Ph.D. Dissertation of Forest Environmental Science

Effects of Community Forest Management on Biodiversity and Utilization of Non-Timber Forest Products in Northern Thailand

태국 북부의 공동체숲 산림경영이 종다양성과 비목재 임산물의 이용에 미치는 영향

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Abstract

Forest resources are crucial to local livelihoods, and effective management of community forests is likewise essential to the sustainability of those resources. The overriding goal of this study was to explore solutions and provide insight into improving rural livelihoods and conserving biodiversity of a community forest. The study area was Ban Mae Chiang Rai Lum Community Forest located in Pa Mae Phrik National Forest Reserve in northern Thailand.

Tree species composition and distribution in the deciduous forests were assessed and the environmental factors that influence tree biodiversity were identified and analyzed. Further, levels and behavior of the local people in the utilization of non-timber forest products (NTFPs) were examined as was the effectiveness of community forest management (CFM). The socio-demographics and CFM factors that influenced NTFP dependence and that were correlated to participation in CFM were also identified.

A systematic sampling of the forest's total area of 3,925 ha was conducted and twenty-five 0.16 ha survey plots were established in three different stands of the deciduous forests. These plots were used to estimate and characterize the biological diversity of the stands. A canonical correspondence analysis (CCA) was used to identify the environment factors that contributed to the distinctive stand-to-stand biodiversity. Households were surveyed to garner information regarding their NTFP utilization and their CFM engagement behavior and attitudes.

The study area features exceptionally diverse plant species as 197 species, 144 genera, and 62 plant families were recorded. The CCA identified the environmental factors that significantly influenced the diversity and distribution of the tree species ($p < 0.05$). Elevation, distance to streams, soil moisture, organic matter, and distance to communities were the factors that were most impactful on tree composition and distribution. The findings indicate that the implementation of drought reduction measures such as building check dams, fire protection, and monitoring community forest-product usage would be recommended to support biodiversity conservation efforts and advance the sustainable use of community forest resources.

The study area was rich in NTFPs as 160 of the populating species have medicinal uses, 89 are used as food, 37 as extractives, 32 as fuelwoods, and 12 species as fibers. However, over-exploitation of these NTFPs has negatively impacted biodiversity; 26 species are on the IUCN Red List of Threatened Species. A majority of surveyed households (68.55%) depended on NTFPs. The value of the harvested NTFPs was 6.35% of the annual community income. A correlation between NTFP income and participation in CFM suggests that combining CFM with responsible utilization of NTFPs can create greater income opportunities while also advancing conservation efforts.

In addition, NTFP dependence and participation in CFM were directly related to the socio-economics of identifiable groups in the community and their engagement in CFM processes. Females, respondents 60 years old and younger, married people, those who listed their principal occupation as ‘farmer’, and people who participated in CFM at a ‘very high’ level were more dependent on NTFPs. Similarly, landowners and people who were NTFP dependent were more likely to participate in CFM. However, participation in decision-making, monitoring and evaluation activities was comparatively limited.

Having insight into the behavior and attitudes of local residents regarding forest management and utilization of NTFPs provides knowledge useful for the sustainable management of the study area and for community forests countrywide. In general**,** the findings have implications for successful forest management, maximization of benefits and conservation of biodiversity. Specifically, the harvesting of NTFPs should not go unchecked, especially of species that are threatened or likely to be threatened if over-harvested. Furthermore, efforts to enhance utilization by lower income households, more equitably distribute the benefits, and incentivize community involvement should be prioritized as doing so is crucial to maintaining a sustainable supply of NTFPs and safeguard the community forest biodiversity.

Keywords: Biodiversity, Utilization, Non-timber forest products, Community forest management, Livelihoods, Northern Thailand

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Abbreviations

#	Population trend decreasing
%	Percent
°C	Celsius
ANOVA	One-way analysis of variance
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
AS	Aspect
ASEAN	Association of South-East Asian Nations
B	Beta
B	Bamboo
C	Climber
Ca	Exchange calcium
CBD	Convention on Biological Diversity
CCA	Canonical correspondence analysis
CF	Climbing fern
CFM	Community forest management
CI	Confidence interval
CL	Clay
cm	Centimeter
D	Simpson index
DBH	Diameter at breast height
DC	Distance to communities
DD	Data deficient
DNP	Department of National Parks, Wildlife and Plant Conservation
DR	Distance to roads
DS	Distance to streams
E	Easting / Species evenness
EL	Elevation
EN	Endangered
EP	Edible plant
EX	Extractive
ExH	Exotic herb

ExS	Exotic shrub
F	Fern
FAO	Food and Agriculture Organization
FI	Fiber
FW	Fuelwood
GIS	Geographic information system
GPS	Global positioning system
H	Herb
H′	Shannon-Wiener index
ha	Hectare
HC	Herbaceous climber
ICEM	International Centre for Environmental Management
IRR	Internal rate of return
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
IVI	Importance value index
K	Exchange potassium
KCL	Potassium chloride
Km	Kilometer
LC	Least concern
LCL	Lower confidence limit
m	Meter
MLS	*Millettia leucantha-Lagerstroemia duperreana* stand
mm	Millimeter
MP	Medicinal plant
MPSAO	Mae Phrik Subdistrict Administrative Organization
n	Sample size
N	Northing / Population size
N.S.	Not significant
N/A	Not applicable
NH4OAc	Ammonium acetate
NPV	Net present value
NSO	National Statistical Office

NT	Near threatened
NTFPs	Non-timber forest products
o	Not listed on the IUCN Red List of Threatened Species
OM	Organic matter
ONEP	Office and Natural Resources and Environmental Policy and Planning
OR	Odds ratio
P	Available phosphorus / Palm
p	*p*-value
pH	Acidity
Q	Quartile
r	Correlation coefficient
RECOFTC	Regional Community Forestry Training Center for Asia and the Pacific
RFD	Royal Forest Department
S	Shrub / Southing / Species richness
s.e.	Standard error
SA	Sand
ScanS	Saprophytic shrub
SD	Standard deviation
SI	Silt
SL	Slope
SM	Soil moisture
SOS	*Shorea obtusa*-*Sindora siamensis* stand
SSS	*Shorea siamensis*-*Shorea obtusa* stand
ST	Shrubby tree
Std	Standard
T	Tree
TerO	Terrestial orchid
TFSMP	Thai Forestry Sector Master Plan
UCL	Upper confidence limit
US $	United States Dollar
US	Undershrub
VU	Vulnerable
W	Westing

Chapter 1. Introduction

1.1. Statement of Problems

Forest resources are important for ecosystem services and human well-being. Approximately 1.6 billion people, more than 25% of the world's population, depend locally on bio-diverse forest resources for their livelihoods (The World Bank 2001). The value of biodiversity in maintaining commercial forest productivity alone is estimated to be as much as US $166 - 490 billion per year (Liang et al. 2016).

Thailand is one of the most bio-diverse countries in Southeast Asia. Forests cover approximately 32% of its total land area (RFD 2019a) and are inhabited by roughly 8% of the world's plant species (ONEP 2009).

Non-timber forest products (NTFPs) sourced from the biodiversity of forest ecosystems are also crucial contributors to rural communities. Dependence on NTFPs by lower income households to support their livelihoods has been reported in many parts of the world (Amgrose-Oji 2003; Heubach et al. 2011; Melaku et al. 2014; Liu and Moe 2016; Saifullah et al. 2018). In a survey conducted by Angelson et al. (2014), twenty-four developing countries were found to rely on forests for 28% of total household incomes.

In Thailand, roughly 23 million people live near national forest reserve areas in which NTFPs are significant in helping to meet basic daily needs of rural communities (Witchawutipong 2005). NTFPs are used for daily household consumption and are often traded in local markets to provide and supplement household income. Commonly, the NTFPs utilized in the communities include edible plants, wild fruit, medicinal plants, fuelwood, mushrooms, insects, wild animals, fibers, and extractives (Jarensuk et al. 2015; Larpkerna et al. 2017; Mianmit et al. 2017). The average annual income from selling NTFPs in local markets in Thailand is estimated to be over US $25,000 per village (ONEP 2004) and over US $2 billion nationwide (ITTO 2006). In Southeast Asia, Community Forest Management (CFM) has been recognized as an effective approach to restore degraded forests, augment the income of the poor, and help meet the needs of local residents for food and medicine (Blair and Olpadwala 1988). CFM has been applied in pursuit of sustainability and forest biodiversity conservation in Thailand (Srisutham and Kaewjampa 2010); the Royal Forest Department (RFD) has been promoting CFM since 1987. To date, CFM has been implemented in approximately 7% of the country's total forest area, or more than 1.2 million ha, within roughly 17,400 villages nationwide (RFD 2014, 2020).

Although community forest management can facilitate biodiversity conservation, there is insufficient information as to how environmental factors influence biodiversity and how CFM affects that biodiversity in community forests. In addition, Thailand is facing a rapid decline in forest ecosystem plant species. At least 1,442 plant species, including 715 endemic species are classified as vulnerable, 207 as endangered, and 18 species are critically endangered (DNP 2017).

Previous studies have shown that there are numerous environmental factors that are closely related to the composition and distribution of trees in forest ecosystems. Topographic features such as elevation, slope, aspect, and streams (Zhang and Zhang 2007; Zhang et al. 2013; Zhang et al. 2016; Asanok et al. 2017), soil properties (e.g. acidity, texture, moisture, and its organic matter) (Oliveira-Filho et al. 1998; Hejcmanovā-Nežerková and Hejcman 2006; Han et al. 2011; Zhao et al. 2015), and anthropogenic factors such as distance to communities and roads can have environmental, social, and economic impact on service functions and available resources in the forest and, as a result, on the concomitant benefits inuring to the people of the community (Chen et al. 2014; Måren and Sharma 2018; Eghdami et al. 2019).

In addition, the underlying causes of forest biodiversity loss are associated with the utilization and over-exploitation of forests and their resources (Millennium Ecosystem Assessment 2005). Extraction of forest resources can alter species composition and distribution (Thapa and Chapman 2010) and unsustainable utilization of forest resources can result in decreased regeneration of tree species and tree populations in general (Murali et al. 1996; Popradit et al. 2015). Over-exploitation of forest resources not only affects species diversity, but also has a long term, harmful impact on ecosystem health and resiliency (Rew 2005). Consequently, there is inherent conflict between forest utilization and biodiversity conservation that can affect people's livelihoods; using resources in an inappropriate manner, or over-use of resources, may decrease the ecosystem services that provide benefits to the neighboring communities. Implementing CFM can safeguard species diversity and ecosystem services as well as improve rural livelihoods.

1.2. Research Questions

This study identified ecological characteristics, ascertained species diversity indices, and investigated pertinent environmental factors that impacted three unique forest stands in the community forest. In addition, the nature and extent of household utilization of NTFPs, opinions as to the implementation and effectiveness of CFM, and household socio-demographics were analyzed to identify how and to what extent the forest was being managed and benefits to livelihoods were being derived. This study focused on the following questions:

1) What are key environmental factors that influence species distribution in the different stands?

2) What economic value is and can be realized through participation in CFM?

3) What factors influence NTFP dependence and participation in CFM?

1.3. Research Objectives

The following three objectives were established to address the research questions.

1) Investigate key environmental factors that influence species distribution in the different stands

2) Determine the relationship between NTFP income and people's participation in CFM

3) Identify the factors that impact NTFP dependence and participation in CFM

1.4. Research Structure

The focuses and sources of data in this study were forest biodiversity, the environment, and demographic and other pertinent information generated via survey of participating households. Three objectives were pursued with an overriding goal of analyzing conservation and the utilization of the NTFPs of the Ban Mae Chiang Rai Lum Community Forest. Seven chapters inform the research structure as follows:

Chapter 1 provides an overview of the relationship between forest biodiversity and its enhancement of rural livelihoods as well as an identification of the inherent conflict between utilization of NTFPs and biodiversity conservation under CFM.

Chapter 2 illustrates the diversity and composition of tree species in the community forest. In addition, the environmental factors that influence tree species and distribution were investigated to inform CFM which would be effective in safeguarding species diversity, its continued positive impact as well as overall forest livelihood.

Chapter 3 describes the utilization of NTFPs under CFM. The deciduous forests' structure and the diversity of tree species are outlined. A presentation of the socio-demographics of the respondents, the nature and extent of their NTFP utilization, and the effectiveness of CFM is provided. The relationships between NTFP income and CFM and the socio-economic and CFM factors that influence NTFP dependence and participation in CFM are presented.

In Chapter 4, the impacts of CFM on biodiversity and on the utilization of NTFPs are detailed and what insights this information provides for sustainable community forest management are discussed. Pertinent subject matter knowledge gaps are identified and recommendations to better manage community forests are made. Vital information regarding harvesting levels of NTFPs is detailed as are ways in which this information can be applied under CFM for the enhancement of rural livelihoods and biodiversity conservation. Finally, the limitations of this study and suggestions for subsequent studies are presented.

The research structure is shown in Figure 1.1.

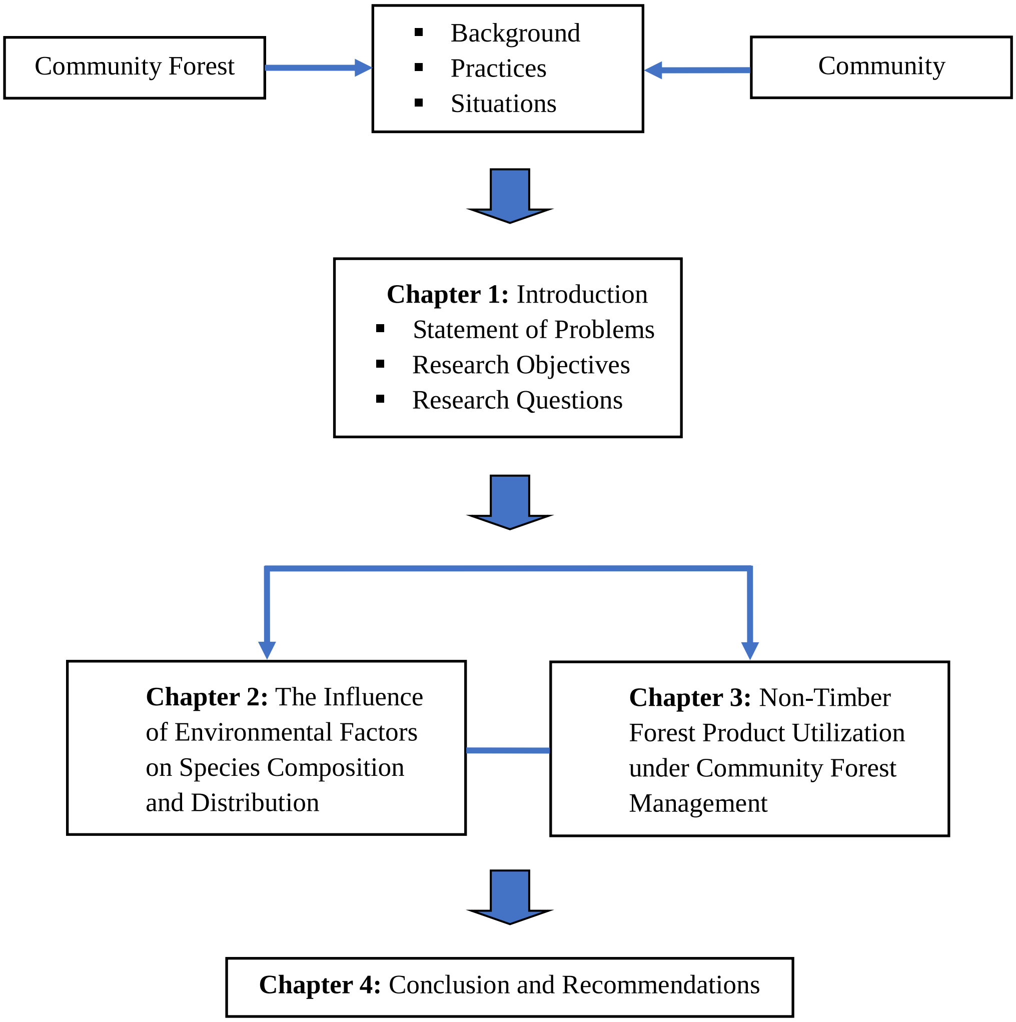


Figure 1.1 Research structure

Chapter 2. The Influence of Environmental Factors on Species Composition and Distribution

2.1. Literature Review

2.1.1. Forest Resources in Thailand

Thailand’s forest resources are among the most abundant in Southeast Asia. In 2019, the RFD estimated the forest area of Thailand to be 102,484,072.71 rai or roughly 16.40 million ha (RFD 2019b), representing 31.68% of the country’s total land area (Table 2.1).

Table 2.1 Temporal changes in forest area in Thailand (1973 - 2019)

Years	Total forest area (rai)	% of forest cover
1973	138,566,875.00	43.21
1976	124,010,625.00	38.67
1978	109,515,000.00	34.15
1982	97,875,000.00	30.52
1985	94,291,250.00	29.40
1988	89,876,875.00	28.03
1989	89,635,625.00	27.95
1991	85,436,250.00	26.64
1993	83,471,250.00	26.03
1995	82,178,125.00	25.62
1998	81,076,250.00	25.28
2000	106,319,239.47	33.15
2004	104,744,360.00	32.66
2005	100,625,812.50	31.38
2006	99,157,868.75	30.92
2008	107,241,031.25	33.44
2013	102,119,537.50	31.57
2014	102,285,400.00	31.62
2015	102,240,981.88	31.60
2016	102,174,805.09	31.58
2017	102,156,350.53	31.58
2018	102,488,302.19	31.68
2019	102,484,072.71	31.68

Source: Royal Forest Department, 2019

1 ha = 6.25 rai

The variety of vegetation types in Thailand reflects the wide range of ecological and climatic conditions (Boonkird et al. 1984). The RFD (2019a) classified the country's forest into sixteen types with the deciduous forest (including both mixed deciduous and dry dipterocarp forests) as the primary forest type, as it covers the largest percentage of the total country's forest area at 18.26%. Other major forest types include the dry evergreen forest (4.30%), the moist evergreen forest (3.68%), and montane forest (3.38%) (Table 2.2).

Table 2.2 Forest types and area in Thailand as of 2019

Forest types	Total forest area (rai)	% of forest cover
Moist evergreen forest	11,916,400.68	3.68
Dry evergreen forest	13,904,871.12	4.30
Montane forest	10,944,716.68	3.38
Pine forest	541,822.97	0.17
Peat swamp forest	273,263.28	0.08
Mangrove forest	1,538,185.33	0.48
Freshwater swamp forest	263,905.58	0.08
Beach forest	65,840.83	0.02
Mixed deciduous forest	47,194,211.82	14.59
Dry dipterocarp forest	11,885,932.37	3.67
Bamboo forest	407,905.88	0.13
Teak plantation	915,326.73	0.28
Other plantations	27,552.42	0.01
Secondary forest	1,805,895.34	0.56
Savana	386,971.31	0.12
Vegetation on pen rock platform	415,499.84	0.13

Source: Royal Forest Department, 2019

1 ha = 6.25 rai

As shown in Table 2.3, the 56,392,370.41 rai (9.02 million ha) of forest in the North of Thailand represents 52.46% of that region's total area (RFD 2019b). Forests in the North are considered to be the most important watershed areas of the country (RFD 1988; FAO 2009). Most of the northern forests are deciduous forests which are generally favored as sources of NTFPs (and as an illegal and pre-regulation legal source of timber) over other forest ecosystems in Thailand. A mixed deciduous forest is broadly subdivided according to species composition into mixed deciduous forests that contain teak and mixed deciduous forests that do not (FAO 2009). A mixed deciduous forest provides the most valuable timber, whereas dry dipterocarp forests provide food and firewood NTFPs for remote, rural communities to access to supplement their livelihoods (Kutintara 1975; Larpkerna et al. 2017).

Table 2.3 Forest area in 2019 by region in Thailand

Regions	Total area (rai)	Forest area (rai)	% of forest cover
North	107,489,799.49	56,392,370.41	52.46
North-East	104,823,709.23	15,751,998.41	15.03
East	22,889,386.44	5,128,000.46	22.40
Central	42,170,903.09	13,983,942.96	33.16
South	46,154,901.40	11,227,760.46	24.33

Source: Royal Forest Department, 2019

1 ha = 6.25 rai

2.1.2. Forest Transition and Ongoing Challenges

Mirroring a 1985 forest policy declaration, the 12th National Economic and Social Development Plan (2017 - 2021) reiterated Thailand's goal of maintaining at least 40% of the country's total area as forests, 25% for conservation forests and 15% for economic forests. In spite of this, Thailand still faces significant issues regarding the depletion of natural forest resources.

In 1961, forests covered 53.33% of the country's total land area (FAO 2009). By 1973, the forest area had been reduced to 43.21%. From 1973, it diminished further to 25.28% in 1998. In just under four decades, forest coverage decreased to less than half of what it was in 1961 (RFD 2019b).

After 2000, technological advancements allowed for more accurate analysis of forest coverage and a re-evalation of rates of deforestation. Prior thereto, LANDSAT-5 imageries of a 1:200,000 scale were produced and assessed. Due to an improvement in scale to 1:50,000 and a modified method of calculation, new forest area standards were established (FAO 2009). This expanded the detectable areas to include smaller, previously inestimable forest areas.

Upon review of Table 2.1, it can be calculated that the annual rate of deforestation had been about 2,211,000 rai or 353,760 ha per year between 1973 and 1998. Subsequent to the advent of the enhanced technology, deforestation was projected to be 201,000 rai or 32,260 ha per year between 2000 and 2018. Also, data indicated that forest area increased from 1998 to 2000. The forest area changes from 1961 to 2019 are shown in Figure 2.1.

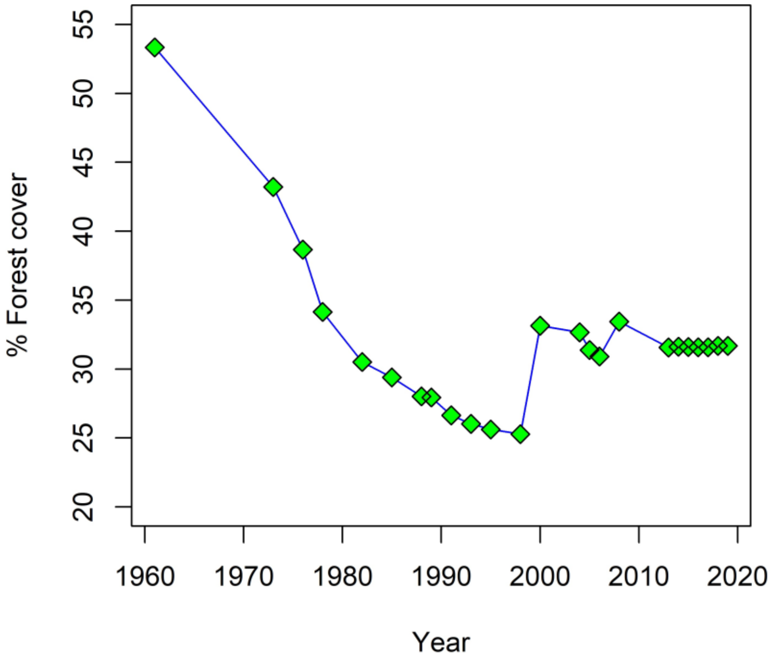


Figure 2.1 Changes in forest area from 1961 to 2019

Deforestation in Thailand has been primarily fueled by commercial logging and the elevated demand for agricultural use of land to satisfy the needs of a burgeoning population (TFSMP 1993). Forest encroachment and illegal logging continue to pose serious threats to the forests and those who rely on them, especially in the North where the most illegal activities and the highest forest conversion rates were reported (Lakanavichian 2001). Illegal logging has wide-reaching and detrimental impacts on, most notably, the economy, the environment, and the local residents. These ramifications serve as key drivers prompting increased community management of forests throughout Asia (Rosander 2008).

In the 1960s and 1970s, illegal logging caused a rapid reduction in forest resources (ICFM 2003). Resulting in significant deforestation and forest degradation, this trend continued into the 1980s in Thailand (FAO 2016). In 1989, severe floods in the South of Thailand that killed more than 370 people and caused US $240 million worth of damage was a seminal moment in changing the country's forest policies (Sadoff 1992). In response to the destruction, a wide-reaching resolution was passed. The Thai government imposed a nationwide logging ban through an emergency decree in January 1989. Consequently, it revoked all logging licenses in natural forests which effectively banned commercial logging, particularly in the upland (Lakanavichian 2001).

The primary problem was that many forests had been converted into rubber plantations. Rubber plantation soil is characteristically unstable and prone to landslides. In the 1989 event, flooding and landslides occurred after excessive rainfall of 1,051 mm during a 6-day period, and it was subsequently reported that large quantities of rubber tree debris and previously stockpiled timber were found at the foot of Khao Luang Mountain in the area (Nalampoon 1991).

Thereafter, pertinent forest policy, laws, and institutional frameworks were re-directed to address what had become and was then acknowledged to be a growing and significant problem. In addition, the government's approach to combat deforestation and illegal logging then focused on involving local communities in the protection of forests by promoting eco-tourism and emphasizing and reinforcing the benefits to the community of NTFPs (ICEM 2003).

Most recently, the Thai government approved the Community Forest Act B.E. 2562 which authorized local forest management decision-making (Royal Thai Government 2019). This reflects the present underlying policy philosophy regarding forest management that emphasizes participation in all phases of management efforts. In addition, focus is on the environmental, social, and economic benefits to the people and their surroundings provided by forest resources and forest ecosystem equilibrium.

2.1.3. Ecological Characteristics of Deciduous Forests

Forests cover 31.68% of the country's area with deciduous forests representing 18.26% of that total. The distribution of Thailand's deciduous forests occurs throughout most areas in the country, particularly in the northern region (RFD 2019a). Deciduous forests primarily consist of two main subtypes: dry dipterocarp forest and mixed deciduous forest (Smitinand 1966, 1977; Kutintara 1975; FAO 2009). These forest types play vital roles in contributing to the diversity of tree species in the forest ecosystem in providing social, economic, and environmental benefits and in supporting the livelihoods of nearby rural communities (Kabir and Webb 2006; Larpkerna et al. 2017; Mianmit et al. 2017).

Deciduous forests occur in areas with 5 - 6 month dry seasons, with a mean annual rainfall of 1,000 - 1,500 mm in dry dipterocarp forests and 1,000 - 1,800 mm in mixed deciduous forest (Bunyavejchewin 1983; Satisuk 1988). Mixed deciduous forests typically grow on moderate fertile loam soil while dry dipterocarp forests have more sandy lateritic soil (Bunyavejchewin 1983, 1985; Santisuk 1988). Forest fires are a regular feature of dry season in deciduous forests (Sukwong and Dhamanittakul 1977; Bunyavejchewin 1983).

A deciduous forest is composed of many tree species reflecting local climates, topography, and soil conditions (Kutintara 1975). The dry dipterocarp forest is mainly composed of trees belonging to the Dipterocarpaceae family. The dominant tree species generally found in a dry dipterocarp forest are *Dipterocarpus tuberculatus*, *D. obtusifolius*, *D. intricatus*, *Shorea obtusa*, *S. siamensis*, *Sindora siamensis*, *Xylia xylocarpa*, *Pterocarpus macrocarpus*, *Irvingia malayana*, *Lagerstroemia calyculata*, and *Terminalia chebula*. The most important auxiliary species commonly associated with the dominant trees are *Schleichera oleosa*, *Albizia lebbeck*, *Phyllanthus embica*, *Terminalia alatus*, *T. chebula*, *T. bellerica*, and *Vitex limonifolia* (Kutintara 1975; Khemnark 1979; Bunyavejchewin et al. 2011).

The mixed deciduous forest is composed of a very distinctive set of dominant species and can be classified into two subtypes, mixed deciduous forest with teak and mixed deciduous forest without teak. *Tectona grandis*, *Shorea siamensis*, *Dillenia pariflora*, *Pterocarpus macrocarpus*, *Xylia xylocarp*, *Afzelia xylocarpa*, *Lagerstroemia calyculatus*, *Vitex peduncularis*, and *Terminalia* spp. are the main species in a mixed deciduous forest. Other common trees in these forest types are *Dipterocarpus alatus*, *Gmelina arborea*, *Canarium subulatum*, *Millettia brandisiana*, *Careya arborea*, and *Vitex canescens* (Khemnark 1979; Marod et al. 1999; Bunyavejchewin et al. 2011).

2.1.4. Environmental Factors and the Impact on Tree Species and Distribution

Climatic factors can threaten the extinction of vulnerable species (e.g. atmospheric pressure, temperature, precipitation, solar radiation, etc.) (Körner 2007; Diem et al. 2018). Factors such as temperature and precipitation are key drivers in controlling species distribution directly when they exceed the ecophysiological tolerances of species and affect photosynthetic activity and biological processes directly (Rowe 2009). Topographic features such as slope, aspect, and elevation can impact local climate as well as soil conditions that in turn have varied effects on vegetation structure (Xianping et al. 2006; Zhang and Zhang 2007; Zhang et al. 2013; Zhang et al. 2016). The relative distance from a water source can also affect the composition and distribution of woody vegetation because of the resulting varying amount of water available for growth (Marod et al. 1999; Scalley et al. 2009; Tavili et al. 2009; Sarvade et al. 2016; Asanok et al. 2017). Physical and chemical soil properties can inform vegetation patterns on a local scale (Oliveira-Filho et al. 1998; Hejcmanovā-Nežerková and Hejcman 2006; Han et al. 2011; Zhao et al. 2015). For example, higher sand-soil ratio lessens water-holding capacity that can lead to water stress on trees (Aranguren et al. 1982; Toledo et al. 2012; Zhang et al. 2013), and acidity levels affect the distribution of species and is linked to slope and elevation in lowland tropical forests (Nguyen et al. 2015; Vahdati et al. 2017). Soil moisture also significantly changes the growth patterns of trees in drought areas (Fu et al. 2004; Yoshifuji et al. 2006; Asanok and Marod 2016; Tilk et al. 2017).

