.30
20	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	30	9.55	9.40
21	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	38	12.10	8.30
22	มะค่าแต้	*Indora siamensis* Teijsm. & Miq.	30	9.55	8.50
23	พลอง	*Dipterocarpus tuberculatus* Roxb.	27	8.60	7.10
24	-	-	69	21.97	7.30
25	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	25	7.96	6.30
26	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	60	19.10	6.30
27	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	40	12.73	6.30
28	ปีน (ฟีน)	-	38	12.10	8.30
29	กร่าง (ไทรทอง)	*Ficus altissima* Blume	49	15.60	7.80
30	พลอง	*Dipterocarpus tuberculatus* Roxb.	40	12.73	9.00
31	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	36	11.46	6.50
32	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	52	16.56	6.30
33	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	49	15.60	6.30
34	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	36	11.46	6.50
35	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	42	13.37	7.30
36	ตะขบป่า (ตะขบหนาม)	*Flacourtia indica* (Burm.f.) Merr.	34	10.82	11.30
37	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	60	19.10	9.80
38	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	48	15.28	8.30
39	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	30	9.55	10.00
40	กระเบากลัก	*Hydnocarpus anthelminthicus* Pierre ex Laness.	44	9.55	10.60
41	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	34	14.01	10.30
42	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	43	10.82	10.30
43	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	48	13.69	10.30
44	พลอง	*Dipterocarpus tuberculatus* Roxb.	42	15.28	10.30

Table C.23 Detail of MDF Plot 7. (X: 151793 Y: 1634121, AGB 3,099.30 kg) (Continued).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
45	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	29	13.37	8.50
46	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	33	9.23	10.00
47	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	41	10.51	12.40
48	มะนาวผี (มะนาวป่า)	*Atalantia monophylla* (DC.) Correa	38	13.05	8.80
49	ปอหูช้าง	*Pterospermum acerifolium* (L.) Willd.	36	12.10	10.50

Table C.24 Detail of MDF Plot 8. (X: 155449 Y: 1629545, AGB 3,537.79 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	70	22.29	13.80
2	ฉนวน (สนวน)	*Dalbergia nigrescens* Kurz	48	15.28	11.80
3	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	32	10.19	13.80
4	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	34	10.82	12.90
5	พลับพลา	*Microcos paniculata* L.	36	11.46	11.70
6	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	81	25.79	16.30
7	พลับพลา	*Microcos paniculata* L.	31	9.87	9.60
8	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	68	21.65	9.80
9	พลับพลา	*Microcos paniculata* L.	51	16.24	9.00
10	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	65	20.69	13.10
11	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	80	25.47	16.30
12	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	31	9.87	11.40
13	กระทุ่ม (ตะโก)	*Anthocephalus chinensis* (Lam.) A.Rich ex Walp.	33	10.51	9.80
14	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	40	12.73	6.90
15	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	63	20.06	10.50
16	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	82	26.11	13.60
17	พลับพลา	*Microcos paniculata* L.	65	20.69	6.70
18	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	32	10.19	12.30
19	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	39	12.42	10.80
20	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	120	38.17	16.50
21	หมากหม้อ (ขี้หมู)	*Rothmannia wittii* (Craib) Bremek.	55	17.51	9.90
22	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	130	41.39	17.80
23	พลับพลา	*Microcos paniculata* L.	41	13.05	11.20
24	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	33	10.51	8.20
25	ทะยิง	*Diospyros oblonga* Wall. ex G.Don	35	11.14	6.20
26	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	37	11.78	6.30
27	ขันทองพยาบาท (กระดูก)	*Suregada multiflorum* (A.Juss.) Baill.	54	17.19	9.80
28	สะแก	*Combretum quadrangulare* Kurz	27	8.60	5.20
29	นนทรี (กระถินป่า)	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	46	14.65	11.90
30	กระบก (กระบกพลาย)	*Irvingia malayana* Oliv. ex A.W.Benn.	48	15.28	9.30
31	ประดู่ป่า (ประดู่)	*Pterocarpus macrocarpus* Kurz	46	14.65	13.00

Table C.25 Detail of FPT Plot 1. (X: 149236 Y: 1630925, AGB 2,717.33 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	80	25.47	19.90
2	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	23	7.32	5.90
3	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	42	13.37	12.00
4	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	41	13.05	5.90
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	65	20.69	16.00
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	54	17.19	16.00
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	33	10.51	6.90
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	59	18.78	15.70
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	50	15.92	10.40
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	64	20.38	15.10
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	89	28.33	15.20
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	80	25.47	18.90
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	50	15.92	15.80
14	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	82	26.11	17.80
15	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	55	17.51	12.50
16	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	45	14.33	8.80
17	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	85	27.06	19.60
18	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	42	13.37	9.80
19	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	48	15.28	16.40

