SYSTEMATIC CONSERVATION PLANNING IN THAILAND

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Systematic Conservation Planning in Thailand

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Abstract

Thailand supports a variety of tropical ecosystems and biodiversity. The country has approximately 12,050 species of plants, which account for 8% of estimated plant species found globally. However, the forest cover of Thailand is under threats: habitat degradation, illegal logging, shifting cultivation and human settlement are the main causes of the reduction in forest area. As a result, rates of biodiversity loss have been high for some decades. The most effective tool to conserve biodiversity is the designation of protected areas (PA). The effective and most scientifically robust approach for designing networks of reserve systems is systematic conservation planning, which is designed to identify conservation priorities on the basis of analysing spatial patterns in species distributions and associated threats. The designation of PAs of Thailand were initially based on expert consultations selecting the areas that are suitable for conserving forest resources, not systematically selected. Consequently, the PA management was based on individual management plans for each PA. The previous work has also identified that no previous attempt has been made to apply the principles and methods of systematic conservation planning. Additionally, tree species have been neglected in previous analyses of the coverage of PAs in Thailand. These indicate the importance of this research.

This research deals with the identification of complementary areas to the PA network in Thailand, specifically to support the conservation of tree species. This work also contributes to the improvement of conservation planning and PA network design in Thailand using the application of systematic conservation planning techniques. The research focused specifically on 783 target tree species, belonging to 92 families in Thailand, consisting of four groups of tree species that are respectively threatened with extinction, dominate the different forest types in Thailand, are of particular economic importance, and are important to *in situ* genetic conservation. A GIS-based multi-criteria analysis (MCA) approach was used to support systematic conservation

planning. ILWIS, a GIS support software was used to identify priority conservation areas in this research.

With currently data available, the crucial finding from this research is that the priority areas that should be considered for establishment of new PAs, or to expand existing PAs comprise: (1) areas next to current PAs in the Southern region and (2) areas near to Cambodia in Trat province in the Eastern region, areas near to PAs on Ko Chang and Ko Kut islands in the Gulf of Thailand. It also confirmed that the systematic conservation planning approach should be introduced to PA managers or planners. This should be possible because it is transparent and beneficial, and utilizes user-friendly spatial software to generate spatial data and easy to understand output maps.

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Abbreviations

AHP	Analytic Hierarchy Process
AHPs	ASEAN heritage parks
APFORGEN	Asia Pacific Forest Genetic Resources Programme
AUC	Area Under Curve
ASEAN	Association of Southeast Asian Nations
BKF	Forest Herbarium, Bangkok
CBD	Convention on Biological Diversity
CE	Critically endangered
CI	Comparison index
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMIP5	Coupled Model Intercomparison Project Phase 5
DEM	Digital Elevation Model
DNP	Department of National Parks, Wildlife and Plant Conservation
ECN	Elephant Conservation Network Foundation
EN	Endangered
ENM	Ecological niche modelling
EnvPs	Environmental parameters
EOO	Extent of occurrence
FGR	Forest genetic resources
GAP	Gap analysis projects
GARP	Genetic algorithm for rule-set prediction
GBIF	Global Biodiversity Information Facility
GCM	Global climate model
GIS	Geographic information system
GISTDA	Geo-Informatics and Space Technology Development Agency
GSPC	Global Strategy for Plant Conservation
ILWIS	Integrated Land and Water Information System
IPAs	Important Plant Areas
IUCN	International Union for Conservation of Nature
JSR	Joint Research Centre

MCA	Multi-criteria analysis
MCP	Minimum convex polygon
MODIS	Moderate Resolution Imaging Spectroradiometer
NGOs	Non-governmental organizations
NP	National park
NT	Near threatened
PA	Protected area
PARDO	Protected Area Rehabilitation and Development Office
PCA	Principal Components Analysis
RCP	Representative Concentration Pathway
RFD	Royal Forest Department
ROC	Receiver operating characteristic
SDM	Species distribution modelling
SEDAC	Socioeconomic Data and Applications Center
VU	Vulnerable
WCS	Wildlife Conservation Society
WS	Wildlife sanctuary
WWF	World Wide Fund for Nature

Author's declaration

I confirm that this thesis is my own work, including the development of thesis idea, data collection, analyses and interpretations with the following exceptions of the approaches and software used in the thesis below.

1. The approach of systematic conservation planning for designing protected area networks in Thailand followed the approach described by Margules and Pressey (2000).

2. **Chapter 3**: Gap analysis was conducted following *Scenario* B of the gap analysis method described by Rodrigues et al. (2003).

3. **Chapter 4**: Maxent version 3.3.3k used for modelling species distribution was downloaded from http://www.cs.princeton.edu/~schapire/Maxent/ (Phillips et al. 2006; Phillips and Dudík 2008).

4. **Chapter 5**: The multi-criteria analysis (MCA) method modified from the approach described by Regan et al. (2007). Also, ILWIS, a MCA support programme used for generating conservation priority areas was downloaded from http://52north.org/downloads/ilwis/ilwis-3-08-04/ilwis-3-08-04-zip/n52-ilwis-v3-08-04 (Schouwenburg et al. 2007).

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Chapter 1: Introduction

1.1 Introduction

The IUCN (2011) defines a protected area (PA) as "a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". PAs are among the most important tools for conservation of biodiversity, performing many functions that are essential for delivering vital ecosystem services, recreation, research and education, as well as supporting the economy (IUCN 2011). PAs have been classified according to their management objectives into six categories, namely: Ia strict nature reserve; Ib wilderness area; II national park; III natural monument or feature; IV habitat/species management area; V protected landscape/seascape; and VI protected area with sustainable use of natural resources (Dudley 2008). PAs in 2014 number 200,000 worldwide, covering approximately: 14.6% of the terrestrial and inland water areas; and 2.8% of the coastal and marine areas (IUCN 2014). Target 11 of the strategic plan for biodiversity 2011-2020 aims to increase the effective management of conservation areas by 2020, including: increasing protected terrestrial and inland water areas to 17% of the global area; and increasing the coastal and marine protected areas to 10% of the global area (CBD 2010).

Thailand is one of the biodiversity hotspots of Southeast Asia (Middleton 2003), situated in the centre of Southeast Asia covering 513,115 km^2 (GISTDA 2012a). The country is geographically divided into six regions, these are: North, Northeast, Central, West, East, and South (Figure 1.1) (GISTDA 2012a). Thailand began efforts to conserve biodiversity using a PA system by declaring a PA in order to conserve natural resources (especially forest) in 1959 by the Royal Forest Department (RFD) with the supervision of Dr. George C. Ruhle, an expert from the International Union for Conservation of Nature (IUCN). Khao Yai national park was the first Thai PA, declared in October 1959 under the responsibility of RFD. In 1961, forest covered 53% of the country's area, declining to 25% in 1998. Almost all remnant natural forests are in PAs (Santisuk et al. 2006). In 2002, the Department of National Parks, Wildlife and Plant Conservation (DNP) was instituted under the 2002 Ministry and

Department Reformation Royal Decree, and has been responsible for PAs of Thailand (The Prime Minister's Office, 2002). PAs, under the responsibility of DNP, consist of 123 national parks (covering 70,170 km^2, 13.70% of country area), 58 wildlife sanctuaries (covering 32,636 km^2, 7.10% of country area) comprising category II and Ia of IUCN respectively, and other types of PAs (1.28% of country area) including no-hunting areas, forest parks, arboretums, and botanical gardens. A map of four Thai natural PA types, including national parks, wildlife sanctuaries, no-hunting areas, and forest parks is shown in Figure 1.2. There are two PAs in Thailand that are recognised as being important on the global scale as natural world heritage sites, namely: the Thungyai-Huai Kha Khaeng wildlife sanctuaries; and the Dong Phayayen-Khao Yai forest complex. Moreover, Thailand also has four Association of Southeast Asian Nations (ASEAN) Heritage Parks (AHPs) consisting of three national parks and a forest complex.

Regarding PA management in Thailand, DNP (former RFD) initiated integrated PA management planning in 1999 using ecosystem-based management, by grouping all national parks and wildlife sanctuaries into 19 forest complexes (Figure C1 in Appendix C). Additionally, almost all national parks and wildlife sanctuaries, and some forest complexes have now developed master plans or management plans for their area management. Annual action plans for each PA are based on such plans. The PA management of Thailand seems to be performed by individual organisations. Nevertheless, some Thai PAs have indigenous people, who have lived in the PAs before they were designated; as a result, these indigenous people are hardly going to be excluded from the PAs. Therefore, there have been some attempts from both government agencies and non-governmental organisations (NGOs), to introduce co-management approaches to manage the PAs in Thailand. Co-management is cooperation in regulating a resource between key stakeholders such as government, NGOs and local communities to equally share responsibility of management of PAs and resources; to participate in making decisions; and to own natural resources (Nursey-Bray and Rist 2009). The joint management of PAs project is the obvious example, the project aims to promote participatory management of PAs in the target sites between government and local communities with the support of NGOs (SEUB 2009). Co-management in this project is specifically relevant to the cooperation in regulating a resource in PAs between the government and local communities who have lived in PAs, before they were designated. The local communities are allowed to live in PAs with some conditions. Community settlement areas and the environmentally-friendly agricultural practices are allowed in the areas, so long as no expansion occurs. This also allows local communities to participate in terms of exchanging information and public awareness. Additionally, some local people have participated in tourism, such as acting as local guides (SEUB 2009).

As mentioned earlier, the designation of PAs of Thailand has been based on expert consultations. The areas that experts considered suitable for biological diversity conservation (especially forests) have been proposed to be protected by law. These conservation areas have not been selected based on empirical data. Systematic conservation planning based on empirical evidence could support the identification of new potential biodiversity conservation areas that can fulfil the representativeness and persistence of biodiversity and organisms (Knight et al. 2006).

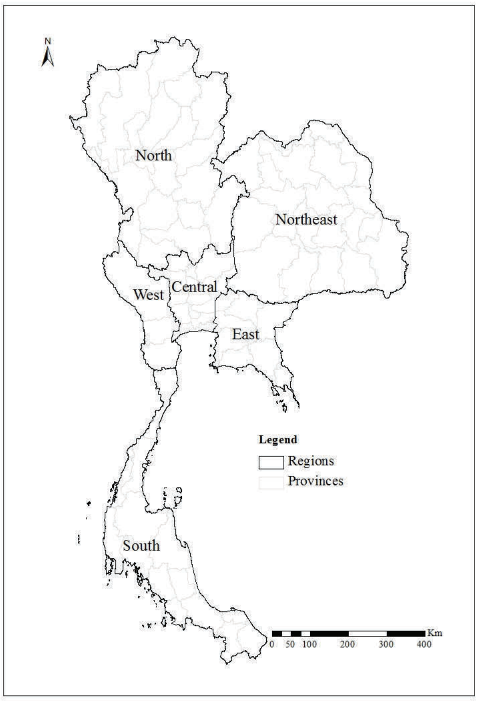


Figure 1.1 Regions of Thailand 2012 (created using data from GISTDA (2012a))

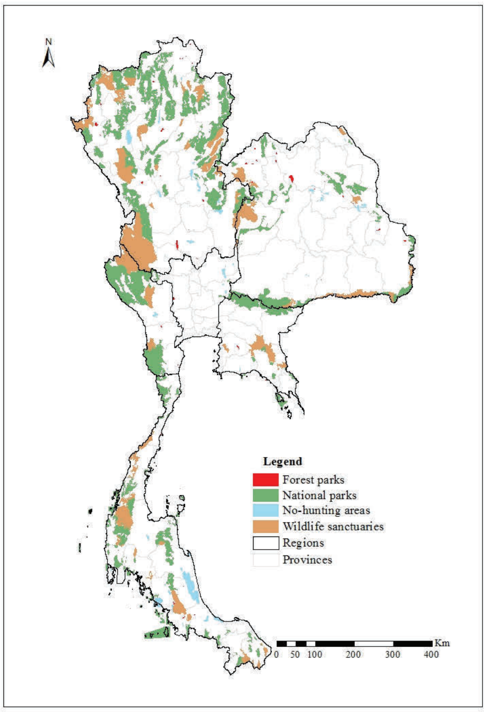


Figure 1.2 Protected areas of Thailand 2012 (created using data from DNP (2012))

1.2 Systematic conservation planning

A basic strategy to protect biodiversity is to create networks of ecologically representative nature reserves (Meir et al. 2004; Smith et al. 2006), and the reserves should achieve two objectives, namely representativeness and persistence (Margules and Pressey 2000). The two objectives for fulfilling a reserve's role can be achieved using a systematic conservation planning (SCP) approach (Margules and Pressey 2000), which is the most effective approach for designing networks of reserve systems (Meir et al. 2004; Smith et al. 2006). SCP has been defined as the process of locating and managing conservation areas with explicit objectives (Margules and Pressey 2000). SCP is a planning process designed to conserve important biodiversity, which measures existing protection levels and identifies new areas for potential conservation, a process referred to as a conservation assessment (Knight et al. 2006). This approach is considered to be efficient because it uses complementary-based approaches and predefined targets, ensuring that the process is objective (Pressey and Cowling 2001; Cowling et al. 2003; Smith et al. 2006). Analytical tools are used in systematic conservation planning, through the use of specialist computer programs, to identify representative networks and complementary conservation areas. Key advantages of systematic conservation planning techniques are that they are goal-directed, transparent and defensible (Wilson et al. 2005).

Owing to incomplete information on the distribution of species, SCP generally uses surrogates to represent targeted biodiversity networks such as assemblages of species (Clark and Slusher 2000) or forest types (Woinarski et al. 1996). When species are selected as surrogates, it is often the case that information on species distributions is incomplete. Predicted species distributions, that are derived from the modelled relationships between species distribution data and mapped environmental data, have been used in un-surveyed areas (Guisan and Zimmermann 2000). However, use of predicted species distributions can be limited by inaccuracies or biases in species survey data, errors in satellite image or aerial photograph interpretation, and by the assumptions used in developing the models (Fleishman et al. 2003).

Smith et al. (2006) mentioned that the uptake of SCP approaches has been limited by five factors: a perception that the software used to carry it out is complicated; a perceived need for intensive biodiversity distribution information; difficulties in setting conservation targets; low cost-effectiveness; and the fact that SCP may identify areas that are low priority for conservation according to the knowledge of practitioners. These authors provide evidence to counter these perceptions, based on the fact that there are now some freely available conservation planning software programs that are relatively easy to use. Biodiversity surrogates are species or taxonomic groups that can be used to represent wider biodiversity (Smith et al. 2006) such as: broad vegetation types; land cover types (Smith et al. 2006); well-known taxonomic groups; and species assemblages (Sarkar et al. 2006). In addition, low-cost satellite imagery is available that could be used in the planning process (Smith et al. 2006). SCP should therefore be a useful tool for PA designation in Thailand.

Margules and Pressey (2000) divided the process of systematic conservation planning into six stages as follows.

1. Compile data on the biodiversity of the planning region: by reviewing existing data and choose surrogates for biodiversity to provide an adequate coherent data set throughout the planning region.

2. Identify conservation goals for the planning region: by identifying quantitative conservation targets for three main aspects: (i) for surrogates such as species or forest types; (ii) for minimum size, connectivity or other design criteria; and (iii) for complementary areas.

3. Review existing conservation areas: by determining the scope of quantitative targets for representation and design that have been achieved by existing conservation areas; by identifying the imminent threats and threats to under-represented attributes; and by identifying the areas that are vital to secure the design targets.

4. Select additional conservation areas: by considering existing conservation areas as constraints for an extended system design; subsequently, by identifying preparatory

sets of new conservation areas for expanding the existing areas. Optional approaches for achieving this include reserve selection algorithms or decision-support software, to support the decision-making process by stakeholders.

5. Implement conservation actions: by making a decision on the most appropriate management interventions for each area, based on the resources available; and by identifying alternative areas in case the chosen areas are difficult to protect or are more degraded than anticipated.

6. Maintain the required values of conservation areas: by establishing conservation goals at the scale of individual PAs, which can recognize the particular values of the whole network; and by implementing management actions and zoning in and around each area to achieve the management goals. It is also important to monitor important indicators and revise management if required (Margules and Pressey 2000).

1.3 Plants and forests of Thailand

Around 1,900 genera and 12,050 species of vascular plants have been found in Thailand, of which 10% are endemic species (Chayamarit, 2014). Thai plant species richness stems from its location situated across three floristic regions, namely Indo-Himalaya, Indo-China and Malesia (Santisuk et al. 2006). Thailand published the first checklist of plant species at risk of extinction called ‘Thailand red data: plants’ in 2006 by using IUCN categories and criteria of threat. This checklist presents data on conservation status and identifies conservation priorities for 1,407 rare, endemic, vulnerable and endangered vascular plant species of which 211 species are trees. The checklist aims to provide a basic plant database for effective plant conservation in Thailand in order to improve the status of threatened species in the future and to help the country to implement a program on PAs in support of the Convention on Biological Diversity (CBD) (Santisuk et al. 2006).

In the past, forest types of Thailand were broadly classified and sometimes were classified without clear criteria. This led to confusion regarding the classification of different forest types or the vegetation communities of Thailand. The spatial vegetation types of Thailand 2000 map created by the DNP showed 7 natural vegetation communities and one manmade vegetation community. These are: (1) Dry dipterocarp forest; (2) Evergreen forest; (3) Mangrove forest; (4) Mixed deciduous forest; (5) Swamp forest; (6) Grassland; (7) Secondary growth forest; and (8) Forest plantation: the manmade vegetation community (Figure 1.3) (DNP 2000). However, Marod and Kutintara 2009 classified 11 forest types in Thailand, these are: (1) Mixed deciduous forest; (2) Deciduous dipterocarp forest; (3) Savannah forest; (4) Grassland; (5) Moist evergreen forest; (6) Dry evergreen forest; (7) Montane evergreen forest; (8) Pine forest; (9) Beach forest; (10) Mangrove forest; and (11) Swamp forest (Marod and Kutintara 2009). Because of this confusion, DNP in support of Santisuk (2006) then reclassified Thailand's forest/vegetation types. The approach used to identify vegetation types focused on the original vegetation communities, focusing on climax forests, and was based on floristic composition information. The factors influencing the distribution and composition of different forest types in Thailand are a combination of climatic, edaphic, elevation and biotic factors. Based on consideration of this information, forest types of Thailand have been classified into two major types, namely evergreen forest and deciduous forest, with numerous subtypes within these.

The following descriptions and table are based on those presented by Santisuk (2006) (see Table 1.1):

1. Evergreen forest is dominated by tree species that are green all year round, although some deciduous trees can be found in this forest type. Evergreen forest can be classified into 14 forest types.

2. Deciduous forest is dominated by tree species that shed their leaves seasonally (i.e. during the dry season). This type of forest is distributed throughout the country where there are 4 - 7 months of dry season, except in some Southern and Southeastern areas of Thailand. This main forest type can be found at elevations < 1,000 ms (with the exception of pine-deciduous dipterocarp forest). Deciduous forest can be classified into three forest types.

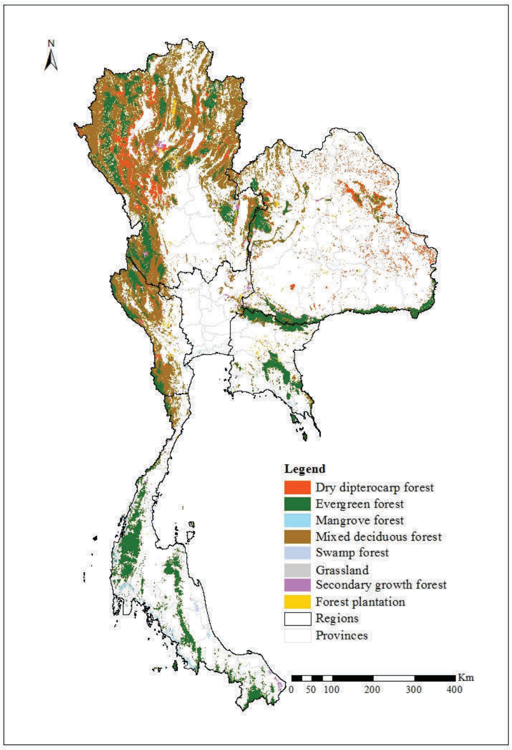


Figure 1.3 Vegetation types of Thailand 2000 (created using data from DNP (2000))

Table 1.1 Distribution and composition of the principal forest/vegetation types of Thailand (after Santisuk (2006))

Forest type	Distribution	Typical plant families or species
1. Evergreen forest (i) Tropical evergreen rain forest or Tropical rain forest	Lower Southern Thailand and some areas in Eastern Thailand where the rainfall rate is consistent and high, as well as soil moisture is high throughout the year.	- The tree species of crown cover mainly are Dipterocarp species such as: *Dipterocarpus kerrii*, *D. grandiflorus*, *D. gracilis*, *D. chartaceus*, *D. dyeri*, etc. - Other important plant families are: Fabaceae, Meliaceae, Lythraceae, Moraceae, Apocynaceae, Bombacaceae, Anacardiaceae, Sterculiaceae, Myrtaceae, Annonaceae, Anacardiaceae, Sapotaceae, Clisiaceae, Arecaceae, etc.
(ii) Seasonal rain forest, Semi-evergreen forest or	Moist plain area, piedmont, mountain slope and valleys where the elevations above	- The typical deciduous tree species are: *Tetrameles nudiflora* (Tetramelaceae), *Pterocymbium*

Forest type	Distribution	Typical plant families or species
Dry evergreen forest	mean sea level (MSL) are lower than 950 m in Central, Northern, Northeastern and Southeastern Thailand.	*tinctorium* (Malvaceae), *Gmelina arborea* (Lamiaceae), *Choerospondias axillaris* (Anacardiaceae), *Chukrasia tabularis* (Meliaceae), *Ailanthus triphysa* (Simaroubaceae), *Acrocarpus fraxinifolius* (Fabaceae), *Holoptelea integrifolia* (Ulmaceae), *Crypteronia paniculata* (Crypteroniaceae), *Arfeuillea arborescens* (Sapindaceae), *Lagerstroemia calyculata, L. cochinchinensis*, and *L. tomentosa* (Lythraceae). - Other typical tree families also found are: Dipterocarpaceae, Malvaceae, Irvingiaceae, Meliaceae, Moraceae, Euphorbiaceae, Cardiopteridaceae, Sapindaceae, Celastraceae, Combretaceae, Achariaceae, Leguminosae-Mimosoideae, Lauraceae, Magnoliaceae, Rhizophoraceae, Anacardiaceae, Melastomataceae, Bignoniaceae, Simaroubaceae, Annonaceae, Myristicaceae, etc. Remark: Seasonal rain forest found at the coast and on islands, includes trees in families with hard and thick leaves such as Sapotaceae, Melastomataceae, Rubiaceae, Rutaceae, Achariaceae and Moraceae.
(iii) Lower montane rain forest	Mountains where the elevations above MSL are from 1,000 - 1,900 m. Vegetation consists of temperate species, montane species, which need rather cold weather throughout the year, and lowland species. However, this forest is now found as	- The typical trees found are: *Castanopsis acuminatissima, C. armata, C. calathiformis* (Fagaceae), and etc. - Other trees families found are: Magnoliaceae, Theaceae, Lauraceae, Oleaceae, Burseraceae, Ulmaceae,

Forest type	Distribution	Typical plant families or species
	patches on mountains in Northern, Western, Eastern Thailand, sandstone mountains in Northeastern Thailand as well as on high mountains of Southern Thailand.	Sapindaceae, Anacardiaceae, Meliaceae, Clusiaceae, Elaeocarpaceae, Sapindaceae, Theaceae, Symplocaceae, Sapindaceae, Cornaceae, Actinidiaceae, Sabiaceae, Rosaceae, Proteaceae, Myrtaceae, Polygalaceae. - Some conifer species have also found such as: *Cephalotaxus mannii* (Cephalotaxaceae), *Podocarpus neriifolius*, *Nageia wallichiana* (Podocarpaceae).
(iv) Lower montane oak forest	Regularly found on mountains in Northern Thailand and also found as patches on sandstone mountains in Northeastern Thailand where the elevations above MSL are more than 900 metres.	- The typical trees found are for example: *Castanopsis acuminatissima*, *C. argyrophylla*, *C. armata*, *C. calathiformis, C. diversifolia* (Fagaceae), *Anneslea fragrans*, *Ternstroemia gymnanthera* (Pentaphylacaceae), *Schima wallichii* (Theaceae), *Beilschmiedia gammieana*, *Persea gamblei* (Lauraceae), etc. - Other plant families also found are: Proteaceae, Juglandaceae, Betulaceae, Myricaceae, Rosaceae, Oleaceae, Fabaceae, Myrtaceae, Rubiaceae, Phyllanthaceae, Styracaceae, Ericaceae, Symplocaceae, Bignoniaceae and Icacinaceae, etc.
(v) Lower montane pine-oak forest	This is forest disturbed by human activities. The other important factor for this forest is forest fire during January to March. As a result, the pure stand of *Pinus kesiya* has been replaced between gaps of forest especially at mountain ridges and braes, low soil moisture, gravelly or sandy loam as well as calcifuges.	- The typical tree species found are: *Pinus kesiya* and *P. merkusii* (Pinaceae). - Other plant families typically found are: Fagaceae, Theaceae, Proteaceae, Juglandaceae, Myrtaceae, Ericaceae, Leguminosae, Symplocaceae, Rubiaceae, Styracaceae, Phyllanthaceae.

Forest type	Distribution	Typical plant families or species
(vi) Lower montane coniferous forest	This forest type has been found on sandstone plateau in Northeastern Thailand at elevations between 1,100 – 1,300 m. Soil texture consists of 65-90% of sand.	- The tree species dominant in crown cover layer of the original natural forest structure is *Calocedrus macrolepis* (Cupressaceae). - Other plant families found are: Podocarpaceae, Fagaceae, Rubiaceae, Myrtaceae. Remark: On mountain ridges on sandy loam with elevation up to 1,500 metres in lower Southern Thailand, *Dacrydium elatum* (Podocarpaceae) has been found.
(vii) Lower montane scrub	Found as small patches in stone fields on sandstone plateau in Northeastern Thailand where the elevations are between 1,000 – 1,500 m a.s.l.. Forest fire is occasional and strong winds regularly affect this forest type. Trees are stunted at only 2 – 8 m height. Sometimes small forest patches can be found in the limestone areas at between 1,000 – 1,700 m a.s.l.	The typical plants found are such as: *Lithocarpus recurvatus, L. fenestratus* (Fagaceae), *Rhododendron ciliicalyx, R. simsii, Lyonia foliosa, Agapetes saxicola* (Ericaceae), *Ilex triflora* (Aquifoliaceae), *Frangula crenata* (Rhamnaceae), *Anneslea fragrans* (Pentaphylacaceae), *Wightia speciosissima* (Paulowniaceae), *Helicia nilagirica* (Proteaceae), *Osbeckia stellata* (Melastomataceae), *Sorbus corymbifera* (Rosaceae), *Persea gamblei* (Lauraceae), etc.
(viii) Upper montane rain forest or Cloud forest	Found elevations > 1,900 m a.s.l. that are always misty, for example at Doi Inthanon in Northern Thailand.	The typical tree species found are such as: *Quercus rex, Lithocarpus aggregatus* (Fagaceae), *Schima wallichii, Gordonia dalglieshiana* (Theaceae), *Neolitsea umbrosa, Litsea martabarnica, Neocinnamomum caudatum* (Lauraceae), *Mastixia euonymoides* (Cornaceae), *Myrica esculenta* (Myricaceae), *Heliciopsis terminalis* (Proteaceae), *Acer laurinum, A. calcaratum* (Sapindaceae), *Exbucklandia populnea*

Forest type	Distribution	Typical plant families or species
		(Hamamelidaceae), *Myrsine semiserrata* (Primulaceae), *Osmanthus fragrans* (Oleaceae), *Symplocos dryophila* (Symplocaceae), *Macropanax dispermus* (Araliaceae), *Turpinia cochinchinensis* (Staphyleaceae), etc.
(ix) Upper montane scrub	Only found at open areas along mountain ridges and mountaintops of limestone mountain at elevations between 1,900 - 2,200 m a.s.l of Doi Chiang Dao in Northern Thailand	- There are only shrubby trees/small trees in this forest type. Plants that are mainly found are herbs. *Trachycarpus oreophilus* (Arecaceae) has been broadly found. - Other plant families found are such as: *Rosa helenae, Cotoneaster franchetii* (Rosaceae), *Luculia gratissima* var. *glabra* (Rubiaceae), *Viburnum atrocyaneum* (Adoxaceae), *Zanthoxylum acanthopodium* (Rutaceae), *Rhododendron ludwigianum* (Ericaceae), *Cornus oblonga* (Cornaceae), etc. Remark: Almost all plant composition is of temperate species and some of them are endemic species of Thailand.
(x) Montane peat bog or Sphagnum bog	This forest type has been found in basin areas with deposits of peat on mountaintops or plateaux at elevations > 1,200 m. There is cold, moist and damp throughout the year. *Sphagnum* mosses continuously cover the peat in the ground layer. Small trees have been rarely found in this vegetation community.	Plant species found is typically in Ericaceae family such as: *Rhododendron* spp., *Lyonia* spp., *Vaccinium* spp., *Gaultheria* spp.
(xi) Mangrove forest	Found along the coastline and in estuaries. This forest consists of	- The typical trees found are such as: *Rhizophora* spp., *Bruguiera* spp.

Forest type	Distribution	Typical plant families or species
	tree species that have special adaptations like buttress roots or pneumatophores. Mangrove tree species have been found in coastal zones depending on environmental factors such as tides, salinity, influence of wave and wind.	(Rhizophoraceae), *Avicennia* spp. (Acanthaceae), *Sonneratia* spp. (Lythraceae). - Other plants found are: *Avicennia marina, A. alba* (Acanthaceae), *Sonneratia alba* (Lythraceae), *Rhizophora mucronata, Bruguiera* spp., *Ceriops* spp. (Rhizophoraceae), *Xylocarpus granatum* (Meliaceae), *Heritiera littoralis* (Malvaceae), *Intsia bijuga* (Fabaceae), *Lumnitzera* spp. (Combretaceae), *Sonneratia caseolaris* (Lytharaceae), *Excoecaria agallocha* (Euphorbiaceae), *Dolichandrone spathacea* (Bignoniaceae), etc.
(xii) Peat swamp forest or Coastal peat swamp forest	Found near the coastline at lower Southern Thailand where there are waterlogged basins deriving water mainly from rainfall and accumulated with layer of un-decomposed acidic peat. It can be found at the elevations from lower than MSL to 30 metres above MSL. This forest also consists of tree species that have special adaptations like buttress roots or pneumatophores.	The typical plants found are such as: *Neesia malayana* (Malayana), *Calophyllum teysmannii* (Calophyllaceae), *Campnosperma coriaceum* (Anacardiaceae), *Dacryodes incurvata* (Burseraceae), *Madhuca motleyana* (Sapotaceae), *Myristica iners* (Myristicaceae), *Elaeocarpus macrocerus* (Elaeocarpaceae), *Sandoricum beccarianum* (Meliaceae), *Stemonurus secundiflorus* (Stemonuraceae), *Dialium patens* (Fabaceae), *Myristica elliptica* (Myristicaceae), *Xylopia ferruginea* (Annonaceae), *Baccaurea bracteata* (Phyllanthaceae), *Chisocheton patens* (Meliaceae), etc.
(xiii) Freshwater swamp forest	Found along the rivers where there are basins inundated with freshwater from rivers without an accumulation of peat. Sometimes small forest patches can be found where there are	The typical trees found are for example: *Horsfieldia irya* (Myristicaceae), *Fagraea fragrans* (Gentianaceae), *Homalium foetidum* (Salicaceae), *Barringtonia racemosa* (Lecythidaceae), *Vatica pauciflora*

Forest type	Distribution	Typical plant families or species
	underground wellsprings in the area of limestone mountains in Southern Thailand.	(Dipterocarpaceae), *Xanthophyllum lanceatum* (Polygalaceae), *Combretum quadrangulare* (Combretaceae), *Mangifera gedebe* (Anacardiaceae), *Neolamarckia cadamba* (Rubiaceae), *Carallia brachiata* (Rhizophoraceae), *Lagerstroemia speciosa* (Lythraceae), *Elaeocarpus griffithii* (Elaeocarpaceae), *Syzygium cumini* (Myrtaceae), *Calophyllum pisiferum* (Calophyllaceae), etc.
(xiv) Strand vegetation	Found as strips or patches in Northern, Central, and Southern Thailand along the sand strand or rock strand's seashore.	- The typical trees found are: *Casuarina equisetifolia* (Casuarinaceae), *Calophyllum inophyllum* (Calophyllaceae), *Hibiscus tiliaceus, Thespesia populnea* (Malvaceae), *Terminalia catappa* (Combretaceae), *Pemphis acidula* (Lythraceae), *Guettarda speciosa* (Rubiaceae), *Cerbera manghas* (Apocynaceae), *Syzygium grande* (Myrtaceae), *Barringtonia asiatica* (Lecythidaceae), *Pouteria obovata* (Sapotaceae), *Cordia subcordata* (Boraginaceae), *Xylocarpus rumphii* (Meliaceae), *Hernandia nymphaeifolia* (Hernandiaceae), *Derris indica* (Fabaceae), etc. - Other plant families also found are: Goodeniaceae, Lamiaceae, Salvadoraceae, Pandanaceae, Apocynaceae, Convolvulaceae, Fabaceae, Colchicaceae, Asparagaceae.
2. Deciduous forest (i) Mixed deciduous forest	Mainly found in Northern and Central Thailand, scattered in Northeastern Thailand but has not occurred in Southern Thailand.	- The typical trees are such as: *Albizia lebbeck* (Fabaceae), *Afzelia xylocarpa* (Fabaceae), *Butea monosperma* (Fabaceae), *Pterocarpus macrocarpus* (Fabaceae), *Terminalia bellirica*

Forest type	Distribution	Typical plant families or species
		(Combretaceae), *Stereospermum tetragonum, Millingtonia hortensis* (Bignoniaceae), *Careya arborea* (Lecythidaceae), *Berrya cordifolia* (Malvaceae), *Morinda pubescens* (Rubiaceae), *Melia azedarach* (Meliaceae), *Croton persimilis* (Euphorbiaceae), *Dillenia obovata* (Dilleniaceae), *Diospyros montana* (Ebenaceae), *Sisyrolepis muricata* (Sapindaceae), *Wrightia arborea* (Apocynaceae), etc. - The other plant family found is Poaceae. Remark: - From Northern to West-southern Thailand where soil was decomposed from limestone or sediment stones, stands of *Tectona grandis* (Lamiaceae) can be found. - In areas where there is sandy loam, xeric, and occasionally forest fire occurred, thorn and dwarf trees occur such as: *Acacia tomentosa, A. harmandiana, A. leucophloea* (Fabaceae), *Harrisonia perforate* (Simaroubaceae), *Feroniella lucida, Naringi crenulata* (Rutaceae), *Maerua siamensis* (Capparaceae), and *Flacourtia indica* (Salicaceae).
(ii) Deciduous dipterocarp forest or Dry dipterocarp forest	Mainly found in Northeastern Thailand, generally found in plain and mountainous in Northern and scattered found in Central Thailand at elevations <1,000 m a.s.l., well drained sandy loam or laterite soil, xeric with yearly forest fires.	- The most important deciduous dipterocarp species are: *Shorea obtusa, S. siamensis, Dipterocarpus intricatus, D. obtusifolius* and *D. tuberculatus*. - Other typical tree families found are: Rubiaceae, Fabaceae, Anacardiaceae, Burseraceae, Lecythidaceae,

Forest type	Distribution	Typical plant families or species
		Irvingiaceae, Chrysobalanaceae, Phyllanthaceae, Apocynaceae, Lythraceae, Hypericaceae, Sapindaceae, Loganiaceae, Combretaceae, Myrtaceae, Bignoniaceae, Oleaceae, Opiliaceae and Connaraceae.
(iii) Pine-deciduous dipterocarp forest	- This forest type has pine species occurring together with deciduous dipterocarp forest at elevations from 70 to 1,350 m a.s.l.. - On high mountains at elevations > 500 – 1,350 m a.s.l. and regularly occurring forest fire in Northern Thailand, *Pinus merkusii* and *P. kesiya* have occurred together with deciduous dipterocarp forest. - At elevations >750 – 900 m a.s.l. on sandstone mountains in Northeastern Thailand, *Pinus kesiya* mainly found in deciduous dipterocarp forest. - At elevations >120 – 250 m a.s.l. in sandy loam areas in the south of Northeastern Thailand, only *Pinus merkusii* has been found in deciduous dipterocarp forest. - This forest can also be found in some provinces of Central Thailand at elevations <500 m a.s.l.	- The typical trees are: *Shorea obtusa, S. siamensis, Dipterocarpus obtusifolius, D. tuberculatus* (Dipterocarpaceae), *Pinus merkusii, P. kesiya* (Pinaceae). - Other plant families are: Pentaphylacaceae, Lauraceae, Ericaceae, Myrtaceae, Phyllanthaceae, Rubiaceae, Juglandaceae, Symplocaceae, Juglandceae, Symplocaceae, Fabaceae, Dilleniaceae, Fagaceae, Styracaceae and Proteaceae.

1.4 Research on protected areas in Thailand

A number of publications have been produced by researchers, NGOs, and research organisations in Thailand relating to protected areas (PAs) at site and landscape scales, such as the representation of ecosystems within PAs, PA connectivity, threats to PAs, the impact and conflict, as well as the PA management effectiveness. A number of previous studies have employed a range of techniques, including field work, interviews, GIS-based analyses, and camera trapping. An overview of this previous research is provided in the following section.

The representation and gaps of ecosystems within the PA network in Thailand was assessed using the application of a comparison index (CI). Spatial analyses were applied to measure three aspects of representativeness, namely forest type, altitude, and natural land system. Digital maps derived from DNP of the forest types, the digital elevation model (DEM), and the natural land systems were used to measure representation and to assess gaps in PA network. The analyses indicate that the existing PA system covers 24.4% of the country's land area, nearly meeting the 25% target proposed by the National Forest Policy 1989 (ICEM 2003); and 83.8% of these areas are forested. Most PAs are situated at relatively high altitudes. Mangrove forest and riparian floodplain are extremely underrepresented in the existing PA system, whereas peat swamp forest, dry dipterocarp forest, and beach forest are relatively well represented. The limitation of this study is the unavailability of several data that future research should consider in setting new priority conservation areas. The examples of data are: animal distribution pattern, population viability, ecological integrity, aquatic and marine ecosystems. (Trisurat 2007). Species richness in PAs was also explored by Petersen and Courtney (2010), who collected crane flies (Limoniidae, and Limoniinae) from PAs across Central to Northern Thailand to observe patterns of species richness and faunal turnover in the Indo-Burma biodiversity hotspot. This study found that mountainous Northern Thailand is projected to have the highest species richness of this group; landscape topology was also found to be significantly related to the increased diversity. The change in community assemblages across elevation gradients illustrated that faunas were more alike at similar elevations between mountain ranges, than they were along elevation gradients within individual national parks (Petersen and Courtney 2010).

The studies of threats to Thai PAs, particularly to the terrestrial PAs, have also been reviewed. Cropper et al. (2001) used plot-level data and a bivariate probit model to explain land clearing and the siting of PAs in Northern Thailand. The maps considered in the analysis were: land use, soil characteristics, slope, elevation, road, PAs. All spatial maps were converted to 100 m^2 resolutions, resulting in 28,000,000 data plots over 17 provinces in Northern Thailand. Subsequently, 6,550 sampling plots considered in the analysis were systematically selected at 5 km-intervals from all 28,000,000 data plots. The model showed where road building was likely to have greatest impact and threaten PAs (Cropper et al. 2001). Srikosamatara and Brockelman (2002) reviewed the conservation of PAs in Thailand, based on their personal experiences. Several problems affecting Thailand's PAs were identified. In Central Thailand, overuse by visitors was a central concern. In the North, hunting and forest clearance by tribal people represents a long-standing issue. Commercial-scale logging occurred in a few PAs near the Myanmar border, and the last few wild riverine ecosystems were threatened by proposed dams. Phoonjampa and Brockelman (2008) studied pileated gibbon (*Hylobates pileatus*) in Thailand in relation to threats from hunting and habitat degradation. The study used remotely sensed Landsat images and GIS to identify the remaining suitable habitat within the species' range and conducted auditory surveys to census the gibbon populations in the five largest PAs. Another 12 small PAs within the range of the gibbon were also evaluated using questionnaires and interviews with local staff and villagers. The results suggested that the largest populations of gibbon should be viable over the long-term, provided that hunting, habitat degradation and further fragmentation are controlled. Hunting is now the most significant problem, and gibbon densities are well below the carrying capacity of the habitat and are declining (Phoonjampa and Brockelman 2008). Chaiyarat and Srikosamatara (2009) studied domesticated cattle populations and their possible impacts on the wildlife community in a forest complex, by interviewing the cattle keepers in and near the study area. This investigation found that most of the cattle have been released to forage in PAs, which tended to have a high impact on wildlife communities (Chaiyarat and Srikosamatara 2009). Jotikapukkana et al. (2010) studied the effects of human disturbance on wildlife in the buffer-zone of a Huai Kha Kaeng wildlife sanctuary by monitoring a four-kilometre-width buffer zone. The study recorded the occurrence of signs of large mammals along 37 transects, and the relationships of: distance to settlements; human activities; occurrence of domestic animals; and different wildlife species were analysed. In addition, 210 respondents from adjacent villages, who used the buffer zone, were interviewed. This research showed that wildlife used more than 25% of buffer areas (plots), whereas human and domestic cattle used around 71% of buffer areas (plots). Signs of several wild animals such as: sambar deer (*Cervus unicolor*), banteng (*Bos javanicus*) and elephant (*Elephas maximus*) were negatively related to signs of domestic cattle presented in the sampling plots. Signs of common muntjac (*Cervulus vaginalis*) was negatively related to signs of human activities (Jotikapukkana et al. 2010).

In contrast, PA designation has also impacted on communities, causing some conflict. Almost all research conducted to date in this field has pointed out that PAs have resulted in negative impacts on local communities, especially to ethnic minority groups living in PAs. For example, Dearden et al. (1996) studied hill tribes in the Doi Inthanon national park, in Northern Thailand. The study found that the national park has excluded human settlements and natural resource consumption, which has caused problems for ethnic groups. Nevertheless, ethnic groups can also have a negative impact on ecosystems. The study suggested that a more refined management response is required regarding the assessment of ecosystem impacts. Moreover, different ethnic minority groups have different impacts and demand different management responses (Dearden et al. 1996). Buergin (2003) studied the designation of Thung Yai Naresuan wildlife sanctuary in Western Thailand, which is now a world heritage site. The research points to three major problems that were raised with regard to the PA, symptomatic of modern conservationism: inconsistencies between normative claims (a statement of moral judgment or an opinion of whether something is right or wrong) and political practice; distortions of scale between conceptions designed at different levels of social space from the local to the global; and the problem of reconciling conflicting cultural patterns and conceptualizations. The paper argued for a reframing of the conflict to conceive an ethnic minority group situated within a PA as an integral part of global heritage (Buergin 2003). Likewise the study of Hares (2009) on forest conflict in Thailand, focusing on minorities in Northern Thailand, found that local conflict has been related to the dilemma of conserving the forest from all human interference. Furthermore, the conflicts between the local communities and government staff have been nourished by political and public discussions. The studies suggested that conflict resolution begins with efforts toward better joint understanding, and the structures and attitudes changes are vital. Local cooperation, utilization of traditional methods, and local institutions are central to conflict solution (Hares 2009).

Analyses have also been conducted of the connectivity of PAs and corridors throughout Thailand, using a variety of methods. Most of these corridor and connectivity projects used analyses of habitat suitability and GIS to identify potential biological corridors. The Wildlife Conservation Society (WCS), Thailand, the Elephant Conservation Network Foundation (ECN), DNP, and individual researchers have independently conducted a series of biodiversity conservation corridor and forest fragmentation projects. WCS focused on selected species such as Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), serow (*Capricornis sumatraensis*), great hornbill (*Buceros bicornis*), common muntjac (*Cervulus vaginalis*), sambar deer (*Cervus unicolor*), Indochinese tiger (*Panthera tigris*), and leopard (*Panthera pardus*) for analyses of wildlife corridors (WCS 2009). ECN focused exclusively on Asian elephants in the analyses. The study areas were PAs in the Western forest complex. ECN in collaboration with PA rangers undertook month-long surveys three times per year, from 2005 to 2007, in three zones of a Salakpra wildlife sanctuary. This was to plot elephant seasonal distribution, their habitat use, as well as threats from humans. The study found that elephants are threatened directly by killing and indirectly through resource competition, such as bamboo cutting and forest product collection by humans. Shortages of food and water in the dry season also threatened elephants in the areas. The study suggests that linkage between fragmented forests is one of the important keys to elephant conservation (Stewart-Cox et al. 2007). The largest connectivity project undertaken to date examined the possibility of establishing biological corridors to connect 19 important forest complexes in Thailand. Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar deer (*Cervus unicolor*), and wild pig (*Sus scrofa*) were selected for the potential corridors between the complexes. The development of 10-year-master plans for all forest complexes in Thailand was among other important objectives of this project (DNP 2011). Pattanavibool and Dearden (2002) compared wildlife numbers between large forest and small forest patches in two contiguous wildlife sanctuaries. This research shows that PAs that maintain large patches still support populations of wildlife that have been extirpated in PAs characterised by small habitat patches. Where it occurs, a high rate of fragmentation in PAs often interacts synergistically with other pressures to reduce biodiversity (Pattanavibool and Dearden 2002). Leimgruber et al. (2003) used Principal Components Analysis (PCA) to identify three fragmentation clusters together with using Asian elephant (*Elephas maximus*) population size to identify different elephant monitoring and management zones in Thailand, Myanmar and India. The study concluded that elephant population size and habitat fragmentation vary tremendously among regions. Moreover, large unfragmented areas and populations exist in Southeast Asia that have received little attention, but will play a significant role in long-term elephant conservation (Leimgruber et al. 2003).

The identification of habitat suitability for fauna within PAs has also explored forest connectivity. Podchong et al. (2009) identified habitat suitability of forests for sambar deer (*Cervus unicolor*) in a Phu-Khieo wildlife sanctuary, Northern Thailand, using ecological niche analysis and environmental categorization. In this study, the environmental parameters were arranged into four features that affect the movement, behaviour and activity of the sambar deer. The research used an already existing dataset of sambar deer occurrences, human activities and visitations collected over four years, to produce habitat suitability maps. All dataset was collected by the wildlife sanctuary staff during 2004-2006. 156 observations collected during 2004-2005 were used to generate the species habitat suitability. Subsequently, 125 observations collected in 2006 were used to evaluate the habitat suitability map (Podchong et al. 2009). Trisurat (2010) presented a method for combining a rapid ecological assessment, landscape indices, GIS-based wildlife-habitat models for five large mammal species, namely: sambar deer (*Cervus unicolor*), banteng (*Bos javanicus*), gaur (*Bos gaurus*), Asian elephant (*Elephas maximus*), and tiger (*Panthera tigris*). In addition, knowledge of minimum viable population sizes was used to guide landscape-management decisions and improve conservation outcomes through habitat restoration. The study suggested that if managers in the forest complex wish to upgrade the viabilities of selected species within the next decade, park rangers and stakeholders should aim to increase the amount of suitable habitats. Key strategies identified as a result of this research are to reduce human pressures, enhance ungulate habitats and increase connectivity of suitable habitats outside the current distributions (Trisurat et al. 2010). Klorvuttimontara et al. (2011) used modelled distribution data for 161 butterfly species and reserve-design software ('Zonation') to investigate the current and future conservation value of PAs of Thailand. The research ranked areas based on species richness, complementarity and forest cover to evaluate the effectiveness of PAs for conserving butterflies. The results suggested that larger PAs have higher conservation value, but some small PAs were ranked as highly as some of the largest sites (Klorvuttimontara et al. 2011).

In addition, international-scale analyses have examined the connectivity of PAs between Thailand and neighbouring countries. The RFD in Thailand initiated a strategy for cooperation in transboundary biodiversity conservation with Cambodia and Laos. Two important outputs derived from the pilot project phase 1 (2001 – 2004) were a long-term management plan in a framework of transboundary biodiversity conservation, and a cooperation initiative between those three countries. Forest cover in the buffer zone has been encroached for agricultural practices. Ecological management zones defined using a bioregional approach were developed to provide a framework for transboundary biodiversity conservation in the adjoining PAs, and to reduce the conflict of resource uses by local residents in the buffer zone (Trisurat 2006).

As the analyses on PA connectivity noted above, almost all of the research that has been conducted in PAs in Thailand has shown that large and unfragmented forests can better serve species richness than small and fragmented forests. Nevertheless, a few papers have argued that even small and isolated forests can benefit wildlife. The research conducted by Klorvuttimontara et al. (2011) studied 161 butterfly species distribution in Thailand, the results showed that small forests are also likely to be of vital importance to conserve restricted range butterflies (Klorvuttimontara et al. 2011). The other example is the research of Kitamura et al. (2010) that set 15 camera traps to conduct a three-year camera-trapping survey (2004-2007) in the Bala forest, which is part of the Hala-Bala wildlife sanctuary in Southern Thailand. The Bala forest is isolated from other forests of the wildlife sanctuary by agricultural areas. Based on the results of a three-year camera-trapping survey that accumulated the total of 11,106 camera-days, it showed that small and isolated forests can also support significant numbers of species (35 mammal species, 8 birds and 1 reptile). The examples of large mammals found in the study area are: Malayan tapir (*Tapirus indicus*), leopard (*Panthera pardus*), tiger (*Panthera tigris*), and binturong (*Arctictis binturong*), to mention but a few. In addition, the total number of species photographed was similar among forest types namely primary, logged, and hill forests (Kitamura et al. 2010).

There are some issues regarding PA management and the suggestions from the previous research. Srikosamatara and Brockelman (2002) suggested that community-based conservation did not persuade villagers to conserve PAs. Armed enforcement was most effective when it was perceived as fair. In addition, research and monitoring could be important activities to support PAs protection effectiveness. In addition to this, commercially driven poaching was nearly impossible to control, which demands an expanded approach to conservation (Srikosamatara and Brockelman 2002). In contrast, other research published in the same year found very different results. Delang (2002) explored the social, economic, and political context of deforestation and watershed degradation in the highlands of Northern Thailand by gathering information in Hmong village (an ethnic minority group) and a RFD station. The research found that the RFD was unsuccessful in dealing with the problems, and that its policies ultimately led to further deforestation, worsened the water imbalance, and resulted in the harassment of the resident ethnic minorities (Delang 2002). Nepal (2002) compared efforts in partnership between indigenous peoples and PA authority in three Asian countries: Nepal, Thailand, and China. One PA of each country was selected for comparison in the study. These were: Sagarmatha (Mt. Everest) national park, Nepal; Doi Inthanon national park, Thailand; and Xishuangbanna nature reserve, China. The study was based on field research in study areas together with the researcher's experience on the interaction between PAs and local communities. The paper showed that the improvement of indigenous people's livelihood conditions and combination of their ideas on PA management would reduce the conflicts between governments and indigenous people. Participation of local communities in PA management benefits long-term PA sustainability (Nepal 2002).

It can be concluded that previous research conducted in Thai PAs has employed several methods ranging from expert experiences, field study, review literature, and use of secondary datasets in co-operation with specific programs. Therefore, the reliability of research findings are uncertain mainly due to the availability and quality of datasets employed (Chape et al. 2005). Nevertheless, this previous work is important in terms of providing the fundamental understanding of PAs in Thailand. In a nutshell, this review of research and previous work related to PAs could conclude that the current PAs are showing a good representation of species, especially wild animals. However, organism persistence within the PAs is under threat. Threats to Thai's PAs, and wildlife living in them, are: human disturbance, habitat degradation, forest clearance, hunting, logging, forest fragmentation, road building, overuse by visitors, domesticated cattle, etc. Large and unfragmented forests can better serve species richness than small and fragmented forests. However, sometimes small and isolated forests can also support species richness. Local participation in conservation strategies is a vital element in the success of conservation strategies.

The designation of PAs of Thailand was initially based on expert consultations selecting the areas that are suitable for conserving forest resources, not systematically selected. Consequently, the PA management was based on individual management plans for each PA. The previous work has also identified that no previous attempt has been made to apply the principles and methods of systematic conservation planning. Additionally, tree species have been neglected in previous analyses of the coverage of PAs in Thailand. These indicate the importance of this research.

1.5 Trees: the surrogates for biodiversity selected in the research

Where information on biological components represented within a PA is incomplete, systematic conservation planning typically uses surrogates to represent biological components (Stoms et al. 2005). Surrogates are used to represent biodiversity such as habitat types, species assemblages, and subsets of species (Margules and Pressey 2000). Trees can be surrogates for biodiversity in many reasons. Trees are an important component of ecosystems, and play a crucial role in the provision of multiple ecosystem services. For example, trees protect soil erosion, slow down the change of temperature and water runoff, release O_2, store CO_2 (which is known as one of the main gases causing climate change). Trees are also sources of food and wood. Loss of trees can lead to changes in microclimate that can affect other forest-dwelling organisms (Butt et al. 2014). In addition, plants, especially trees, are the main producers of the food chain. If they have been threatened by being removed continually from the food chain, it affects the whole ecology as a domino effect. It starts from affecting herbivores, the primary consumers in the food chain, then omnivores and carnivores. Trees can serve directly as habitats for other species such as birds, animals and fungi. If trees are conserved within the region, these other species should be conserved as well.

1.6 Aims and hypotheses

(a) Aims

The aim of this research is to apply the techniques and approaches of systematic conservation planning in Thailand. A review of previous research on protected areas in this country has been completed, and has indicated a significant body of previous work. For example, analyses have been conducted concerning the connectivity of PAs throughout Thailand, using a variety of methods. The Department of National Parks, Wildlife and Plant Conservation (DNP), Wildlife Conservation Society (WCS), Thailand, and Elephant Conservation Network Foundation (ECN) have independently conducted a series of biodiversity conservation corridor and forest fragmentation projects. However, these have focused primarily on animal species (WCS 2009; Stewart-Cox et al. 2007). Some research has also been conducted on gap analysis in the PAs of Thailand (Trisurat 2007). However, no previous attempt has been made to apply the principles and methods of systematic conservation planning in Thailand. In addition, tree species have been neglected in previous analyses of the coverage of protected areas in Thailand. This research aims to address this knowledge gap.

(b) Hypotheses

The research tested the following hypotheses:

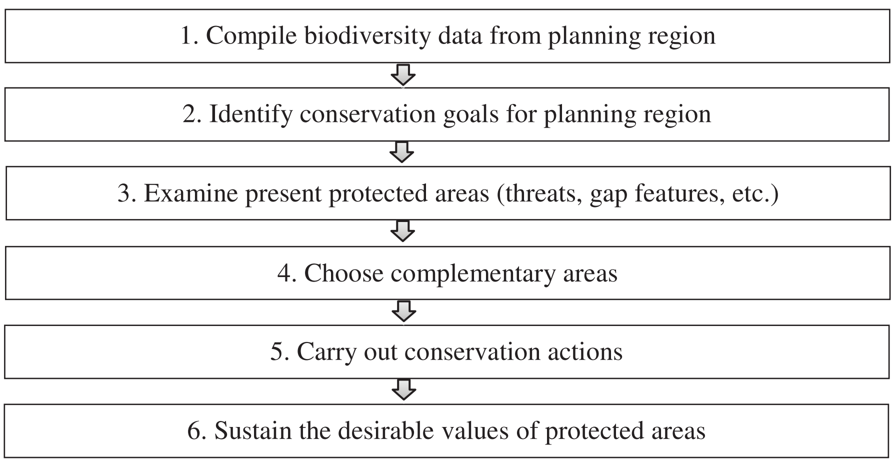
i. The current protected area network in Thailand is not adequate to conserve tree species richness in the country.

ii. Tree species in Thailand are being subjected to a wide variety of threats, which are increasing their risk of extinction, and are limiting the effectiveness of protected areas.

iii. The application of systematic conservation planning techniques will enhance the planning and implementation of protected area networks in Thailand, with specific reference to the conservation of tree species.

1.7 Methods

The thesis hypotheses were tested by examining: tree species that are threatened with extinction; tree species that dominate the different forest types in Thailand; tree species that are of particular economic importance; and tree species that are important to *in situ* genetic conservation. The methods used in the thesis followed the standard approach to systematic conservation planning, described by Margules and Pressey (2000), which consists of 6 main stages as shown in the diagram below:



(Margules and Pressey 2000)

This thesis involves only stages 1 to 4. Secondary data has been compiled on biodiversity throughout Thailand and surrogates for biodiversity have been identified which were tree species, following Margules and Pressey (2000). Secondary data were compiled from databases, research papers, reports, documents and related websites of Thailand's tree species that form the basis of this research, based on existing information about conservation status, pattern of distribution, composition, diversity as well as ecological importance.

Methods used to select four groups of tree species

In this research, I chose tree species as surrogates for biodiversity. Including all tree species found in the country into the analysis is the ideal. Approximately 2,300 species of trees are known to occur in Thailand including trees, small trees, and shrubby trees (Chayamarit 2014). Because it was unfeasible to include all of these, I applied selection criteria as detailed below. These criteria were based on the assumptions that the most important species for conservation are those that represent forest communities of Thailand along with tree species that are of interest to public and individual conservation organisations.

For the first reason, I chose all trees listed in the book: Forest types of Thailand (Santisuk, 2006). This is because the tree species mentioned in the book are typical of those found in each of the different forest types found in Thailand. In addition, species from five families representing all the different forest types were derived from consultation with botanists from the Forest Herbarium (BKF), Bangkok. These five families are: Magnoliaceae, Dipterocarpaceae, Fagaceae, Fabaceae (or Leguminosae) and Ebenaceae, and they are typically found in several forest types.

For the second reason, trees were chosen following national concern. These are: tree species that are threatened with extinction; tree species that are of particular economic importance; and tree species that are important to *in situ* genetic conservation (see below for details of how these lists were compiled).

Therefore, the four groups of tree species chosen to act as surrogates were: tree species that are threatened with extinction; species that dominate the different forest types in Thailand; species that are particular economic importance; and species that are important to *in situ* genetic conservation. Specifically, these four tree species groups include:

i. Tree species with status of endemic, rare, threatened, or vulnerable (472 species) as catalogued by Santisuk et al. (2006) and Pooma (2008) including: 351 species from the book 'Thailand red data: Plants'; and 121 species from the book 'Rare Plants of Thailand' respectively (Table A1 and A2 in Appendix A, mentioned only trees and shrubby trees).

The lists from the former book include endemic, rare and endangered plant taxa in Thailand based on IUCN version 1994 for endemic and rare species, and version 2001 for vulnerable and endangered species. This book defines rarity criteria as those species with restricted distribution ranges and few specimens collected and describes that most of threatened species are found to be endemic, however, their range size is diverse from broadly distributed across Thailand to narrowly limited to certain areas (Santisuk et al. 2006). The latter book defines rare plants as plants species that are nowadays rarely to be found, with restricted distribution ranges, or scattered distribution ranges, or plant species that used to be typical species in the past, but at present have small populations, or plant species that are typical of neighbouring countries, but their distributions end at the boundaries of the countries (Pooma 2008).

ii. Selected tree families and species that dominate the different forest types in Thailand. These include:

(1) Tree species that are typically found in Thailand forest ecosystems mentioned in the book 'Forest types of Thailand' (Santisuk 2006) (Table A3 in Appendix A).

(2) Five tree families: Magnoliaceae, Dipterocarpaceae, Fagaceae, Fabaceae (or Leguminosae) and Ebenaceae (Table A4 in Appendix A).