In addition, the organic matter in the soil is relevant to an analysis of environmental factors and plant communities in the forest (Sarker et al. 2014; An et al. 2015; Zhang et al. 2016). Soil nutrients such as nitrogen, potassium, phosphorus, calcium, and magnesium are correlated with the richness and distribution of plant species in tropical forests (Paulo et al. 2007; Zhang et al. 2013; Tilk et al. 2017). Further, the human impact of resource utilization through road construction and residential development significantly affects plant diversity (Chen et al. 2014; Måren and Sharma 2018; Eghdami et al. 2019).

Overall, the environment's impact on the biodiversity in community forests is complex as it involves a multitude of factors and considerations that provide limited answers, present additional clues and raise new questions that are crucial to a more thorough and useful understanding of the relationship.

2.2. Theoretical Framework, Variables and Hypothesis

2.2.1. Research Framework

Previous studies pointedly document the inherent conflict between conservation of biodiversity and the utilization of forest resources. In spite of the widespread acceptance of CFM as a principle for sustainable forest management, researchers continue to document biodiversity loss resulting from utilization of forest resources in Thailand. Combined with environmentally driven changes to species composition and distribution, livelihoods and conservation effectiveness continue to be impacted.

The goal is the furtherance of successful and sustainable management of deciduous forests and the enhancement of biodiversity. Identifying the influence of topographic, edaphic, and anthropogenic factors on species composition and distribution is a crucial component to a thorough understanding of pertinent data. The framework of this study is displayed in Figure 2.2.

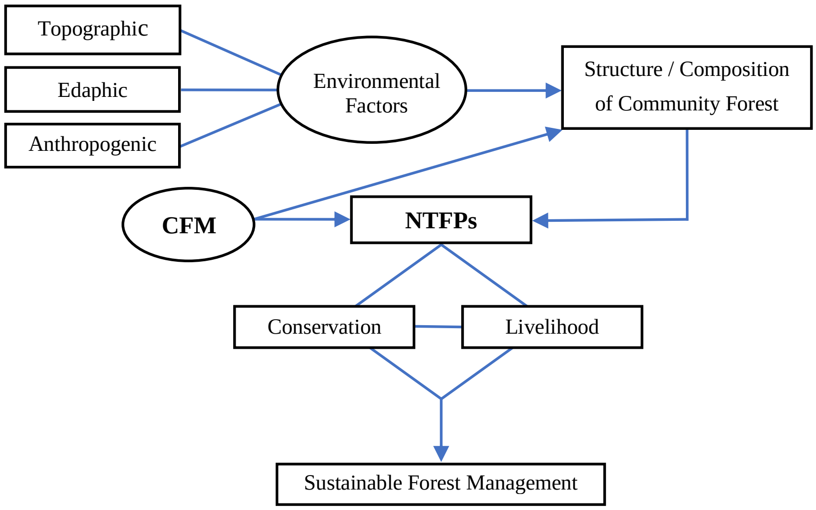


Figure 2.2 Conceptual framework of the relationship between environmental factors and tree species under CFM

2.2.2. Environmental Variables

Fifteen (15) different variables categorized into three types of environmental factors, topographic, edaphic, and anthropogenic, and their relationship to species composition and distribution in the community forest were analyzed (Figure 2.3).

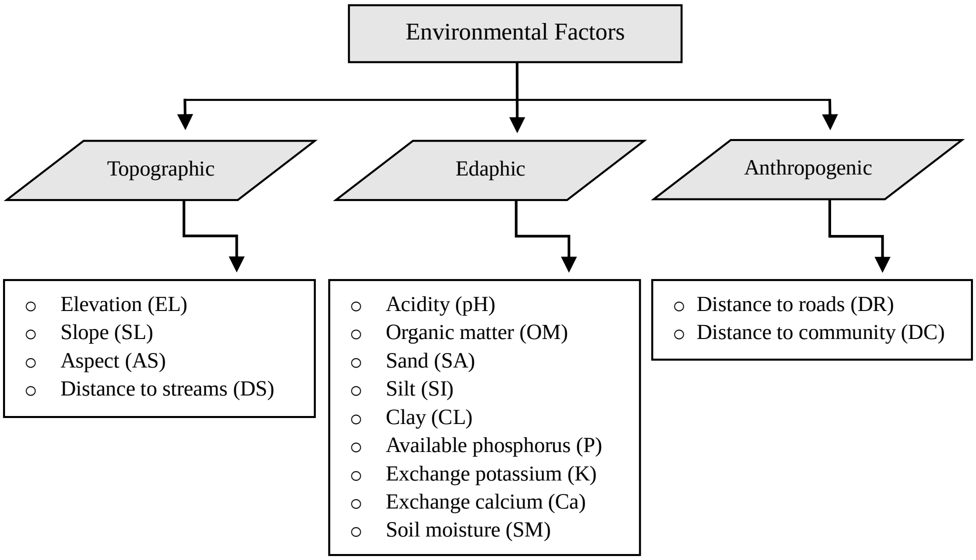


Figure 2.3 The 15 environmental variables investigated to determine their relationship to the composition and distribution of tree species in the community forest

2.2.3. Hypothesis

The conceptual framework of the study sought to increase awareness of CFM’s role in the furtherance of biodiversity conservation and to enhance the understanding of the relationship between environmental factors and tree species, leading to this hypothesis:

Hypothesis: Topographic, edaphic, and anthropogenic factors impact species composition and distribution in the community forest

2.3. Material and Methods

The Pa Mae Phrik National Forest Reserve is located in Thailand's northern province of Lampang. Situated in the southern region of this Forest Reserve is the Ban Mae Chiang Rai Lum Community Forest (N 17°22'48" to N 17°27'47" and E 99°00'47" to E 99°05'48"), wherein this study was conducted (Figure 2.4).

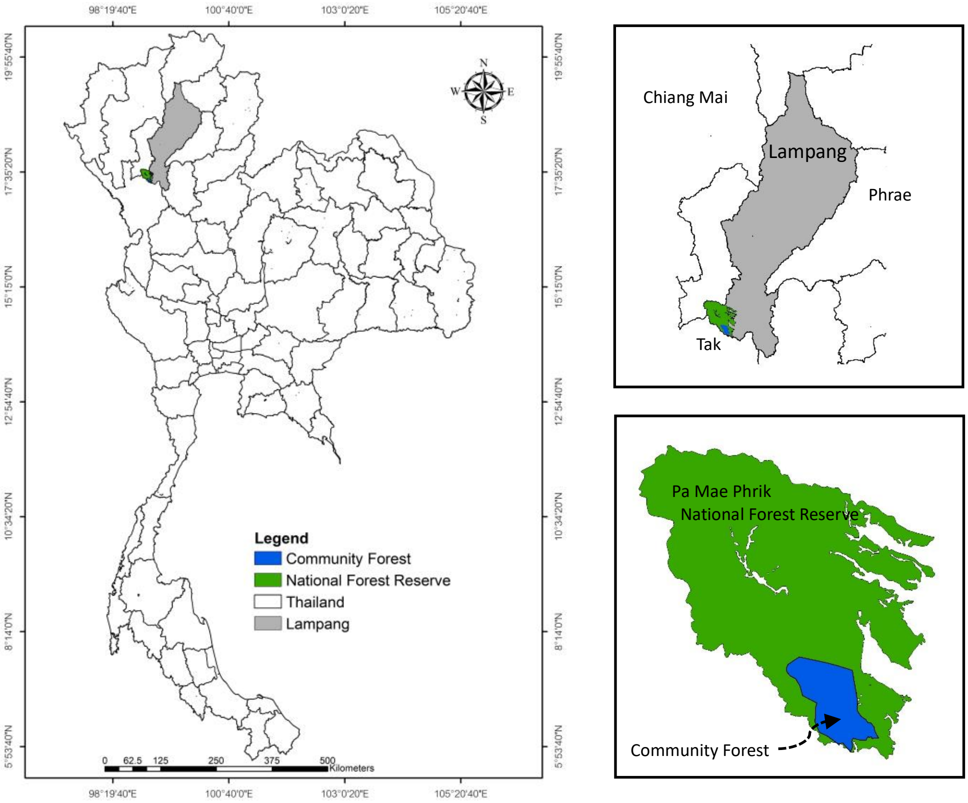


Figure 2.4 Location of the Ban Mae Chiang Rai Lum Community Forest in northern Thailand

This community forest has a total area of 3,925 ha, is at an elevational range of 140–660 m and is composed of mixed deciduous and dry dipterocarp forest subtypes. A previous study identified *Xylia xylocarpa*, *Schleichera oleosa*, *Sindora siamensis, Shorea obtusa,* and *Terminalia mucronata* as the dominant species in the study area (RFD 2017).

Northern Thailand in general, and Lampang in specific, have unique climatic features (Diem et al. 2018). The study area features a wet season from April to October and a dry season from November to March. Historically, this region also experiences drought conditions. Temperatures ranged from a minimum of 31.7°C (January and November) to a maximum of 37.1°C (March). The mean annual temperature, relative humidity, and rainfall were 33.6°C, 76.1%, 1,129.4 mm, respectively (Thai Meteorological Department 2018).

2.3.1. Field Survey

A field survey was conducted in the forest from July to October 2018. Results of a 2016 study conducted by the RFD in the same area were used to calculate the sampling intensity with a confidence interval of 95% (RFD 2017). An estimate of the sampling was obtained by using the standard deviation from previous surveys (Avery and Burkhart 1983; Asrat and Tesfaye 2013). The formula was expressed as:

$$n = (Z\sigma/E)^2 \tag{1}$$

where, n = the sampling intensity, Z = the z-value for the confidence interval of 95%, σ = the density of tree species, and E = the percent standard deviation of the precision required.

Based on the sampling intensity calculation, a total of 25 sampling plots of 40 × 40 m (0.16 ha) each were surveyed through a systematic sampling method (ANSAB 2010). In each plot, trees with a diameter at breast height (DBH) ≥ 4.5 cm were identified and measured in every 10 × 10 m sub-quadrat. Within 10 m sub-quadrats, samplings with DBH < 4.5 cm and height > 1.30 m were recorded in 4 × 4 m sub-quadrats, whereas seedlings were documented in 1 × 1 m sub-quadrats within each 4 m sub-quadrat. The sample plots locational information is shown in Table 2.4 and Figure 2.5.

Table 2.4 The GPS coordinates of the 25 systematically established sample plots in the community forest

Plots	Elevation (m)	GPS Coordinate	
		Longitude (N)	Latitude (E)
1	160	17° 23' 21"	99° 03' 56"
2	164	17° 23' 47"	99° 03' 22"
3	180	17° 24' 13"	99° 02' 49"
4	280	17° 25' 58"	99° 01' 40"
5	215	17° 25' 31"	99° 02' 14"
6	200	17° 25' 05"	99° 02' 48"
7	186	17° 24' 39"	99° 03' 22"
8	180	17° 24' 13"	99° 03' 56"
9	163	17° 23' 47"	99° 04' 30"
10	180	17° 24' 13"	99° 05' 04"
11	179	17° 24' 39"	99° 04' 30"
12	201	17° 25' 05"	99° 03' 56"
13	221	17° 25' 31"	99° 03' 23"
14	227	17° 25' 57"	99° 02' 48"
15	262	17° 26' 22"	99° 02' 14"
16	449	17° 26' 47"	99° 01' 43"
17	591	17° 27' 13"	99° 01' 09"
18	359	17° 27' 14"	99° 02' 16"
19	296	17° 26' 49"	99° 02' 48"
20	240	17° 26' 23"	99° 03' 22"
21	229	17° 25' 57"	99° 03' 56"
22	209	17° 25' 31"	99° 04' 30"
23	220	17° 26' 23"	99° 04' 27"
24	294	17° 26' 49"	99° 03' 56"
25	290	17° 27' 15"	99° 03' 22"

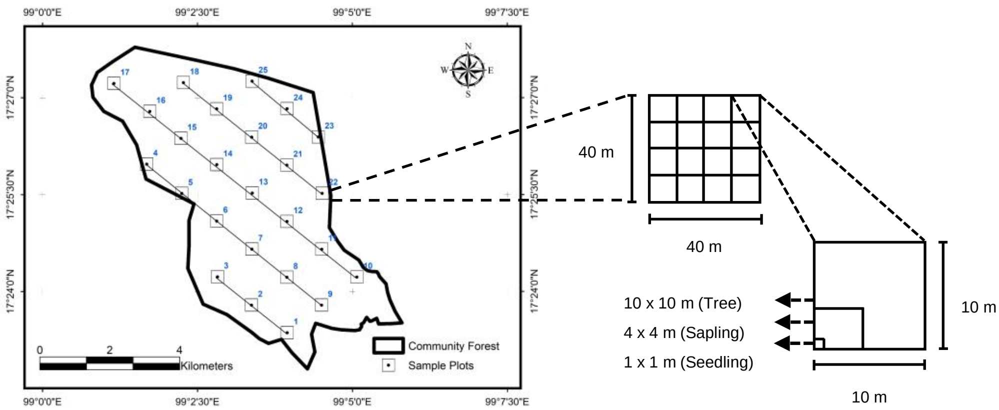


Figure 2.5 Sampling plots and sub-quadrats used for plant identification and measurement

2.3.2. Environmental Survey

Climate data were generated by Hobo U23-001 and UA-002-64 which operated in six stations located in plots 3, 10, 13, 15, 17, and 24. The monitoring equipment was spread out and placed in these representative plots to provide the optimal coverage to accumulate climate data from throughout the study area. Historically, relevant climatic data did not vary significantly during the dry season. In addition, the dry season often featured forest fires. As such, data on temperature, relative humidity and light intensity were collected for 92 days during the wet season from July 11 to October 11, 2018.

Data regarding 15 environmental factors were collected from the 25 sampling plots. Those factors were broadly classified into topographic, edaphic, and anthropogenic. The topographic factors were elevation (EL), slope (SL), and aspect (AS), and the data were extracted out of 1:50,000 topographic maps produced by 20 m contour lines using the ArcGIS. The edaphic factors were investigated from samples collected at a depth of 15 - 20 cm in three random locations within each 40 × 40 m plot during June and July 2018. Acidity (pH), organic matter (OM), soil texture [sand (SA), silt (SI), clay (CL)], available phosphorus (P), exchange potassium (K), exchange calcium (Ca), and soil moisture (SM) in the samples were analyzed. Soil pH was measured by 1:1 soil/water mol^{-1} KCL (National Soil

Survey Center 1996). OM was estimated by wet digestion and titration using the Walkley-Black method (Nelson and Sommers 1996). Soil texture was determined by Pipette method (Gee and Bauder 1986). P was measured by Bray II (Bray and Kurtz 1945), while K and Ca were extracted with 1 M NH4OAc at pH 7.0 (Thomas 1982), respectively. The soil moisture analysis was performed by oven drying at 105°C (National Soil Survey Center 1996). ArcGIS's Euclidean distance tool was used to calculate the distance to streams (DS), distance to roads (DR), and distance to communities (DC) from the sampling plots.

2.3.3. Data Analysis

1) Forest Structure, Species Composition and Diversity

The data analysis consisted of examining the biological diversity of the community forest and exploring environmental factors that affect tree species composition and distribution.

The forest stands in the community forest were identified by cluster analysis employing importance value index (IVI) matrices in each sampling plot. A cluster analysis requires pruning of the dendrogram at a level representing a compromise between the group and the number of groups. Optimum pruning for the dendrogram was selected by applying the Relative Sorensen Distance and Ward's Linkage Method (McCune and Grace 2002).

Trees (DBH $\geq$ 4.5 cm) were identified into family and species to determine the ecological characteristics of the forest stands. A comparison of unknown specimens to those in the herbarium of the Department of National Parks, Wildlife and Plant Conservation was conducted to identify species that were not initially identifiable (DNP 2014).

To compare species composition between the forest stands, the Jaccard similarity index was calculated (Magurran 1988), and the differences in the stand characteristics were analyzed. The stand density and basal area of each tree species were calculated and subjected to a one-way analysis of variance (ANOVA).

Four species diversity indices: species richness (S), species evenness (E), Simpson index (D), and Shannon-Wiener index (H′) were analyzed to examine the diversity of trees in each stand type (Magurran 2004). They were calculated as:

$$E = H' / \ln S \tag{2}$$

$$D = 1 - \sum pi^2 \tag{3}$$

$$H' = -\sum pi \, (ln) \, pi \tag{4}$$

where, S = the number of species recorded, and pi = the proportion of individuals found in the i^{th} species.

A comparison of stand-to-stand diversity was examined. Analyzing different sized pool samples can yield different species diversity findings (Hill 1973; Colwell et al. 2012). A rarefaction approach was implemented in order to compare the diversity from the three different data-source stands (Colwell et al. 2012). Individual based interpolation and extrapolation of Hill numbers (Hill 1973) were carried out for each stand and the species diversity among the three forest stands was estimated as follows: species richness (q = 0), Shannon diversity (the exponential of Shannon entropy, q = 1), and Simpson diversity (the inverse of Simpson concentration, q = 2). Profile and crown cover diagrams were also created to compare the structure of the deciduous stands.

In addition, the ecological importance of the tree species in each stand was quantified through the IVI using the equation:

$$IVI = R.D + R.F + R.D_o \tag{5}$$

where, $R.D$ is the relative density of the tree species, $R.F$ is their relative frequency, and $R.Do$ is their relative dominance. They were calculated as $R.D$ = number of individuals of the species × 100 / total number of quadrate studies, $R.F$ = number of quadrates in which species occurred × 100 / total number of quadrate studies, and $R.D_o$ = total basal area of species × 100 / total basal area of all the species (Curtis and Mclntosh 1951).

2) Environmental Factors Affecting Tree Species

To investigate the environmental factors that affect tree species in the community forest, a dataset of 15 factors was tested for normality using the Shapiro-Wilk test for an alpha level of 0.05. The abnormal data was transformed to a normal distribution to improve the linearity. In this study, AS, SI, SM, DR, and DC were normally distributed ($p > 0.05$). Ten factors had values less than the chosen alpha level; log10(y) was used to transform SL, pH, OM, CL, K, and Ca, and (y)^3, 1/(y), sqrt(y), and -1/sqrt(y) were used to transform SA, EL, DS, and P, respectively.

The differences in stand characteristics such as stand density, basal area, and the environmental factors relevant to the three stand types were subjected to a one-way analysis of variance (ANOVA) with a post-hoc Tukey's honestly significant difference (HSD) test (Zhang et al. 2016). Species compositions in the three forest stands were compared using the Jaccard similarity index (Magurran 1988). The correlations between environmental factors were determined through Pearson correlation analysis. In case of a high correlation in which a matrix of two independent variables had correlation coefficients (r) > 0.7 across all environmental factors, only one of the factors was selected for the ordination analysis (Sarker et al. 2014).

The relationship between tree species distribution and environmental factors was ultimately assessed using the canonical correspondence analysis (CCA) (McCune and Grace 2002). The matrices between the IVI of mature trees (DBH ≥ 4.5 cm) in each stand and the environmental factors were analyzed in the CCA ordination. The correlation significance between the matrices was determined using the Monte Carlo test with 999 permutations. Only the environmental factors significantly related (Monte Carlo permutation test, $p < 0.05$) to the mature tree species were retained.

In this study, all the statistical calculations were performed using PC.ORD version 5.10 (McCune and Mefford 2006) and the R program version 3.6.2 for Windows software (R Development Core Team 2019).

2.4. Results

2.4.1. Forest Stand Classification

The resulting dendrogram reflected 5.83% chaining and was cut with 25% of the remaining information explained by three stand types: *Millettia leucantha-Lagerstroemia duperreana* stand (MLS), *Shorea siamensis-Shora obtusa* stand (SSS), and *Shorea obtusa-Sindora siamensis* stand (SOS). The MLS contained 4 plots: plots 5, 14, 15, and 20. The SSS contained 11 plots: plots 2, 4, 6, 9, 10, 11, 16, 17, 18, 19, and 24. The SOS contained 10 plots: plots 1, 3, 7, 8, 12, 13, 21, 22, 23, and 25 (Figure 2.6).

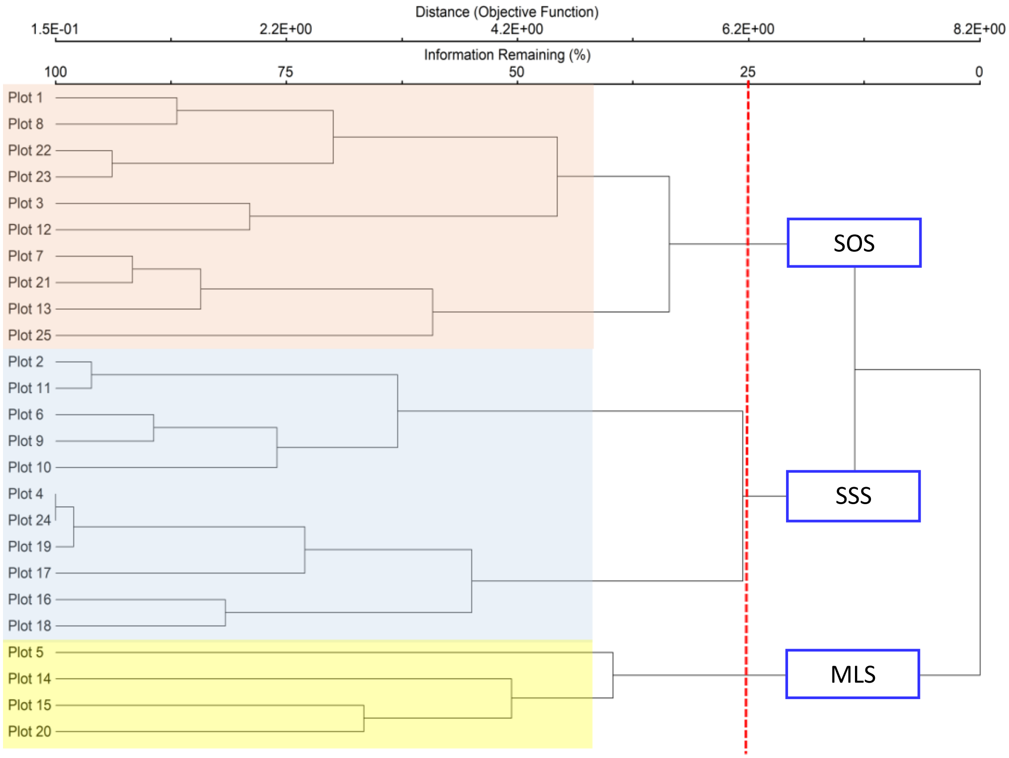


Figure 2.6 Classification of the stand types in the deciduous area of the Ban Mae Chiang Rai Lum Community Forest in northern Thailand. MLS=*Millettia leucantha-Lagerstroemia duperreana* stand, SSS=*Shorea siamensis-Shora obtusa* stand, SOS=*Shorea obtusa-Sindora siamensis* stand

2.4.2. Climate of Study Area

The climate data were generated by Hobo U23-001 and UA-002-04 which operated in each of distinct stations during the rainy season for 92 days between 11 July and 11 October, 2018. Figure 2.7 shows temperature variations, relative humidity, and light intensity during the relevant period.

(a)

(b)

(c)

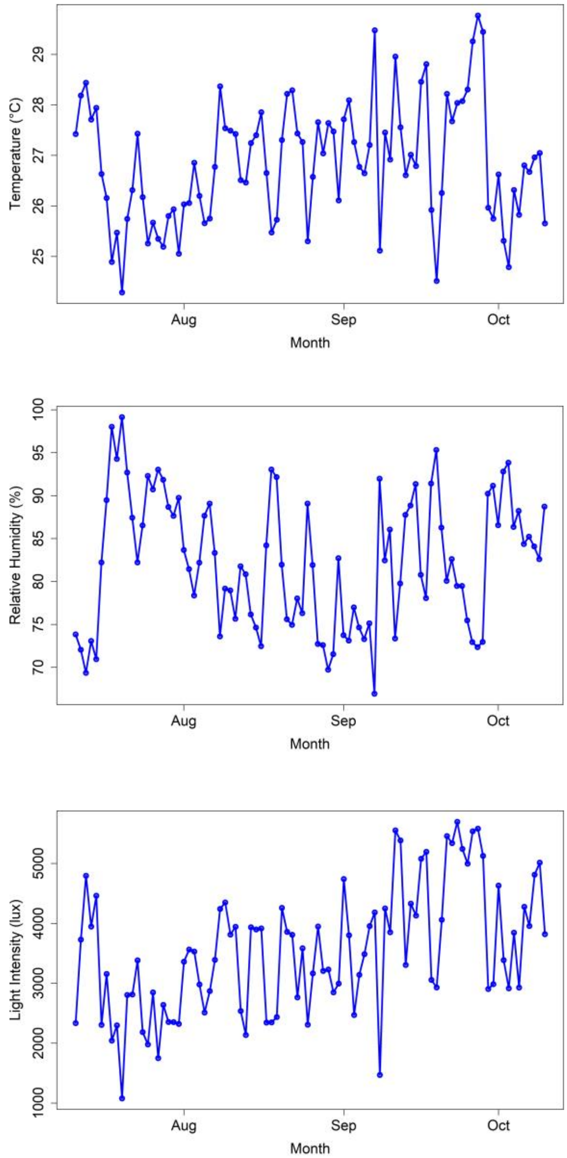


Figure 2.7 Climatic variability in the study area between July and October, 2018: (a) temperature (°C), (b) relative humidity (%), and (c) light intensity (lux)

Figure 2.8 displays climate data by station. The boxplots reveal that plots 3 (SOS), 10 (SSS), 13 (SOS), 15 (MLS), and 24 (SSS) had nearly identical median temperatures whereas the median temperature in plot 17 in the SSS stand was lower. The relative humidity in plots 3 (SOS), 10 (SSS), 13 (SOS), and 17 (SSS) varied slightly, whereas the median relative humidity in plot 15 in the MLS stand and plot 24 in the SSS stand were significantly lower. There were also variations in median light intensity values. The median values in plots 10 and 17 in the SSS stand were higher than the median values in plots 3 and 13 in the SOS stand, plot 15 (MLS) and plot 24 (SSS), but the median values in these four plots were very similar.

(a)

(b)

(c)

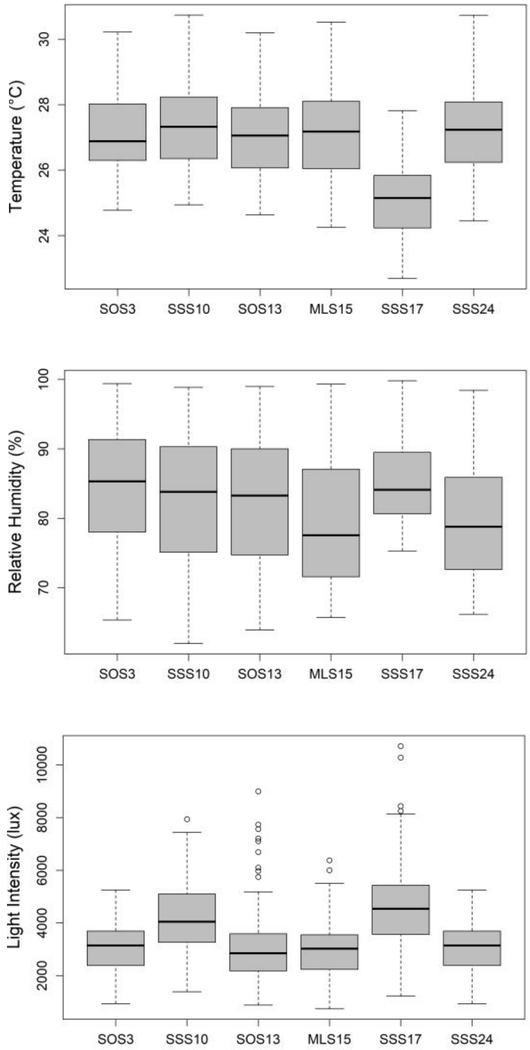


Figure 2.8 Average (a) temperature (°C), (b) relative humidity (%), and (c) light intensity (lux)

Relative humidity and light intensity data did not vary significantly plot-to-plot, but temperature data was significantly different ($p < 0.001$). The average temperature during the 92-day collection period varied between 25.09°C (plot 17) and 27.37°C (plot 10). The average relative humidity ranged from 79.19% (plot 15) to 85.10% (plot 17), and the average light intensity ranged from 3,011.67 lux (plot 15) to 4,698.48 lux (plot 17). The overall average temperature, relative humidity, and light intensity throughout the study area were 26.85°C, 82.23%, and 3,549.09 lux, respectively (Table 2.5).