Table C.26 Detail of FPT Plot 2. (X: 152896 Y: 1624035, AGB 2,359.32 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	40	12.76	8.30
2	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	83	26.42	21.60
3	สะเดา	*Azadirachta indica* A.Juss	22	7.00	3.80
4	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	62	19.74	8.70
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	67	21.33	17.90
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	38	12.10	10.40
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	40	12.73	10.20
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	63	20.06	10.80
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	70	22.29	12.40
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	80	25.47	17.50
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	50	15.92	14.60
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	76	24.20	19.90
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	55	17.51	11.80
14	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	94	29.93	19.10
15	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	65	20.69	12.40

Table C.27 Detail of FPT Plot 3. (X: 149881 Y: 1630557, AGB 2,756.29 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	56	17.83	15.30
2	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	86	27.38	21.80
3	สะเดา	*Azadirachta indica* A.Juss	30	9.55	5.00
4	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	80	25.47	4.50
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	50	15.92	13.20
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	88	28.02	15.80
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	103	32.79	17.80
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	97	30.88	12.90
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	60	19.10	17.40
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	70	22.29	22.10
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	55	17.51	13.20
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	44	14.01	10.90
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	32	10.19	13.80
14	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	55	17.51	12.80
15	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	35	10.60	7.20
16	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	77	24.51	12.70
17	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	45	14.33	5.30

Table C.28 Detail of FPT Plot 4. (X: 151794 Y: 1627078, AGB 2,107.30 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	68	21.56	15.80
2	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	49	15.60	15.40
3	สะเดา	*Azadirachta indica* A.Juss	18	5.73	8.80
4	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	51	16.24	9.30
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	31	9.87	8.80
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	67	21.33	16.60
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	84	26.74	18.10
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	74	23.56	19.70
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	46	14.65	8.00
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	75	23.88	13.80
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	78	24.83	17.30
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	66	21.01	17.50
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	60	19.10	13.80
14	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	59	18.78	16.50

Table C.29 Detail of FPT Plot 5. (X: 149956 Y: 1629965, AGB 2,683.17 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	59	18.78	18.40
2	สะเดา	*Azadirachta indica* A.Juss	31	9.87	12.90
3	สะเดา	*Azadirachta indica* A.Juss	50	15.92	6.80
4	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	72	22.92	13.80
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	24	7.64	11.30
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	64	20.38	12.10
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	63	20.06	16.40
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	92	29.29	16.00
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	66	21.01	16.90
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	78	24.83	19.80
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	74	23.56	18.80
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	130	41.39	15.70
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	71	22.60	13.30

Table C.30 Detail of FPT Plot 6. (X: 153016 Y: 1623425, AGB 3,429.04 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	65	20.69	13.10
2	สะเดา	*Azadirachta indica* A.Juss	42	13.37	18.30
3	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	83	26.42	18.50
4	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	48	15.28	13.40
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	60	19.10	17.10
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	60	19.10	14.60
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	97	30.88	21.60
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	70	22.29	14.70
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	72	22.92	11.90
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	68	21.65	18.50
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	48	15.28	16.30
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	78	24.83	19.10
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	86	27.38	22.80
14	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	41	13.05	14.10
15	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	57	18.15	18.80
16	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	35	11.14	12.00
17	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	42	13.37	16.60
18	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	54	17.19	13.80
19	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	49	15.60	20.10
20	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	42	13.38	19.70

Table C.31 Detail FPT Plot 7. (X: 150466 Y: 1629155, AGB 2,827.63 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	97	30.88	17.80
2	โมกมัน (มูกมัน)	*Wrightia arborea* (Dennst.) Mabb.	10	3.18	7.80
3	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	65	20.69	11.00
4	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	88	28.02	11.30
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	62	19.74	8.80
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	34	10.82	8.80
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	65	20.69	14.70
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	97	30.88	19.60
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	67	21.33	16.10
10	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	101	32.16	20.50
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	42	13.37	9.70
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	70	22.29	15.30
13	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	88	28.02	17.80

Table C.32 Detail of FPT Plot 8. (X: 150811 Y: 1628646, AGB 3,046.15 kg).

No	Local name	Scientific name	GBH (cm.)	DBH (cm.)	Height (m.)
1	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	67	21.33	17.20
2	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	98	31.20	18.40
3	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	80	25.47	16.30
4	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	101	32.16	18.10
5	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	54	17.19	8.10
6	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	60	19.10	10.10
7	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	44	14.01	13.10
8	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	67	21.33	17.50
9	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	112	35.66	17.30
10	สะเดา	*Azadirachta indica* A.Juss	41	13.05	8.50
11	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	91	28.97	18.00
12	ยูคาลิปตัส	*Eucalyptus camaldulensis* Dehnh.	79	25.15	15.90

CURRICULUM VITAE

Name : Tinn Thirakultomorn

Date of Birth : 11 February 1979

Place of Birth : Lampang, Thailand.

Education :

2000 Bachelor of Science (Geography): Department of Geography, Faculty of Social Sciences, Chiang Mai University, Thailand.

2010 Master of Science (Geoinformatics): School of Remote Sensing, Institute of Science, Suranaree University of Technology, Thailand

Grants and Fellowships :

External Grants and Scholarships for Graduate Students (One Research One Graduate, OROG)

Position and Place of Work :

Photogrammetrist in The Center for Scientific and Techonological Equipment, Suranaree University of Technology, Thailand.