With respect to the five tree families:

- **Magnoliaceae**, *Magnolia* is the only genus, of which 27 taxa are found in Thailand. They have been considered by several botanists as the most evolutionarily primitive family of all Angiosperms (Nooteboom and Chalermglin 2009). Also, they are admired extensively and to be treated as ornamental plants for their glamorous flowers (Cicuzza et al. 2007). They have been found in several forest types such as Upper montane rain forest, Lower montane rain forest, and Seasonal rain forest (Santisuk 2006).

- **Dipterocarpaceae**, 5 genera, of which 65 taxa are found in the country (Pooma and Newman 2001), occupy a large variety of habitats and different environments in Asia from coastal to inland, riverine to dry land, wide range of quality of soils and drainage (Pooma and Newman 2001). They are found in different types of forest such as Tropical evergreen rain forest, Seasonal rain forest, Freshwater swamp forest, and Deciduous dipterocarp forest (Santisuk 2006). As all taxa of Dipterocarpaceae are trees; they are important in terms of commercial timber such as *Dipterocarpus* spp., *Shorea* spp., and *Hopea* spp. Several species have symbiotic ecotomycorrhiza such as *Dipterocarpus obtusifolius* Teijsm. Ex Miq., *D. tuberculatus*, *Shorea roxburghii* G.Don, etc. (Chalermpong and Boonthaweekhun 1981). The relationship supports the growth and nutrient absorption of plants (Tawaraya et al. 2003).

- **Fagaceae**, 4 genera, of which 127 taxa are found in Thailand (Phengklai et al. 2008; Strijk et al. 2014), dominates forests in the temperate, seasonally dry regions of the Northern Hemisphere, with a centre of diversity in tropical Southeast Asia (Chokchaichamnankit et al. 2007). Trees in Fagaceae family are typical in several forest types such as: Lower montane rain forest; Lower montane oak forest; Lower montane pine-oak forest; Lower montane coniferous forest; Lower montane scrub; Upper montane rain forest; and Pine-deciduous dipterocarp forest (Santisuk 2006). They are of global ecological and economic importance such as timber, food, animal fodder, ornamental plants especially Oaks (*Quercus* spp.) (Oldfield et al. 2007).

- Fabaceae (or Leguminosae), 102 genera, of which 614 taxa are found in Thailand (Niyomdham 1989). They consist of three subfamilies, which are Mimosoideae, Caesalpinioideae, and Faboideae (or Papilionoideae). Fabaceae are large and economically important plants in light of timber supply, vital agricultural and food plants. They are widespread over the world, growing in many different environments and climates. They have been found in several forest types such as: Tropical evergreen rain forest; Seasonal rain forest; Lower montane pine-oak forest; Upper montane scrub; Mangrove forest; Peat swamp forest; Freshwater swamp forest; and Strand vegetation (Santisuk 2006).

- Ebenaceae, *Diospyros* is the only genus found in Thailand with 62 species (Phengklai 1978; Phengklai 2005) and distributed widely throughout the country (Utsunomiya et al. 1998). They are woody plants that very resistant to decay, are considered as ornamental trees because of their beautiful foliage, and also are the greatest source of valuable ebony wood. Several species produce edible fruits such as *Diospyros virginia*, *D. digyna, D. lotus* and *D. kaki* are the most famous taxa planted in Thailand. They have been found in Mixed deciduous forest, and Deciduous dipterocarp forest (Santisuk 2006).

iii. Trees species that are important in terms of economic value (i.e. some extraction is allowed). These are ‘the restricted logging trees’ under two Thai laws: the Royal decree on restricted logging trees 1987 (The Prime Minister's Office 1987); and the Forest Act 1941 (The Prime Minister's Office 1941).

A permit from the Royal Forest Department (RFD) is required for extraction of ‘restricted logging trees’ (The Prime Minister's Office 1941). There are 158 entries of ‘the restricted logging trees’ in the Royal decree on restricted logging trees 1987 (The Prime Minister's Office 1987). It is noted that, individual entries are listed in different forms. Some entries are listed as one individual species, other entries contain more than one species within a genus (but not necessarily all species within that genus) whilst others cover a whole genus (Table A5 in Appendix A). There are additionally two restricted logging trees listed in the Forest Act 1941, these are: *Tectona grandis* L.f. and *Dipterocarpus alatus* Roxb. ex G.Don (The Prime Minister's Office 1941).

iv. Thailand's priority tree species, which are of particular value in terms of the conservation and sustainable use of forest genetic resources (FGR). The species lists are derived from country reports of Thailand, which is a part of the Proceedings of the Asia Pacific Forest Genetic Resources Programme (APFORGEN) Inception Workshop 2003, Malaysia (Luoma-Aho et al. 2003).

APFORGEN is a regional network programme to promote collaboration amongst the member countries in the Asia Pacific region on conservation and sustainable management of forest genetic resources, and employment of genetic diversity of priority forest species, both in natural and man-made forests (Luoma-Aho et al. 2003). The priority forest species were categorised by the member countries themselves. Regarding 35 priority species of Thailand, they were identified by the development of an initial listing and ranking of important native species based on the species lists from the related programmes of the RFD, such as the Seed Management programme, and Gene Bank programme. Subsequently, the lists were reviewed by a working group of Thai forest experts at Kasetsart University, Bangkok in 2000 (Sumantakul et al. 2004) (Table A6 in Appendix A).

It is worth taking into consideration that each tree species can be considered in more than one group. Additionally, not all occurrence points of the selected tree species can be included in the thesis. This is because of erroneous spatial locality data of some occurrence points. Initially, there were 16,455 records of 819 tree species that were compiled from DNP during 1925 - 2012. However, when duplicates, erroneous records, and records before 1982 were removed, there were 6,339 records of 749 species, belonging to 93 families, which could be used in the research (Table A7 in Appendix A). More detail of tree data collection is shown in Chapter 3.

1.8 Structure of thesis

The structure of this thesis was formed based on stages 1 - 4 of the systematic conservation planning approach described by Margules and Pressey (2000). This thesis comprised six chapters: beginning with an introduction; then four chapters of main analyses which include some discussion; followed by the general discussion. The summary of each chapter is outlined as follows.

(a) Chapter 1: Introduction

In Chapter 1, information, research and work in relation to PAs were reviewed globally and for Thailand in the Introduction Chapter. The definition of what comprises a PA; their classification; the types of PA found in Thailand; and the organisations involved in the management of the reserves were reviewed. Basic information on the plants and forests of Thailand was also reviewed. Previous research on PAs in Thailand by relevant bodies was provided by both site and regional scales in relation to: the representation of ecosystems within the PAs; the connectivity; threats to PAs; the impact and conflict of both communities on PAs and PAs on communities; as well as the PA management effectiveness. The introduction also outlined the aim and hypotheses of this thesis.

(b) Chapter 2: Analysis of threats to the protected areas of Thailand

Chapter 2 investigated the direct threats that caused a reduction in forest area or cutting of tree species that have happened within Thailand's PA network. This was achieved by the analysis of records of different threats, made by the staff of national parks and wildlife sanctuaries throughout Thailand. The analysis was done by calculating the number and percentage of each type of threats from both legal and illegal activities that happened in the two PA types in each region. The results showed the magnitude of threats in each region and each type of PA.

(c) Chapter 3: Gap Analysis of the protected areas of Thailand in relation to the conservation of tree species

Surrogates for biodiversity were selected, namely four groups of tree species and the identification of conservation gaps was performed in Chapter 3. The coverage of selected tree species by the existing PA network of Thailand was investigated to determine whether or not they are adequately conserved within PAs. PA types considered in this chapter were four natural PA types (national park, wildlife sanctuary, no-hunting area and forest park). The other two man-made PA types (botanical garden, and arboretum) were excluded. The analysis was conducted using two methods. Firstly, the number and percentage of species occurrence points within PA boundaries were calculated for all species (749 species, belonging 93 families). Secondly, the species' ranges were calculated for species with precise locations and $\geq$ 5 records/species (57 species belonging to 10 families) following *Scenario* B of the gap analysis method described by Rodrigues et al. (2003). Then the percentage of range inside PA of each species was compared to the percentage of representation target that has been set individually for each species, to identify whether the species are considered as covered, partial gap, or gap species. Both methods were implemented by using ESRI ArcGIS 10.

(d) Chapter 4: The potential geographical distribution of selected tree species in Thailand

The potential geographic distributions of selected tree species were analysed and mapped in Chapter 4. Maxent was used to predict the potential geographic distributions of 35 selected tree species with $\geq$ 8 records/species throughout Thailand using species' occurrence localities in association with eleven uncorrelated environmental variables (3 topographic and 8 climatic variables). The important environmental variables influencing the distribution of the selected tree species were also explored in this Chapter.

(e) Chapter 5: Systematic conservation planning

Chapter 5 pooled all data together from Chapters 1 – 4, as well as adding more data. This is to determine the priority areas outside the current PA network that maximize tree conservation and minimise threats. A conservation planning method called multi-criteria analysis (MCA), was applied in this Chapter. Priority areas were generated using the Integrated Land and Water Information System (ILWIS), a GIS programme used for MCA. The degree of priority for conservation was identified according to four categories from very low to very high priority, based on the MCA output scores. Additionally, different weights were applied to both the main criteria and the level I subcriteria groups to identify the sensitivity of the final output to the methods used.

(f) Chapter 6: Discussion

Chapter 6 provided an overall research discussion in three parts. It began with a summary of the research findings, which summarised the results of three research hypotheses. Subsequently, the limitations and uncertainties of the research were considered in relation to data and analyses used in the research. Finally, recommendations for future research were suggested.

Chapter 2: Analysis of threats to the protected areas of Thailand

Abstract

Protected areas (PA) were designated accounting for 177,547 PAs worldwide in 2010, covering 12.7% of the terrestrial area. Many PAs are under pressure from human activities and economic development. The understanding and the measurement of the threats to PAs are important for monitoring conservation effectiveness, and supporting effective planning and management. Therefore, the objective of this chapter was to systematically investigate the direct threats to forest habitats and associated tree species occurring within PAs in Thailand. This was achieved by analysis of records of different threats, made by the staff of PAs throughout Thailand. This chapter studied threats to 181 PAs by focusing on two main types, consisting of 123 national parks and 58 wildlife sanctuaries. The research focused on the period from 1999 to 2011, particularly on those direct threats that are likely to have contributed to a reduction in forest area or the loss of tree species. These threats are: forest fire; both illegal and legal activities that caused a reduction in forest area or cutting of tree species within PAs. Illegal cases were categorized into two main groups, namely illegal forest clearing cases and illegal logging cases. In this chapter, the number of PAs where each threat occurred, and the frequency and magnitude of threats were analysed for each region.

The results showed that forest fire threatened PAs in almost all regions of Thailand over the past decade. PAs in the Northern and the Northeastern regions were at the greatest risk of forest fire occurring, while those in the Southern region were much less affected. However, the risk of forest fire occurrence did not vary much between types of PA. The illegal area clearing and illegal logging also threatened almost all PAs in all regions, but were more severe in wildlife sanctuaries than in national parks. However, the greatest risk of illegal area clearing was in the Northeastern and the Southern regions, whilst it was much less evident in the Eastern region. The PA in the Southern region had the greatest risk of illegal logging, which was less evident in the Eastern region. Legal activities permitted by the government also threatened both types of PA, although they were less evident in wildlife sanctuaries than in national parks. PA in the Northern and the Northeastern regions were at greatest risk

of permitted legal activities, while much less of these was recorded in the Eastern and Central regions. Road construction was the most common activity permitted, followed by electricity lines and infrastructural development related to tourism in national parks, whereas infrastructural development not related to tourism was the most prevalent activity in wildlife sanctuaries.

Overall, threats to PAs from illegal cases differed from those associated with legal activities. The number of illegal cases substantially outnumbered legal activities permitted in PAs, with more than 38,000 illegal offense cases in three fiscal years 2009 - 2011, and around 260 legal permissions over the six fiscal years 2006 - 2011. Additionally, the prominent threats to Thailand's PAs are: forest fire, illegal logging, illegal area clearing, road construction, electricity lines, infrastructural development related to tourism and infrastructural development not related to tourism.

Chapter 2: Analysis of threats to the protected areas of Thailand

2.1 Introduction

Protected areas (PA) are widely recognised to be the most important tool for conserving biodiversity. In 2010, there were 177,547 PAs worldwide, covering 12.7% of the terrestrial area (Bertzky et al. 2012). However, many PAs are ineffectively managed (Ervin 2003). Some existing PAs are downsizing, downgrading, or even ceasing to be protected altogether (Bertzky et al. 2012). Increasing pressures from human activities and economic development are also reducing the protection ability of PAs within their boundaries (Pimbert 1997). Threats include a rapid growth in tourism, insufficient funding for PA infrastructure and maintenance, conflicting development of communities and public lands around PAs, logging, mining, invasive species, pollution (of air, water), and climate change (Prato 2004). The acceleration of natural resource extraction, habitat degradation, fragmentation, and overexploitation are also of increasing concern in PAs worldwide (Stoner et al. 2007). Critical threats to PAs also arise from mineral and energy exploration as well as large-scale infrastructure development (Naughton-Treves et al. 2005). The lack of appropriate conservation management plans or strategies, and the capacity to deliver them, are further threats that can undermine the effectiveness of PAs (Parrish et al. 2003). For example, Colding (2000) studied 201 PAs of 16 countries in tropical regions and found that 70% were affected by threats such as poaching, encroachment and logging. Bruner et al. (2001) studied 93 PAs in 22 tropical countries and found that almost all PAs are under pressure from clearing, grazing, fire, hunting, and logging, the most severe threats being logging and hunting.

Carey et al. (2000) studied threats to 46 individual PAs in ten countries and explained that the importance of different threats depends on their potential severity and the probability of occurrence. According to these authors, there are four significant categories of threats to PAs affecting the long-term survival of biodiversity and ecosystem functions. These are: (1) individual elements removed from PAs such as the wild plant and bushmeat trade, illegal logging; (2) overall impoverishment of the ecology of PAs such as pollution, settlement, conversion to agriculture, alien species invasion and diseases; (3) major conversion and degradation such as mining, logging, natural disasters (fire), climate change; (4) isolation of PAs, as areas that are too small are unable adapt to environmental change and species in such areas are at increased risk of extinction (Carey et al. 2000).

Chape et al. (2005) highlighted the importance of understanding and measuring the threats to PAs in order to monitor conservation effectiveness, and to support effective planning and management. Wilson et al. (2005) reviewed the methods used for analysing threatening processes and the relative vulnerability of different conservation areas, as an integral part of systematic conservation planning. The effectiveness of conservation planning is partly dependent upon how to reduce threatening processes and the relative vulnerability of PA networks, especially the reduction of proximate or direct threatening processes affecting biodiversity. Vulnerability refers to the possibility of biodiversity loss owing to current or impending threatening processes (Pressey et al. 1996). Wilson (2005) noted that vulnerability of areas can be defined by three dimensions, consisting of exposure (or risk), intensity and impact. In this context, exposure is defined as the predisposition or sensitivity of an area to a threat. It can be measured as the probability of a threat affecting an area over a specified time, or the expected time until an area is affected. The probability of exposure value can range from 0 to 1 (no vulnerability to high vulnerability) or from a zero year to many years (low to imminent or high). The intensity of a threat can be measured in terms of magnitude, frequency and duration (Harwood 2000), and can be measured in many forms depending on the nature of the specific threat, such as density, cubic meters per hectare or through the use of categorical variables. Impact refers to outcomes or specific risks (Dilley and Boudreau 2001). This can include specific effects on species distribution, abundance or persistence, and may reflect life history characteristics of the species concerned (Pereira et al. 2004).

Since 1973 the forest area of Thailand has decreased from 43.2% of the area of the country to 25.3% in 1998. Thereafter, it has gradually increased, to 33.4% in 2008 (RFD 2010). This reflects the efforts that Thailand has made to conserve and protect forest areas and natural resources, of which one was the declaration of six PA types, namely: national park, wildlife sanctuary, no hunting area, forest park, botanical garden, and arboretum. The number of national parks has increased from 103 to 123 since 2006, and the number of wildlife sanctuaries has increased from 55 to 58 in the same period (DNP 2010). However, negative environmental impacts of human activity have been reported within some PAs in Thailand. For example, Hares (2009) reports slash and burn cultivation, opium poppy cultivation, water pollution, illegal logging, and poor fire control both within and near the Doi Inthanon national park in Northern Thailand. In addition, Chaiyarat and Srikosamatara (2009) have documented grazing by domesticated cattle in the forest complex in Western Thailand, which can lead to destruction of wildlife habitats, decreased growth rate and high mortality of plants. Ngoprasert et al. (2007) have documented road construction and other development in the Kaeng Krachan national park in central Thailand, which has negatively affected the behaviour of wildlife. Cropper et al. (2001) also have documented that road building is likely to have the greatest impact to PAs, including both national parks and wildlife sanctuaries, in Northern Thailand. Trisurat (2006) mentioned agricultural encroachment, cattle grazing, forest fire, poaching, land-mines and low capacity of field staff as threats to the Pha Taem Protected Forest Complex in Northeastern Thailand. Furthermore Pattanavibool and Dearden (2002) have documented the high rate of fragmentation and reduced biodiversity in two wildlife sanctuaries (Mae Tuen and Om Koi) in Northern Thailand, mostly resulting from human impact, in particular shifting cultivation, hunting and flooding and from some development forms such as roads, human settlements, commercial agriculture, and forestry.

The review of previous research showed that four threat categories classified by Carey et al. (2000) have always threatened PAs worldwide. These are: removal of organisms from PAs; PA ecological impoverishment; PA conversion and degradation; as well as PA isolation. Despite the increase in number of PAs within Thailand, it is clear that not all Thai PAs are free from threats. Threats to PAs in Thailand) based on previous studies) included: illegal logging, road construction, agricultural encroachment, cattle grazing, forest fires, land-mines, low capacity of field staff, fragmentation, hunting and human settlements. However, these previous studies have identified threats to PAs within specific small areas of Thailand. Only the study of Cropper et al. (2001) reviewed a larger area in Northern Thailand, but this work focussed only on road impacts. This review therefore confirmed that no previous study has systematically investigated all threats to PAs throughout the country. The objective of this research was therefore to identify the threats to forest habitats and associated tree species occurring within PAs in Thailand. This was achieved by analysis of records of different threats, made by the staff of national parks and wildlife sanctuaries throughout Thailand.

2.2 Objectives

To identify the threats to forest habitats and associated tree species occurring within protected areas in Thailand.

2.3 Methods

This research studied direct threats to Thailand's protected areas (national parks and wildlife sanctuaries). Direct threats in this research are defined as: forest fires, the majority of which were caused by people (DNP, 2014); and both illegal and legal activities that caused or are likely to have caused forest clearance or cutting of tree species within the protected areas. The threats were analysed in the following way;

i. Forest fire in PAs was estimated using the estimated burned area occurring in each PA in 1999 – 2002, and using the frequency of forest fires that occurred in each PA in 2011. Information on the area of vegetation that burned within PAs was obtained for four years during the period 1999 - 2002, from a statistical data report (2003) of the Department of National Parks, Wildlife and Plant Conservation (DNP). The data were reported as total burned forest area (km^2) for each year in each PA. Measures of burned areas were derived from calculating burned boundaries in the GIS database of DNP. This incorporated forest fire information that was recorded by staff of the Forest Fire Control Units throughout Thailand in a standard form. The form consists of main forest fire information such as: (1) name of the Forest Fire Control Unit that reported the forest fire; (2) location of forest fire; (3) frequency of forest fire; and (4) total burned area. This information was reported to the Forest Fire Control Division under the Regional Protected Areas Administration Office, which is part of DNP. Subsequently, the information was processed by the Division of Protection and

Forest Fire Control, which is part of DNP. Monthly and annual reports have been compiled and produced by Division of Protection and Forest Fire Control.

In this research, the number of PAs in which forest fire occurred in each region was analysed in percentage to variation in the incidence of forest fire. The burned area data were analysed by calculating the burned area as a proportion of the total area of each PA. Subsequently, the mean percentage of burned area and standard error (S.E.) were calculated for each region, producing a mean value for all PAs surveyed within each region.

In this research, for each PA, the area burned was calculated as a percentage (%) of the total area of the PA, as follows:

$$PAB = \frac{AB}{PA} * 100$$

Where PAB is proportion of area burned (%) and AB is area burned (km^2) and PA is size of PA (km^2) that the forest fire occurred in.

The mean and S.E. of area burned per PA was estimated for each respective region. This was then compared between regions to determine the propensity for, and scale of, forest fires in PA.

Further data on forest fire for the year 2011 was obtained directly from the Division of Protection and Forest Fire Control. 2011 is the first year for which these data are available for individual PAs. Previously, data were presented in terms of each Forest Fire Control Unit, province, and Regional Protected Areas Administration Office. The number of forest fires that occurred within each PA was recorded, and divided by the area of each PA, to provide an indication of fire frequency. Subsequently, the mean frequency of forest fires and S.E. were calculated for each region, as above.

ii. Illegal cases that caused a reduction in forest area or cutting of tree species in each PA.

This research considered two major types of illegal cases in PAs that could have caused a reduction in forest area or cutting of tree species. There are: (1) illegal area clearing; and (2) illegal logging. The illegal cases data was obtained for three fiscal years during the period 2009 - 2011 (1 October 2008 – 30 September 2011) directly from the Division of Protection and Forest Fire Control, which is part of the DNP. The data were collected by PA staff at the scale of individual PAs, and reported all cases of illegal hunting, area clearing and logging. The illegal case information was recorded by staff of each PA throughout Thailand on a standard form. The form consists of the principal illegal case information, such as: (1) name of the PA that reported the illegal case; (2) type of illegal case; (3) name and number of offenders; (4) place and location that the case happened; (5) lists of confisicated items; (6) log or veneer volume (cubic metre); (7) total clearing area (Rai: Thai area unit); (8) value of confiscated items/cleared area (Thai baht); and so on. The information was then reported monthly to the Regional Protected Areas Administration Office, which is part of DNP. Subsequencely the information was processed by the Division of Protection and Forest Fire Control, which is part of the DNP where annual reports have been compiled and produced.

In this research, the number of PAs where illegal forest clearing and illegal logging occurred in each region was analysed by calculating the following: (1) the number of illegal area clearing cases; (2) the number of illegal logging cases; (3) total areas of forest cleared (convert from rai units to square kilometre units); and (4) total volumes of log and veneer harvested (cubic metre).

The number of: (1) the illegal area clearing cases; and (2) the illegal logging cases that occurred within each PA were recorded, and divided by the area of each PA, to provide an indication of the frequency of such events. Subsequently, mean frequencies $\pm$ S.E. were calculated for each region. Similarly, the total area that was cleared illegally was expressed as a percentage of the area of each PA, and the mean percentage $\pm$ S.E. calculated for each region.

Total log and veneer volumes were expressed on an area basis by dividing by the total area of each PA. Subsequently, the mean volume per unit area $\pm$ S.E. was calculated for each region.

iii. Legal activities that likely caused a reduction in forest area or cutting of tree species.

This research considered legal activities that were permitted in PAs but that were likely to have caused a reduction in forest area or the cutting of tree species. The data were obtained for six fiscal years during the period 2006 - 2011 (1 October 2005 – 30 September 2011) directly from: (1) the National Park Office (in case of national parks); and (2) the Wildlife Conservation Office (in case of wildlife santuaries), which are parts of DNP. The data reported all details of legal activities, based on formal submissions made by PA staff, at the scale of individual PAs. The information reported consisted of all activities that have been permitted to take place within each PA by PA officials. However, this research grouped and summarised only activities that are likely to have caused a decline in forest area. The relevant activities consist of the following: (1) dam/ reservoir; (2) small water body; (3) national security project; (4) road; (5) nature trail; (6) electricity line; (7) tourism facility; (8) landscape development for tourism; (9) landscape development for non-tourism; (10) religious building; (11) broadcasting station; (12) training centre/educational institute; (13) harbour; (14) research area/centre; (15) pipe line; (16) monument/buddha image; (17) facility for non-tourism; (18) solar cell area; and (19) telemetry station.

In the case of national parks, construction projects within national park territories are only permitted for specified purposes: protection and maintenance of national parks; education or research; tourism; capacity building; lodging; and safety of people. The routine process of consideration is as follows. (1) Organisations that would like to make use of land in the area of national park have to prepare a project proposal in collaboration with the head of that national park. The proposal must be submitted together with documents consisting of a site plan and location, as well as reports and comments of the head of the national park concerning the potential impacts and benefits of the project. The purpose of the project must not be in conflict with related national park laws and regulations. (2) The head of the national park submits the proposal with related documents to the Division of National Parks under the Regional Protected Areas Administration Office for further comments or recommendations on the project before proceeding to the National Park Office of

DNP. The National Park Office may consider and make more comments before submitting to the Director General of DNP for project approval. Information on permitted projects are collected and recorded by the National Park Office.

In the case of wildlife sanctuaries, construction projects within wildlife sanctuary territories will be permitted only for particular purposes: protection and maintenance of wildlife sanctuaries; breeding programs; education or research; capacity building; lodging; and safety of people. The routine process of consideration is as follows. (1) Organisations that would like to make use of land in the area of wildlife sanctuary have to prepare project proposal in collaboration with the head of that wildlife sanctuary. The proposal must be submitted together with documents consisting of the site plan and location, as well as reports and comments of the head of wildlife sanctuary concerning the impacts and benefits of the project. The purpose of the project must not be in conflict with related wildlife laws and regulations. (2) The head of the wildlife sanctuary submits the proposal with related documents to the division of Wildlife Conservation under the Regional Protected Areas Administration Office for further comments or recommendations on the project before proceeding to the Wildlife Conservation Office of DNP. The Wildlife Conservation Office may consider and make more comments before submitting to the Director General of DNP for project approval. Information on permitted projects are collected and recorded by the Wildlife Conservation Office.

The information on project activities implemented both in national parks and wildlife sanctuaries were not reported in the same format. Some activities were reported in area units such as dam and small water body, but some were reported in distance units such as electricity line, road. In this research, all activities were presented in terms of the number of projects that were permitted in each PA in each fiscal year and throughout the six year period that was analysed. Subsequently, these data were summarised and reported for each region individually. Moreover, the number of PAs that had projects permitted in their territories was also presented in each fiscal year and throughout the six year period.

iv. The difference in the number of threats was compared between national parks and wildlife sanctuaries in each region. This was to determine whether the possibility or risk of threats differed in different PA types. These were also compared between regions. Specifically, the details of comparison were:

(1) Forest fire: the comparison between the two PA types in each region were as follows. In 1999 – 2002, ‘the percentage of PAs where fire occurred’, and ‘the mean percentage of area burned’ were analysed. In 2011, again ‘the mean percentage of area burned’, and ‘mean number of fires occurring per unit area’ were analysed.

(2) Illegal cases: the comparison between the two PA types in each region in the fiscal year 2009 - 2011 were as follows. ‘The mean percentage of PAs that have illegal cases’ (illegal clearing cases and illegal logging cases), and ‘the mean number of illegal cases per unit area’ were analysed. In addition to the illegal area clearing, ‘the mean percentage of illegal area clearing’ were compared. Similar to the illegal logging, ‘the mean log and veneer volumes per unit area’ were also compared.

(3) Legal activities: the comparison between the two PA types in the entire country in the fiscal year 2006 - 2011 were: ‘the number of PAs that have each activity permitted in each region’; and ‘the frequency of activities permitted in PAs in each region’.

2.4 Results

(a) Forest fire in protected areas

i. Forest fires in national parks

The analysis of forest fire in national parks (NP) in 1999 - 2002 indicated that the percentage of NP in which forest fire occurred varied markedly between regions. The highest values were recorded in the Northern region, where 'the overall percentage of NPs which fire occurred' was 78.0%, and 'the overall mean (± S.E.) percentage of area burned' was 1.91 (± 0.54)%. A substantial percentage of NPs in the other regions also recorded fires, with 'the overall percentage of NPs' which fire occurred' accounting for 50%, 45% and 67.1% recorded in the Central, the Eastern and the Northeastern regions respectively. In contrast, fewer NPs recorded incidences of forest fire in the Southern region with 'the overall percentage of NPs' which fire occurred, accounting for 2.44%. A similar overall pattern was observed when the mean percentage of area burned within each PA was analysed, with overall values of mean (± S.E.) percentage of area burned, ranging from 0 (± 0)% in the Southern region to 1.91 (±0.54)% in the Northern region (Table 2.1).

Data for 2011 showed that both the percentage of NPs in which forest fire occurred (73.9%) and the mean (± S.E.) number of forest fires occurring per unit area (0.04 ± 0.02) were again highest in the Northeastern region. Again, values were much lower for the Southern region than for the others considered with 'the percentage of NPs in which forest fire occurred' value of 2.94%; only a single fire was recorded in this region during this year (Table 2.2).

ii. Forest fires in wildlife sanctuaries

When fires in wildlife sanctuaries (WS) in 1999 - 2002 were considered, the highest percentage of WS in which forest fire occurred was recorded in the Northeastern region, with 'the overall percentage of WSs' which fire occurred, recorded as 88.9%. However, the overall mean (± S.E.) percentage of area burned was highest in the Northern region (1.22 ± 0.19)%. The region associated with lowest figures was again the Southern region, where 'the overall percentage of WSs, which fire occurred' was 9.09%, and the overall mean percentage of area burned (± S.E.)' was 0.06 (± 0.04)% (Table 2.3).

Data for 2011 showed that both the percentage of WSs in which forest fire occurred (100%) and the mean (± S.E.) number of forest fires occurring per unit area (0.08 ± 0.07) were highest in the Eastern region. Again, values were much lower for the Southern region than for the others considered; no fire was recorded during 2011 (Table 2.4).

iii. Differences of forest fires in PA types

When fires were compared between PA types, fires occurred in WS slightly more than NP in relation to 'the percentage of PAs where fire occurred' both in 1999 – 2002, and 2011. In 1999 – 2002, the highest differences were recorded in the Northeastern region, where WS were 1.32 times more likely to experience forest fires than NPs (Table 2.5). The same was true for the Eastern region in 2011 with the WS:NP ratio of 1.8:1 (Table 2.6). However, in 2011 the opposite result was recorded in the Northern region, where NPs were almost twice as likely (ratio 1.95:1) to experience fires than WSs. (Table 2.6).

The opposite result was recorded in terms of the area burned. NP had a slightly higher proportion of area burned than WS in 1999-2002, especially in the Northern region where 'the mean percentage of area burned' was higher than those of WS with the NP:WS ratio 1.57:1 (Table 2.5). Differences in 'the mean percentage of area burned' between PA types in other regions (apart from the Southern region) had NP:WS ratios ranging from 0.36:1 in the Eastern region to 0.73:1 in the Northeastern region (Table 2.5), however the absolute numbers involved were small. It is worth mentioning that in the Southern region there was area burned recorded in the WSs, but no fires occurred in NPs.

In regard to frequency of fire in 2011, fires happened more often in WS than in NP per unit area. This situation was especially recorded in the Eastern region, where the 'mean number of fires occurring per unit area' of WS was higher than those of NP by 0.07 fires per km^2. The Northeast was the only region where fires per unit area was higher in NP than in WS; the difference between the 'average number of fires occurring per unit area' was 0.02. It is noted that no differences were recorded in the Northern region. Additionally, the 'mean number of fires occurring per unit area' of both WS and NP were zero in the Southern region (Table 2.6).

(b) Illegal cases that caused a reduction in forest area or cutting of tree species in each protected area.

i. Illegal cases in national parks

(1) Illegal area clearing

The analysis of illegal area clearing in NPs in three fiscal years 2009 - 2011 (1 October 2008 – 30 September 2011) indicated that the percentage of NPs in which cases of illegal area clearing occurred varied between regions. The highest values were recorded in the Southern region with the overall percentage of NPs that have illegal clearing cases being 87.3%, and the overall mean (± S.E.) number of illegal clearing cases per unit area was 0.05 (± 0.01) no. cases km^{-2}. However, the overall mean (± S.E.) percentage area of NPs that was cleared illegally was highest in the Northeastern region (0.44 ± 0.41%). The value of the area illegally cleared in the Northeastern region was markedly higher in 2011 than in other fiscal years at 1.27 (± 1.24)%. A substantial percentage of NP in the other regions also recorded illegal clearing cases, with the overall percentage of NPs that have illegal clearing cases being 61.9%, 76.7% and 79.7% in the Central, the Northern, and the Northeastern regions respectively. In contrast, the value recorded in the Eastern region was much lower with the overall percentage of NPs that have illegal clearing cases of 48.1%. The overall mean values of number of illegal clearing cases per unit area varied between 0.01 - 0.05 no. cases km^{-2} according to the different regions (Table 2.7).

(2) Illegal logging

When illegal logging in NP in the three fiscal years 2009 - 2011 was analysed, the highest value of overall percentage of NPs that have illegal logging cases (88.4%) was recorded in the Northern region. However, the overall mean (± S.E.) number of illegal logging cases per unit area was highest in the Northeastern region (0.04 $\pm$ 0.01 no. cases km^{-2}). The overall mean ($\pm$ S.E.) volume of log and veneer removed illegally per unit area of the NP was highest in the Southern region (0.23 $\pm$ 0.06 m^3 km^{-2}). The Southern region had fewer but more intensive incidences of illegal logging. A substantial percentage of NPs in the other regions also recorded illegal logging cases, with the overall percentage of NPs that had illegal logging cases accounting for 78.6%, 63.0%, and 66.7% recorded in the Central, the Eastern, and the Southern regions respectively. The overall mean values of the volume of log and veneer removed illegally per unit area of the NP varied between 0.02 - 0.23 m^3km^{-2}, depending on region, (Table 2.8).

ii. Illegal cases in wildlife sanctuaries

(1) Illegal area clearing

The analysis of illegal area clearing in WSs in the three fiscal years 2009 - 2011 indicated that the percentage of WS in which cases of illegal area clearing occurred did not vary much between regions (Table 2.9). The overall values were highest in the Northeastern region where 97.2% of WS experienced some illegal clearance and the overall mean ($\pm$ S.E.) number of illegal clearing cases per unit area was 0.05 $\pm$ 0.02 no. cases km^{-2}. However, the overall mean ($\pm$ S.E.) number of illegal area clearing cases per unit area and the overall mean ($\pm$ S.E.) percentage area of WSs illegally cleared were highest in the Southern region (0.21 $\pm$ 0.07 no. cases km^{-2} and 0.41 $\pm$ 0.18% respectively). A substantial percentage of WS in the other regions also recorded illegal clearing cases, with the overall percentage of WS affected being 83.3%, 83.3%, 73.3% and 84.6% recorded in the Eastern, the Northern, the Central, and the Southern regions respectively. When expressed as a percentage of the area of the WS, overall mean values affected by illegal clearing varied from 0.02 - 0.41% between regions (Table 2.9).

(2) Illegal logging

When illegal logging in WS in the three fiscal years 2009 - 2011 was analysed, the highest percentage of WS that had illegal logging cases was in the Central region (100%). However, the overall mean ($\pm$ S.E.) number of illegal logging cases per unit area was highest in the Northeastern region (0.14 $\pm$ 0.04 no. cases km^{-2}) (Table 2.10). Again, the overall mean ($\pm$ S.E.) of log and veneer volumes per unit area was highest in the Southern region (0.68 $\pm$ 0.26 m^3 km^{-2}). A substantial overall percentage of WS in the other regions also recorded illegal logging cases, with overall percentage of WS that have illegal logging cases being 75.0%, 83.3% and 84.6% recorded in the Eastern, the Northern and the Southern regions respectively. Overall mean values of volume of log and veneer that were removed illegally varied between 0.03 - 0.68 m^3 km^{-2}, depending on the region (Table 2.10).

iii. Differences of illegal cases in PA types

Illegal area clearing threatened WS more than NP in three fiscal years 2009 - 2011 in all three aspects. These are: (1) mean percentage of PAs that have illegal clearing cases; (2) mean number of illegal area clearing cases per unit area; and (3) mean percentage of illegal area clearing. The WS:NP ratios of those three aspects were 1.19:1, 3.9:1, and 1.23:1 respectively (Table 2.11). These three aspects threatened WS more than NP in almost all regions. However, in the Southern region, the mean percentage of NPs that have illegal clearing cases recorded was slightly higher than those of WS with the NP:WS ratio 1.03:1, the mean percentage area illegally cleared in NP was still lower than those of WS with the NP:WS ratio 0.15:1. The Northeast was the only region where the mean percentage area illegally cleared in NP was higher than those of WS with the NP:WS ratio 6.29:1(Table 2.11).

The same was true for illegal logging, where all three aspects of illegal logging threatened WS more than NP. Illegal logging aspects included: (1) mean percentage of PAs that have illegal clearing cases; (2) mean number of illegal logging cases per unit area; and (3) mean log and veneer volumes per unit area. The WS:NP ratios of those three aspects accounted for 1.15:1, 3:1 and 3.11:1 respectively (Table 2.12). Again, these three aspects threatened WS more than NP in almost all regions.

The highest difference was recorded in the Southern region, where WS were 5 times more threatened by illegal logging than NPs in terms of number of illegal logging cases per unit area, with almost 3 times more log and veneer volumes per unit area removed. The North was the only region where the mean percentage of NPs that have illegal logging cases was slightly higher than those of WS with the NP:WS ratio 1.06:1 (Table 2.12).

(c) Legal activities that likely caused a reduction in forest area or cutting of tree species

i. Legal activities permitted in national parks

The analysis of legal activities permitted in NP that likely caused a reduction in forest area or cutting of tree species in six fiscal years 2006 - 2011 (1 October 2005 – 30 September 2011) indicated that there was a total of 211 activities that were permitted across Thailand. The highest number of permitted activities was recorded in the Northern region and the lowest in the Eastern region (Table 2.13). In the Northern region, the most common activity was the creation of electricity lines, followed by road construction. Overall, considering all regions, road construction was the most prevalent activity permitted.

ii. Legal activities permitted in wildlife sanctuaries

The overall analysis of legal activities permitted in WS that likely caused a reduction in forest area or cutting of tree species in six fiscal years 2006 - 2011 indicated that there were 48 activities permitted in WS. The highest number of activities was recorded in the Northeastern region, where the main activity was infrastructural development not related to tourism. Overall, this was the main activity across regions. The lowest permitted activity was recorded in the Central region (Table 2.14).

iii. Differences of legal activities permitted in PA types

Legal activities permitted in PA were compared between the PA types in the six fiscal years 2006 – 2011. This indicated that the incidents happened in NP more than WS in all regions in both aspects, namely: 'the number of PAs that have each activity permitted in each region'; and 'the frequency of activities permitted in PAs in each region'. There were 132 more NPs than WS with legal activities occurring within them and 163 more incidences of legal activity within NPs than WS (Table 2.15 and 2.16). It is worth noting that there were 19 types of activities permitted in NP, while 15 types of activities were permitted in WS. The four activity types that were not recorded to be permitted in WS were: religious buildings; harbour; research area/centre; and telemetry station.

Even though almost all activities permitted in NP outweighed those in WS in terms of the number of PAs that have each activity permitted in all regions, the dam/reservoir was the only activity that threatened WS more than NP. There were five WSs where dams/reservoirs were permitted, while only one NP where a dam/ reservoir was permitted (Table 2.15). Again almost all activities permitted in NP outweighed those in WS in terms of 'the frequency of activities permitted in PAs in all regions', apart from two activities that were permitted in WS more than in NP. These are: dam/reservoir; and landscape development for non tourism (Table 2.16).

Table 2.1 Forest area burned in national parks in 1999 – 2002

No.	Region	Area of NP (km^2)	No. of NP	No. of NP that forest fire occurred	Percentage of NP that forest fire occurred	Total area burned (km^2)	Percentage of area burned	
							Mean	S.E
Year 1999								
1	Central	8,545	10	4	40.0	31.5	0.23	0.15
2	East	1,714	5	2	40.0	1.45	0.04	0.03
3	North	15,258	25	19	76.0	847	5.60	2.16
4	Northeast	9,526	18	9	50.0	42.4	0.78	0.35
5	South	3,682	9	0	0.00	0.00	0.00	0.00
	Summary	38,725	67	34	50.7	922	2.34	0.86
Year 2000								
1	Central	8,545	10	2	20.0	0.37	0.00	0.00
2	East	1,714	5	2	40.0	0.13	0.00	0.00
3	North	15,258	25	16	64.0	107	0.72	0.22
4	Northeast	9,526	18	12	66.7	16.6	0.16	0.08

No.	Region	Area of NP (km^2)	No. of NP	No. of NP that forest fire occurred	Percentage of NP that forest fire occurred	Total area burned (km^2)	Percentage of area burned	
							Mean	S.E
5	South	3,682	9	0	0.00	0.00	0.00	0.00
	Summary	38,725	67	32	47.8	124	0.31	0.09
Year 2001								
1	Central	8,545	10	5	50.0	1.60	0.06	0.05
2	East	1,714	5	2	40.0	0.56	0.02	0.02
3	North	16,962	26	20	76.9	59.1	0.29	0.10
4	Northeast	9,526	18	10	55.6	9.24	0.23	0.13
5	South	3,682	9	0	0.00	0.00	0.00	0.00
	Summary	40,429	68	37	54.4	70.5	0.18	0.05
Year 2002								
1	Central	8,545	10	9	90.0	10.5	0.31	0.15
2	East	1,714	5	3	60.0	3.79	0.11	0.06
3	North	20,951	33	30	90.9	265	1.09	0.25
4	Northeast	9,723	19	18	94.7	57.0	0.33	0.08
5	South	5,507	14	1	7.14	0.01	0.00	0.00
	Summary	46,441	81	61	75.3	337	0.57	0.12
	Total (1999-2002)	-	-	-	-	1,453	0.85	0.50

Table 2.2 Forest fire frequency in national parks in 2011

No.	Region	Area of NP (km^2)	No. of NP	No. of NP in which forest fire occurred	Percentage of NP in which forest fire occurred	Total no. of forest fires occurred	No. of forest fires occurring per unit area (no. fires km^{-2})	
							Mean	S.E
1	Central	10,589	14	7	50.0	69	0.01	0.01
2	East	2,811	9	5	55.6	13	0.01	0.00
3	North	25,200	43	28	65.1	309	0.01	0.00
4	Northeast	10,477	23	17	73.9	333	0.04	0.02
5	South	11,243	34	1	2.94	1	0.00	0.00
	Summary	60,320	123	58	47.1	725	0.01	0.01

Table 2.3 Forest area burned in wildlife sanctuaries in 1999 – 2002

No.	Region	Area of WS (km^2)	No. of WS	No. of WS that forest fire occurred	Percentage of WS that forest fire occurred	Total burned area (km^2)	Percentage of area burned	
							Mean	S.E
Year 1999								
1	Central	5,815	5	5	100	108	0.66	0.56
2	East	1,969	3	2	66.7	6.29	0.20	0.18
3	North	14,409	16	12	75.0	436	2.29	0.79
4	Northeast	4,683	9	8	88.9	21.2	0.38	0.10
5	South	5,410	11	2	18.2	5.31	0.21	0.16
	Summary	32,285	44	29	65.9	577	1.05	0.33

No.	Region	Area of WS (km^2)	No. of WS	No. of WS that forest fire occurred	Percentage of WS that forest fire occurred	Total burned area (km^2)	Percentage of area burned	
							Mean	S.E
Year 2000								
1	Central	5,815	5	1	20.0	0.24	0.01	0.01
2	East	1,969	3	2	66.7	0.61	0.02	0.01
3	North	14,409	16	11	68.8	128	1.11	0.42
4	Northeast	4,683	9	7	77.8	7.35	0.12	0.05
5	South	5,410	11	0	0.00	0.00	0.00	0.00
	Summary	32,285	44	21	47.7	136	0.43	0.17
Year 2001								
1	Central	5,815	5	2	40.0	2.94	0.03	0.02
2	East	1,969	3	0	0.00	0.00	0.00	0.00
3	North	14,409	16	10	62.5	58.2	0.39	0.11
4	Northeast	4,683	9	8	88.9	33.6	1.14	0.76
5	South	5,410	11	1	9.09	0.69	0.02	0.02
	Summary	32,285	44	21	47.73	95.4	0.38	0.17
Year 2002								
1	Central	5,815	5	5	100	17.5	0.15	0.08
2	East	1,969	3	2	66.7	6.38	0.21	0.15
3	North	14,409	16	12	75.0	88.5	1.11	0.36
4	Northeast	4,683	9	9	100	18.2	0.45	0.16
5	South	5,410	11	1	9.09	0.28	0.01	0.01
	Summary	32,285	44	29	65.9	131	0.53	0.15
	Total (1999-2002)	-	-	-	-	939	0.60	0.15

Table 2.4 Forest fire frequency in wildlife sanctuaries in 2011

No.	Region	Area of WS (km^2)	No. of WS	No. of WS that forest fire occurred	Percentage of WS that forest fire occurred	Total no. of forest fire occurred	No. of forest fire occurring per unit area (no. fires km^{-2})	
							Mean	S.E
1	Central	5,815	5	4	80.0	49	0.02	0.01
2	East	2,234	4	4	100	54	0.08	0.07
3	North	17,329	24	8	33.3	140	0.01	0.00
4	Northeast	5,455	12	9	75.0	108	0.02	0.00
5	South	6,096	13	0	0.00	0	0.00	0.00
	Summary	36,929	58	25	43.1	351	0.03	0.01

Table 2.5 Comparison of forest area burned between national parks and wildlife sanctuaries in 1999-2002.

Region	Percentage of PAs in which forest fire occurred		Percentage of area burned			
			NP		WS	
	NP	WS	Mean	S.E.	Mean	S.E.
Year 1999-2002						
Central	50.0	65.0	0.15	0.05	0.21	0.16
East	45.0	50.0	0.04	0.03	0.11	0.08
North	78.0	70.3	1.91	0.54	1.22	0.19
Northeast	67.1	88.9	0.38	0.11	0.52	0.17
South	2.44	9.09	0.00	0.00	0.06	0.04
Average	48.51	56.66	0.50	0.15	0.42	0.13

Table 2.6 Comparison of forest fire frequency between national parks and wildlife sanctuaries in 2011

Region	Percentage of PAs in which forest fire occurred		No. of forest fires occurring per unit area (no. fires km^{-2})			
			NP		WS	
	NP	WS	Mean	S.E.	Mean	S.E.
Year 2011						
Central	50.0	80.0	0.01	0.01	0.02	0.01
East	55.6	100	0.01	0.00	0.08	0.07
North	65.1	33.3	0.01	0.00	0.01	0.00
Northeast	73.9	75.0	0.04	0.02	0.02	0.00
South	2.94	0.00	0.00	0.00	0.00	0.00
Average	49.51	57.66	0.01	0.01	0.03	0.02

Table 2.7 Illegal area clearing in national parks in fiscal year 2009 – 2011

No.	Region	Area of NP (km^2)	No. of NP	No. of NP that have illegal area clearing cases	Percentage of NP that have illegal area clearing cases	Total no. of illegal area clearing cases	No. of illegal area clearing cases per unit area (no. cases km^{-2})		Illegal area clearing (km^2)	Percentage of illegal area clearing	
							Mean	S.E		Mean	S.E
Fiscal year 2009											
1	Central	10,589	14	8	57.1	126	0.01	0.00	1.48	0.01	0.01
2	East	2,811	9	5	55.6	20	0.01	0.01	0.34	0.03	0.03
3	North	25,200	43	33	76.7	345	0.01	0.00	2.41	0.01	0.00
4	Northeast	10,477	23	18	78.3	114	0.02	0.01	1.69	0.03	0.01
5	South	11,243	34	29	85.3	532	0.05	0.01	8.39	0.07	0.02
	Summary	60,320	123	93	75.6	1,137	0.02	0.01	14.3	0.03	0.01
Fiscal year 2010											
1	Central	10,589	14	8	57.1	66	0.00	0.00	0.71	0.01	0.00
2	East	2,811	9	4	44.4	8	0.00	0.00	0.03	0.00	0.00
3	North	25,200	43	35	81.4	357	0.01	0.00	3.09	0.01	0.00

No.	Region	Area of NP (km^2)	No. of NP	No. of NP that have illegal area clearing cases	Percentage of NP that have illegal area clearing cases	Total no. of illegal area clearing cases	No. of illegal area clearing cases per unit area (no. cases km^{-2})		Illegal area clearing (km^2)	Percentage of illegal area clearing	
							Mean	S.E		Mean	S.E
4	Northeast	10,477	23	18	78.3	122	0.02	0.01	1.51	0.02	0.01
5	South	11,243	34	30	88.2	576	0.06	0.01	7.18	0.07	0.02
	Summary	60,320	123	95	77.2	1,129	0.02	0.01	12.5	0.03	0.01
Fiscal year 2011											
1	Central	10,589	14	10	71.4	117	0.01	0.00	2.19	0.02	0.01
2	East	2,811	9	4	44.4	14	0.01	0.00	0.05	0.00	0.00
3	North	25,200	43	31	72.1	321	0.01	0.00	2.28	0.01	0.00
4	Northeast	10,477	23	19	82.6	157	0.02	0.00	5.06	1.27	1.24
5	South	11,243	34	30	88.2	351	0.04	0.01	3.92	0.04	0.01
	Summary	60,320	123	94	76.4	960	0.02	0.01	13.5	0.25	0.23
Total (2009 - 2011)		-	-	-	-	3,226	0.02	0.00	40.3	0.10	0.07

Table 2.8 Illegal logging in national parks in fiscal year 2009 – 2011

No.	Region	Area of NP (km^2)	No. of NP	No. of NP that have logging cases	Percentage of NP that have illegal logging cases	Total no. of illegal logging cases	No. of illegal logging cases per unit area (no. cases km^{-2})		Log& veneer volumes (m^3)	Log& veneer volumes per unit area (m^3/km^2)	
							Mean	S.E		Mean	S.E
Fiscal year 2009											
1	Central	10,589	14	10	71.4	92	0.01	0.00	194.8	0.02	0.01
2	East	2,811	9	6	66.7	34	0.02	0.01	52.49	0.03	0.02
3	North	25,200	43	39	90.7	500	0.02	0.00	668.1	0.03	0.01
4	Northeast	10,477	23	17	73.9	210	0.02	0.01	280.9	0.03	0.01
5	South	11,243	34	20	58.8	122	0.01	0.00	2,556	0.21	0.06
	Summary	60,320	123	92	74.8	958	0.02	0.00	3,752	0.06	0.04
Fiscal year 2010											
1	Central	10,589	14	11	78.6	97	0.01	0.00	110.9	0.01	0.00
2	East	2,811	9	6	66.7	43	0.01	0.01	75.74	0.03	0.02
3	North	25,200	43	40	93.0	469	0.02	0.00	573.7	0.03	0.01
4	Northeast	10,477	23	20	87.0	223	0.03	0.01	265.3	0.03	0.01
5	South	11,243	34	26	76.5	126	0.01	0.00	1,878	0.16	0.04
	Summary	60,320	123	103	83.7	958	0.02	0.00	2,903	0.05	0.03
Fiscal year 2011											
1	Central	10,589	14	12	78.6	97	0.01	0.00	262.0	0.05	0.02
2	East	2,811	9	5	66.7	45	0.01	0.01	48.82	0.01	0.01
3	North	25,200	43	35	93.0	419	0.02	0.00	507.1	0.02	0.00
4	Northeast	10,477	23	22	87.0	541	0.06	0.01	556.3	0.06	0.01
5	South	11,243	34	22	76.5	96	0.01	0.00	2,730	0.31	0.09
	Summary	60,320	123	96	78.0	1,198	0.02	0.01	4,104	0.09	0.06
Total (2009 - 2011)		-	-	-	-	3,114	0.02	0.00	10,760	0.07	0.01

Table 2.9 Illegal area clearing in wildlife sanctuaries in fiscal year 2009 – 2011

No.	Region	Area of WS (km^2)	No. of WS	No. of WS that have illegal area clearing cases	Percentage of WS that have illegal area clearing cases	Total no. of area clearing cases	No. of illegal area clearing cases per unit area (no. cases km^{-2})		Illegal area clearing (km^2)	Percentage of illegal area clearing	
							Mean	S.E		Mean	S.E
Fiscal year 2009											
1	Central	5,815	5	3	60.0	115	0.03	0.03	2.08	0.06	0.05
2	East	2,234	4	4	100	13	0.01	0.00	0.20	0.01	0.01
3	North	17,329	24	19	79.2	177	0.01	0.00	1.40	0.01	0.00
4	Northeast	5,455	12	11	91.7	56	0.01	0.00	0.55	0.01	0.01
5	South	6,096	13	10	76.9	461	0.10	0.04	9.12	0.23	0.11
	Summary	36,929	58	47	81.0	822	0.03	0.02	13.4	0.06	0.04
Fiscal year 2010											
1	Central	5,815	5	4	80.0	364	0.10	0.09	5.13	0.15	0.14
2	East	2,234	4	3	75.0	45	0.03	0.02	0.59	0.04	0.03
3	North	17,329	24	21	87.5	512	0.03	0.01	4.09	0.03	0.01
4	Northeast	5,455	12	12	100	286	0.06	0.03	5.21	0.10	0.05
5	South	6,096	13	12	92.3	1,133	0.26	0.09	20.3	0.50	0.22
	Summary	36,929	58	52	89.7	2,340	0.10	0.04	35.3	0.16	0.09
Fiscal year 2011											
1	Central	5,815	5	4	80.0	364	0.10	0.09	5.13	0.15	0.14
2	East	2,234	4	3	75.0	45	0.03	0.02	0.59	0.04	0.03
3	North	17,329	24	20	83.3	509	0.03	0.01	4.08	0.03	0.01
4	Northeast	5,455	12	12	100	286	0.06	0.03	5.21	0.10	0.05
5	South	6,096	13	11	84.6	1,131	0.26	0.09	20.3	0.50	0.22
	Summary	36,929	58	50	86.2	2,335	0.10	0.04	35.3	0.16	0.09
Total (2009 - 2011)		-	-	-	-	5,497	0.08	0.02	84.0	0.13	0.03

Table 2.10 Illegal logging in wildlife sanctuaries in fiscal year 2009 – 2011

No.	Region	Area of WS (km^2)	No. of WSs	No. of WS that have logging cases	Percentage of WS that have illegal logging cases	Total no. of illegal logging cases	No. of illegal logging cases per unit area (no. cases km^{-2})		Log& veneer volumes (m^3)	Log& veneer volumes per unit area (m^3/km^2)	
							Mean	S.E		Mean	S.E
Fiscal year 2009											
1	Central	5,815	5	5	100	45	0.01	0.00	228.8	0.08	0.07
2	East	2,234	4	3	75.0	29	0.01	0.00	35.78	0.02	0.00
3	North	17,329	24	20	83.3	118	0.01	0.00	172.1	0.01	0.00
4	Northeast	5,455	12	11	91.7	181	0.04	0.01	299.1	0.08	0.02
5	South	6,096	13	10	76.9	102	0.02	0.01	2,241	0.29	0.12
	Summary	36,929	58	49	84.5	475	0.02	0.01	2,976	0.10	0.05
Fiscal year 2010											
1	Central	5,815	5	5	100	105	0.03	0.01	524.3	0.16	0.12
2	East	2,234	4	3	75.0	59	0.02	0.01	66.23	0.03	0.01
3	North	17,329	24	20	83.3	367	0.03	0.01	806.0	0.05	0.02

No.	Region	Area of WS (km^2)	No. of WSs	No. of WS that have logging cases	Percentage of WS that have illegal logging cases	Total no. of illegal logging cases	No. of illegal logging cases per unit area (no. cases km^{-2})		Log& veneer volumes (m^3)	Log& veneer volumes per unit area (m^3/km^2)	
							Mean	S.E		Mean	S.E
4	Northeast	5,455	12	12	100.0	782	0.19	0.06	1,005	0.25	0.08
5	South	6,096	13	12	92.3	251	0.06	0.02	5,539	0.86	0.33
	Summary	36,929	58	52	89.7	1,564	0.07	0.03	7,941	0.27	0.15
Fiscal year 2011											
1	Central	5,815	5	5	100	105	0.03	0.01	524.3	0.16	0.12
2	East	2,234	4	3	75.0	59	0.02	0.01	66.23	0.03	0.01
3	North	17,329	24	20	83.3	366	0.03	0.01	805.9	0.06	0.02
4	Northeast	5,455	12	12	100	782	0.19	0.06	1,005	0.25	0.08
5	South	6,096	13	11	84.6	250	0.06	0.02	5,552	0.87	0.32
	Summary	36,929	58	51	87.9	1,562	0.07	0.03	7,954	0.27	0.15
Total (2009 - 2011)		-	-	-	-	3,601	0.05	0.02	18,871	0.21	0.06

Table 2.11 Comparison between national parks and wildlife sanctuaries regarding the illegal area clearing in fiscal year 2009 – 2011

Region	Percentage of NPs that have illegal clearing cases		No. of illegal area clearing cases per unit area (no. cases km^{-2})				Percentage of illegal area clearing			
	NP	WS	NP		WS		NP		WS	
			Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Year 2009-2011										
Central	61.9	73.3	0.01	0.00	0.08	0.07	0.01	0.01	0.12	0.11
East	48.1	83.3	0.01	0.00	0.02	0.01	0.01	0.01	0.03	0.02
North	76.7	83.3	0.01	0.00	0.03	0.00	0.01	0.00	0.02	0.00
Northeast	79.7	97.2	0.02	0.00	0.05	0.02	0.44	0.41	0.07	0.03
South	87.3	84.6	0.05	0.01	0.21	0.07	0.06	0.01	0.41	0.18
Average	70.74	84.34	0.02	0.00	0.08	0.03	0.11	0.09	0.13	0.07

Table 2.12 Comparison between national parks and wildlife sanctuaries regarding the illegal logging in fiscal year 2009 – 2011

Region	Percentage of NPs that have illegal logging cases		No. of illegal logging cases per unit area (no. cases km^{-2})				Log& veneer volumes per unit area (m^3/km^2)			
	NP	WS	NP		WS		NP		WS	
			Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Year 2009-2011										
Central	78.6	100	0.01	0.00	0.03	0.01	0.03	0.01	0.15	0.12
East	63	75	0.01	0.01	0.02	0.00	0.02	0.01	0.03	0.01
North	88.4	83.3	0.02	0.00	0.03	0.01	0.03	0.00	0.04	0.01
Northeast	85.5	97.2	0.04	0.01	0.14	0.04	0.04	0.01	0.19	0.06
South	66.7	84.6	0.01	0.00	0.05	0.02	0.23	0.06	0.68	0.26
Average	76.44	88.02	0.02	0.00	0.05	0.02	0.07	0.02	0.22	0.09

Table 2.13 The legal activities permitted in national parks in fiscal year 2006 – 2011