Table 2.5 Climate conditions at six plots in study area

Plots	Stand types	Temperature (°C)	Relative humidity (%)	Light intensity (lux)
3	SOS	27.14	83.89	3,098.58
10	SSS	27.37	82.97	4,182.67
13	SOS	27.06	82.92	3,204.57
15	MLS	27.16	79.19	3,011.67
17	SSS	25.09	85.10	4,698.48
24	SSS	27.29	79.32	3,098.58
Comprehensive average		26.85	82.23	3,549.09

MLS = *Millettia leucantha-Lagerstroemia duperreana* stand, SSS = *Shorea siamensis-Shora obtusa* stand, SOS = *Shorea obtusa-Sindora siamensis* stand

2.4.3. Ecological Characteristics of Deciduous Forests

1) Forest Structure and Species Composition

The field survey recorded 18,567 trees comprising 197 species (129 tree, 99 sapling and 141 seedling species), 144 genera, and 62 plant families. The Jaccard index showed a 21.29% similarity (33 species) between the MLS and SSS, a 36.30% similarity (53 species) between the SSS and SOS, and a 17.78% similarity (24 species) between the MLS and SOS. The forest had an average density of 966 trees/ha and an average basal area of 16.74 m^2/ha (Table 2.6). The one-way ANOVA test showed that the average density was significantly different stand-to-stand ($p < 0.01$), though average basal area did not vary significantly.

Table 2.6 Ecological characteristics of the three stand types in the Ban Mae Chiang Rai Lum Community Forest in northern Thailand

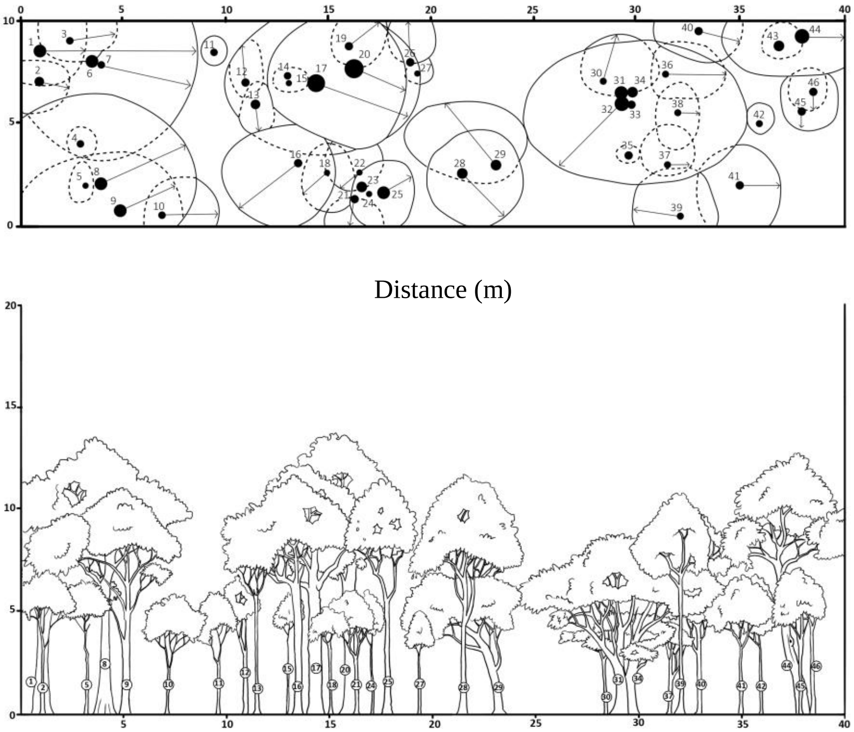
Ecological characteristics	Stand types			Total
	MLS	SSS	SOS	
Number of species	72	83	63	129
Number of genera	53	66	53	91
Number of families	30	32	33	43
Density (trees/ha)	1,229.69	1,078.41	736.88	966
Basal area (m^2/ha)	17.19	18.53	14.60	16.74

MLS=*Millettia leucantha-Lagerstroemia duperreana* stand, SSS=*Shorea siamensis-Shora obtusa* stand, SOS=*Shorea obtusa-Sindora siamensis* stand

Four diagrams were created based on elevation and forest type. The dipterocarp forest consisted of three elevation levels: low (163 m), medium (359 m), and high (591 m), while the mixed deciduous forest was at an elevation of 215 m (Figure 2.9 - 2.12). The diagram profile reflected that the tree species varied in the structure of their canopies. At each elevation, there were three levels of canopy height. At low and medium elevations, the canopy heights were 1) less than 5 m 2) 5 - 10 m, and 3) 10 - 15 m. At high elevation, the layers were at 1) 5 - 10 m, 2) 10 - 15 m, and 3) greater than 15 m.

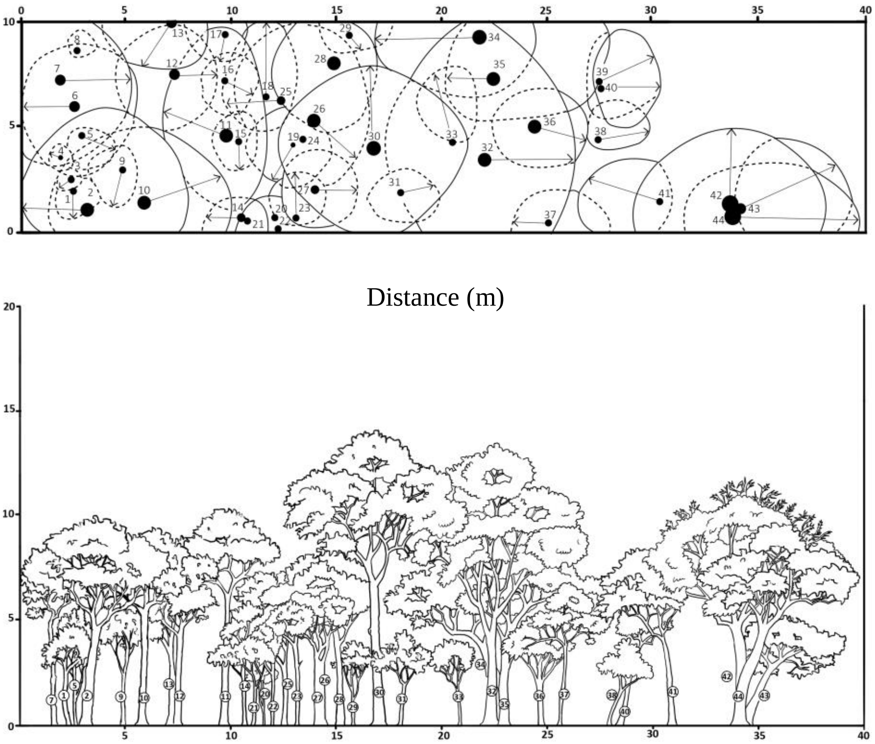
The crown cover diagram revealed that the tree cover in the dry dipterocarp forest was closed and dense; however, there were gaps among trees in the stand. At higher elevation, tree cover was closed and dense. *Terminalia mucronata*, *Shorea obtusa* and *Xylia xylocarpa* were the dominant species in the low elevation area. The medium elevation area was populated by *Shorea siamensis*, *Pterocarpus macrocarpus* and *Mellenttia leucantha.* At high elevation, *Shorea obtusa* was tallest tree canopy, followed in rank order by *S. siamensis, Dipterocarpus obtusifolius* and *Irvingia Malayana*, respectively.

In contrast, the mixed deciduous forest had a greater number of tree species when compared with the dry dipterocarp forest. The height canopy ranged from 5 - 10 m, 10 - 15 m, and over 15 m. The crown cover diagram showed overlapping canopies. The stand was more closed and denser than the dry dipterocarp forest. *Anogeissus acuminata*, *Millettia brandisiana*, *Albizia lebbeck*, *Lagerstroemia villosa*, *Diospyros mollis*, and *Haldina cordifolia* were important species populating the mixed deciduous forest.



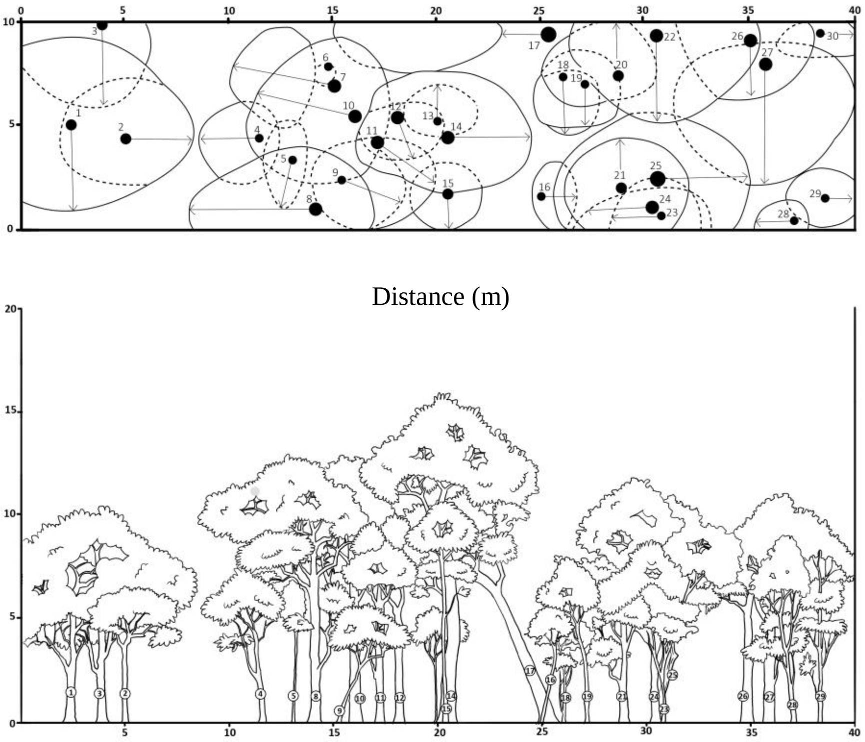
1,3,10,12,44,45	*Xylia xylocarpa*
2,4,5,13,30	*Ellipanthus tomentosus*
6-8,16,19,26,28,29,31-34,39,40	*Terminalia mucronata*
9,24	*Azadirachta indica*
11,14,15,27	*Flacourtia rukam*
17	*Canarium subulatum*
18,21-23	*Mellettia brandisiana*
20,25,37,41	*Shorea obtusa*
38,42,43,46	*Shorea siamensis*
35	*Stereospermum neuranthum*
36	*Memecylon edule*

Figure 2.9 Profile diagram and crown cover diagram of dry dipterocarp forest at 163 m



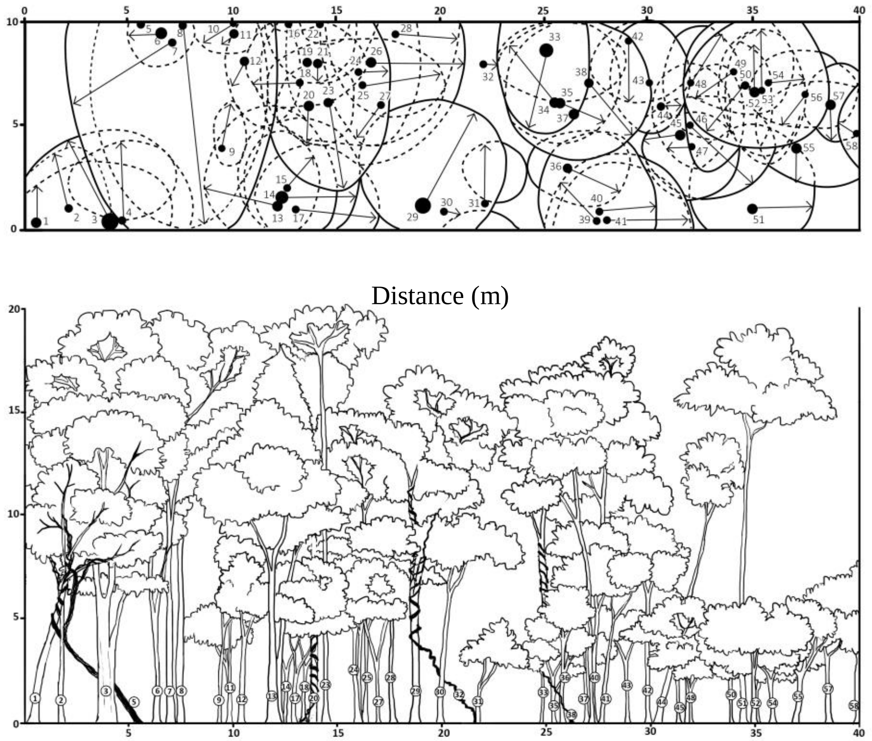
1,4,5,8,10-14,16,17,19-24,27,30,31	*Shorea siamensis*
2,32,35	*Pterocarpus macrocarpus*
3	*Buchanania lanza*
6,7,18,25,26,28	*Antidesma acidum*
9,29,33,38	*Croton hutchinsonianus*
15	*Buchanania glabra*
34,43,44	*Millettia leucantha*
36	*Walsura trichostemon*
37	*Sema garrettiana*
39-41	*Terminalia mucronata*
42	*Chukrasia tabularis*

Figure 2.10 Profile diagram and crown cover diagram of dry dipterocarp forest at 359 m



1-3,7,9,13,15-16,19,27	*Dipterocarpus obtusifolius*
4,10,18,20-21,26	*Shorea siamensis*
5	*Buchanania glabra*
6	*Millettia leucantha*
8,12,14,17,22-24	*Shorea obtusa*
11	*Tristaniopsis burmanica*
25	*Irvingia malayana*
28,30	*Tristaniopsis burmanica*
29	*Croton hutchinsonianus*

Figure 2.11 Profile diagram and crown cover diagram of dry dipterocarp forest at 591 m



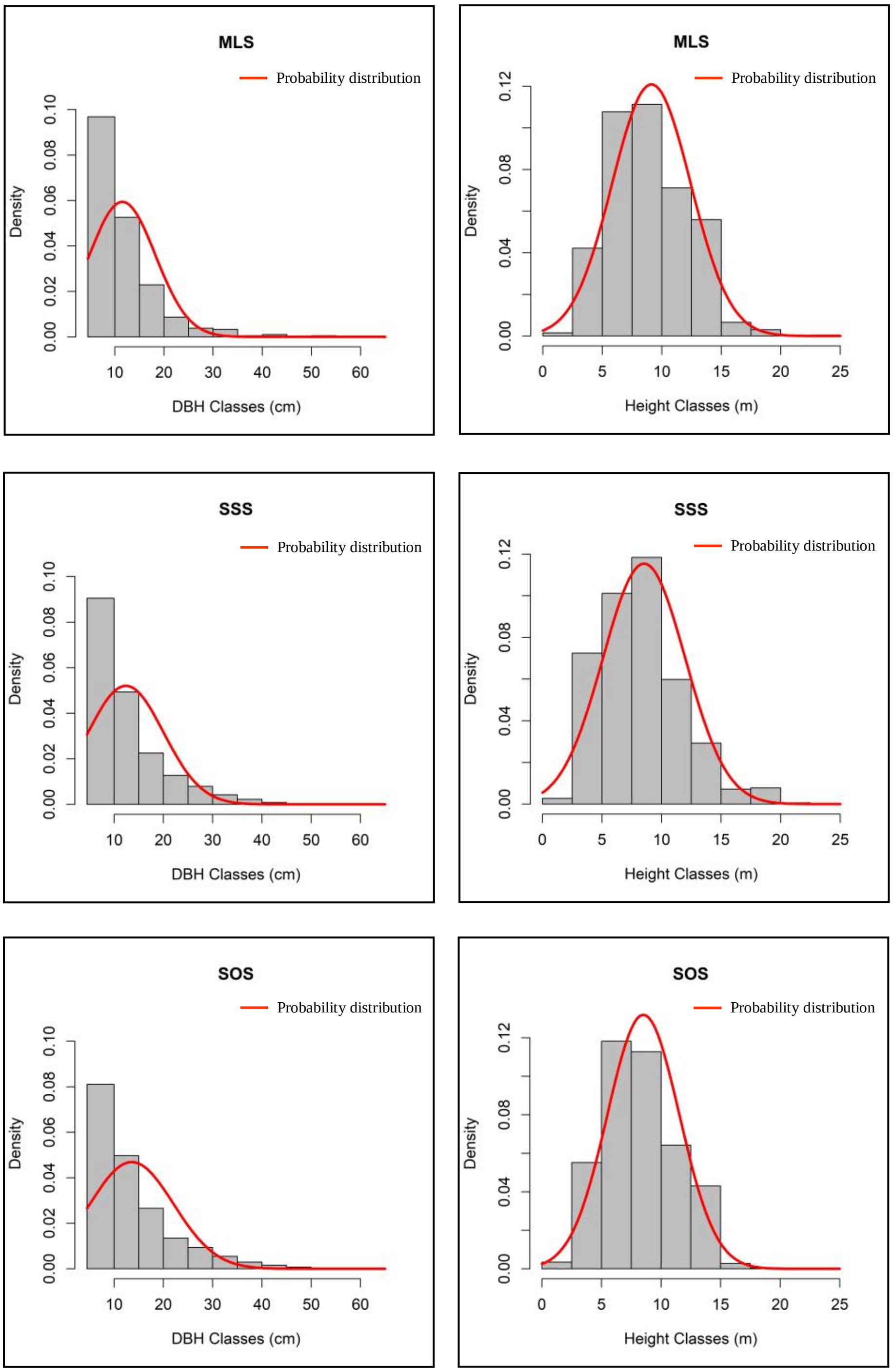
1	*Millettia leucantha*
2	*Cassia fistula*
3,4,24,25,36,44,51,57	*Anogeissus acuminata*
5,20,32,37	*Bauhinia glauca*
6,23	*Lagerstroemia villosa*
7,8	*Albizia lebbeck*
9,43	*Alangium salviifolium*
10-12	*Schleichera oleosa*
13-15,39-41	*Diospyros mollis*
18,34,35,42,45-48,50, 52-54	*Cleistanthus hirsutulus*
19,29,33,49,58	*Millettia brandisiana*
21,38	*Haldina cordifolia*
26,28,56	*Sisyrolepis muricata*
27	*Flacourtia rukam*
30	*Diospyros montana*
31,55	*Harrisonia perforata*

Figure 2.12 Profile diagram and crown cover diagram of mixed deciduous forest at 215 m

2) DBH and Height Classes

The tree density distribution of diameter and height classes of the deciduous forests is shown in Figure 2.13. The MLS stand had a DBH range of 4.77 - 53.80 cm with a mean of 11.53 ± 6.71 cm. Specifically, trees with DBH < 10 cm (53.24%) were the most abundant, followed by trees with DBH 10 - 20 cm (37.74 %), 20 - 30 cm (6.23%), and > 30 cm (2.79%). In the SSS stand, DBH ranged between 4.50 - 64.34 cm with a mean of 11.53 ± 6.71 cm. Specifically, trees with DBH < 10 cm (53.24%) were the most abundant, followed by trees with DBH 10-20 cm (35.93%), 20 - 30 cm (10.33%), and > 30 cm (3.95%). Similarly, in the SOS stand, DBH ranged between 4.50 - 61.03 cm with a mean of 13.57 ± 8.50 cm. Trees with DBH < 10 cm (44.62 %) were the most abundant followed by trees with DBH of 10 - 20 cm (38.16%), 20 - 30 cm (11.45%), and > 30 cm (5.77%).

The height classes of the MLS ranged between 2.00 - 25.00 m with a mean height of 9.12 ± 3.29 m. The height of the trees in the SSS varied between 2.00 - 25.00 m with a mean height of 8.53 ± 3.46 m. The height of the trees in the SOS varied between 1.30 - 18.00 m with a mean height of 8.51 ± 3.02 m. In the MLS, SSS, and SOS, respectively the 5 - 10 m class (54.76%, 54.90%, 57.73%) had the highest density followed in descending order by the 10 - 15 m class (31.77%, 22.29%, 26.81%), 1.3 - 5 m class (10.93%, 18.81%, 14.68%), and the >15 m-class (2.54%, 4.00%, 0.78%). Overall, the DBH ranged from 4.50 to 64.34 cm with a mean of 12.55 ± 7.73 cm. Height ranged from 1.30 m to 25 m with a mean of 8.65 ± 3.29 m.



(a) (b)

Figure 2.13 Distribution of trees by (a) DBH-class and (b) height-class within the deciduous forests in Ban Mae Chiang Rum Community Forest

3) Importance Value Index (IVI)

The five species with the highest IVI in the MLS were *Millettia leucantha* (8.40%), *Lagerstroemia duperreana* (7.23%), *M. brandisiana* (7.16%), *Antidesma sootepense* (6.13%), and *Pterocarpus macrocarpus* (4.84%). The most dominant tree species in terms of its IVI in the SSS was *Shorea siamensis* (18.42%), followed by *S. obtusa* (12.11%), *Xylia xylocarpa* (5.99%), *Terminalia mucronata* (5.61%), and *Dipterocarpus tuberculatus* (4.92%). *Shorea obtusa* (20.14%) was the most common species in the SOS which also included *Sindora siamensis* (12.36%), *Xylia xylocarpa* (12.14%), *Canarium subulatum* (6.22%), and *Ellipanthus tomentosus* (5.41%) (Table 2.7).

Table 2.7 The importance value indices (IVI) of the most important species of mature trees in each stand type

Stand types/Ranking		Species	R.D (%)	R.F (%)	R.D$_o$ (%)	IVI (%)
MLS	1)	*Millettia leucantha*	11.44	6.23	7.53	8.40
	2)	*Lagerstroemia duperreana*	7.24	6.23	8.23	7.23
	3)	*Millettia brandisiana*	7.88	5.97	7.63	7.16
	4)	*Antidesma sootepense*	10.17	5.71	2.52	6.13
	5)	*Pterocarpus macrocarpus*	2.80	4.16	7.57	4.84
	6)	*Walsura trichostemon*	3.38	7.21	14.27	4.76
	7)	*Anogeissus acuminata*	3.64	4.06	12.40	4.13
	8)	*Garuga pinnata*	2.86	7.22	11.85	3.95
	9)	*Zizyphus oenoplia*	4.16	2.19	10.92	3.64
	10)	*Cleistanthus hirsutulus*	2.86	1.66	10.62	3.54
		62 other species	39.64	54.81	44.17	46.21
SSS	1)	*Shorea siamensis*	20.01	12.51	22.72	18.42
	2)	*Shorea obtusa*	10.42	9.77	16.16	12.11
	3)	*Xylia xylocarpa*	6.32	7.20	4.46	5.99
	4)	*Terminalia mucronata*	6.49	5.60	4.76	5.61
	5)	*Dipterocarpus tuberculatus*	4.16	3.80	6.82	4.92
	6)	*Lannea coromandelica*	3.53	3.70	4.79	4.01
	7)	*Canarium subulatum*	2.48	3.22	5.41	3.71
	8)	*Dipterocarpus obtusifolius*	3.00	3.12	3.82	3.31
	9)	*Buchanania glabra*	3.01	4.18	2.12	3.10
	10)	*Sindora siamensis*	3.37	2.56	3.36	3.10
		73 other species	37.20	44.34	25.63	52.95
SOS	1)	*Shorea obtusa*	18.83	14.91	26.67	20.14
	2)	*Sindora siamensis*	16.20	6.46	14.42	12.36
	3)	*Xylia xylocarpa*	12.04	13.77	10.60	12.14
	4)	*Canarium subulatum*	2.97	4.65	11.04	6.22
	5)	*Ellipanthus tomentosus*	6.36	7.80	2.06	5.41
	6)	*Millettia brandisiana*	3.73	1.82	5.07	3.54
	7)	*Morinda coreia*	2.63	3.14	4.25	3.34
	8)	*Gardenia obtusifolia*	2.71	3.83	0.87	2.47
	9)	*Terminalia mucronata*	2.21	2.83	1.81	2.28
	10)	*Stereospermum neuranthum*	2.29	3.00	1.54	2.27
		53 other species	30.03	37.78	21.67	29.83

MLS = *Millettia leucantha-Lagerstroemia duperreana* stand, SSS = *Shorea siamensis-Shora obtusa* stand, SOS = *Shorea obtusa-Sindora siamensis* stand. R.D = relative density, R.F = relative frequency, R.D$_o$ = relative dominance, IVI = importance value index

4) Species Diversity

The species diversity indices of mature trees, saplings, and seedlings in each stand are shown in Table 2.8. The species richness of mature trees was highest in the MLS. The diversity as demonstrated by the species evenness and the Simpson and Shannon-Wiener indices was highest in the MLS. In contrast, the species richness of saplings was highest in the SOS. The species evenness of the saplings was highest in the SSS. The Simpson and Shannon-Wiener indices were highest in the SSS. Similarly, the species richness of seedlings was highest in SSS, followed in decreasing order by SOS and MLS. The species evenness and the Simpson and Shannon-Wiener indices were highest in the SOS. The average diversity index of the deciduous forest stands in the Ban Mae Chiang Rai Lum Community Forest was calculated to be 2.49 ± 0.28 (mature trees), 2.25 ± 0.32 (saplings), and 2.44 ± 0.43 (seedlings).

Table 2.8 The species diversity of mature trees, saplings, and seedlings in the three stand types

Stand types	Tree			
	S	E	D	H′
MLS	31.00 ± 9.27	0.79 ± 0.05	0.89 ± 0.02	2.68 ± 0.16
SSS	25.81 ± 5.89	0.80 ± 0.03	0.88 ± 0.03	2.60 ± 0.29
SOS	20.00 ± 3.94	0.76 ± 0.03	0.83 ± 0.03	2.28 ± 0.16
Average	24.32 ± 6.87	0.78 ± 0.04	0.86 ± 0.04	2.49 ± 0.28
Stand types	Sapling			
	S	E	D	H′
MLS	14.00 ± 2.82	0.78 ± 0.13	0.81 ± 0.07	2.03 ± 0.23
SSS	17.90 ± 5.04	0.82 ± 0.09	0.85 ± 0.07	2.33 ± 0.33
SOS	18.20 ± 3.35	0.77 ± 0.09	0.84 ± 0.06	2.24 ± 0.33
Average	17.40 ± 4.26	0.79 ± 0.10	0.84 ± 0.07	2.25 ± 0.32
Stand types	Seedling			
	S	E	D	H′
MLS	28.25 ± 4.85	0.65 ± 0.14	0.78 ± 0.15	2.18 ± 0.55
SSS	30.45 ± 6.08	0.73 ± 0.11	0.83 ± 0.12	2.49 ± 0.46
SOS	29.10 ± 5.76	0.74 ± 0.08	0.85 ± 0.07	2.50 ± 0.35
Average	29.56 ± 5.62	0.72 ± 0.10	0.83 ± 0.11	2.44 ± 0.43

S = species richness, E = species evenness, D = Simpson index, H′ = Shannon-Wiener index. MLS = *Millettia leucantha-Lagerstroemia duperreana* stand, SOS = *Shorea obtusa-Sindora siamensis* stand, SSS = *Shorea siamensis-Shora obtusa* stand

The rarefaction-produced tree species diversity values in different sample sizes of three forest stands are shown in Table 2.9. A comparison of extrapolated species diversity shows that species richness was estimated to be the highest in the MLS, followed by the SSS and the SOS, respectively. The Shannon diversity and Simpson diversity also estimates are highest in the MLS, the SSS and the SOS, in descending order (Figure 2.14).

Table 2.9 A comparison of species diversity among stand types by rarefaction in the Ban Mae Chiang Rai Lum Community Forest in northern Thailand

Stand types	Diversity	Observed diversity	Estimated asymptote	Estimated s.e.	95% confidence interval	
					LCL	UCL
MLS	Species richness	72.00	88.18	10.03	77.29	121.46
	Shannon diversity	31.37	33.33	1.35	31.37	35.98
	Simpson diversity	19.66	20.14	1.07	19.66	22.24
SSS	Species richness	83.00	107.49	14.33	91.45	153.93
	Shannon diversity	26.98	27.81	0.89	26.98	29.54
	Simpson diversity	14.07	14.16	0.62	14.07	15.37
SOS	Species richness	63.00	84.32	14.51	69.36	134.45
	Shannon diversity	20.54	21.33	0.89	20.54	23.07
	Simpson diversity	11.25	11.34	0.49	11.25	12.30

s.e. = standard error, LCL = Lower confidence limit, UCL = Upper confidence limit. MLS = *Millettia leucantha-Lagerstroemia duperreana* stand, SSS = *Shorea siamensis-Shora obtusa* stand, SOS = *Shorea obtusa-Sindora siamensis* stand

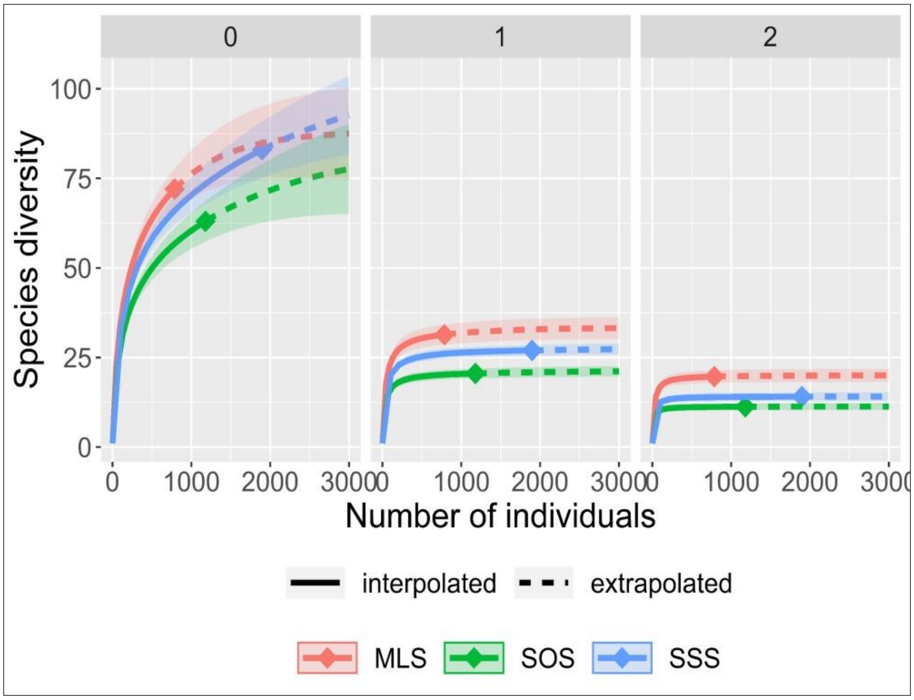


Figure 2.14 Comparison of individual-based rarefaction and extrapolation of species diversity for Hill numbers among three forest stands: species richness (q = 0), Shannon diversity (q = 1), and Simpson diversity (q = 2)

2.4.4. Relationship between Environmental Factors and Species Diversity

The mean values and standard deviation of the 15 environmental factors analyzed in the Ban Mae Chiang Rai Lum Community Forest are shown in Table 2.10. The degree of soil acidity (pH), organic matter (OM), silt (SI), clay (CL), exchange potassium (K), soil moisture (SM), distance to roads (DR), and distance to communities (DC) were greater in the MLS than in the SSS and SOS. The values of elevation (EL), slope (SL), available phosphorus (P), and exchange calcium (Ca) were highest in the SSS, and in decreasing order in the MLS and SOS. The value of aspect (AS), distance to streams (DS), and sand ratio (SA) were greater in the SOS than in the SSS and MLS.