No.	Activities permitted in NP	Frequency of activities permitted in NP in each region					Sum. frequency of activities	No. of NP that have each activity permitted in each region					Sum no. of NP
		C	E	N	N-E	S		C	E	N	N-E	S	
Fiscal year 2006													
1	Dam/ Reservoir	0	0	0	0	1	**1**	0	0	0	0	1	**1**
2	Small water body	0	0	0	0	0	**0**	0	0	0	0	0	**0**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	2	0	2	3	1	**8**	2	0	2	2	1	**7**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	0	0	1	1	0	**2**	0	0	1	1	0	**2**
7	Infrastructural development related to tourism	0	0	1	2	0	**3**	0	0	1	2	0	**3**
8	Landscape development for tourism	0	0	2	1	0	**3**	0	0	2	1	0	**3**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Religious building	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Broadcasting station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
12	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Harbour	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Research area/centre	0	0	1	0	0	**1**	0	0	1	0	0	**1**
15	Pipe line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
16	Monument/Buddha image	0	0	0	0	2	**2**	0	0	0	0	2	**2**
17	Infrastructural development not related to tourism	0	0	0	0	1	**1**	0	0	0	0	1	**1**
18	Solar cell area	0	0	0	0	0	**0**	0	0	0	0	0	**0**
19	Telemetry station	1	0	0	0	0	**1**	1	0	0	0	0	**1**
	Summary	3	0	7	7	5	**22**	-	-	-	-	-	**-**
Fiscal year 2007													
1	Dam/ Reservoir	0	0	0	0	0	**0**	0	0	0	0	0	**0**
2	Small water body	0	0	0	0	0	**0**	0	0	0	0	0	**0**
3	National security project	0	0	0	0	2	**2**	0	0	0	0	2	**2**
4	Road	1	0	4	1	2	**8**	1	0	3	1	2	**7**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	1	0	1	1	1	**4**	1	0	1	1	1	**4**
7	Infrastructural development related to tourism	2	0	2	3	1	**8**	2	0	2	3	1	**8**
8	Landscape development for tourism	0	0	3	1	0	**4**	0	0	2	1	0	**3**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Religious building	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Broadcasting station	0	0	1	2	0	**3**	0	0	1	2	0	**3**
12	Training centre/educational institute	0	0	1	0	0	**1**	0	0	1	0	0	**1**
13	Harbour	0	0	0	0	1	**1**	0	0	0	0	1	**1**

No.	Activities permitted in NP	Frequency of activities permitted in NP in each region					Sum. frequency of activities	No. of NP that have each activity permitted in each region					Sum no. of NP
		C	E	N	N-E	S		C	E	N	N-E	S	
14	Research area/centre	0	0	2	0	0	**2**	0	0	2	0	0	**2**
15	Pipe line	0	0	2	0	0	**2**	0	0	2	0	0	**2**
16	Monument/Buddha image	0	0	0	0	2	**2**	0	0	0	0	2	**2**
17	Infrastructural development not related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
18	Solar cell area	0	0	0	0	0	**0**	0	0	0	0	0	**0**
19	Telemetry station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	Summary	4	0	16	8	9	**37**	-	-	-	-	-	**-**
Fiscal year 2008													
1	Dam/ Reservoir	0	0	0	0	0	**0**	0	0	0	0	0	**0**
2	Small water body	0	0	0	2	0	**2**	0	0	0	2	0	**2**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	3	0	3	0	1	**7**	2	0	3	0	1	**6**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	1	0	1	0	0	**2**	1	0	1	0	0	**2**
7	Infrastructural development related to tourism	0	0	1	0	0	**1**	0	0	1	0	0	**1**
8	Landscape development for tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Religious building	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Broadcasting station	0	0	2	2	0	**4**	0	0	2	2	0	**4**
12	Training centre/educational institute	0	0	0	0	1	**1**	0	0	0	0	1	**1**
13	Harbour	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Research area/centre	0	0	1	0	0	**1**	0	0	1	0	0	**1**
15	Pipe line	1	0	3	0	3	**7**	1	0	3	0	3	**7**
16	Monument/Buddha image	0	0	1	1	0	**2**	0	0	1	1	0	**2**
17	Infrastructural development not related to tourism	0	1	3	0	0	**4**	0	1	2	0	0	**3**
18	Solar cell area	0	0	0	2	0	**2**	0	0	0	2	0	**2**
19	Telemetry station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	Summary	5	1	15	7	5	**33**	-	-	-	-	-	**-**
Fiscal year 2009													
1	Dam/ Reservoir	0	0	0	0	0	**0**	0	0	0	0	0	**0**
2	Small water body	0	0	1	0	0	**1**	0	0	1	0	0	**1**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	1	0	1	0	0	**2**	1	0	1	0	0	**2**
5	Nature trail	1	0	1	0	0	**2**	1	0	1	0	0	**2**
6	Electricity line	0	0	5	0	1	**6**	0	0	3	0	1	**4**
7	Infrastructural development related to tourism	2	1	0	0	0	**3**	2	1	0	0	0	**3**
8	Landscape development for tourism	0	1	0	0	0	**1**	0	1	0	0	0	**1**

No.	Activities permitted in NP	Frequency of activities permitted in NP in each region					Sum. frequency of activities	No. of NP that have each activity permitted in each region					Sum no. of NP
		C	E	N	N-E	S		C	E	N	N-E	S	
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Religious building	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Broadcasting station	0	0	2	1	3	**6**	0	0	2	1	3	**6**
12	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Harbour	0	0	0	0	1	**1**	0	0	0	0	1	**1**
14	Research area/centre	0	0	0	0	0	**0**	0	0	0	0	0	**0**
15	Pipe line	1	0	0	0	0	**1**	1	0	0	0	0	**1**
16	Monument/Buddha image	0	0	0	0	1	**1**	0	0	0	0	1	**1**
17	Infrastructural development not related to tourism	0	0	1	0	2	**3**	0	0	1	0	2	**3**
18	Solar cell area	0	0	0	0	1	**1**	0	0	0	0	1	**1**
19	Telemetry station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	Summary	5	2	11	1	9	**28**	-	-	-	-	-	**-**
Fiscal year 2010													
1	Dam/ Reservoir	0	0	0	0	0	**0**	0	0	0	0	0	**0**
2	Small water body	1	0	0	0	1	**2**	1	0	0	0	1	**2**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	4	1	1	3	0	**9**	3	1	1	2	0	**7**
5	Nature trail	0	0	0	0	1	**1**	0	0	0	0	1	**1**
6	Electricity line	3	0	4	0	0	**7**	2	0	4	0	0	**6**
7	Infrastructural development related to tourism	0	2	1	1	0	**4**	0	2	1	1	0	**4**
8	Landscape development for tourism	1	1	1	0	2	**5**	1	1	1	0	2	**5**
9	Landscape development for non tourism	1	0	0	0	1	**2**	1	0	0	0	1	**2**
10	Religious building	0	0	0	0	1	**1**	0	0	0	0	1	**1**
11	Broadcasting station	0	0	0	1	2	**3**	0	0	0	1	2	**3**
12	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Harbour	0	1	0	0	0	**1**	0	1	0	0	0	**1**
14	Research area/centre	1	0	0	1	0	**2**	1	0	0	1	0	**2**
15	Pipe line	1	0	0	0	1	**2**	1	0	0	0	1	**2**
16	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**
17	Infrastructural development not related to tourism	1	0	0	0	0	**1**	1	0	0	0	0	**1**
18	Solar cell area	1	0	0	1	0	**2**	1	0	0	1	0	**2**
19	Telemetry station	0	0	0	1	0	**1**	0	0	0	1	0	**1**
	Summary	14	5	7	8	9	**43**	-	-	-	-	-	**-**
Fiscal year 2011													
1	Dam/ Reservoir	0	0	0	0	0	**0**	0	0	0	0	0	**0**
2	Small water body	0	0	0	0	0	**0**	0	0	0	0	0	**0**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**

No.	Activities permitted in NP	Frequency of activities permitted in NP in each region					Sum. frequency of activities	No. of NP that have each activity permitted in each region					Sum no. of NP
		C	E	N	N-E	S		C	E	N	N-E	S	
4	Road	2	0	2	1	0	**5**	2	0	2	1	0	**5**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	1	0	3	1	2	**7**	1	0	3	1	2	**7**
7	Infrastructural development related to tourism	3	2	1	2	1	**9**	2	2	1	2	1	**8**
8	Landscape development for tourism	0	3	0	4	3	**10**	0	3	0	3	2	**8**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Religious building	0	0	1	0	0	**1**	0	0	1	0	0	**1**
11	Broadcasting station	0	1	0	0	0	**1**	0	1	0	0	0	**1**
12	Training centre/educational institute	1	0	0	0	0	**1**	1	0	0	0	0	**1**
13	Harbour	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Research area/centre	0	0	0	0	0	**0**	0	0	0	0	0	**0**
15	Pipe line	0	1	0	0	0	**1**	0	1	0	0	0	**1**
16	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**
17	Infrastructural development not related to tourism	3	1	3	0	1	**8**	3	1	3	0	1	**8**
18	Solar cell area	0	0	1	3	0	**4**	0	0	1	3	0	**4**
19	Telemetry station	0	0	1	0	0	**1**	0	0	1	0	0	**1**
	Summary	10	8	12	11	7	**48**	-	-	-	-	-	**-**
Fiscal year 2006-2011													
1	Dam/ Reservoir	0	0	0	0	1	**1**	0	0	0	0	1	**1**
2	Small water body	1	0	1	2	1	**5**	1	0	1	2	1	**5**
3	National security project	0	0	0	0	2	**2**	0	0	0	0	2	**2**
4	Road	13	1	13	8	4	**39**	6	1	10	5	4	**26**
5	Nature trail	1	0	1	0	1	**3**	1	0	1	0	1	**3**
6	Electricity line	6	0	15	3	4	**28**	3	0	9	3	3	**18**
7	Infrastructural development related to tourism	7	5	6	8	2	**28**	5	3	5	6	2	**21**
8	Landscape development for tourism	1	5	6	6	5	**23**	1	5	5	5	4	**20**
9	Landscape development for non tourism	1	0	0	0	1	**2**	1	0	0	0	1	**2**
10	Religious building	0	0	1	0	1	**2**	0	0	1	0	1	**2**
11	Broadcasting station	0	1	5	6	5	**17**	0	1	5	4	5	**15**
12	Training centre/educational institute	1	0	1	0	1	**3**	1	0	1	0	1	**3**
13	Harbour	0	1	0	0	2	**3**	0	1	0	0	1	**2**
14	Research area/centre	1	0	4	1	0	**6**	1	0	2	1	0	**4**
15	Pipe line	3	1	5	0	4	**13**	3	1	5	0	4	**13**
16	Monument/Buddha image	0	0	1	1	5	**7**	0	0	1	1	5	**7**
17	Infrastructural development not related to tourism	4	2	7	0	4	**17**	3	2	6	0	3	**14**
18	Solar cell area	1	0	1	6	1	**9**	1	0	1	4	1	**7**

No.	Activities permitted in NP	Frequency of activities permitted in NP in each region					Sum. frequency of activities	No. of NP that have each activity permitted in each region					Sum no. of NP
		C	E	N	N-E	S		C	E	N	N-E	S	
19	Telemetry station	1	0	1	1	0	**3**	1	0	1	1	0	**3**
	Summary	41	16	68	42	44	**211**	-	-	-	-	-	**-**

Table 2.14 The legal activities permitted in wildlife sanctuaries in fiscal year 2006 – 2011

No.	Activities permitted in WS	Frequency of activities permitted in WS in each region					Sum. frequency of activities	No. of WS that have each activity permitted in each region					Sum no. of WS
		C	E	N	N-E	S		C	E	N	N-E	S	
Fiscal year 2006													
1	Dam/ Reservoir	0	0	0	0	1	**1**	0	0	0	0	1	**1**
2	Small water body	0	0	0	0	0	**0**	0	0	0	0	0	**0**
3	National security project	0	0	0	1	0	**1**	0	0	0	1	0	**1**
4	Road	0	0	0	0	0	**0**	0	0	0	0	0	**0**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
7	Infrastructural development related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
8	Landscape development for tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Broadcasting station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
12	Pipe line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Infrastructural development not related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
15	Solar cell area	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	Summary	0	0	0	1	1	**2**	-	-	-	-	-	**-**
Fiscal year 2007													
1	Dam/ Reservoir	0	0	0	1	0	**1**	0	0	0	1	0	**1**
2	Small water body	0	0	0	0	0	**0**	0	0	0	0	0	**0**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	0	0	0	1	0	**1**	0	0	0	1	0	**1**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
7	Infrastructural development related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
8	Landscape development for tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Broadcasting station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
12	Pipe line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**

No.	Activities permitted in WS	Frequency of activities permitted in WS in each region					Sum. frequency of activities	No. of WS that have each activity permitted in each region					Sum no. of WS
		C	E	N	N-E	S		C	E	N	N-E	S	
14	Infrastructural development not related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
15	Solar cell area	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	Summary	0	0	0	2	0	**2**	-	-	-	-	-	**-**
Fiscal year 2008													
1	Dam/ Reservoir	0	0	0	2	1	**3**	0	0	0	2	1	**3**
2	Small water body	0	0	0	0	0	**0**	0	0	0	0	0	**0**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	0	0	0	0	0	**0**	0	0	0	0	0	**0**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
7	Infrastructural development related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
8	Landscape development for tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
9	Landscape development for non tourism	0	0	0	0	1	**1**	0	0	0	0	1	**1**
10	Broadcasting station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
12	Pipe line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Monument/Buddha image	1	0	0	0	0	**1**	1	0	0	0	0	**1**
14	Infrastructural development not related to tourism	0	2	0	1	1	**4**	0	2	0	1	1	**4**
15	Solar cell area	0	0	0	0	0	**0**	0	0	0	0	0	**0**
	Summary	1	2	0	3	3	**9**	-	-	-	-	-	**-**
Fiscal year 2009													
1	Dam/ Reservoir	0	0	0	0	1	**1**	0	0	0	0	1	**1**
2	Small water body	0	2	0	0	0	**2**	0	1	0	0	0	**1**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	0	0	0	1	0	**1**	0	0	0	1	0	**1**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
7	Infrastructural development related to tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
8	Landscape development for tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
9	Landscape development for non tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
10	Broadcasting station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Training centre/educational institute	0	0	1	0	0	**1**	0	0	1	0	0	**1**
12	Pipe line	1	0	0	0	0	**1**	1	0	0	0	0	**1**
13	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Infrastructural development not related to tourism	0	0	1	1	0	**2**	0	0	1	1	0	**2**
15	Solar cell area	1	0	1	0	0	**2**	1	0	1	0	0	**2**
	Summary	2	2	3	2	1	**10**	-	-	-	-	-	**-**

No.	Activities permitted in WS	Frequency of activities permitted in WS in each region					Sum. frequency of activities	No. of WS that have each activity permitted in each region					Sum no. of WS
		C	E	N	N-E	S		C	E	N	N-E	S	
Fiscal year 2010													
1	Dam/ Reservoir	0	0	0	0	2	**2**	0	0	0	0	1	**1**
2	Small water body	0	0	0	1	0	**1**	0	0	0	1	0	**1**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	0	0	1	0	0	**1**	0	0	1	0	0	**1**
5	Nature trail	0	0	0	0	0	**0**	0	0	0	0	0	**0**
6	Electricity line	0	0	1	0	0	**1**	0	0	1	0	0	**1**
7	Infrastructural development related to tourism	1	0	0	0	0	**1**	1	0	0	0	0	**1**
8	Landscape development for tourism	0	1	0	0	0	**1**	0	1	0	0	0	**1**
9	Landscape development for non tourism	0	0	1	0	0	**1**	0	0	1	0	0	**1**
10	Broadcasting station	0	0	0	1	0	**1**	0	0	0	1	0	**1**
11	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
12	Pipe line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Infrastructural development not related to tourism	0	0	1	2	0	**3**	0	0	1	2	0	**3**
15	Solar cell area	1	0	3	0	0	**4**	1	0	3	0	0	**4**
	Summary	2	1	7	4	2	**16**	-	-	-	-	-	**-**
Fiscal year 2011													
1	Dam/ Reservoir	0	0	0	0	0	**0**	0	0	0	0	0	**0**
2	Small water body	0	1	0	1	0	**2**	0	1	0	1	0	**2**
3	National security project	0	0	0	0	0	**0**	0	0	0	0	0	**0**
4	Road	0	0	0	0	0	**0**	0	0	0	0	0	**0**
5	Nature trail	0	1	0	0	0	**1**	0	1	0	0	0	**1**
6	Electricity line	0	2	0	0	0	**2**	0	1	0	0	0	**1**
7	Infrastructural development related to tourism	0	1	0	0	0	**1**	0	1	0	0	0	**1**
8	Landscape development for tourism	0	0	0	0	0	**0**	0	0	0	0	0	**0**
9	Landscape development for non tourism	0	0	0	0	1	**1**	0	0	0	0	1	**1**
10	Broadcasting station	0	0	0	0	0	**0**	0	0	0	0	0	**0**
11	Training centre/educational institute	0	0	0	0	0	**0**	0	0	0	0	0	**0**
12	Pipe line	0	0	0	0	0	**0**	0	0	0	0	0	**0**
13	Monument/Buddha image	0	0	0	0	0	**0**	0	0	0	0	0	**0**
14	Infrastructural development not related to tourism	1	0	0	0	0	**1**	1	0	0	0	0	**1**
15	Solar cell area	0	0	1	0	0	**1**	0	0	1	0	0	**1**
	Summary	1	5	1	1	1	**9**	-	-	-	-	-	**-**
Fiscal year 2006-2011													
1	Dam/ Reservoir	0	0	0	3	5	**8**	0	0	0	3	2	**5**
2	Small water body	0	3	0	2	0	**5**	0	2	0	1	0	**3**
3	National security project	0	0	0	1	0	**1**	0	0	0	1	0	**1**

No.	Activities permitted in WS	Frequency of activities permitted in WS in each region					Sum. frequency of activities	No. of WS that have each activity permitted in each region					Sum no. of WS
		C	E	N	N-E	S		C	E	N	N-E	S	
4	Road	0	0	1	2	0	**3**	0	0	1	1	0	**2**
5	Nature trail	0	1	0	0	0	**1**	0	1	0	0	0	**1**
6	Electricity line	0	2	1	0	0	**3**	0	1	1	0	0	**2**
7	Infrastructural development related to tourism	1	1	0	0	0	**2**	1	1	0	0	0	**2**
8	Landscape development for tourism	0	1	0	0	0	**1**	0	1	0	0	0	**1**
9	Landscape development for non tourism	0	0	1	0	2	**3**	0	0	1	0	1	**2**
10	Broadcasting station	0	0	0	1	0	**1**	0	0	0	1	0	**1**
11	Training centre/educational institute	0	0	1	0	0	**1**	0	0	1	0	0	**1**
12	Pipe line	1	0	0	0	0	**1**	1	0	0	0	0	**1**
13	Monument/Buddha image	1	0	0	0	0	**1**	1	0	0	0	0	**1**
14	Infrastructural development not related to tourism	1	2	2	4	1	**10**	1	1	2	2	1	**7**
15	Solar cell area	2	0	5	0	0	**7**	2	0	4	0	0	**6**
	Summary	6	10	11	13	8	**48**	-	-	-	-	-	**-**

Table 2.15 The difference regarding number of PAs that have legal activities permitted in each region in national parks and wildlife sanctuaries in fiscal year 2006 – 2011

No.	Activities permitted in PAs	No. of PAs that have each activity permitted in each region										Sum no. of PAs	
		Central		East		North		Northeast		South			
		NP	WS	NP	WS	NP	WS	NP	WS	NP	WS	NP	WS
Fiscal year 2006-2011													
1	Dam/ Reservoir	0	0	0	0	0	0	0	3	1	2	**1**	**5**
2	Small water body	1	0	0	2	1	0	2	1	1	0	**5**	**3**
3	National security project	0	0	0	0	0	0	0	1	2	0	**2**	**1**
4	Road	6	0	1	0	10	1	5	1	4	0	**26**	**2**
5	Nature trail	1	0	0	1	1	0	0	0	1	0	**3**	**1**
6	Electricity line	3	0	0	1	9	1	3	0	3	0	**18**	**2**
7	Infrastructural development related to tourism	5	1	3	1	5	0	6	0	2	0	**21**	**2**
8	Landscape development for tourism	1	0	5	1	5	0	5	0	4	0	**20**	**1**
9	Landscape development for non tourism	1	0	0	0	0	1	0	0	1	1	**2**	**2**
10	Religious building*	0	-	0	-	1	-	0	-	1	-	**2**	-
11	Broadcasting station	0	0	1	0	5	0	4	1	5	0	**15**	**1**
12	Training	1	0	0	0	1	1	0	0	1	0	**3**	**1**

No.	Activities permitted in PAs	No. of PAs that have each activity permitted in each region										Sum no. of PAs	
		Central		East		North		Northeast		South			
		NP	WS	NP	WS	NP	WS	NP	WS	NP	WS	NP	WS
	centre/educational institute												
13	Harbour*	0	-	1	-	0	-	0	-	1	-	**2**	-
14	Research area/centre*	1	-	0	-	2	-	1	-	0	-	**4**	-
15	Pipe line	3	1	1	0	5	0	0	0	4	0	**13**	**1**
16	Monument/Buddha image	0	1	0	0	1	0	1	0	5	0	**7**	**1**
17	Infrastructural development not related to tourism	3	1	2	1	6	2	0	2	3	1	**14**	**7**
18	Solar cell area	1	2	0	0	1	4	4	0	1	0	**7**	**6**
19	Telemetry station*	1	-	0	-	1	-	1	-	0	-	**3**	**-**
	Summary	28	6	14	7	54	10	32	9	40	4	168	36
	Average	1.47	0.40	0.74	0.47	2.84	0.67	1.68	0.60	2.11	0.27	8.84	2.40

Note: * = activities that occurred only in national parks

Table 2.16 The difference regarding frequency of legal activities permitted in PAs in each region in national parks and wildlife sanctuaries in fiscal year 2006 – 2011

No.	Activities permitted in PAs	Frequency of activities permitted in PAs in each region										Sum. frequency of activities in PAs	
		Central		East		North		Northeast		South			
		NP	WS	NP	WS	NP	WS	NP	WS	NP	WS	NP	WS
	Fiscal year 2006-2011												
1	Dam/ Reservoir	0	0	0	0	0	0	0	3	1	5	**1**	**8**
2	Small water body	1	0	0	3	1	0	2	2	1	0	**5**	**5**
3	National security project	0	0	0	0	0	0	0	1	2	0	**2**	**1**
4	Road	13	0	1	0	13	1	8	2	4	0	**39**	**3**
5	Nature trail	1	0	0	1	1	0	0	0	1	0	**3**	**1**
6	Electricity line	6	0	0	2	15	1	3	0	4	0	**28**	**3**
7	Infrastructural development related to tourism	7	1	5	1	6	0	8	0	2	0	**28**	**2**
8	Landscape development for tourism	1	0	5	1	6	0	6	0	5	0	**23**	**1**
9	Landscape development for non tourism	1	0	0	0	0	1	0	0	1	2	**2**	**3**
10	Religious building*	0	-	0	-	1	-	0	-	1	-	**2**	**-**
11	Broadcasting station	0	0	1	0	5	0	6	1	5	0	**17**	**1**
12	Training centre/educational	1	0	0	0	1	1	0	0	1	0	**3**	**1**

No.	Activities permitted in PAs	Frequency of activities permitted in PAs in each region										Sum. frequency of activities in PAs	
		Central		East		North		Northeast		South			
		NP	WS	NP	WS	NP	WS	NP	WS	NP	WS	NP	WS
	institute												
13	Harbour*	0	-	1	-	0	-	0	-	2	-	**3**	**-**
14	Research area/centre*	1	-	0	-	4	-	1	-	0	-	**6**	**-**
15	Pipe line	3	1	1	0	5	0	0	0	4	0	**13**	**1**
16	Monument/Buddha image	0	1	0	0	1	0	1	0	5	0	**7**	**1**
17	Infrastructural development not related to tourism	4	1	2	2	7	2	0	4	4	1	**17**	**10**
18	Solar cell area	1	2	0	0	1	5	6	0	1	0	**9**	**7**
19	Telemetry station*	1	-	0	-	1	-	1	-	0	-	**3**	**-**
	Summary	41	6	16	10	68	11	42	13	44	8	**211**	**48**
	Average	2.16	0.40	0.84	0.67	3.58	0.73	2.21	0.87	2.32	0.53	11.11	3.20

Note: * = activities that occurred only in national parks

2.5 Discussion

This research studied threats to 181 protected areas (PA) in Thailand focusing on two main types of PA, consisting of 123 national parks (IUCN category II) and 58 wildlife sanctuaries (IUCN category Ia). The research focussed on the period from 1999 to 2011, particularly on those direct threats that are likely to have contributed to a reduction in forest area or the loss of tree species. These threats are: forest fire; and both illegal and legal activities that caused a reduction in forest area, or cutting of tree species within PAs. Illegal cases were categorized into two main groups, namely illegal forest clearing cases and illegal logging cases.

Forest fire threatened PAs in almost all regions of Thailand over the past decade. PAs in the Northern and the Northeastern regions were at the greatest risk of forest fire occurring, while those in the Southern region were much less affected. However, the risk of forest fire occurrence did not vary much between types of PA. It is worth mentioning that some forest types are considered as the fire climax community such as mixed deciduous forest, deciduous dipterocarp forest, and coniferous forest. Especially, within deciduous dipterocarp forest, fire is an important factor of the forest type called the pyric climax community. If fire is controlled for some years continually, the structure of the forests will change, resulting in transformation to other forest types (Santisuk 2012). Plants that are found in the forests that require fire have adapted to be able to survive fire. For example, trees have thick barks to protect the cambium from heat. Some plants first develop root system until their roots are strong enough, only then developing their trunks, known as the burn back phenomena (Santisuk 2012). Therefore, this can possibly be one of the reasons that fire was recorded in the Northern and the Northeastern regions. Another reason why fires were more in the Northern and the Northeastern regions than other regions is that there are savannah and tropical grasslands found in those two regions. Savannah and tropical grassland have been found in the areas with a short rainy season (precipitation $\leq$ 900 mm/year), poor soil quality (such as high salinity, acidic soil) (Kutintara 1999). Severe fires have occurred every year because of the accumulation of dry grasses and drought (Kutintara 1999). The possible reasons that fire occurred much less in the Southern region include the fact that almost all forest in the Southern region is tropical rain forest, where high moisture in soil and the quantity of precipitation is higher than other vegetation communities (Santisuk 2012). There are rains over 8 months continuously with more than 1,600 mm/year in tropical rain forest (Kutintara 1999). This result is supported by some previous research that mentioned forest fire threatened a PA. Hares (2009) reported that slash and burn cultivation and poor fire control threatened areas, both within and near, the Doi Inthanon national park in Northern Thailand. Trisurat (2006) mentioned that forest fire threatened the Forest Complex in the Northeastern region. Carey et al. (2000) published a WWF report that carried out a series of studies of the effectiveness of PAs in many countries of the world, including Thailand, which mentioned that forest fire: occurred in vast areas of a national park in the Northeastern region in 1997 – 1999; and also occurred in a wildlife sanctuary in the Western region in 1998 and 2000. The occurrence of fire as a threat within PAs is also supported by some research conducted in other countries. For example, Bruner et al. (2001) studied 93 PAs in 22 tropical countries and found that almost all PAs are under pressure from fire. Again, Carey et al. (2000) mentioned that forest fire is a threat to many PAs such as: in Colombia's national parks, where 67% are affected by forest fire; the cloud forest in the South-western reserve of Rwanda was threatened by forest fire in 1997. In addition, the research conducted in Indonesia's PAs similarly mentioned that forest fire is a severe threat to PAs (Carey et al. 2000).

Illegal area clearance and illegal logging also threatened almost all PAs in all regions, but were more severe in WS than in NP. However, the greatest risk of illegal area clearing was in the Northeastern and the Southern regions, while it was much less evident in the Eastern region. PAs in the Southern region had the greatest risk of illegal logging, which was less evident in the Eastern region. This result is supported by some previous research in Thailand. For example, Pattanavibool and Dearden (2002) mentioned human impacts, in particular: shifting cultivation; human settlements; and commercial agriculture, led to the high rate of fragmentation and reduction of biodiversity in two wildlife sanctuaries in Northern Thailand. Again, Trisurat (2006) mentioned that agricultural encroachment threatened the Forest Complex in the Northeastern region. Also, Carey et al. (2000) mentioned that in a wildlife sanctuary in the Eastern region and a national park in the Northern region, the invasion of people and poor farming practices have badly degraded the PA. Carey et al. (2000) also found that the one of the national parks in the Northern region was threatened by large-scale logging, pointing out that after the introduction of a logging ban in 1998, it caused an increase in the illegal timber trade by exporting and re-importing with fraud. Similarly, the research conducted by Hares (2009) in a Northern national park, illegal logging was again mentioned as a threat. Moreover, the result is supported by research conducted in other countries. Carey et al. (2000) mentioned that: one main threat that caused habitat loss in Pakistan's PAs was encroachment; the proportion of Colombia's national parks affected by logging 79%; and apart from forest fire, the severest threats to Indonesia's PAs were land encroachment by local people and illegal logging. Vuohelainen et al. (2012) studied the extent of deforestation between 1991 - 2008 in Madre de Dios region in Peru and found that the area was clearly concentrated around roads and waterways, and deforestation rates have tripled in the last ten years. Hull et al. (2011) mentioned human activities, such as: roads; houses and tourism facilities, affected China's PAs. Additionally, forest cover of the PAs also changed over time, which possibly reflected timber harvesting and afforestation (Hull et al. 2011).

Legal activities permitted by the Thailand government also threatened both types of PA, although they were less evident in WS than in NP. PAs in the Northern and the Northeastern regions were at greatest risk of permitted legal activities, while much less of these was recorded in the Eastern and the Central regions. Road construction was the most common activity permitted, followed by electricity lines and infrastructural development related to tourism in NP, whereas infrastructural development not related to tourism was the most prevalent activity in WS. The results indicated clearly that the number of permissions in NPs have increased substantially in the last two analysed fiscal years. This result is supported by previous research, for example, Ngoprasert et al. (2007) mentioned road construction and other developments were threatening the Kaeng Krachan national park in Central Thailand. Cropper et al. (2001) documented that road building is likely to have the greatest impact to PAs in Northern Thailand. Again, Pattanavibool and Dearden (2002) mentioned some development forms, such as: roads; human settlements; and commercial agriculture, affected WSs in Northern Thailand. The result is also supported by research conducted in other countries, for example, Prato (2004) mentioned some threats to PAs of USA including a rapid growth in tourism. Naughton-Treves et al. (2005) mentioned the critical threats to PAs also arise from large-scale infrastructure development in some tropical PAs. Hull et al. (2011) mentioned that human activities, such as: roads; houses; and tourism facilities, affected China's PAs. Again, Carey et al. (2000) mentioned that during 1995 and 1996, tourism and visitor facilities were reported to be causing significant impacts in 72% of national parks in Canada; the main threats that caused habitat loss in Pakistan's PAs were also from infrastructure construction. Similarly these authors reported that the road building also threatened Indonesia's PAs, but was less severe than land encroachment by local people, illegal logging and forest fire (Carey et al. 2000). However, the result from this research is in contrast to the research of Gimmi et al. (2011), which was conducted on two national lakeshores in the United States. These authors found that both national lakeshores successfully stopped fragmenting impacts of road development and building growth, after park establishment within their boundaries. Active management efforts, such as: the removal of a number of vacation homes; and the closure of their access roads, were implemented soon after creation of the national lakeshores (Gimmi et al. 2011).

It is interesting to note that the legal activities, that tend to be permitted within Thai PAs, have occasionally not been welcomed by: the public; local communities; NGOs; or naturalists, especially projects that can cause forest fragmentation or the loss of large amount of forest area, such as dams and roads (Bangkok Post 2010;

Thairath 2013). The highlight event, when people protested against 'legal' developments, was the 388 km-protest-walk against the Environmental Health Impact Assessment (EHIA) report of the planned Mae Wong Dam that took place in October 2014. The rally was led by the Secretary General of the Seub Nakasatien foundation, with support from activists, naturalists and the public. The protest happened against the EHIA report for many reasons. For example, if the dam was developed, 5,100 acres of Mae Wong national park area, where the dam would be built, would be flooded. As well as the loss of forest area itself, this area includes: a large area of teak-dominated forest; and wildlife habitats inhabited by important mammals such as tigers (*Panthera tigris*), tapirs (*Tapirus indicus*), etc. (Kutintara 2013). In addition to this, the water storage capacity is expected to be comparatively low 200-250 million cubic metres for a high-priced dam construction (13 billion baht or approximately 400 million USD) (Thairath 2013; Vipoosanapat 2014). DNP, which superintends the Mae Wong national park, has also resisted the Mae Wong dam project (Thairath 2013).

Overall, threats to PAs in Thailand from illegal cases, differed from those associated with legal activities. The number of illegal cases subtantially outnumbered legal activities permitted in PAs, with more than 38,000 illegal offense cases in three fiscal years 2009 - 2011, and around 260 legal permissions over the six fiscal years 2006 - 2011. In summary, the prominent threats to Thailand's PAs are: forest fire; illegal logging; illegal area clearing; road construction; electricity lines; infrastructural development related to tourism; and infrastructural development not related to tourism. These threats could potentially lead to: degradation and loss of biodiversity; forest fragmentation (which also directly affects wildlife habitat, genetic loss and risk of extinction); as well as soil erosion. Loss of forest area, logging and forest fire are recognised as pre-eminent causes of climate change, increasing emission of greenhouse gases, especially carbon dioxide (CO_2). As specified in the National Park and Wildlife Sanctuary Acts, development of infrastructure in PAs could possibly be permitted for specific purposes including: education; research; capacity building; lodging; safety of people; tourism (for national parks); and breeding programs (for wildlife sanctuaries), which ultimately promote natural conservation. However, some infrastructure forms, such as: roads; dams; electricity lines; and accommodation, may have been developed in PAs, as they were considered to be producing greater marginal benefits than the costs to nature conservation value. For example, building lodges in national parks could encourage visits by tourists, who could provide a source of income, which could potentially be used to support conservation actions. Roads constructed in PAs are likely to provide both pros and cons to the natural resources in PAs, as they can be considered to support the regular patrolling by PA staff. However, they may also allow simple access to the PA by poachers, increasing negative impacts on wildlife in PAs.

All threats found in this research can imply human impact, even though fires in some areas may be a part of a natural cycle. Therefore, the measures that can be recommended to decrease threats to Thailand's PAs are as follows:

(i) Because fire is a vital factor in determining the climax of some forest communities, fire management strategies should be set differently, regarding types of forests. If fires occur in the evergreen forest, they should be eliminated immediately. If fires occurred in mixed deciduous forest, deciduous dipterocarp forest and coniferous forest, firefighters should consider controlling the severity of the fire, but it is unnecessary to eliminate all fires.

(ii) Using a drone to support fire control could be considered, especially where severe fires happen. A drone is a flyable-unmanned device operated remotely using radio controls. It can be equipped with instruments such as a video-camera to fly over difficult to reach areas (Halton et al. 2014). Branford Fire Department, USA has used drones for assessing fire situations and capturing aerial photographs and filming fire incidents (Halton et al. 2014).

(iii) The threat from forest fire is likely to be reduced by educational information provided to visitors, the public and local communities in and around PAs about: the impact of forest fire; controlling visitor camp fires; promoting pre-caution forest fire such as early dry season burning of organic residues accumulating on the forest ground.

(iv) Promote the participation of local communities in and around PAs in forest protection such as co-operating in regular patrols.

(v) Awareness campaigns and capacity building programmes should be promoted to train or educate local people living around the PAs to raise awareness of the negative impacts of illegal logging and area clearing.

(vi) Establishment of both private and government plantation programs should be widely promoted for domestic consumption and for the export of wood industries. In addition, the government should also promote community forestry programmes and household plantations. By doing this, local communities could reduce the use of wood from the forests and help the government protect them.

(vii) Increase forest ranger units over the country, both in the areas of national parks and wildlife sanctuaries, to strengthen forest protection. Regular smart patrolling by PAs' rangers throughout the area of PAs is also required. In addition, forest fire control should be accorded high priority in the PA's operation plan or management plan.

(viii) Strategic plans, including increasing secondary and tertiary jobs supporting initiatives to increase tourism and employment that would benefit local communities, should be developed.

This research is limited in a number of ways. First, this study only assessed a limited number of threats to PAs, which were those included in the survey data on which the analyses were based. Future research should ideally try to systematically assess a comprehensive range of potential threats, as other researchers have done in several countries. For example, the threat of climate change was not directly assessed by this research, given that data on its impacts on PAs in Thailand is not currently available. However, factors on climate change will be referred and discussed in other chapters of my research. The research was dependent on reports provided by PA staff, and the analyses are based on the assumption that the reports were an accurate representation of the situation occurring in the field. Such uncertainties are difficult to estimate with precision, without any independent assessments using an alternative source of data. Potentially these limitations could be addressed by attempting to independently verify the accuracy of the reports, for example: through interviews with the PA staff involved; or by conducting an independent field survey of the areas in which threats have been reported. Future research might therefore usefully attempt to provide such verification, to assess the validity of the results presented here.

Chapter 3: Gap Analysis of the protected areas of Thailand in relation to the conservation of tree species

Abstract

Many species and ecosystems are inadequately covered by existing protected area (PA) networks, which is an issue of concern, especially for threatened and endemic species. Gap analysis is a method to identify biodiversity components such as species, ecosystems and ecological processes that are inadequately conserved within existing PA networks. Gap analysis is an important part of the information required for systematic conservation planning. The aim of this chapter is to analyse the coverage of existing Thailand's PAs in relation to tree species, and to determine the extent to which selected tree species are currently conserved by the PA network of Thailand.

The selected species considered in this chapter are: species that are threatened with extinction; species that dominate the different forest types in Thailand; species that are of particular economic importance; and species that are important to *in situ* genetic conservation. Four management categories of Thailand PAs were considered in this research, these were: (1) forest park; (2) national park; (3) no-hunting area; and (4) wildlife sanctuary.

For all 6,339 records of 749 species, belonging 93 families of all four groups of selected trees, the number and the percentage of species occurrence points that occurred within PA boundaries were then calculated for each species, in relation to management categories. For trees with precise locations and $\geq$ 5 records/species comprising 1,725 records of 57 species, 10 families, *Scenario B* of the gap analysis method described by Rodrigues et al. (2003) was applied by setting 'a representation target' for each species, in light of the percentage of the extent of occurrence (EOO) of each species that ought to be overlapped by PAs to consider that a species is 'covered'. A species distribution that is not overlapped at all by the PAs is considered a 'gap'. Species that meets only a fraction of their representation target is considered as a 'partial gap'. All species with ranges $\leq$ 1,000 km^2 needed to have 100% range covered, whereas species with ranges $\geq$ 250,000 km^2 needed to have < 10%

range covered. Intermediate range sizes were defined by interpolation using a logarithmic transformation (Rodrigues et al. 2003).

For all 749 species, the results showed that more species member of all tree groups were located outside than inside a PA, especially the species in Group 1- trees that are threatened with extinction. Regarding species in Group 2- trees that dominate the different forest types in Thailand, there were 75.35% or 431 species were found inside PA. Species in Group 3- trees that are of particular economic importance and Group 4- trees that are important to *in situ* genetic conservation have been well protected as almost of them could be found both inside and outside a PA. Considering the number of species in different types of PA, it was clear that most species were found in national parks, followed by wildlife sanctuaries, no-hunting areas and forest parks. For 57 species analysed using *Scenario B* of the gap analysis, it was found that 17 species were considered as 'covered species'. There were no gap species, but approximately 70% of 57 analysed species were partial gap species.

Chapter 3: Gap Analysis of the protected areas of Thailand in relation to the conservation of tree species

3.1 Introduction

One of the most effective ways to conserve species abundance and diversity is through *in situ* conservation approaches such as protected area (PA) networks (Balmford et al., 1996), where species are often legally protected and managed appropriately (Langhammer 2007). PAs now number 200,000 worldwide, covering 14.6% of terrestrial land area in 2014 (IUCN 2014). However many species and ecosystems are inadequately covered by existing PA networks, which is an issue of concern, especially for threatened and endemic species (Dudley and Parish 2006). Gap analysis is a method to identify biodiversity components such as species, ecosystems and ecological processes that are inadequately conserved within existing PA networks. It can also be considered as a strategy to identify representative biological gaps for accomplishing the management effectiveness of PA networks, and for maintaining native species and natural ecosystems, by identifying priorities and designing new PAs to fill the gaps (Scott et al. 1993; Dudley and Parish 2006; Langhammer 2007). Carrying out a national gap analysis of PAs is one of the main priority activities identified by the Convention on Biological Diversity (CBD), to achieve biodiversity conservation targets (Dudley and Parish 2006).

Several methods have been developed to conduct gap analysis, which have been widely applied in different countries by researchers and environmental organisations such as IUCN and WWF. Dudley and Parish (2006) provided a guide to conduct gap analysis as a technical support for the Parties of the CBD, which identified five steps: (1) set conservation targets for the PA networks; (2) evaluate biodiversity distribution and describe its status; (3) analyse the existing PAs and assess their status and characteristics; (4) identify gaps using maps or matrices to verify representative, ecological and management gaps; and (5) prioritise gaps to be filled, agree on strategies and take action.

Jennings (2000) described briefly a process to conduct a gap analysis for the National Gap Analysis Projects (GAP), by combining vegetation communities and species with PA coverages to assess how well they are conserved by existing PA networks. The vegetation and species that are insufficiently represented in existing PAs are identified as gaps that require specific strategies for further conservation (Jennings 2000).

Rodrigues et al. (2003) assessed the effectiveness of current global PAs using a two-stage process of global gap analysis. Global gap analysis is the analysis of biodiversity gaps of the current PA network globally. The analysis encompassed priority areas to ensure that a wide range of life forms are represented in the PA network. Mammals, amphibians, and threatened birds were utilized as surrogate species in the analysis. The gaps in the coverage by the global network of PAs of the analyzed species were identified, then methods of filling the gaps were explored by identifying new priority conservation areas. This paper described how data may be analysed to identify gaps using the Geographic Information System (GIS) software, ArcView, under two scenarios. *Scenario A* relies on two possible assumptions: Firstly, all conservation areas are equally sufficient for protecting each species; and secondly, species are able to be equally effectively conserved by the protection of a fraction of their range in any part of the range. After overlaying conservation areas and each species' distribution map using the GIS software, species are examined to ascertain if any conservation area overlaps their range. Any species that is not covered by any conservation area is considered a gap species. The areas where gap species occur are considered to be urgent priorities for conservation effort to expand PA networks. *Scenario B* provides a more realistic measurement by using more demanding targets in the percentage of the species range for considering species covered, such as all species with ranges ≤ 1,000 km^2 needed to have 100 % range covered, whereas species with ranges ≥ 250,000 km^2 needed to have < 10 % range covered. Intermediate range sizes were defined by interpolation using a logarithmic transformation. Only PAs over 100 hectares (1 km^2) in area were considered in *Scenario B*, which considered species as partial gap species if the criteria were only partially met. Hence *Scenario B* is used to compute the opportunity that specific sites are needed for achieving representation targets of each species, but is unable to represent the obvious boundaries between covered and gap species (Rodrigues et al. 2003).

Scenario B has been used for identifying globally significant sites for biodiversity conservation or Key Biodiversity Areas (KBAs), which describes the gap analysis in two main steps. Step 1- defines the percentage of each species range covered by existing PA networks, with targets varying between 100% for species with very limited ranges (less than 1,000 $km^{2)}$ to 10% for widespread species with ranges over 250,000 km^2. This step is evaluated by overlaying land class maps, land stewardship maps, management status and/or species distributions, then the percentage of the targets species within existing PAs is calculated (Langhammer 2007). Step 2- identifies and establishes priorities for expanding PA networks where all species meet the target based on irreplaceability and vulnerability, often utilizing C-plan or MARXAN software (Langhammer 2007).

Using such methods, gap analysis has been widely applied in different parts of the world. For example, Araujo et al. (2007) described an example of plants and vertebrate species represented in Iberian PAs in Spain. Vimal et al. (2011) employed distribution data of vascular plants, reptiles and amphibian species in Southern France to explore the effect of targets in the stages of gap analysis. Some research applied gap analysis to explore how well endangered species were covered by conservation areas. For example, Randrianasolo et al. (2002) studied the conservation status of five threatened genera of Anacardiaceae in conservation network in Madagascar. Vellak et al. (2009) examined the effectiveness of PAs to cover rare plants in Estonia. Similarly, Jackson et al. (2009) studied relationship between the distribution of threatened plants and PAs in Britain, while Riemann and Ezcurra (2005) analysed the distribution of the endemic vascular flora of the peninsula of Baja California, Mexico in existing PAs. In Thailand, Trisurat (2007) applied a gap analysis and a Comparison Index (CI) to assess the ecosystem representation of Thailand's PAs. Three representativeness aspects, including: forest type; altitude; and natural land system, were assessed using spatial analyses. To assess vegetation communities within existing PA networks, conservation area maps were laid over a vegetation type map. Subsequently, to determine the representation of altitude, a Digital Elevation Model (DEM) at the same resolution was classified into six classes, from 0 – 400 m. to > 2,000 m. The DEM map then was overlaid on conservation area maps. Finally, the output map was analysed to determine the natural land systems distribution represented in the vegetation type and topographic maps. The analyses indicated that the existing PA system covers 24.4% of the country's land area, nearly meeting the 25% target proposed by the National Forest Policy1989 (ICEM 2003); and 83.8% of these areas are forested. Most PAs are situated at relatively high altitudes. Mangrove forest and riparian floodplain are extremely under-represented in the existing PA system, whereas peat swamp forest, dry dipterocarp forest and beach forest are relatively well represented (Trisurat 2007).

Gap analysis is therefore an important part of the information required for systematic conservation planning. In this context, the aim of this chapter is to measure the extent to which quantitative targets for representative areas are being achieved by existing PAs in Thailand (Margules and Pressey, 2000), in relation to the conservation of tree species. In Thailand, gap analysis has been completed only for forest types (Trisurat 2007). No previous research has been undertaken into gap analysis for individual tree species in this country. Therefore, this chapter will examine how well selected tree species are incorporated in PAs, the results should contribute to improve design and effectiveness of the PA network in Thailand.

3.2 Objectives

To analyse the coverage of existing Thailand’s PAs in relation to the conservation of tree species, and to determine the extent to which selected tree species are currently conserved by the PA network of Thailand.

3.3 Methods

The gap analysis was conducted following *Scenario B* of the gap analysis method described by Rodrigues et al. (2003). The selected species are: tree species that are threatened with extinction; species that dominate the different forest types in Thailand; species that are particular economic importance; and species that are important to *in situ* genetic conservation. Specifically, these include:

i. Tree species with status of endemic, rare, threatened, or vulnerable as catalogued by Santisuk et al. (2006) and Pooma (2008) (Tables A1 and A2 in Appendix A).

ii. Selected tree families and species that dominate the different forest types in Thailand. These include:

(1) Tree species that are typically found in each of Thailand's forest ecosystems mentioned in the book 'Forest types of Thailand' (Santisuk 2006) (Table A3 in Appendix A).

(2) Five tree families consisting of Magnoliaceae, Dipterocarpaceae, Fagaceae, Fabaceae (or Leguminosae) and Ebenaceae (Table A4 in Appendix A).

iii. Trees species that are important in terms of economic value (i.e. some extraction is allowed). These are 'the restricted logging trees' under two Thai laws: (1) 158 entries of 'the restricted logging trees' in the Royal decree on restricted logging trees (The Prime Minister's Office 1987) (Table A5 in Appendix A); and (2) two restricted logging trees listed in the Forest Act 1941, these are: *Tectona grandis* L.f. and *Dipterocarpus alatus* Roxb. ex G.Don (The Prime Minister's Office 1941).

iv. Thailand's priority tree species, which are of particular value in terms of the conservation and sustainable use of forest genetic resources (FGR). The species lists are derived from country reports of Thailand, which is a part of the Proceedings of the Asia Pacific Forest Genetic Resources Programme (APFORGEN) Inception Workshop 2003, Malaysia (Sumantakul et al. 2004) (Table A6 in Appendix A).

It is noted that each tree species can be considered in more than one group.

Data compilation and analysis were conducted in the following way.

i. Compilation of data

Occurrence points of the selected tree species were compiled from two sources. Firstly, the specimen labels of the Forest Herbarium (BKF), Bangkok during 1925 - 2012 were inspected and used to collect 15,820 records of 817 tree species. Secondly, data were obtained directly from the Division of Protection and Forest Fire Control, which is part of the DNP, for three fiscal years during the period 2009 -

2011 (1 October 2008 - 30 September 2011). These data include 635 records of *Tectona grandis* L.f. and *Dalbergia cochinchinensis* Pierre. When duplicates, erroneous records, and records before 1982 were removed, this left a total of 2,151 records of 293 species, belonging to 51 families, with precise locations. In addition, a second set of data provided only tree presence locations according to placenames, such as places in PAs (waterfalls and islands), districts, villages, provinces, etc. There were 4,188 records of 720 species, belonging to 91 families, of this data type. Overall, there were 6,339 records of 749 species, belonging 93 families, which could be used in the gap analysis (Table A7 in Appendix A).

PA boundary maps for Thailand were obtained from the Protected Area Rehabilitation and Development Office (PARDO) which is part of the DNP (DNP 2012). The maps characterise the pattern of PA networks.

ii. Data analysis

PA boundaries and management categories were overlaid with the distribution data for the selected tree species. Four management categories of Thailand PAs were considered in this research, consisting of: (1) forest park; (2) national park; (3) no-hunting area; and (4) wildlife sanctuary. The other man-made PAs (arboretum and botanical garden) were excluded. The number and the percentage of species occurrence points that occurred within PA boundaries were then calculated for each species, in relation to management categories.

For trees with precise locations and $\geq$ 5 records/species (Pearson et al. 2007) comprising 1,725 records of 57 species from 10 families, *Scenario B* of the gap analysis method described by Rodrigues et al. (2003) was applied by setting ‘a representation target’ for each species, in light of the percentage of the extent of occurrence (EOO) of each species that ought to be overlapped by PAs to consider that a species is ‘covered’. A species distribution that is not overlapped at all by the PAs is considered a ‘gap’. Species that meet only a fraction of their representation target are considered to be ‘partial gap’ species.

The extent of occurrence (EOO) is the area within the shortest continuous imaginary boundary which is able to be drawn to cover all the known, inferred or projected sites of current species' existence, not including the vagrancy cases (IUCN 2001, see Figure 3.1a). ArcGIS 10 (ESRI 2010a) was used to create a minimum convex polygon (MCP) around the distribution data for each targeted species. The MCP is the smallest polygon in which no internal angle exceeds 180 degrees. The area of the MCP was calculated for each species and clipped to the boundary of Thailand to exclude the sea as well as areas in other countries for which the PA coverage was not known, to represent the EOO. Subsequently, the EOO of each species contained within PAs was calculated by overlaying the EOO and PA layers within GIS (e.g. see Figure 3.1b). Finally, the percentage of EOO contained within PAs was calculated for each species and considered in relation to 'a representation target', to identify covered species, gap species or partial gap species.

A 'covered species' is a species having higher percentage of EOO inside PA than percentage of species representation target. A 'partial gap species' is a species having less percentage of EOO inside PA than percentage of species representation target. A 'gap species' is a species where none of the EOO is inside a PA (Rodrigues et al. 2003).

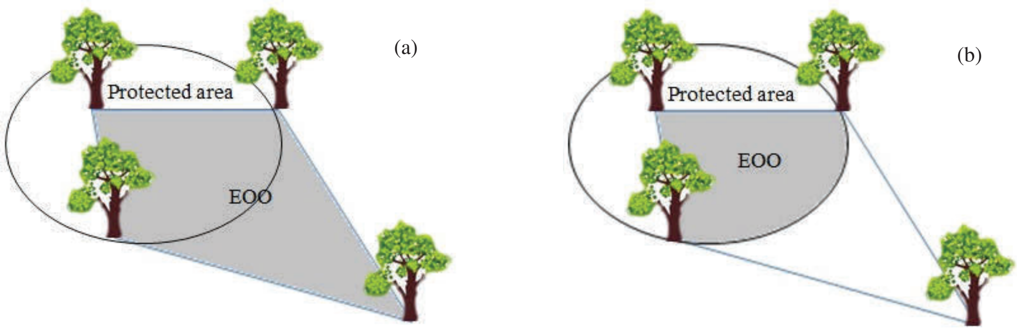


Figure 3.1 - The entire extent of occurrence (EOO) of a tree species (a) and its EOO contained inside the protected area (b)

'A representation target' for each species was set as described by Rodrigues et al., (2003) specifically:

(1) Species with ranges $\leq$ 1,000 km^2 were set a target of needing 100% of the range covered;

(2) Species with ranges $\geq$ 250,000 km^2 were set as needing $\geq$ 10 % of the range covered;

(3) For species with ranges between $\leq$ 1,000 km^2 and $\geq$ 250,000 km^2, the representation target was interpolated between these two figures, using a log transformation (Figure 3.2) (Rodrigues et al. 2003).

Intermediate percentage values can be calculated from a simple linear formula: $\frac{Y2-Y1}{X2-X1}$

When Y_2 = % of Maximum range cover needed (which is set for 100%)

Y_1 = % of Minimum range cover needed (which is set for 10%)

X_2 = value of $\log_{10}$ (minimum EOO set for at least 10% of range cover needed, which is 250,000 km^2)

X_1 = value of $\log_{10}$ (maximum EOO set for 100% of range cover needed, which is 1,000 km^2)

In this case, $\log_{10}$ (1,000) = 3, and $\log_{10}$ (250, 000) = 5.4

Therefore, $\frac{Y2-Y1}{X2-X1} = \frac{100-10}{5.40-3} = 37.53$

This means that the species representation target decreases by 37.53% when the value of $\log_{10}$ (EOO) increases by 1 unit. For example, if the EOO increases from 1,000 km^2 to 10,000 km^2, the value of log (EOO) increases from 3 to 4 (from $\log_{10}$ (1,000) to log (10,000)). This means that the species representation target decreases from 100% to 62.47%. By doing this calculation, the representation target of all species was interpolated between 10% and 100%. To illustrate this further, the calculation for the representation target of *Diospyros pubicalyx* Bakh. can be given as an example. The EOO of this species is 53,904.8 km^2, and the value of $\log_{10}$ (53,904.8) is equal to 4.731. So that the increase of the value = 4.731 – 3 = 1.731 units. That is, the species representation target decreases by 64.96% (or = 1.731*37.53), from 100% to 35.04%. Therefore, the species representation target of *D. pubicalyx* Bakh. is 35.04%.

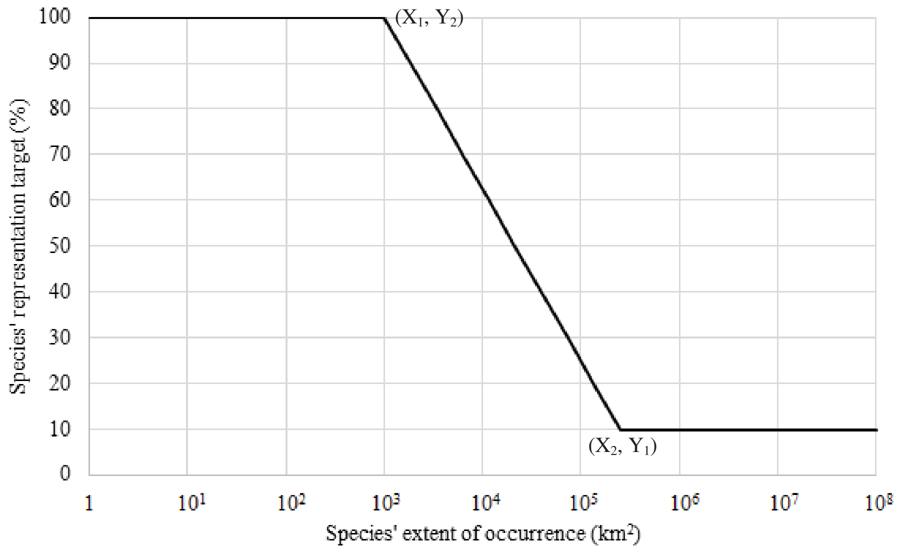


Figure 3.2 - Relationship between the extent of occurrence (EOO) of each species and its representation target (Rodrigues et al. 2003)

3.4 Results

This research studied the extent to which targeted tree species are covered by natural PAs of Thailand, which comprise: forest parks; national parks; no-hunting areas; and wildlife sanctuaries. The analysed species are categorized into four groups: Group 1- trees that are threatened with extinction; Group 2- trees that dominate the different forest types in Thailand; Group 3- trees that are of particular economic importance; and Group 4- trees that are important to *in situ* genetic conservation. The analysis was conducted using two methods. Firstly, the number and the percentage of species occurrence points within PA boundaries were calculated for all of the species (749 species belonging to 93 families). Secondly, the species' ranges were calculated for species with precise locations and $\geq$ 5 records/species (57 species belonging to 10 families) following *Scenario B* of the gap analysis method described by Rodrigues et al. (2003). Then, the percentage of range inside PA of each species was compared to the percentage of representation target that was set individually for each species, to identify whether the species were considered as covered, partial gap, or gap species.

(a) All tree species that occurred within PA boundaries

Overall, there were 6,339 records from 749 species, belonging to 93 families of all four groups of selected trees that were used in this analysis. Considering the number of species protected inside and outside PA, there were 88 species (11.75%) that were found only within PA boundaries. In addition, 222 species (29.64%) were found only outside PA. Therefore, 439 species (58.61%) were found both inside and outside PA boundaries (Figure 3.3).

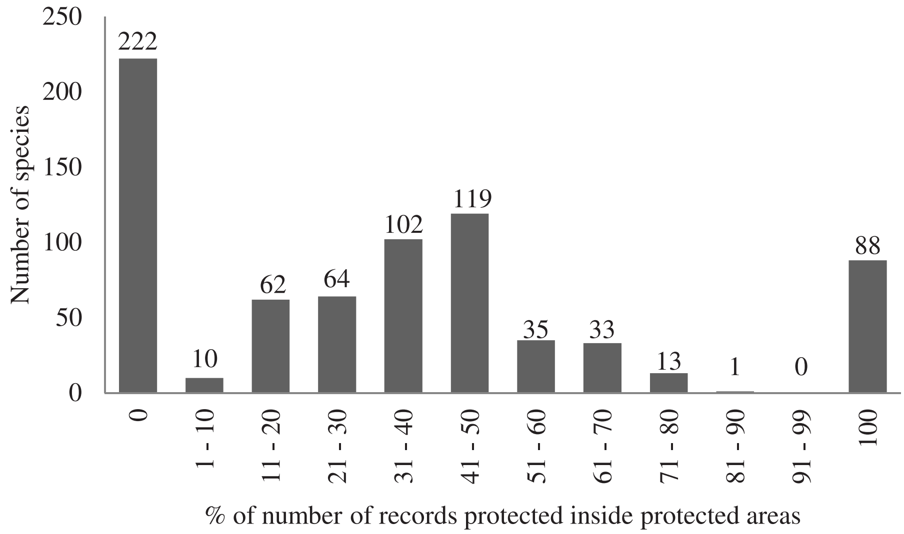


Figure 3.3 - Percentage of number of records per species protected by current protected areas of Thailand, as identified by part of the records of species occurring within a protected area boundary

Almost all species (572 species) are member of Group 2, only 8.74% of which were found only within a PA, while 24.65% were only located outside a PA. Only a small number of tree species (32 species) were in Group 4, 3.13% of which (1 species) were found only in a PA and 12.50% (4 species) were only found outside a PA. Group 1 contained 292 species, of which 15.75% were found only inside a PA, 39.38% were found only outside, and 44.86% were found both inside and outside a PA. Group 3 contained a large number of species (341 species), of which 8.21% (28 species) were located only inside a PA, 21.99% (75 species) were located only outside a PA, and 69.79% (238 species) were found both inside and outside a PA (Table 3.1). The most effective type of PA for tree conservation, which covered the highest proportion of species, was a national park covering 452 species (29.88% of records), while forest parks and no-hunting areas covered much fewer species with 9 and 120 species (0.14% and 1.89% of records) respectively. Wildlife sanctuaries were associated with 233 species (8.66% of records) (Table 3.2).