Five factors differed significantly among the three stand types. SL, OM, SA, CL, and K differed from one stand type to another ($p < 0.05$). There was no significant difference in EL, AS, DS, pH, SI, P, Ca, SM, DR, and DC among the stands. The post-hoc Tukey's HSD test identified that the CL value was different between the MLS and the SOS, between the SOS and the SSS, and between the SSS and the MLS. OM and SA differed substantially between the MLS and the SOS, but they did not differ in the SSS. Similarly, SL differed between the SOS and the SSS, but it did not differ in the MLS. K varied when comparing the MLS with the SOS and the SSS with the SOS.

A matrix of two independent environmental factors showed that there were high correlation coefficients (r > 0.7) between the factors (Table 2.11). OM was positively correlated with K (r = 0.932). SA was positively associated with EL (r = 0.704), but negatively associated with SI (r = -0.890), CL (r = -0.929), DR (r = -0.746), and K (r = -0.724). CL positively correlated to DR (r = 0.710), but negatively correlated to EL (r = -0.707). EL negatively related to SL (r = -0.740). DC was positively related with DR (r = 0.853). Considering those correlations between the environmental factors, the ten variables, EL, AS, DS, pH, OM, P, Ca, SM, SI, and DC, were selected for further analysis using CCA. In the preliminary CCA, two poorly correlated factors, Ca and SI, were eliminated; the remaining eight factors were used in the final CCA.

Table 2.10 Statistics of the environmental factors in the 25 sampling plots of the community forest

Categories	Environmental factors	Abbreviation	Stand types (Mean ± SD)		
			MLS	SSS	SOS
Topographic	Elevation (m) N.S.	EL	236.00 ± 20.11	286.81 ± 136.09	207.60 ± 36.33
	Slope (%) *	SL	7.60 ± 9.99^{ab}	17.76 ± 16.94^{a}	2.26 ± 3.47^{b}
	Aspect (^{o}) N.S.	AS	155.25 ± 65.85	175.90 ± 79.12	184.00 ± 79.23
	Distance to streams (m) N.S.	DS	166.00 ± 145.68	311.45 ± 197.59	392.40 ± 334.19
Edaphic	Soil acidity (pH) N.S.	pH	5.82 ± 0.41	5.80 ± 0.65	5.60 ± 0.27
	Organic matter (%) *	OM	3.87 ± 1.92^{a}	2.50 ± 2.39^{ab}	0.70 ± 0.47^{b}
	Sand (%) **	SA	63.00 ± 7.48^{b}	73.72 ± 11.60^{ab}	82.00 ± 3.43^{a}
	Silt (%)	SI	17.00 ± 3.82	15.63 ± 5.64	13.20 ± 2.52
	Clay (%) ***	CL	20.00 ± 4.76^{a}	10.63 ± 6.50^{b}	4.80 ± 1.98^{c}
	Available phosphorus (mg kg^{-1}) N.S.	P	4.89 ± 2.28	16.10 ± 30.35	4.55 ± 2.14
	Exchange potassium (mg kg^{-1}) **	K	127.00 ± 33.95^{a}	78.27 ± 60.00^{a}	28.10 ± 9.70^{b}
	Exchange calcium (mg kg^{-1}) N.S.	Ca	1,182.50 ± 883.17	1,466.54 ± 3,274.68	201.70 ± 221.54
	Soil moisture (%) N.S.	SM	8.56 ± 1.53	6.10 ± 2.19	5.89 ± 2.42
Anthropogenic	Distance to roads (m) N.S.	DR	6,050.00 ± 726.05	4,613.90 ± 2,217.31	3,721.20 ± 962.39
	Distance to communities (m) N.S.	DC	6,068.00 ± 902.32	5,151.45 ± 1,769.59	4,050.60 ± 1,010.93

N.S. = not significant at *p < 0.05, **p < 0.01, ***p < 0.001. The letters after values indicate the significant difference among the stands. MLS = *Millettia leucantha-Lagerstroemia duperreana* stand, SSS = *Shorea siamensis-Shora obtusa* stand, SOS = *Shorea obtusa-Sindora siamensis* stand

Table 2.11 Pearson correlation coefficient matrix between the groups of environmental factors

Variables	EL	SL	AS	DS	pH	OM	SA	SI	CL	P	K	Ca	SM	DR
SL	-0.740***													
AS	0.068	0.017												
DS	-0.236	0.088	-0.161											
pH	-0.284	0.398*	0.079	-0.221										
OM	-0.370	0.364	-0.073	-0.286	0.563**									
SA	0.704***	-0.627***	0.259	-0.001	-0.307	-0.692***								
SI	-0.631***	0.559**	-0.296	0.080	0.391	0.622***	-0.890***							
CL	-0.707***	0.680***	-0.223	0.004	0.231	0.631***	-0.929***	0.684***						
P	-0.308	0.343	-0.006	-0.093	0.547**	0.604**	-0.276	0.358	0.247					
K	-0.430*	0.416*	-0.117	-0.293	0.669***	0.923***	-0.724***	0.626***	0.681***	0.507**				
Ca	0.175	0.031	-0.037	-0.615**	0.085	0.655***	-0.274	0.232	0.226	0.343	0.493*			
SM	-0.175	0.194	-0.138	0.142	0.267	0.316	-0.436*	0.378	0.450*	0.325	0.405*	-0.002		
DR	-0.692***	0.631***	0.057	-0.077	0.523**	0.594**	-0.746***	0.677***	0.710***	0.510**	0.649***	0.164	0.440*	
DC	-0.692***	0.579**	0.087	-0.161	0.345	0.459*	-0.635***	0.499*	0.672***	0.354	0.543**	0.161	0.284	0.853***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. EL = elevation, SL = slope, AS = aspect, DS = distance to streams, pH = soil acidity, OM = organic matter, SA = sand, SI = silt, CL = clay, P = available phosphorus, K = exchange potassium, Ca = exchange calcium, SM = soil moisture, DR = distance to roads, DC = distance to communities

The IVI values (i.e. R.D, R.F, and R.D_o) of each of the 129 mature tree species and the eight explanatory environmental factors (pH, OM, P, SM, EL, AS, DS, and DC) in the 25 sampling plots were subjected to the CCA. The results of the CCA showed strong correlations between the distribution of tree species and the environmental factors (Table 2.12). The eigenvalues obtained for the first and second axes were 0.531 and 0.363, respectively. The Pearson correlation showed that the environmental factors had a high correlation to the species for axis 1 (0.924) and axis 2 (0.917). Therefore, these axes were considered as good indicators of relationships between the environmental factors and the species distribution in the community forest. The Monte Carlo permutation test confirmed that the first axis explained the significant variation in the community forest ($p < 0.05$). The significance of the second and third axes was not reported for the reason that a simple randomization test for these axes could bias the *p* values (McCune and Mefford 2006).

Table 2.12 Results of the canonical correspondence analysis (CCA) on the relationship between the distribution of tree species and the environmental factors

CCA results	Axis 1	Axis 2	Axis 3
Eigenvalues	0.531	0.363	0.239
Variance in species data			
% of variance explained	13.5	9.2	6.1
Cumulative % explained	13.5	22.7	28.8
Pearson correlation (species-environment)	0.924	0.917	0.777
Monte Carlo test	0.015*	-	-

$*p < 0.05$

The correlations between the environmental factors and the CCA axes are listed in Table 2.13. OM (r = -0.546) had the highest negative correlation coefficient with the first axis, and SM (r = -0.470), DC (r = -0.402), and pH (r = -0.158) were also negatively correlated with it. Conversely, DS (r = 0.409) had a positive correlation, followed by AS (r = 0.163), EL (r = 0.125), and P (r = 0.061). The second axis revealed a negative correlation with DC (r = -0.513), OM (r = -0.398), DS (r = -0.281), pH (r = -0.142), and AS (r = -0.140), but it displayed a positive correlation with EL (r = 0.810) and SM (r = 0.060). The comparison among the environmental factors showed that pH was positively correlated with

OM (r = 0.563) and P (r = 0.547) as was OM with P (r = 0.604) (Table 2.11).

Table 2.13 Correlation coefficients between the eight environmental factors with the first three axes of the CCA

Environmental factors	Abbreviation	Axis 1	Axis 2	Axis 3
Soil acidity	pH	-0.158	-0.142	0.389
Organic matter	OM	-0.546*	-0.398*	0.068
Available phosphorus	P	0.061	-0.270	0.388
Soil moisture	SM	-0.470*	0.060	0.196
Elevation	EL	0.125	0.810***	-0.268
Aspect	AS	0.163	-0.140	-0.259
Distance to streams	DS	0.409*	-0.281	-0.125
Distance to communities	DC	-0.402*	-0.513**	0.435*

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

The CCA results demonstrate the relationships between environmental factors and species distribution (Figure 2.15 and 2.16). In Grouping 1, the EL was an important factor in species distribution in plots 2, 9, and 11 of the SSS and in plots 1, 7, 8, and 12 of the SOS. The abundant species in this grouping were *Atalantia monophylla* (ATMO), *Antidesma ghaesembilla* (ANGH), *Gluta usitata* (GLUS), *Bauhinia bracteata* (BABR), *Flacourtia indica* (FLIN), *Memecylon edule* (MEED), and *Flacourtia rukam* (FLRU). In Grouping 2, DS was linked to *Ochna integerrima* (OCIN), *Syzygium cumini* (SYCU), *Madhuca dongnaiensis* (MADO), *Morinda elliptica* (MOEL), and *Tectona grandis* (TEGR) in plots 6 & 10 of the SSS and 3, 13, 21, and 23 of the SOS. This suggests that these species can be impacted by their distance from streams. Regarding Grouping 3, SM, OM, and DC were closely related to *Polyalthia cerasoides* (POCE), *Zollingeria dongnaiensis* (ZODO), *Hymenodictyon orixense* (HYOR), *Zizyphus oenoplia* (ZIOE), *Pterocarpus macrocarpus* (PTMA), *Mitragyna rotundifolia* (MIRO), *Lannea coromandelica* (LACO), *Bridelia retusa* (BRRE), and *Wendlandia tinctoria* (WETI) in plots 14, 15, and 20 of the MLS and in plot 24 of the SSS. This indicates that they were restricted by moisture content, limited by OM, and closely correlated to human disturbance.

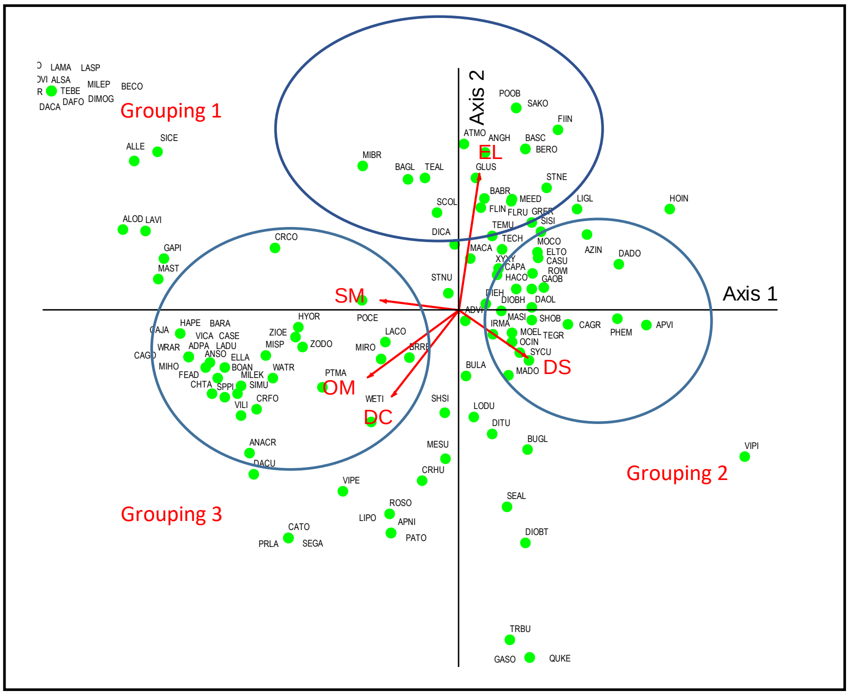


Figure 2.15 The CCA ordination diagram representing the relationship between the distribution of tree species and the environmental factors. Full names of tree species by abbreviation are listed in Appendix II.

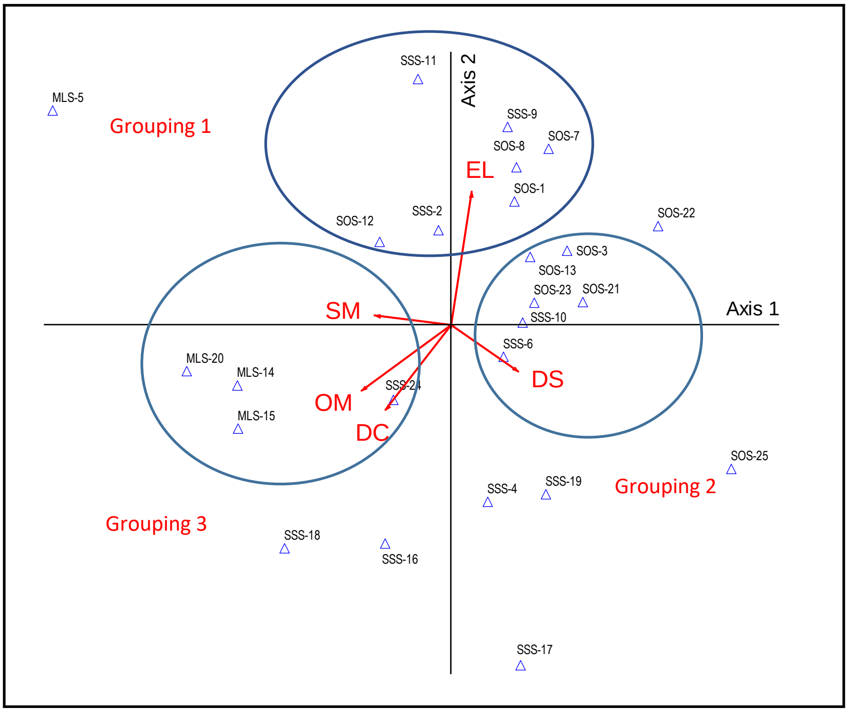


Figure 2.16 The five most important environmental factors explaining the characteristics of different stand types in the CCA ordination: elevation (EL), distance to streams (DS), soil moisture (SM), organic matter (OM), and distance to communities (DC) affecting 25 plots in the three stands (Δ): *Millettia leucantha-Lagerstroemia duperreana* stand (MLS), *Shorea siamensis-Shora obtusa* stand (SSS), and *Shorea obtusa-Sindora siamensis* stand (SOS)

2.5. Discussion

2.5.1. The Deciduous Forests' Structure and Diversity of Species

Ban Mae Chiang Rai Lum Community Forest's 197 species of 18,567 trees in 62 families collectively exhibit a larger diversity than recorded in other deciduous forests in Thailand. 125 species were recorded in the Na Haeo Forest Reserve (Larpkern et al. 2009), 97 species in the Khok Bung Preu Forest (Kabir and Webb 2006), and 42 species in the Sakaerat Environmental Research Station (Lamotte et al. 1998).

As reflected in Figure 2.9 - 2.12 and Table 2.7, the SSS and SOS were predominantly populated by these tree species: *Shorea obtusa*, *S. siamensis*, *Dipterocarpus obtusifolius*, *Irvingia malayana*, *Xylia xylocarpa*, *Sindora siamensis*, and *Canarium subulatum*, whereas *Millettia leucantha*, *Anogeissus acuminata*, *Albizia lebbeck*, *Diospyros mollis*, *Antidesma sootepense*, *Lagerstroemia duperreana*, *M. brandisiana*, *Pterocarpus macrocarpus*, *L. villosa*, and *Haldina cordifolia* were the principal species in the MLS. This is consistent with previous studies of similar stands in Thailand wherein these species were found to be prominent and of significant importance (Lamotte et al. 1998; Marod et al. 1999; Teejuntuk et al. 2003; Kabir and Webb 2006; Bunyavejchewin et al. 2011; Khamyong et al. 2018).

The findings also demonstrated that in the MLS, SSS, and SOS tree density decreased as DBH increased (Figure 2.13). Represented graphically, this pattern forms an inverted-J shape. This is characteristic of a forest wherein trees regenerate consistently as noted in previous studies (Culmsee et al. 2010; Alvarez et al. 2012; Magalhães and Seifert 2015; Zhao et al. 2015). The result also revealed the height-class of tree species was normally distributed, resulting in a balanced height class size. These are positive indicators of future natural regeneration of tree species in the forests (Kimmis 1987; Myo et al. 2016; Hermhuk et al. 2019). Historical encroachment, illegal logging and deforestation robbed the forest of older and larger trees. Positive regeneration efforts are reflected in the planting of new trees under CFM since 2008.

The species diversity indices of the forests reflected in Table 2.8 reveal that the species diversity index of mature trees in the community forest (H′ = 2.49) was considered mid-range when compared with other deciduous forests in northern Thailand. The average species diversity index was higher than the dry dipterocarp forests in the Mae Ping National Park (H′ = 2.46) and the Chiang Dao Wildlife Sanctuary (H′ = 2.059) (DNP 2015, 2016), but lower than the dry dipterocarp forest (H′ = 2.60) and mixed deciduous forest (H′ = 2.96) in the Mae Khum Mee Watershed (Papakjan et al. 2017), the Baan Ta Pa Pao community forest in natural forest utilization (H' = 3.04) and natural forest succession (H' = 3.31) areas (Pothawong et al. 2015). These results suggest the potential for diverse tree species providing ecosystem services to support rural livelihoods.

2.5.2. Environmental Factors that Impact Species Composition and Distribution

The Ban Mae Chiang Rai Lum Community Forest was divided into three forest stands: the mixed deciduous MLS and the dry dipterocarp SSS and SOS (Figure 2.6). A rarefaction prediction of species diversity (Table 2.9 and Figure 2.14) and the wide array of species, genera, and families (Table 2.6) recorded via the field survey indicate remarkable diversity which is similar to other forests of Northern Thailand (Popradit et al. 2015; Khamyong et al. 2018). There were no noteworthy differences in the average basal areas, but average density varied significantly among the three stand types. There was a degree of species similarity among the stands whereas the forest structures and species compositions were distinct (Table 2.7), In addition, the importance of the environmental factors varied stand-to-stand (Table 2.10) as did their degree of correlation (Table 2.11).

The resulting data show that the heterogeneity of species distribution patterns among the different forest stand types could be a response to a variation in the environmental factors; distinct environmental conditions in forest stands can be effective indicators of species distribution in the Ban Mae Chiang Rai Community Forest in northern Thailand.

The CCA demonstrated that species composition and distribution of the mature trees were related to topographic, edaphic, and anthropogenic factors (Table

2.12). The environmental factors showed both positive and negative impacts on species diversity. Specifically, EL, DS, SM, OM, and DC were the most evidently linked to species distribution (Table 2.13). Moreover, environmental factors had different effects on species distribution between stand types (Figure 2.15 and 2.16). This indicates that species composition and distribution can be limited by a combination of environmental factors across distinct forests.

Among the five most noteworthy factors (i.e. EL, DS, SM, OM, and DC), EL appeared to be the most influential on species distribution. The IVI of mature trees was positively related to elevation in the SSS and SOS; elevational gradients promote not only species diversification but also soil differentiation (Zhang and Zhang 2007; Zhang et al. 2013; Zhang et al. 2016). Though, climatic factors can vary with elevation (Xianping et al. 2006; Körner 2007), the elevational features of dry dipterocarp in Thailand occur mainly in elevations up to 900 m (Bunyavejchewin et al. 2011). At this elevation, there is no drastic change in lowland vegetation similar to that found in most tropical zones at elevations above 1,000 m, including in the North of Thailand (Küchler and Sawyer 1967). Thus, the various soil properties unique to elevation could be key to the composition and distribution of tree species in the dipterocarp forest stands this study area (Bunyavejchewin et al. 2011).

Other tree species associated with dominant species were also found in the dry dipterocarp stand. This suggests that higher elevation promotes species diversity in dry dipterocarp forests. Teejuntuk et al. (2003) reported that the diversity of tree species in northern Thailand’s Doi Inthanon National Park increased up to an elevation of 1,800 m. Also, it has been found that tree species in dry dipterocarp forests can move into higher land to grow with other species in an ecotone zone (Kutintara 1975; Marod et al. 2015) which may be related to a more favorable environment for growth at slightly higher elevation (Ivanov et al. 2008).

Elevational gradients often limit the distribution of tree species by decreasing soil moisture and nutrient levels (Bridge and Johnson 2000). Several studies have reported that an increase in species diversity may have an elevational limit above which diversity would become negatively correlated (Liu et al. 2018). For instance, the resources necessary for plant growth are limited at extremely high elevations because of strong winds and shallow soils (Zhang et al. 2013).

In this study area, elevation ranged between 140 - 660 m. Higher elevation and SI, CL, and K were negatively correlated, whereas SA was positively correlated (Table 2.11). Poor sandy soil is an important indicator of tree species in dry dipterocarp forests (Bunyavejchewin 1983, 1985; Santisuk 1998). Therefore, some tree species in the SSS and the SOS may be able to grow at higher elevation because of more favorable soil conditions without the limiting climatic conditions found at extremely high elevation.

In this study, it appears that DS and SM influenced species diversity and distribution. The positive correlation between species diversity in the SSS and SOS with the DS revealed that diversity is related to water availability. This indicates that dry conditions may negatively impact species diversity and distribution. Several species in the dry dipterocarp forests are strongly associated with proximity to water sources. This suggests that tree species adapt to drought areas that have low soil moisture, high aridity, and fire disturbance. These are important factors that determine the species occurrence in dry dipterocarp forests in Thailand (Rundel and Boonprakob 1995; Marod et al. 2002; Bunyavejchewin et al. 2011).

Similarly, the negative correlation of species diversity in the MLS and SSS with SM substantiated the occurrence of these forests in dry regions (Marod et al. 1999). Tree species such as *Pterocarpus macrocarpus* (PTMA), *Polyalthia cerasoides* (POCE), *Zollingeria dongnaiensis* (ZODO), *Hymenodictyon orixense* (HYOR), and *Lannea coromandelica* (LACO) were closely associated with SM, which suggests that they were restricted by moisture levels and sensitive to drought conditions. Generally, these species had a higher water demand than the other tree species in deciduous forests that could adapt and survive in arid areas (Marod et al. 1999). Previous findings indicate that SM decreased as the distance from a reservoir increased (Sarvade et al. 2016), suggesting that the species in MLS and SSS were also related to distance from a water source.

Deciduous forests often occur in arid areas with sandy soil; 53% of the soils in mixed deciduous forests and 70% of those in dry dipterocarp forests consist of sand (Myo et al. 2016). Sandy soils are more susceptible to leaching which can lead to drought (Aranguren et al. 1982; Zhang et al. 2013). Soils with higher sand content have lower water-holding capacity thereby causing plants to compete more for soil moisture (Toledo et al. 2012). Contrarily, trees growing in clay soil have more efficient root system and are less susceptible to drought stress because of the greater capacity of the soil for water retention. Trees with deeper roots in sandy soil have a greater chance of surviving as they adapt to reduce drought stress (Wessel 1971). Hence, a deep root system enables plants to adapt to and survive in extremely dry conditions, such as being distant from a water supply or being in an area with limited soil moisture.

This study's results imply that trees survive and grow well despite the dry conditions in the SSS and SOS; the sufficient depth of root system of trees in the both stands has enabled them to adapt to drought stress. However, the existence of some species in the MLS and SSS may be limited by the level of moisture in soil for their growth.

The negative correlation of the dominant species in the MLS and SSS with OM and DC explains that both environmental factors constrain tree growth and diversity in their corresponding forest stands. The growth, species distribution, and composition of trees in tropical areas are influenced by soil nutrients (John et al. 2007; Santiago et al. 2012). Many studies have shown that OM is a key environmental factor in plant communities (Zhang and Zhang 2007; Slik et al. 2009; Sarker et al. 2014), and that it contributes to the availability of nutrients and water by improving soil structure and physical conditions, increasing the water holding capacity of the soil, and providing a habitat for plant roots and soil organisms (Carter 2002; Meng et al. 2014). Thus, soils with more OM are more fertile and more favorable for the optimal growth of trees (Vahdati et al. 2017).

In the study forest, however, there were tree species in the MLS and SSS that were inversely associated with OM indicating that this environmental factor restricted their growth. As explained by Grime (1997), if nutrients are scarcely available in the soil, then plants will have to adapt to low-resource and nutrient-poor conditions, making natural selection predominant in the process.

Plant productivity is positively linked with OM, as reported by Bauer and

Black (1994). Thus, more OM should be made available for plants to increase their productivity. Data also revealed that OM had a positive correlation with pH and P (Table 2.11) indicating that trees are not only affected by OM content but that pH and P are consequential soil properties involved in plant growth. In a previous study conducted in a tropical forest in Ben En National Park, Vietnam, it was reported that an increase in OM could augment P and pH and thereby enhance species composition and distribution of plants in the area (Hoang et al. 2011).

The dominant species were closely correlated with DC which supports a previous report that human disturbance is a threat to plant diversity loss (Millennium Ecosystem Assessment 2005). Not only were dominant species found distributed in the stands, but shrub species such as *Wendlandia tinctorial* (WETI), *Mitragyna rotundifolia* (MIRO), *Bridelia retusa*, and *Zizyphus oenoplia* (ZIOE) were also distributed near the communities. These species are often used for firewood and construction. As such, there is a high risk of them being harvested and their distribution being impacted. Furthermore, they are a pioneer species that plays a vital role in ecological succession after disturbances (DNP 2007; Asanok et al. 2020). Based upon their unique role and characteristics, their utilization by communities may have an impact on the natural restoration of forest ecosystems in the community forest.

Many studies have shown that the impact on tree species in forests could be worse if they were in closer proximity to a community (Thapa and Chapman 2010; Hoang et al. 2011; Chen et al. 2014; Asanok et al. 2017; Martínez-Camilo et al. 2018). These studies reported that trees would be more abundant in less disturbed plots located far from human settlements. Furthermore, Teejuntuk et al. (2003) discussed that at an elevation less than 1,800 m in northern Thailand, the occurrence of ecologically similar species increased at higher elevation since forests at higher elevation are more distant and more inaccessible. Lowland forests, conversely, have become significantly more fragmented and degraded because of deforestation through illegal logging, burning, and grazing. Human disturbance is more rampant in areas with easy access, poor monitoring and weak enforcement of regulations (Måren and Sharma 2018). The apathy of locals to forest management also aggravates the problem and contributes to the decline of forest biodiversity.

2.6. Summary and Conclusions

Understanding the environmental factors that influence tree species composition is essential for successful management of biodiversity and sustainable use of community forest resources. This study aims to assess tree species composition and distribution in the deciduous Ban Mae Chiang Rai Lum Community Forest in northern Thailand and to analyze the influence of environmental factors on tree biodiversity in the forest.

A stratified systematic sampling of the forest's total area of 3,925 ha was conducted, and twenty-five 0.16 ha survey plots were established in three different stands of the deciduous forests to estimate and characterize the difference in biological diversity among the stands. Canonical correspondence analysis (CCA) was used to investigate the environment factors affecting such differences in biodiversity of the stands. The results showed a high diversity of trees in the forest as 197 species, 144 genera, and 62 plant families were recorded. The CCA ordination identified the environmental factors—the most important of which were elevation, distance to streams, soil moisture, organic matter, and distance to communities—that significantly influenced the diversity and distribution of tree species ($p < 0.05$) in the community forest.