Table 3.1 Number of species of targeted groups of trees found inside and outside protected areas

Group	Total no. of records	Total no. of species	Only inside PA		Both inside and outside PA		Only outside PA	
			No. of spp.	%	No. of spp.	%	No. of spp.	%
1.Trees that are threatened with extinction	1,255	292	46	15.75	131	44.86	115	39.38
2. Trees that dominate the different forest types in Thailand	5,800	572	50	8.74	381	66.61	141	24.65
3. Trees that are of particular economic importance	4,132	341	28	8.21	238	69.79	75	21.99
4. Trees that are important to *in situ* genetic conservation	1,487	32	1	3.13	27	84.38	4	12.50
All groups	6,339	749	88	11.75	439	58.61	222	29.64

Note: Each species can be in more than one group of selected trees.

Table 3.2 Species of targeted groups of trees found in different types of protected areas

Group	Forest park		National park		No-hunting area		Wildlife sanctuary	
	No. of rec.	No. of spp.	No. of rec.	No. of spp.	No. of rec.	No. of spp.	No. of rec.	No. of spp.
1.Trees that are threatened with extinction	3	3	318	140	30	28	80	58
2. Trees that dominate the different forest types in Thailand	9	9	1,749	377	105	91	519	209
3. Trees that are of particular economic importance	7	7	1,297	232	73	64	395	135
4. Trees that are important to *in situ* genetic conservation	3	3	636	28	9	6	221	19
All groups	9	9	1,894	452	120	105	549	233

Note: Each species can be in more than one group of selected trees.

Each species can be also in more than one type of PA.

Fabaceae was the family that had the highest number of records and species that lay entirely outside the PA network (55 records, 23 species). Dipterocarpaceae and Rubiaceae also displayed a relatively large number of species that were found only outside a PA (36 records belonging to 18 species and 19 records belonging to 16 species respectively) (Table 3.3). In contrast, Lauraceae had the highest number of records and species that were included within the current PA network of Thailand (15 records, 10 species). Fabaceae and Ebenaceae also demonstrated relatively high values (10 records belonging to 8 species and 11 records belonging to 7 species respectively) (Table 3.4).

Species protected only inside PA comprised 117 records from 88 species, with between 1 - 5 records/species (mean = 1.3 records/species $\pm$ SD = 0.7). Specifically, 67 species had only one record; 17 species had 2 records; one species had 3 records; two species had 4 records; and one species had 5 records. Of these species with 100% of their records inside PAs, the one with the largest number of records was *Neolitsea zeylanica* (Nees.) Merr. of Lauraceae (5 records). National parks had the highest number of tree records for species protected only inside a PA (88 records). Fewer records were available in forest parks and no-hunting areas (1 and 8 records respectively) (Table 3.5).

Species that were neglected by PA networks had 419 records, between 1 - 11 records/species (mean = 1.9 records/species $\pm$ SD = 1.5). Specifically, 127 species had only one record; 50 species had 2 records; 22 species had 3 records; 12 species had 4 records; 2 species had 5 records; 2 species had 6 records; 5 species had 7 records; only 1 species had 10 and 11 records each. The species with the highest number of records that were not included within any PA type were *Lithocarpus sundaicus* (Blume) Rehder of Fagaceae (11 records), followed by *Butea monosperma* (Lam.) Taub. of Fabaceae (10 records) (Table 3.6).

(b) Trees with precise locations and $\geq$ 5 records/species

Species ranges were considered only for species with precise locations and $\geq$ 5 records/species (1,725 records of 57 species, belonging to 10 families) enabling them to be identified as ‘covered species’, ‘partial gap species’, or ‘gap species’. The percentage of species representation target and the percentage of the extent of occurrence (EOO) inside PA of each species were analysed and compared. It was found that 17 species (30%) were considered as ‘covered species’ including

Dipterocarpaceae (12 species), Lamiaceae (one species) as well as Ebenaceae and Pentaphylacaceae (two species each). The other species were considered as 'partial gap species' (40 species, belonging to 9 families). No species were full 'gap species'. Considering each group of targeted trees, it was found that: Group 1- trees that are threatened with extinction included only one 'covered species' and 12 'partial gap species'; Group 2- trees that dominate the different forest types in Thailand included 17 'covered species' and 40 'partial gap species' (all 57 species are in this group); Group 3- trees that are of particular economic importance included 13 'covered species' and 26 'partial gap species'. Additionally, Group 4- trees that are important to *in situ* genetic conservation included 6 'covered species' and 4 'partial gap species' (Table 3.7).

Table 3.3 Number of all families of each group of selected tree species that are found 100% outside protected areas

No.	Family	Sum no. of records	Sum no. of species	No. of records and no. of species in each tree group							
				Trees that are threatened with extinction		Trees that dominate the different forest types in Thailand		Trees that are of particular economic importance		Trees that are important to *in situ* genetic conservation	
				rec.	spp.	rec.	spp.	rec.	spp.	rec.	spp.
1	Achariaceae	7	1	0	0	7	1	7	1	0	0
2	Altingiaceae	2	1	2	1	2	1	2	1	0	0
3	Anacardiaceae	6	2	0	0	6	2	2	1	0	0
4	Annonaceae	11	8	8	5	3	3	0	0	0	0
5	Apocynaceae	12	5	12	5	5	2	0	0	0	0
6	Aquifoliaceae	1	1	0	0	1	1	0	0	0	0
7	Bignoniaceae	24	8	16	5	8	3	0	0	0	0
8	Bombacaceae	6	2	0	0	6	2	0	0	0	0
9	Boraginaceae	3	1	3	1	3	1	0	0	0	0
10	Burseraceae	7	5	6	4	1	1	1	1	0	0
11	Calophyllaceae	11	6	4	3	7	3	4	2	0	0
12	Capparaceae	2	1	0	0	2	1	0	0	0	0
13	Combretaceae	10	3	1	1	9	2	0	0	0	0
14	Dilleniaceae	3	3	1	1	2	2	3	3	0	0
15	Dipterocarpaceae	36	18	31	14	36	18	17	8	0	0
16	Ebenaceae	23	13	9	5	23	13	23	13	0	0
17	Elaeocarpaceae	5	2	0	0	5	2	5	2	0	0
18	Ericaceae	5	2	5	2	0	0	0	0	0	0
19	Euphorbiaceae	15	9	13	7	2	2	0	0	0	0
20	Fabaceae	55	23	14	5	55	23	7	4	1	1
21	Fagaceae	32	13	11	4	32	13	32	13	0	0
22	Gentianaceae	3	1	0	0	3	1	3	1	3	1
23	Hamamelidaceae	2	1	2	1	0	0	0	0	0	0

No.	Family	Sum no. of records	Sum no. of species	No. of records and no. of species in each tree group							
				Trees that are threatened with extinction		Trees that dominate the different forest types in Thailand		Trees that are of particular economic importance		Trees that are important to *in situ* genetic conservation	
				rec.	spp.	rec.	spp.	rec.	spp.	rec.	spp.
24	Hernandiaceae	2	1	0	0	2	1	0	0	0	0
25	Hypericaceae	1	1	1	1	0	0	1	1	0	0
26	Icacinaceae	2	2	0	0	2	2	0	0	0	0
27	Lamiaceae	9	3	5	2	0	0	4	1	0	0
28	Lauraceae	11	8	1	1	10	7	7	4	0	0
29	Lecythidaceae	2	2	1	1	2	2	0	0	0	0
30	Lythraceae	12	3	0	0	12	3	10	2	0	0
31	Magnoliaceae	11	7	6	3	11	7	10	6	0	0
32	Malvaceae	11	7	9	5	2	2	1	1	0	0
33	Melastomataceae	1	1	0	0	0	0	1	1	0	0
34	Meliaceae	10	5	0	0	8	4	7	3	2	1
35	Myristicaceae	5	2	2	1	3	1	0	0	0	0
36	Myrtaceae	7	7	5	5	2	2	0	0	0	0
37	Olacaceae	1	1	1	1	0	0	1	1	0	0
38	Oleaceae	2	2	2	2	0	0	0	0	0	0
39	Opiliaceae	1	1	0	0	1	1	0	0	1	1
40	Oxalidaceae	1	1	1	1	0	0	0	0	0	0
41	Phyllanthaceae	8	5	4	4	4	1	4	1	0	0
42	Picrodendraceae	1	1	1	1	0	0	0	0	0	0
43	Podocarpaceae	1	1	1	1	0	0	0	0	0	0
44	Putranjivaceae	3	3	3	3	0	0	0	0	0	0
45	Rubiaceae	19	16	10	8	9	8	3	3	0	0
46	Rutaceae	1	1	0	0	1	1	0	0	0	0
47	Salicaceae	4	2	3	1	1	1	0	0	0	0
48	Sapotaceae	4	4	4	4	0	0	1	1	0	0
49	Sauraulaceae	1	1	1	1	0	0	0	0	0	0
50	Schisandraceae	3	2	3	2	0	0	0	0	0	0
51	Theaceae	2	1	2	1	2	1	0	0	0	0
52	Thymelaeaceae	2	2	2	2	0	0	0	0	0	0
	Grand Total	419	222	206	115	290	141	156	75	7	4

Note: Each species can be in more than one group of selected trees

Table 3.4 Number of all families of each group of selected tree species that are found 100% inside protected areas

No.	Family	Sum no. of records	Sum no. of species	No. of species in each selected tree group: Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation	No. of records and no. of species in each PA type: Forest park		National park		No-hunting area		Wildlife sanctuary	
								rec.	spp.	rec.	spp.	rec.	spp.	rec.	spp.
1	Actinidiaceae	1	1	0	1	0	0	0	0	1	1	0	0	0	0
2	Akaniaceae	2	1	1	0	0	0	0	0	2	1	0	0	0	0
3	Anacardiaceae	5	3	0	3	1	0	0	0	4	2	0	0	1	1
4	Annonaceae	3	3	1	1	1	0	0	0	1	1	1	1	1	1
5	Apocynaceae	2	1	0	1	0	1	0	0	1	1	0	0	1	1
6	Berberidaceae	1	1	0	1	0	0	0	0	1	1	0	0	0	0
7	Bignoniaceae	1	1	0	1	0	0	0	0	1	1	0	0	0	0
8	Chrysobalanace	2	1	0	1	1	0	0	0	2	1	0	0	0	0
9	Combretaceae	2	2	0	2	0	0	0	0	2	2	0	0	0	0
10	Cornaceae	2	1	0	1	0	0	0	0	2	1	0	0	0	0
11	Dilleniaceae	2	2	1	1	2	0	0	0	2	2	0	0	0	0
12	Dipterocarpaceae	5	4	3	4	3	0	0	0	2	2	0	0	3	2
13	Ebenaceae	11	7	2	7	7	0	0	0	7	5	1	1	3	3
14	Ericaceae	3	2	2	1	0	0	0	0	1	1	0	0	2	1
15	Erythroxylaceae	1	1	0	0	1	0	0	0	1	1	0	0	0	0
16	Euphorbiaceae	1	1	1	0	0	0	0	0	1	1	0	0	0	0
17	Fabaceae	10	8	2	8	2	0	0	0	8	6	1	1	1	1
18	Fagaceae	4	3	1	3	3	0	0	0	4	3	0	0	0	0
19	Hamamelidaceae	4	3	3	1	0	0	0	0	2	2	0	0	2	1

No.	Family	Sum no. of records	Sum no. of species	No. of species in each selected tree group				No. of records and no. of species in each PA type							
				Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation	Forest park		National park		No-hunting area		Wildlife sanctuary	
								rec.	spp.	rec.	spp.	rec.	spp.	rec.	spp.
20	Lauraceae	15	10	6	2	2	0	0	0	11	6	2	2	2	2
21	Magnoliaceae	2	2	0	2	2	0	0	0	1	1	0	0	1	1
22	Malvaceae	2	2	2	0	0	0	0	0	2	2	0	0	0	0
23	Myristicaceae	1	1	1	0	0	0	0	0	1	1	0	0	0	0
24	Myrtaceae	5	5	5	0	0	0	0	0	2	2	2	2	1	1
25	Ochnaceae	4	1	0	1	0	0	0	0	4	1	0	0	0	0
26	Oleaceae	2	2	2	0	0	0	0	0	2	2	0	0	0	0
27	Phyllanthaceae	1	1	1	0	0	0	0	0	1	1	0	0	0	0
28	Polygalaceae	4	2	0	2	2	0	0	0	4	2	0	0	0	0
29	Primulaceae	1	1	1	0	0	0	0	0	1	1	0	0	0	0
30	Proteaceae	3	2	1	2	0	0	1	1	2	1	0	0	0	0
31	Putranjivaceae	2	2	2	0	0	0	0	0	2	2	0	0	0	0
32	Rubiaceae	6	5	4	1	0	0	0	0	5	4	1	1	0	0
33	Rutaceae	1	1	1	0	0	0	0	0	1	1	0	0	0	0
34	Salicaceae	2	2	1	1	0	0	0	0	2	2	0	0	0	0
35	Sapindaceae	1	1	1	1	1	0	0	0	1	1	0	0	0	0
36	Symplocaceae	1	1	0	1	0	0	0	0	1	1	0	0	0	0
37	Theaceae	2	1	1	0	0	0	0	0	0	0	0	0	2	1
	Grand Total	117	88	46	50	28	1	1	1	88	66	8	8	20	16

Note: Each species can be in more than one group of selected trees

Table 3.5 Number of all species of each group of selected tree species that are found 100% inside protected areas

No.	Family	Botanical name	Sum no. of records	Member of selected tree group: Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation	No. of records in each protected area type: Forest park	National park	No-hunting area	Wildlife sanctuary
1	Actinidiaceae	*Saurauia napaulensis* DC.	1	0	1	0	0	0	1	0	0
2	Akaniaceae	*Bretschneidera sinensis* Hemsl.	2	1	0	0	0	0	2	0	0
3	Anacardiaceae	*Buchanania lanzan* Spreng.	1	0	1	1	0	0	1	0	0
4	Anacardiaceae	*Campnosperma coriaceum* (Jack) Hall.f. ex Steenis	1	0	1	0	0	0	0	0	1
5	Anacardiaceae	*Choerospondias axillaris* (Roxb.) B.L. Burtt & Hill	3	0	1	0	0	0	3	0	0
6	Annonaceae	*Goniothalamus cheliensis* Hu	1	1	0	0	0	0	1	0	0
7	Annonaceae	*Monoon lateriflorum* Blume	1	0	1	0	0	0	0	1	0
8	Annonaceae	*Platymitra siamensis* Craib	1	0	0	1	0	0	0	0	1
9	Apocynaceae	*Wrightia arborea* (Dennst.) Mabb.	2	0	1	0	1	0	1	0	1
10	Berberidaceae	*Mahonia duclouxiana* Gagnep.	1	0	1	0	0	0	1	0	0
11	Bignoniaceae	*Stereospermum neuranthum* Kurz	1	0	1	0	0	0	1	0	0
12	Chrysobalanace	*Parinari annamense* Hance	2	0	1	1	0	0	2	0	0
13	Combretaceae	*Combretum quadrangulare* Kurz	1	0	1	0	0	0	1	0	0
14	Combretaceae	*Terminalia mucronata* Craib & Hutch.	1	0	1	0	0	0	1	0	0
15	Cornaceae	*Mastixia euonymoides* Prain	2	0	1	0	0	0	2	0	0
16	Dilleniaceae	*Dillenia pentagyna* Roxb.	1	0	1	1	0	0	1	0	0
17	Dilleniaceae	*Dillenia scabrella* (D.Don) Roxb. ex Wall.	1	1	0	1	0	0	1	0	0
18	Dipterocarpaceae	*Hopea griffithii* Kurz	1	0	1	1	0	0	1	0	0
19	Dipterocarpaceae	*Hopea recopei* Pierre ex Laness.	1	1	1	1	0	0	1	0	0
20	Dipterocarpaceae	*Shorea faguetiana* F.Heim	1	1	1	1	0	0	0	0	1
21	Dipterocarpaceae	*Vatica bella* Slooten	2	1	1	0	0	0	0	0	2
22	Ebenaceae	*Diospyros dasyphylla* Kurz	2	1	1	1	0	0	2	0	0
23	Ebenaceae	*Diospyros diepenhorstii* Miq.	1	0	1	1	0	0	1	0	0

No.	Family	Botanical name	Sum no. of records	Member of selected tree group				No. of records in each protected area type			
				Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation	Forest park	National park	No-hunting area	Wildlife sanctuary
24	Ebenaceae	*Diospyros fulvopilosa* H.R.Fletcher	1	0	1	1	0	0	0	0	1
25	Ebenaceae	*Diospyros lanceifolia* Roxb.	1	0	1	1	0	0	1	0	0
26	Ebenaceae	*Diospyros pilosiuscula* G.Don	1	0	1	1	0	0	1	0	0
27	Ebenaceae	*Diospyros sumatrana* Miq.	4	0	1	1	0	0	2	1	1
28	Ebenaceae	*Diospyros thaiensis* Phengklai	1	1	1	1	0	0	0	0	1
29	Ericaceae	*Rhododendron delavayi* Franch.	1	1	1	0	0	0	1	0	0
30	Ericaceae	*Rhododendron simsii* Planch.	2	1	0	0	0	0	0	0	2
31	Erythroxylaceae	*Erythroxylum cuneatum* (Miq.) Kurz	1	0	0	1	0	0	1	0	0
32	Euphorbiaceae	*Ptychopyxis plagiocarpa* Airy Shaw	1	1	0	0	0	0	1	0	0
33	Fabaceae	*Acacia meanrsii* De Wild.	1	0	1	0	0	0	1	0	0
34	Fabaceae	*Acrocarpus fraxinifolius* Wight ex Arn.	1	0	1	1	0	0	1	0	0
35	Fabaceae	*Albizia garrettii* I.C.Nielsen	2	1	1	0	0	0	2	0	0
36	Fabaceae	*Cassia bakeriana* Craib	1	0	1	0	0	0	1	0	0
37	Fabaceae	*Crudia caudata* Prain ex King	1	1	1	0	0	0	0	0	1
38	Fabaceae	*Erythrina stricta* Roxb. var. *stricta*	1	0	1	0	0	0	1	0	0
39	Fabaceae	*Millettia leucantha* Kurz var. *leucantha*	2	0	1	1	0	0	2	0	0
40	Fabaceae	*Senna siamea* (Lam.) H.S. Irwin & Barneby	1	0	1	0	0	0	0	1	0
41	Fagaceae	*Castanopsis fissa* (Champ. ex Benth.) Rehder & E.H.Wilson	2	0	1	1	0	0	2	0	0
42	Fagaceae	*Castanopsis pseudo-hystrix* Phengklai	1	1	1	1	0	0	1	0	0
43	Fagaceae	*Quercus vestita* Griff.	1	0	1	1	0	0	1	0	0
44	Hamamelidaceae	*Distylium annamicum* (Gagnep.) Airy Shaw	2	1	0	0	0	0	0	0	2
45	Hamamelidaceae	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.	1	1	1	0	0	0	1	0	0
46	Hamamelidaceae	*Loropetalum chinense* (R.Br.) Oliv. var. *chinense*	1	1	0	0	0	0	1	0	0

No.	Family	Botanical name	Sum no. of records	Member of selected tree group: Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation	No. of records in each protected area type: Forest park	National park	No-hunting area	Wildlife sanctuary
47	Lauraceae	*Beilschmiedia elegantissima* Kosterm.	2	1	0	0	0	0	2	0	0
48	Lauraceae	*Beilschmiedia inconspicua* Kesterm.	1	1	0	0	0	0	0	0	1
49	Lauraceae	*Beilschmiedia velutinosa* Kosterm.	1	1	0	0	0	0	1	0	0
50	Lauraceae	*Cinnamomum parthenoxylon* (Jack) Meisn.	1	0	0	1	0	0	0	1	0
51	Lauraceae	*Litsea kerrii* Kosterm.	1	1	0	0	0	0	1	0	0
52	Lauraceae	*Litsea pseudo-umbellata* Kosterm.	1	1	0	0	0	0	1	0	0
53	Lauraceae	*Litsea punctulata* Kosterm.	1	1	0	0	0	0	0	1	0
54	Lauraceae	*Litsea semecarpifolia* (Wall ex Nees) Hook	1	0	1	0	0	0	1	0	0
55	Lauraceae	*Neolitsea zeylanica* (Nees & T.Nees) Merr.	5	0	0	1	0	0	5	0	0
56	Lauraceae	*Persea gamblei* (Hook.f.) Kosterm.	1	0	1	0	0	0	0	0	1
57	Magnoliaceae	*Magnolia cathcartii* (Hook.f. &Thomson) Noot.	1	0	1	1	0	0	1	0	0
58	Magnoliaceae	*Magnolia elegans* (Blume) H.Keng	1	0	1	1	0	0	0	0	1
59	Malvaceae	*Burretiodendron esquirolii* (Lév.) Rehder	1	1	0	0	0	0	1	0	0
60	Malvaceae	*Firmiana kerrii* (Craib) Kosterm	1	1	0	0	0	0	1	0	0
61	Myristicaceae	*Knema tenuinervia* W.J. de Wilde subsp. *kanburiensis* W.J. de Wilde	1	1	0	0	0	0	1	0	0
62	Myrtaceae	*Syzygium aksornii* Chantar. & J.Parn.	1	1	0	0	0	0	0	1	0
63	Myrtaceae	*Syzygium cacuminis* (Craib) Chantar. & J.Parn subsp. *inthanonense* P.Chan. & J.Parn	1	1	0	0	0	0	1	0	0
64	Myrtaceae	*Syzygium kerrii* Chantar. & J.Parn.	1	1	0	0	0	0	0	0	1
65	Myrtaceae	*Syzygium myrtifolium* Walp.	1	1	0	0	0	0	0	1	0
66	Myrtaceae	*Syzygium rigens* (Craib) Chantar. & J. Parn.	1	1	0	0	0	0	1	0	0
67	Ochnaceae	*Ochna integerrima* (Lour.) Merr.	4	0	1	0	0	0	4	0	0
68	Oleaceae	*Chionanthus maxwelli* P.S.Green	1	1	0	0	0	0	1	0	0
69	Oleaceae	*Chionanthus sutepensis* (Kerr) P.S.Green	1	1	0	0	0	0	1	0	0

No.	Family	Botanical name	Sum no. of records	Member of selected tree group: Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation	No. of records in each protected area type: Forest park	National park	No-hunting area	Wildlife sanctuary
70	Phyllanthaceae	*Aporosa globifera* Hook.f.	1	1	0	0	0	0	1	0	0
71	Polygalaceae	*Xanthophyllum lanceatum* J.J.Sm.	2	0	1	1	0	0	2	0	0
72	Polygalaceae	*Xanthophyllum virens* Roxb.	2	0	1	1	0	0	2	0	0
73	Primulaceae	*Ardisia nervosa* H.R.Fletcher	1	1	0	0	0	0	1	0	0
74	Proteaceae	*Helicia formosana* Hemsl. var. *oblanceolata* Sleumer	2	0	1	0	0	0	2	0	0
75	Proteaceae	*Helicia vestita* W.W. Sm.	1	1	1	0	0	1	0	0	0
76	Putranjivaceae	*Drypetes helferi* (Hook.f.) Pax & K.Hoffm.	1	1	0	0	0	0	1	0	0
77	Putranjivaceae	*Drypetes subsessile* (Kurz) Pax & K.Hoffm.	1	1	0	0	0	0	1	0	0
78	Rubiaceae	*Fosbergia thailandica* Tirveng. & Sastre	1	1	0	0	0	0	1	0	0
79	Rubiaceae	*Gardenia thailandica* Tirveng.	2	1	0	0	0	0	2	0	0
80	Rubiaceae	*Gardiniopsis longifolia* Miq.	1	1	0	0	0	0	0	1	0
81	Rubiaceae	*Ixora grandifolia* Zoll. & Moritzi	1	0	1	0	0	0	1	0	0
82	Rubiaceae	*Rothmannia sootepensis* (Craib) Bremek.	1	1	0	0	0	0	1	0	0
83	Rutaceae	*Citrus halimii* B.C.Stone	1	1	0	0	0	0	1	0	0
84	Salicaceae	*Homalium ceylanicum* (Gardner) Benth.	1	0	1	0	0	0	1	0	0
85	Salicaceae	*Homalium peninsulare* Sleum.	1	1	0	0	0	0	1	0	0
86	Sapindaceae	*Nephelium maingayi* Hiern	1	1	1	1	0	0	1	0	0
87	Symplocaceae	*Symplocos cochinchinensis* (Lour.) S. Moore var. *cochinchinensis*	1	0	1	0	0	0	1	0	0
88	Theaceae	*Gordonia axillaris* (Roxb. ex Ker Gawl) Endl.	2	1	0	0	0	0	0	0	2
	Grand total		117	46	50	28	1	1	88	8	20

Note: Each species can be in more than one group of selected trees

Table 3.6 Number of all species of each group of selected tree species that are found 100% outside protected areas

No.	Family	Botanical name	Sum no. of records	Member of selected tree group: Trees that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
1	Achariaceae	*Hydnocarpus ilicifolia* King	7	0	1	1	0
2	Altingiaceae	*Altingia excelsa* Noranha	2	1	1	1	0
3	Anacardiaceae	*Parishia insignis* Hook.f.	4	0	1	0	0
4	Anacardiaceae	*Pentaspadon velutinus* Hook.f.	2	0	1	1	0
5	Annonaceae	*Mitrephora sirikitiae* Weeras., Chalermglin & R.M.K.Saunders	1	1	0	0	0
6	Annonaceae	*Mitrephora wangii* Hu	1	1	0	0	0
7	Annonaceae	*Monoon sclerophyllum* (Hook.f. &Thomson) B.Xue & R.M.K. Saunders	1	0	1	0	0
8	Annonaceae	*Polyalthia stenopetala* (Hook & Thomson) Finet. & Gagnep.	2	1	0	0	0
9	Annonaceae	*Polyalthia suberosa* (Roxb.) Thwaites	1	0	1	0	0
10	Annonaceae	*Pseuduvaria macrophylla* (Oliv.) Merr. var. *sessilicarpa* J.Sinclair	1	1	0	0	0
11	Annonaceae	*Trivalvaria macrophylla* Miq.	3	1	0	0	0
12	Annonaceae	*Xylopia ferruginea* (Hook.f. & Thomson) Hook.f. & Thomson	1	0	1	0	0
13	Apocynaceae	*Alstonia spatulata* Blume	1	1	1	0	0
14	Apocynaceae	*Dyera costulata* (Miq.) Hook.f.	4	1	1	0	0
15	Apocynaceae	*Kopsia rosea* D.J.Middleton	1	1	0	0	0
16	Apocynaceae	*Tabernaemontana macrocarpa* Jack	2	1	0	0	0
17	Apocynaceae	*Wrightia sirikitiae* D.J.Middleton & Santisuk	4	1	0	0	0
18	Aquifoliaceae	*Ilex triflora* Blume	1	0	1	0	0
19	Bignoniaceae	*Dolichandrone serrulata* (Wall. ex D.C.) Seem	5	0	1	0	0
20	Bignoniaceae	*Fernandoa collignonii* (P.Dop) Steenis	1	1	0	0	0
21	Bignoniaceae	*Mayodendron igneum* (Kurz) Kurz	2	0	1	0	0
22	Bignoniaceae	*Radermachera boniana* Dop	1	1	0	0	0
23	Bignoniaceae	*Radermachera peninsularis* Steenis	4	1	0	0	0
24	Bignoniaceae	*Radermachera pinnata* (Blanco) Seem.	3	1	0	0	0
25	Bignoniaceae	*Santisukia kerrii* (Barnett & Sandwith) Brummitt	7	1	0	0	0
26	Bignoniaceae	*Stereospermum fimbriatum* (Wall. ex G. Don) A.DC.	1	0	1	0	0

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27	Bombacaceae	*Bombax anceps* Pierre var. *anceps*	5	0	1	0	0
28	Bombacaceae	*Bombax ceiba* L.	1	0	1	0	0
29	Boraginaceae	*Cordia subcordata* Lam.	3	1	1	0	0
30	Burseraceae	*Canarium pavum* Leenh.	1	1	0	0	0
31	Burseraceae	*Canarium subulatum* Guillaumin	1	0	1	1	0
32	Burseraceae	*Dacryodes kingii* (Engl.) Kalkman	3	1	0	0	0
33	Burseraceae	*Santiria rubiginosa* Blume	1	1	0	0	0
34	Burseraceae	*Santiria tomentosa* Blume	1	1	0	0	0
35	Calophyllaceae	*Calophyllum canum* Hook.f. ex T.Anderson	1	1	0	0	0
36	Calophyllaceae	*Calophyllum inophyllum* L.	2	0	1	1	0
37	Calophyllaceae	*Calophyllum pisiferum* Planch. & Triana	3	0	1	0	0
38	Calophyllaceae	*Calophyllum rupicolum* Ridl.	2	1	0	0	0
39	Calophyllaceae	*Calophyllum sclerophyllum* Vesgue	1	1	0	0	0
40	Calophyllaceae	*Mammea harmandii* Kosterm.	2	0	1	1	0
41	Capparaceae	*Maerua siamensis* (Kurz) Pax	2	0	1	0	0
42	Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	7	0	1	0	0
43	Combretaceae	*Terminalia franchetii* Gagnep.	1	1	0	0	0
44	Combretaceae	*Terminalia nigrovenulosa* Pierre	2	0	1	0	0
45	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	1	0	1	1	0
46	Dilleniaceae	*Dillenia pulchella* (Jack) Gilg	1	0	1	1	0
47	Dilleniaceae	*Dillenia reticulata* King	1	1	0	1	0
48	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King	6	1	1	0	0
49	Dipterocarpaceae	*Anisoptera laevis* Ridl.	2	1	1	0	0
50	Dipterocarpaceae	*Cotylelobium lanceolatum* Craib	2	1	1	1	0
51	Dipterocarpaceae	*Dipterocarpus acutangulus* Vesque	1	1	1	0	0
52	Dipterocarpaceae	*Dipterocarpus hasseltii* Blume	1	1	1	0	0
53	Dipterocarpaceae	*Hopea sangal* Korth.	1	1	1	1	0
54	Dipterocarpaceae	*Hopea sublanceolata* Symington	4	1	1	1	0
55	Dipterocarpaceae	*Hopea thorelii* Pierre	3	1	1	1	0
56	Dipterocarpaceae	*Parashorea densiflora* Slooten & Symington subsp. *Kerrii* (Tardieu) R.Pooma	2	1	1	1	0
57	Dipterocarpaceae	*Shorea assamica* Dyer	1	0	1	0	0
58	Dipterocarpaceae	*Shorea bracteolata* Dyer	1	1	1	0	0
59	Dipterocarpaceae	*Shorea curtisii* Dyer ex King	2	0	1	1	0
60	Dipterocarpaceae	*Shorea farinosa* C.E.C.Fisch.	2	1	1	1	0

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61	Dipterocarpaceae	*Shorea macroptera* Dyer	2	1	1	0	0
62	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *velutinata* P.S.Ashton	1	0	1	1	0
63	Dipterocarpaceae	*Vatica mangachapoi* subsp. *obtusifolia* (Elmer) P.S.Ashton	3	1	1	0	0
64	Dipterocarpaceae	*Vatica philastreana* Pierre	1	1	1	0	0
65	Dipterocarpaceae	*Vatica umbonata* (Hook.f.) Burck	1	0	1	0	0
66	Ebenaceae	*Diospyros apiculata* Hiern	1	0	1	1	0
67	Ebenaceae	*Diospyros areolata* King & Gamble	3	0	1	1	0
68	Ebenaceae	*Diospyros bambuseti* H.R.Fletcher	1	1	1	1	0
69	Ebenaceae	*Diospyros castanea* (Craib) H.R.Fletcher	1	0	1	1	0
70	Ebenaceae	*Diospyros curranii* Merr.	2	0	1	1	0
71	Ebenaceae	*Diospyros dumetorum* W.W.Sm.	2	1	1	1	0
72	Ebenaceae	*Diospyros gracilis* H.R.Fletcher	4	1	1	1	0
73	Ebenaceae	*Diospyros hasseltii* Zoll.	1	0	1	1	0
74	Ebenaceae	*Diospyros insidiosa* Bakh.	1	0	1	1	0
75	Ebenaceae	*Diospyros kurzii* Hiern.	2	0	1	1	0
76	Ebenaceae	*Diospyros scalariformis* H.R.Fletcher	1	1	1	1	0
77	Ebenaceae	*Diospyros trianthos* Phengklai	1	1	1	1	0
78	Ebenaceae	*Diospyros venosa* Wall. ex A.DC.	3	0	1	1	0
79	Elaeocarpaceae	*Elaeocarpus griffithii* (Wight) A. Gray	1	0	1	1	0
80	Elaeocarpaceae	*Elaeocarpus macrocerus* (Turcz.) Merr.	4	0	1	1	0
81	Ericaceae	*Diplycosia heterophylla* Blume var. *latifolia* (Blume) Sleum.	1	1	0	0	0
82	Ericaceae	*Rhododendron longiflorum* Lindl.	4	1	0	0	0
83	Euphorbiaceae	*Blumeodendron kurzii* (Hook.f.) Sm.	1	0	1	0	0
84	Euphorbiaceae	*Blumeodendron tokbrai* (Blume) J.J.Sm	1	1	0	0	0
85	Euphorbiaceae	*Claoxylon putii* Airy Shaw	1	1	0	0	0
86	Euphorbiaceae	*Cleidion javanicum* Blume	1	0	1	0	0
87	Euphorbiaceae	*Dimorphocalyx muricatus* (Hook.f.) Airy Shaw	3	1	0	0	0
88	Euphorbiaceae	*Hancea kingii* (Hook.f.) S.E.C.Sierra, Kulju & Welzen	3	1	0	0	0
89	Euphorbiaceae	*Mallotus calocarpus* Airy Shaw	2	1	0	0	0

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90	Euphorbiaceae	*Mallotus kongkandae* Welzen & Phattar.	2	1	0	0	0
91	Euphorbiaceae	*Sauropus thyrsiflorus* Welzen	1	1	0	0	0
92	Fabaceae	*Acacia tomentosa* Willd.	2	0	1	1	0
93	Fabaceae	*Albizia vialeana* Pierre	3	1	1	0	0
94	Fabaceae	*Archidendron bubalinum* (Jack) I.C.Nielsen	4	0	1	0	0
95	Fabaceae	*Archidendron ellipticum* (Blume) I.C.Nielsen	1	0	1	0	0
96	Fabaceae	*Archidendron lucidum* (Benth.) I.C.Nielsen	1	0	1	0	0
97	Fabaceae	*Archidendron quocense* (Pierre) I.C.Nielsen	7	1	1	0	0
98	Fabaceae	*Bauhinia saccocalyx* Pierre	2	0	1	0	0
99	Fabaceae	*Bauhinia variegata* L.	2	0	1	0	0
100	Fabaceae	*Butea monosperma* (Lam.) Taub.	10	0	1	0	0
101	Fabaceae	*Cathormion umbellatum* (Vahl) Kosterm.	3	0	1	0	0
102	Fabaceae	*Crudia speciosa* Prain	1	1	1	0	0
103	Fabaceae	*Cynometra craibii* Gagnep.	1	1	1	0	0
104	Fabaceae	*Cynometra malaccensis* Meeuwen	1	0	1	0	0
105	Fabaceae	*Dalbergia cana* Graham ex Kurz var. *kurzii* (Prain) Niyomdham	2	0	1	1	0
106	Fabaceae	*Dalbergia lanceolaria* L.f.	1	0	1	0	0
107	Fabaceae	*Dalbergia oliveri* Gamble ex Prain	1	0	1	1	1
108	Fabaceae	*Derris indica* (Lam.) Bennet	2	0	1	0	0
109	Fabaceae	*Erythrina subumbrans* (Hassk.) Merr.	2	0	1	0	0
110	Fabaceae	*Gymnocladus burmanicus* C.E. Parkinson	2	1	1	0	0
111	Fabaceae	*Ormosia sumatrana* (Miq.) Prain	1	0	1	0	0
112	Fabaceae	*Peltophorum dasyrrhachis* (Miq.) Kurz	2	0	1	1	0
113	Fabaceae	*Pterocarpus indicus* Willd.	2	0	1	0	0
114	Fabaceae	*Sindora echinocalyx* Prain	2	0	1	0	0
115	Fagaceae	*Castanopsis megacarpa* Gamble	1	1	1	1	0
116	Fagaceae	*Castanopsis rhamnifolia* (Miq.) A. DC.	2	0	1	1	0
117	Fagaceae	*Lithocarpus cyclocarpus* (Endl.) A. Camus	1	0	1	1	0
118	Fagaceae	*Lithocarpus echinops* Hjelmq.	2	1	1	1	0
119	Fagaceae	*Lithocarpus pattaniensis* Barnett	7	1	1	1	0

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120	Fagaceae	*Lithocarpus rassa* (Miq.) Rehd.	2	0	1	1	0
121	Fagaceae	*Lithocarpus siamensis* A. Camus	1	1	1	1	0
122	Fagaceae	*Lithocarpus sundaicus* (Blume) Rehder	11	0	1	1	0
123	Fagaceae	*Quercus franchetii* Skan	1	0	1	1	0
124	Fagaceae	*Quercus lanata* Sm.	1	0	1	1	0
125	Fagaceae	*Quercus mespilifolia* Wall ex A. DC var. *mespilifoli*	1	0	1	1	0
126	Fagaceae	*Quercus quangtriensis* Hickel & A. Camus	1	0	1	1	0
127	Fagaceae	*Quercus semecarpifolia* Sm.	1	0	1	1	0
128	Gentianaceae	*Fagraea fragrans* Roxb.	3	0	1	1	1
129	Hamamelidaceae	*Rhodoleia championii* Hook.f.	2	1	0	0	0
130	Hernandiaceae	*Hernandia nymphaeifolia* (J.Presl) Kubitzki	2	0	1	0	0
131	Hypericaceae	*Cratoxylum arborescens* (Vahl) Blume	1	1	0	1	0
132	Icacinaceae	*Pittosporopsis kerrii* Craib	1	0	1	0	0
133	Icacinaceae	*Stemonurus secundiflorus* Blume	1	0	1	0	0
134	Lamiaceae	*Gmelina racemosa* (Lour.) Merr.	2	1	0	0	0
135	Lamiaceae	*Peronema canescens* Jack	4	0	0	1	0
136	Lamiaceae	*Vitex longisepala* King & Gamble	3	1	0	0	0
137	Lauraceae	*Beilschmiedia villosa* Kosterm.	1	1	0	0	0
138	Lauraceae	*Cinnamomum ilicioides* A. Chev.	2	0	1	1	0
139	Lauraceae	*Litsea martabarnica* (Kurz) Hook.f.	1	0	1	0	0
140	Lauraceae	*Litsea monopetala* (Roxb.) Pers.	1	0	1	1	0
141	Lauraceae	*Neocinnamomum caudatum* (Nees) Merrs.	1	0	1	0	0
142	Lauraceae	*Phoebe lanceolata* (Nees) Nees	2	0	1	1	0
143	Lauraceae	*Phoebe paniculata* (Nees) Nees	2	0	1	1	0
144	Lauraceae	*Phoebe tavoyana* (Meisn.) Hook.f.	1	0	1	0	0
145	Lecythidaceae	*Barringtonia asiatica* (L.) Kurz	1	1	1	0	0
146	Lecythidaceae	*Barringtonia racemosa* (L.) Spreng.	1	0	1	0	0
147	Lythraceae	*Lagerstroemia calyculata* Kurz	6	0	1	1	0
148	Lythraceae	*Lagerstroemia cochinchinensis* Pierre	4	0	1	1	0

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149	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	2	0	1	0	0
150	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *pubinervia* (Blume) Figlar & Noot.	1	0	1	1	0
151	Magnoliaceae	*Magnolia citrata* Noot. & Chalermglin	1	0	1	1	0
152	Magnoliaceae	*Magnolia duperreana* Pierre	1	1	1	1	0
153	Magnoliaceae	*Magnolia gustavii* King	2	0	1	1	0
154	Magnoliaceae	*Magnolia insignis* Wall.	1	0	1	0	0
155	Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar	3	1	1	1	0
156	Magnoliaceae	*Magnolia sirindhorniae* Noot. & Chalermglin	2	1	1	1	0
157	Malvaceae	*Dicellostyles zizyphifolia* (Griff.) Phup.	3	1	0	0	0
158	Malvaceae	*Durio graveolens* Becc.	1	1	0	0	0
159	Malvaceae	*Neesia malayana* Bakh.	1	0	1	1	0
160	Malvaceae	*Reevesia pubescens* Mast. var. *pubescens*	1	1	0	0	0
161	Malvaceae	*Reevesia pubescens* Mast. var. *siamensis* (Craib) Anthony	3	1	0	0	0
162	Malvaceae	*Scaphium linearicarpum* (Mast.) Pierre	1	0	1	0	0
163	Malvaceae	*Sterculia gilva* Miq.	1	1	0	0	0
164	Melastomataceae	*Memecylon ovatum* Sm.	1	0	0	1	0
165	Meliaceae	*Azadirachta excelsa* (Jack) Jacobs	2	0	0	0	1
166	Meliaceae	*Sandoricum beccarianum* Baill.	1	0	1	0	0
167	Meliaceae	*Xylocarpus granatum* J. Koenig	3	0	1	1	0
168	Meliaceae	*Xylocarpus moluccensis* (Lam.) M. Roem.	3	0	1	1	0
169	Meliaceae	*Xylocarpus rumphii* (Kostel.) Mabb.	1	0	1	1	0
170	Myristicaceae	*Horsfieldia crassifolia* (Hook.f.et.Th.) Warb.	3	0	1	0	0
171	Myristicaceae	*Knema austrosiamensis* W.J. de Wilde	2	1	0	0	0
172	Myrtaceae	*Melaleuca cajuputi* Powell	1	0	1	0	0
173	Myrtaceae	*Syzygium hemsleyanum* (King) Chantar. & J.Parn subsp. *paucinervium* Chantar. & J.Parn	1	1	0	0	0
174	Myrtaceae	*Syzygium ixoroides* Chantar.& J.Parn	1	1	0	0	0
175	Myrtaceae	*Syzygium lakshrakarae* Chantar.& J.Parn	1	1	0	0	0

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176	Myrtaceae	*Syzygium oblatum* (Roxb.) Wall. ex A.M. Cowan & Cowan var. *oblatum*	1	0	1	0	0
177	Myrtaceae	*Syzygium putii* Chantar.& J.Parn	1	1	0	0	0
178	Myrtaceae	*Syzygium samarangense* (Blume) Merr. & L.M.Perry	1	1	0	0	0
179	Olacaceae	*Scorodocarpus borneensis* (Baill.) Becc.	1	1	0	1	0
180	Oleaceae	*Chionanthus decipiens* P.S.Green	1	1	0	0	0
181	Oleaceae	*Chionanthus velutinus* (Kerr) P.S.Green	1	1	0	0	0
182	Opiliaceae	*Melientha suavis* Pierre	1	0	1	0	1
183	Oxalidaceae	*Sarcotheca laxa* (Ridl.) Kunth	1	1	0	0	0
184	Phyllanthaceae	*Baccaurea sumatrana* (Miq.) Müll.Arg.	1	1	0	0	0
185	Phyllanthaceae	*Bischofia javanica* Blume	4	0	1	1	0
186	Phyllanthaceae	*Cleistanthus hirsutopetalus* Gage	1	1	0	0	0
187	Phyllanthaceae	*Glochidion santisukii* Airy Saw	1	1	0	0	0
188	Phyllanthaceae	*Phyllanthus angkorensis* Beille	1	1	0	0	0
189	Picrodendraceae	*Austrobuxus nitidus* Miq.	1	1	0	0	0
190	Podocarpaceae	*Dacrycapus imbricatus* (Blume) de Laub.	1	1	0	0	0
191	Putranjivaceae	*Drypetes curtisii* (Hook.f.) Pax & K.Hoffm	1	1	0	0	0
192	Putranjivaceae	*Drypetes ochrothrix* Airy Saw	1	1	0	0	0
193	Putranjivaceae	*Drypetes viridis* Airy Saw	1	1	0	0	0
194	Rubiaceae	*Ceriscoides kerrii* Azmi	1	1	0	0	0
195	Rubiaceae	*Ceriscoides mamillata* (Craib) Tirveng.	1	1	0	0	0
196	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Hook. f.	1	0	1	1	0
197	Rubiaceae	*Haldina cordifolia* (Roxb.) Ridsdale	1	0	1	1	0
198	Rubiaceae	*Luculia gratissima* (Wall.) Sweet var. *glabra* Fukuoka	1	0	1	0	0
199	Rubiaceae	*Mitragyna diversifolia* (Wall. ex G. Don) Havil	1	0	1	0	0
200	Rubiaceae	*Nauclea orientalis* (L.) L.	1	0	1	1	0
201	Rubiaceae	*Nauclea subdita* (Korth.) Steud.	1	0	1	0	0
202	Rubiaceae	*Neolamarckia cadamba* (Roxb.) Bosser	1	0	1	0	0
203	Rubiaceae	*Ochreinauclea maingayi* (Hook.f.) Ridsdale	2	0	1	0	0

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204	Rubiaceae	*Pertusadina malaccensis* Ridsdale	1	1	0	0	0
205	Rubiaceae	*Pitardelia poilanei* Tirveng.	1	1	0	0	0
206	Rubiaceae	*Rennellia morindiformis* (Korth.) Ridl.	2	1	0	0	0
207	Rubiaceae	*Vidalasia fusca* (Craib) Tirveng.	2	1	0	0	0
208	Rubiaceae	*Vidalasia murina* (Criab) Tirveng.	1	1	0	0	0
209	Rubiaceae	*Vidalasia pubescens* (Tirveng. & Sastre) Tirveng.	1	1	0	0	0
210	Rutaceae	*Naringi crenulata* (Roxb.) Nicolson	1	0	1	0	0
211	Salicaceae	*Homalium foetidum* (Roxb.) Benth.	1	0	1	0	0
212	Salicaceae	*Homalium longifolium* Benth.	3	1	0	0	0
213	Sapotaceae	*Diploknema siamensis* H.R.Fletcher	1	1	0	0	0
214	Sapotaceae	*Madhuca esculenta* H.R.Fletcher	1	1	0	1	0
215	Sapotaceae	*Madhuca klackenbergii* Chantar.	1	1	0	0	0
216	Sapotaceae	*Weinmannia fraxinea* (D.Don) Miq.	1	1	0	0	0
217	Sauraulaceae	*Saurauia pentapetala* (Jack) Hoogland	1	1	0	0	0
218	Schisandraceae	*Illicium peninsulare* A.C. Sm.	1	1	0	0	0
219	Schisandraceae	*Illicium tenuifolium* (Ridl.) A.C. Sm.	2	1	0	0	0
220	Theaceae	*Pyrenaria diospyricarpa* Kurz var. *diospyricarpa*	2	1	1	0	0
221	Thymelaeaceae	*Gonystylus confusus* Airy Shaw	1	1	0	0	0
222	Thymelaeaceae	*Gyrinops vidalii* P.H.Hô	1	1	0	0	0
	Grand total		419	115	141	75	4

Note: Each species can be in more than one group of selected trees

Table 3.7 The comparison between the species representation target (%) and the percentage of the extent of occurrence (EOO) of each species covered by protected areas

No.	Family	Botanical name	Extent of occurrence (km^2)	Species representation target (%)	Area of EOO inside PA (km^2)	% Area of EOO inside PA	Result
1	Pentaphylacaceae	*Adinandra integerrima* T. Anderson ex Dyer[2]	483,746	10	68,867	14.2	covered
2	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib[2, 3, 4]	72,211	30.2	4,600	6.37	partial gap
3	Fabaceae	*Albizia odoratissima* (L.f.) Benth.[2, 3]	44,070	38.3	9,470	21.5	partial gap
4	Dipterocarpaceae	*Anisoptera costata* Korth.[2]	665,475	10	52,330	7.86	partial gap
5	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King[1, 2]	7,245	67.7	642	8.85	partial gap
6	Fagaceae	*Castanopsis wallichii* King ex Hook.f.[2, 3]	8,526	65.1	1,224	14.4	partial gap
7	Fabaceae	*Dalbergia cochinchinens* Pierre[2, 3, 4]	83,913	27.8	5,559	6.63	partial gap
8	Ebenaceae	*Diospyros andamanica* (Kurz) Bakh.[1, 2, 3]	8,527	65.1	525	6.16	partial gap
9	Ebenaceae	*Diospyros bejaudii* Lecomte[2, 3]	317,039	10	55,408	17.5	covered
10	Ebenaceae	*Diospyros defectrix* H.R.Fletcher[2, 3]	224,803	11.7	22,885	10.2	partial gap
11	Ebenaceae	*Diospyros mollis* Griff.[2, 3]	148,588	18.5	27,378	18.4	partial gap
12	Ebenaceae	*Diospyros montana* Roxb.[1, 2, 3]	53,905	35	9,500	17.6	partial gap
13	Ebenaceae	*Diospyros wallichii* King & Gamble[2, 3]	63,435	32.4	10,744	16.9	partial gap
14	Ebenaceae	*Diospyros winitii* H.R.Fletcher[1, 2, 3]	252,552	10	39,480	15.6	covered
15	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don[2, 3, 4]	468,578	10	25,704	5.49	partial gap
16	Dipterocarpaceae	*Dipterocarpus baudii* Korth.[2]	132,905	20.3	11,234	8.45	partial gap
17	Dipterocarpaceae	*Dipterocarpus chartaceus* Symington[2]	18,639	52.3	3,282	17.6	partial gap
18	Dipterocarpaceae	*Dipterocarpus costatus* C.F.Gaertn.[2]	513,360	10	53,932	10.5	covered
19	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.[1, 2]	127,197	21	16,445	12.9	partial gap
20	Dipterocarpaceae	*Dipterocarpus gracilis* Blume[2]	328,754	10	26,705	8.12	partial gap
21	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco[2, 3]	339,303	10	22,866	6.74	partial gap
22	Dipterocarpaceae	*Dipterocarpus intricatus* Dyer[2, 3]	163,383	16.9	14,039	8.59	partial gap

No.	Family	Botanical name	Extent of occurrence (km^2)	Species representation target (%)	Area of EOO inside PA (km^2)	% Area of EOO inside PA	Result
23	Dipterocarpaceae	*Dipterocarpus kerrii* King[2]	44,751	38	9,846	22	partial gap
24	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.[2, 3]	685,866	10	72,142	10.5	covered
25	Dipterocarpaceae	*Dipterocarpus retusus* Blume[1, 2]	169,118	16.4	11,473	6.78	partial gap
26	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.[2, 3, 4]	364,261	10	70,661	19.4	covered
27	Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.[2]	475,743	10	66,759	14	covered
28	Pentaphylacaceae	*Eurya acuminata* DC. var. *acuminata*[2]	228,733	11.5	50,369	22	covered
29	Dipterocarpaceae	*Hopea ferrea* Laness.[2, 3, 4]	555,202	10	70,644	12.7	covered
30	Dipterocarpaceae	*Hopea helferi* (Dyer) Brandis[1, 2, 3]	97,940	25.3	5,008	5.11	partial gap
31	Dipterocarpaceae	*Hopea oblongifolia* Dyer[1, 2, 3]	2,276	86.6	1,579	69.4	partial gap
32	Dipterocarpaceae	*Hopea odorata* Roxb.[2, 3, 4]	701,259	10	73,759	10.5	covered
33	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington[1, 2, 3]	7,862	66.4	1,591	20.2	partial gap
34	Fagaceae	*Lithocarpus falconeri* (Kurz) Rehder[2, 3]	160,311	17.2	14,278	8.91	partial gap
35	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*[2, 3]	71,712	30.4	21,471	29.9	partial gap
36	Magnoliaceae	*Magnolia liliifera* (L.) Baill[1, 2]	3,601	79.1	789	21.9	partial gap
37	Dipterocarpaceae	*Parashorea stellata* Kurz[2, 3, 4]	201,894	13.5	33,567	16.6	covered
38	Fabaceae	*Saraca indica* L.[2]	139,391	19.5	7,073	5.07	partial gap
39	Malvaceae	*Scaphium scaphigerum* (Wall. ex G.Don) G.Planch.[2]	91,733	26.3	4,990	5.44	partial gap
40	Theaceae	*Schima wallichii* (DC.) Korth.[2, 3]	65,067	31.9	8,129	12.5	partial gap
41	Dipterocarpaceae	*Shorea assamica* Dyer subsp. *globifera* (Ridl.) Y.K.Yang & J.K.Wu[2]	2,672	84	504	18.8	partial gap
42	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume[1, 2, 3]	76,900	29.2	2,091	2.72	partial gap
43	Dipterocarpaceae	*Shorea henryana* Pierre[2, 3, 4]	202,769	13.4	18,332	9.04	partial gap
44	Dipterocarpaceae	*Shorea hypochra* Hance[2, 3]	130,080	20.7	9,820	7.55	partial gap
45	Dipterocarpaceae	*Shorea leprosula* Miq.[2, 3]	2,414	85.6	672	27.8	partial gap

No.	Family	Botanical name	Extent of occurrence (km^2)	Species representation target (%)	Area of EOO inside PA (km^2)	% Area of EOO inside PA	Result
46	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume[2, 3]	237,476	10.8	46,768	19.7	covered
47	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*[2, 3]	10,589	61.5	1,706	16.1	partial gap
48	Dipterocarpaceae	*Shorea roxburghii* G.Don[2, 3, 4]	605,780	10	72,046	11.9	covered
49	Dipterocarpaceae	*Shorea siamensis* Miq.[2, 3]	676,516	10	86,551	12.8	covered
50	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.[1, 2, 3]	412,867	10	42,172	10.2	covered
51	Moraceae	*Streblus ilicifolius* (S.Vidal) Corner[2]	15,842	55	3,884	24.5	partial gap
52	Lamiaceae	*Tectona grandis* L.f.[2, 3, 4]	328,779	10	71,319	21.7	covered
53	Dipterocarpaceae	*Vatica harmandiana* Pierre[2, 3]	181,365	15.2	11,757	6.48	partial gap
54	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington[2, 3]	522,078	10	56,500	10.8	covered
55	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume[2, 3]	14,493	56.4	2,315	16	partial gap
56	Dipterocarpaceae	*Vatica stapfiana* (King) Slooten[1, 2]	27,485	46	3,908	14.2	partial gap
57	Lamiaceae	*Vitex pinnata* L.[2, 3]	234,286	11.1	16,308	6.96	partial gap

Note: [1] = trees that are threatened with extinction; [2] = trees that dominate the different forest types in Thailand; [3] = trees that are of particular economic importance; [4] = trees that are important to *in situ* genetic conservation.

3.5 Discussion

The result of the analysis conducted using first method (where the number and the percentage of species occurrence points within PA boundaries were calculated for all 749 species belonging to 93 families) showed that more records across all four tree groups were located outside a PA (Table 3.1), especially species in Group 1- trees that are threatened with extinction. 39.38% (115 out of 292 species) of this group's members were found only outside a PA, meanwhile 60.62% had at least some records within a PA (15.75% found only inside a PA and 44.86% found both inside and outside a PA). This means that 177 out of 292 species have been already conserved to some extent (Table 3.1). Regarding the other three groups: Group 2- trees that dominate the different forest types in Thailand; Group 3- trees that are of particular economic importance; and Group 4- trees that are important to *in situ* genetic conservation, members of each group have been well protected, with over 75% of their records protected to some extent in a PA (Table 3.1). This compares favourably to the target set by the Global Strategy for Plant Conservation (GSPC), that about 75% of known threatened plant species should be conserved *in situ* by 2020 (GSPC 2010).

The result of the analysis conducted using second method: gap analysis on the EOO of 57 species belonging to 10 families with precise locations and $\geq$ 5 records/species (the percentage of range inside PA of each species was compared to the representation target that was set individually for each species, to identify whether the species were considered as covered, partial gap, or gap species), it was clearly observed that there were no gap species. However, approximately 70% of the 57 analysed species were partial gap species (Table 3.7). Specifically, these partial gap species comprised: 92.3% of 12 species of Group 1; 70.2% of 57 species of Group 2; 66.7% of the 39 species of Group 3; and 40% of the 10 species of Group 4 (Table 3.7). Even though some parts of these species' ranges have been protected by PAs to some extent, conservation actions are still required. This is to increase the protection of 'partial gap species' in PA networks to improve their status to 'covered species' in the future.

Again, the results from two methods analysed in this research revealed that some tree species are not adequately covered by Thai PA networks. Conservation areas needed to be expanded, particularly to allow some tree ranges to reach their representation targets. These results are supported by Dudley and Parish (2006), who mentioned in the guide to conducting gap assessments of PA systems for the CBD, that species and ecosystems are inadequately covered by existing PA networks, especially for threatened and endemic species (Dudley and Parish 2006). Additionally, according to the GSPC, about 75% of known threatened plant species should be conserved *in situ* by 2020 (GSPC 2010), therefore, for some species protection programmes should be emphasized, especially the species of Group 1 (trees that are threatened with extinction) that were not found in any type of PA (in total 115 species as shown in Tables 3.1 and 3.6).

Considering the number of species in different types of PA, it was clear that most species were found in national parks, followed by wildlife sanctuaries, no-hunting areas and forest parks (Table 3.2). This is because the national parks cover the largest proportion of all PA types, in terms of both number and area covered. In addition, all species in national parks and wildlife sanctuaries are well protected by law enforcement under the National Park Act and the Wild Animal Reservation and Protection Act. In addition, it could be noted that some species were differently identified based on different analysis methods. For example, *Vitex pinnata* was considered a partial gap species by species range method as shown in Table 3.7 and Figure 3.4 (b), whereas this species seemed to be a gap species, as all its records (species occurrence points) were located outside a PA as shown in Table 3.8 and Figure 3.4 (a). Another example is the comparison between *Dalbergia cochinchinensis* and *Tectona grandis*. Approximately 81% of *D. cochinchinensis*'s records were located within a PA (Table 3.8 and Figure 3.5 (a)), while 71% of *T. grandis* records were located in a PA (Table 3.8 and Figure 3.6 (a)). On the basis of species locations, both could be considered as partial gap species (i.e. some location records were outside PAs). However, as a result of gap analysis considering the EOO inside PAs and the species representation target, *D. cochinchinensis* was identified as a partial gap species (Table 3.7 and Figure 3.5 (b)), whereas *T. grandis* was identified as a covered species (Table 3.7 and Figure 3.6 (b)). This is due to the fact that *D. cochinchinensis* is distributed in a smaller range of habitats which are naturally found only in the Northeastern region, near the borders of Thailand, Cambodia and Laos, covering a small area of PAs. In the case of *D. cochinchinensis*, higher protected priority is needed when compared to *T. grandis*, which has a wider range of habitats distributed in the Northern and Central regions of the country covering most areas of PAs.