Even through tree species in deciduous forests are able to shift to higher elevation to find more favorable conditions and adapt to grow in drought areas, the limitation of organic matter, water availability, and soil moisture can still impact tree species diversity. This could prove to be important and useful information for community forest management. It is recommended that management practices for drought reduction such as building check dams and fire protection be implemented to protect biodiversity, especially in the MLS and SSS.

In addition, biodiversity conservation would be better served by monitoring the utilization of forest resources by nearby communities. Species propagation, silviculture, and transplantation should be initiated and/or expanded, particularly in neighboring villages or private farms, to enhance the productivity and viability of the community forest.

Chapter 3. Non-Timber Forest Product Utilization under Community Forest Management

3.1. Literature Review

3.1.1. Utilization of Non-Timber Forest Products (NTFPs)

Worldwide, forest resources are crucial to the livelihoods of people who live in proximity. Approximately 1.6 billion local people, or more than 25% of the world's population, depend on bio-diverse forest resources for their livelihoods (The World Bank 2001). The value of biodiversity in maintaining commercial forest productivity alone is estimated to be as much as US $166 - 490 billion per year (Liang et al. 2016). NTFPs obtained from the biodiversity of forest ecosystems are crucial contributors to household incomes. Dependence on NTFPs by lower income households to support their livelihoods has been reported in many parts of the world (Amgrose-Oji 2003; Heubach et al. 2011; Melaku et al. 2014; Liu and Moe Liu 2016; Saifullah et al. 2018). In a survey conducted by Angelson et al. (2014), twenty-four developing countries were found to rely on forests for 28% of total household incomes.

Thailand is a remarkably bio-diverse country of which 31.68% is covered by forest (RFD 2019a). It has over 15,000 species of plants, accounting for 8% of the plant species found globally (ONEP 2009). Roughly 23 million people live near national forest reserve areas which serve as providers of the NTFPs that have become important resources that help to satisfy basic needs of rural communities (Witchawutipong 2005). NTFPs are used for daily household consumption and are often traded in local markets to provide and supplement household income. Commonly, the NTFPs utilized in the communities include edible plants, wild fruits, medicinal plants, fuelwood, mushrooms, insects, wild animals, fibers, and extractives (ONEP 2004; Jarernsuk et al. 2015; Larpkerna 2017; Mianmit et al. 2017). The average annual income from selling NTFPs in local markets in Thailand is estimated to be over US $25,000 per village (ONEP 2004) and over US $2 billion nationwide (ITTO 2006).

3.1.2. Community Forest Management (CFM)

The concept of the community forest management (CFM) has been widely accepted and implemented in numerous countries, particularly in Southeast Asia. Yet, ‘community forest’ and its ‘management’ have been assigned different meanings and opined to have differing components.

For instance, FAO (1978) described community forestry as “any situation which intimately involves local people in a forestry activity. It embraces a spectrum of situations ranging from woodlots in areas which are short of wood and other forest products for local needs, through the growing of trees at the farm level to provide cash crops and the processing of forest products at the household, artisan or small industry level to generate income, to the activities of forest dwelling communities”. Gilmour and Fishes (1991) explained that community forest management is “the control and management of forest resources by the rural people who use them especially for domestic purposes and as an integral part of their farming system”. According to Duinkerl et al. (1994) “a community forest is a tree-dominated ecosystem managed for multiple community values and benefits by the community”. A community forest is “a process by which communities of forest users protect forests of the public domain in partnership with the government” (Hobley et al. (1996), and it is one in which “local people can collect forest products to meet their local needs”. “Community forestry means that local people have the right to make their own decisions about how and what a forest is managed for, as long as it is in a sustainable manner” Sukwong (2004).

There are common threads among this range of characterizations leading to a description of CFM as a collaborative forest management effort among those with the right to make decisions regarding their local government and the management of resources. It is accepted that CFM plays an important role in rural development and provides long-term economic, social, and environmental benefits to the local community. Community forest management is also generally recognized as an effective sustainable forest management tool.

An estimated 14% of all forests in developing countries are governed by CFM; it has been adopted and implemented in many such countries, including Thailand (Gilmour 2004). This is an approach primarily borne out of governments' apparent ineffectiveness in controlling forest degradation thereby prompting alternative actions and strategies to do so (White and Martin 2002).

In the 1970s and 1980s, CFM was adopted in several Southeast Asian countries and recognized as an effective approach to restore degraded forests and to resurrect their benefits. Community forests provide not only environmental benefits, but social and economic benefits as well (RECOFTC 2007). A community forest affects the lives of local people by helping them to meet their basic needs, by supplementing income and benefiting lower income households (Blair and Olpadwala 1988). Implementation of CFM can support the sustainability of NTFPs and help alleviate poverty in remote areas (Gilmour et al. 2004; Thammanu and Caihong 2014; Mianmit et al. 2017). Increased trade in NTFPs has been shown to slow deforestation by increasing the economic value of forest biodiversity (Shanley et al. 2002); effective local institutional management can reduce forest degradation (Ostrom et al. 1994; Ostrom 2005). In addition, the responsible use of NTFPs under CFM can lead to successful forest management that is beneficial to human well-being and ecosystem services thereby improving rural livelihoods and conserving forest biodiversity (Jumbe and Angelsen 2007; Coulibaly-Lingani et al. 2011; Soe and Youn 2019b).

In Thailand, the RFD has promoted CFM since 1987 (RFD 2014). In these past three decades, evidence of the acceptance, advent and expansion of CFM is reflected in the widespread level of participation. Most recently, on May 24, 2019, the Thai government approved the Community Forest Act B.E. 2562 that granted local decision making authority to communities who managed community forest projects (Royal Thai Government 2019). Community forest establishment projects have been implemented in more than 17,400 villages, covering a total area of 1.2 million ha, or 7% of the country's total forest area (RFD 2020). Community forest projects have proven very successful in providing NTFPs and benefits to local communities (Table 3.1).

Table 3.1 Number and area of community forests established during 2000 - 2020

Regions	Number of projects	Number of villages	Area (rai)
North	5,919	5,414	4,852,397-1-79
North East	8,488	7,038	1,741,288-1-25
Central	1,750	1,612	737,419-1-86
South	1,285	1,273	303,156-1-51
Total	17,442	15,337	7,634,261-2-41

Source: Royal Forest Department, 2020. 1 ha = 6.25 rai

3.1.3. NTFP Income and Increased Participation in CFM

NTFP income is expected to positively correlate with effective forest management. Benefitting from forest biodiversity plays an important role in encouraging participation in forest management, supplementing household incomes, and in contributing to the overall effectiveness of CFM. Greater engagement in CFM will expand the opportunities for increased NTFP income while increased income will ultimately incentivize CFM development. Previous studies have suggested this correlation; increased income from NTFPs could lead to enhanced participation in conservation and management programs (Lise 2000; Jumbe and Angelsen 2007; Coulibaly-Lingani et al. 2011; Tugume 2015; Soe and Youn 2019b).

3.1.4. Socio-economic Factors that Influence NTFP Dependence and Participation in CFM

Previous studies have shown that various factors could influence the utilization of resources and forest management. In the instant study, two dependent variables were emphasized: 1) dependency on NTFPs for income, and 2) participation in CFM.

It was expected that some socio-economic factors would be indicators of NTFP income and the degree of participation. For instance, older people have a higher level of NTFP extraction than younger people due to their experience in doing so (Heubach et al. 2011; Mutenje et al. 2011). Because gathering NTFPs is difficult labor and physically taxing, males have higher NTFP income than females (Schaafsma et al. 2014; Soe and Youn 2019a). Being married is positively correlated with NTFP income (Aminu et al. 2017). Household heads gathered NTFPs less than non-heads of households (Tugume et al. 2015). NTFP utilization is likely to decrease as education levels increase; those with less education have more limited employment opportunities prompting a reliance on forest resources (Heubach et al. 2011; Mutenje et al. 2011; Kar and Jacobson 2012; Soe and Youn 2019a). Larger households are more likely to engage in NTFP extraction because they have more available labor to do so (Babulo et al. 2008; Coulibaly-Linganiab et al. 2011; Aminu et al. 2017; Suleiman et al. 2017). A main occupation as a laborer or a merchant positively correlates with NTFP utilization (Mutenje et al. 2011). Household income was also expected to relate to income derived from NTFPs; a lack of a secure income source created a need to otherwise enhance household income (Kar and Jacobson 2012; Melaku et al. 2014). Land ownership was related to NTFP income; non-landowners tended to engage more in NTFP collection for subsistence because of insufficient crop harvestings (Soe and Youn 2019a).

In terms of CFM participation, the expectation was that females would take part in management activities more than males (Dolisca et al. 2006; Musyoki et al. 2016). Enhanced age and its concomitant impact on physical strength resulted in less participation (Dolisca et al. 2006; Zang et al. 2019). Those who are married would have greater opportunity and participate to a higher degree than a single person who is solely responsible for the household (Coulibaly-Linganiab et al. 2011). The head of a family, who is more concerned with sources of income and more prominent in household decision making, participates more (Coulibaly-Linganiab et al. 2011). Those with higher levels of education will be more involved as they are more informed and generally have a longer-term vision (Bahdur et al. 2013; Musyoki et al. 2016). The number of household members is also related to the level of participation as larger families have more potential workers that can be involved in CFM (Lise 2000; Dolisca et al. 2006; Coulibaly-Linganiab et al. 2011; Bahdur et al. 2013). Households in which the main occupation was a farmer are positively correlated with participation in CFM (Lestari et al. 2015). Higher income families are likely to have greater participation in social forest activities because they are more acutely aware of the fatal consequence of deforestation

(Dolisca et al. 2006). However, those who owned land participated less than renters whose interest in acquiring land use rights prompts more involvement in CFM (Dolisca et al. 2006).

3.1.5. CFM Factors that Influence NTFP Dependence and Participation in CFM

CFM emphasizes local interest and participation in protecting forest resources. Successful implementation of forest management depends on this local participation as well as on other factors and forms of engagement in CFM, the analysis and understanding of which can help to define effective CFM practices. People's participation in management activities, management regulations, knowledge and perceptions regarding forest management, and benefit sharing can all provide useful insight into how CFM can be implemented to maximize the benefit while safeguarding the resources (Ostrom et al. 1994; Pragtong 1995; Ostrom 2005; Salam et al. 2006; Sunderlin 2006; Negi et al. 2018).

Other studies have identified a positive relationship between NTFP income and participation in CFM (Lise 2000; Jumbe and Angelsen 2007; Coulibaly-Lingani et al. 2011; Tugume 2015; Soe and Youn 2019b). A close relationship between income derived from forests and increased participation in forest management was similarly detected in this study.

For the foregoing reasons, 'People's participation', 'Community forest regulations', 'Perception and understanding', 'Benefit sharing', (inclusive of their components as fully described below in Table 3.2), and income derived from NTFPs were identified as CFM factors consequential to promoting livelihood improvement and biodiversity conservation in the community forest. Focus was directed on these factors, and it was expected that they would be positively correlated to NTFP dependence and participation in CFM.

3.2. Theoretical Framework, Variables and Hypotheses

3.2.1. Research Framework

To increase the livelihoods of the local community and to conserve biodiversity, forests should be managed for sustainability. CFM has been embraced by institutions, academics, and governments, and employed in different ways. Several reports have shown that CFM can enhance local livelihoods and contribute to sustainable forest conservation (Salam et al. 2006; Chen et al. 2012; Chechina et al. 2018). To be successful, CFM should effectively manage forest resources.

The framework of this study is displayed in Figure 3.1. Under community management, forests provide diverse tree species and NTFPs that are beneficial to the rural communities. The success and effectiveness of CFM in doing so can be evaluated by investigating the four components of CFM (Pragtong 1995; Salam et al. 2006; Sunderlin 2006; Negi, et al. 2018). Generally, these are 1) people's level of participation in management efforts, 2) knowledge and opinions as to regulations and their effectiveness, 3) perception and understanding of CFM, and 4) benefit sharing. Effective management can expand the provision of NTFPs in support of rural community livelihoods and to conserve the community forest biodiversity. Because NTFP income could incentivize participation in CFM, a relationship between NTFP income and people's participation was presumed.

In addition, different socio-economic and CFM related factors could impact NTFP extraction and participation in CFM. In order to be able to understand how to promote engagement in forest management, this study analyzed the socio-economic and CFM factors that influence NTFP dependence and participation.

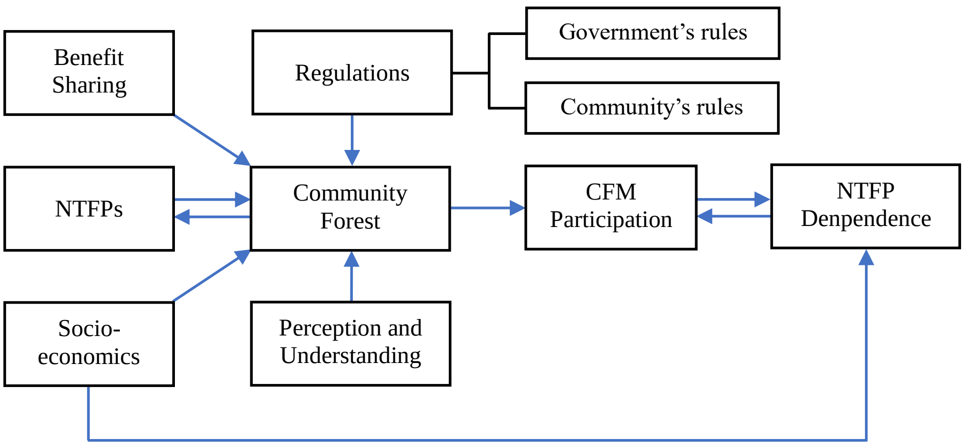


Figure 3.1 Conceptual framework links between utilization of NTFPs and CFM

3.2.2. Household Variables

Pertinent data was collected by using a questionnaire specifically designed for this purpose. Interviews were conducted with 159 household heads and/or the representatives who engaged in NTFP utilization. The following socio-economic data and opinions regarding CFM were also obtained:

1) NTFP income: Income of a household obtained by collecting and utilizing NTFPs: edible plants, wild fruits, medicinal plants, fuelwood, mushrooms, honey and insects, small animals, fibers, and extractives (Jarernsuk et al. 2015; Larpkerna et al. 2017; Mianmit et al. 2017). In this study, 'NTFP dependence' was defined as receiving NTFP income in excess of US $50.00 and those receiving income in excess of that amount were considered "NTFP dependent'.

2) Community forest management (CFM): The four components of CFM effectiveness are generally identified in 'Framework' above. The degree of people's engagement in the community forest project as demonstrated by an analysis of these four components evidences the success and/or effectiveness of CFM. A more detailed explanation of each of these four components and their specific focuses is reflected in Table 3.2.

Table 3.2 Components of CFM effectiveness

CFM	Definition
People's participation	1) Involvement in decision making, attending meeting, determining regulations, and forest development planning activities. 2) Participation in activities: forest plantation and rehabilitation, forest patrols, forest fires prevention, forest surveys and alignment, building check dams, and forest culture and tradition. 3) Receiving environmental, social, and economic benefits from the community forest. 4) Following up on performance, presenting problems and obstacles, and finding solutions to CFM.
Community forest regulations	Level of knowledge regarding community forest regulations, and opinions as to a) perception of CFM, b) the appropriateness and efficiency of regulation enforcement, and c) level of compliance with community forest regulations.
Perception and understanding	Level of knowledge about CFM, NTFP utilization, and sustainable forest management.
Benefit sharing	Level of satisfaction from sharing the benefits of the community forest.

CFM = community forest management, NTFP = non-timber forest product

3) Socio-demographics: Previous studies have found that certain personal and household demographics are related to the amount of NTFP income and participation in CFM (Lise 2000; Dolisca et al. 2006; Babulo et al. 2008; Coulibaly-Linganiab et al. 2011; Heubach et al. 2011; Mutenje et al. 2011; Kar and Jacobson 2012; Bahdur et al. 2013; Melaku et al. 2014; Schaafsma et al. 2014; Musyoki et al. 2016; Aminu et al. 2017; Suleiman et al. 2017; Soe and Youn 2019a, b; Zang, et al. 2019). The ten factors selected as variables are: gender, age, marital status, household status, education levels, number of household members, main occupation, household income, land ownership, and land rental.

3.2.3. Hypotheses

Based on the conceptual framework of the study, the following two hypotheses were developed:

Hypothesis 1: Greater NTFP income results in a higher rate of participation in CFM

Hypothesis 2: Socio-economic and CFM factors influence NTFP dependence and participation in CFM

Socio-economics and participation were considered factors that impact NTFP dependence; therefore, this hypothesis can be broken down into a series of sub-hypotheses as follows:

1) Females are less dependent on NTFPs than males

2) Those not over 60 years old are less dependent on NTFPs

3) Married people are positively related to NTFP dependence

4) Heads of s household, as opposed to a non-head member of a household, were negatively related to NTFP dependence

5) The uneducated or those with a primary school education tend to be more NTFP dependent

6) Households with more than 3 members are positively related to NTFP dependence

7) A farmer is positively related to NTFP dependence to a lesser degree than other occupations

8) Lower income households are more likely to be dependent on NTFPs than higher income households

9) Land ownership is negatively related to NTFP dependence

10) Those who rent land are positively related to NTFP dependence

11) People who participate in CFM at a ‘very high’ level are more likely to be NTFP dependent

Similarly, socio-economics and CFM factors can impact levels of participation in CFM. Thus, this hypothesis can be streamlined into the following sub-hypotheses:

1) Female participate in CFM more than males

2) Those not over 60 years of age are more likely to participate in CFM

3) Married people are more likely to participate in CFM

4) Heads of households participate more in CFM than other members

5) The uneducated or those with a primary school education participated less in CFM

6) Households with more than 3 members are more likely to participate in CFM

7) A farmer tends to participate more in CFM compared to other occupations

8) Low income households are less likely to participate in CFM

9) Land ownership is negatively related to CFM participation

10) People who rent land are positively related to CFM participation

11) Those who reported a ‘very high’ level in the category of ‘Community forest regulations’ are likely to participate more in CFM

12) Those who reported a ‘very high’ level in the category of ‘Perception and understanding’ of forest management are likely to participate more in CFM

13) People whose satisfaction level regarding benefit sharing is ‘very high’ are more likely to participate in CFM

14) People who depend on NTFP income are likely to participate more in CFM

A description of the variables and the expected impact of specific socio-economic and CFM factors on NTFP dependence and participation are shown in Table 3.3 and 3.4.

Table 3.3 Variables, descriptions, and expected impact on NTFP dependence of socio-economic and CFM factors

Variables	Discription and Measurement	Expected Impact
Dependent variables		
NTFP dependence	The income of a household from harvesting NTFPs: 1 if received NTFP income > US $50.00, and 0 if otherwise	
Explanatory variables		
Gender	1 if female, 0 if otherwise	Negative (−)
Age	1 if ≤ 60 years, 0 if otherwise	Negative (−)
Marital status	1 if married, 0 if otherwise	Positive (+)
Household status	Role in family: 1 if head, 0 if otherwise	Negative (−)
Education levels	1 if ≤ primary school, 0 if otherwise	Positive (+)
Number of household members	1 if > 3 people, 0 if otherwise	Positive (+)
Main occupation	1 if farmer, 0 if otherwise	Negative (−)
Household income	1 if < US $4,145.16 (the third quartile), 0 if otherwise	Positive (+)
Land ownership	The land tenure of a household (rai)	Negative (−)
Rented land	The rented land of a household (rai)	Positive (+)
Participation in CFM	The level of engagement in CFM: 1 if very high, 0 if otherwise	Positive (+)

NTFPs = non-timber forest products, CFM = community forest management, US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018), 1 ha = 6.25 rai

Table 3.4 Variables, descriptions, and expected impact on participation in CFM of socio-economic and CFM factors

Variables	Description and Measurement	Expected Impact
Dependent variables		
Participation	The level of engagement in CFM: 1 if 'very high', 0 if otherwise	
Explanatory variables		
Gender	1 if female, 0 if otherwise	Positive (+)
Age	1 if ≤ 60 years, 0 if otherwise	Positive (+)
Marital status	1 if married, 0 if otherwise	Positive (+)
Household status	Role in family: 1 if head, 0 if otherwise	Positive (+)
Education levels	1 if ≤ primary school, 0 if otherwise	Negative (−)
Number of household members	1 if > 3 people, 0 if otherwise	Positive (+)
Main occupation	1 if farmer, 0 if otherwise	Positive (+)
Household income	1 if < US $4,145.16 (the third quartile), 0 if otherwise	Negative (−)
Land ownership	The land tenure of a household (rai)	Negative (−)
Rented land	The rented land of a household (rai)	Positive (+)
Community forest regulations	The level of knowledge and opinion regarding 'Community forest regulations': 1 if 'very high', 0 if otherwise	Positive (+)
Perception and understanding	The level of knowledge about forest management: 1 if 'very high', 0 if otherwise	Positive (+)
Benefit sharing	The level of satisfaction with sharing of benefits: 1 if 'very high', 0 if otherwise	Positive (+)
NTFP income	Dependent on NTFPs: 1 if received > US $50.00, 0 if otherwise	Positive (+)

NTFPs = non-timber forest products, CFM = community forest management, US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018), 1 ha = 6.25 rai

3.3. Material and Methods

3.3.1. Study Area

Ban Mae Chiang Rai Lum (village no. 3), in Mae Phrik District of Lampang Province in northern Thailand, was chosen as the study area. It is located between N 17^{o}22'48" and N 17^{o}27'47" and the E 99^{o}00'47" and E 99^{o}05'48" in the Pa Mae Phrik National Forest Reserve. The total area of the community forest is 3,925 ha.

The village has 265 households and a population of approximately 1,060, 508 males and 552 females. Village life is simple and peaceful. Most residents have lived in the village since birth, and they are predominantly farmers, merchants, and laborers. People normally work on their farms during the growing season cultivating, for the most part, rice, soybeans, peanuts, fruit (lime, longan, banana, papaya, and mango), garlic, and livestock. The range of the average annual household income is US $645.16 - $1,612.90 (20,000 - 50,000 baht).

Some ‘middle age’ people move to the city seeking jobs and extra income. Grandparents generally stay in the village and support their children by being the primary caregivers of the grandchildren. Most people are Buddhists with a primary school education; some have attended secondary school in a nearby community while a very small percentage have and take advantage of post-secondary education opportunities (MPSAO 2018).

A unifying strength of the community is their shared interest in social events that advance community development. Villagers regularly participate in activities in the community to discuss their work and confront problems in search of solutions for their mutual benefit.

The location of the study-area village and community forest are shown below in Figure 3.2.

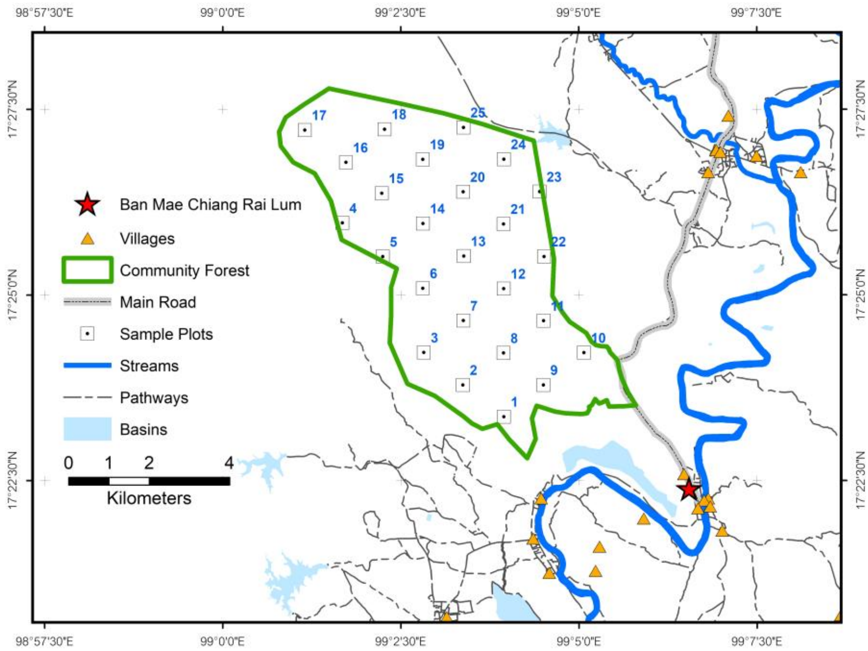


Figure 3.2 Location of Ban Mae Chiang Rai Lum and the community forest in Lampang Province

This study area was classified as deciduous forests: mixed deciduous forest and dry dipterocarp forest. Generally, deciduous forests in Thailand represent 18.26% of the country's total forest area (RFD 2019a). These forests play a vital role as a source of biodiversity while contributing to forest ecosystem services that improve the livelihoods of those who live in close proximity (Kabir and Webb 2006; Chaiyo et al. 2011; Larpkerna et al. 2017; Mianmit et al. 2017). Similarly, the Ban Mae Chiang Rai Lum Community Forest has and continues to provide these services to its local residents. People in the community utilize NTFPs such as edible plants, medicinal plants, wild fruits, mushrooms, fuelwood, edible and small insects, and honey for daily subsistence and to sell for income. However, 'necessary' forest resources are not synonymous with an 'endless' supply, and the unchecked extraction of these forest resources can create an existential threat to the viability of the forest and its services, evidence of which has been widespread, recognized and the impetus for remedial action.

Since 2008, local people have managed the Ban Mae Chiang Rai Lum Community Forest in collaboration with the RFD under a community forest project. Implementation of this CFM project was in response to the significant and impactful damage caused by forest land encroachment and illegal logging. Under CFM, awareness of the importance of the forest expanded, increased income was realized and livelihoods were improved. Efforts such as forest patrols, plantation and restoration, fire prevention, and check dam construction were implemented to protect the trees and to safeguard the benefits provided by the forest. Moreover, providing, enhancing, and having the ability to transfer the skill and knowledge required to manage the forest appropriately while raising public awareness of the importance and value of the forest are all crucial components to conservation and sustainable management of the community forest.

This area experienced the damage, ramifications and long-term threats posed by the pre-CFM conditions as well as the benefits of the responsive implementation of CFM. Thus, it is a suitable model to study in order to develop strategies to ascertain the impact of CFM and to improve sustainable forest management in Thailand.

3.3.2. Data Collection

1) Field Survey

A field survey was conducted from July to October 2018. The goal of the survey was to assess the plant species diversity in the community forest. This research utilized the results of a study conducted in the same area by the RFD in 2016 to calculate the sampling intensity with a confidence probability of 95% (RFD 2017). This provided an estimate of sample plots using the standard deviation obtained from previous samplings of similar populations (Avery and Burkhart 1983; Asrat and Tesfaye 2013). The formula used to calculate sampling intensity is:

$$n = (Z\sigma/E)^2 \tag{1}$$

where, n = the sampling intensity, Z = the z-value for confidence interval of 95%, σ = the standard deviation for density of tree species, and E = % acceptable level of sampling error.

The result indicated that 25 sampling plots were representative of the total area. Thus, 0.1% of the total forest inventory was sampled and surveyed using a systematic sampling method (ANSAB 2010). Sample plots of 40 × 40 m (0.16 ha) were established. In each plot, trees with a diameter at breast height (DBH) ≥ 4.5 cm were measured and identified in 10 × 10 m subplots. Saplings with a DBH < 4.5 cm and height > 1.30 m were also measured and identified in 4 × 4 m subplots. In addition, within each plot, 1 × 1 m subplots were laid and all seedlings were identified and counted.

2) Household Survey

Interviews were conducted to gather information regarding how the households utilized NTFPs and to evaluate their participation in CFM. In addition, the survey sought to ascertain households' opinions about forest management, as well as their perception of the effectiveness of regulations and benefit sharing by the community.

Proportional allocation was used for the sample size determination using the formula proposed by Yamane (1967). The formula is:

$$n = N / (1 + Ne^2) \tag{2}$$

where, n = the sampling to be estimated, N = the number of households, and e = the significance level (0.05).

Based on 265 community households, the calculation showed that 159 households provided sufficient sampling intensity for the household interview. Three types of questions were developed for the questionnaire: 1) requests for specific demographics, 2) multiple choice (single/multiple answers and Likert scales), and 3) open-ended. The questionnaire comprised three sections related to: 1) socio-demographics, 2) NTFP utilization, and 3) community forest management.

3.3.3. Data Analysis

In order to assess species diversity and their current status, plants were classified into species, genera, and families. Species classification was based on binomial nomenclature (DNP 2014). The habit of the plants was classified as tree, shrub, shrubby tree, herb, climber, etc. In addition, specimens of initially unknown species were eventually identified by comparing them with known specimens in the Herbarium of Department of National Park, Wildlife and Plant Conservation. Referencing the IUCN Red List of Threatened Species (The IUCN Red List of Threatened Species 2019), the statuses of identified plant species were classified as vulnerable, endangered or critically endangered, and the species' population numbers in the region were also investigated. Moreover, the plant species were categorized based on how they were used as NTFPs in Thailand as food, medicine, fuelwood, fiber, or as an extractive product.