Table 3.8 The number of records of tree species with precise locations and ≥ 5 records/species found inside each protected area type and outside protected areas

No.	Family	Botanical name	No. of records	No. of records in each PA type				
				Forest park	National park	No-hunting area	Wildlife sanctuary	Outside PA
1	Pentaphylacaceae	*Adinandra integerrima* T. Anderson ex Dyer[2]	8	0	1	0	1	6
2	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib[2, 3, 4]	6	0	2	0	0	4
3	Fabaceae	*Albizia odoratissima* (L.f.) Benth.[2, 3]	5	0	1	0	1	3
4	Dipterocarpaceae	*Anisoptera costata* Korth.[2]	34	0	8	0	3	23
5	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King[1, 2]	6	0	0	0	0	6
6	Fagaceae	*Castanopsis wallichii* King ex Hook.f.[2, 3]	5	0	2	0	1	2
7	Fabaceae	*Dalbergia cochinchinensis* Pierre[2, 3, 4]	126	0	25	0	77	24
8	Ebenaceae	*Diospyros andamanica* (Kurz) Bakh.[1, 2, 3]	5	0	0	1	0	4
9	Ebenaceae	*Diospyros bejaudii* Lecomte[2, 3]	10	0	1	0	1	8
10	Ebenaceae	*Diospyros defectrix* H.R.Fletcher[2, 3]	7	0	2	0	0	5
11	Ebenaceae	*Diospyros mollis* Griff.[2, 3]	10	0	2	0	1	7
12	Ebenaceae	*Diospyros montana* Roxb.[1, 2, 3]	8	0	3	0	0	5
13	Ebenaceae	*Diospyros wallichii* King & Gamble[2, 3]	10	0	4	1	3	2
14	Ebenaceae	*Diospyros winitii* H.R. Fletcher[1, 2, 3]	11	0	3	0	0	8
15	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don[2, 3, 4]	26	1	1	0	1	23
16	Dipterocarpaceae	*Dipterocarpus baudii* Korth.[2]	15	0	5	0	2	8
17	Dipterocarpaceae	*Dipterocarpus chartaceus* Symington[2]	9	0	0	0	1	8
18	Dipterocarpaceae	*Dipterocarpus costatus* C.F.Gaertn.[2]	15	0	5	0	2	8
19	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.[1, 2]	8	0	1	0	1	6
20	Dipterocarpaceae	*Dipterocarpus gracilis* Blume[2]	21	0	8	0	3	10
21	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco[2, 3]	12	0	4	1	1	6
22	Dipterocarpaceae	*Dipterocarpus intricatus* Dyer[2, 3]	17	0	0	0	1	16
23	Dipterocarpaceae	*Dipterocarpus kerrii* King[2]	15	0	4	0	1	10
24	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.[2, 3]	51	0	3	1	1	46
25	Dipterocarpaceae	*Dipterocarpus retusus* Blume[1, 2]	5	0	0	0	1	4
26	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.[2, 3, 4]	13	0	1	0	3	9
27	Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.[2]	15	0	5	0	2	8
28	Pentaphylacaceae	*Eurya acuminata* DC. var. *acuminata*[2]	6	0	3	0	0	3
29	Dipterocarpaceae	*Hopea ferrea* Laness.[2, 3, 4]	31	0	10	0	3	18
30	Dipterocarpaceae	*Hopea helferi* (Dyer) Brandis[1, 2, 3]	5	0	1	0	0	4
31	Dipterocarpaceae	*Hopea oblongifolia* Dyer[1, 2, 3]	9	0	5	0	1	3
32	Dipterocarpaceae	*Hopea odorata* Roxb.[2, 3, 4]	35	1	13	0	2	19

No.	Family	Botanical name	No. of records	No. of records in each PA type: Forest park	National park	No-hunting area	Wildlife sanctuary	Outside PA
33	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington[1, 2, 3]	5	0	3	0	0	2
34	Fagaceae	*Lithocarpus falconeri* (Kurz) Rehder[2, 3]	6	0	1	0	2	3
35	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*[2, 3]	6	0	3	1	0	2
36	Magnoliaceae	*Magnolia liliifera* (L.) Baill[1, 2]	7	0	0	1	0	6
37	Dipterocarpaceae	*Parashorea stellata* Kurz[2, 3, 4]	27	0	9	0	3	15
38	Fabaceae	*Saraca indica* L.[2]	5	0	0	1	0	4
39	Malvaceae	*Scaphium scaphigerum* (Wall. ex G.Don) G.Planch.[2]	5	0	0	1	0	4
40	Theaceae	*Schima wallichii* (DC.) Korth.[2, 3]	8	0	1	0	0	7
41	Dipterocarpaceae	*Shorea assamica* Dyer subsp. *globifera* (Ridl.) Y.K.Yang & J.K.Wu[2]	5	0	1	0	1	3
42	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume[1, 2, 3]	8	0	1	0	2	5
43	Dipterocarpaceae	*Shorea henryana* Pierre[2, 3, 4]	17	0	4	0	4	9
44	Dipterocarpaceae	*Shorea hypochra* Hance[2, 3]	13	0	8	0	0	5
45	Dipterocarpaceae	*Shorea leprosula* Miq.[2, 3]	9	0	0	0	1	8
46	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume[2, 3]	30	0	3	0	2	25
47	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*[2, 3]	7	0	1	0	1	5
48	Dipterocarpaceae	*Shorea roxburghii* G.Don[2, 3, 4]	37	1	10	0	1	25
49	Dipterocarpaceae	*Shorea siamensis* Miq.[2, 3]	45	0	9	0	3	33
50	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.[1, 2, 3]	16	0	4	0	1	11
51	Moraceae	*Streblus ilicifolius* (S.Vidal) Corner[2]	5	0	1	2	0	2
52	Lamiaceae	*Tectona grandis* L.f.[2, 3, 4]	861	0	504	3	109	245
53	Dipterocarpaceae	*Vatica harmandiana* Pierre[2, 3]	7	0	3	0	0	4
54	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington[2, 3]	20	1	5	0	1	13
55	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume[2, 3]	7	0	4	0	0	3
56	Dipterocarpaceae	*Vatica stapfiana* (King) Slooten[1, 2]	5	0	2	1	0	2
57	Lamiaceae	*Vitex pinnata* L.[2, 3]	5	0	0	0	0	5
		Grand total	1,725	4	700	14	245	762

Note: [1] = trees that are threatened with extinction; [2] = trees that dominate the different forest types in Thailand; [3] = trees that are of particular economic importance; [4] = trees that are important to *in situ* genetic conservation.

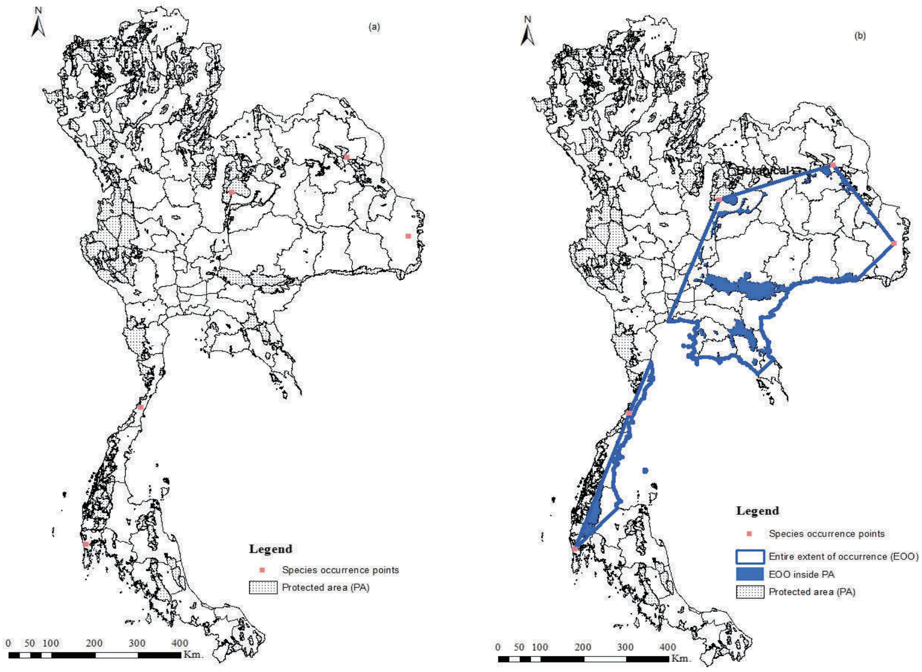


Figure 3.4 - The comparison between points (a), entire extent of occurrence (EOO) of *Vitex pinnata* L. and its EOO contained inside the protected area (b)

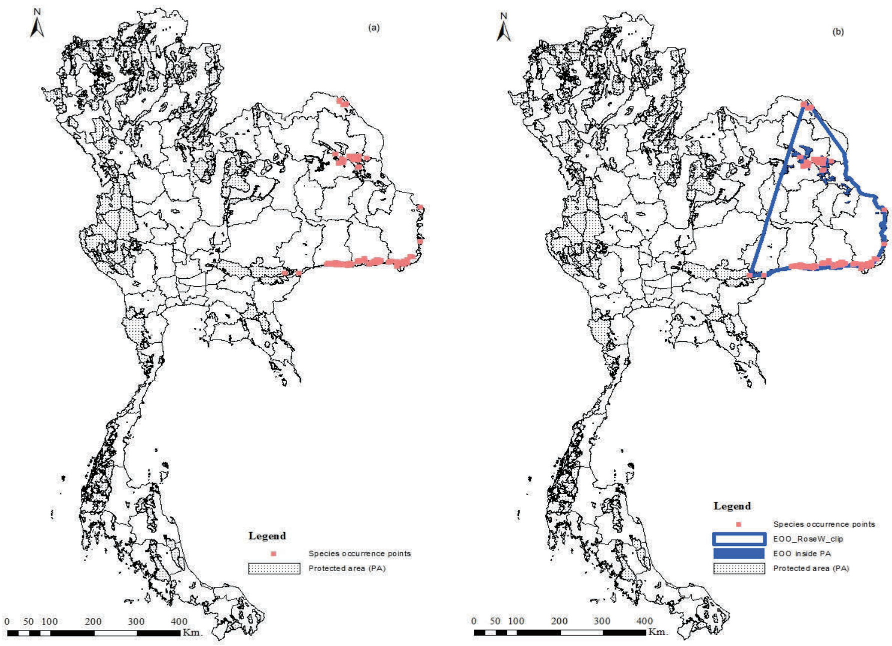


Figure 3.5 - The comparison between points (a), entire extent of occurrence (EOO) of *Dalbergia cochinchinensis* Pierre and its EOO contained inside the protected area (b)

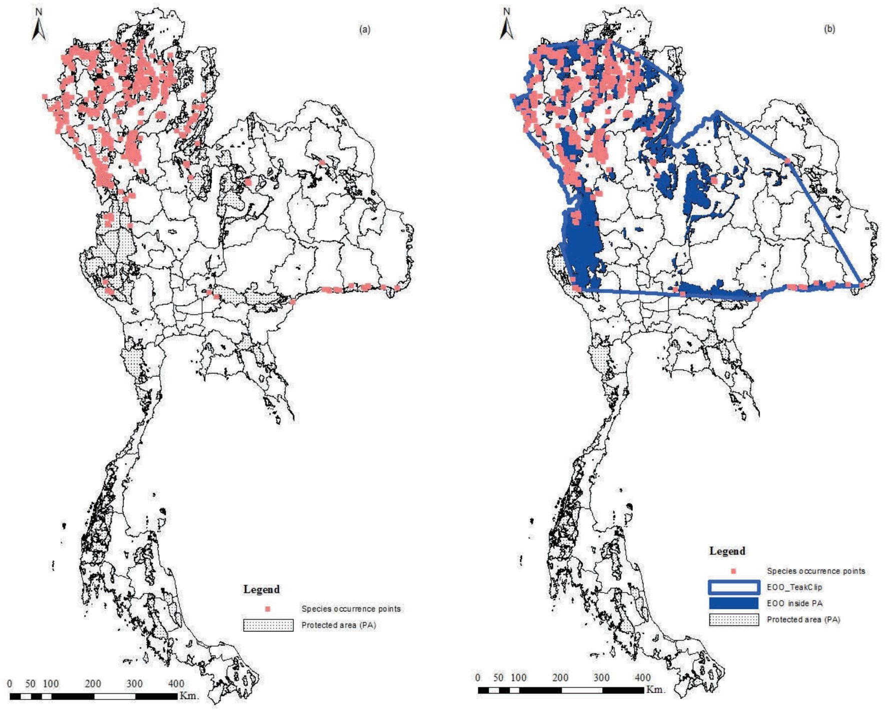


Figure 3.6 - The comparison between points (a), entire extent of occurrence (EOO) of *Tectona grandis* L.f. and its EOO contained inside the protected area (b)

These results are supported by some research conducted in other countries. For example, Yip et al. (2004) studied some taxa of animals and rare vascular plants in Hong Kong PAs. Results indicated that over half of the 623 species of the globally, regionally, or locally restricted species were under-represented in a PA (Yip et al. 2004). Ma et al. (2007) used endangered and endemic species to represent plant diversity as a whole for the North-western Yunnan. 98 endangered species and 703 endemic species are found in the area. Nine plant diversity conservation areas were identified by experts for the project area. The research also found that the existing reserve system plays a major role in the protection of plant diversity, although several reserves were not specifically designed for plant diversity conservation (Ma et al. 2007). Randrianasolo et al. (2002) studied the conservation status of five genera of Anacardiaceae, which are considered threatened (i.e. CE, EN, or VU) in Madagascar. The assessment revealed that for nine out of 14 species of Malagasy Anacardiaceae, there were zero or one subpopulation occurring in PAs (64%), and suggested that their chance of survival in the wild is very reduced (Randrianasolo et al. 2002).

Vellak et al. (2009) grouped vascular plant species on the basis of conservation need and natural and anthropogenic rarity, to examine the effectiveness of PAs for rare plants at a national scale in Estonia during the last 100 years (1910 - 2004). The result showed that rare vascular plant species have been partly covered by Estonia's PAs, but about twice as many PAs are required to achieve 60% coverage by PAs (Vellak et al. 2009).

Nonetheless, the result is also contradicted by some research, such as Jackson et al. (2009) who studied the relationship between distributions of threatened plants and PAs in Britain. 331 (88%) of 371 analysed threatened plants were represented at least once within PAs. Over 80% of the species in each of the four threat categories (critically endangered (CE), endangered (EN), vulnerable (VU), and near threatened (NT)) have been recorded in at least one statutory PA where they receive legal backing. However, considering all records across the 371 species, only 26.5% overlap the statutory PAs, similar to the situation in Thailand. More than 50% of the species were represented within PAs by less than ten occurrence records, and over 80% by fewer than 30% (Jackson et al. 2009). Irfan-Ullah et al. (2007) used ecological niche modeling (ENM) to explore the distribution of *Aglaia bourdillonii*, a narrowly endemic plant to the southern Western Ghats, India. Almost 66% of the species distribution is protected by current PAs; however, the remaining 34% that is not protected is close to PAs (Irfan-Ullah et al. 2007). Kohlmann et al. (2010) analysed the distribution of areas with high species richness and endemism of fauna and flora with three plant families included (Araceae, Arecaceae, and Bromeliaceae) in Costa Rica. The analysis showed that a high number of the total species were conserved by the existing PAs (Araceae 89%, Arecaceae 89%, and Bromeliaceae 83%) (Kohlmann et al. 2010). Riemann and Ezcurra (2005) analysed the distribution of the endemic vascular flora of the peninsula of Baja California, Mexico in existing PAs and also identified regions with greater numbers of endemic species not currently under protected status. 76.4% of total number of endemic taxa was located within PAs. These included the families Asteraceae, Cactaceae, Fabaceae, Begoniaceae, Thymeliaceae, Araliaceae and Hippocastanaceae. The first three families contained 40% of endemic species; the remaining families are entirely endemic in the study region. The gap endemic taxa totally absent from PAs are

Adenothamnus, Carterothamnus, Faxonia, and Ornithostaphylos (Riemann and Ezcurra 2005).

Blasi et al. (2011) measured the extent to which the targets of the Global Strategy for Plant Conservation (GSPC-CBD) were fulfilled in Italy by assessing the level of protection afforded to Important Plant Areas (IPAs) and species. The GSPC-CBD aims to protect 50% of the most important areas for plant diversity and to conserve *in situ* 60% of the threatened species by 2010. The result found that over 80% of the Italian IPAs have some form of legal protection and more than 60% of the selected species are concerned by the present PAs (Blasi et al. 2011). Hou et al. (2010) collected data for 6,506 vascular plant species in Guangxi Province, Southern China. The result pointed out that most centres of species richness and endemism were covered by existing nature reserves. However, the research also found that the surrounding areas, that were also rich in species and endemics, are relatively neglected (Hou et al. 2010). Araujo et al. (2007) studied the level of plant species (Dicotyledons, Monocotyledons, Gymnosperms, Pteridophytes) represented on Iberian protected-area maps. The research found the proportion of ranges among restricted-range species was greater in PAs than outside PAs (Araujo et al. 2007). The natural populations of tamarind (*Tamarindus indica*) in the Sudanian region were well represented in PAs in contrast to populations in the Sudano-Guinean region. However, protection does not guarantee the long-term persistence of the species (Fandohan et al. 2011).

Gove et al. (2008) examined the Western Australian reserve designs' effectiveness to conserve angiosperm diversity. The result showed that between 174 (5.7%) and 570 (18.7%) of species were not represented in the reserve designs, depending on the method utilized. Gap species' geographical range sizes were six times smaller than the protected species. Also, the research found out that conservation effectiveness was most dependent on the reserve system characteristics rather than size and positioning of species ranges (Gove et al. 2008).

It is suggested, at this point, that there are basically two possible ways to address the conservation needs of targeted tree species located outside PAs (as was found here for 222 species), depending upon the location of these species and the types of

PA: (1) by expansion of the existing PA (supported by Gove et al., 2008); or (2) by establishment of new PAs (supported by Fearnside and Ferraz, 1995). The expansion or establishment of national parks and wildlife sanctuaries takes long periods of time to finish the entire legal processes. In many cases, the establishment of no-hunting areas is more practical and feasible way to initially protect the forest from encroachment prior to the expansion of a nearby PA. In addition to this, conservation projects can be carried out, such as community forestry projects, to support tree conservation and reduce the speed of deforestation as well.

This research has a limitation. This study was dependent on presence-only data of trees from specimens in the Forest Herbarium (BKF), Bangkok and Division of Protection and Forest Fire Control, which are parts of DNP. There may be problems with the accuracy of taxonomic identification and determination. Nevertheless, this problem was minimised by the plant specimens, that their names were initially identified by collectors and were rechecked by experts (who specialize on such plant families) or botanists, before depositing the specimens in a herbarium (Pattharahirantricin 2015). There may be geographical bias in collection data such as tree specimens being collected in areas where they might be expected to be found, and were accessible (Margules and Pressey 2000). Insufficient records per species also affected the accuracy (Mckelvey and Noon 2001). Also, some taxa tended to be collected more than others, depending on collectors' preferences (Mckelvey and Noon 2001). This might cause differences in recording effort for species with different levels of interest/concern. However, the variety of species considered in this research and the fact that species data have accumulated for decades across several collectors, would reduce this bias. Future research on in-depth surveys for species, especially partial gap species, should be systematically conducted in the existing conservation network. If the analysis confirms that such species are genuinely underrepresented, conservation actions should be considered regarding how to conserve such species. Also, alternative data sources should be considered, such as from related plant survey projects or related websites such as Global Biodiversity Information Facility (GBIF).

Chapter 4: The potential geographical distribution of selected tree species in Thailand

Abstract

Lack of knowledge of the distribution patterns and ecological requirements of species limits the effectiveness of conservation management. Therefore, information is needed on the potential geographic distribution of tree species. Species distribution modelling (SDM) methods have been widely employed to identify the potential distribution areas of species. SDM can be used to predict potential distribution in unsurveyed areas, and to support the targeting of future field surveys. It can also be used to identify spatial patterns in biological diversity, which are important for developing priorities for conservation and for improving conservation and land use planning. This chapter aimed to analyse the potential geographic distributions of selected tree species, and to identify the principal factors influencing the distribution and conservation status of selected tree species in Thailand.

Only tree species with precise locations and ≥ 8 records/species were employed, these included a total 1,454 records from 35 species, belonging to 5 families, collected during 1982 – 2012. Maxent was applied to predict the potential geographic distribution of the selected tree species throughout Thailand using presence-only data of selected tree species in conjunction with the eleven uncorrelated environmental variables. The eleven environmental variables were: Annual Mean Temperature; Temperature Seasonality (standard deviation *100); Max Temperature of Warmest Month; Min Temperature of Coldest Month; Annual Precipitation; Precipitation Seasonality (Coefficient of Variation); Precipitation of Warmest Quarter; Precipitation of Coldest Quarter; Altitude; Aspect; and Slope.

The results revealed that 24 species were well predicted at the test locations and were considered further. The most important environmental variables influencing the distribution of the selected tree species was temperature seasonality (BIO4), followed by annual precipitation (BIO12), while annual mean temperature (BIO1) was the least important variable. The predicted patterns of suitable conditions for selected species varied throughout the country, with the Central area being unsuitable for

most species. Almost all patterns of suitable conditions for tree species are predicted to be near the border of Thailand and Cambodia, Thailand and Laos, Thailand and Malaysia, also in the Southern region of Thailand. Only a few species (e.g. *Tectona grandis, Dipterocarpus tuberculatus* and *Diospiros winitii*) had suitable areas predicted in the Northern region, while *Dalbergia cochinchinensis* was predicted in the Northeastern region. Most *Dipterocarpus* spp. were predicted to occur in the Southern and the Eastern regions, apart from: *D. kerrii*, which was predicted to occur in the Southern region; and *D. turbinatus*, which was predicted to occur over almost the entire country, except for the Central region. The Central region had the least suitable conditions for tree species. The best habitat suitability class that was protected within PAs was the moderate habitat suitability, followed by the high habitat suitability, whereas the very high habitat suitability was worst protected within PAs. Furthermore, *Diospyros winitii* and three Dipterocarp species had no areas in the very high suitability class.

Chapter 4: The potential geographical distribution of selected tree species in Thailand

4.1 Introduction

There are approximately 10,250 higher plant species found in Thailand, which is one of the biodiversity hotspots of Southeast Asia (Middleton 2003). However, these figures are underestimated because of a lack of appropriate data for many plant groups (Middleton 2003). Also, there are 314 threatened vascular plant species of which 81 species are endemic to Thailand (Pooma 2008). In 2014, vascular plants were recorded to be around 1,900 genera and 12,050 species in Thailand (Chayamarit 2014). Lack of knowledge of the distribution patterns and ecological requirements of species limits the effectiveness of conservation management (Douglas and Newton 2014). For this reason, information is needed on the potential geographic distribution of tree species in Thailand.

Species distribution modelling (SDM) methods have been widely employed to identify the potential distribution areas of species (Schussman et al. 2006). Such methods can be used to predict potential distribution in unsurveyed areas, and to support the targeting of future field surveys (Cayuela et al. 2009). Distribution maps produced by SDM can also be used to identify spatial patterns in biological diversity, which are important for developing priorities for conservation (Cayuela et al. 2009) and for improving conservation and land use planning (Zhang et al. 2012). SDM has also been applied to study the impact of climate change on the distribution of species (Thomas et al. 2004). A variety of modelling methods have been used to predict species distributions, such as: logistic regression; generalised additive models; the genetic algorithm for rule-set prediction (GARP); generalised linear models; bioclimatic envelopes; and Maximum Entropy Modelling (Maxent) (Guisan and Zimmermann 2000; Bailey et al. 2002; Elith and Burgman 2003; Phillips et al. 2006; Phillips and Dudík 2008; Cayuela et al. 2009).

Maxent has been widely employed in conservation research and was selected here as the modelling method as it is considered to be one of the most robust methods, when only presence-only data are available to model species distributions (Warren et al.

2013). It is able to utilize continuous and categorical data, and to incorporate interactions between different variables (Phillips et al. 2006). Maxent has also been shown to perform well with small samples, and is relatively unaffected by spatial errors in relation to location data (Pearson et al. 2007; Graham et al. 2008; Phillips and Dudík 2008; Baldwin 2009). Maxent has been employed in a variety of previous research. For example, Velasquez-Tibata et al. (2013) evaluated the effect of climate change on range shifts of 199 threatened and range-restricted birds in Colombian protected areas (PAs). Under future climate, species were projected to lose between 33 and 43% of their total range (Velasquez-Tibata et al. 2013). Maxent has also commonly been used in plant conservation research. For example, Zhang et al. (2012) applied Maxent to model 2,319 woody plant species distributions of geo-referenced herbarium collections to identify key aspects of species distributions in Yunnan, China. This study identified species diversity hotspots, floristic regions, and priority areas for conservation (Zhang et al. 2012). Similarly, Kumar and Stohlgren (2009) used Maxent for modelling habitat suitability for *Canacomyrica monticola*, an endangered tree in New Caledonia. The study showed that habitat distribution could successfully be modelled using Maxent with a small number of occurrence records (11 records) and environmental variables (Kumar and Stohlgren 2009).

Maxent has previously been used in Thailand in relation to the conservation of wild animals and plants, and to investigate the effect of climate change on species distributions. For example, Trisurat et al. (2012) used Maxent to analyse habitat suitability and management for 17 mammal species such as elephant (*Elephas maximus*), leopard (*Panthera pardus*), bear (*Ursus thibetanus*) and tiger (*Panthera tigris*). Suitable habitats were found to cover about 37% of the area in the Northern region of the country, 70% of which was predicted to be in large and connected conservation areas (Trisurat et al. 2012). Similarly, Jenks et al. (2012) used Maxent to predict the probability of dhole or Asiatic wild dog (*Cuon alpinus*) presence in 15 Thai PAs in conjunction with climatic variables and predictive occurrence layers of other mammal species, such as sambar deer (*Cervus unicolor*), red muntjac (*Muntiacus muntjak*), leopard (*Panthera pardus*) and tiger (*Panthera tigris*). The research revealed that approximately 7% of the land area in Thailand is potentially suitable for dholes. Maintaining a sufficient prey base is the most important factor for their survival (Jenks et al. 2012). In the case of plants, Trisurat et al. (2009) used Maxent to predict the distributions of 22 deciduous and evergreen trees in relation to current and predicted climate change conditions in 2050 in Northern Thailand. The results revealed that the trees' occurrence was not significantly different between current and predicted climate change conditions, within the study area as a whole. Evergreen tree species richness tended to shift toward the Northern region where the lowest temperatures are expected in the future, whereas the deciduous tree species' distribution ranges were projected to expand. Trisurat et al. (2011) conducted similar research in Peninsular Thailand on 66 plant species, analyzing distribution shifts by 2100. The research showed that 31 species were predicted to lose suitable ecological niches by 2100. They also suggested that the integrity of species hotspots in 2100 will decline substantially because of predicted climate change (Trisurat et al. 2011). Van Welzen et al. (2011) projected the distribution of 1,399 plant species in Thailand under both current and future conditions for the year 2050. Their results showed that there are four phyto-geographical regions in Thailand, and that this was predicted to increase to five regions by 2050. Moreover, 30 plant species could become extinct as a result of climate change.

No previous study has systematically investigated the extent to which the habitat suitability of particular tree groups is covered by PAs throughout Thailand. The objectives of this research were therefore to identify the potential spatial distributions of target species occurring in Thailand, in relation to the distribution and extent of PAs. This was achieved by analysis of records of species distribution data, mainly obtained from the Forest Herbarium (BKF), Bangkok and the Division of Protection and Forest Fire Control, DNP.

4.2 Objectives

i. To analyse the potential geographic distributions of selected tree species, and map current habitat suitability for them.

ii. To identify the principal factors influencing the distribution and conservation status of selected tree species in Thailand.

4.3 Methods

The first step was to compile secondary data of target tree species, which were collated as described in Chapter 3. Only tree species with precise locations (recorded by a Garmin handheld GPS to 100 m. accuracy) and $\geq$ 8 records/species were employed (Anderson and Raza 2010; Klorvuttimontara et al. 2011). This included a total 1,454 records from 35 species, belonging to 6 families, collected during 1925 – 2012. However, the records collected before 1982 were removed to better match the available environmental data, as time correspondence has to be considered, specifically between occurrence localities and environmental variables (Anderson and Martínez-Meyer 2004).

A secondary data set of environmental variables for Thailand was then compiled and employed as follows.

i. ***Bioclimatic variables*** 19 bioclimatic variables at one arc second spatial resolutions were obtained from the WorldClim global climate data, using records from 1950 – 2000 (Hijmans et al., 2005; http://www.worldclim.org: access date: 5 August 2013). The detailed 19 variables are:

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp – min temp))
BIO3 = Isothermality (BIO2/BIO7) (*100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month

BIO15 = Precipitation Seasonality (Coefficient of Variation)

BIO16 = Precipitation of Wettest Quarter

BIO17 = Precipitation of Driest Quarter

BIO18 = Precipitation of Warmest Quarter

BIO19 = Precipitation of Coldest Quarter

ii. ***Topographic variables*** namely altitude, aspect, and slope (Trisurat 2007) were extracted from a Digital Elevation Models (DEM), which was obtained from the Protected Area Rehabilitation and Development Office (PARDO) of DNP. The 30 m resolution DEM was modified in order to obtain the same resolution as the environmental variables (one arc second) using the feature 'Extract by mask' in ArcMap v 10.0 (ESRI 2010b). In addition, the DEM was employed to generate slope and aspect using the spatial analyst toolbox in ArcMap.

Correlations between all environmental variables were tested using Pearson's correlation. Variables with correlation coefficient values $\geq$ 0.80 were eliminated (Giovanelli et al. 2010) to avoid poor predictive performance or over-fitting in the model (Pearson et al. 2007). Where pairwise correlations were present, variables were selected for inclusion by retaining the variable with the fewest correlations with other variables and/or the most biological relevance to tree species. I also aimed to include an equal number of temperature and precipitation variables.

After eliminating correlated variables, eleven environmental variables were used for modelling species geographic distributions. These were: Annual Mean Temperature; Temperature Seasonality (standard deviation *100); Max Temperature of Warmest Month; Min Temperature of Coldest Month; Annual Precipitation; Precipitation Seasonality (Coefficient of Variation); Precipitation of Warmest Quarter; Precipitation of Coldest Quarter; Altitude; Aspect; and Slope.

Maxent (version 3.3.3k, http://www.cs.princeton.edu/~schapire/Maxent/ Phillips et al. 2006; Phillips and Dudík 2008) was applied using presence-only data of selected tree species (Phillips et al. 2006; Phillips and Dudík 2008) in conjunction with the eleven environmental variables to generate a distribution model for each species. Records for each species were randomly partitioned into a training set with 70% of the records and a test set with 30% of the records. The training set was used to fit the best model for each species, the test set was used to evaluate the model performance (Phillips et al. 2006). I used the default settings within Maxent, including all possible feature types. The set of features that can be fitted depends on the number of presence records available for modelling the species distribution. For species with $\leq$ 10 records, linear features are employed; species with 10 – 14 records, linear and quadratic features are employed; species with 15 – 79 records, linear, quadratic and hinge features are employed; and species with $\geq$ 80 records, all feature types are employed (Phillips et al. 2006; Phillips and Dudík 2008; Merow et al. 2013). The limitation imposed by the features (environmental response curves) indicates the ecological assumptions made by the model, as the features represent all the environmental factors that constrain the species' geographical distribution (Phillips et al. 2006). Because there were no *a priori* assumptions about the relationships between species and environmental variables, I included the maximum number of feature types that was possible given the data available.

The Maxent model performance was evaluated for two phases. First, the model fit of the predicted presence was evaluated against the training set of presence data and randomly generated pseudo-absences. Secondly, the model predictions were compared to the test data. The fit and accuracy of the species distribution model was tested by employing receiver operating characteristic (ROC) plots, which can be used to evaluate how well the data correctly predicts presence (Fielding and Bell 1997). An effective model is defined by a curve that maximizes sensitivity (i.e. presences are correctly detected) for low values of the false-positive proportion (Hernandez et al. 2006). The curve is assessed by calculating the area under curve (AUC), which has values that range from 0 – 1.0. The AUC determines the probability that a presence location will be ranked higher than a random background location (Phillips et al. 2006). Such random background locations serve as pseudo-absences for all analyses in Maxent (Baldwin 2009). Values close to 0.5 indicate a fit that is no better than that expected at random, while a value of 1.0 indicates a perfect fit. Models with AUC values above or equal 0.75 are considered potentially useful (Elith 2000). Separate AUC values were generated to test the fit of the models to the training and test data.

Maxent was run using occurrence localities for each tree species together with 11 uncorrelated environmental variables. Maxent first predicted environmental suitability for the tree species (Phillips et al. 2006). Predicted potential geographic distributions (habitat suitability maps) for target tree species were then produced, based on the best model generated projected across the whole of Thailand using the 11 environmental variables. Habitat suitability was assessed on a scale of 0 - 1, which was divided into five classes to represent the suitability of environmental conditions for each species. These were: very low suitability (0 - 0.2); low suitability (> 0.2 - 0.4); moderate suitability (> 0.4 - 0.6); high suitability (> 0.6 - 0.8); and very high suitability (> 0.8 - 1). For the analysis of PA coverage, the three highest categories of suitability were considered. The area of each category was clipped by PA boundaries maps using feature 'Clip' in ArcMap v 10.0 (ESRI 2010b), then a percentage of each category within PAs was calculated using the 'calculate geometry' feature.

4.4 Results

There were 35 tree species (having ≥ 8 presence records/species) that were examined in this chapter. *Tectona grandis* had the highest number of records (722 records), while five species had only eight records each (Mean ± S.E. = 41.54 ± 20.32) (Table 4.1). Each partition for tree species held between 6 – 506 training localities and between 2 - 216 testing localities (Mean ± S.E. = 29.54 ± 14.23 and 12.00 ± 6.09 respectively). For the training data, Maxent consistently produced predictions that were better than random (All species AUC > 0.5, Table 4.1). *Schima wallichii* had the lowest training value of AUC (0.73), whereas a Mean ± S.E. value of 0.88 ± 0.14 was obtained across all 35 species. All but two species (*S. wallichii* and *D. turbinatus*) had AUC values of training data ≥ 0.75. This indicated that the model variables were potentially useful for Maxent to obtain a good fit to the training data when compare to a random model. Moreover, there were 19 species having a high value of AUC of training data (≥ 0.9), particularly *Shorea leprosula* and *Dalbergia cochinchinensis* (value of AUC = 0.99). The model for *Hopea oblongifolia* had a perfect fit (as its value of AUC for training data was equal to 1.0).

In regard to AUC of testing data, the 30% of species occurrences reserved for testing the resulting model showed how well the distribution model predicted occurrence at the test locations (Phillips et al., 2006). *Hopea oblongifolia* also had the highest AUC value of testing data (0.99), whereas *Schima wallichii* had the lowest AUC value of 0.40 (with Mean ± S.E. = 0.83 ± 0.26 across all 35 species). There were 24 species with an AUC value for the test data ≥ 0.75, indicating that models based on the training data predicted presence at the test locations well. On the other hand, there were 11 species models that were not well predicted (having AUC value of testing data under 0.75). Therefore, the models for 11 species were eliminated, namely *Adinandra integerrima, Dipterocarpus alatus, D. obtusifolius, Diospyros mollis, Hopea ferrea, Schima wallichii, Shorea siamensis, S. henryana, S. obtuse, S. roxburghii* and *Vatica odorata.*

Owing to the difference in the number of presence records/species for modelling, the set of features employed to build response curves varies from simple to complex. Table 4.1 shows that there were 13 species that the linear feature type was used (training records are ≤ 10 records), 10 species that linear and quadratic feature types were used (training records are 10 – 14 records), 10 species that linear, quadratic and hinge feature types were used (training records are 15 – 79 records), and two species that all features including product, linear, quadratic, hinge and threshold feature types were used (training records are ≥ 80 records). Of the 24 species with adequate models, models for 10 species included linear features only, 8 species included linear and quadratic features, 4 species included linear, quadratic and hinge features, and 2 species included all features (Table 4.1).

Table 4.1 Presence records partitions of training and testing records, the results of areas under curve (AUC) of each tree species produced with Maxent using the environmental variables of both training and testing records, and their feature types used in Maxent

No.	Botanical name	Presence records		AUC		Feature types used
		Training	Testing	Training	Testing	
1	*Adinandra integerrima* T. Anderson ex Dyer[2]	6	2	0.8	0.5	linear
2	*Diospyros montana* Roxb.[1, 2, 3]	6	2	0.93	0.76	linear
3	*Dipterocarpus dyeri* Pierre ex Laness.[1, 2]	6	2	0.92	0.94	linear
4	*Schima wallichii* (DC.) Korth.[2, 3]	6	2	0.73	0.4	linear
5	*Shorea guiso* (Blanco) Blume[1, 2, 3]	6	2	0.98	0.91	linear
6	*Diospyros wallichii* King & Gamble[2, 3]	7	2	0.93	0.94	linear
7	*Dipterocarpus chartaceus* Symington[2]	7	2	0.97	0.99	linear
8	*Hopea oblongifolia* Dyer[1, 2, 3]	7	2	1	0.99	linear
9	*Shorea leprosula* Miq.[2, 3]	7	2	0.99	0.99	linear
10	*Diospyros bejaudii* Lecomte[2, 3]	7	3	0.75	0.8	linear
11	*Diospyros mollis* Griff.[2, 3]	7	3	0.79	0.7	linear
12	*Diospyros winitii* H.R. Fletcher[1, 2, 3]	8	3	0.79	0.86	linear
13	*Dipterocarpus grandiflorus* (Blanco) Blanco[2, 3]	9	3	0.95	0.97	linear
14	*Dipterocarpus tuberculatus* Roxb.[2, 3, 4]	10	3	0.79	0.76	linear quadratic
15	*Shorea hypochra* Hance[2, 3]	10	3	0.97	0.95	linear quadratic
16	*Dipterocarpus baudii* Korth.[2]	11	4	0.95	0.93	linear quadratic
17	*Dipterocarpus costatus* C.F.Gaertn.[2]	11	4	0.83	0.86	linear quadratic
18	*Dipterocarpus kerrii* King[2]	11	4	0.97	0.99	linear quadratic
19	*Dipterocarpus turbinatus* C.F.Gaertn.[2]	11	4	0.74	0.87	linear quadratic
20	*Shorea thorelii* Pierre ex Laness.[1, 2, 3]	12	4	0.84	0.98	linear quadratic
21	*Dipterocarpus intricatus* Dyer[2, 3]	12	5	0.78	0.84	linear quadratic
22	*Shorea henryana* Pierre[2, 3, 4]	12	5	0.87	0.72	linear quadratic
23	*Vatica odorata* (Griff.) Symington[2, 3]	14	6	0.75	0.71	linear quadratic
24	*Dipterocarpus gracilis* Blume[2]	15	6	0.91	0.89	linear quadratic hinge
25	*Dipterocarpus alatus* Roxb. ex G.Don[2, 3, 4]	19	7	0.93	0.74	linear quadratic hinge
26	*Parashorea stellata* Kurz[2, 3, 4]	19	7	0.95	0.92	linear quadratic hinge
27	*Hopea ferrea* Laness.[2, 3, 4]	21	9	0.9	0.72	linear quadratic hinge

No.	Botanical name	Presence records		AUC		Feature types used
		Training	Testing	Training	Testing	
28	*Shorea obtusa* Wall. ex Blume[2, 3]	21	9	0.88	0.71	linear quadratic hinge
29	*Anisoptera costata* Korth.[2]	24	10	0.93	0.87	linear quadratic hinge
30	*Shorea roxburghii* G.Don[2, 3, 4]	26	11	0.91	0.6	linear quadratic hinge
31	*Hopea odorata* Roxb.[2, 3, 4]	27	10	0.86	0.94	linear quadratic hinge
32	*Shorea siamensis* Miq.[2, 3]	31	12	0.79	0.5	linear quadratic hinge
33	*Dipterocarpus obtusifolius* Teijsm. ex Miq.[2, 3]	35	15	0.8	0.74	linear quadratic hinge
34	*Dalbergia cochinchinensis* Pierre[2, 3, 4]	87	36	0.99	0.98	product linear quadratic hinge threshold
35	*Tectona grandis* L.f.[2, 3, 4]	506	216	0.94	0.92	product linear quadratic hinge threshold

Note: [1] = Trees that are threatened with extinction; [2] = Trees that dominate the different forest types in Thailand; [3] = Trees that are of particular economic importance; [4] = Trees that are important to *in situ* genetic conservation.

The percent contribution (importance) of environmental variables for determining the distributions of 24 tree species with testing AUC values $\geq$ 0.75 varied across species. Some variables were included in the models for several species; some contributed to only a few species. The environmental variables with relative high percentage contribution in Maxent were temperature seasonality (BIO4), which ranged from 0.00 to 91.0 (Mean $\pm$ S.E. = 33.82 $\pm$ 6.68), which was also included in the models for the highest number of species (17 species). This was followed by annual precipitation (BIO12), which ranged from 0.00 to 80.10 (Mean $\pm$ S.E. = 20.65 $\pm$ 6.22) and contributed to 15 species. Precipitation of the coldest quarter (BIO19) also contributed to 15 species (its percent contribution ranging from 0.00 to 82.5 with Mean $\pm$ S.E. = 14.88 $\pm$ 4.95). Annual mean temperature (BIO1) was the variable with least percent contribution, ranging from 0.00 to 21.90 (Mean $\pm$ S.E. = 1.02 $\pm$ 0.91) and also contributed to the lowest number of species (5 species). The other seven variables provided percent contributions in Maxent with Mean values from 1.89 to 5.89 and contributed to 9 - 14 species (Table 4.2).

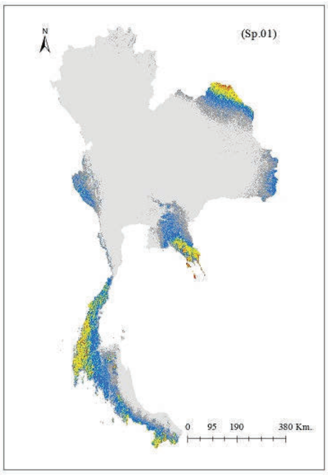
There were only two species, *Dalbergia cochinchinensis* and *Hopea odorata*, for which the model retained all 11 environmental variables. Meanwhile, *Anisoptera costata* and *Tectona grandis* retained 10 variables, whereas *Dipterocarpus gracilis* retained 9 variables. It is interesting to note that the presence of *Diospyros bejaudii* was predicted by only two variables: temperature seasonality (BIO4) and annual precipitation (BIO12). The Mean number of variables retained in models ± S.E. across all 24 species was 5.54 ± 0.57 (Table 4.2).

Table 4.2 Selected environmental variables and their percent contribution in Maxent for targeted tree species in Thailand

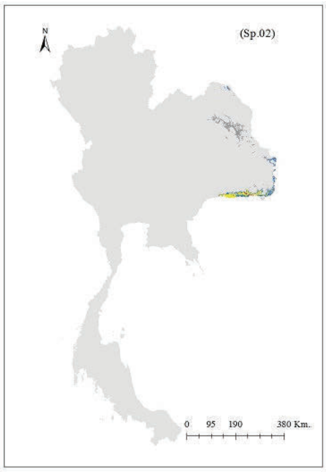
No.	Botanical name	Environmental variables										
		BIO 1	BIO 4	BIO 5	BIO 6	BIO 12	BIO 15	BIO 18	BIO 19	Altitude	Aspect	Slope
1	*Anisoptera costata* Korth.[2]	0	1.5	1	1.1	72	0.6	8.9	3.1	3.9	2.4	5.9
2	*Dalbergia cochinchinensis* Pierre[2, 3, 4]	0.8	17	5.8	2.7	6.7	27	8.7	10	15.8	0.1	5
3	*Diospyros bejaudii* Lecomte[2, 3]	0	63	0	0	37	0	0	0	0	0	0
4	*Diospyros montana* Roxb.[1, 2, 3]	0	27	0	35	0	0	0	0.9	0	13	25
5	*Diospyros wallichii* King & Gamble[2, 3]	0	91	0	0.3	0	0.2	0	0	0	0	8.5
6	*Diospyros winitii* H.R. Fletcher[1, 2, 3]	0	69	0	29	0	0	0	0	0	1.8	0
7	*Dipterocarpus baudii* Korth.[2]	0	82	0	0.9	15	0.9	0	0.1	2.2	0	0
8	*Dipterocarpus chartaceus* Symington[2]	0	25	0	0	3.4	0	0	72	0	0	0
9	*Dipterocarpus costatus* C.F.Gaertn.[2]	0	0	0	0	75	9.4	15	0	0	0.6	0
10	*Dipterocarpus dyeri* Pierre ex Laness.[1, 2]	0	58	0	0.1	0	32	0	0	0	9.9	0
11	*Dipterocarpus gracilis* Blume[2]	0.7	55	0.1	0	7.1	1.5	0.5	27	0	6.5	1.7
12	*Dipterocarpus grandiflorus* (Blanco) Blanco[2, 3]	0	0	12	0	78	0	0	10	0	0	0
13	*Dipterocarpus intricatus* Dyer[2, 3]	0	0	12	0	0	0	0	42	36.8	0	9.1
14	*Dipterocarpus kerrii* King[2]	0	83	0	0	0	0	5.7	0	8.8	0	3.1
15	*Dipterocarpus tuberculatus* Roxb.[2, 3, 4]	0	0	0	54	0	1.2	39	0	4.9	0	0.7
16	*Dipterocarpus turbinatus* C.F.Gaertn.[2]	0	0	57	0	36	0.7	0	0	0	0	6.3
17	*Hopea oblongifolia* Dyer[1, 2, 3]	0	20	0.3	2.9	73	0	1.6	0.9	0	0	1.6
18	*Hopea odorata* Roxb.[2, 3, 4]	22	17	7.4	1.9	1.9	0.5	5.8	32	1.8	3.8	5.8
19	*Parashorea stellata* Kurz[2, 3, 4]	0.2	0	0	1.5	4.2	2.6	0	83	1.8	7.1	0.1
20	*Shorea guiso* (Blanco) Blume[1, 2, 3]	0	65	14	0	0	21	0	0	0	0	0
21	*Shorea hypochra* Hance[2, 3]	0	84	1	0	0	0	0	4.2	0	0	10
22	*Shorea leprosula* Miq.[2, 3]	0	28	0	0.1	6.7	13	0	53	0	0	0
23	*Shorea thorelii* Pierre ex Laness.[1, 2, 3]	0	0	1.6	0	80	0	0.3	18	0	0	0
24	*Tectona grandis* L.f.[2, 3, 4]	0.8	27	9	12	0.5	3.6	17	1.2	3.5	0	25

Note: [1] = Trees that are threatened with extinction; [2] = Trees that dominate the different forest types in Thailand; [3] = Trees that are of particular economic importance; [4] = Trees that are important to *in situ* genetic conservation. BIO1 = Annual Mean Temperature; BIO4 = Temperature Seasonality (standard deviation *100); BIO5 = Max Temperature of Warmest Month; BIO6 = Min Temperature of Coldest Month; BIO12 = Annual Precipitation; BIO15 = Precipitation Seasonality (Coefficient of Variation); BIO18 = Precipitation of Warmest Quarter; BIO19 = Precipitation of Coldest Quarter.

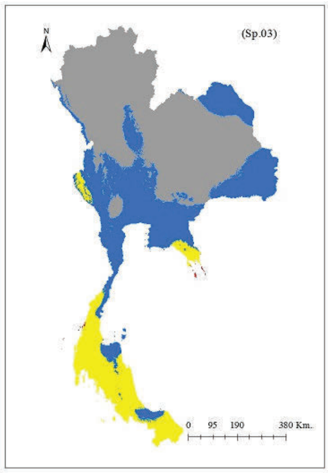
Maxent predicted patterns of suitable conditions for selected species varied throughout the country with the Central area being unsuitable for most species. Almost all patterns of suitable conditions for tree species are predicted to be near the border of Thailand and Cambodia, Thailand and Laos, Thailand and Malaysia, also in the Southern region of Thailand. Maxent indicated similar patterns of suitable conditions for six species, including *Anisoptera costata, Diospyros bejaudii, Dipterocarpus costatus, Dipterocarpus grandiflorus, Dipterocarpus turbinatus*, and *Shorea thorelii* (Figure 4.1 sp.01, sp.03, sp.09, sp.12, sp.16, sp.23). These were predicted to be present throughout most regions of Thailand adjacent to neighbouring countries but absent from Central Thailand. In contrast, for three species (*Diospyros winitii, Dipterocarpus tuberculatus,* and *Tectona grandis),* Maxent showed suitable conditions in the Northern region and some areas in the Northeastern and Central regions (Figure 4.1 sp. 06, sp.15, sp.24). For the other 8 species, Maxent predicted suitable conditions in the Southern and the Eastern regions (*Diospyros montana, Diospyros wallichii, Dipterocarpus baudii, Dipterocarpus kerrii, Hopea oblongifolia, Parashorea stellate, Shorea guiso*, and *Shorea hypochra* (Figure 4.1 sp.04, sp.05, sp.07, sp.14, sp.17, sp.19, sp.20, sp.21). Uniquely for *Dalbergia cochinchinensis*, Maxent predicted suitable conditions in the Northeastern region (Figure 4.1 sp.02).



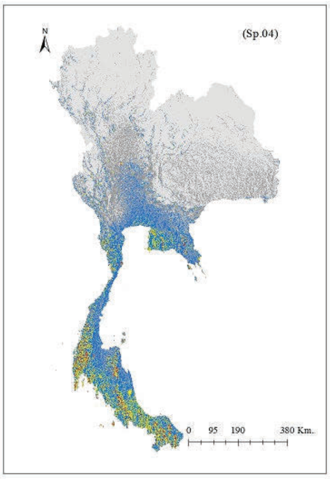
Anisoptera costata
(Dipterocarpaceae)



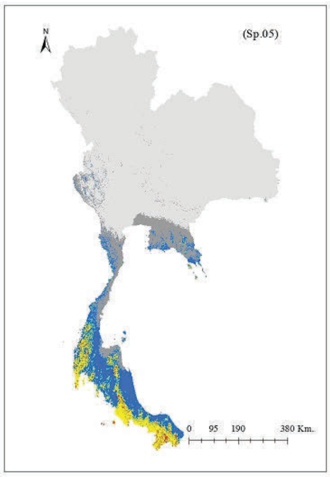
Dalbergia cochinchinensis
(Fabaceae)



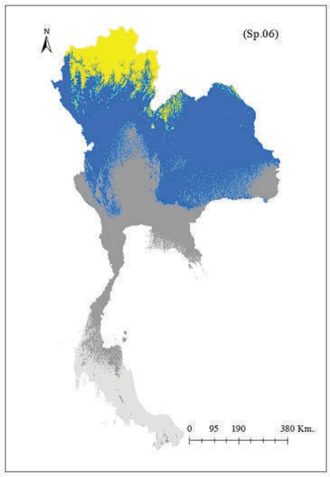
Diospyros bejaudii
(Ebenaceae)



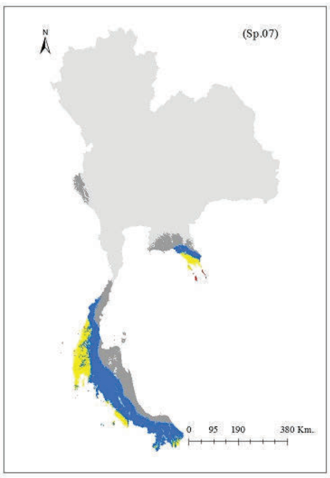
Diospyros montana
(Ebenaceae)



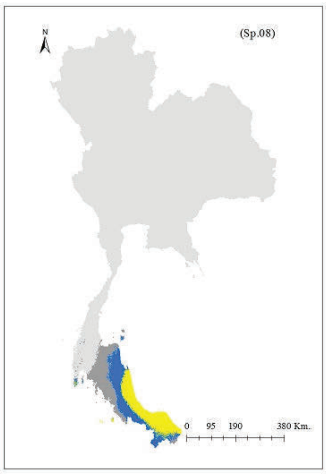
Diospyros wallichii
(Ebenaceae)



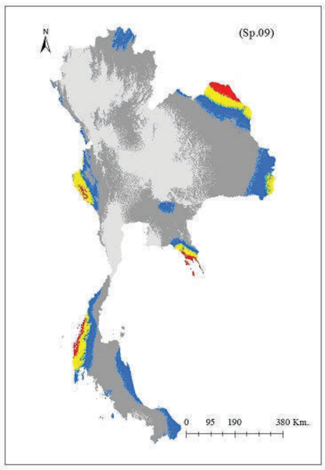
Diospyros winitii
(Ebenaceae)



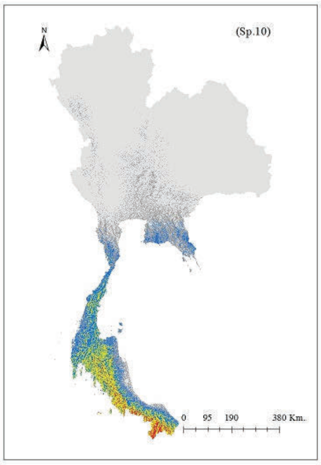
Dipterocarpus baudii
(Dipterocarpaceae)



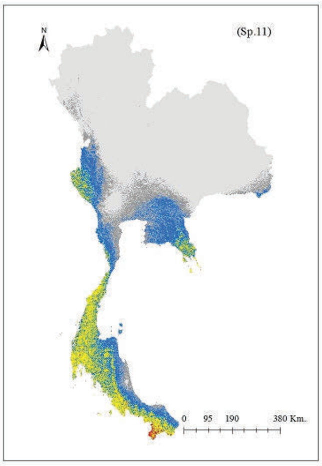
Dipterocarpus chartaceus
(Dipterocarpaceae)



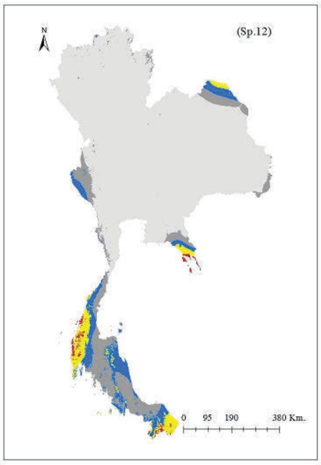
Dipterocarpus costatus
(Dipterocarpaceae)



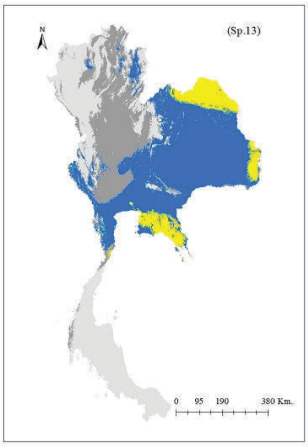
Dipterocarpus dyeri
(Dipterocarpaceae)



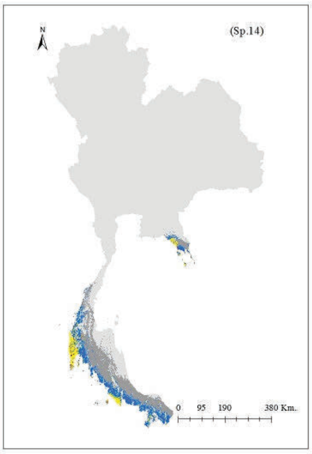
Dipterocarpus gracilis
(Dipterocarpaceae)



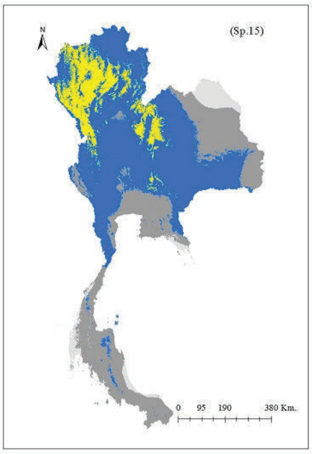
Dipterocarpus grandiflorus
(Dipterocarpaceae)



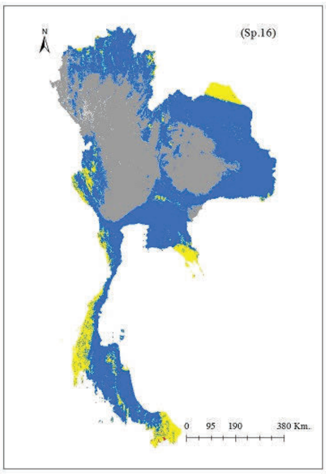
Dipterocarpus intricatus
(Dipterocarpaceae)



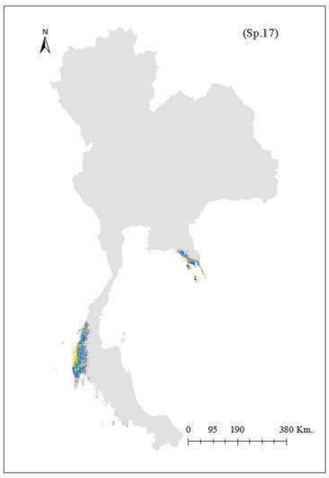
Dipterocarpus kerrii
(Dipterocarpaceae)



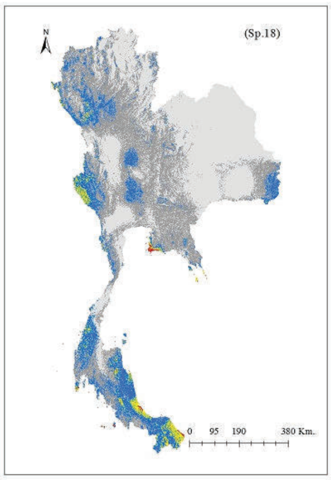
Dipterocarpus tuberculatus
(Dipterocarpaceae)



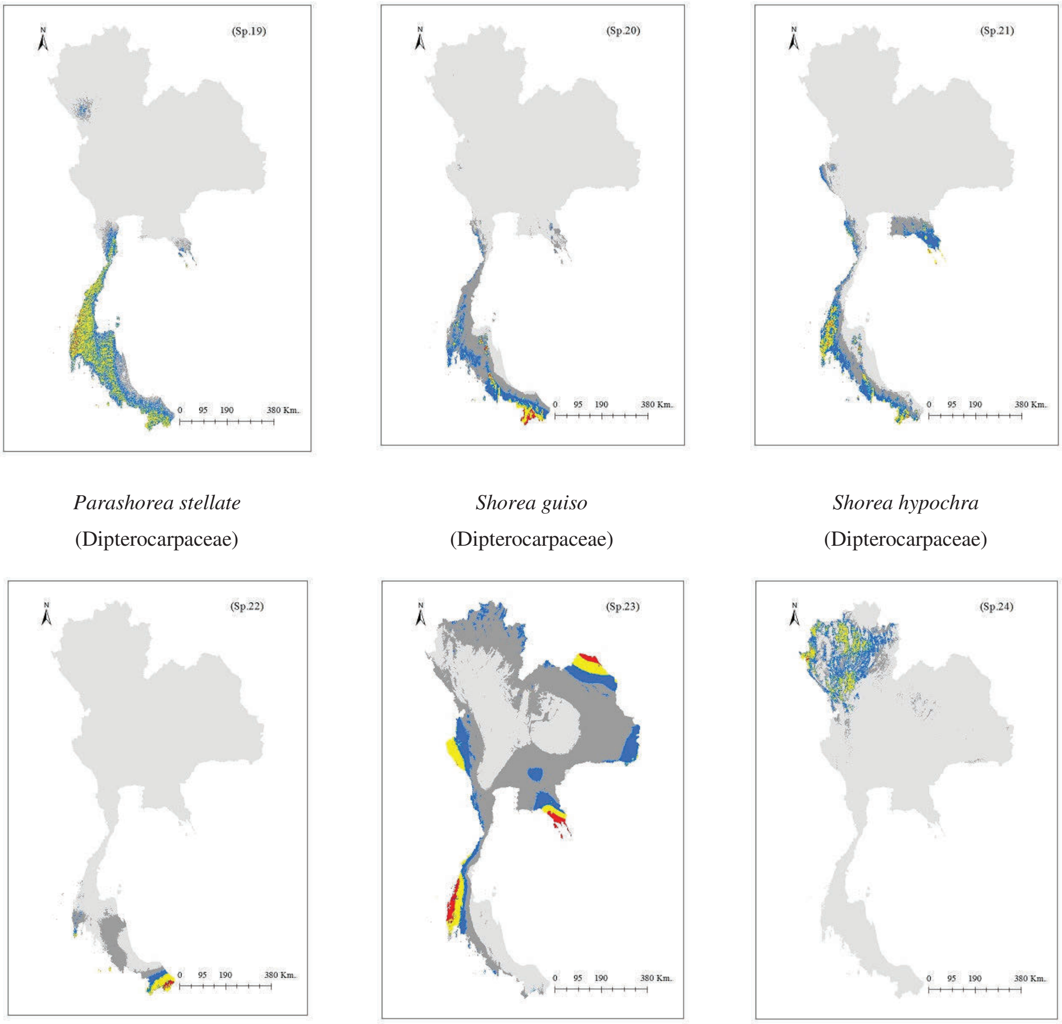
Dipterocarpus turbinatus
(Dipterocarpaceae)



Hopea oblongifolia
(Dipterocarpaceae)



Hopea odorata
(Dipterocarpaceae)



Parashorea stellate (Dipterocarpaceae)

Shorea guiso (Dipterocarpaceae)

Shorea hypochra (Dipterocarpaceae)

Shorea leprosula (Dipterocarpaceae)

Shorea thorelii (Dipterocarpaceae)

Tectona grandis (Lamiaceae)

Figure 4.1 – Predicted potential geographic distributions for targeted species in Thailand. Five colours are used to show the strength of the prediction for each map pixel: light grey = 0 – 0. 2 (very low suitability); grey = > 0.2 – 0.4 (low suitability); blue = > 0.4 – 0.6 (moderate suitability); yellow = > 0.6 – 0.8 (high suitability); and red = > 0.8 – 1 (very high suitability)

All 24 tree species had potential distribution area in the moderate habitat suitability class with 19 species having large amount percent protected in PA ($\geq$ 90%). *Dipterocarpus tuberculatus* had the majority (99.49%) of this class protected in PA, while *Diospyros montana* had the least (84.53%) of this class protected in PA (Mean $\pm$ S.E. = 95.01 $\pm$ 0.96, see Table 4.3 and Figure 4.2).

In addition, all 24 tree species had potential distribution area in the high habitat suitability class with 15 species having large amount percent protected in PA ($\geq$ 90%). *Diospyros bejaudii* had the highest percentage (99.54%) of this class protected in PA, while *Diospyros montana* had the lowest percentage (64.42%) of this class protected in PA (Mean $\pm$ S.E. = 90.29 $\pm$ 1.82, see Table 4.3 and Figure 4.2).

20 of 24 tree species had potential distribution area in the very high suitability class and only two species had a large amount of this class protected in PA ($\geq$ 90%) namely *Shorea guiso* (97.95%) and *S. thorelii* (97.13). *Dipterocarpus baudii* had the smallest percentage (15.19%) of this class protected in PA (Mean $\pm$ S.E. = 54.54 $\pm$ 6.57, see Table 4.3 and Figure 4.2). Four further species (*Diospyros winitii*, *Dipterocarpus chartaceus, D. intricatus,* and *D. tuberculatus*) had no area that was predicted to be in the very high suitability class both in and outside PAs (Table 4.3).

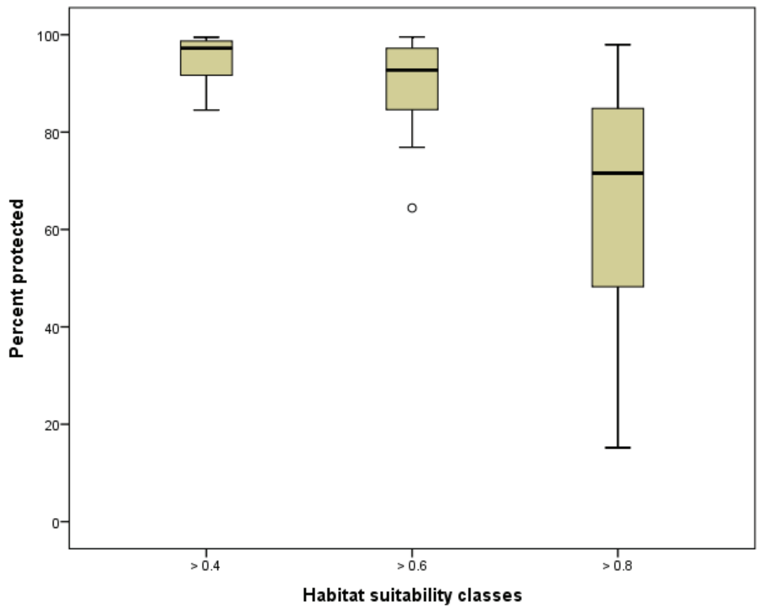


Figure 4.2 – The percentage of the area of the different habitat suitability classes of tree species that were protected in protected areas, when: > 0.4 = moderate habitat suitability (24 species); > 0.6 = high habitat suitability (24 species); and > 0.8 = very high habitat suitability (20 species)

Table 4.3 Whole area of three classes of habitat suitability of targeted tree species (moderate, high, and very high suitabilities), their habitat suitability areas and percentage of protection in protected areas

No.	Botanical name	Moderate suitability			High suitability			Very high suitability		
		All area (sq.km)	Area in PA (sq.km)	% Protected	All area (sq.km)	Area in PA (sq.km)	% Protected	All area (sq.km)	Area in PA (sq.km)	% Protected
1	*Anisoptera costata* Korth.[2]	63,835	57,466	90.02	22,725	17,848	78.54	1,830	971	53.05
2	*Dalbergia cochinchinensis* Pierre[2, 3, 4]	2,788	2,486	89.17	1,510	1,388	91.92	103	73	71.20
3	*Diospyros bejaudii* Lecomte[2, 3]	241,463	240,171	99.47	69,032	68,714	99.54	355	154	43.44
4	*Diospyros montana* Roxb.[1, 2, 3]	96,138	81,270	84.53	28,566	18,402	64.42	3,676	2,487	67.66
5	*Diospyros wallichii* King & Gamble[2, 3]	71,544	69,489	97.13	26,345	24,047	91.28	2,481	1,790	72.14
6	*Diospyros winitii* H.R. Fletcher[1, 2, 3]	301,175	294,713	97.85	56,453	53,319	94.45	-	-	-
7	*Dipterocarpus baudii* Korth.[2]	53,121	52,755	99.31	13,555	13,084	96.53	257	39	15.19
8	*Dipterocarpus chartaceus* Symington[2]	32,242	31,626	98.09	16,768	16,406	97.84	-	-	-
9	*Dipterocarpus costatus* C.F.Gaertn.[2]	81,916	80,428	98.18	28,331	27,954	98.67	7,082	5,998	84.69
10	*Dipterocarpus dyeri* Pierre ex Laness.[1, 2]	61,501	57,418	93.36	28,662	24,114	84.13	3,424	1,930	56.36
11	*Dipterocarpus gracilis* Blume[2]	103,490	97,306	94.02	41,972	35,718	85.10	1,024	431	42.13
12	*Dipterocarpus grandiflorus* (Blanco) Blanco[2, 3]	49,656	48,702	98.08	20,697	20,357	98.36	2,980	2,144	71.93
13	*Dipterocarpus intricatus* Dyer[2, 3]	235,880	233,770	99.11	41,244	39,698	96.25	-	-	-
14	*Dipterocarpus kerrii* King[2]	19,779	17,741	89.70	5,822	5,053	86.79	431	249	57.85
15	*Dipterocarpus tuberculatus* Roxb.[2, 3, 4]	326,246	324,585	99.49	58,008	55,878	96.33	-	-	-
16	*Dipterocarpus turbinatus* C.F.Gaertn.[2]	319,413	316,891	99.21	45,131	43,830	97.12	335	253	75.41
17	*Hopea oblongifolia* Dyer[1, 2, 3]	5,562	4,846	87.12	2,231	1,715	76.87	230	76	33.04

No.	Botanical name	Moderate suitability			High suitability			Very high suitability		
		All area (sq.km)	Area in PA (sq.km)	% Protected	All area (sq.km)	Area in PA (sq.km)	% Protected	All area (sq.km)	Area in PA (sq.km)	% Protected
18	*Hopea odorata* Roxb.[2, 3, 4]	74,262	64,093	86.31	13,072	10,982	84.01	976	379	38.89
19	*Parashorea stellata* Kurz[2, 3, 4]	55,878	52,615	94.16	25,295	19,968	78.94	673	497	73.81
20	*Shorea guiso* (Blanco) Blume[1, 2, 3]	25,135	24,469	97.35	6,931	6,743	97.29	1,516	1,485	97.95
21	*Shorea hypochra* Hance[2, 3]	36,950	35,464	95.98	10,781	9,630	89.32	742	637	85.82
22	*Shorea leprosula* Miq.[2, 3]	7,922	7,789	98.32	4,849	4,537	93.56	612	521	85.05
23	*Shorea thorelii* Pierre ex Laness.[1, 2, 3]	75,853	75,158	99.08	27,457	27,122	98.78	6,879	6,682	97.13
24	*Tectona grandis* L.f.[2, 3, 4]	36,257	34,545	95.28	11,843	10,771	90.95	134	116	86.10

Note: [1] = Trees that are threatened with extinction; [2] = Trees that dominate the different forest types in Thailand; [3] = Trees that are of particular economic importance; [4] = Trees that are important to *in situ* genetic conservation.

4.5 Discussion

Maxent was applied to predict the potential geographic distribution of 35 selected tree species throughout Thailand using species' occurrence localities in association with eleven uncorrelated environmental variables. There were 24 species having AUC value of testing data ≥ 0.75, indicating that models predicted presence at the test locations well. However, 11 species were not well predicted at the test locations, having AUC value of testing data under 0.75. Therefore, only models of 24 species were considered further. The most important environmental variables influencing the distribution of the selected tree species was temperature seasonality (BIO4), followed by annual precipitation (BIO12), while annual mean temperature (BIO1) was the least important variable. The predicted patterns of suitable conditions for selected species varied throughout the country with the Central area being unsuitable for most species. Almost all patterns of suitable conditions for tree species are predicted to be in the Southern region, and near to borders between Thailand and neighboring countries such as Cambodia and Laos. Only a few species (e.g. *Tectona grandis, Dipterocarpus tuberculatus* and *Diospiros winitii*) had suitable areas predicted in the Northern region, while *Dalbergia cochinchinensis* was predicted in the Northeastern region. Most *Dipterocarpus* spp. were predicted to occur in the Southern and the Eastern regions, apart from *D. kerrii* which was predicted to occur in the Southern region and *D. turbinatus* which was predicted to occur over almost the entire country except for the Central region. The Central region had the least suitable conditions for tree species. The best habitat suitability class that was protected within PA was moderate habitat suitability, followed by high habitat suitability, whereas the very high habitat suitability was worst protected within PA. Furthermore, *Diospyros winitii* and three Dipterocarp species had no areas in the very high suitability class.

Regarding patterns of suitable conditions for selected tree species: even though the area for predicted presence will typically be larger than the species' realized distribution, Maxent produced reasonable predictions of the potential distribution for some species such as *Tectona grandis* and *Dalbergia cochinchinensis*. It is because their prediction areas appeared to be predicted within the mentioned species' known ranges. As Maxent predicted *T. grandis* suitability areas are found in the Northern region, while suitability areas of *D. cochinchinensis* are predicted in the Northeastern region. When their predicted suitable areas are compared to the habitat of others: *T. grandis* is commonly found in Mix Deciduous forest mainly located in the Northern region, some found in the Central, the Western and the Northeastern regions (Orwa et al. 2009). *D. cochinchinensis* is a drought tolerant species and commonly found in the Northeastern Thailand (CITES 2013). As a matter of fact, suitable habitat areas are generally well-protected by PAs (median 97.24 % found within PAs). However, areas of very high habitat suitability are less protected within PAs than the moderate and high habitat suitabilities.

Even though AUC has been broadly used to evaluate the model fit, caution should be used when interpreting AUC values. This is because high AUC values are not necessarily produced by more realistic models, so that it should not be considered as a single measure of model performance (Sheppard 2013). Also, species distribution maps should not be interpreted as a species niche, but as guiding the process of estimating potential distributions (Golicher et al. 2012a). Artificially high AUC values may be caused by reasons such as having few presence records, or spatial aggregation of those that are available (Golicher et al. 2012a) as these locations will have the same environmental variables. Four of 24 tree species in my research had some spatial aggregation (more than one record per 1 km^2). Nevertheless, none of the species had fewer than 8 locations when counting the aggregated pairs/groups of records as one location (Table 4.4). Also, testing AUC values of species, that had or did not have spatial aggregation, did not appear to be different.

Table 4.4 The target trees species that have spatial aggregation more than one record per 1 km^2

No.	Botanical name	All records	Records that were not aggregated	No. of pairs/groups of records that were aggregated	Sum records and groups that were not aggregated	AUC of testing
1	*Dalbergia cochinchinensis* Pierre	123	109	7	116	0.98
2	*Diospyros wallichii* H.R. Fletcher	10	8	1	9	0.94
3	*Hopea oblongifolia* Roxb.	9	7	1	8	0.99
4	*Tectona grandis* L.f.	722	528	84	612	0.92

Jiménez-Valverde (2012) mentioned that because the lower the proportionate area predicted as suitable, the higher the AUC value, as more background data are predicted as absences. On the other hand, VanDerWal et al. (2009) indicated that the model poorly performed at smaller background sizes and there was a gradual decline in AUC values when records were generated from larger regions (VanDerWal et al. 2009). To be as conservative as possible, 11 species having AUC < 0.75 were not considered in further analysis as their distribution models did not perform well enough when predicting the test data. These were *Adinandra integerrima, Dipterocarpus alatus, D. obtusifolius, Diospyros mollis, Hopea ferrea, Schima wallichii, Shorea siamensis, S. henryana, S. obtuse, S. roxburghii,* and *Vatica odorata*. This is because there might be other determinants that may contribute to model performance that the eleven environmental variables considered in this research were not covered. For example *D. obtusifolius* is found along river banks beyond the tidal reaches (Smitinand et al. 1980). *Hopea ferrea* is found abundantly on rocky limestone hills and tends to be in pure stand on a sandstone formation. *S. henryana* prefers granite and quartzite soils, while *S. siamensis* tends to grow in clusters on poor and rocky soils (Smitinand et al. 1980).

Regarding factor importance to species distribution, it is as expected that temperature seasonality and annual precipitation are the most important factors for tree distribution. This is because there are three major factors affecting forest types of Thailand including annual precipitation, duration of drought (minimum precipitation $\leq$ 200 mm.), and mean sea level (MSL) (Kutintara 1999). Also, annual precipitation has been recognized as a major determinant of plant distributions for a long period of time (Woodward and Williams 1987). Temperature seasonality (standard deviation*100) is the temperature variation over a given year. It was calculated from 100*SD of mean monthly temperatures in degree Celcius. It means that the higher standard deviation values, the greater the variability of temperature in the considered area (O'Donnell and Ignizio 2012). The variability of temperature affects types of forest. For example, deciduous forest can be found where there is obvious differences in seasons between wet and dry seasons, therefore, the deciduous forest can be found in the Central, the Northeastern, the Northern regions where the value of temperature seasonality is higher than those of the Southern region. Therefore, this type of forest does not appear in the Southern region (Santisuk, 2006) where the temperature seasonality is low. The results were supported by the study of Kumar and Stohlgren (2009) indicating that temperature seasonality is one of the most important predictors of habitat distribution of *Canacomyrica monticola*, an endangered plant.

Some possible reasons that affect species distribution are edaphic factors (Kutintara 1999), geographic barriers to dispersal, biotic interaction, human modification of the environment (Phillips et al. 2006; Jiménez-Valverde 2012). Here, I was, limited to including only climatic and topographic factors. This is because there are some limitations of available quality data. For example, Thailand soil maps had coarser resolution than the scale run by Maxent in this research. Therefore, future research should include the other determinants to analyze the tree distribution where possible.

The dataset used for this study was mainly obtained from the herbarium, and the small number of species data was collected from the Central region. This may be because plant specimens tend to be collected from forest areas both officially protected by law and unprotected by law. Those forest areas are mainly found further away from the capital city of Thailand, Bangkok, which is located in the Central region. Also, the Central region has few forest remained as it is mainly urbanized. Because the Central appeared to be the region where the potentially suitable areas are least. It could be the result of the data insufficiency, however, rather than having unsuitable climate, trees might instead have been removed, so the distribution is not in equilibrium with the climate. Lacking of representative occurrence data can severely limit the SDM predictive ability (Syfert et al. 2013) as the number of occurrence points are too low to estimate the reliability of model (Golicher et al. 2012b). In addition to this, the bias from data obtained from herbaria may come from the old data collected. The older records may give the occurrence localities error as they may lack sufficient geographic details (Phillips et al. 2006). The bias may be from the collecting tree specimens by a number of botanists and the methods used which could not be controlled. These may also affect geographical sampling bias in the data obtained as mentioned by some researchers. For example, species localities might be collected intensively near the roads and rivers (Phillips et al. 2006). The locality of trees may be erroneous because of the manual transfer of the tree locations, from GPS to the datasheet (Phillips et al. 2006). Such bias disguised the species biological pattern (Phillips et al. 2006; Merow et al. 2013) and geographical sampling bias is critical to the accuracy of SDMs generated from presence-only datasets (Phillips et al. 2009). Nevertheless, the predictive performance can be greatly improved by correcting sampling bias. Syfert et al. (2013) suggested careful evaluation of the potential geographical sampling bias before generating the SDM (Syfert et al. 2013).

Ultimately, the potential habitat suitability maps help support the development of knowledge regarding tree species distribution patterns and the factors influencing them (Kumar and Stohlgren 2009), including an improved ecological understanding of the abiotic factors influencing tree distribution (McCann et al. 2006). The findings from this study can also be used as baseline information for future research, especially when habitat suitability maps are considered together with expert knowledge, relevant spatial maps such as land use maps, PA maps, etc. Moreover, they can be used in the process of identifying the priority areas for species conservation more effectively. For example, such models can be used as a guide to support decision making in relation to the conservation management options (Douglas and Newton 2014) such as identifying the restoring species habitat near the species populations found (Kumar and Stohlgren 2009; Crossman et al. 2011). Nevertheless, the approach depends on the reliability, accuracy and precision of the information employed (Newton 2007).

Chapter 5: Systematic conservation planning

Abstract

Protected area (PA) should achieve two objectives, namely representativeness and persistence that can be achieved using a systematic conservation planning approach, which is the most effective approach for designing networks of reserve systems. Multi-criteria analysis (MCA) is a widely used technique undertaken to support systematic conservation planning. MCA has been employed to select possible alternatives from a set of options or different perspectives by analysing the strength and uncertainty of the options. The objectives of this chapter were: (1) to identify complementary areas/priority areas that are important to support tree conservation, based on species representation, richness, and persistence, especially priority areas for conservation that lie outside the current PA network; and (2) to identify the sensitivity of systematic conservation planning to the major criteria used in identifying priority areas for conserving tree species. The analysis was conducted using MCA, a conservation planning method, modified from the method described by Regan et al. (2007). MCA in this chapter is a GIS-based MCA approach using ILWIS as a support tool to identify priority areas.

The analysis was based on three components, namely: a determination goal; criteria lists to achieve the determination goal; and list of options to achieve the determination goal, this part of the analysis aimed to identify the sensitivity of the goal to changes in the weighting of the major criteria. Three main criteria relevant to terrestrial biodiversity were selected to achieve the overall goal are: (1) current biological value; (2) fully restored biological value; and (3) threats. The spatial MCA output maps produced by ILWIS were ranked in each pixel within the whole region, on a scale from 0 to 1. The degree of priority was identified according to four categories, based on the MCA output scores from very low to very high priority areas. Subsequently, different weights were applied to both the three main criteria and the six level I subcriteria groups to identify the sensitivity of the overall goal to the criteria.

The results showed that areas of very high priority for conservation that lie outside existing PAs, are extremely limited in extent. Areas accorded high priority were substantially more extensive. The location and extent of priority areas were found to be sensitive to the weightings that were used. In particular, results were sensitive to alteration of the weight given to (1) the 'fully restored biological value' criterion (Alternative A3); (2) the 'biotic composition' level I subcriterion (Alternative B2); and (3) the 'ecological context' level I subcriterion (Alternative B3) in relation to areas accorded very high priority and locations that those areas were found. In conclusion, the specific areas where decision-makers should focus on PA expansion, based on areas with greatest robustness, comprised: (1) areas next to current PAs in the Southern region; (2) areas near to Cambodia in Trat province in the Eastern region, and areas near to PAs on Ko Chang and Ko Kut islands in the Gulf of Thailand.

Chapter 5: Systematic conservation planning

5.1 Introduction

According to Article 2 of the Convention on Biological Diversity (CBD), a protected area (PA) is 'a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives' (CBD 1992). Some researchers refer to PAs as conservation areas, where a conservation plan or action is in effect (Sarkar 2003; Watson et al. 2011). A number of different types of PA have been identified, including wilderness areas, national parks, and privately owned reserve areas (IUCN 2014). A set of areas managed together for long-term biodiversity persistence is known as a Conservation Area Network (CAN) (Sarkar 2003; Fuller et al. 2006). PAs have been established all over the world, covering approximately 17.4% of land and oceans in 2014 (IUCN 2014). PAs in Thailand are under the responsibility of the Department of National Parks, Wildlife and Plant Conservation (DNP). They comprise: 123 national parks (13.70% of country area); 58 wildlife sanctuaries (7.10% of country area); and other types of PAs (1.28% of country area) such as no-hunting areas, arboretums, and botanical gardens (DNP, 2010). Even though the number of new PAs has been increasing worldwide, the health and integrity of biodiversity, including species and ecosystems, are still often under threat (Lockwood et al. 2012).

PAs should achieve two objectives, namely representativeness and persistence (Margules and Pressey 2000). Representation refers to the extent to which reserves contain features of biodiversity that are protected (Watson et al. 2011). Persistence refers to the long-term biodiversity maintained over time in PA networks (Cabeza and Moilanen 2001). The two objectives for fulfilling a reserve's role can be achieved using a systematic conservation planning approach (Margules and Pressey 2000), which is the most effective approach for designing networks of reserve systems (Meir et al. 2004; Smith et al. 2006). This refers to a planning process designed to conserve important biodiversity, which measures existing protection levels and identifies new areas for potential conservation to complement existing PAs, a process referred to as a conservation assessment (Knight et al. 2006). The systematic conservation planning approach is based on definition of explicit objectives and an understanding of limitations on the implementation of where and how conservation actions are feasible (Smith et al. 2006). The approach also supports conservation planners to make decisions on how to conserve the persistence of biological diversity and its associated features *in situ* (Margules and Pressey 2000; Watson et al. 2011).

Systematic conservation planning software and techniques that have been widely used for identifying priority areas for biology conservation include Marxan, Zonation, C-plan, and Multi-criteria analysis (MCA). Marxan is historically the most widely used conservation planning software (Watts et al. 2009). For example, Smith et al. (2006) used Marxan to identify new areas that could be the focus of community-run or privately-run ecotourism or game ranching ventures based on the distribution of region's land cover types in Maputaland, South Africa. Carwardine et al. (2008) employed Marxan to identify conservation priority areas for the whole of Australia. The paper used 2,590 biodiversity features as surrogates including: (1) 1,763 vegetation types; (2) 515 environmental domains represented by the classification of climate; topographic conditions; (3) 563 bird species distributions; and (4) distributions of 1,222 plant and animal species of national environmental significance. There are limitations to Marxan. For example, the management of setting up input files is complex as the required input formats do not match the standard data. The interpretation of output files is also complex. In addition, the operations are, again, considered as complex because of the technical description of the algorithm. These lead to frustration using Marxan, from some users. (Ball et al. 2009).

Zonation was employed to identify areas to expand PAs for forest conservation in Southern Finland. The surrogates that were used in this paper were: the different productivity classes; and the dominant tree species based on forest age and the volume of 20 forest types' growing stock (Lehtomaki et al. 2009). In Thailand, Klorvuttimontara et al. (2011) used Zonation to examine current and future PA conservation value by ranking areas based on butterfly species richness and forest cover across the entire country. Zonation also contains some limitations. Vector maps cannot be included in the analysis (Wintle 2008). It takes excessively long time to perform computations if the datasets are large (Moilanen et al. 2009). Zonation is not a multi-objective planning tool, therefore it cannot deal with multiple alternative land-use choices (Wintle 2008; Moilanen et al. 2009).

C-plan was used to identify priority areas in relation to conservation value and vulnerability to processes that threaten biodiversity in South Africa's Cape Floristic Region. The surrogates for biodiversity considered were 'broad habitat units' derived from the combination layers of vegetation, climate zones, geology and topography (Cowling et al. 2003). Similarly, Lawler et al. (2003) used C-plan to identify sites for conservation using species distributions and site vulnerabilities as surrogates for the states of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia, USA. For species distribution, 497 native vertebrate species (birds, amphibians, reptiles, fish and mammals) were considered. For site vulnerability, three indicators were considered including: the percentage of sites covered by urban development; the percentage committed to agriculture; and the percentage covered with mines and quarries. C-plan uses a similar approach to Marxan, but it is unable to provide globally or near-optimal reserve network solutions (Wintle 2008). C-plan can link or combine to Marxan (Pressey et al. 2009). C-plan limitations are therefore implied to be similar to Marxan limitations in terms of complexity. Even though these two programmes are free applications, users need training/workshop sessions to operate the software (Pressey et al. 2009) and thus they are not suitable for researchers without access to such training.

MCA is a widely used technique undertaken to support systematic conservation planning, especially in the context of land management (Lesslie, 2008). Lesslie (2008) explained that there are three groups of spatial applications that have used MCA, and a variety of software programs supporting each type of application. First, GIS-based applications: the related software is a GIS program, such as IDRISI, ILWIS, etc. Second, hybrid applications: examples of software include PROMETHEE, HERO, etc. Lastly, stand-alone software: examples include LMAS, GIWN, etc. (further details can be found in Lesslie, 2008). However, there is also a non-spatial application used for MCA, that is DEFINITE (Janssen 2001; Massam and Wang 2002). It has been used to support other software such as ILWIS in MCA (Geneletti 2004; Orsi and Geneletti 2010). MCA has been employed to select possible alternatives from a set of options or different perspectives by analysing the strength and uncertainty of the options (Geneletti 2002; Massam and Wang 2002;

Moffett and Sarkar 2006). Its role is to construct a transparent decision-making process and support the management of information for stakeholders (Janssen 2001).

A GIS-based MCA approach has several advantages. Spatial data can be integrated together with value judgments and goals with flexibility and transparency (Lesslie, 2008), which can support the practical process of making decisions (Geneletti and van Duren 2008). It is transparent as all data layers can be examined and revised (Geneletti and van Duren 2008). The production of map-based outputs, illustrating options to be considered by decision-makers, is a further advantage. The approach provides a range of alternatives that can vary with the preferences of relevant stakeholders, enabling different options to be explored (Wood and Dragicevic 2007). The alternatives can be developed and refined at any time when the criteria are updated in the light of new information (Lesslie, 2008) such as new data layers, which can be inserted in the analysis (Geneletti and van Duren 2008). It provides effective tools for raster data transformation and analysis (Geneletti 2004).

Interestingly, little previous research has employed spatial MCA to support systematic conservation planning in terms of identifying priority conservation areas, however MCA has largely been employed in land allocation to support decision-making (Geneletti 2004; Wood and Dragicevic 2007). The MCA approach using ILWIS has been employed to explore alternatives to conserve habitat of the volcano rabbit (*Romerolagus diazi*) in Mexico (Velazquez and Bocco 1994). Some previous research has used ILWIS in cooperation with other programs to identify priority areas for the improvement of biodiversity conservation. For example, Geneletti (2004) used ILWIS 3.0 and DEFINITE to identify priority of nature conservation from remnant ecosystems in an alpine valley in Trentino region of Italy. ILWIS was used in the criteria evaluation and setting-up of a GIS database, then DEFINITE was used to conduct a non-spatial MCA (Geneletti, 2004). Similarly, Orsi and Geneletti (2010) described the use of both ILWIS and DEFINITE to identify priority areas for forest landscape restoration in the Western Chiapas, Mexico. The researchers performed an aggregation to obtain a single non-spatial value for each alternative and each criterion, followed by combining all values through non-spatial MCA to obtain the final ranking (Orsi and Geneletti 2010).

As mentioned in Chapter 1, the designation of PAs in Thailand was initially based on expert consultations to select the suitable areas for forest resource conservation, rather than systematic selection. In addition, no previous attempt has been undertaken to apply the principles and methods of systematic conservation planning to identify priority conservation areas. Also, tree species have been neglected in previous analyses of the coverage of PAs in Thailand. Additonally, the analysis of tree coverage in the Thai current PAs in Chapter 3 showed that approximately 70% of analysed species were considered as partial gap species with conservation actions required. Therefore, the aim of this chapter is to identify complementary areas using a systematic conservation planning approach, specifically for conserving tree species. The MCA approach using ILWIS was selected to analyse complementary areas for tree conservation in this research, as it is a user-friendly approach. It uses basic GIS operations and is less time consuming for computation to produce spatial output maps (Orsi and Geneletti 2010). These complementary areas will be identified based on the consideration of factors related to the conservation of tree species in Thailand, such as current and future threats (some were identified in Chapter 2), tree richness, and tree species distribution (identified in Chapter 4). This chapter addresses a crucial knowledge gap in PA network design and conservation planning, and contributes to the improvement of PA network effectiveness in Thailand.

5.2 Objectives

i. To identify complementary areas or priority areas that are important to support tree conservation, based on species representation, richness, and persistence, especially priority areas for conservation that lie outside the current PA network, and thereby to strengthen PA networks in Thailand.

ii. To identify the sensitivity of systematic conservation planning to changes to the weighting of the major criteria used in identifying priority areas for conserving tree species.

5.3 Methods

The analysis was conducted using an MCA, modified from the method described by Regan et al. (2007). The analysis was based on three components, namely: (a) a determination goal, (b) criteria lists to achieve the determination goal, and (c) list of options to achieve the determination goal (Regan et al. 2007).

(a) A determination goal

A determination goal is the identification of priority areas for conservation, which should be areas that support tree species representation, richness, and persistence with minimum threats.

The tree species list that was considered in this Chapter is the same set used in Chapter 3. 57 tree species with $\geq$ 5 records/species (1,725 records, belonging to 10 families) were considered in terms of species representation, richness, and persistence (Table 5.1). Regarding tree persistence, 24 tree species with an AUC value of testing data $\geq$ 0.75 in Chapter 4 were considered (Table 5.1).

Table 5.1 57 tree species with $\geq$ 5 records/species, together with the AUC value of 24 of 57 species with AUC value $\geq$ 0.75 (Chapter 4), and the consideration from the gap analysis whether the species are considered as covered species, partial gap species, or gap species (Chapter 3). To identify whether the species are considered as covered, partial gap, or gap species, the percentage of range inside PA of each species was compared to the percentage of representation target that was set individually for each species (more details showed in Chapter 3)

No.	Family	Botanical name	No. of records	AUC of testing data	Consideration of species from gap analysis
1	Dipterocarpaceae	*Anisoptera costata* Korth.[2]	34	0.87	partial gap
2	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King[1, 2]	6	-	partial gap
3	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don[2, 3, 4]	26	-	partial gap
4	Dipterocarpaceae	*Dipterocarpus baudii* Korth.[2]	15	0.93	partial gap
5	Dipterocarpaceae	*Dipterocarpus chartaceus* Symington[2]	9	0.99	partial gap

No.	Family	Botanical name	No. of records	AUC of testing data	Consideration of species from gap analysis
6	Dipterocarpaceae	*Dipterocarpus costatus* C.F.Gaertn.[2]	15	0.86	covered
7	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.[1, 2]	8	0.94	partial gap
8	Dipterocarpaceae	*Dipterocarpus gracilis* Blume[2]	21	0.89	partial gap
9	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco[2, 3]	12	0.97	partial gap
10	Dipterocarpaceae	*Dipterocarpus intricatus* Dyer[2, 3]	17	0.84	partial gap
11	Dipterocarpaceae	*Dipterocarpus kerrii* King[2]	15	0.99	partial gap
12	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.[2, 3]	50	-	covered
13	Dipterocarpaceae	*Dipterocarpus retusus* Blume[1, 2]	5	-	partial gap
14	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.[2, 3, 4]	13	0.76	covered
15	Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.[2]	15	0.87	covered
16	Dipterocarpaceae	*Hopea ferrea* Laness.[2, 3, 4]	30	-	covered
17	Dipterocarpaceae	*Hopea helferi* (Dyer) Brandis[1, 2, 3]	5	-	partial gap
18	Dipterocarpaceae	*Hopea oblongifolia* Dyer[1, 2, 3]	9	0.99	partial gap
19	Dipterocarpaceae	*Hopea odorata* Roxb.[2, 3, 4]	37	0.94	covered
20	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington[1, 2, 3]	5	-	partial gap
21	Dipterocarpaceae	*Parashorea stellata* Kurz[2, 3, 4]	26	0.92	covered
22	Dipterocarpaceae	*Shorea assamica* Dyer subsp. *globifera* (Ridl.) Y.K.Yang & J.K.Wu[2]	5	-	partial gap
23	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume[1, 2, 3]	8	0.91	partial gap
24	Dipterocarpaceae	*Shorea henryana* Pierre[2, 3, 4]	17	-	partial gap
25	Dipterocarpaceae	*Shorea hypochra* Hance[2, 3]	13	0.95	partial gap
26	Dipterocarpaceae	*Shorea leprosula* Miq.[2, 3]	9	0.99	partial gap
27	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume[2, 3]	30	-	covered
28	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*[2, 3]	7	-	partial gap
29	Dipterocarpaceae	*Shorea roxburghii* G.Don[2, 3, 4]	37	-	covered
30	Dipterocarpaceae	*Shorea siamensis* Miq.[2, 3]	43	-	covered
31	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.[1, 2, 3]	16	0.98	covered
32	Dipterocarpaceae	*Vatica harmandiana* Pierre[2, 3]	7	-	partial gap
33	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington[2, 3]	20	-	covered
34	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume[2, 3]	7	-	partial gap
35	Dipterocarpaceae	*Vatica stapfiana* (King) Slooten[1, 2]	5	-	partial gap
36	Ebenaceae	*Diospyros andamanica* (Kurz) Bakh.[1, 2, 3]	5	-	partial gap

No.	Family	Botanical name	No. of records	AUC of testing data	Consideration of species from gap analysis
37	Ebenaceae	*Diospyros bejaudii* Lecomte[2, 3]	10	0.8	covered
38	Ebenaceae	*Diospyros mollis* Griff.[2, 3]	10	-	partial gap
39	Ebenaceae	*Diospyros montana* Roxb.[1, 2, 3]	8	0.76	partial gap
40	Ebenaceae	*Diospyros defectrix* H.R.Fletcher[2, 3]	7	-	partial gap
41	Ebenaceae	*Diospyros wallichii* King & Gamble[2, 3]	10	0.94	partial gap
42	Ebenaceae	*Diospyros winitii* H.R.Fletcher[1, 2, 3]	11	0.86	covered
43	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib[2, 3,]	6	-	partial gap
44	Fabaceae	*Albizia odoratissima* (L.f.) Benth.[2, 3]	5	-	partial gap
45	Fabaceae	*Dalbergia cochinchinensis* Pierre[2, 3, 4]	126	0.98	partial gap
46	Fabaceae	*Saraca indica* L.[2]	5	-	partial gap
47	Fagaceae	*Castanopsis wallichii* King ex Hook.f.[2, 3]	5	-	partial gap
48	Fagaceae	*Lithocarpus falconeri* (Kurz) Rehder[2, 3]	6	-	partial gap
49	Lamiaceae	*Tectona grandis* L.f.[2, 3, 4]	722	0.92	covered
50	Lamiaceae	*Vitex pinnata* L.[2, 3]	5	-	partial gap
51	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*[2, 3]	6	-	partial gap
52	Magnoliaceae	*Magnolia liliifera* (L.) Baill[1, 2]	7	-	partial gap
53	Malvaceae	*Scaphium scaphigerum* (Wall. ex G.Don) G.Planch.[2]	5	-	partial gap
54	Moraceae	*Streblus ilicifolius* (S.Vidal) Corner[2]	5	-	partial gap
55	Pentaphylacaceae	*Adinandra integerrima* T. Anderson ex Dyer[2]	8	-	covered
56	Pentaphylacaceae	*Eurya acuminata* DC. var. *acuminata*[2]	6	-	covered
57	Theaceae	*Schima wallichii* (DC.) Korth.[2, 3]	8	-	partial gap

Note: [1] = trees that are threatened with extinction; [2] = trees that dominate the different forest types in Thailand; [3] = trees that are of particular economic importance; [4] = trees that are important to *in situ* genetic conservation.

(b) Criteria lists to achieve the determination goal

Three main criteria relevant to terrestrial biodiversity were selected to achieve the overall goal, which were modified from Regan et al. (2007). These are: (1) current biological value; (2) fully restored biological value; and (3) threats. The main criteria and subcriteria (level I, II and III) are shown in Figure 5.1.

(c) List of options to achieve the determination goal

This part of the analysis aimed to identify the sensitivity of the goal to changes in the weighting of the major criteria. The analysis was based on the weighting of criteria using ILWIS v. 3.08.04, the GIS programme used for the MCA (Schouwenburg et al. 2007).

All 22 criteria layers were prepared using ArcMap v. 10.0 (ESRI 2010b) to convert the data into raster maps, in ASCII format, with the same resolution, coordinate system and number of columns and rows. The resolution used for all layers was 30 arc-seconds, which is approximately 0.93 km x 0.93 km (= 0.86 km^2) at the equator in Thailand. Details of how each layer was produced are shown in Table 5.2. Subsequently, the ‘spatial multi-criteria evaluation’ operation in ILWIS 3.08.04 programme (Schouwenburg et al. 2007) was used. A criteria tree was created and the 22 raster layers were added.

Each criterion was considered either as a ‘benefit’ or ‘cost’ (Table 5.3), together with an interval method which was used for criteria standardisation. The interval method employs a linear function between minimum and maximum values of input (Schouwenburg et al. 2007).

The criteria were then weighted using a ‘direct method’, namely user-defined weights were assigned to criteria. This was achieved by manually inputting weight figures for all criteria, which were then normalised automatically to a standard scale (0 - 1) (Table 5.3).

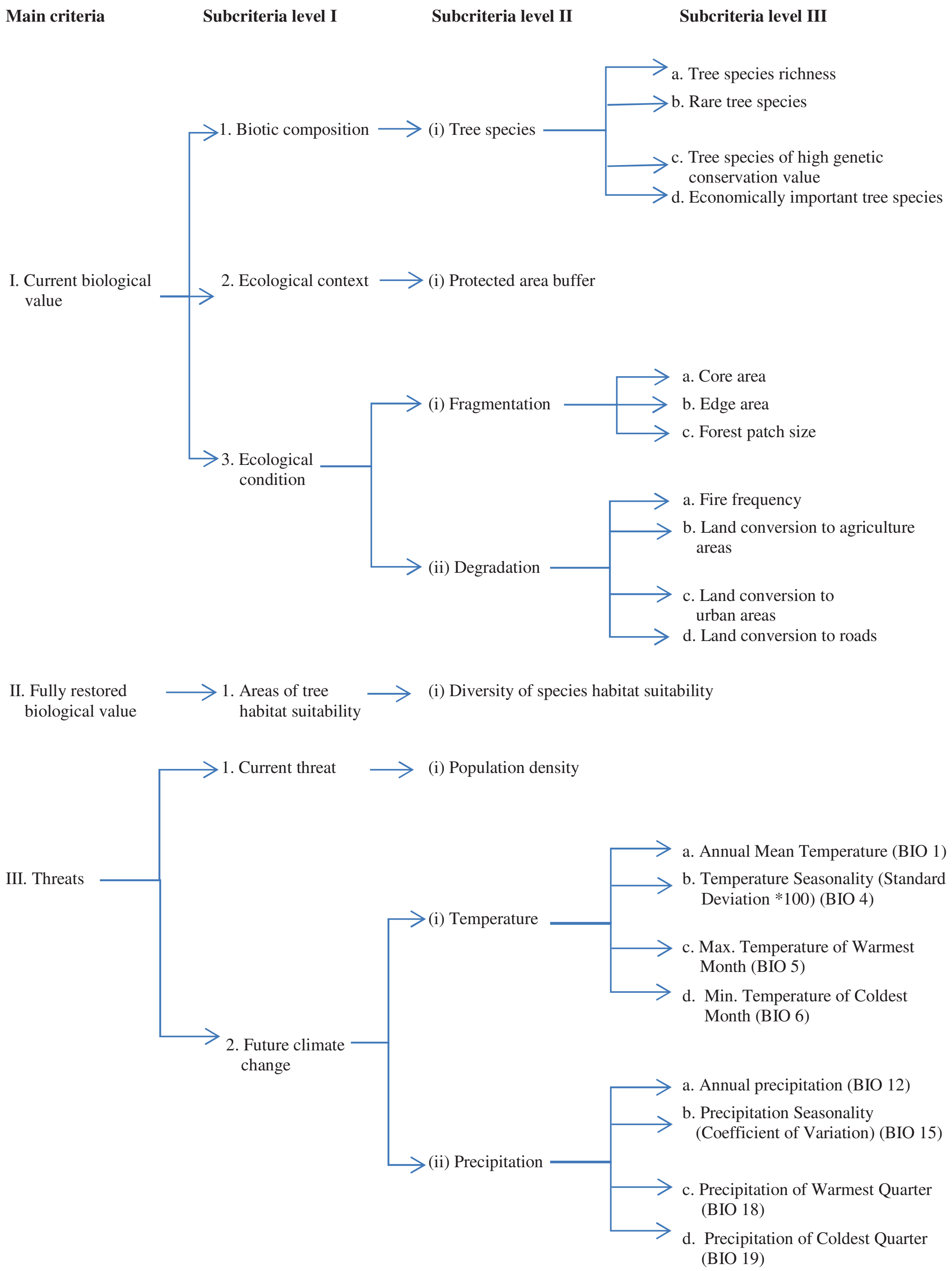


Figure 5.1 - Diagram of all main criteria and their subcriteria level I, II and III (modified from Regan et al. 2007)

Note: *I. 'current biological value'* refers to the current ecological status of option areas and how it contributes to biodiversity (Regan et al. 2007);

1. ‘biotic composition’ refers to the ecological resources of a site that contributes to biodiversity (Regan et al. 2007);

2. ‘ecological context’ refers to the value of a site for offering connectivity or buffering adjoining areas (Regan et al. 2007);

3. ‘ecological condition’ refers to the physical situation of a site concerning disturbances (Regan et al. 2007);

(i) ‘fragmentation’ refers to the process of forest degradation that involves its reduction into smaller and more isolated patches;

(ii) ‘degradation’ refers to the long-term loss of forest values such as carbon stocks, and the reduction of tree crown cover (Penman and Kikan 2003);

II. ‘fully restored biological value’ refers to the condition that the degraded sites can be achieved in regard to terrestrial biodiversity if they were restored;

III. ‘threats’ refers to short-term (1 - 5 years) and long-term potential changes (> 10 years) to a site from a change of environment;

1. ‘current threat’ refers to short-term (1 - 5 years) potential changes to a site from a change of environment; and

2. ‘future climate change’ refers to long-term (> 10 years) potential changes to a site from a change of environment.

Table 5.2 Criteria definitions, processes of producing raster maps of all criteria layers, and sources of criteria

Layer no.	Criteria	Definitions	Processes	Sources
Layer 1	Tree species richness	The total number of tree species found to occur within each pixel.	All 57 tree species were included in this calculation. All known tree occurrence points of 57 species were converted to raster data for each species using the conversion tool 'point to raster', resulting in 57 raster maps of tree species presence. Subsequently, the tree species richness map was produced by calculating the total number of all tree species present within each pixel in Thailand using the feature 'raster calculator'. In the window 'map algebra expression' of feature 'raster calculator', 57 raster maps were calculated simply used the expression: 'species 1 + species 2 + … + species 57' to obtain the total number of all tree species present within each pixel.	Tree occurrence points derived from Department of National Parks, Wildlife, and Plants Conservation (DNP).
Layer 2	Rare tree species	The total number of tree species that are threatened with extinction found to occur within each pixel.	16 of the 57 species were included in this calculation. The process to produce layer 2 was the same as the process of layer 1	Same source as layer 1
Layer 3	Tree species of high genetic conservation value	The total number of tree species that are important to in situ genetic conservation found to occur within each pixel.	10 of the 57 species were included in this calculation. The process to produce layer 3 was the same as the process of layer 1	Same source as layer 1

Layer no.	Criteria	Definitions	Processes	Sources
Layer 4	Economically important tree species	The total number of tree species that are of particular economic importance found to occur within each pixel.	12 of the 57 species were included in this calculation. The process to produce layer 4 was the same as the process of layer 1	Same source as layer 1
Layer 5	Protected area buffer	A 4 km-buffer outside the PA boundaries	The feature 'buffer' was used to create a 4 km-buffer outside the PA boundaries. This is because a 4 km-buffer is suggested to reduce human and domestic cattle impacts (Jotikapukkana et al. 2010). Subsequently, the conversion tool 'feature to raster' was used to convert shapefile to raster file. Then the feature 'reclassify' was used to convert the 4 km-buffer area to '1', the other areas to '0'	A protected area boundaries map 2012 derived from DNP (DNP 2012).
	Layers 6 – 8 are related to forest fragmentation.		The forest cover map 2013 was used to produce forest fragmentation layers. This forest cover shapefile was converted to a raster file using the conversion tool 'feature to raster'. Then, the feature 'reclassify' was used to convert forest to '1' and non-forest to'0'. Note: forest fragmentation causes the changes in forest micro-environment, and has been associated with a high rate of tree mortality from drought and wind turbulence near forest edges (Laurance et al. 2000; Harper et al. 2005), and migration of sensitive species such as birds (Pattanavibool and Dearden 2002).	The forest cover map 2013 derived from Royal Forest Department (RFD 2014).

Layer no.	Criteria	Definitions	Processes	Sources
Layer 6	Core area	Areas inside forest patches after excluding 300 m from the forest edge (following Echeverría et al. 2011)	The core area map was created using the feature ‘buffer’ (negative buffer) to create a 300 m-buffer inside each forest patch. Subsequently, the conversion tool ‘feature to raster’ was used to convert the shapefile to a raster file. Then the feature ‘reclassify’ was used to convert the forest core area to ‘1’, the other areas to ‘0’.	
Layer 7	Edge area	The 300 m-outer area of forest patches from forest edge to core area	The edge area map was created by using the feature ‘erase’ to subtract the core area map from the forest cover map, resulting in edge area map. The edge area map was then converted from a shapefile to a raster file using the conversion tool ‘feature to raster’, then the edge areas were reclassified to ‘1’, the other areas to ‘0’ afterwards.	
Layer 8	Forest patch size	Size of forest patches	The forest cover raster map was reclassified to six patch size categories depending on area (km^2) of forest patches. These are no forest area = ‘0’; $> 0 - \leq 5$ km^2 = ‘1’ (small patch size), $> 5 - \leq 10$ km^2 = ‘2’ (rather small patch size), $> 10 - \leq 50$ km^2 = ‘3’ (medium patch size), $> 50 - \leq 100$ km^2 = ‘4’ (rather large patch size) and > 100 km^2 = ‘5’ (large patch size) (following Echeverría et al. 2011).	

Layer no.	Criteria	Definitions	Processes	Sources
Layer 9	Fire frequency	Fire frequency category found to occur within each pixel	The fire locations 2000-2014 were imported to ArcMap 10.0 and were clipped, to include only those fires that occurred within the Thailand national boundary, using the feature 'clip'. Then, the number of fire occurrences in each pixel were counted and converted from point data to a raster file using the feature 'point to raster'. After that, the fire raster map was reclassified to four fire frequency categories: no fire/pixel = '0'; 1 - 32 fires/ pixel = '1' (low fire frequency), 33 - 64 fires/ pixel = '2' (medium fire frequency), and 65 - 96 fires/ pixel = '3' (high fire frequency).	Moderate Resolution Imaging Spectroradiometer (MODIS) hotspot/fire locations and burned area information were downloaded from http://www.fao.org/nr/gfims/gf-home/en/ (GFIMS 2014).
	Layers 10 – 12 are related to land conversion		The Global Land Cover 2000 map was clipped to the Thailand national boundary using the feature 'clip'. The result was a land cover map 2000 for Thailand, which was used as basis for Layers 10 and 11.	The Global Land Cover 2000 map v.2 for South and South East Asia (Tropical Asia) of the Joint Research Centre (JSR), European Commission was downloaded from http://bioval.jrc.ec.europa.eu/products/glc2000/products.php (JSR 2010).
Layer 10	Land conversion to agricultural areas	Areas that were changed into agricultural areas	The land cover map 2000 for Thailand was reclassified into 2 classes; the agricultural areas were reclassified to '1', other areas were reclassified to '0'.	
Layer 11	Land conversion to urban areas	Areas that were changed into urban areas	The land cover map 2000 for Thailand was reclassified into 2 classes; the urban areas were reclassified to '1' and other areas were reclassified to'0'.	

Layer no.	Criteria	Definitions	Processes	Sources
Layer 12	Land conversion to roads	Areas that were changed into roads with width > 10 m	On the Road attribute table, the value '1' was added where the road with width > 10 m and '0' was added where roads were < 10 m width. Then, the conversion tool 'polyline to raster' was used to convert the data to a raster file.	Road locations 2008 derived from the Geo-Informatics and Space Technology Development Agency (GISTDA 2012b).
Layer 13	Diversity of tree species habitat suitability	The number of tree species based on a provision of suitable habitat	24 tree species with AUC of testing data > 0.7 were included in this calculation. 24 maps of predicted habitat suitability for 24 species were reclassified. Pixels with tree habitat suitability ≤ 0.5 were reclassified to '0' (unsuitable habitat), while those > 0.5 were reclassified to '1' (suitable habitat). Subsequently, the diversity of tree species habitat suitability map was produced by calculating the total number of all suitable habitat of 24 tree species present within each pixel in Thailand using the feature 'raster calculator'. In the window 'map algebra expression' of feature 'raster calculator', 24 raster maps were calculated simply used the expression: 'species 1 + species 2 + … + species 24' to get the total number of all suitable habitats within each pixel.	Maps of predicted habitat suitability for 24 species with AUC of testing data > 0.7 derived from Chapter 4.
Layer 14	Population density	Population density category found to occur within each pixel	The feature 'resample' was used to change the resolution of the map from 2.5 arc-minutes to 30 arc-seconds. There is no standard way to categorize population density, however, it has been suggested that any unit with > 5,000 residents should be considered urban (United Nations and Department of Economic	The Population density map 2000 of Socioeconomic Data and Applications Center (SEDAC) was downloaded from http://sedac.ciesin.columbia.edu/dat

Layer no.	Criteria	Definitions	Processes	Sources
			and Social Affairs 2014). From this figure in conjunction with the maximum value within the dataset (20,689 people km^{-2}), I then decided to reclassify the population density raster map to six population density categories from low to high. These are no people = '0'; ≤ 10 people km^{-2} = '1' (low population density); > 10 - 100 people km^{-2} = '2' (rather low population density); > 100 - 1,000 people km^{-2} = '3' (medium population density); > 1,000 - 10,000 people km^{-2} = '4' (rather high population density); and > 10,000 people km^{-2} = '5' (high population density).	a/collection/gpw-v3 (Center for International Earth Science Information Network - CIESIN - Columbia University, 2005). The downloaded map consists of estimates of human population density for the year 2000 km^{-2} at a resolution of 2.5 arc-minutes.
	Layers 15 – 22 relate to 'Future climate change'	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to bioclimatic variables. The environmental variables that were considered are the eight uncorrelated environmental variables that were included in Chapter 4.	To provide maps of the degree of projected climate change, maps of mean value of current climate were subtracted from those of the future climate using the feature 'raster calculator' for each variable.	Regarding current climate, the bioclimatic variables at 30 arc-seconds resolution were obtained from the WorldClim global climate data, using records from 1950 – 2000 downloaded from http://www.worldclim.org (Hijmans et al. 2005). For future climate, bioclimatic variables were also obtained from the same website, using model 'downscaled global climate model

Layer no.	Criteria	Definitions	Processes	Sources
				(GCM) data' from the IPPC Fifth Assessment (CMIP5) and the Representative Concentration Pathways 8.5 Watts m^{-2} (RCP8.5) of the year 2050 by 30 arc-seconds resolution, downloaded from http://www.worldclim.org (Hijmans et al. 2005). Representative Concentration Pathways (RCP) is a concentration of four greenhouse gases namely water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). RCP8.5 is a possible range of radiative forcing values in the year 2050 (average for 2041 - 2060) (8.5 Watts m^{-2}) relative to pre-industrial values. The RCP8.5 was chosen because it is related to the highest greenhouse gas emissions to the Representative Concentration Pathways (Riahi et al. 2011).

Layer no.	Criteria	Definitions	Processes	Sources
Layer 15	Annual Mean Temperature (BIO 1)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 1	A projected climate change in relation to BIO1 map was produced by calculating the change of mean value within each pixel in Thailand using the feature ‘raster calculator’. The mean values of current BIO 1 were subtracted from those of the future BIO 1.	
Layer 16	Temperature Seasonality (standard deviation *100) (BIO 4)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 4	The process to produce layer 16 was the same as the process of layer 15	
Layer 17	Max Temperature of Warmest Month (BIO 5)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 5	The process to produce layer 17 was the same as the process of layer 15	
Layer 18	Min Temperature of Coldest Month (BIO 6)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 6	The process to produce layer 18 was the same as the process of layer 15	
Layer 19	Annual precipitation (BIO 12)	The difference of mean value between current (1950	The process to produce layer 19 was the same as the process of layer 15	

Layer no.	Criteria	Definitions	Processes	Sources
		- 2000) and predicted future (2050) climate in relation to BIO 12		
Layer 20	Precipitation Seasonality (Coefficient of Variation) (BIO 15)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 15	The process to produce layer 20 was the same as the process of layer 15	
Layer 21	Precipitation of Warmest Quarter (BIO 18)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 18	The process to produce layer 21 was the same as the process of layer 15	
Layer 22	Precipitation of Coldest Quarter (BIO 19)	The difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 19	The process to produce layer 22 was the same as the process of layer 15	

Table 5.3 Input values of all criterion layers. Maximum and minimum input values are presented, together with a consideration of criteria regarding whether they were considered as a benefit or as a cost in the process of standardisation, prior to weighting and normalisation

Layer no.	Criteria	Input value		Criteria consideration
		Min.	Max.	
Layer 1	Tree species richness	0	12	Benefit
Layer 2	Rare tree species	0	6	Benefit
Layer 3	Tree species of high genetic conservation value	0	4	Benefit
Layer 4	Economically important tree species	0	2	Benefit
Layer 5	Protected area buffer	0	1	Benefit
Layer 6	Core area	0	1	Benefit
Layer 7	Edge area	0	1	Benefit
Layer 8	Forest patch size	0	5	Benefit
Layer 9	Fire frequency	0	3	Cost
Layer 10	Land conversion to agricultural areas	0	1	Cost
Layer 11	Land conversion to urban areas	0	1	Cost
Layer 12	Land conversion to roads	0	1	Cost
Layer 13	Diversity of tree species habitat suitability	0	17	Benefit
Layer 14	Population density	0	5	Cost
Layer 15	Annual Mean Temperature (BIO 1) (°C * 10)	5	29	Cost
Layer 16	Temperature seasonality (standard deviation *100) (BIO 4) (°C * 10)	-321	206	Cost
Layer 17	Max Temperature of Warmest Month (BIO 5) (°C * 10)	4	31	Cost
Layer 18	Min Temperature of Coldest Month (BIO 6) (°C * 10)	8	31	Cost
Layer 19	Annual precipitation (BIO 12) (mm)	-280	167	Benefit
Layer 20	Precipitation Seasonality (Coefficient of Variation) (BIO 15) (mm)	-12	17	Benefit
Layer 21	Precipitation of Warmest Quarter (BIO 18) (mm)	-467	456	Benefit
Layer 22	Precipitation of Coldest Quarter (BIO 19) (mm)	-548	1,549	Benefit

An output map was produced as an output of the spatial MCA, which ranked each pixel within the whole region. This illustrates the extent to which criteria are met in different areas, on a scale from 0 to 1. To assist in the interpretation of the output maps, the degree of priority for conservation was identified according to four categories, based on the MCA output scores. These were: ≤ 0.2 very low priority area; > 0.2 – ≤ 0.4 low priority area; > 0.4 – ≤ 0.6 high priority area; and > 0.6 very high priority area.

Sensitivity analysis was performed to explore the effect of different sets of weights on the output maps (Geneletti and van Duren 2008). To identify the sensitivity of achieving the overall goal to the criteria, different weights were applied to both the three main criteria and the six level I subcriteria groups. These are described in the following section.

The main criteria and the level I subcriteria were each double weighted in turn, the decision to increase weights by this factor, as oppose to alternative values, was essentially arbitrary in the absence of any *a priori* reason for exploring particular weights. The objective was to examine the potential impact of changing weights on the results to provide an insight into the sensitivity of the results to different weighting of importance by different stakeholder groups' preferences.

i. Sensitivity of the overall goal to the three main criteria group

Three main criteria were considered, namely: (1) current biological value, (2) fully restored biological value, and (3) threats. These three main criteria in combination were considered to value high potential areas to reach the overall goal. Each of the main criteria was associated with a number of subcriteria (either level II or level III) (Figure 5.1). There were 12, 1, and 9 subcriteria within 'current biological value', 'fully restored biological value' and 'threats' criteria respectively (see Figure 5.1).

To identify the sensitivity of the overall goal to the three main criteria, four different alternatives generated by MCA were repeated using four different sets of weights (see Table 5.4). Higher weights reflect a higher degree of importance accorded to the criterion compared to the other criteria (Regan et al. 2007).

Hereafter, Alternative A1 refers to the situation where all three main criteria were weighted equally. Alternatives A2 – A4 refer to situations where doubled weights were applied to the main criteria 'current biological value', 'fully restored biological value' and 'threats' respectively. In each case, weights were defined for each individual subcriterion to achieve this distribution of weights for the main criteria. Subsequently, all user-defined weights were normalised automatically, to values between 0 and 1 (Table 5.4).