Representatives of 159 households were interviewed in order to determine the nature and extent of NTFPs collected and utilized. Descriptive statistics were used to explain the socio-demographics. The total net return and economic value of the NTFPs obtained from the forest were estimated based on utilization and income from sale in local markets in one year. An opportunity labor cost of 300 baht/day (US $9.68) was used to calculate the value of the time involved in NTFP collection. Transportation costs incurred in collecting NTFPs were also considered in determining net returns using this formula (Tejaswi 2008).

$$\text{Rate of return from NTFP collection} = \sum_{i=1}^{n} PiQ_i^h - (WL^h + Tc^h) \qquad (3)$$

where, Pi = price of the good, i = counter of NTFPs, Q_i^h = quantity of goods collected by households h, W = wage rate, L^h = hours worked by households h, and Tc^h = transportation costs used by households h.

The classification of household income was categorized into four quartiles based on household income from least to highest: first quartile (Q1 < 25^{th} percentile), second quartile (Q2 < 50^{th} percentile), third quartile (Q3 < 75^{th} percentile), and fourth quartile (Q4 > 75^{th} percentile). The household's relative dependence on NTFP income was measured in each quartile by calculating the percentage of household income derived from the NTFPs. Gini index or Gini coefficient is a statistical measure of ecnomic inequality in a population that represents income inequality within a group of people. Thus, the Gini index of inequality was used to compute the difference in benefit sharing of NTFP income in the community.

$$\text{Gini index} = 1 - \sum_{i=1}^{C} (pi)^2 \tag{4}$$

where, C = number of samples and pi = NTFP income of households.

CFM projects can be renewed with the RFD every 10 years. Therefore, the Net Present Value (NPV) of NTFP collection over time was computed, assuming 10, 20 and 30 year periods of CFM, to determine the present value of an investment. There were four principal categories of forest management costs during 2009 - 2018: 1) forest fire prevention, 2) forest culture and forest plantation, 3) forest patrol, and 4) check dam construction. There is no available data for other costs and, therefore, none other were included in this study. Thus, investment in CFM was used to compute the NPV of collecting NTFPs during periods under CFM. The 4% discount rate was applied to evaluate an investment in CFM using the World Bank's 2018 lending interest rate for Thailand (The Work Bank 2018). Further, the Internal Rate of Return (IRR), a discount rate that makes the NPV of all cash flows equal to zero in a discounted cash flow analysis, was applied to estimate the potential profitability of investments in CFM. The formula used to determine the NPV and IRR is as follows:

$$0 = NPV = \sum_{t=i}^{T} \frac{Ct}{(1 + IRR)^t} - Co \tag{5}$$

where, Ct = net cash inflow during the period t, Co = total initial investment costs, IRR = the internal rate of return, and t = the number of time periods.

The survey data regarding effectiveness of CFM was analyzed and measured on a 5-level Likert scale. The minimum and the maximum length of the Likert scale were broken down into equal mean intervals of 0.80 in the 5 levels in order to provide a weighted mean in efficiency of CFM. The scale's intervals are interpreted in Table 3.5.

Table 3.5 Measurement and interpretation of Likert scales

Likert scale	Interval	Interpretation
5	4.21 - 5.00	Very High
4	3.41 - 4.20	High
3	2.61 - 3.40	Moderate
2	1.81 - 2.60	Low
1	1.00 - 1.80	Very Low

A Spearman Rho coefficient correlation was performed to analyze the correlation between NTFP income and CFM using the equation:

$$p = 1 - 6\sum d_i^2 / n(n^2 - 1) \tag{6}$$

where, p = Spearman rank correlation, di = the difference between the ranks of variables, and n = number of observations.

In addition, a logistic regression analysis was used to examine the relationship between variables to determine the key factors affecting NTFP dependence and participation in CFM using the following:

$$ln(\frac{P}{1-P}) = \beta_o + \sum_{i=1}^{n} \beta_i X_i + \varepsilon \tag{7}$$

where, P = the probability of the event that Y = 1 (NTFP dependence or CFM participation), β_o = the regression intercept, β_i = the regression coefficient of the ith factor, X_i = the ith factor influencing the NTFP dependence or CFM participation, and ε = the random disturbance term.

The current situations of forest biodiversity and NTFP utilization were reviewed through CFM for rural livelihood improvement and biodiversity conservation. Moreover, the status of plant species in providing NTFPs was also considered for managing forest resources in the community forest.

All statistical calculations were performed using R program version 3.6.2 for Windows software (R Development Core Team 2019).

3.4. Results

3.4.1. Current Status of Plant Species and NTFPs

The inventory of the area in this study yielded a total of 18,567 trees comprising 197 species, 144 genera, and 62 plant families: 129 tree, 99 sapling, and 141 seedling species were identified. Of these, 160 plant species have been classified as having medicinal use, 89 are used as food, 37 as extractive products, 32 as fuelwood, and 12 as fibers. These NTFPs are grouped into categories shown in Appendix I.

Twenty-six plant species were classified and listed on the IUCN Red List of Threatened Species with seven of these species also listed therein as experiencing a decreasing population. In addition, nine species were reported to have ≤ 10 stems, 20 species were listed as of Least Concern (LC) including these 7 species with ≤ 10 stems: *Casearia grewiifolia*, *Cassia fistula*, *Dalbergia cana*, *Holarrhena pubescens*, *Oxystelma esculentum*, *Siphonodon celastrineus*, and *Vitex pinnata.* Two species, *Chukrasia tabularis and Globba winitii*, were listed as having a decreasing population. The Red List classification also showed four species that were Near Threatened (NT) with decreasing populations: *Dalbergia cultrata*, *Dipterocarpus obtusifolius*, *Dipterocarpus tuberculatus*, and *Shorea obtusa*. Moreover, *Dalbergia oliveri* is an Endangered (EN) species with a very high risk of extinction in the wild. Additionally, *Cycas siamensis* is considered Vulnerable (VU) with a decreasing population and highly likely to become endangered if its main threats persist (Table 3.6).

Table 3.6 Current IUCN (International Union for Conservation of Nature) status of plant species in the community forest

Status	Species	Habit	Number of stems			
			Tree	Sapling	Seedling	Total
Least Concern (LC)	*Azadirachta indica*	T	30	18	5	53
	Bauhinia glauca	C	48	15	67	130
	Casearia grewiifolia	T	3	4	-	7
	Cassia fistula	T	3	-	-	3
	Chukrasia tabularis #	T	3	3	207	213
	Cratoxylum cochinchinense	T	4	9	21	34
	Cratoxylum formosum	T	16	65	386	467
	Cyperus rotundus	H	-	-	197	197
	Dalbergia cana	T	1	-	-	1
	Globba winitii #	H	-	-	66	66
	Holarrhena pubescens	S/T	-	6	-	6
	Irvingia malayana	T	30	3	20	53
	Markhamia stipulata	T	11	3	15	29
	Oxystelma esculentum	C	-	-	2	2
	Phyllodium pulchellum	S	-	12	10	22
	Shorea siamensis	T	390	46	79	515
	Sindora siamensis	T	263	50	49	362
	Siphonodon celastrineus	T	5	-	-	5
	Vitex pinnata	T	4	1	5	10
	Wendlandia tinctoria	ST	18	10	18	46
Near Threatened (NT)	*Dalbergia cultrata* #	T	2	1	3	6
	Dipterocarpus obtusifolius #	T	72	14	26	112
	Dipterocarpus tuberculatus #	T	92	20	30	142
	Shorea obtusa #	T	420	107	161	688
Vulnerable (VU)	*Cycas siamensis* #	S	-	488	116	604
Endangered (EN)	*Dalbergia oliveri*	T	1	3	5	9

C = climber, H = herb, S = shrub, ST = shrubby tree, T = tree. # = population trend decreasing

3.4.2. Socio-economics of the Respondents

The socio-economics are presented in Table 3.7 below. The majority of the respondents (62.89%) were female. The respondents ranged from 26 to 86 years old with an average age of 57, possibly because of the middle aged people moving to the city seeking better paying jobs leaving a higher percentage of elderly in the community. Most respondents were married (72.33%). 17.61% reported as widowed and 5.66% as single. Fewer than 5% of the respondents were divorced. 62.26% of the respondents were heads of household and 37.74% were other household members. Most respondents had a primary school education (67.92%), followed in decreasing order by secondary school (27.67%), bachelor's degree (2.52%), non-educated (1.26%), and post-graduate (0.63%). This is reflective of Thai society in its entirety as generally the education level is primary to secondary schools (NSO, 2018). Most families (57.86%) had 1 - 3 people while 42.14% of families had more than 3 members. Being a farmer was listed as the most common primary occupation (83.65%), while 8.80% of respondents were laborers, 4.40% were merchants, 2.52% were government officials or company employees, and 0.63% were unemployed. Annual household incomes ranged from US $348.39 to US $ 46,212.90, while the mean was US $3,587.79, less than the reported average household income of 26,915 baht or US $868.23 per month (US $10,418.76 per year) in Thailand (NSO, 2018). The vast majority of respondents were landowners (88.05%) and did not rent land (81.76%). This is a significantly elevated number compared with the 22% of people throughout northern Thailand that own land (NSO, 2018).

Table 3.7 Socio-economics of sampled households in Ban Mae Chiang Rai Lum

Socio-demographics	Frequency	%
Gender		
Female	100	62.89
Male	59	37.11
Age (years)		
< 30	4	2.51
30 - 45	15	9.43
45 - 60	85	53.46
> 60	55	34.59
Marital status		
Single	9	5.66
Married	115	72.33
Divorced	7	4.40
Widow	28	17.61
Household status		
Head	99	62.26
Member	60	37.74
Education level		
Uneducated	2	1.26
Primary school	108	67.92
High school	44	27.67
Bachelor's degree	4	2.52
Postgraduate	1	0.63
Number of household members		
1 - 3	92	57.86
> 3	67	42.14
Main occupation		
Farmer	133	83.65
laborer	14	8.80
Merchant	7	4.40
Government/Company employee	4	2.52
Unemployed	1	0.63
Household income (US $)		
< 2,000	56	35.22
2,000 - 4,000	61	38.36
> 4,000	42	26.42
Land ownership		
No	19	11.95
Yes	140	88.05
Rented land		
No	130	81.76
Yes	29	18.24

US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018)

3.4.3. NTFP Extraction and Income

1) NTFP Utilization and Economic Value

In 2018, 109 households collected NTFPs from the Ban Mae Chiang Rai Lum Community Forest. An average household gathered NTFPs 22.55 times per year and 3.89 hours were expended each time. The average distance traveled to collect NTFPs was 4.69 km/time. Table 3.8 shows the total net return to these 109 households was estimated to be US $36,215.15 (1,122,670 baht) with an average of US $332.25 (10,299.75 baht) per household. When comparing income with the cost of collection, mushrooms provided the highest percentage of net return (73.47%) followed in descending order by wild fruits (14.93%), small animals (6.04%), edible plants (3.18%), and honey keeping and insect collection (2%). Data regarding other NTFPs such as medicinal plants, firewood, fibers, and extractives were not included as their value was insignificantly low or, in the case of extractives, were not collected for household use. If the benefit were shared among these households, each would receive an average of US $227.76 (7,060.82 baht) per year. The total value of the consumption and sale of NTFPs accounted for 6.35% of the total annual income of the community (US $60,358.62 or 1,871,117.30 baht).

Table 3.8 Total net NTFP income return from Ban Mae Chiang Rai Lum Community Forest in 2018

NTFPs	Number of households engaged	Economic value of NTFPs (US $)				Relative NTFP income (%)
		Income	Costs		Net Returns	
			Opportunity	Transportation		
Edible Plants	34	2,154.19	740.32	263.23	1,150.65	3.18
Wild Fruits	71	9,773.71	3,630.48	735.16	5,408.06	14.93
Mushrooms	105	34,306.61	5,802.39	1,889.03	26,615.19	73.47
Honey and Insects	15	1,225.81	408.87	90.65	726.29	2.00
Small Animals	57	3,700.48	1,172.18	341.77	2,186.53	6.04
Medicinal Plants	7	32.26	13.31	9.03	9.92	0.03
Fuelwoods	5	170.94	33.87	13.71	123.35	0.34
Fibers	1	9.68	14.52	-	-4.84	-
Total	109	51,373.68	11,815.94	3,342.58	36,215.15	100

NTFPs = non-timber forest products, US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018)

2) Benefit Sharing of NTFP Income in Community

A comparison of mean household income and NTFP income by income quartile is reflected in Table 3.9 below. It demonstrates that, regardless of income level, households obtained additional income through NTFPs. The mean NTFP income varied somewhat between quartiles (US $85.23 - US $307.93). The lower income quartiles (Q1 = 7.34%, Q2 = 12.38%, and Q3 = 8.89%) experienced a much larger percentage of income boost from NTFPs than the highest income quartile (Q4 = 3.37%). However, unexpected the Q1 was lower when Q2 and Q3.

Analyzing how the NTFP income inequality among income quartile and household, the income from harvesting NTFPs from community forest was calculate. The Gini coefficient is based on the comparison of cumulative proportions of the population against cumulative proportions of income they receive, and it ranges between 0 in the case of perfect equality and 1 in the case of perfect inequality. In this study, the Gini coefficient was converted to percent. The Gini coefficients reflect that the degree of inequality in NTFP income between households in the community was 71.98%. Upon comparison of the income quartiles, it can be seen that there was also a high degree of inequality.

Table 3.9 Mean comparison between NTFP income and household income

Income quartile (poor to rich)	Number of households	Income range (US $)	Mean household income (US $)	Mean NTFP income (US $)	Relative NTFP income (%)	Gini coefficient (%)
Q1	40	348.39 - 1,612.90	1,161.40	85.23	7.34	63.33
Q2	40	1,612.90 - 2,806.45	2,132.74	264.01	12.38	69.82
Q3	39	2,806.45 - 4,145.16	3,463.27	307.93	8.89	71.78
Q4	40	4,145.16 - 46,212.90	7,950.65	255.91	3.37	69.01

Q = quartile, NTFP = non-timber forest product, US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018)

3) Net Present Value (NPV) and Internal Rate of Return (IRR)

Since Ban Mae Chiang Rai Lum started implementing forest management, US $35,741.94 (1,108,000 baht) has been invested by both the government and private organizations to improve CFM in the four principal areas listed in Table 3.10 that follows.

Table 3.10 Investment in Ban Mae Chiang Rai Lum Community Forest between 2009 and 2018

Activities	Amount (US $)
Forest fire prevention	15,483.87
Forest culture and forest plantation	2,580.65
Forest patrol	1,935.48
Check dam construction	15,741.94
Total	35,741.94

US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018)

In order to evaluate the efficacy of an investment in CFM, the 'initial' investments reflected in Table 3.10 and present value of NTFPs collected were used to calculate the future value of NTFPs over 10, 20, and 30 year periods of CFM, and the NPV and IRR were used to consider the soundness of a long-term CFM investment.

At the discount rate of 4%, the NPV of 10-year continuous CFM was US $257,995.37 (7,997,856.47 baht) and the IRR was 101.23%. In 20 and 30-year investments, the NPV were estimated to be US $420,736.83 (13,042,841.73 baht) and US $519,007.76 (16,089,240.56 baht), while the IRR was estimated to be 50.64% and 33.67%, respectively (Table 3.11).

Table 3.11 Net Present Value and Internal Rate of Return on 10, 20, and 30-year investments in CFM

Year	NPV (US $)	IRR (%)
10	257,995.37	101.23
20	420,736.83	50.64
30	519,007.76	33.67

US $ = United States Dollar

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018)

3.4.4. Effectiveness of CFM

The effectiveness of CFM in this study was reflected in results plotted on a Likert scale with 5 levels: ‘very high’ = 5 points (4.21-5.00), ‘high’ = 4 points (3.41 - 4.20), ‘moderate’ = 3 points (2.61 - 3.40), ‘low’ = 2 point (1.81 - 2.60), and ‘very low’ (1.00 - 1.80). Table 3.12 presents a mean of respondents’ opinions regarding, and participation levels in, CFM. Overall, people were highly engaged (3.92). The enforcement of community forest regulations, the perception and understanding of people in managing their forest resources, and benefits derived from forest biodiversity of the Ban Mae Chiang Rai Lum Community Forest were reported as ‘very high’ (4.40, 4.75, and 4.61, respectively), while the overall involvement of people in forest management activities was ‘high’ (3.55). Participation, specifically in forest activities, and in sharing benefits were high (3.76 and 3.82). However, participation in decision-making (3.35) and in monitoring and evaluation (3.03) were at a ‘moderate’ level. Overall, the level of involvement was ‘high’ (3.55).

Table 3.12 Effectiveness of CFM and level of participation

CFM	Mean	SD	Level
People’s participation	3.55	0.72	High
Community forest regulations	4.40	0.39	Very high
Perception and understanding	4.75	0.29	Very high
Benefit sharing	4.61	0.47	Very high
Total	3.92	0.52	High
People’s participation	Mean	SD	Level
Decision-making	3.35	0.91	Moderate
Forest activities	3.76	0.74	High
Co-benefits	3.82	0.82	High
Monitoring and evaluation	3.03	0.92	Moderate
Total	3.55	0.72	High

CFM = community forest management, SD = standard deviation

3.4.5. Relationship between NTFP Income and Participation in CFM

The Spearman’s Rho correlation coefficients (r = 0.522) in Table 3.13 show that NTFP income and participation in CFM were significant (p < 0.001). Specifically, NTFP income was positively correlated to decision-making (r =

0.467), forest activities (r = 0.480), co-benefits (r = 0.479), and monitoring and evaluation (r = 0.403). This indicates that NTFP income was related to the levels of decision-making, forest activities, co-benefits, and monitoring and evaluation. Thus, the result implies that greater NTFP income results in a higher rate of participation in CFM.

Table 3.13 Participation correlations (Spearman) to NTFP income (n = 159)

People's participation	Correlation (r)	*p*-value
Decision-making	0.467	0.000***
Forest activities	0.480	0.000***
Co-benefits	0.479	0.000***
Monitoring and evaluation	0.403	0.000***
Total	0.522	0.000***

***$p < 0.001$

3.4.6. Socio-economic and CFM Factors Affecting NTFP Dependence and Participation in CFM

The Logistic Regression was analyzed to determine how certain socio-economic and CFM factors were related to NTFP dependence and CFM participation. The explanatory variables shown in Table 3.3 and 3.4 were included in the logit models.

The model with predictors showed that some factors significantly affect NTFP income. Females, respondents under 60 years old or younger, married people, those who listed their principal occupation as 'farmer', and people who participated in CFM at a 'very high' level were positively related to NTFP dependence; people with those characteristics are more likely to be NTFP dependent (Table 3.14).

An analysis of how the socio-economic and CFM factors listed in the above Table affect participation in CFM found that among respondents with those characteristics, only those who owned land and depended on NTFPs were positively related to participation in CFM. In other words, most factors did not positively impact participation. This indicates that land ownership and NTFP utilization promote participation in CFM (Table 3.15).

Table 3.14 Result of a Logistic Regression for variables predicting NTFP dependence (n = 159)

Predictors	*B* coefficients	Std.Error	Wald	*p*-value	OR	95% CI
(Intercept)	-5.093	1.208	17.762	0.000***		
Gender (female)	0.951	0.470	4.080	0.043*	2.589	1.029 - 6.515
Age (≤ 60 years)	1.323	0.471	7.893	0.004**	3.757	1.492 - 9.459
Marital status (married)	1.356	0.494	7.536	0.006**	3.884	1.474 - 10.233
Household status (head)	0.369	0.467	0.626	0.428	1.447	0.579 - 3.615
Education levels (≤ primary school)	0.543	0.455	1.428	0.232	1.723	0.706 - 4.204
Number of household members (> 3 people)	0.402	0.426	0.889	0.345	1.495	0.648 - 3.449
Main occupation (farmer)	1.439	0.548	6.881	0.008**	4.218	1.439 - 12.366
Household income (≤ US $4,145.16)	0.612	0.509	1.449	0.228	1.846	0.681 - 5.005
Land ownership (rai)	0.021	0.039	0.296	0.586	1.022	0.946 - 1.104
Rented land (rai)	-0.025	0.113	0.051	0.820	0.975	0.780 - 1.218
People's participation (very high)	2.501	0.669	13.953	0.000***	12.197	3.283 - 45.311
Chi-square, χ^2	32.5***					
Pseudo R^2 (Nagelkerke)	0.375					
Log-likelihood	-82.747					
Accurancy	0.635					

B = beta, Std = standard, US $ = United States Dollar, OR = odds ratio, CI = confidence inveral.

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018), 1 ha = 6.25 rai. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 3.15 Result of a Logistic Regression for variables predicting participation in CFM (n = 159)

Predictors	*B* coefficients	Std.Error	Wald	*p*-value	OR	95% CI
(Intercept)	-21.424	1215.903	0.000	0.985		
Gender (female)	-0.770	0.559	1.896	0.168	0.463	0.154 - 1.386
Age (≤ 60 years)	-0.097	0.542	0.032	0.857	0.907	0.314 - 2.625
Marital status (married)	-0.434	0.688	0.399	0.527	0.647	0.168 - 2.494
Household status (head)	-0.421	0.614	0.469	0.493	0.656	0.197 - 2.190
Education levels (≤ primary school)	-0.065	0.555	0.013	0.906	0.937	0.315 - 2.784
Number of household members (> 3 people)	0.122	0.509	0.057	0.810	1.130	0.416 - 3.067
Main occupation (farmer)	-0.860	0.808	1.132	0.287	0.423	0.087 - 2.063
Household income (≤ US $4,145.16)	0.418	0.599	0.486	0.485	1.519	0.469 - 4.921
Land ownership (rai)	0.159	0.053	8.753	0.003**	1.173	1.055 - 1.304
Rented land (rai)	0.104	0.111	0.875	0.349	1.110	0.892 - 1.383
Community forest regulations (very high)	0.849	0.739	1.319	0.250	2.338	0.549 - 9.959
Perception and understanding (very high)	18.450	1215.902	0.000	0.987	102998243.643	0 - Inf
Benefit sharing (very high)	-0.460	0.501	0.844	0.358	0.631	0.236 - 1.685
NTFP dependence (> US $50.00)	2.413	0.669	13.011	0.000***	11.177	3.011 - 41.49
Chi-square, χ^2	24.6*					
Pseudo R^2 (Nagelkerke)	0.388					
Log-likelihood	-61.64					
Accurancy	0.798					

NTFP = non-timber forest product, US $ = United States Dollar, *B* = beta, Std = standard, OR = odds ratio, CI = confidence interval

US $1 = 31 baht (Bank of Thailand as of 31 January, 2018), 1 ha = 6.25 rai. *p < 0.05, **p < 0.01, ***p < 0.001

3.5. Discussion

3.5.1. Plant Species Diversity and Sources of NTFPs

The Ban Mae Chiang Rai Lum Community Forest is the source of a vast array of NTFPs. At least 160 species can be used for medicinal purposes, 89 for food, 37 for extractive production, 32 as fuelwood, and 12 for fiber (Appendix I). This was consistent with findings in other studies wherein it was found that forest biodiversity could assist to meet basic needs while otherwise enhancing livelihoods and generating income (Kim et al. 2008; Kumar 2015; Rijal et al. 2019).

Deciduous forests are important tropical dry forests with the potential to provide services to rural communities in remote areas (Kabir and Webb 2006; Chaiyo et al. 2011; Thammanu and Caihong 2014; Larpkerna et al. 2017). Nearly one fifth of Thailand's forest area is covered by deciduous forests (RFD 2019a). Consequently, they play a critical role in providing NTFPs to nearby communities.

Though they presently have high populations and are accessible to support local livelihoods, 26 plant species found in this study were listed on the IUCN Red List of Threatened Species (Table 3.6). Six species were listed as LC: *Chukrasia tabularis*, *Globba winitii*, VU: *Cycas siamensis* and NT species: *Dipterocarpus obtusifolius*, *Dipterocarpus tuberculatus*, and *Shorea obtusa*. Even though their numbers in the community forest were not low, their regional populations were decreasing according to the IUCN report. Moreover, *Dalbergia cultrata* was designated as NT as a result of having a low and decreasing population both in the community forest and region-wide. This suggests that protecting these species should be prioritized for conservation.

In addition, nine plant species had a population of 10 or less stems including critical species *Dalbergia oliveri* (EN). Further, *Cycas siamensis* (VU) is an ornamental plant species that has been over-exploited in Thailand due to increasing demand for it as garden decoration. Thus, it is urgent for a strategic plan of forest management to maintain plant species and monitor NTFP utilization.

3.5.2. Utilization of NTFPs for Rural Livelihoods

Most households in the community relied on NTFPs for food, medicine, fuelwood, and fibers (Table 3.8). This was similar to the findings of previous studies that people in Thailand rely on NTFPs for their living in various ways (Jarernsuk et al. 2015; Larpkerna et al. 2017; Mianmit et al. 2017). The estimated value of NTFPs collected and utilized as cash income or for other subsistence during the study period was US $60,360. This highlights the role of NTFPs in supporting rural communities (ONEP 2004; Witchawutipong 2005; ITTO 2006).

Naturally, different NTFPs provided different levels of income. Mushrooms and wild fruits were the most valuable providing higher monetary value. Lower household income tended to obtain a higher income from NTFPs than higher household income (Table 3.9). This suggests that the economic status of a household influences the level of NTFP extraction and production. Therefore, the result of this study supports the proposition that NTFP utilization enables lower income households to improve their living condition, as shown in other studies (Blair and Olpadwala 1988; Babulo et al. 2008; Mulenga et al. 2011; Kar and Jacobson 2012; Sharma et al. 2015; Tugume et al. 2015).

This study also revealed that it has a very diverse composition of species, especially of those used for medicine and foods (Appendix I). However, this research found that NTFP usage levels of various plant species were very low when compared to the available NTFPs (Table 3.8) indicating a greater potential for NTFP utilization for increased improvement of livelihoods.

NTFPs provided food, served other daily functions, and generated sales income which accounted for 6.35% of the total annual household income. Compared to the other case studies in developing countries (Angelsen et al. 2014), this percentage of income was low. In Zambia, it was estimated to be 34% of the total household income (Saifullah et al. 2018), in Northern Benin it was 39% (Heubach et al. 2011) and in Myanmar, it accounted for 44.37% of the total household income (Liu and Moe 2016). A study in Malaysia reported that NTFPs contributed 24% of total annual household incomes (Mulenga et al. 2011). This research showed that a potential for greater income exists and enhancing forest biodiversity to provide a larger and ongoing supply of NTFPs is needed. In addition, the Gini coefficient reflected a high level of inequality between income quartiles and households. This suggests that the benefit sharing of NTFPs varied disproportionally in the community.

This study also demonstrated the IRR values were positive for 10, 20 and 30 year periods of CFM (Table 3.11). As such, investment in the Ban Mae Chiang Rai Lum Community Forest could be a good investment opportunity with a sufficient rate of return to justify ongoing support of CFM.

3.5.3. Implementation of CFM in the Community Forest

People were generally engaged and involved in the implementation of CFM at the ‘high’ level (Table 3.12).

However, involvement in decision making, a key process in managing local forest resources, was limited. This study suggests that Ban Mae Chiang Rai Lum should prioritize participation, especially in decision making, and identify it as fundamentally important for successful forest management (Pragtong 1995; Blair and Olpadwala 1988).

Community involvement in monitoring and evaluation of CFM was at the ‘moderate’ level which indicated that it could be an obstacle to more collaborative forest management. A lack of thorough monitoring and evaluation of the utilization of NTFPs could have a detrimental impact on species diversity and the ongoing supply of varied and numerous NTFPs.

3.5.4. Link between NTFP Income and Participation in CFM

NTFP income levels had an impact on and were related to the participation in CFM (Table 3.13). As such, more NTFP income can lead to increased participation. This is in line with previous studies that supported the proposition that higher dependency on the forest induced higher participation and, as a result, more effective management (Lise 2000; Jumbe and Angelsen 2007; Coulibaly-Linganiab et al. 2011; Tugume et al. 2015; Soe and Youn 2019b).

Concomitantly, higher engagement and improved CFM could create income opportunities and improve living condition. This study also showed that people had a ‘very high’ level of participation in the enforcement of regulations, in perception and understanding, regarding benefit sharing (Table 3.12). Thus, enforced regulations, ‘very high’ knowledge regarding CFM and the sharing of benefits can facilitate successful community forest management.

According to Ostrom et al. (1994) and Ostrom (2005), a forest system can be influenced by three factors: natural attributes, economic attributes, and rules. If there is CFM in a community, it denotes that formal rules governing forest management exist and forestry activities conform to those rules. With proper rules and design, forestry activities could have a positive impact on rural livelihoods and community forest improvement.

3.5.5. Socio-economic and CFM Factors that Influence NTFP Dependence

Dedendency from NTFPs was influenced by various socio-economic and CFM factors. As reflected in Table 3.14, a female, people aged 60 years or less, married people, someone who cites their principal occupation as a ‘farmer’, and people who participated in CFM at a ‘very high’ level were characteristics of those that relied more heavily on NTFPs. This means that people with those characteristics are more likely to rely on NTFPs and be more NTFP dependent.

Non-timber forest product dependence was higher for females which was an unexpected finding. This may be a result of the male being primarily responsible for the family income and general support of the household and seeking more income from outside the community to fulfill these responsibilities. Recently the situation in Thailand in which off-farm employment and expanded income opportunities have become available lends support for this explanation. This is partly because the 2018 government wage policy increased the minimum wage to 300 baht per day. Generally, workers can find jobs in their villages or in nearby cities. Higher wages as a laborer could exceed and be more cost-efficient than income derived from NTFPs, especially when considering the high labor opportunity costs of NTFP collection (Table 3.8). Consequently, males would depend less on NTFPs.