Table 5.4 The normalised value of weights applied to subcriteria in four Alternatives (A1 - A4) examined by MCA

Main criteria	Subcriteria level I	Subcriteria level II	Subcriteria level III	Normalised value of weights			
				Alternative A1	Alternative A2	Alternative A3	Alternative A4
I. Current biological value							
	1. Biotic composition						
		(i) Tree species					
Layer 1			a. Tree species richness	0.028	0.042	0.021	0.021
Layer 2			b. Rare tree species	0.028	0.042	0.021	0.021
Layer 3			c. Tree species of high genetic conservation value	0.028	0.042	0.021	0.021
Layer 4			d. Economically important tree species	0.028	0.042	0.021	0.021
	2. Ecological context						
Layer 5		(i) Protected area buffer		0.028	0.042	0.021	0.021
	3. Ecological condition						
		(i) Fragmentation					
Layer 6			a. Core area	0.028	0.042	0.021	0.021
Layer 7			b. Edge area	0.028	0.042	0.021	0.021
Layer 8			c. Forest patch size	0.028	0.042	0.021	0.021
		(ii) Degradation					
Layer 9			a. Fire frequency	0.028	0.042	0.021	0.021
Layer 10			b. Land conversion to agriculture areas	0.028	0.042	0.021	0.021
Layer 11			c. Land conversion to urban areas	0.028	0.042	0.021	0.021

Main criteria	Subcriteria level I	Subcriteria level II	Subcriteria level III	Normalised value of weights			
				Alternative A1	Alternative A2	Alternative A3	Alternative A4
Layer 12			d. Land conversion to roads	0.028	0.042	0.021	0.021
Overall weight for main criterion				***0.333***	***0.504***	***0.252***	***0.252***
II. Fully restored biological value							
	1. Areas of tree habitat suitability						
Layer 13		(i) Diversity of species habitat suitability		0.333	0.249	0.499	0.249
Overall weight for main criterion				***0.333***	***0.249***	***0.499***	***0.249***
III. Threats							
Layer 14	1. Current threat						
		(i) Population density		0.037	0.028	0.028	0.055
	2. Future climate change						
		(i) Temperature					
Layer 15			(i) Annual Mean Temperature (BIO 1)	0.037	0.028	0.028	0.055
Layer 16			(ii) Temperature Seasonality (Standard deviation *100) (BIO 4)	0.037	0.028	0.028	0.055
Layer 17			(iii) Max Temperature of Warmest Month (BIO 5)	0.037	0.028	0.028	0.055
Layer 18			(iv) Min Temperature of Coldest Month (BIO 6)	0.037	0.028	0.028	0.055
		(ii) Precipitation					
Layer 19			(i) Annual Precipitation (BIO 12) (mm)	0.037	0.028	0.028	0.055
Layer 20			(ii) Precipitation Seasonality (Coefficient of Variation) (BIO 15)	0.037	0.028	0.028	0.055
Layer 21			(iii) Precipitation of Warmest Quarter (BIO 18)	0.037	0.028	0.028	0.055
Layer 22			(iv) Precipitation of Coldest Quarter (BIO 19)	0.037	0.028	0.028	0.055
Overall weight for main criterion				***0.333***	***0.252***	***0.252***	***0.495***
Total				**1.000**	**1.005**	**1.003**	**0.996**

ii. Sensitivity of the overall goal to the six level I subcriteria group

To identify the sensitivity of the overall goal to the six level I subcriteria, seven different alternatives were explored in the MCA using seven different sets of weights. In Alternative B1, all six level I subcriteria were weighted equally. In Alternative B2 – B7, each of the following level I subcriteria was accorded a value twice the weight of the other level I subcriteria, respectively: 'biotic composition'; 'ecological context'; 'ecological condition'; 'tree habitat suitability area'; 'current threat'; and 'future climate change'. Again, weights were defined for each individual subcriterion to achieve this distribution of weights for the six level I subcriteria. Consequently, all user-defined weights were normalised automatically, to values between 0 and 1 (Table 5.5).

Table 5.5 The normalised value of weights applied to subcriteria in seven Alternatives (B1 - B7) examined by MCA

Main criteria	Subcriteria level I	Subcriteria level II	Subcriteria level III	Normalised value of weights						
				Alternative B1	Alternative B2	Alternative B3	Alternative B4	Alternative B5	Alternative B6	Alternative B7
I. Current biological value										
	1. Biotic composition									
		(i) Tree species								
Layer 1			a. Tree species richness	0.042	0.071	0.036	0.036	0.036	0.036	0.036
Layer 2			b. Rare tree species	0.042	0.071	0.036	0.036	0.036	0.036	0.036
Layer 3			c. Tree species of high genetic conservation value	0.042	0.071	0.036	0.036	0.036	0.036	0.036
Layer 4			d. Economically important tree species	0.042	0.071	0.036	0.036	0.036	0.036	0.036
	Overall weight for level I subcriterion			***0.167***	***0.284***	***0.144***	***0.144***	***0.144***	***0.144***	***0.144***
	2. Ecological context									
Layer 5		(i) Protected area buffer		0.167	0.143	0.284	0.142	0.143	0.143	0.142
	Overall weight for level I subcriterion			***0.167***	***0.143***	***0.284***	***0.142***	***0.143***	***0.143***	***0.142***
	3. Ecological condition									
		(i) Fragmentation								
Layer 6			a. Core area	0.024	0.021	0.020	0.041	0.020	0.020	0.020

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Main criteria	Subcriteria level I	Subcriteria level II	Subcriteria level III	Normalised value of weights						
				Alternative B1	Alternative B2	Alternative B3	Alternative B4	Alternative B5	Alternative B6	Alternative B7
Layer 7			b. Edge area	0.024	0.021	0.020	0.041	0.020	0.020	0.020
Layer 8			c. Forest patch size	0.024	0.021	0.020	0.041	0.020	0.020	0.020
		(ii) Degradation								
Layer 9			a. Fire frequency	0.024	0.021	0.020	0.041	0.020	0.020	0.020
Layer 10			b. Land conversion to agriculture areas	0.024	0.021	0.020	0.041	0.020	0.020	0.020
Layer 11			c. Land conversion to urban area	0.024	0.021	0.020	0.041	0.020	0.020	0.020
Layer 12			d. Land conversion to roads	0.024	0.021	0.020	0.041	0.020	0.020	0.020
	Overall weight for level I subcriterion			***0.167***	***0.147***	***0.140***	***0.287***	***0.140***	***0.140***	***0.140***
II. Fully restored biological value										
	1. Areas of tree habitat suitability			0.167	0.143	0.143	0.142	0.284	0.143	0.142
Layer 13		(i) Diversity of species habitat suitability		***0.167***	***0.143***	***0.143***	***0.142***	***0.284***	***0.143***	***0.142***
	Overall weight for level I subcriterion									
III. Threats										
Layer 14	1. Current threat									
		(i) Population density		0.167	0.143	0.143	0.142	0.143	0.284	0.142
	Overall weight for level I subcriterion			***0.167***	***0.143***	***0.143***	***0.142***	***0.143***	***0.284***	***0.142***

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Main criteria	Subcriteria level I	Subcriteria level II	Subcriteria level III	Normalised value of weights						
				Alternative B1	Alternative B2	Alternative B3	Alternative B4	Alternative B5	Alternative B6	Alternative B7
	2. Future climate change									
		(i) Temperature								
Layer 15			(i) Annual Mean Temperature (BIO 1)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
Layer 16			(ii) Temperature Seasonality (Standard deviation *100) (BIO 4)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
Layer 17			(iii) Max Temperature of Warmest Month (BIO 5)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
Layer 18			(iv) Min Temperature of Coldest Month (BIO 6)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
		(ii) Precipitation								
Layer 19			(i) Annual Precipitation (BIO 12)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
Layer 20			(ii) Precipitation Seasonality (Coefficient of Variation) (BIO 15)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
Layer 21			(iii) Precipitation of Warmest Quarter (BIO 18)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
Layer 22			(iv) Precipitation of Coldest Quarter (BIO 19)	0.021	0.018	0.018	0.018	0.018	0.018	0.036
	Overall weight for level I subcriterion			***0.167***	***0.144***	***0.144***	***0.144***	***0.144***	***0.144***	***0.288***
Total				**1.000**	**1.004**	**0.998**	**1.001**	**0.998**	**0.998**	**0.998**

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5.4 Results

(a) Main criteria

Under the Alternative A1 scenario, very limited areas were accorded very high priority (MCA output scores > 0.6) in the country as a whole, representing 0.719% of the total area of Thailand (Table 5.6). However, less than half of this area (39.04%) was located outside PAs. This indicates that a relatively small area (1,447 km^2) of very high priority lies outwith the current PA network. This is primarily located in the middle and Southern parts of the Southern region of Thailand (Figure 5.2). In addition, some very high priority areas outside PAs were located sparsely in Trat province in the Eastern region adjacent to Cambodia, and on the Ko Chang and the Ko Kut islands in the Gulf of Thailand (Figure 5.2 and the details of provinces of Thailand are shown in Figure D1 in Appendix D). Areas accorded high priority (MCA output scores > 0.4 - $\leq$ 0.6) were substantially more extensive, accounting for 11.37% of the total area of Thailand and 63.05% of this lies outside the existing PAs. Such areas occurred at a high density from the middle to Southern parts of the Southern region of Thailand (Figure 5.2). Further areas of high priority outside PAs also occurred in the Trat province in the Eastern region, and on the Ko Chang and the Ko Kut islands in the Gulf of Thailand. Scattered areas were also located in Kanchana Buri province in the Western region. Very lightly scattered areas were located near the current PAs in the Northern region as a whole, and within two provinces, namely Ubon Ratchatani and Nakhon Phanom in the Northeastern region next to Laos (Figure 5.2).

The application of different weightings had a pronounced effect on the total area accorded very high priority across Thailand as a whole. In particular, Alternative A3 led to an almost threefold increase in the total area accorded very high priority, whereas Alternatives A2 and A4 led to a near threefold decrease (Table 5.6). Converse results were obtained in relation to areas of high priority, which increased substantially in Alternatives A2 and A4, but declined in Alternative A3 (Table 5.6).

With respect to areas outside PAs, weighting again had a pronounced effect on the results obtained. However, the percentage accorded very high priority increased under Alternatives A2, A3 and A4 compared to Alternative A1. The same was true for areas of high priority, with the exception of Alternative A2, which declined relative to that of Alternative A1 (Table 5.6).

The priority area distributions outside PAs of Alternatives A2, A3, A4 compared to Alternative A1 were located similarly to those accorded very high priority, but differed in the degree of density. Under Alternative A3, density of very high priority increased substantially in a number of locations, including from the middle to Southern parts of the Southern region, in the Trat province, on the Ko Chang and the Ko Kut islands in the Gulf of Thailand (Figure 5.4). Converse results were obtained for Alternative A4, where the density of very high priority areas in all locations was considerably lower than that of Alternative A1, especially the areas in the Southern part of the Southern region of Thailand (Figure 5.5). Results for Alternative A2 remained almost unchanged compared to Alternative A1, with only slightly lower density of very high priority areas occurring in all locations (Figure 5.3). With regard to areas accorded high priority, different results in relation to both the area distribution and the degree of density were obtained, compared to Alternative A1. Under Alternative A2, high priority areas were found in all locations, but they occurred at much lower density in the Southern and the Eastern regions. Further areas of high priority were located near the current PAs in the Northern and the Western regions as a whole, also around the Dong Phaya Yen - Khao Yai Forest Complex in the Northeastern and the Central regions of Thailand (Figure 5.3). Under Alternative A3, the areas scored as high priority almost disappeared from the Northern region. However, an almost unchanged pattern compared to Alternative A1 was obtained in the Southern, the Eastern, and the Northeastern regions, with a few additional areas found in Nong Khai province in the Northeastern region (Figure 5.4). Alternative A4 showed the most similar distribution pattern to Alternative A1, but with increased high priority areas in the Southern region (Figure 5.5).

Table 5.6 The area (km^2) of different categories of prioritisation resulting from spatial MCA, applying different weights to three main criteria

No.	Priority area	Inside and outside PAs		Outside PAs only	
		Area (km^2)	% of total area	Area (km^2)	% of priority area
Alternative A1: all three main criteria were accorded equal weight					
1	Very low priority area	316	0.061	316	100.0
2	Low priority area	452,749	87.85	368,946	81.49
3	High priority area	58,580	11.37	36,934	63.05
4	Very high priority area	3,707	0.719	1,447	39.04
Alternative A2: 'current biological value' was accorded a value twice the weight of the other criteria					
1	Very low priority area	1,039	0.202	1,039	100.0
2	Low priority area	418,491	81.20	358,178	85.59
3	High priority area	94,559	18.35	47,583	50.32
4	Very high priority area	1,265	0.245	844	66.69
Alternative A3: 'fully restored biological value' was accorded a value twice the weight of the other criteria					
1	Very low priority area	86,592	16.80	86,064	99.39
2	Low priority area	375,767	72.91	286,880	76.35
3	High priority area	42,654	8.277	29,656	69.53
4	Very high priority area	10,340	2.006	5,044	48.78
Alternative A4: 'threats' was accorded a value twice the weight of the other criteria					
1	Very low priority area	116,536	22.61	116,024	99.56
2	Low priority area	309,251	60.01	234,699	75.89
3	High priority area	88,339	17.14	56,395	63.84
4	Very high priority area	1,227	0.238	525	42.82
	Total	515,353	100.0	407,644	79.10

Note: Very low priority area refers to values < 0.2; low priority area refers to values > 0.2 – ≤ 0.4; high priority area refers to values > 0.4 – ≤ 0.6; and very high priority area refers to values > 0.6.

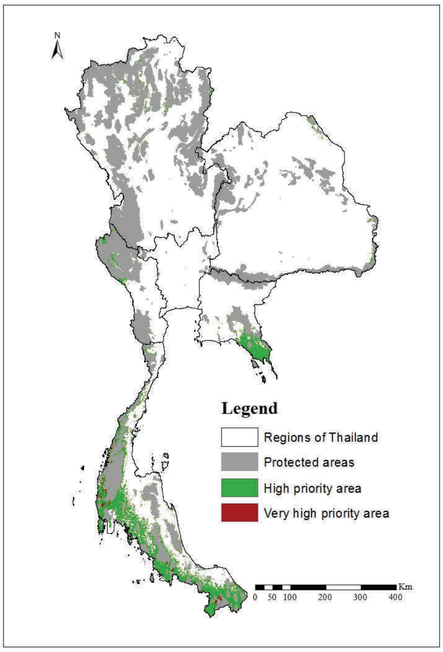

Figure 5.2 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative A1 (all three main criteria were accorded equal weight) outside existing PA of Thailand

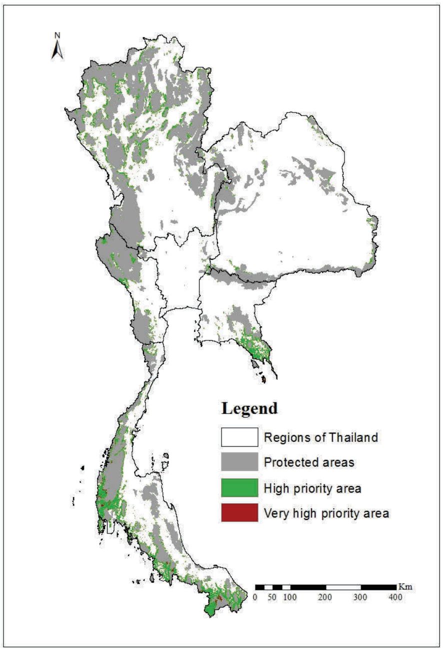

Figure 5.3 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative A2 ('current biological value' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

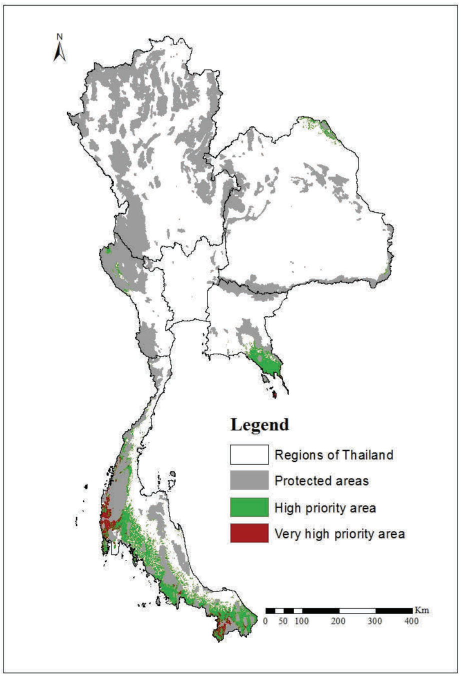

Figure 5.4 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative A3 ('fully restored biological value' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

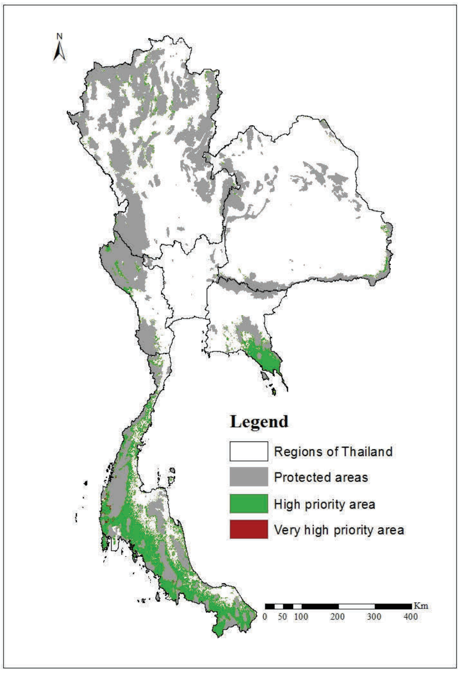

Figure 5.5 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative A4 ('threats' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

(b) Subcriteria level I

Under Alternative B1, extremely limited areas were accorded very high priority (MCA output scores > 0.6) in the entire country, representing 0.318% of the total area of Thailand. Almost all of this area (96.64%) lay inside the current PA network (Table 5.7) and a relatively small area (1,585 km^2) was located outside the existing PAs. This was primarily located sparsely next to current PAs in the middle and Southern parts of the Southern region of Thailand (Figure 5.6). In addition, extremely limited areas of very high priority outside PAs were located on the Ko Chang island in the Gulf of Thailand (Figure 5.6). Areas accorded high priority (MCA output scores > 0.4 - ≤ 0.6) were considerably more extensive with 18.67% of the total area of the country. 85.57% of this was located outside the current PAs, close to the PA buffer in particular, in all regions over the country (Figure 5.6).

The application of altered weightings had a pronounced effect on the total area accorded very high priority at the scale of the entire country. Specifically, Alternative B3 led to an over fourfold increase in the total area accorded very high priority, whereas the total area accorded very high priority of Alternative B2 decreased to near zero. In addition, the total area accorded very high priority was an over twofold decrease under Alternative B7, and was slightly increased under B4, B5, and B6 (Table 5.7). Contrasting results were obtained in relation to areas of high priority. It was apparent that Alternative B2 led to a more than twofold decline in the total area accorded high priority compared to B1. Converse results were received under Alternative B4, which led to a nearly twofold increase in the total area accorded high priority. Furthermore, slight changes of the area accorded high priority were obtained under Alternatives B3, B5, B6 and B7. Areas of high priority slightly declined at 2.15%, and 4.80% under Alternatives B3 and B5 respectively, while values were slightly increased at 3.53%, and 1.02% under Alternatives B6 and B7 respectively (Table 5.7).

With regard to areas outside PAs, weighting had an effect on the results obtained. The percentage accorded very high priority increased minimally, by less than one percent, under Alternatives B3, B4 and B5 compared to Alternative B1, but slightly declined under Alternatives B2, B6 and B7 (1.64%, 3.08%, and 0.59% respectively).

The same was true for areas of high priority outside PAs, with the exception of Alternatives B2, B4 and B5, where converse results were obtained. In particular, the percentage accorded high priority of Alternative B4 substantially declined to 57.23% lying outwith the current PAs. In addition, the percentage accorded high priority increased under Alternative B2 (7.09%) compared to Alternative B1, however that of Alternative B5 slightly decreased (3.80%) (Table 5.7).

For areas accorded very high priority, the distributions outside PAs of Alternatives B2 - B7 compared to Alternative B1 were differed in both locations and degree of density. Under Alternative B2, areas accorded very high priority decreased substantially, with very few areas in the country as a whole (Figure 5.7). Converse results were obtained in Alternative B3, where areas accorded very high priority increased substantially. These were located next to the existing PAs: from the middle to Southern parts of the Southern region; and in Kanchana Buri province in the Western region. In addition, sparse areas accorded very high priority were also found: in Tak and Mae Hong Son provinces in the Northern region; in Ubon Ratchatani province in the Northeastern region; and in the Trat province in the Eastern region, and on the Ko Chang island in the Gulf of Thailand (Figure 5.8). Similar patterns to those produced by Alternative B1 was obtained under Alternatives B4 - B6. Under Alternative B5, areas of very high priority were located in the same locations as that of Alternative B1, but at a slightly higher density (Figure 5.10). Under Alternatives B4 and B6, apart from similar locations of very high priority areas to those obtained with Alternative B1, further small areas of very high priority were found in Kanchana Buri province in the Western region of Thailand adjacent to Myanmar (Figure 5.9 and Figure 5.11).

With regard to areas accorded high priority, the distributions outside PAs and the degree of density remained almost unchanged under Alternatives B3, B4, B6 and B7 compared to B1 (Figures 5.8, 5.9, 5.11, and 5.12 respectively). High priority areas were located next to the current PAs in the country as a whole. Under Alternatives B2 and B5, substantial alterations of high priority areas in terms of density compared to B1 were obtained. Under Alternative B2, even though high priority areas were found next to the current PAs in the country as a whole, but much lower density in all regions (Figure 5.7). Similar patterns to those produced by Alternative B2 was obtained under Alternative B5, with the exception of areas in the Southern and the Eastern regions, where much higher density were obtained at the scale of the whole of those two regions (Figure 5.10).

Table 5.7 The area (km^2) of different categories of prioritisation resulting from spatial MCA, applying different weights to six level I subcriteria

No.	Priority area	Inside and outside PAs		Outside PAs only	
		Area (km^2)	% of area	Area (km^2)	% of priority area
Alternative B1: all six level I subcriteria were accorded equal weight					
1	Very low priority area	2,935	0.569	2,935	100.0
2	Low priority area	414,552	80.44	320,788	77.38
3	High priority area	96,226	18.67	82,336	85.57
4	Very high priority area	1,640	0.318	1,585	96.64
Alternative B2: 'biotic composition' was accorded a value twice the weight of the other level I subcriteria					
1	Very low priority area	99,171	19.24	98,917	99.74
2	Low priority area	370,459	71.88	266,359	71.90
3	High priority area	45,707	8.869	42,351	92.66
4	Very high priority area	17	0.003	16	95.00
Alternative B3: 'ecological context' was accorded a value twice the weight of the other level I subcriteria					
1	Very low priority area	116,461	22.60	116,154	99.74
2	Low priority area	306,554	59.48	202,228	65.97
3	High priority area	85,156	16.52	82,271	96.61
4	Very high priority area	7,183	1.394	6,991	97.33
Alternative B4: 'ecological condition' was accorded a value twice the weight of the other level I subcriteria					
1	Very low priority area	1,495	0.290	1,495	100.0
2	Low priority area	337,402	65.47	304,201	90.16
3	High priority area	174,006	33.76	99,577	57.23
4	Very high priority area	2,451	0.476	2,371	96.74
Alternative B5: 'areas of tree habitat suitability' was accorded a value twice the weight of the other level I subcriteria					
1	Very low priority area	72,605	14.09	72,409	99.73
2	Low priority area	368,616	71.53	274,213	74.39
3	High priority area	71,471	13.87	58,441	81.77
4	Very high priority area	2,661	0.516	2,581	96.96

No.	Priority area	Inside and outside PAs		Outside PAs only	
		Area (km^2)	% of area	Area (km^2)	% of priority area
Alternative B6: 'current threat' was accorded a value twice the weight of the other level I subcriteria					
1	Very low priority area	1,809	0.351	1,808	99.95
2	Low priority area	396,522	76.94	316,304	79.77
3	High priority area	114,432	22.20	87,108	76.12
4	Very high priority area	2,590	0.503	2,423	93.56
Alternative B7: 'future climate change' was accorded a value twice the weight of the other level I subcriteria					
1	Very low priority area	242	0.047	242	100.0
2	Low priority area	412,855	80.11	320,899	77.73
3	High priority area	101,452	19.69	85,730	84.50
4	Very high priority area	805	0.156	773	96.05
	Total	515,353	100.0	407,644	79.10

Note: Very low priority area refers to the values < 0.2; low priority area refers to values > 0.2 – ≤ 0.4; high priority area refers to values > 0.4 – ≤ 0.6; and very high priority area refers to values > 0.6.

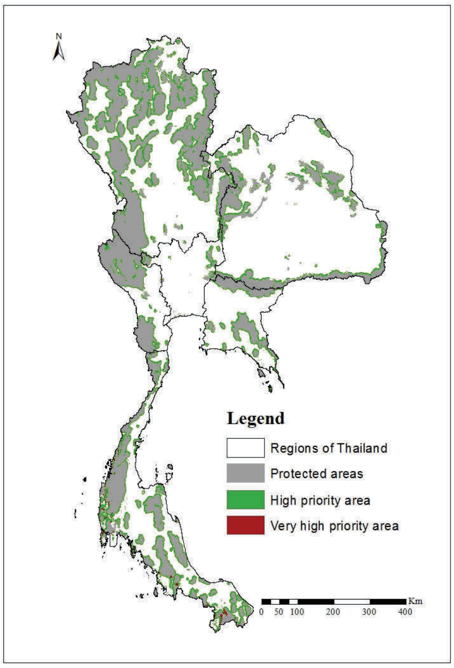

Figure 5.6 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B1 (all six level I subcriteria were accorded equal weight) outside existing PA of Thailand

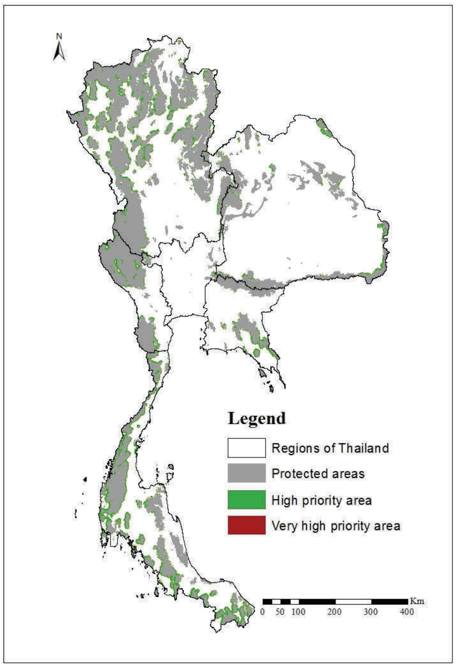

Figure 5.7 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B2 ('biotic composition' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

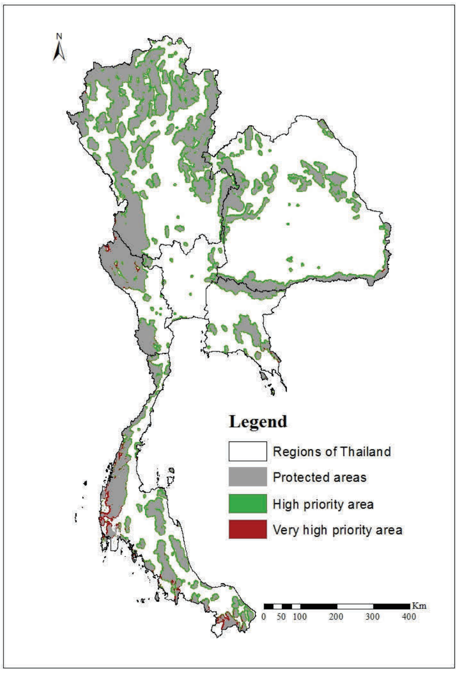

Figure 5.8 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B3 ('ecological context' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

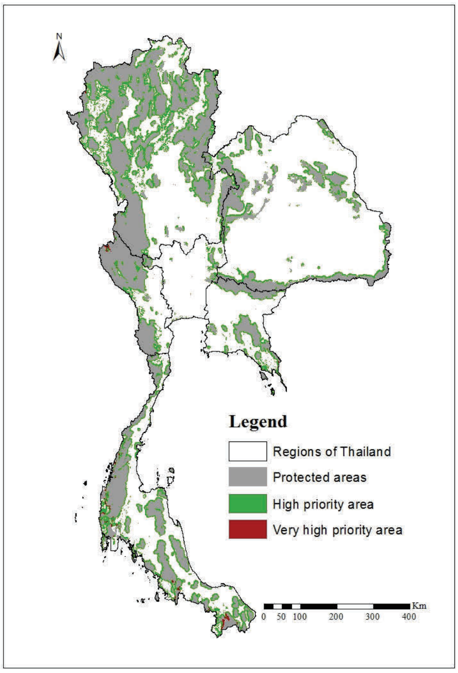

Figure 5.9 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B4 ('ecological condition' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

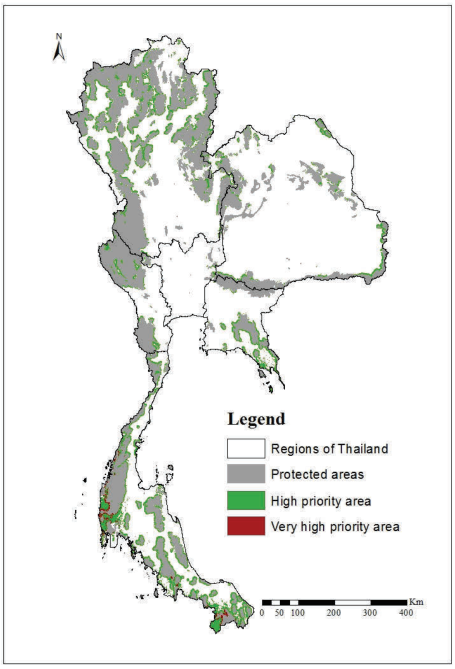

Figure 5.10 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B5 ('areas of tree habitat suitability' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

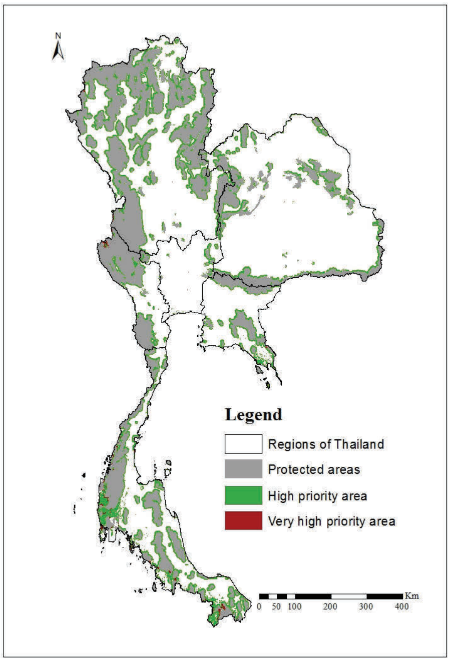

Figure 5.11 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B6 ('current threat' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

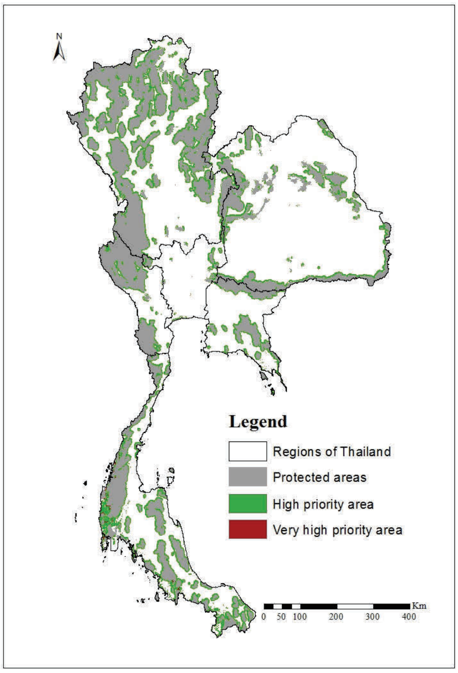

Figure 5.12 - Distribution of high and very high priority area categories produced as an output of the spatial MCA for Alternative B7 ('future climate change' was accorded a value twice the weight of the other criteria) outside existing PA of Thailand

5.5 Discussion

According to the results of this analysis, areas of very high priority for conservation that lie outside existing PAs are extremely limited in extent (between 0.003 – 2.006% of the total area of Thailand, Table 5.6 and 5.7). However, these deserve the highest and most urgent consideration in terms of future conservation actions in Thailand. These areas are primarily located near to current PAs in the Southern and the Eastern regions of Thailand. Specifically, such areas were found to be sparsely located from the middle to the Southern parts of the Southern region, while the areas in the Eastern region were located in Trat province, the Ko Chang and the Ko Kut islands in the Gulf of Thailand.

High priority areas located outside PAs should also be addressed in future conservation strategies. Areas of high priority were again primarily located near to current PAs. They were found from the middle to Southern parts of the Southern region of Thailand, in the Trat province in the Eastern region, on the Ko Chang and the Ko Kut islands in the Gulf of Thailand. Scattered areas were also located in Kanchana Buri province in the Western region, in Ubon Ratchatani and Nakhon Phanom provinces in the Northeastern region next to Laos. Also, very lightly scattered areas were located in the Northern region. The lower extent of high priority areas found in the Northeastern and the Central regions may be attributed to the influence of intensive human disturbance, both in terms of settlement and agriculture, as observed from the land use map used in the analysis.

The reason why areas of very high and high priorities for conservation are mainly found in the Southern and the Eastern regions is possibly driven by several tree species having high habitat suitability areas (11 of 24 species) located in those two regions. The example of tree species having high and very high habitat suitability areas in the Southern and the Eastern regions are: *Anisoptera costata, Diospyros montana, Diospyros wallichii, Dipterocarpus baudii, Dipterocarpus dyeri, Dipterocarpus gracilis, Dipterocarpus grandiflorus, Dipterocarpus turbinatus, Parashorea stellate, Shorea guiso, Shorea hypochra* (Figure 4.1 in Chapter 4).

The location and extent of priority areas were found to be sensitive to the weightings that were used. In particular, results were sensitive to alteration of the weight given to the 'fully restored biological value' criterion (Alternative A3), in relation to the increase of areas accorded very high priority and their locations where those areas were found. Increasing the weight, applied to this criterion, substantially increased the extent of very high priority areas. Additionally, areas of very high priority can be found at higher density from the middle to Southern parts of the Southern region, in the Trat province of the Eastern region, on the Ko Chang and the Ko Kut islands in the Gulf of Thailand (Figure 5.4). PA practitioners/planners might choose to weight this criterion higher than the others, if they give high importance to the condition that degraded sites could achieve in regard to terrestrial biodiversity if they were restored (Regan et. al. 2007). In this research, the potential future condition after restoration is measured by having high predicted suitability for a large number of tree species (layer 13) (Figure B13 in Appendix B).

The implication of the analysis for conservation planning is that the results are very uncertain as they are high sensitivity; therefore it depends on PA practitioner/planner preferences to provide values to alternatives. Areas that remain high and very high priorities in the same locations in every sensitivity analyses assigned by the change of weighting sets, can also indicate the robustness of results (Wood and Dragicevic 2007). These particular areas might be of interest to PA practitioners/planners because these might confirm the area importance or show low risk alternatives for investment in the interested areas (Wilson 2010). The uniformly very high priority areas shown in almost all alternatives are: areas next to current PAs in the Southern region; areas near to Cambodia in Trat province in the Eastern region; and areas near to PAs on Ko Chang and Ko Kut islands in the Gulf of Thailand. These locations were confirmed by the result maps of several Alternatives including A1- A4, B1, B3- B6 (Figure 5.2 - 5.5, 5.6, 5.8 – 5.11 respectively).

The possible reasons for this sensitivity derive from: (1) the input values to individual pixel of all criterion layers (subcriteria); (2) whether subcriteria were considered as a 'benefit' or as a 'cost' in the MCA; and (3) the different number of subcriteria under each main criterion. The first reason is straightforward; a low input value produces a low output value. The second reason relates to the consideration of whether each criterion is considered either as a 'benefit' or a 'cost', using an 'interval method' to standardise the input value of each criterion. The interval method refers to standardisation of input values with a linear function, using minimum and maximum values of input. Using the 'interval method for a benefit', the minimum value will be standardised to 0; the maximum value will be standardised to 1. On the other hand, the 'interval method for a cost' is opposite to the 'interval method for a benefit' (Schouwenburg et al. 2007). The example is that if any subcriterion has high input value but considered as a 'cost', its standardised value becomes low leading to the low output in the MCA. The third reason, relates to the fact that any main criterion that has a higher number of subcriteria under it, will have low weight value for each subcriterion under it, but any main criterion that has a lower number of subcriteria under it will have a higher weight value for each subcriterion under it. Such weights will affect the output in the MCA.

The output map of Alternative A3 showed most sensitivity to areas accorded very high priority because of three reasons. First, the 'fully restored biological value' main criterion has only one subcriterion under it, that is 'diversity of species habitat suitability'. Second, this one subcriterion was considered as a 'benefit'. Lastly, the input values to individual pixel of the 'diversity of species habitat suitability' subcriterion accorded higher values in areas at the middle to Southern parts of the Southern region, in the Trat province of the Eastern region, on the Ko Chang and the Ko Kut islands in the Gulf of Thailand compared to values in the other areas of the rest of Thailand (Figure B13 in Appendix B) where areas accorded very high priority were located. When double weight was given to this main criterion ('fully restored biological value'), the value of weight was multiplied directly by the standardised value of the subcriterion under it ('diversity of species habitat suitability') before being normalised. As a result, the output values of MCA calculated by the combination of double weight of the 'fully restored biological value' criterion, together with the normal weights of the other two main criteria, then showed high values enough to be categorized in 'very high priority' category in the areas that accorded very high priority mentioned above.

Regarding the six level I subcriteria, the location and extent of priority areas were found to be sensitive to the weightings that were used. In particular, results were sensitive to alteration of the weight of the 'biotic composition' level I subcriterion (Alternative B2) and to 'ecological context' level I subcriterion (Alternative B3) the most in relation to areas accorded very high priority and locations that areas were found, but in different ways. The extent of areas accorded very high priority was almost zero in the output map of Alternative B2. On the other hand, a substantially larger area accorded very high priority was present in the output map of Alternative B3. Alternative B3 showing areas accorded very high priority were located next to the existing PAs from the middle to Southern parts of the Southern region, in Kanchana Buri province in the Western region. Additionally, sparse areas accorded very high priority were also found: in Tak and Mae Hong Son provinces in the Northern region; in Ubon Ratchatani province in the Northeastern region; and in the Trat province in the Eastern region, and on the Ko Chang island in the Gulf of Thailand (Figure 5.8).

There are reasons supporting the variation seen in Alternative B2. First, there are four subcriteria under the 'biotic composition' level I subcriterion. Second, only the 'tree species richness' subcriterion has input values in a number of pixels of its layer map (Figure B1 in Appendix B). The other three subcriteria, namely: 'rare tree species'; 'tree species of high genetic conservation value'; and 'economically important tree species', have limited pixels in their layer maps that have values (most pixels have a value of zero) (Figures B2, B3 and B4 in Appendix B respectively). Therefore, when this level I subcriterion was given double weight, the weight values were divided by four subcriteria under it, before multiplying the weight by individual standardised value of the four subcriteria. In this regard, where values accorded zero happened in numerous pixels of the three mentioned subcriteria layer maps, then the MCA output value calculated by this level I subcriterion given double weight together with the other five level I subcriteria was low. For this reason, the values that were categorized very high priority were very limited.

The reasons that support the result from Alternative B3 are rather similar to the reasons of Alternative A3. The output map of Alternative B3 showed most sensitivity to areas accorded very high priority for various reasons. First, the 'ecological context' level I subcriterion has only one subcriterion under it, that is 'protected area buffer'. Second, this subcriterion was considered as a 'benefit'. Lastly, the input values to individual pixels of the 'protected area buffer' subcriterion, accorded higher values in very high priority areas (next to the existing PAs from the middle to Southern parts of the Southern region, in Kanchana Buri province in the Western region), compared to values in the other areas of the rest of Thailand (Figure B5 in Appendix B). When double weight was given to this level I subcriterion ('ecological context'), the value of weight was multiplied directly by the standardised value of the subcriterion under it ('protected area buffer') before being normalised. As a result, the output values of MCA calculated by the combination of double weight of the 'ecological context' level I subcriterion together with the normal weights of the other five level I subcriteria then showed high values enough to be categorized in 'very high priority' category, in the areas that accorded very high priority mentioned above.

The results from 8 of 11 Alternatives revealed that areas accorded very high priority were located outside current PAs more than inside PAs (Alternatives A2, B1 - B7). Additionally, areas accorded high priority from all 11 Alternatives' results were located outside existing PAs more than inside PAs (Tables 5.7 – 5.8). This is supported by the study of Lehtomaki et al. (2009) who showed the highest forest conservation potential in Southern Finland is mainly located in privately owned land outside PAs (Lehtomaki et al. 2009). Similarly, Zhang et al. (2012) found that priority areas in Yunnan province, China tend to follow the boundaries of the floristic regions, and the areas form biodiversity conservation corridors. However, Klorvuttimontara et al. (2011) found that similar amounts of high priority areas (based on species richness of butterflies, complementarity and forest connectivity) in Thailand were found within current PAs and outside PAs. The results of Klorvuttimontara et al. (2011) suggested that larger PAs have higher conservation value, but some small PAs were ranked as highly as some of the largest sites. Smaller forests may be important to conserve restricted range taxa that are not necessarily found in larger forests (Klorvuttimontara et al. 2011). Nevertheless, conserving intact and larger ecosystems is better than conserving small and isolated ecosystems. This is because larger and intact forests conserve their biodiversity and structure, and also they are associated with species resulting in lower possibility of extinction (Geneletti 2004). Additionally, having well-connected landscape or corridors between PAs, or individual PAs situated closely to one another enhances the persistence probability at a regional scale, by supporting species dispersal and movement, maintenance of genetic variability and recolonisation (Prendergast et al. 1999; Wilson et al. 2009).

The quality of any PA analysis depends on the accuracy and resolution of available data (Chape et al. 2005). A high quality of data supports robust reserve design (Cabeza and Moilanen 2001). Unfortunately, there are some limitations on the data used in this chapter, both in terms of quality and quantity. The accuracy of the data used here cannot be verified, as no ground checking was undertaken. Uncertainty in this analysis originates from several sources. Layer maps used in this analysis were produced from a variety of sources that may cause uncertainties. For example, a forest cover map (RFD 2014) and a global land cover map (JSR 2010) were based on analysis of remote sensing imagery. There are problems with the accuracy of remote sensing data, and the maps that are based on them. Uncertainty may derive from image classification. Newton (2007) mentioned that maps produced from satellite imagery contain errors. Accuracy approximations of < 80% are common for image classification (Newton 2007). The maps were produced from different partners and techniques, which can also cause uncertainty, as the consistency of them cannot be verified (JSR 2010). For this reason, uncertainty may be associated with the global land cover map (JSR 2010). Such maps, when based on remote sensing data, are typically associated with a degree of error arising as a result of the image classification process (Newton 2007).

Layer maps that involved tree species data, such as the tree species richness map and the diversity of species habitat suitability map, used locations of tree species mainly from the Forest Herbarium (BKF), Bangkok and the Division of Protection and Forest Fire Control, both of which are parts of the DNP. Uncertainty is possible from the geographical bias of data collection, accuracy of taxonomic identification and determination, and insufficient records per species to model the species distribution. This uncertainty affects the layer maps produced from these tree species data. Again, in-depth surveys for tree species should be undertaken, to reduce the uncertainty.

The selection of models used for the predicted future climate may also be associated with uncertainty. Climate change in the future projected by different climate models provides different results. For example, the study of Baek et al. (2013) assessed projected climate change impact using four IPCC RCP scenarios (RCPs 2.6, 4.5, 6.0 and 8.5). The results from these four scenarios showed that by 2100 the projected global temperature rise would be between 1.2^{o} C (RCP2.6) and 4.5^{o} C (RCP8.5) from the year 2000. The suggestion from this research is that a combination of multiple models is used to reduce this uncertainty (Baek et al. 2013).

In fact, there are updated land use maps of Thailand available, but they are in the form of site scale maps and need to be interpreted before using them. Overall, uncertainties can be reduced mainly by ground checking to verify maps. However, this process would be highly demanding in terms of time and resource, and for this reason, was not pursued here. The verification of criteria and their weights are typically decided by the discussion and consensus of experts such as planners, local authorities and policy makers (Jeong et al. 2013). Although such a process of stakeholder consultation was not undertaken for the research described here, the selected set of criteria followed the research of Regan et al. (2007), which was based on a previous expert consultation. Criteria selection was also determined on the basis of direct relationship to the goal, computability, and available data. In the current analysis, it was not possible to include all subcriteria listed by Regan et al. (2007)

owing to a lack of suitable data. This was the case, for example, for the 'site contributes to watershed value' subcriterion of 'ecological context' used by Regan et al. (2007). Even though a watershed raster map for 2012 of Thailand was available at DNP, the data was incomplete. As a result, the map was not included in the analysis.

Some criteria and subcriteria used by Regan et al. (2007), that seem relevant to this current analysis, could not be included in this research because spatial data for these variables were not available. For example, under 'degradation' and 'threats', there are six subcriteria namely: (1) 'vegetation structure'; (2) 'invaded by exotics'; (3) 'soil quality'; (4) 'air quality'; (5) 'water quality'; and (6) 'natural disturbance regimes' considered by Regan et al. (2007). Nevertheless, the different four subcriteria were used to support the 'degradation' criterion instead. These are: 'fire frequency'; 'land conversion to agriculture areas'; 'land conversion to urban areas'; and 'land conversion to roads'. This is because these four subcriteria led to the loss of tree species and clearing of areas. Additionally, in this analysis incorporated 'threats' with: 'population density'; and 'future climate change' (the difference of mean value between current climate (1950 - 2000) and predicted future climate (2050) in relation to bioclimatic variables).

The mentioned subcriteria of Regan et al. (2007) could be considered in future research, should appropriate data become available. Soil depth can also be useful for identification of suitable areas for plants (Ceballos-Silva and López-Blanco 2003), and could potentially be included in future analyses. In addition, some data that might be useful to the analysis, but were not included in the analysis, are logging and land clearing locations. Social, political and economic criteria should also be considered as they can affect conservation planning (Smith et al. 2006; Lehtomaki et al. 2009). This is one of the limitations of the current research. Therefore, real decision making by policy makers would not be as straightforward as the current results might imply. If possible, future analysis should incorporate such criteria and data before making decisions (Geneletti, 2004; Lesslie, 2008). An example of this is that the financial cost of land is likely to have a major influence on which priority areas for conservation can actually be protected (Watson et al. 2011). Further costs include those of managing and implementing reserve areas, and the opportunity cost of foregone economic development (Naidoo et al. 2006).

Furthermore, opinions of stakeholders and experts should be incorporated when considering related criteria, their rankings and weights, in order to achieve robust decision making (Geneletti and van Duren 2008; Orsi and Geneletti 2010). In addition, as the achievement of management actions also depends on the willingness of landowners (Watson et al. 2011), it is essential to investigate the land ownership and their willingness to participate in conservation actions of potential conservation areas. In case PA planners are keen to implement conservation actions, the extension of surveys should be considered in order to improve dataset quality (Cabeza and Moilanen 2001), and to refine the prioritisation maps. A further step should include comparing expert-based assessments with the results of the current research. If both analyses suggest similar locations with high priority, then greater confidence can be placed on the results obtained (Lehtomaki et al. 2009).

Some previous research has compared different conservation planning software to identify conservation priority areas. For example, Wilson (2003) compared the analyses using C-plan and Maxan software to identify conservation priority areas in threatened and poorly protected Box-Ironbark ecosystem of Victoria, Australia. The surrogates considered in this research were four plant species namely *Acacia ausfeldii, Eucalyptus tricarpa, Hibbertia exutacies* and *Pultenaea largiflorens*. The results indicated that the two software provided similar results in terms of the final reserve network composition (Wilson 2003). Carwardine et al. (2007) also compared analyses using Marxan and C-plan to identify areas for ecosystems protection in the Brigalow Belt Bioregion, Queensland, Australia. The analyses used 83 regional ecosystems that classified by the combinations of landform, geology, and soil as surrogates. Again, the results from the analyses of Marxan and C-Plan were similar. A comparison between Marxan and Zonation to identify priority areas was explored by Delavenne et al. (2012), who focused on the analysis of conservation priority areas in the Eastern English Channel for invertebrate communities and eight fish species. The results showed similar priority areas generated by the two programs. However, no previous research has compared MCA to other conservation planning approaches. It is therefore difficult to evaluate whether similar results would have been obtained in the current research if alternative programs, such as Marxan or

C-Plan, had been used. Further research should, therefore, consider the comparison of MCA to other conservation planning approaches.

MCA in this research is a GIS-based MCA approach using ILWIS as a support tool to identify priority areas. First, the goal was set: in this regard the goal is the identification of priority areas for tree conservation. Second, criteria to achieve the goal were listed and were prepared into raster maps using ArcMap v. 10.0. From this point, the analysis was based on the weighting of criteria using ILWIS v. 3.08.04. Preferences on criteria are demonstrated as weights assigned by decision makers. In this research, the criteria were weighted using a 'direct method' achieved by manually inputting weight figures for all criteria, which were then normalised automatically. Consequently, the combination of criteria maps and weights generated the output maps of priority areas. The output map contains the accumulated suitability for all criteria, weighted, and normalised values as specified in earlier processes. The values in pixels of the output maps are between 0 and 1 showing from lowest priority areas to highest priority areas respectively.

The results of this research should support the improvement of decision-making processes in PA management and planning in Thailand, particularly in relation to the conservation of tree species. Potentially, the results could be used to guide suitable alternatives for different conservation management targets (Alvarez-Guerra, 2009). The results indicated locations where future PAs could potentially be situated, expanding current PAs in order to improve tree representation and persistence, with least threats. Results indicated that almost all priority areas (very high and high priority) tended to occur in areas close to existing PAs, therefore the areas that can be recommended to decision-makers should focus on expanding or linking existing PAs. Specifically, the following recommendations can be defined based on the results obtained:

(i) Encourage relevant government agencies to consider the establishment of new PAs in very high and high priority areas, or to expand existing PAs. The expansion of current PAs would enable them to better support large-scale processes, for example, prey-predator interactions and species migration (Cowling et al. 2003). In fact, the existing PA system of Thailand covers 24.4% of the country's land area, nearly meeting the target that the National Forest Policy set, aiming to bring back forest cover to 25% of country area as protected forest for conservation (Trisurat 2007) and 15% of those as economic forest (Sutthisrisinn and Noochdumrong 1998). Therefore, in terms of areas, there is only 0.6% needed to be proposed as a PA, to reach the protected forest target of the National Forest Policy. The specific areas where decision-makers should focus on PA expansion, based on areas with the greatest robustness, comprised:

(1) Areas next to current PAs in the Southern region (Figure 5.13).

(2) Areas near to Cambodia in Trat province in the Eastern region. In addition, areas near to PAs on Ko Chang and Ko Kut islands in the Gulf of Thailand (Figure 5.14).

The figures 5.13 - 5.14 were from the Alternatives A1, however, these locations were confirmed by the results of Alternatives A2, A3, A4, B1, B3, B4, B5, B6 (Figure 5.3 - 5.5, 5.6, 5.8 – 5.11 respectively).

In case the first priority lists are unable to be designated as new PAs, the second priority lists should be the high priority areas based on Alternative A1 of which all three main criteria were given equal importance. These areas are:

(1) Sparse areas near to PAs in almost all provinces in the Northern region. These are priority areas in Uthai Thani, Tak, Sukhothai, Lampang, Lamphun, Nan, Phayao, Chiangrai, Chiang Mai, Mae Hong Son, and Phetchabun provinces (Figure 5.15).

(2) Areas next to current PAs in Kanchana Buri, Ratchaburi, and Phetchaburi provinces in the Western region (Figure 5.16).

(3) A few areas in Suphan Buri and Saraburi provinces near to PAs in the Central region (Figure 5.17).

(4) Areas next to current PAs in Chaiyaphum, Bueng Kan, Nakhon Phanom, and Ubon Ratchathani in the Northeastern region (Figure 5.18).

(5) Areas in Trat provinces as a whole, areas near to PAs in Chanthaburi, Rayong, Chonburi and Chachoengsao provinces, in the Eastern region. Also, areas near to PAs on Ko Chang and Ko Kut islands in the Gulf of Thailand (Figure 5.19).

(6) Areas next to current PAs in the Southern region as a whole (Figure 5.20).

All priority areas, if designated, would promote connectivity between the existing PAs surrounding them and also expand current PAs. If these areas were protected, the movement of wildlife would be supported resulting in enhanced ecological processes through PA networks. Bennett (2003) explained that forest corridors/ linkages, or expansion of the existing PAs supports landscape connectivity. These forms of linkages and connectivity: contribute values as additional habitats for plants and animals; provide ecosystem services such as soil erosion reduction, water quality maintenance. They also enhance species richness, support genetic variation, and reduce species inbreeding (Bennett 2003). Protection of the areas next to existing PAs can also reduce the edge effects which are the biological and physical effects at forest edges because of the habitat changes that can affect flora and fauna. It can reduce microclimatic changes in humidity, solar radiation, and wind speed. For example, it can reduce the disturbance to species intolerant of disturbed landscapes (Bennett 2003). It can protect and buffer core areas that may contain undisturbed tree communities, animal habitats from external disturbances such as grazing of domestic cattle, intensively developed areas (agriculture and settlement) (Bennett 2003). Small and medium-sized PAs can also be important, such as priority areas in the Central region (Cowling et al. 2003). This is because smaller forests are also likely to be of vital importance to conserve restricted range species (Klorvuttimontara et al. 2011). Conserving forest patches can support landscape connectivity as a stepping stone habitat. They support animal species movement and plants dispersal (Bennet 2003).

(ii) Additional recommendations that are not directly from results of the analysis but support PA conservation are:

(1) Investigate the land ownership of the priority areas outside PAs. In cases where the areas belong to private sections or local communities, consideration should be given to the participation of local communities surrounding PAs in forest protection such as the creation of community forestry, or private plantations.

(2) Conservation incentives for communities and private landowners should be considered when they involve in the area protection (Cowling et al. 2003) such as the permission to utilize forest by-products (firewood, fruits and mushroom collection).

(3) Promote awareness campaigns to educate local communities who are living in the PAs buffer to better understand deforestation impacts.