Several studies have shown that, with more experience doing so, older people extracted NTFPs more (Heubach et al. 2011; Mutenje et al. 2011). This study's findings, however, were contrary as people 60 years old or less were found to be positively related to extraction of NTFPs to a higher degree than those even older. This could be because of a combination of factors unique to the study area, including a limitation on physical strength concomitant with advanced age as exacerbated by the time, distance and other practical difficulties presented by the harvesting locations. In general, more abundant forest resources are often located far away from human settlements (Thapa and Chapman 2010; Hoang et al. 2011; Chen et al. 2014; Asanok et al. 2017; Martínez-Camilo et al. 2018). Thus, those who are a somewhat younger are more suitable to endure what could be the taxing undertaking of NTFP extraction (Cavendish 2000; Suleiman et al. 2017; Mugido and Shackleton 2019; Talukdar et al. 2021). In addition, those over 60 years of age can receive a government pension minimizing the need for NTFP income.

Married people had higher dependency on NTFPs which was expected as it is consistent with previous studies finding that most married people partake in collection activities as a family responsibility (Opaluwa et al. 2011; Balama et al. 2016). This may be related to the number of members in 'married' households which, by nature, include more people and a higher need and demand for resources. Having a higher number of household members means a greater need for subsistence and need to augment income (Babulo et al. 2008; Coulibaly-Linganiab et al. 2011; Aminu et al. 2017; Suleiman et al. 2017). Thus, married people were more likely to extract NTFPs.

'Laborers' and 'merchants' have been found to utilize NTFPs to a higher degree than other occupations (Mutenje et al. 2011). Such a result was expected. However, in this study, those who cited their principal occupation as a 'farmer' were positively related to NTFP dependence to a higher degree than other occupations.

By definition, the livelihood of a farmer is directly related to agriculture and its inherent vagaries and uncertainties. It is exceptionally difficult to have and retain the resources and the ability to react to uncontrollable and unexpected events, or shocks that can reduce agricultural productivity, food security and income (Hertel and Rosch 2010; McDowell and Hess 2012). Ackowledging the risks of relying solely on farming and extracting NTFPs as a contingency plan for subsistence would support the result in the instant study that farmers are more dependent on NTFPs. In Dash et al. (2016) and Nguyen et al. (2020), it was found that agricultural income levels affected NTFP utilization behavior; households that produce high agricultural economic value show decreasing NTFP income. The security of higher income lessens the need to prepare for unexpected events and the resulting reduction in agricultural productivity.

In addition, people with a 'very high' level of CFM participation were more likely to extract NTFPs. Other studies have demonstrated that engagement in forest management was closely related to NTFP utilization; people acknowledge and are motivated by the fact that conserving forest resources enhances the benefits provided by those resources (Lise 2000; Jumbe and Angelsen 2007; Coulibaly-Lingani et al. 2011; Tugume 2015; Soe and Youn 2019b). This study also implied that people are more involved in forest management because they need more return from the benefits of the forest. Thus, enhanced benefits from NTFPs would incentivize greater participation in CFM.

3.5.6. Socio-economic and CFM Factors that Influence Participation in CFM

Different socio-economics and levels of NTFP dependence also affected CFM participation (Table 3.15). The logit model illustrates that land ownership and NTFP dependence were key factors that influence participation, while most other factors did not significantly affect participation in forest management activites.

People who owned land shows a positive relationship to CFM participation. This indicated that landowners are more likely to be engaged in community forest activities than those who were landless. It was similarly observed in several studies that security of tenure contributed to increased participation in public programs (Zhang and Owiredu 2007; Musyoki et al. 2016; Zang, et al. 2019). A possible explanation could be that people who owned land are more concerned about the benefits of the community forest to their agriculture lands. This idea that farmers are more closely involved is consistent with the findings of Lestari et al. (2015) and Apipoonyanon et al. (2020). Thus, land tenure status influences participation in CFM (Atmiş et al. 2006).

Similarly, the predicted model showed that people who were NTFP dependent were likely to participate more in CFM. This finding is consistent with previous studies' conclusions that obtaining income from NTFPs plays an important role related to participation in forest management (McNeely 1988; Chou 2018; Harbia et al. 2018). It indicates that the utilization of NTFPs under CFM could increase participation and result in community forest development. This is useful information for CFM strategies and policies to move toward sustainable forest management.

3.6. Summary and Conclusions

Forest resources are a salient and critical issue requiring ongoing attention by the Thai government. Community forest management (CFM) is a practice used to, among other things, resolve land use issues and regulate the extraction and use of non-timber forest product (NTFPs). Managing as a community forest can not only enhance the livelihoods of the local people but also improve their socio-economic condition. This research was conducted at the Ban Mae Chiang Rai Lum community forest which is located in Pa Mae Phrik National Forest Reserve in Thailand's northern province of Lampang. Species biodiversity data of the forest's total area of 3,925 ha was collected using a systematic sampling method, and twenty-five 40 × 40 m (0.16 ha) survey plots were established in the community forest. Interviews of 159 household heads and/or other household representatives were conducted using a designed questionnaire. The questionnaire focused on information regarding the households' NTFP utilization habits and engagement in CFM processes.

A forest survey was conducted which found that there were 197 plant species, 144 genera, and 62 families in the community forest. Of these, 160 plant species were classified as having medicinal uses, 89 were used as food, 37 as extractives, 32 for firewood, and 12 for fibers. This study also revealed that unmonitored over-exploitation of NTFPs may negatively impact forest biodiversity. As surveyed, 68.55% of households depended on NTFPs. The value of the harvested NTFPs was 6.35% of the total annual community income.

A positive correlation between NTFP income and participation in CFM suggests that utilization of NTFPs combined with people's participation could create income opportunities and promote CFM. It has been demonstrated that greater NTFP income leads to a higher rate of participation in CFM and the utilization of NTFPs contributes to more successful management of the community forest.

In addition, income earned from NTFPs and participation in CFM were directly related to the socio-economics and CFM factors of identifiable groups in this community. Females, those 60 years of age or less, married people, respondents who listed their principal occupation as 'farmer', and those engaged in CFM at a 'very high' level were more dependent on NTFPs. Similarly, landowners and those who were NTFP dependent were more likely to participate in CFM.

Based on the results of this study, the following insights into improving forest management were developed to improve living conditions and conserve the biodiversity of the Ban Mae Chiang Rai Community Forest:

1) The community forest's remarkable diversity plays an important role in providing NTFPs. NTFPs from the Ban Mae Chiang Rai Community Forest supported livelihoods through CFM. However, 26 species were listed on the IUCN Red List of Threatened Species, 7 of which were listed as experiencing decreasing populations. In addition, a very low number of stems of 9 additional species were recorded in the community forest. The status of these NTFP-providing species is concerning because of these numbers. The continued extraction of NTFPs should be strictly monitored and the harvesting of threatened or species at risk of becoming threatened should not go unchecked.

2) NTFP utilization in the community forest tends to improve the economic condition of lower income households. However, this study demonstrates that the level of NTFP utilization was relatively low when compared with the diversity of species available in the community forest. Hence, efforts to promote NTFP

utilization of lower income households, especially those in the lowest income quartiles (Q1), should be enhanced. In addition, there should be a focus on ensuring a more equitable sharing of the benefits in the community.

3) Receiving NTFP income leads to contribution to the management of community forest. Contribution leads to effectiveness which can create opportunities for more income. A relationship exists between NTFP dependence and participation for the benefit of all; this is a relationship that should be demonstrated and used to incentivize participation.

4) Participation in CFM and income derived from NTFPs are related to socio-economic and CFM factors. To promote overall participation, there should be a focus on those with the characteristics positively related to participation and the derivation of income. Furthermore, strategies to prompt the involvement in monitoring and evaluation activities as well as in the decision-making process should be developed.

Chapter 4. Conclusion and Recommendations

This study encompassed forest biodiversity, the utilization of NTFPs and CFM in the Ban Mae Chiang Rai Lum Community Forest, located in Pa Mae Prik National Forest Reserve, Lampang Province in northern Thailand. In all, 0.1 % of the total forest inventory was sampled. Twenty-five sample plots were established in its area of 3,925 ha. The systematic sampling method was used to determine the potential forest biodiversity in the community forest. Household surveys were submitted to, and completed by 159 households to gather information about their utilization of NTFPs and engagement in CFM in order to explore ways to improve rural livelihoods and conserve biodiversity.

4.1. The Influence of Environmental Factors on Species Composition and Distribution

The inventory of the area of forest in this study yielded a total of 18,567 trees encompassing 197 species, 144 genera and 60 plant families; 129 tree, 99 sapling and 141 seedling species, respectively, were identified. The average Shannon-Wiener index value of mature trees was 2.49 ± 0.28. As NTFPs, 160 of these species have been classified as having medicinal uses, 89 are used as food, 37 as extractives, 32 as fuelwoods, and 12 species as fibers.

An analysis of the available forest resources in the community forest indicates that more plant species than those regularly harvested are available to provide additional livelihood support, subsistence and income. Furthermore, the balanced distributions of trees by DBH and height classes can reflect increasing tree density, growth rate, and successful regeneration of species in the community forest under CFM and are positive indicators of future natural regeneration of tree species in the forests. This all suggests the effectiveness of local management of forest resources and a safeguarding of biodiversity in the forest ecosystems.

CFM was implemented in 2008 partially in response to historical and protracted encroachment, illegal logging and the damage being done to the viability of the forest. Collaborative management efforts between the government and local residents became more focused on forest plantation, fire protection and patrol, and the utilization of check dams. As the result, the community forest was restored, and the damage caused by years of deforestation and degradation was mitigated. It is evident that the community forest sector, through successful management, can play a significant role in biodiversity conservation.

The CCA reflected that the most significant influences on species composition and distribution were distance to communities, distance to streams, elevation, soil moisture, and organic matter. Although tree species in deciduous forests can shift to higher elevation with more favorable conditions or adapt to drought areas, water availability, soil moisture, and the limits of organic matter can still restrict tree species diversity.

Several factors such as the forest′s distance to communities were reported to have a negative impact on utilization meaning, of course, that the closer a community was to the available NTFPs, the more those NTFPs were accessed. The CCA revealed that utilization of various species was correlated with their proximity to communities, especially tree species used for fuelwood and construction.

In forest ecosystems, there is relationship between biodiversity and ecosystem functions. For instance, naturally occurring mushrooms are often closely correlated to mycorrhizal fungi of dipterocarp tree species roots in deciduous forests that provide various edible mushrooms to support local people as food in remote areas. In Thailand, dipterocarp species are often used as firewood in households. In this study, the CCA also found that people utilized various species located closer to the community for fuelwood and construction. These facts can demonstrate the impact of CFM on biodiversity and on the ongoing supply of NTFPs; it is important and useful information for sustainable community forest management.

Therefore, management practices to reduce drought conditions such as building check dams and fire prevention should be implemented in the community forest to facilitate species biodiversity and foster an ongoing supply of NTFPs. Furthermore, NTFP utilization should be monitored to support sustainable use of the forest resources.

4.2. Non-Timber Forest Product Utilization under Community Forest Management

The Ban Mae Chiang Rai Community Forest provides a diverse array of NTFPs which support livelihoods. Information regarding the utilization of NTFPs from the Ban Mae Chiang Rai Lum Community Forest showed that most households surveyed (109 of 159) depended on NTFPs for subsistence and income. Mushrooms, wild fruits, and small animals were the primary NTFPs depended upon by these households. The economic value of the harvested NTFPs was estimated to be approximately US $60,360 which accounted for 6.35% of the total annual income of the community. Lower income households were likely to obtain a greater relative income from NTFPs than higher income households.

When comparing actual NTFP utilization with the amount and diversity that is available, increased dependence on a wider variety and larger amount of NTFPs is possible. Untapped potential for greater income exists and safeguarding and enhancing forest biodiversity is needed to provide an expanded and ongoing supply of NTFPs. To tap into this potential, focus should be placed on groups with a weaker connection to extraction of NTFPs such as low-income families, in order to promote higher utilization of NTFPs and supplement income.

The efficacy of the NTFPs and the support they provide are strengthened through CFM. The internal rate of return of NTFP collection over 10, 20, and 30 year periods of CFM was positive. This demonstrated investment in the Ban Mae Chiang Rai Lum Community Forest could be a good investment opportunity and should be continued in order to support the ongoing implementation of CFM. Continued implementation of CFM can safeguard the resources while continuing to provide subsistence and income to local residents.

However, CFM is a good long-term investment only if the underlying ‘capital’, the forest itself, is preserved. There is concern about the population and long-term viability of numerous NTFP-providing plant species. The IUCN Red List of Threatened Species lists and classifies 26 species found in this forest, and others were listed as species with a likely decreasing population. In addition, some species in the forest were found to have minimal populations of 10 or less stems. Thus, it is clear that the viability of an ongoing supply of all species, especially those of a status mandating attention in the IUCN Red List, must be weighed against need and extraction.

In this study, NTFP income is positively correlated with participation in CFM; greater NTFP income results in a higher rate of participation and engagement in CFM which lead to more effective CFM. More effective CFM provides increased NTFP income prompting more participation and so on. This relationship should be demonstrated and emphasized to encourage more widespread participation in CFM as it would be beneficial to everyone.

People participated at a ‘high’ level in CFM activities aimed at conserving forest resources and their concomitant benefits. Increased engagement leads to more effective CFM, successful forest management, and improved livelihoods and biodiversity conservation. However, participation in monitoring and evaluation activities was limited. Failure to emphasize in these areas can have a negative impact on tree species and threaten the ongoing supply of NTFPs. Therefore, involvement in monitoring and evaluation activities and in decision-making processes should be developed, as interest in engagement in these areas was lacking.

In addition, relationships between certain socio-demographic groups, the levels and manner of their participation in CFM as well as the income they derive from NTFPs can be identified. For instance, people who owned land and were dependent NTFPs tend to participate more in CFM. Understanding these links and focusing policies and efforts on groups with clearly identifiable relationships can improve overall participation and benefit.

4.3. Challenges and Lessons Learned

This research was conducted in cooperation with the RFD and the people in Ban Mae Mae Chiang Rai Lum. The findings provided knowledge that the RFD can use to improve people’s quality of life and protect forest biodiversity through sustainable CFM.

The primary lesson is that the new management practices learned from this study can be used to plan for CFM to help meet basic social and economic needs and provide environmental benefits. To date, CFM in Thailand has been limited because only information on the current status of forest biodiversity and the utilization of NTFPs in community forests has been available. The findings of this study can change the trend of forest management practices in Ban Mae Chiang Rai Lum Community Forest.

Secondly, the research would enhance collaboration between staff of the RFD and the people in the community. In this study, community leaders and local people worked together in conducting the field survey and questionnaire survey. Collaboration could lead to progress and success of CFM because the relationship between RFD staff and local people is important in promoting CFM in the community. This research can provide new knowledge and ideas to local people on how to develop CFM and provide opportunities to participate and make effective decisions regarding their forest resources under the guidance and supervision of the staff.

Finally, this study can be a model for CFM driven sustainable forest management and applicable to more than 17,400 villages throughout the country. Even though CFM has been implemented in Thailand for three decades, many people still doubt its effectiveness. This study can highlight and exemplify how forest management can improve livelihoods and biodiversity conservation in Thailand through CFM.

4.4. Limitations and Further Research

This study is limited in that only the plant species used as NTFPs in the subject region were considered. The other NTFPs such as mushrooms, honey, and insects were not included in the analysis. Thus, future study should investigate NTFP utilization of these NTFPs in the community forest to obtain additional data to support more effective forest management.

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Appendices

Appendix I List of plant families and the nature of NTFPs in Ban Mae Chiang Rai Lum Community Forest, Lampang, Thailand

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
1	มะก่องข้าว (ma kong khao)	*Abutilon hirtum*	MALVACEAE	US		✓				o
2	มะกล่ำต้น (ma klam ton)	*Adenanthera pavonina*	FABACEAE	T	✓	✓				o
3	ผักสาบ (phak sap)	*Adenia viridiflora*	PASSIFLORACEAE	C	✓					o
4	เฟิร์นก้านดำ (foen kan dam)	*Adiantum sp.*	PARKERIACEAE	F						N/A
5	ส้มลม (som lom)	*Aganonerion polymorphum*	APOCYNACEAE	C	✓	✓				o
6	พรหมตีนสูง (phrom tin sung)	*Aglaonema simplex*	ARACEAE	H		✓				o
7	ปรู๋ (pru)	*Alangium salviifolium*	CORNACEAE	S/ST	✓	✓				o
8	พฤกษ์ (phruek)	*Albizia lebbeck*	FABACEAE	T	✓	✓				o
9	กางขี้มอด (kang khi mot)	*Albizia odoratissima*	FABACEAE	T		✓				o
10	บุกอีรอกเขา (buk i rok khao)	*Amorphophallus brevispathus*	ARACEAE	H	✓	✓				o
11	เครือไส้ตัน (khruea sai tan)	*Amphineurion marginatum*	APOCYNACEAE	C		✓				o
12	ตะเคียนหนู (ta khian nu)	*Anogeissus acuminata*	COMBRETACEAE	T		✓			✓	o
13	เม่าสร้อย (mao soi)	*Antidesma acidum*	PHYLLANTHACEAE	S/ST	✓	✓				o
14	เม่าไข่ปลา (mao khai pla)	*Antidesma ghaesembilla*	PHYLLANTHACEAE	S/T	✓	✓	✓			o
15	มะเม่าสาย (ma mao sai)	*Antidesma sootepense*	PHYLLANTHACEAE	S/ST	✓	✓				o
16	กรมเขา (krom khao)	*Aporosa nigricans*	PHYLLANTHACEAE	T		✓				o
17	เหมือดโลด (mueat lot)	*Aporosa villosa*	PHYLLANTHACEAE	S/ST		✓	✓		✓	o
18	หุน (hun)	*Argyreia osyrensis*	CONVOLVULACEAE	ScanS/C		✓				o
19	คะนองม้า (ka nong ma)	*Aristolochia sp.*	ARISTOLOCHIACEAE	C						N/A
20	มะนาวผี (ma nao phi)	*Atalantia monophylla*	RUTACEAE	ST		✓				o
21	สะเดา (sa dao)	*Azadirachta indica*	MELIACEAE	T	✓	✓			✓	LC
22	จิกสวน (chik suan)	*Barringtonia racemosa*	LECYTHIDACEAE	S/ST	✓	✓				o

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
23	ปอเจี๋ยน (po chian)	*Bauhinia bracteata*	FABACEAE	C						o
24	เสี้ยวเครือ (siao khruea)	*Bauhinia glauca*	FABACEAE	C		✓				LC
25	กระไดลิง (kra dai ling)	*Bauhinia scandens*	FABACEAE	C/ScanS		✓		✓		o
26	ย่านางแดง (ya nang daeng)	*Bauhinia strychnifolia*	FABACEAE	C	✓	✓		✓		o
27	ฝีหมอบ (fi mop)	*Beilschmiedia roxburghiana*	LAURACEAE	T		✓				o
28	เลียงมัน (liang man)	*Berrya cordifolia*	MALVACEAE	T						o
29	เติม (toem)	*Bischofia javanica*	PHYLLANTHACEAE	T	✓	✓			✓	o
30	งิ้วป่า (ngio pa)	*Bombax anceps*	MALVACEAE	T	✓	✓	✓	✓		o
31	เต็งหนาม (teng nam)	*Bridelia retusa*	PHYLLANTHACEAE	T	✓	✓			✓	o
32	มะม่วงนก (ma muang nok)	*Buchanania glabra*	ANACARDIACEAE	T						o
33	มะม่วงหัวแมงวัน (ma muang maeng wan)	*Buchanania lanzan*	ANACARDIACEAE	T	✓	✓	✓		✓	o
34	หนามหัน (nam han)	*Caesalpinia godefroyana*	FABACEAE	C		✓				o
35	กล้วยไม้ดิน (kluai mai din)	*Calanthe sp.*	ORCHIDACEAE	TerO						N/A
36	มะกอกเกลื้อน (ma kok kluean)	*Canarium subulatum*	BURSERACEAE	T	✓	✓			✓	o
37	หนามมะเค็ด (nam ma khet)	*Canthium parvifolium*	RUBIACEAE	S	✓					o
38	กรวยป่า (kruai pa)	*Casearia grewiifolia*	SALICACEAE	T		✓				LC
39	ราชพฤกษ์ (rat cha phruek)	*Cassia fistula*	FABACEAE	T		✓	✓			LC
40	กัลปพฤกษ์ (kan la pa phruek)	*Cassia javanica*	FABACEAE	T		✓	✓		✓	o
41	หนามแท่ง (nam taeng)	*Catunaregum tomentosa*	RUBIACEAE	S/ST		✓	✓			o
42	สาบเสือ (sap suea)	*Chromolaena odorata*	ASTERACEAE	ExH		✓				o
43	สาบหมา (sap ma)	*Chromolaena sp.*	ASTERACEAE	ExH						o
44	ยมหิน (yom hin)	*Chukrasia tabularis*	MELIACEAE	T	✓	✓				LC#
45	นกนอน (nok non)	*Cleistanthus hirsutulus*	PHYLLANTHACEAE	S/ST						o
46	ปอมื่น (po muen)	*Colona floribunda*	MALVACEAE	T				✓		o
47	ผักปลาบ (phak plap)	*Commelina benghalensis*	COMMELINACEAE	H	✓	✓				o
48	ติ้วเกลี้ยง (tio kliang)	*Cratoxylum cochinchinense*	HYPERICACEAE	T	✓	✓	✓		✓	LC
49	ติ้วขน (tio kliang)	*Cratoxylum formosum*	HYPERICACEAE	T			✓		✓	LC

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
50	พลับพลึง (phlap phlueng)	*Crinum asiaticum*	AMARYLLIDACEAE	H		✓				o
51	เปล้าแพะ (plao phae)	*Croton hutchinsonianus*	EUPHORBIACEAE	S/ST		✓	✓			o
52	เปล้าใหญ่ (plao yai)	*Croton roxburghii*	EUPHORBIACEAE	S/ST	✓	✓	✓		✓	o
53	กระเจียว (kra chiao)	*Curcuma sessilis*	ZINGIBERACEAE	H	✓	✓				o
54	ปรงเหลี่ยม (prong liam)	*Cycas siamensis*	CYCADACEAE	S	✓	✓				VU#
55	หญ้าแห้วหมู (ya haeo mu)	*Cyperus rotundus*	CYPERACEAE	H		✓				LC
56	กก (kok)	*Cyperus sp.*	CYPERACEAE	H		✓		✓		N/A
57	กระพี้นางนวล (kra phi nang nuan)	*Dalbergia*	FABACEAE	T		✓				LC
58	กระพี้เขาควาย (kra phi khao khwai)	*Dalbergia cultrata*	FABACEAE	T		✓				NT#
59	เก็ดแดง (ket daeng)	*Dalbergia dongnaiensis*	FABACEAE	T						o
60	กระพี้เครือ (kra phi khruea)	*Dalbergia foliacea*	FABACEAE	C		✓				o
61	ดู่แด้ง (du daeng)	*Dalbergia glomeriflora*	FABACEAE	T						o
62	ชิงชัน (ching chan)	*Dalbergia oliveri*	FABACEAE	T		✓				EN
63	เครือแมด (khruea maet)	*Dalbergia volubilis*	FABACEAE	C						o
64	กระดูกอึ่ง (kra duk ueng)	*Dendrolobium triangulare*	FABACEAE	S	✓	✓				o
65	หางไหลเผือก (hang lai phueak)	*Derris sp.*	FABACEAE	S		✓				N/A
66	ส้านใหญ่ (san yai)	*Dillenia obovata*	DILLENIACEAE	T	✓	✓				o
67	กลอย (kloi)	*Dioscorea hispida*	DIOSCOREACEAE	HC	✓	✓				o
68	กลิ้งกลางดง (kling klang dong)	*Dioscorea sp.*	DIOSCOREACEAE	HC						N/A
69	ตะโกพนม (tako pha nom)	*Diospyros castanea*	EBENACEAE	ST	✓	✓			✓	o
70	ตับเต่าต้น (tap tao ton)	*Diospyros ehretioides*	EBENACEAE	T		✓		✓	✓	o
71	มะเกลือ (ma kluea)	*Diospyros mollis*	EBENACEAE	T	✓	✓			✓	o
72	ถ่านไฟผี (tan fai phi)	*Diospyros montana*	EBENACEAE	T	✓	✓			✓	o
73	ยางเหียง (yang hiang)	*Dipterocarpus obtusifolius*	DIPTEROCARPACEAE	T	✓	✓	✓		✓	NT#
74	ยางพลวง (yang phluang)	*Dipterocarpus tuberculatus*	DIPTEROCARPACEAE	T		✓			✓	NT#
75	ขางครั่ง (khang khrang)	*Dunbaria bella*	FABACEAE	C	✓	✓				o
76	พีพ่าย (phi phai)	*Elaeocarpus lanceifolius*	ELAEOCARPACEAE	T		✓				o

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
77	โด่ไม่รู้ล้ม (do mai ru lom)	*Elephantopus scaber*	ASTERACEAE	H		✓				o
78	คำรอก (kham rok)	*Ellipanthus tomentosus*	CONNARACEAE	ST		✓	✓			o
79	โมกเถา (mok thao)	*Epigynum auritum*	APOCYNACEAE	C						o
80	น้ำนมราชสีห์ (nam nom rat cha si)	*Euphorbia hirta*	EUPHORBIACEAE	H	✓	✓				o
81	แคหางค่าง (khae hang khang)	*Fernandoa adenophylla*	BIGNONIACEAE	T	✓	✓				o
82	ผักเลียบ (phak liap)	*Ficus infectoria*	MORACEAE	T	✓	✓				o
83	ตะขบป่า (ta khop pa)	*Flacourtia indica*	SALICACEAE	ST	✓	✓				o
84	ตะขบไทย (ta khop thai)	*Flacourtia rukam*	SALICACEAE	T	✓	✓			✓	o
85	คำมอกน้อย (kham mok noi)	*Gardenia obtusifolia*	RUBIACEAE	S/ST		✓				o
86	คำมอกหลวง (kham mok luang)	*Gardenia sootepensis*	RUBIACEAE	ST		✓				o
87	ตะคร้ำ (ta khram)	*Garuga pinnata*	BURSERACEAE	T	✓	✓			✓	o
88	หว่านสาวหลง (wan sao long)	*Globba winitii*	ZINGIBERACEAE	H		✓				LC#
89	รักใหญ่ (rak yai)	*Gluta usitata*	ANACARDIACEAE	T		✓	✓		✓	o
90	ปอแก่นเทา (po kaen thao)	*Grewia eriocarpa*	MALVACEAE	T	✓	✓		✓		o
91	ขว้าว (khawao)	*Haldina cordifolia*	RUBIACEAE	T		✓				o
92	คนทา (khon tha)	*Harrisonia perforata*	SIMAROUBACEAE	ScanS		✓			✓	o
93	ปอขี้ตุ่น (po khi tun)	*Helicteres angustifolia*	MALVACEAE	S		✓				o
94	ปอเต่าไห้ (po tao hai)	*Helicteres hirsuta*	MALVACEAE	S		✓				o
95	ปอบิด (po bit)	*Helicteres isora*	STERCULIACEAE	S		✓				o
96	โมกหลวง (mok luang)	*Holarrhena pubescens*	APOCYNACEAE	S/T		✓				LC
97	กระเชา (kra chao)	*Holoptelea integrifolia*	ULMACEAE	T		✓				o
98	ส้มกบ (som kop)	*Hymenodictyon orixense*	RUBIACEAE	T	✓	✓				o
99	คราม (khram)	*Indigofera sp.*	FABACEAE	S		✓			✓	N/A
100	กระบก (kra bok)	*Irvingia malayana*	IRVINGIACEAE	T	✓	✓	✓			LC
101	เข็มขาว (khem khao)	*Ixora sp.*	RUBIACEAE	S		✓				N/A
102	สบู่ดำ (sa bu dam)	*Jatropha curcas*	EUPHORBIACEAE	ExS/ST		✓				o
103	กระดูกไก่ขาว (kra duk kai)	*Justicia sp.*	ACANTHACEAE	S/ST		✓				N/A

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
104	เปราะหอม (pro hom)	*Kaempferia galanga*	ZINGIBERACEAE	H	✓	✓				o
105	ตะแบกเปลือกบาง (ta baek plueak bang)	*Lagerstroemia duperreana*	LYTHRACEAE	T		✓	✓			o
106	อินทนิลบก (in tha nin bok)	*Lagerstroemia macrocarpa*	LYTHRACEAE	T		✓				o
107	อินทนิลน้ำ (in tha nin nam)	*Lagerstroemia speciosa*	LYTHRACEAE	T		✓				o
108	เสลาดำ (sa lao dam)	*Lagerstroemia villosa*	LYTHRACEAE	T						o
109	กุ๊ก (kuk)	*Lannea coromandelica*	ANACARDIACEAE	T	✓	✓				o
110	ก่อนก (ko nok)	*Lithocarpus polystachyus*	FAGACEAE	T	✓		✓			o
111	หมีเหม็น (mi men)	*Litsea glutinosa*	LAURACEAE	T	✓	✓	✓		✓	o
112	สองสลึง (song sa lueng)	*Lophopetalum duperreanum*	CELASTRACEAE	T	✓	✓				o
113	ลิเภา (li phao)	*Lygodium sp.*	LYGODIACEAE	CF	✓	✓		✓		N/A
114	มะซาง (ma sang)	*Madhuca dongnaiensis*	SAPOTACEAE	T						o
115	สารภี (sa ra phi)	*Mammea siamensis*	CALOPHYLLACEAE	T	✓	✓			✓	o
116	มะม่วงป่า (ma muang pa)	*Mangifera caloneura*	ANACARDIACEAE	T	✓	✓	✓		✓	o
117	แคหัวหมู (khae hua mu)	*Markhamia stipulata*	BIGNONIACEAE	T	✓	✓				LC
118	ผักหวานป่า (phak wan pa)	*Melientha suavis*	OPILIACEAE	S/ST	✓	✓				o
119	พลองเหมือด (phlong mueat)	*Memecylon edule*	MELASTOMATACEAE	S/ST	✓	✓			✓	o
120	หัสคุณ (hat sa khun)	*Micromelum minutum*	RUTACEAE	S/ST	✓	✓				o
121	กระพี้จั่น (kra phi chan)	*Millettia brandisiana*	FABACEAE	T		✓	✓	✓		o
122	สาธร (sa thon)	*Millettia leucantha*	FABACEAE	T						o
123	ขะเจ๊าะ (kha cho)	*Millettia leucantha*	FABACEAE	T						o
124	ขะเจ๊าะเครือ (kha cho khruea)	*Millettia sp.*	FABACEAE	C						N/A
125	ปีบ (pip)	*Millingtonia hortensis*	BIGNONIACEAE	T		✓				o
126	กระทุ่มเนิน (kra thum noen)	*Mitragyna rotundifolia*	RUBIACEAE	T		✓	✓			o
127	ยอป่า (yo pa)	*Morinda coreia*	RUBIACEAE	ST	✓	✓			✓	o
128	ยอเถื่อน (yo thuean)	*Morinda elliptica*	RUBIACEAE	ST	✓	✓			✓	o
129	กินกุ้งน้อย (kin kung noi)	*Murdannia nudiflora*	COMMELINACEAE	H	✓	✓				o
130	โปร่งฟ้า (prong fa)	*Murraya siamensis*	RUTACEAE	S		✓				o

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
131	ช้างน้าว (chang nao)	*Ochna integerrima*	OCHNACEAE	S/ST		✓				o
132	จมูกปลาหลด (cha muk pla lot)	*Oxystelma esculentum*	APOCYNACEAE	C	✓	✓				LC
133	ตดหมูตดหมา (tot mu tot ma)	*Paederia linearis*	RUBIACEAE	C	✓	✓				o
134	เครือเขามวก (khruea khao muak)	*Parameria laevigata*	APOCYNACEAE	C	✓	✓		✓		o
135	มะพอก (ma phok)	*Parinari anamense*	CHRYSOBALANACEAE	T	✓	✓	✓		✓	o
136	ข้าวสารป่า (khao san pa)	*Pavetta tomentosa*	RUBIACEAE	S		✓				o
137	เป้ง (peng)	*Phoenix humilis*	ARECACEAE	P						o
138	ลูกใต้ใบ (luk tai bai)	*Phyllanthus amarus*	PHYLLANTHACEAE	H		✓				o
139	มะขามป้อม (ma kham pom)	*Phyllanthus emblica*	PHYLLANTHACEAE	ST/T	✓	✓	✓		✓	o
140	หญ้าใต้ใบ (ya tai bai)	*Phyllanthus urinaria*	PHYLLANTHACEAE	H		✓				o
141	เกล็ดปลาช่อน (klet pla chon)	*Phyllodium pulchellum*	FABACEAE	S	✓	✓				LC
142	กะเจียน (ka chian)	*Polyalthia cerasoides*	ANNONACEAE	ST	✓	✓				o
143	นมน้อย (nom noi)	*Polyalthia evecta*	ANNONACEAE	T	✓	✓				o
144	ยางดง (yang dong)	*Polyalthia obtusa*	ANNONACEAE	T						o
145	ต้องแล่ง (tong laeng)	*Polyalthia sp.*	ANNONACEAE	T						N/A
146	ยางโอน (yang on)	*Polyalthia viridis*	ANNONACEAE	T						o
147	หัวค้อนกระแต (hua khon kra tae)	*Premna herbacea*	LAMIACEAE	US		✓				o
148	หมูหมัน (mu man)	*Premna latifolia*	LABITAE	T						o
149	ประดู่ (pra du)	*Pterocarpus macrocarpus*	FABACEAE	T		✓			✓	o
150	ก่อแพะ (ko phae)	*Quercus kerrii*	FAGACEAE	T	✓		✓			o
151	สะแล่งหอมไก๋ (sa laeng hom kai)	*Rothmannia sootepensis*	RUBIACEAE	ST						o
152	หมักม่อ (mak mo)	*Rothmannia wittii*	RUBIACEAE	S	✓	✓				o
153	มะขามเครือ (ma kham khruea)	*Roureopsis stenopetala*	CONNARACEAE	C		✓				o
154	กระท้อน (kra thon)	*Sandolicum koetjape*	MELIACEAE	T	✓	✓				o
155	ตะคร้อ (ta khro)	*Schleichera oleosa*	SAPINDACEAE	T	✓	✓				o
156	ตีนตุ๊กแก (tin tuk kae)	*Selaginella amblyphylla*	SELAGINELLACEAE	F						o
157	รักขี้หมู (rak khi mu)	*Semecarpus albescens*	ANACARDIACEAE	T						o

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
158	แสมสาร (sa mae san)	*Senna garrettiana*	FABACEAE	T	✓	✓	✓			o
159	เต็ง (teng)	*Shorea obtusa*	DIPTEROCARPACEAE	T		✓	✓		✓	NT#
160	รัง (rang)	*Shorea siamensis*	DIPTEROCARPACEAE	T		✓	✓		✓	LC
161	มะค่าแต้ (ma kha tae)	*Sindora siamensis*	FABACEAE	T	✓	✓	✓		✓	LC
162	มะดูก (ma duk)	*Siphonodon celastrineus*	CELASTRACEAE	T	✓	✓				LC
163	ตะคร้อหนาม (ta khro nam)	*Sisyrolepis muricata*	SAPINDACEAE	S/T	✓					o
164	เขืองใบลาย (khueang bai lai)	*Smilax biumbellata*	SMILACACEAE	C						o
165	แตงเถื่อน (taeng thuean)	*Solena sp.*	APOCYNACEAE	C						o
166	มะกอกป่า (ma kok pa)	*Spondias bipinnata*	ANACARDIACEAE	T	✓	✓				o
167	หนอนตายหยาก (non tai yak)	*Stemona tuberosa*	STEMONACEAE	HC		✓				o
168	แคทราย (khae sai)	*Stereospermum neuranthum*	BIGNONIACEAE	T	✓					o
169	ข่อย (khoi)	*Streblus asper*	MORACEAE	T	✓	✓	✓			o
170	เถาประสงค์ (thao pra song)	*Streptocaulon juventas*	APOCYNACEAE	C	✓	✓				o
171	แสลงใจ (sa laeng cha)	*Strycnos nux-vomica*	LOGANIACEAE	ST		✓				o
172	หว้า (wa)	*Syzygium cumini*	MYRTACEAE	T	✓	✓	✓			o
173	สัก (sak)	*Tectona grandis*	LAMIACEAE	T		✓				o
174	รกฟ้า (rok fa)	*Terminalia alata*	COMBRETACEAE	T		✓			✓	o
175	สมอพิเภก (samo phi phek)	*Terminalia bellirica*	COMBRETACEAE	T	✓	✓			✓	o
176	สมอไทย (sa mo thai)	*Terminalia chebula*	COMBRETACEAE	T	✓	✓				o
177	ตะแบกเลือด (ta baek lueat)	*Terminalia mucronata*	COMBRETACEAE	T		✓				o
178	ปอลมปม (po lom pom)	*Thespesia lampas*	MALVACEAE	S	✓	✓				o
179	หูปากกา (hu pak ka)	*Thunbergia fragrans*	ACANTHACEAE	C		✓				o
180	ไผ่รวก (phai ruak)	*Thyrsostachys siamensis*	POACEAE	B	✓	✓				o
181	โลดทะนง (lot tha nong)	*Trigonostemon reidioides*	EUPHORBIACEAE	S		✓				o
182	ก้าว (kao)	*Tristaniopsis burmanica*	MYRTACEAE	ST		✓				o
183	บุก (buk)	*Typhonium sp.*	ARACEAE	H						N/A
184	อุตพิต (ut ta phit)	*Typhonium trilobatum*	ARACEAE	H	✓	✓				o

No.	Thai name	Scientific name	Family	Habit	Utilization					Status
					EP	MP	FW	FI	EX	
185	หางหมาจอก (hang ma chok)	*Uraria crinita*	FABACEAE	US		✓				o
186	หญ้าหางอ้น (ya hang on)	*Uraria lagopodioides*	FABACEAE	US		✓				o
187	นมแมวป่า (nom maeo pa)	*Uvaria hamiltonii*	ANNONACEAE	C		✓				o
188	ผ่าสิ้ยน (pha sian)	*Vitex canescens*	LAMIACEAE	T		✓				o
189	สวอง (sa wong)	*Vitex limonifolia*	LAMIACEAE	T	✓	✓				o
190	กาสามปีก (ka sam pik)	*Vitex peduncularis*	LAMIACEAE	T	✓	✓				o
191	ตีนนก (tin nok)	*Vitex pinnata*	LAMIACEAE	T	✓	✓				LC
192	กัดลิ้น (kat lin)	*Walsura trichostemon*	MELIACEAE	T	✓	✓				o
193	แข้งกวาง (khaeng kwang)	*Wendlandia tinctoria*	RUBIACEAE	ST		✓				LC
194	โมกมัน (mok man)	*Wrightia arborea*	APOCYNACEAE	ST	✓	✓		✓	✓	o
195	แดง (daeng)	*Xylia xylocarpa*	FABACEAE	T	✓	✓	✓			o
196	เล็บเหยี่ยว (lep yiao)	*Zizyphus oenoplia*	RHAMNACEAE	C	✓	✓				o
197	ขี้หนอน (khi non)	*Zollingeria dongnaiensis*	SAPINDACEAE	T	✓	✓	✓			DD

Utilization: EP = edible plant, MP = medicinal plant, FW = fuelwood, FI = fiber, EX = extractive

Habit: B = bamboo, C = climber, CF = climbing fern, ExH = exotic herb, ExS = exotic shrub, F = fern, H = herb, HC = herbaceous climber, P = palm, S = shrub, ST = shrubby tree, ScanS = saprophytic shrub, T = tree, TerO = terrestial orchid, US = undershrub

Status (IUCN Red List of Threatened): DD = data deficient, LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered, o = not listed on the IUCN Red List of Threatened, N/A = not applicable, # = population trend decreasing

Appendix II List of 129 mature tree species (DBH ≥ 4.5 cm) in Ban Mae Chiang Rai Lum Community Forest

No.	Species	Abbreviation	No.	Species	Abbreviation
1	*Adenanthera pavonina*	ADPA	66	*Irvingia malayana*	IRMA
2	*Adenia viridiflora*	ADVI	67	*Lagerstroemia duperreana*	LADU
3	*Alangium salviifolium*	ALSA	68	*Lagerstroemia macrocarpa*	LAMA
4	*Albizia lebbeck*	ALLE	69	*Lagerstroemia speciosa*	LASP
5	*Albizia odoratissima*	ALOD	70	*Lagerstroemia villosa*	LAVI
6	*Anogeissus acuminata*	ANACG	71	*Lannea coromandelica*	LACO
7	*Antidesma acidum*	ANACR	72	*Lithocarpus polystachyus*	LIPO
8	*Antidesma ghaesembilla*	ANGH	73	*Litsea glutinosa*	LIGL
9	*Antidesma sootepense*	ANSO	74	*Lophopetalum duperreanum*	LODU
10	*Aporosa nigricans*	APNI	75	*Madhuca dongnaiensis*	MADO
11	*Aporosa villosa*	APVI	76	*Mammea siamensis*	MASI
12	*Atalantia monophylla*	ATMO	77	*Mangifera caloneura*	MACA
13	*Azadirachta indica*	AZIN	78	*Markhamia stipulata*	MAST
14	*Barringtonia racemosa*	BARA	79	*Melientha suavis*	MESU
15	*Bauhinia bracteata*	BABR	80	*Memecylon edule*	MEED
16	*Bauhinia glauca*	BAGL	81	*Millettia brandisiana*	MIBR
17	*Bauhinia scandens*	BASC	82	*Millettia leucantha*	MILEK
18	*Beilschmiedia roxburghiana*	BERO	83	*Millettia leucantha*	MILEP
19	*Berrya cordifolia*	BECO	84	*Millettia* spp.	MISP
20	*Bischofia javanica*	BIJA	85	*Millingtonia hortensis*	MIHO
21	*Bombax anceps*	BOAN	86	*Mitragyna rotundifolia*	MIRO
22	*Bridelia retusa*	BRRE	87	*Morinda coreia*	MOCO
23	*Buchanania glabra*	BUGL	88	*Morinda elliptica*	MOEL
24	*Buchanania lanzan*	BULA	89	*Ochna integerrima*	OCIN
25	*Caesalpinia godefroyana*	CAGO	90	*Pavetta tomentosa*	PATO
26	*Canarium subulatum*	CASU	91	*Phyllanthus emblica*	PHEM
27	*Canthium parvifolium*	CAPA	92	*Polyalthia cerasoides*	POCE
28	*Casearia grewiifolia*	CAGR	93	*Polyalthia obtusa*	POOB
29	*Cassia fistula*	CAFI	94	*Polyalthia viridis*	POVI
30	*Cassia javanica*	CAJA	95	*Premna latifolia*	PRLA
31	*Catunaregum tomentosa*	CATO	96	*Pterocarpus macrocarpus*	PTMA
32	*Chukrasia tabularis*	CHTA	97	*Quercus kerrii*	QUKE
33	*Cleistanthus hirsutulus*	CLHI	98	*Rothmannia sootepensis*	ROSO
34	*Cratoxylum cochinchinense*	CRCO	99	*Rothmannia wittii*	ROWI
35	*Cratoxylum formosum*	CRFO	100	*Sandolicum koetjape*	SAKO
36	*Croton hutchinsonianus*	CRHU	101	*Schleichera oleosa*	SCOL
37	*Dalbergia cana*	DACA	102	*Semecarpus albescens*	SEAL
38	*Dalbergia cultrata*	DACU	103	*Senna garrettiana*	SEGA
39	*Dalbergia dongnaiensis*	DADO	104	*Shorea obtusa*	SHOB
40	*Dalbergia foliacea*	DAFO	105	*Shorea siamensis*	SHSI
41	*Dalbergia glomeriflora*	DAGL	106	*Sindora siamensis*	SISI
42	*Dalbergia oliveri*	DAOL	107	*Siphonodon celastrineus*	SICE
43	*Dalbergia volubilis*	DAVO	108	*Sisyrolepis muricata*	SIMU
44	*Dillenia obovata*	DIOBH	109	*Spondias pinnata*	SPPI
45	*Diospyros castanea*	DICA	110	*Stereospermum neuranthum*	STNE
46	*Diospyros ehretioides*	DIEH	111	*Streblus asper*	STAS
47	*Diospyros mollis*	DIMOG	112	*Strycnos nux-vomica*	STNU
48	*Diospyros montana*	DIMOR	113	*Syzygium cumini*	SYCU
49	*Dipterocarpus obtusifolius*	DIOBT	114	*Tectona grandis*	TEGR
50	*Dipterocarpus tuberculatus*	DITU	115	*Terminalia alata*	TEAL
51	*Elaeocarpus lanceifolius*	ELLA	116	*Terminalia bellirica*	TEBE
52	*Ellipanthus tomentosus*	ELTO	117	*Terminalia chebula*	TECH
53	*Fernandoa adenophylla*	FEAD	118	*Terminalia mucronata*	TEMU
54	*Ficus infectoria*	FIIN	119	*Tristaniopsis burmanica*	TRBU
55	*Flacourtia indica*	FLIN	120	*Vitex canescens*	VICA
56	*Flacourtia rukam*	FLRU	121	*Vitex limonifolia*	VILI
57	*Gardenia obtusifolia*	GAOB	122	*Vitex peduncularis*	VIPE
58	*Gardenia sootepensis*	GASO	123	*Vitex pinnata*	VIPI
59	*Garuga pinnata*	GAPI	124	*Walsura trichostemon*	WATR
60	*Gluta usitata*	GLUS	125	*Wendlandia tinctoria*	WETI
61	*Grewia eriocarpa*	GRER	126	*Wrightia arborea*	WRAR
62	*Haldina cordifolia*	HACO	127	*Xylia xylocarpa*	XYXY
63	*Harrisonia perforata*	HAPE	128	*Zizyphus oenoplia*	ZIOE
64	*Holoptelea integrifolia*	HOIN	129	*Zollingeria dongnaiensis*	ZODO
65	*Hymenodictyon orixense*	HYOR			

Appendix III Plant biodiversity assessment data sheet

Plant Biodiversity Data Sheet (Trees)

Date: ☐☐☐ Number of plot: ☐☐ - ☐☐

Forest type : _______________ Elevation: _______________

Slope : _______________ Aspect : _______________

G.P.S (40×40m):

1) E/N 2) E/N

3) E/N 4) E/N

Disturbance:
- ☐ Forest fire
- ☐ Insects or disease
- ☐ Landslide
- ☐ Logging
- ☐ Invasive species
- ☐ Storms
- ☐ Livestock grazing
- ☐ Other (specify): _______________________________________

Description of plot :____

____

No.	Species name	DBH (cm)	Height (m)	Other notes

Plant Biodiversity Data Sheet (Saplings and Seedlings)

No.	Species name	Number of Saplings/Seedlings	Other notes

Profile and Crown Cover (10 × 40 m)

No.	Species name	Position (m)		DBH (cm)	1st Branch height (m)	Total height (m)	Crown width (m)				Other notes
		X	Y				N	S	E	W	

Appendix IV Household utilization of non-timber forest products questionnaire

Household Questionnaire

Name of Respondent:________________________Respondent No.:_________
House No.:_________Telephone: _______________Date:_________________

Part I: Socio-demographic characteristics

1. Gender

O male O female

2. Age……………………………….years old

3. Marital status

O single O married

O divorced O widower/widow

4. Role in the family

O head of the family O member

5. Education

O uneducated O elementary school

O high school O vocational/technical

O bachelor’s degree O postgraduate or higher

6. Number of family members ………………….people

O younger than 15 years old ………………….people

O 15 – 60 years old ………………….people

O older than 60 years old ………………….people

7. Primary occupation

O farmer O laborer O merchant

O government official/company employee

O NTFP collector O other (please specify)………………….…

8. Household income

O primary occupation ………………baht/year

O secondary occupation ………………baht/year

O plant and livestock production for own consumption in household

………………baht/year

Total………………baht/year

9. Household land tenure ……………….rai

10. Land rented by household to earn living ……………….rai

Part II: NTFPs of community forest utilized

1. Has your household harvested any NTFPs from the community forest during the past year?

O Yes O No

2. The number of times NTFPs harvested ……………...times/year

3. The average length of time to harvest NTFPs ………………hours/time

4. The average distance traveled to harvest NTFPs ………..……..km/time

5. NTFPs harvested in the past year

O harvested and utilized O did not harvest but utilized O did not harvest or utilize

List of NTFPs	Month of Harvesting	Frequency (times)	Time Spent (hours)	Quantity (unit)	Utilization		Price/Unit (baht)	Transportation Cost (baht)
					Household (√)	Sold (√)		

Part III: People's participation in community forest management

People's Participation	Level of Participation				
	Very high (5)	High (4)	Moderate (3)	Low (2)	Very low (1)
▪ Decision-making					
1) Attending community meetings on issues related to community forest					
2) Attending community forest planning meetings					
3) Participating in determining community forest regulations					
4) Participating in determining authority, structure and the management of the community forest committee					
5) Determining community forest development activities					
▪ Implementation					
1) Forest plantation and rehabilitation					
2) Forest protection and weeding					
3) Forest patrol to prevent deforestation and forest degradation					
4) Prevention and control of forest fires					
5) Forest survey and alignment					
6) Building check dam					
7) Participation in forest culture/tradition					
8) Donating money or equipment to improve community forest management					
▪ Co-benefits					
1) Economic benefits					
2) Social benefits					
3) Environmental benefits					
▪ Monitoring and Evaluation					
1) Following up on the performance of community forest management					
2) Presenting problems and obstacles to community forest management					
3) Finding solutions to community forest management problems					

Part IV: Efficiency of the enforcement of community forest regulations

Community Forest Regulations	Level of Acceptance and Compliance				
	Very high (5)	High (4)	Moderate (3)	Low (2)	Very low (1)
1) You know the community forest regulations					
2) You agree with the community forest regulations					
3) You think the community forest regulations are appropriate and efficiently enforceable					
4) Compliance with the community forest regulations:					
4.1 Do not cut trees in the community forest without permission from the community forest committee. Five new growing trees must be planted for each tree removed					
4.2 Do not take possession, utilize, construct or expand the agricultural area in a community forest					
4.3 Do not dig or remove soil, stones, or sand without permission					
4.4 Hunting in the community forest is not allowed					
4.5 Do not set fires in the community forest					
4.6 Collecting NTFPs to sell as an occupation, such as charcoal or hunting wild animals is not allowed. Also, using cars or other vehicles to transport collected NTFPs is prohibited					
4.7 Strangers are not allowed to harvest NTFPs from the community forest.					
4.8 You think the community forest regulations should be improved					

Part V: Perception and understanding of community forest management process

Perception and Understanding	Answer		Remarks
	Yes	No	
1) Community forest is a forest from which local people can profit from the forest products to meet their basic needs. They also have the right to make decisions to manage their own forest resources for sustainable forest management.			Sukwong (2004)
2) Community forest is the decentralization of forest resources management which transfers forest management power from the government to a local community			Pragtong (2000)
3) Utilization, community rules, community organizations and support from external organizations are key factors for the success of the management of the community forest			Pragtong (1995)
4) Community forests provide only environmental benefits but also social and economic benefits, particularly increasing income and benefits for poor people			RECOFTC (2007); Blair and Olpadwala (1987)
5) Local communities shall have the right to participate in the management, maintenance, preservation and exploitation of natural resources and environment including the biological diversity in a balanced sustainable manner			Royal Thai Government (2017)
6) Under the concept of sustainable forest resources management, the average annual forest products to be harvested must not exceed the forest productivity capacity for the benefit of the present and future generations			ITTO (1992); FAO (1993)
7) People can access NTFPs in natural forest resources for subsistence, but commercial harvesting of NTFPs needs permission from the government			Royal Thai Government (1987)

Perception and Understanding	Answer		Remarks
	Yes	No	
8) There is no Community Forestry Bill in Thailand. The implementation of forest management is designated under related forest laws. Therefore, community forest regulations should be consistent with the forest laws.			RFD (2014)
9) Setting forest fires for harvesting NTFPs may affect soil fertility, change forest composition and decrease ecosystem productivity			Wanthongchai et al. (2011)
10) Benefit sharing from using genetic resources of community forests should be fair and equitable			CBD (1992)

Part VI: Benefit sharing in community forest

Benefit Sharing	Level of Satisfaction				
	Very high (5)	High (4)	Mode rate (3)	Low (2)	Very low (1)
1) You have a right to access and utilize forest resources from the community forest					
2) All households equally and fairly share the benefits of the community forest					
3) Stakeholders fairly share and equitably benefit from the community forest					
4) Benefit sharing between the government and the community is fair and equitable					
5) Your level of satisfaction from sharing the benefits of the community forest					

Part VII: Comments/recommendations to improve community forest management

Please identify what you believe are the important roles of the government to improve community forest management (Please choose three of the following in order of priority, with ‘1’ being the most important).

………Establish specific community forest laws

………Provide rights for the community to participate in community forest management

………Improve and amend the relevant forest laws as they relate to conservation and utilization

………Support budgets and equipment for community forest operation

………Enhance the community’s knowledge and skill through capacity building activities for the development of community forest

………Promote and support community enterprises in order to generate and distribute income from NTFPs to community

………Other (please specify)…………………………………………………………………

Additional comments/recommendations for community forest development…………

……………………………………………………………………………………………

국문초록

산림자원은 지역주민의 생계에 중요하며 공동체숲의 효과적인 관리는 그러한 산림자원의 지속능력에 필수적이다. 본 연구는 지역 주민의 생계 수준을 높이고 생물다양성을 보전하기 위한 수단으로서 공동체숲 관리의 기능과 역할을 자세히 살펴보고자 수행되었다. 연구대상지는 태국 북부 Pa Mae Phrik 국가산림보호구에 위치한 Ban Mae Chiang Rai Lum 공동체숲이다.

연구의 목적을 달성하기 위하여 먼저 연구대상지의 수종(樹種) 구성과 수목의 분포, 생물다양성에 영향을 미치는 환경인자들을 분석하였다. 뿐만 아니라 지역주민들이 비목재임산물(NTFP: Non-timber Forest Products)을 활용하는 수준과 관련한 행동을 공동체숲 관리(CFM: Community Forest Management)의 효과성 차원에서 조사하였다. 또한 지역주민들의 NTFP 의존도에 영향을 미치는 사회인구학적 요인들과 CFM 참여와의 상관관계를 구명하였다.

표본조사의 경우 계통추출법을 기반으로 총 3,925 ha의 산림에 대한 식생조사를 수행하였다. 이를 위해 0.16 ha 크기의 25개 조사 표본점을 연구대상지 내 서로 다른 임분 세 곳에 설치하였다. 이 표본점들의 조사 결과는 각 임분의 생물다양성을 추정과 임분 간 생물다양성 차이에 기여하는 환경인자들을 밝히는데 활용되었다. 한편, 가구별 NTFP 활용도와 CFM 참여에 대한 행동 및 태도를 분석하기 위하여 공동체숲 내 주민에 대한 설문조사를 수행하였다.

연구대상지에는 197개 종, 144개 속, 62개 과가 분포하는 것으로 조사되어 식물 종다양성이 매우 높은 것으로 나타났다. Canonical Correspondence Analysis 분석 결과, 수목의 종 구성과 분포에 유의미하게 영향을 준 환경인자로 해발고도, 물줄기와의 거리, 토양습도, 유기물, 공동체와의 거리가 선정되었다. 이러한 결과는 보(洑)의 설치와 같은 가뭄 저감 수단의 이행, 산불로부터의 보호, 공동체의 임산물 사용에 대한 모니

터링이 생물다양성의 보전과 공동체 숲의 산림자원에 대한 지속가능한 이용에 기여할 수 있다는 것을 의미한다.

연구대상지에는 의학적으로 이용가능한 160종, 식량으로 이용가능한 89개 종, 추출물을 활용하는 37개 종, 화목으로 이용되는 32개 종, 섬유로 이용되는 12개종 등의 NTFP가 풍부하게 분포해 있었다. 그러나 과다한 NTFP 이용은 생물다양성에 부정적 영향을 미쳐온 것으로 나타났다. 일례로, 위에서 언급된 종 중 26종이 IUCN 적색목록에 등재되어 있었다. 가구 조사 결과에 따르면 전체 가구 중 68.55%에 해당하는 가구가 공동체 숲이 생산하는 NTFP에 의존하고 있었다. 수확된 NTFP의 가치는 공동체 소득의 6.35%를 차지하고 있었으며 NTFP 소득과 CFM간의 상관관계 분석 결과 CFM과 NTFP활용을 결합하는 것이 보전을 위한 노력을 진행하는 동시에 보다 지역주민에게 큰 소득 기회를 제공할 수 있음을 시사하였다.

또한 공동체의 NTFP 소득과 CFM에의 참여 정도는 가구별 사회인구학적 특징과 직접적으로 연결되어 있다. 60세 미만의 여성, 기혼자, 주된 직업을 '농부'로 기재한 가구, 그리고 '매우 높은' 수준에서 CFM에 참여한 사람들은 NTFP에 더 많이 의존했다. 이와 유사하게 토지 소유하거나 NTFP 소득에 의존할수록 CFM에 참여할 가능성이 더 높았다. 그러나 의사결정을 비롯한 모니터링 및 평가 활동에 대한 참여는 비교적 제한적이었다.

NTFP의 이용과 산림관리활동에 관한 지역주민의 행동과 태도에 대한 통찰력을 갖는 것은 연구대상지를 포함한 전국의 지속가능한 공통체숲 관리에 유용한 지식을 제공한다. 일반적으로 이 지식은 성공적인 산림관리, 이익의 극대화, 생물다양성의 보존에 영향을 미친다. 특히, NTFP의 수확은 통제되지 않은채로 이뤄지지 말아야 하며, 과도하게 수확할 경우 위협을 받거나 위협을 받을 가능성이 있는 종에 대한 특별한 관리가 필요하다. 또한, 저소득 가구의 참여율을 높이고, 편익을 보다 공평하게 분배하며, 지역사회 참여를 유도하려는 노력은 NTFP의 지속가능한 공급을 유

지하고, 지역사회 산림의 다양성을 보호하기 위해 중요하므로 우선시 되어야 한다.

키워드: 생물다양성, 이용, 비목재임산물, 공동체숲, 생계, 태국 북부
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