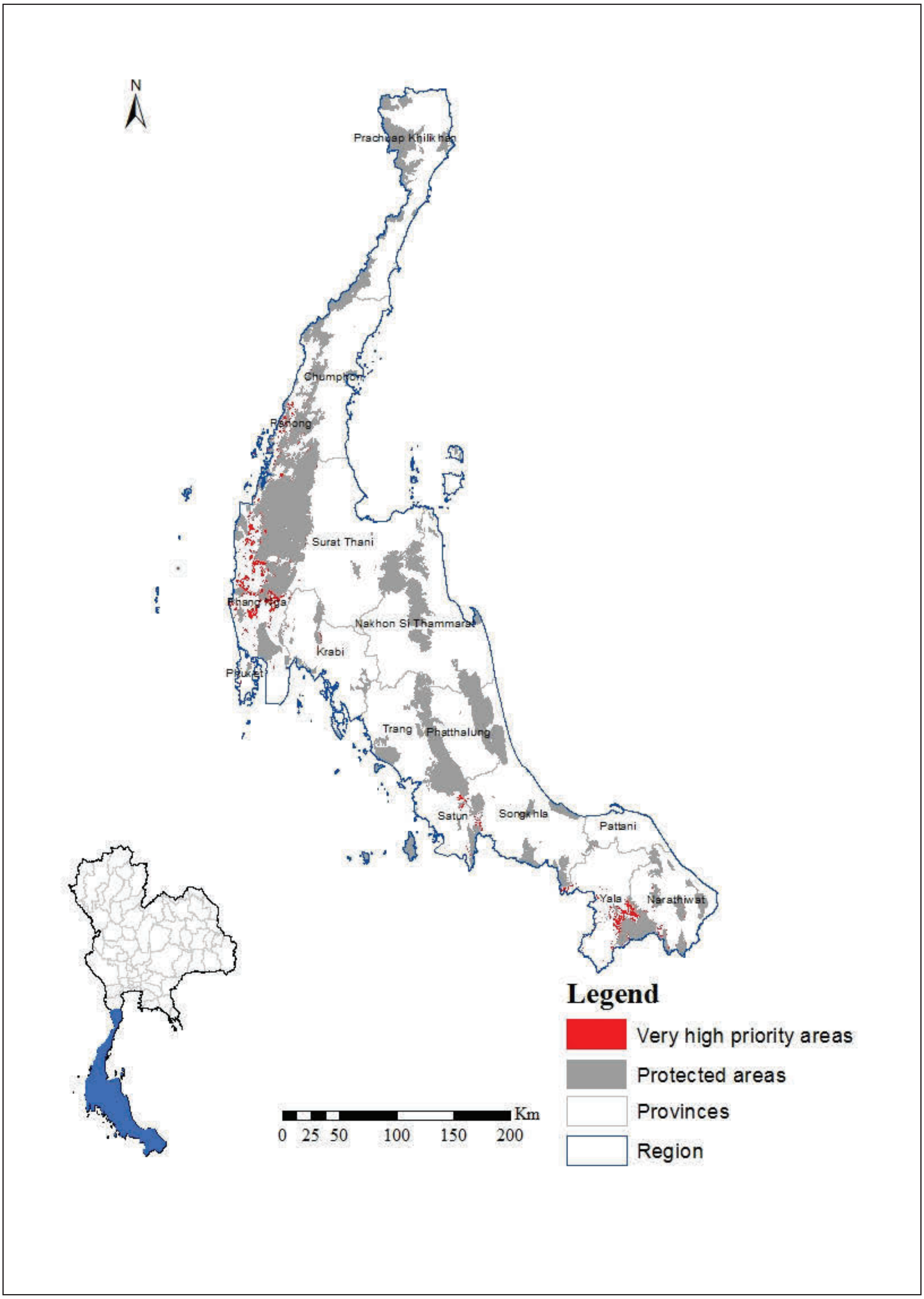

Figure 5.13 - Areas highly recommended to be proposed as new protected areas in Southern Thailand based on Alternative A1 (very high priority areas)

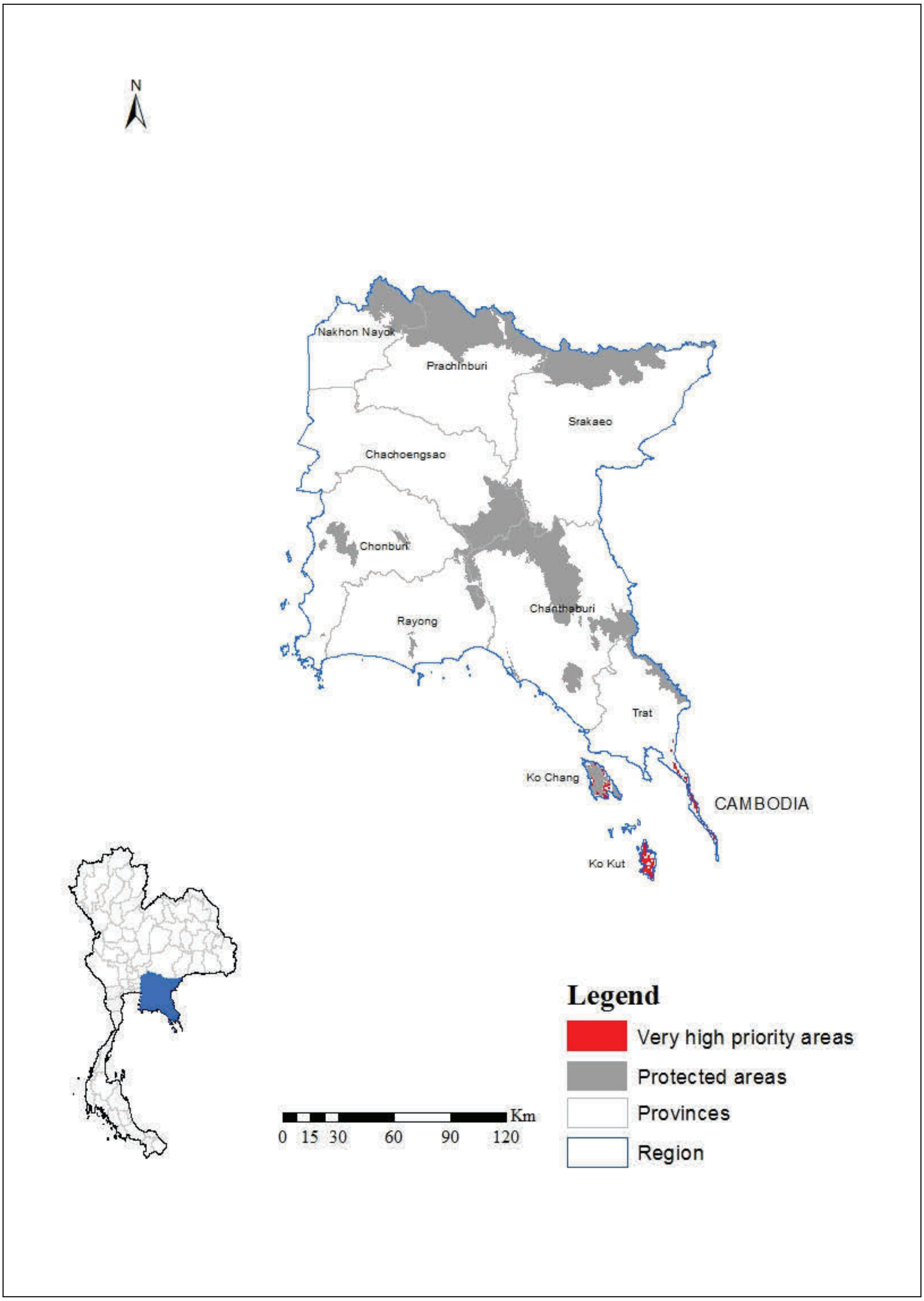

Figure 5.14 - Areas highly recommended to be proposed as new protected areas in Eastern Thailand based on Alternative A1 (very high priority areas)

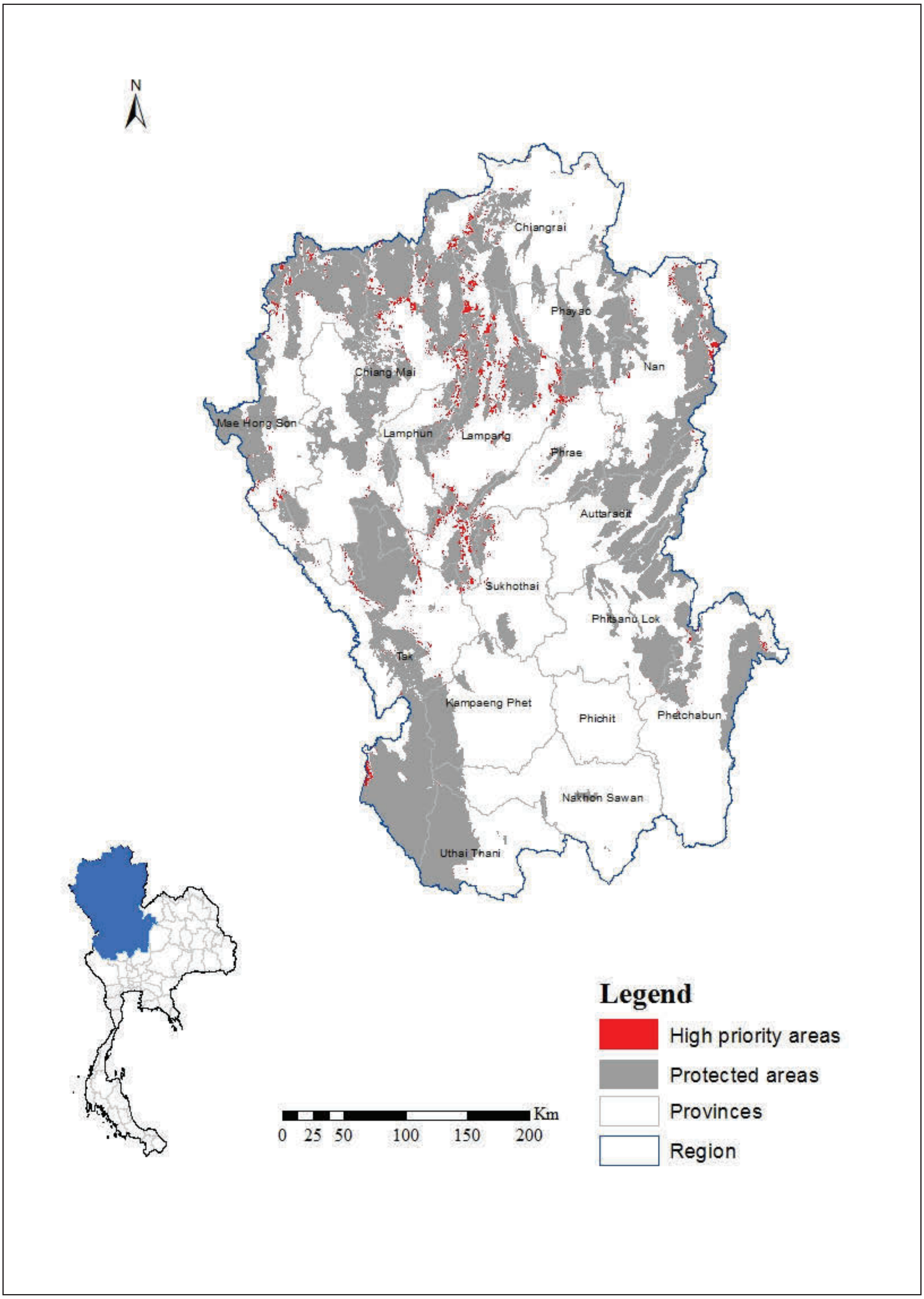

Figure 5.15 - Areas recommended to be proposed as new protected areas in Northern Thailand based on Alternative A1 (high priority areas)

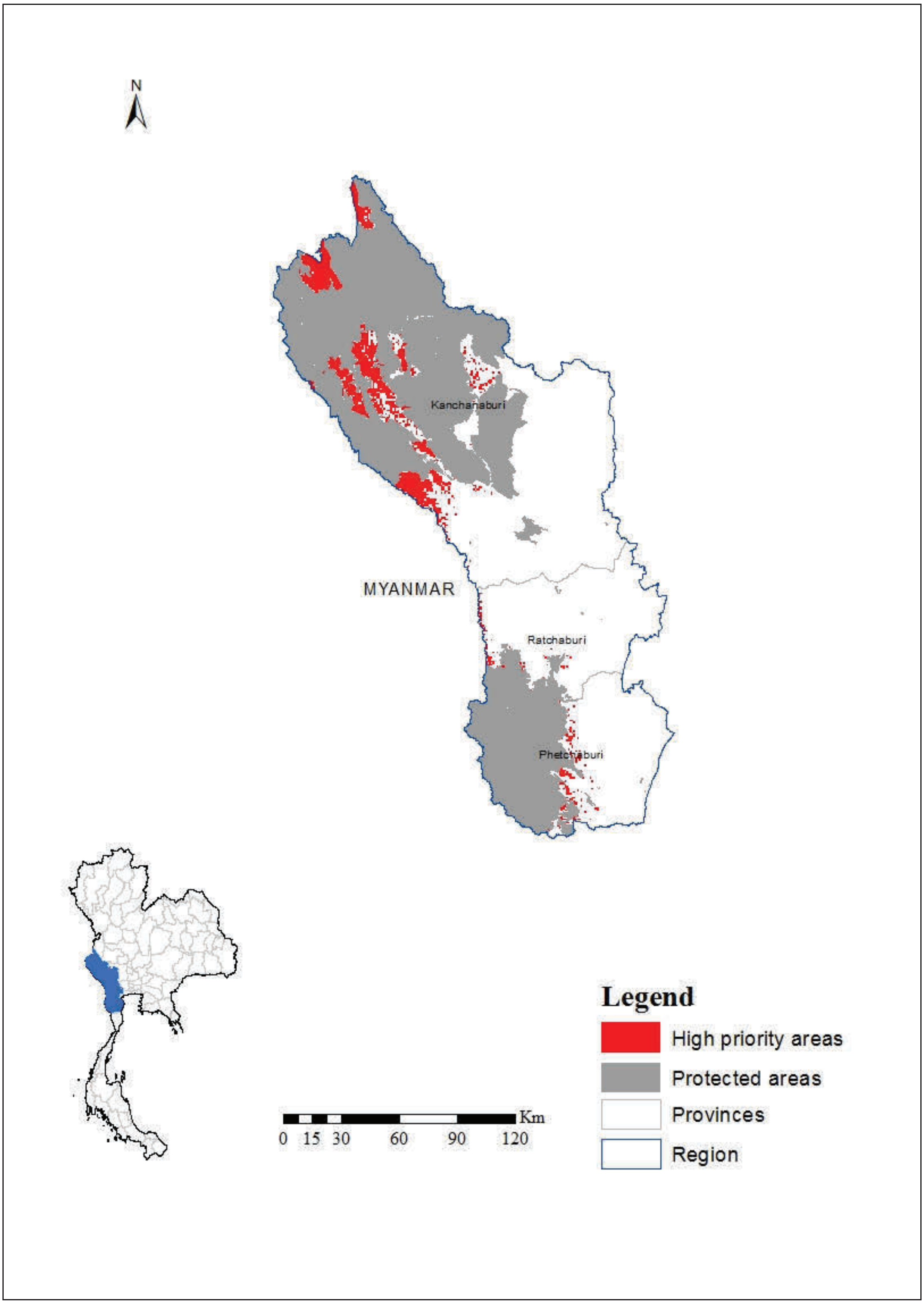

Figure 5.16 - Areas recommended to be proposed as new protected areas in Western Thailand based on Alternative A1 (high priority areas)

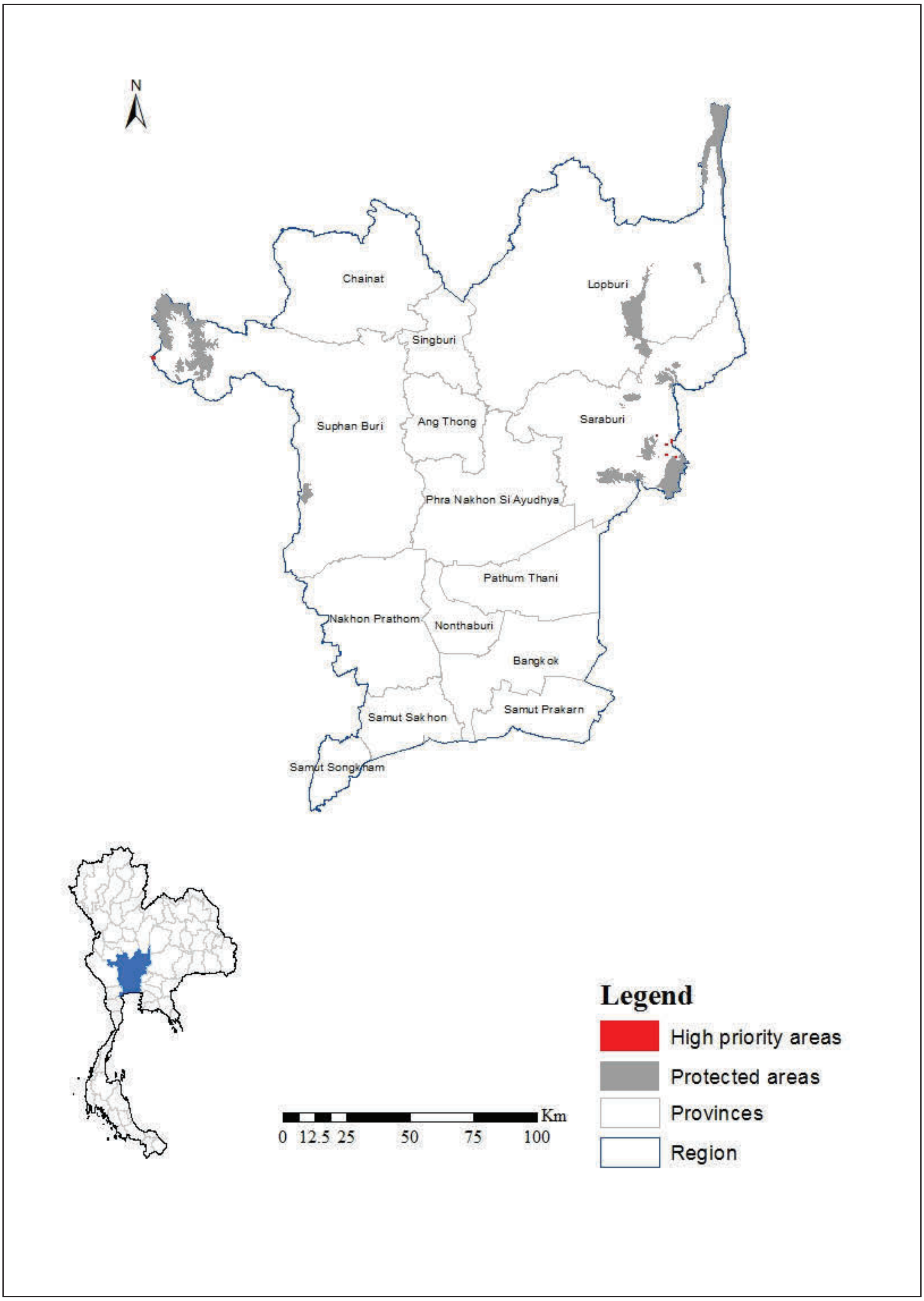

Figure 5.17 - Areas recommended to be proposed as new protected areas in Central Thailand based on Alternative A1 (high priority areas)

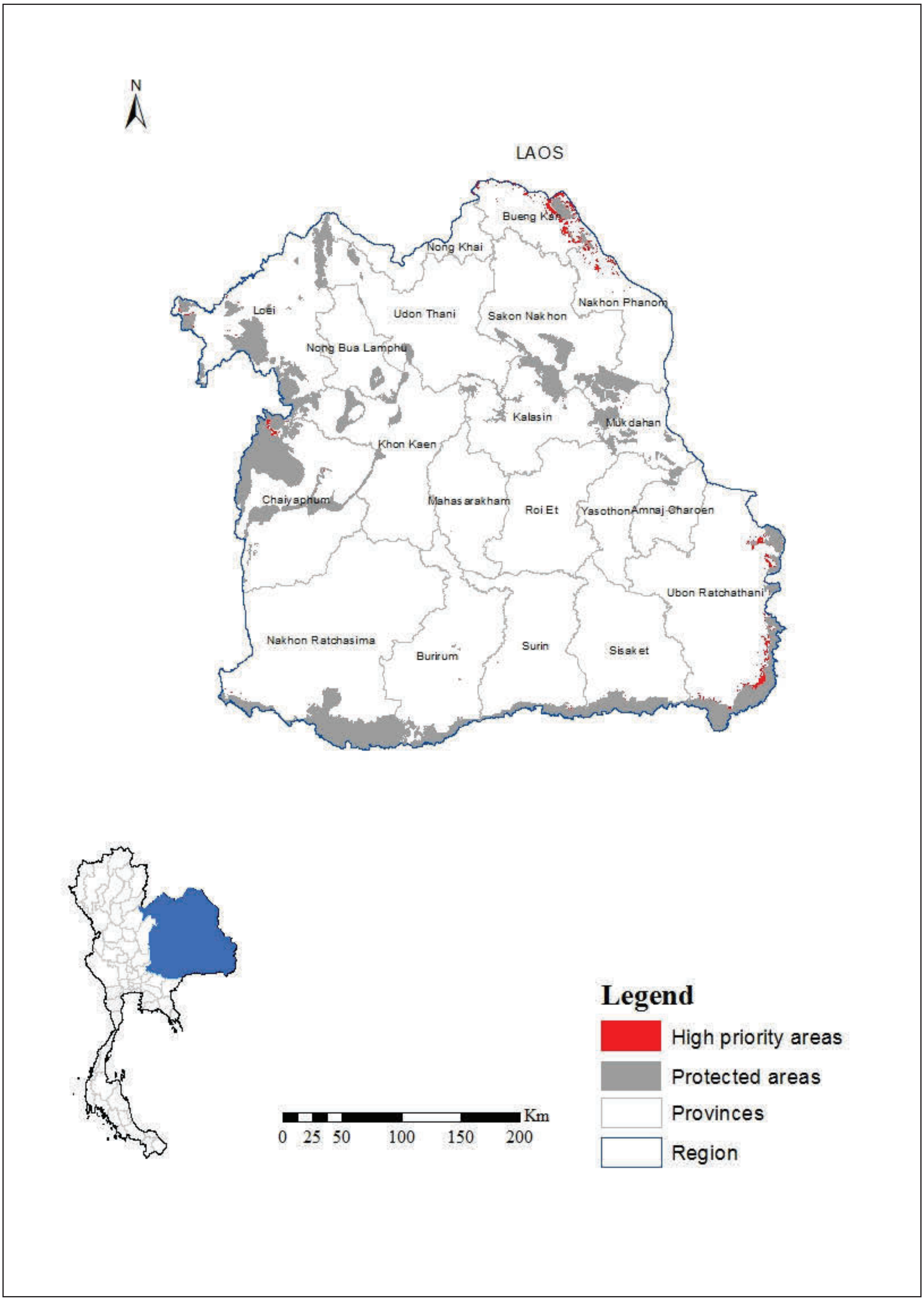

Figure 5.18 - Areas recommended to be proposed as new protected areas in Northeastern Thailand based on Alternative A1 (high priority areas)

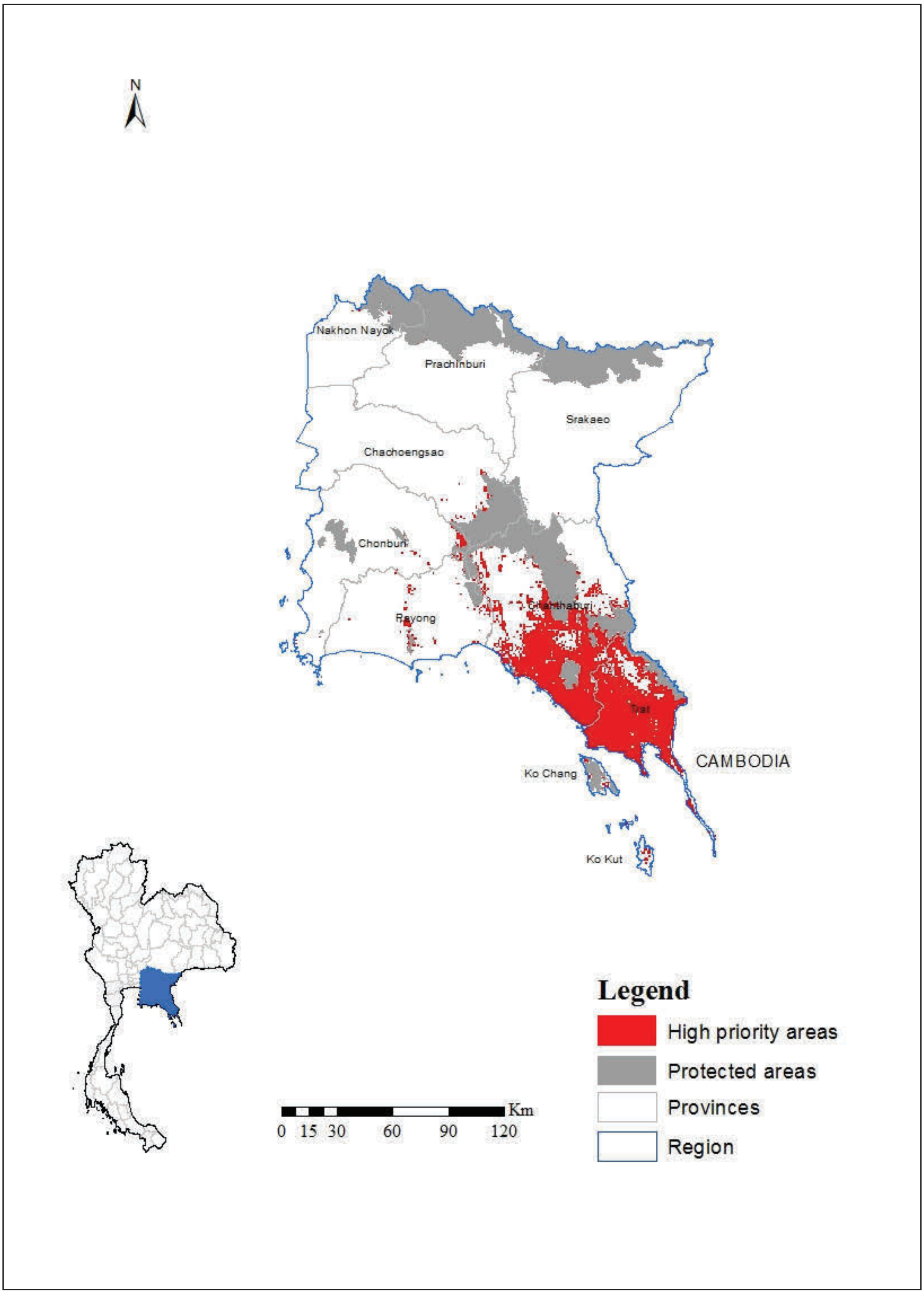

Figure 5.19 - Areas recommended to be proposed as new protected areas in Eastern Thailand based on Alternative A1 (high priority areas)

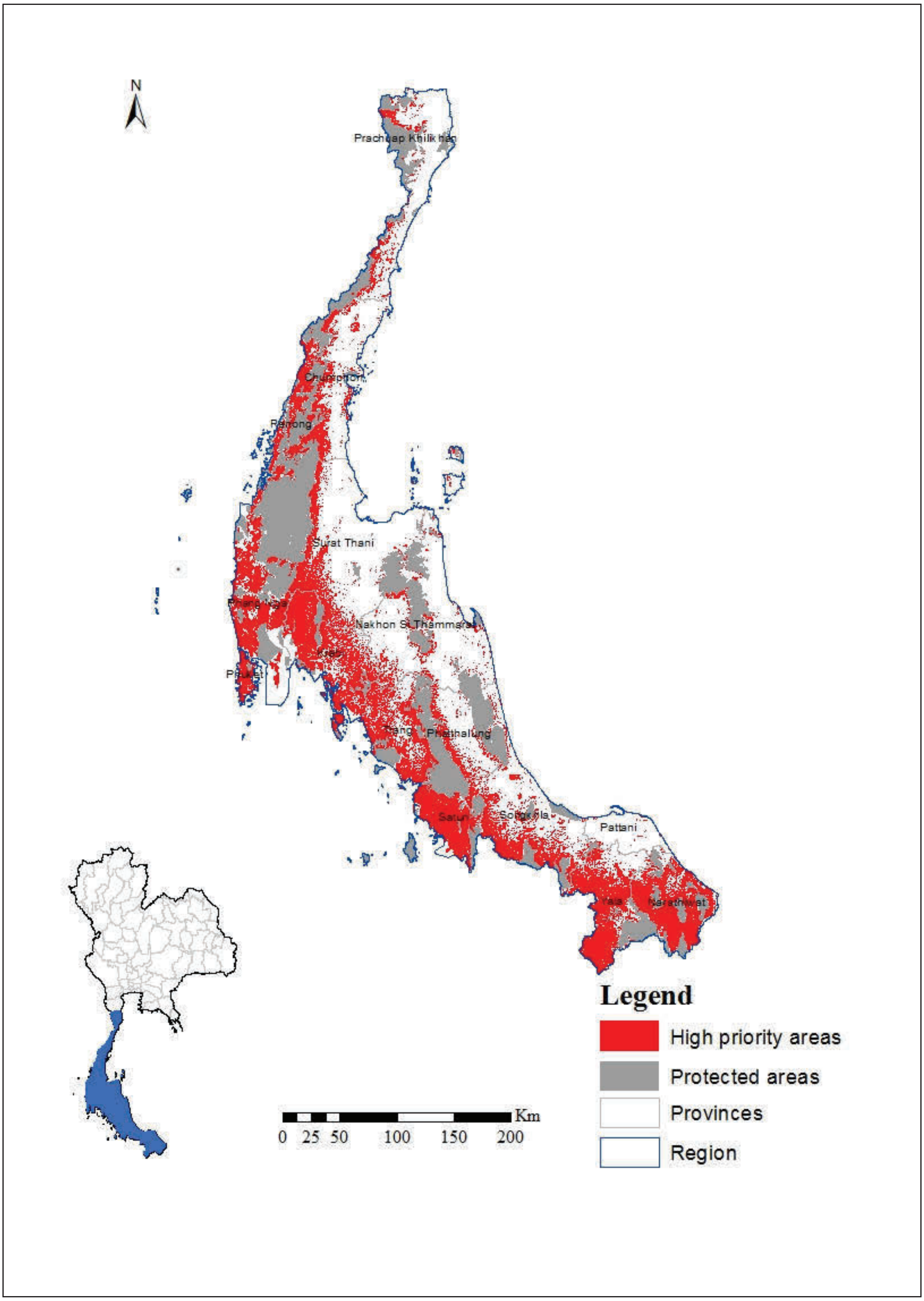

Figure 5.20 - Areas recommended to be proposed as new protected areas in Southern Thailand based on Alternative A1 (high priority areas)

Chapter 6: Discussion

6.1 Summary of the research findings

This research deals with the identification of complementary areas to the protected area (PA) network in Thailand specifically to support the conservation of tree species. It also deals with the imperative to address a crucial knowledge gap on designing PA networks, and contributes to the improvement of conservation planning and PA network design in Thailand. The research aims to be the first that applies the principles and techniques of systematic conservation planning to enhance the planning and implementation of the PA network in Thailand. The review of previous research showed that the systematic conservation planning approach has never been applied in Thailand. In addition to this, tree species have rarely been analysed in terms of the coverage of PAs in Thailand. This indicates the importance of the research presented here.

In this research, three hypotheses were identified at the outset, which were addressed by respective chapters. The conclusions of each hypothesis are shown below.

(a) First hypothesis: the current PA network in Thailand is not adequate to conserve tree species richness in the country.

Chapters 3 and 4 examined the extent to which the target tree species and their potential geographical distributions were represented within the existing PA network. The target species consisted of four groups of tree species that are respectively threatened with extinction, dominate the different forest types in Thailand, are of particular economic importance, and are important to *in situ* genetic conservation. In Chapter 3, the number and the percentage of 749 species occurrence points within PA boundaries were calculated. Additionally, for 57 species with precise locations and $\geq$ 5 records/species, the percentage of geographical range inside PA of each species was compared to the percentage of the representation target that has been set individually for each species, to identify whether the species are considered as covered, partial gap, or gap species. The result of Chapter 3 showed that tree species of all four groups had more occurrences located outside than inside PAs, especially tree species that are threatened with extinction. Within the PA network, most species were found in national parks as they cover the largest proportion of all PA types, both in terms of number and area covered. Even though the result showed there were no full gap species (a species for which the extent of occurrence (EOO) was not overlapped at all by the PAs), 40 of 57 tree species analysed were partial gap species (a species that had less percentage of EOO inside PAs than the representation target, which was set individually for each species). In Chapter 4, the result of generating the potential geographic distribution of 35 selected tree species with $\geq$ 8 records/ species through the country showed that, only 24 tree species for which the distribution models were effective. For these 24 species, suitable habitat areas are well-protected by the current PA network in general. However, areas of very high habitat suitability of these 24 species were less protected within PAs than the moderate and high habitat suitabilities.

Previous research reviewed in Chapters 3 and 4 showed that some plants are: under-represented, partly-represented or well represented within PA networks worldwide, depending on the individual plant species/families. Example of under-represented plant species (resulting in the chance of survival reduced in the wild) was revealed in the research of Malagasy Anacardiaceae in Madagascar. For 9 of 14 species, there were zero or one subpopulation occurring in PAs (64%) (Randrianasolo et al. 2002). Some plants are partly-covered by PAs in some countries/regions such as India, Italy, Iberian Peninsula. The distribution of *Aglaia bourdillonii*, a narrowly endemic plant from the Southern part of the Western Ghats of India, is partly protected (about 66%) by current Indian PAs (Irfan-Ullah et al. 2007). Over 80% of Important Plant Areas (IPAs) in Italy have some form of legal protection and more than 60% of the selected species are concerned by the present PAs (Blasi et al. 2011). Araujo et al. (2007) studied the level of plant species (Dicotyledons, Monocotyledons, Gymnosperms, Pteridophytes) represented on Iberian PA maps. The research found that more of the ranges of restricted-range species were within PAs than outside PAs (Araujo et al. 2007).

In Mexico, some endemic vascular plants are both well represented and under-represented in PAs. 76.4% of the endemic vascular flora was located within PAs on the peninsula of Baja California, Mexico (Asteraceae, Cactaceae, Fabaceae, Begoniaceae, Thymeliaceae, Araliaceae and Hippocastanaceae). However, there were gap endemic taxa totally absent from PAs in this area, from theAdenothamnus, Carterothamnus, Faxonia, and Ornithostaphylos (Riemann and Ezcurra 2005).

Britain, Costa Rica, Australia, and some provinces in China have effective plant conservation within PAs. 371 analysed threatened plants are well represented within PAs of Britain. 331 (88%) of 371 analysed threatened plants were represented at least once within PAs. However, only 26.5% of 371 analysed threatened plants overlap the statutory PAs (Jackson et al. 2009). A high percentage of the plant species belonging to three families in Costa Rica were well conserved by existing PAs (Araceae 89%, Arecaceae 89%, and Bromeliaceae 83%) (Kohlmann et al. 2010). Gove et al. (2008) examined the Western Australian reserve designs' effectiveness to conserve angiosperm diversity. Only between 174 (5.7%) and 570 (18.7%) of angiosperm species were not represented in the reserve designs. Most centres of species richness and endemism of 6,506 vascular plant species in Guangxi Province, Southern China were covered by existing nature reserves (Hou et al. 2010).

From Chapters 3 and 4, I confirmed that the current PA network in Thailand is not adequate to conserve tree species. The expansion of existing PAs or establishment of new PAs should be considered in order to close or minimize the gap for tree species and protect areas of very high and high habitat suitability outside the current PA network. However, compared to the research findings of other countries, the current Thai PAs are effective to conserve tree diversity. This is because there is no full 'gap species' which means that some parts of all 57 species ranges were protected by current PAs. Also, the suitable habitat areas of 24 species are well-protected by the current PA network in general. Only a slightly more conservation effort in terms of expansion of the existing PAs is needed, in order to conserve: (1) the ranges of 'partial gap species' to be able to become 'covered species'; and (2) areas of very high and high habitat suitability outside the current PA network in the future.

(b) Second hypothesis: tree species in Thailand are being subjected to a wide variety of threats, which are increasing their risk of extinction, and are limiting the effectiveness of PAs.

The results from Chapters 3 and 4 showed that tree species are threatened in terms of insufficient coverage by current the PA network. Some tree species were not well covered by existing PAs, and areas of very high potential habitat suitability for target tree species were covered by PAs less than areas with moderate or high habitat suitability. However, the exploration and identification of the direct threats occurring in PAs were systematically investigated in Chapter 2. Direct threats included forest fires, as well as legal and illegal activities that have caused a reduction in forest area or cutting down of tree species in PAs. The results showed that tree species, are under threat in PAs (specifically national parks and wildlife sanctuaries) in all regions of Thailand. Forest fire threatened PAs in almost all regions of the country, although to a lesser extent in the Southern region. It is recognised that both legal and illegal activities threatened PAs. The illegal cases were mainly illegal area clearing and illegal logging, which threatened almost all PAs in all regions and substantially outnumbered the legal activities permitted in PAs. Road construction, electricity lines, and infrastructural development were common legal activities permitted in PAs that caused threat to tree species. Even though the analysis had limitations because the information was dependent on reports provided by PA staff and did not encompass the full number of threats to PAs, it confirms that tree species are being subjected to a wide variety of threats, which are increasing their risk of extinction. In addition to this, some other potential threats that were likely to affect the reduction in forest area or tree species were included in the analysis in Chapter 5 that identified priority areas outside current PAs for tree conservation. Examples of these were population density, climate change and forest fragmentation.

The main threats affecting Thai PAs revealed in this research are: forest fires; illegal area clearing; illegal logging; tree species being insufficiently covered by PAs; climate change; road construction; electricity lines; infrastructural development; population density; and forest fragmentation. Apart from these mentioned threats, Thai PAs have also been threatened by other threats showing in previous studies. These were: cattle grazing; land-mines; low capacity of field staff; and hunting

(Cropper et al. 2001; Pattanavibool and Dearden 2002; Ngoprasert et al. 2007; Chaiyarat and Srikosamatara 2009; Hares 2009).

All types of threats revealed in this research have happened also in PAs in several countries. Threats which have always threatened PAs worldwide (details in Chapter 2) are: elements removed from PAs (such as the wild plant and bushmeat trade); illegal logging; pollution; settlement; conversion to agriculture; alien species invasion and diseases; mining; logging; natural disasters (fire); climate change; pollution (of air, water); isolation of PAs (fragmentation, habitat degradation); grazing; poaching; encroachment; mineral and energy exploration; large-scale infrastructure development; the acceleration of natural resource extraction (overexploitation); conflicting development of communities and public lands around PAs; economic development; rapid growth in tourism; insufficient funding for PA infrastructure and maintenance (Pimbert 1997; Carey et al. 2000; Colding 2000; Bruner et al. 2001; Stoner et al. 2007). Additionally, the lack of appropriate conservation management plans or strategies also threatened PAs (Ervin 2003; Parrish et al. 2003).

It can be concluded that even though the PAs have been designated both in Thailand and worldwide, PAs have still been affected by several threats resulting in the biodiversity degradation within them.

(c) Third hypothesis: the application of systematic conservation planning techniques will enhance the planning and implementation of PA networks in Thailand, with specific reference to the conservation of tree species.

This research, as a whole, applied the systematic conservation planning technique. Chapter 1 gives an overview of systematic conservation planning. The technique is considered to be the most effective approach for designing reserve system networks, and its main stages were reviewed. The data, in relation to the PA network of Thailand, was compiled via review of previous work and research that has been done regarding PA and tree conservations in the country. This review revealed that there has been no previous attempt to apply this technique to PA network design and implementation in Thailand. Afterwards, the selection of surrogates for biodiversity with potentially available data were selected, these were the four groups of tree species mentioned previously. Chapters 2, 3 and 4 examined current PAs, particularly, threats to PAs, gap features, and potential geographic distribution of tree species. Chapter 5 employed all the information from previous chapters in the form of criteria to identify complementary areas for tree species conservation using a GIS-based multi-criteria analysis. Additional relevant criteria that are likely to affect the priority areas were also included in the analysis.

The results showed the locations of very high and high priorities lay outside PA more than inside current PA networks. Very high priority areas are extremely geographically limited, being located in areas surrounding current PAs in the Southern and Eastern regions of Thailand (see Figures 5.13 – 5.14 in Chapter 5). High priority areas lying outside PAs were found in all regions of Thailand, although fewer were found in the Northeastern and Central regions compared to the other regions. The results also pointed out that the locations and area extent of very high and high priorities are sensitive to the weightings that were applied to both the three main criteria and the six level I subcriteria groups.

The conclusion of this chapter confirms that the application of systematic conservation planning techniques could enhance the planning and implementation of PA networks in Thailand for tree conservation. This technique provides the identification and prioritisation of complementary areas for addition to the PA network based on the benefit of tree conservation in the country. It also confirmed that systematic conservation planning should be introduced to PA managers or planners. This should be possible because it is transparent and beneficial, and utilizes user-friendly spatial software to generate spatial data and easy to understand output maps. PA managers or planners are able to go back to check the information at any stage of the approach or add/edit any criteria they wanted to consider for future conservation.

6.2 Limitations and uncertainties of the research

This research has some limitations and contains several uncertainties. The main limitations are the accessibility and availability of datasets. The reliability, accuracy, and resolution of input datasets affect the uncertainty of the systematic conservation planning approach. The quality of analyses and efficiency of the approach clearly depend on data quality and availability in all stages of the approach (Chape et al. 2005).

The spatial datasets used in the research were produced from a variety of sources that may cause uncertainties. For example, a forest cover map (RFD 2014) and a global land cover map (JSR 2010) were based on analysis of remote sensing imagery. Maps produced from satellite imagery contain errors, with accuracy approximations of <80% common for image classification (Newton 2007). Additionally, the maps were produced from different partners and techniques, which can also cause uncertainty, as the consistency of them cannot be verified (JSR 2010). Some information analysed in the research was also dependent on reports provided by PA staff, such as the threat information used in Chapter 2. The analyses were based on the assumption that the reports were an accurate representation of the situation occurring in the field. Such uncertainties are difficult to estimate with precision, without any independent assessments using an alternative source of data.

The analyses in Chapters 3, 4 and 5 were dependent on presence-only data of tree species and there may be associated problems of the accuracy of taxonomic identification and determination. Also, there may be geographical bias in collection data, and insufficient records per species. As mentioned in the discussion part of Chapter 4, the lack of representative occurrence data can severely limit the species distribution modelling (SDM) predictive ability (Syfert et al. 2013), if the number of occurrence points is too low to estimate the reliability of model (Golicher et al. 2012b). Additionally, the bias from data obtained from herbaria may come from the old data collected. There may also be bias because data was collected by a number of different botanists/collectors who may have had different methods for choosing which sites to visit. These may cause geographical sampling bias in the data obtained. For example, species localities might be collected intensively near roads and rivers as these locations are more easily accessed (Phillips et al. 2006), and the extent of these biases may depend on the botanist collecting the data. The location of trees may be associated with an error from the GPS, and errors may also have occurred during manual transfer from GPS to the datasheet (Phillips et al. 2006).

Such bias can obscure the true species distribution pattern (Phillips et al. 2006; Merow et al. 2013). Geographical sampling bias is critical to the accuracy of SDMs generated from presence-only datasets (Phillips et al. 2009). The selection of the model used for the predicted future climate may also be associated with uncertainty. Climate change in the future projected by different climate models provides different results (Baek et al. 2013).

Sensitivity analysis provides an insight into the sensitivity of the results to different weighting of importance by different stakeholder groups' preferences. The results for conservation planning of Chapter 5 are very uncertain, as they are highly sensitive to variations in the importance placed on different criteria. Therefore, it depends on PA practitioner/planner preferences to provide values to alternatives. However, areas that remain high and very high priorities in the same locations in every sensitivity analysis assigned by the change of weighting sets, can indicate the robustness of results (Wood and Dragicevic 2007). These might confirm the area importance or show low risk alternatives for investment in the interested areas (Wilson 2010). Chapter 5 identified several such locations within Thailand (see Figures 5.13 and 5.14 in Chapter 5).

In addition to these limitations, the systematic conservation planning method used in this research treats biological diversity as static, meaning that: environmental conditions; cost and economic conditions, remain unchanged over time (Meir et al. 2004), so that the priority areas derived from the result needed to be immediately implemented, otherwise all information will be changed.

6.3 Recommendations for future research

Systematic conservation planning approaches have been utilized in a number of research, but different supporting tools, such as Marxan, C-plan, and Multi-criteria analysis (MCA), were used for identifying priority/complementary areas. Each tool has different advantages and limitations (details in Chapter 5). This research identified complementary areas using a systematic conservation planning approach, specifically to conserve tree species with the support of the MCA. Even though Marxan, C-plan and ILWIS are free applications to identify complementary areas, users need training/workshop sessions to operate the Marxan and C-plan software, due to their complexity (Pressey et al. 2009). These two software programmes are not suitable for researchers without access to such training, therefore, the MCA approach using ILWIS was selected to analyse complementary areas for tree conservation in this research. The MCA using ILWIS is a user-friendly approach. It uses basic GIS operations and is less time consuming for computation, to produce spatial output maps (Orsi and Geneletti 2010).

However, sensitivity of the results to the specific methods used should be tested in further studies of systematic conservation planning, by employing other conservation tools such as: Marxan (Pressey et al. 2009); Zonation (Lehtomaki et al. 2009; Moilanen et al. 2009); C-plan (Cowling et al. 2003; Pressey et al. 2009). If an agreement is found between the different methods, the outputs can be considered to be robust and can then be acted on with more confidence. Use of non-spatial methods to identify priority areas should be considered such as DEFINITE (Geneletti 2004). This is because, sometimes, useful information such as the cost of conservation implementation, which might be useful to design a new PA, is not available in a spatial format.

To minimize risk from uncertainties, alternative data sources should be considered, such as data from related plant survey projects or related websites. Further data collection should be undertaken to minimise risk from uncertainties. Potentially, the limitations, from using data provided by PA staff, could be addressed by attempting to independently verify the accuracy of the reports, for example through interviews with the PA staff involved. The systematic assessment of a comprehensive range of potential threats to tree species and PAs should be conducted. There is a need to conduct in-depth surveys or an independent field survey of the areas in which threats have been reported. Monitoring of species, especially partial gap species, should be systematically conducted in the current PAs to confirm the results from the analyses. Also, a combination of multiple climate models is suggested, to quantify the uncertainty (Baek et al. 2013).

This research applied systematic conservation planning to provide an initial identification of priority areas of Thailand with high potential for biodiversity conservation, based on a species-based surrogate. In this case, the surrogate was tree species. To conserve overall biodiversity in Thailand, the incorporation of other biodiversity features is required. More taxonomic groups should be considered to identify complementary areas to maximize the coverage of biodiversity, such as mammals, birds (Fuller et al. 2006), amphibians and reptiles (Pawar et al. 2007). Environmental surrogates should also be considered in future work, as they can incorporate some biotic variables and species distribution. Examples of environmental surrogates include land cover types and vegetation types (Smith et al. 2006). Not only should biodiversity representation be considered when applying systematic conservation planning for PA identification and designation, but ecosystem services contributed by PAs should be considered as well. The distribution of ecosystem services such as: aesthetic value; recreation; water quality and supply are also important to human activities, so that they should be considered when new PAs will be designed (Pyke 2007).

The planning region in this research was set based on ecological criteria, and the findings from the research can be used as baseline information for future research. However, I suggest investigating the use of planning regions based on political criteria (Sarkar and Illoldi-Rangel 2010), this is to explore the joint boundaries of priority areas to increase the opportunity of successful conservation implementations. The combination of this research with expert knowledge could improve future conservation planning. The knowledge of experts should be involved in future work at every stage of the systematic conservation planning approach to identify priority areas, to refine PA network design and improve the conservation planning effectiveness (Pressey & Cowling, 2001).

The other important point is that systematic conservation planning does not provide conservation implementation strategies, therefore further exploration of potential conservation actions and collaborations should be carried out, such as the exploration of activities that might interest stakeholders. One example is that private landowners and local communities might be interested to collaborate in biodiversity conservation strategies in selected priority areas outside PAs, (Smith et al. 2006) such as community forestry projects. Stakeholders could receive benefits from the projects;

in return, the project result can also support tree conservation and reduce the speed of forest encroachment by humans.

Finally, with currently data available, the crucial finding from this research is that the priority areas that would benefit tree conservation were verified. The priority areas that should be considered for establishment of new PAs, or to expand existing PAs comprise: (1) areas next to current PAs in the Southern region (Figure 5.13 in Chapter 5); and (2) areas near to Cambodia in Trat province in the Eastern region, areas near to PAs on Ko Chang and Ko Kut islands in the Gulf of Thailand (Figure 5.14 in Chapter 5).

As mentioned earlier, one of the limitations of systematic conservation planning method is that it treats biological diversity as static, meaning that conditions have not changed over time (Meir et al. 2004). If more potentially useful data or updated data were available to be added into future analyses, the location of tree conservation priority areas would be affected. Chapter 5 suggested some criteria that can affect conservation planning, such as the social, political and economic criteria (Smith et al. 2006; Lehtomaki et al. 2009). If these criteria are added in future analyses, the locations of tree conservation priority areas will be changed. However, in terms of utilizing the same criteria but updated to reflect the current situation (such as landuse map, tree habitat suitability map, etc.) in future analyses, it would refine the results regarding the tree conservation priority areas. For the use of updated criteria, I believe that generally the areas of high and very high priority from the future analyses would not change substantially as these were robust to changes in weighting of the different criteria in the current analyses. A possible exception to this is that if land use changes within a high priority currently forested area (i.e. the trees are chopped down) then the new high priority area would not include this location, which is sensible given the aims of SCP.

It is also hoped that this research will provide useful information for future PA conservation planning in Thailand utilizing limited resources. It is also hoped to introduce the systematic conservation planning approach to stakeholders such as PA planners, managers or policy makers. As the approach is transparent, practical, scientifically robust and flexible, it may be of value to the stakeholders to design PA networks and conserve important areas for biodiversity based on clear goals, while understanding the limitations. It offers options that can be changed depending on stakeholder preferences. The results of this research should therefore contribute to improving design and effectiveness of the PA network in Thailand in the future.

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Appendices

Appendix A: Lists of tree species

Table A1 List of tree species mentioned in Thailand red data: plants (Santisuk et. al. 2006)

No.	Family	Botanical name
1	Actinidiaceae	*Saurauia leprosa* Korth.
2	Akaniaceae	*Bretschneidera sinensis* Hemsl.
3	Anacardiaceae	*Gluta obovata* Craib
4	Anacardiaceae	*Spondias bipinnata* Airy Shaw & Forman
5	Annonaceae	*Alphonsea cylindrica* King
6	Annonaceae	*Alphonsea gaudichaudiana* (Baill.) Finet & Gagnep.
7	Annonaceae	*Alphonsea siamensis* Kessler
8	Annonaceae	*Disepalum pulchrum* (King) J.Sinclair
9	Annonaceae	*Goniothalamus cheliensis* Hu
10	Annonaceae	*Goniothalamus giganteus* Wall. ex Hook.f. &Thomson
11	Annonaceae	*Mitrephora keithii* Ridl.
12	Annonaceae	*Mitrephora wangii* Hu
13	Annonaceae	*Mitrephora winitii* Craib
14	Annonaceae	*Monocarpia maingayi* (Hook.f. &Thomson) I.M.Turner
15	Annonaceae	*Monoon anomalum* (Becc.) B.Xue & R.M.K. Saunders
16	Annonaceae	*Orophea kerrii* Kessler
17	Annonaceae	*Polyalthia cauliflora* Hook.f. & Thomson var. *wrayi* (Hemsl.) J.Sinclair
18	Annonaceae	*Polyalthia lateritia* J.Sincl.
19	Annonaceae	*Polyalthia stenopetala* (Hook & Thomson) Finet. & Gagnep.
20	Annonaceae	*Trivalvaria macrophylla* (Blume) Miq.
21	Apocynaceae	*Kopsia angustipetala* Kerr
22	Apocynaceae	*Tabernaemontana macrocarpa* Jack
23	Apocynaceae	*Wrightia sirikitiae* D.J.Middleton & Santisuk
24	Apocynaceae	*Wrightia viridiflora* Kerr
25	Araliaceae	*Arthrophyllum ferrugineum* Craib
26	Araliaceae	*Arthrophyllum meliifolium* Craib
27	Araliaceae	*Polyscias lucens* (Craib) Lowry & G.M.Plunkett
28	Araliaceae	*Schefflera siamensis* W.W.Sm. ex Craib
29	Betulaceae	*Alnus nepalensis* D. Don
30	Bignoniaceae	*Fernandoa collignonii* (P.Dop) Steenis
31	Bignoniaceae	*Pauldopia ghorta* (Buch.-Ham. ex G.Don) Steenis
32	Bignoniaceae	*Radermachera boniana* Dop
33	Bignoniaceae	*Radermachera eberhardtii* Dop
34	Bignoniaceae	*Radermachera hainanensis* Merr.
35	Bignoniaceae	*Radermachera peninsularis* Steenis
36	Bignoniaceae	*Radermachera pinnata* (Blanco) Seem.
37	Bignoniaceae	*Santisukia kerrii* (Barnett & Sandwith) Brummitt
38	Bignoniaceae	*Santisukia pagetii* (Craib) Brummitt
39	Boraginaceae	*Cordia mhaya* Kerr
40	Burseraceae	*Canarium euphyllum* Kurz.
41	Burseraceae	*Canarium littorale* Blume
42	Burseraceae	*Canarium patentinervium* Miq.
43	Burseraceae	*Canarium pavum* Leenh.

No.	Family	Botanical name
44	Burseraceae	*Canarium pseudodecumanum* Hochr.
45	Burseraceae	*Canarium pseudosumatranum* Leenh.
46	Burseraceae	*Canarium strictum* Roxb.
47	Burseraceae	*Canarium sumatranum* Boerl. & Koord.
48	Burseraceae	*Dacryodes kingii* (Engl.) Kalkman
49	Burseraceae	*Garuga floribunda* Decne. var. *gamblei* (King ex W.W.Sm) Kalkman
50	Burseraceae	*Santiria laeviagata* Blume
51	Burseraceae	*Santiria rubiginosa* Blume
52	Burseraceae	*Santiria tomentosa* Blume
53	Calophyllaceae	*Calophyllum canum* Hook.f. ex T.Anderson
54	Calophyllaceae	*Calophyllum drybalanoides* Pierre
55	Calophyllaceae	*Calophyllum molle* King
56	Calophyllaceae	*Calophyllum rupicolum* Ridl.
57	Calophyllaceae	*Calophyllum sclerophyllum* Vesgue
58	Calophyllaceae	*Calophyllum teysmannii* Miq.
59	Celastraceae	*Glyptopetalum sclerocarpus* M.A.Lawson
60	Cephalotaxaceae	*Cephalotaxus mannii* Hook.f.
61	Combretaceae	*Terminalia franchetii* Gagnep.
62	Combretaceae	*Terminalia myriocarpa* Heur & Muell.Arg. var. *hirsuta* Craib
63	Composite	*Gochnatia decora* (Kurz) Cabrera
64	Cornaceae	*Cornus oblonga* Wall. var. *siamica* Geddes
65	Cupressaceae	*Calocedrus macrolepis* Kurz
66	Dilleniaceae	*Dillenia excelsa* (Jack) Martelli ex Gilg
67	Dilleniaceae	*Dillenia ovata* Wall. ex Hook.f. & Thomson
68	Dilleniaceae	*Dillenia scabrella* (D.Don) Roxb. ex Wall.
69	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King
70	Dipterocarpaceae	*Anisoptera laevis* Ridl.
71	Dipterocarpaceae	*Anisoptera scaphula* (Roxb.) Kurz
72	Dipterocarpaceae	*Cotylelobium lanceolatum* Craib
73	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.
74	Dipterocarpaceae	*Dipterocarpus hasseltii* Blume
75	Dipterocarpaceae	*Dipterocarpus retusus* Blume
76	Dipterocarpaceae	*Hopea helferi* (Dyer) Brandis
77	Dipterocarpaceae	*Hopea oblongifolia* Dyer
78	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington
79	Dipterocarpaceae	*Hopea pierrei* Hance
80	Dipterocarpaceae	*Hopea recopei* Pierre ex Laness.
81	Dipterocarpaceae	*Hopea sangal* Korth.
82	Dipterocarpaceae	*Hopea siamensis* F.Heim
83	Dipterocarpaceae	*Hopea sublanceolata* Symington
84	Dipterocarpaceae	*Hopea thorelii* Pierre
85	Dipterocarpaceae	*Neobalanocarpus heimii* (King) P.S.Ashton
86	Dipterocarpaceae	*Parashorea densiflora* Slooten & Symington subsp. *kerrii* (Tardieu) R.Pooma
87	Dipterocarpaceae	*Shorea bracteolata* Dyer
88	Dipterocarpaceae	*Shorea dasyphylla* Foxw.
89	Dipterocarpaceae	*Shorea faguetiana* F.Heim
90	Dipterocarpaceae	*Shorea farinosa* C.E.C.Fisch.
91	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume
92	Dipterocarpaceae	*Shorea longisperma* Roxb.
93	Dipterocarpaceae	*Shorea singkawang* (Miq.) Miq.
94	Dipterocarpaceae	*Shorea sumatrana* (Slooten ex Thorenaar) Symington ex Desch
95	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.

No.	Family	Botanical name
96	Dipterocarpaceae	*Vatica bella* Slooten
97	Dipterocarpaceae	*Vatica diospyroides* Symington
98	Dipterocarpaceae	*Vatica mangachapoi* subsp. *obtusifolia* (Elmer) P.S.Ashton
99	Dipterocarpaceae	*Vatica philastreana* Pierre
100	Dipterocarpaceae	*Vatica stapfiana* (King) Slooten
101	Ebenaceae	*Diospyros andamanica* (Kurz) Bakh.
102	Ebenaceae	*Diospyros bambuseti* H.R.Fletcher
103	Ebenaceae	*Diospyros cauliflora* Blume
104	Ebenaceae	*Diospyros coaetanea* H.R.Fletcher
105	Ebenaceae	*Diospyros collinsae* Craib
106	Ebenaceae	*Diospyros confertiflora* (Hiern) Bakh.
107	Ebenaceae	*Diospyros dumetorum* W.W.Sm.
108	Ebenaceae	*Diospyros filipendula* Pierre ex Lecomte
109	Ebenaceae	*Diospyros gracilis* H.R.Fletcher
110	Ebenaceae	*Diospyros kerrii* Craib
111	Ebenaceae	*Diospyros latisepala* Ridl.
112	Ebenaceae	*Diospyros montana* Roxb.
113	Ebenaceae	*Diospyros scalariformis* H.R.Fletcher
114	Ebenaceae	*Diospyros scortechinii* King & Gamble
115	Ebenaceae	*Diospyros thaiensis* Phengklai
116	Ebenaceae	*Diospyros trianthos* Phengklai
117	Ebenaceae	*Diospyros winitii* H.R.Fletcher
118	Elaeocarpaceae	*Elaeocarpus balansae* A.DC.
119	Elaeocarpaceae	*Elaeocarpus braceanus* Watt ex C.B. Clarke
120	Elaeocarpaceae	*Sloanea tomentosa* (Benth.) Rehder & E. H.Wilson
121	Ericaceae	*Rhododendron longiflorum* Lindl.
122	Ericaceae	*Rhododendron ludwigianum* Hosseus
123	Euphorbiaceae	*Blumeodendron tokbrai* (Blume) J.J.Sm.
124	Euphorbiaceae	*Botryophora geniculata* (Miq.) Beumee ex Airy Shaw
125	Euphorbiaceae	*Chorisandrachne diplosperma* Airy Shaw
126	Euphorbiaceae	*Claoxylon putii* Airy Shaw
127	Euphorbiaceae	*Croton kongkandanus* Esser
128	Euphorbiaceae	*Croton phuquocensis* Croizat
129	Euphorbiaceae	*Croton poomae* Esser
130	Euphorbiaceae	*Dimorphocalyx muricatus* (Hook.f.) Airy Shaw
131	Euphorbiaceae	*Hancea kingii* (Hook.f.) S.E.C.Sierra, Kulju & Welzen
132	Euphorbiaceae	*Mallotus calocarpus* Airy Shaw
133	Euphorbiaceae	*Mallotus kongkandae* Welzen & Phattar.
134	Euphorbiaceae	*Mallotus pallidus* (Airy Shaw) Airy Shaw
135	Euphorbiaceae	*Mallotous resinosus* (Blanco) Merr.
136	Euphorbiaceae	*Ptychopyxis plagiocarpa* Airy Shaw
137	Euphorbiaceae	*Sauropus thyrsiflorus* Welzen
138	Euphorbiaceae	*Spathiostemon moniformis* Airy Shaw
139	Euphorbiaceae	*Trigonostemon kerrii* Craib
140	Fabaceae	*Albizia attopeuensis* (Pierre) I.C.Nielsen
141	Fabaceae	*Albizia garrettii* I.C.Nielsen
142	Fabaceae	*Albizia vialeana* Pierre
143	Fabaceae	*Amherstia nobilis* Wall.
144	Fabaceae	*Archidendron conspicuum* (Craib) I.C.Nielsen
145	Fabaceae	*Archidendron glomeriflorum* (Kurz) I.C.Nielsen
146	Fabaceae	*Archidendron quocense* (Pierre) I.C.Nielsen
147	Fabaceae	*Crudia caudata* Prain ex King
148	Fabaceae	*Crudia gracilis* Prain

No.	Family	Botanical name
149	Fabaceae	*Crudia lanceolatum* Ridl.
150	Fabaceae	*Crudia speciosa* Prain
151	Fabaceae	*Cynometra craibii* Gagnep.
152	Fabaceae	*Dalbergia suthepensis* Niyomdham
153	Fabaceae	*Gymnocladus burmanicus* C.E. Parkinson
154	Fabaceae	*Millettia kangensis* Craib
155	Fabaceae	*Saraca thaipingensis* Cantley ex Prain
156	Fagaceae	*Castanopsis fordii* Hance
157	Fagaceae	*Castanopsis malaccensis* Gamble
158	Fagaceae	*Castanopsis megacarpa* Gamble
159	Fagaceae	*Castanopsis pseudo-hystrix* Phengklai
160	Fagaceae	*Castanopsis purpurea* Barnett
161	Fagaceae	*Castanopsis siamensis* Duanmu
162	Fagaceae	*Castanopsis thaiensis* Phengklai
163	Fagaceae	*Lithocarpus echinops* Hjelmq.
164	Fagaceae	*Lithocarpus elephantum* (Hance) A.Camus
165	Fagaceae	*Lithocarpus loratifolius* Phengklai
166	Fagaceae	*Lithocarpus pattaniensis* Barnett
167	Fagaceae	*Lithocarpus revolutus* Hatus ex Soepadmo
168	Fagaceae	*Lithocarpus rufescens* Barnett
169	Fagaceae	*Lithocarpus siamensis* A.Camus
170	Fagaceae	*Lithocarpus xylocarpus* (Kurz) Markgr.
171	Fagaceae	*Quercus kingiana* Craib
172	Fagaceae	*Quercus lamellosa* Sm.
173	Fagaceae	*Quercus lenticellatus* Barnett
174	Fagaceae	*Trigonobalanus doichangensis* (A.Camus) Forman
175	Hamamelidaceae	*Distylium annamicum* (Gagnep.) Airy Shaw
176	Hamamelidaceae	*Loropetalum chinense* (R.Br.) Oliv. var. *chinense*
177	Hamamelidaceae	*Rhodoleia championii* Hook.f.
178	Lamiaceae	*Gmelina racemosa* (Lour.) Merr.
179	Lauraceae	*Beilschmiedia elegantissima* Kosterm.
180	Lauraceae	*Beilschmiedia inconspicua* Kosterm.
181	Lauraceae	*Beilschmiedia velutinosa* Kosterm.
182	Lauraceae	*Beilschmiedia villosa* Kosterm.
183	Lauraceae	*Cinnamomum kerrii* Kosterm.
184	Lauraceae	*Litsea kerrii* Kosterm.
185	Lauraceae	*Litsea membranifolia* Hook.f.
186	Lauraceae	*Litsea pseudo-umbellata* Kosterm.
187	Lauraceae	*Litsea punctulata* Kosterm.
188	Lauraceae	*Temmodaphne thailandica* Kosterm.
189	Lecythidaceae	*Barringtonia asiatica* (L.) Kurz
190	Lecythidaceae	*Planchonia grandis* Ridl.
191	Magnoliaceae	*Magnolia duperreana* Pierre
192	Magnoliaceae	*Magnolia liliifera* (L.) Baill.
193	Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar
194	Magnoliaceae	*Magnolia praecalva* (Dandy) Figlar & Noot.
195	Magnoliaceae	*Magnolia rajaniana* (Craib) Figlar
196	Magnoliaceae	*Magnolia sirindhorniae* Noot. & Chalermglin
197	Magnoliaceae	*Magnolia thailandica* Noot. & Chalermglin
198	Malvaceae	*Burretiodendron umbellatum* Kosterm.
199	Malvaceae	*Dicellostyles zizyphifolia* (Griff.) Phup.
200	Malvaceae	*Durio graveolens* Becc.
201	Malvaceae	*Durio griffithii* (Mast.) Bakh.

No.	Family	Botanical name
202	Malvaceae	*Durio lowianus* Scort. ex King
203	Malvaceae	*Durio mansoni* (Gamble) Bakh.
204	Malvaceae	*Firmiana kerrii* (Craib) Kosterm.
205	Malvaceae	*Heritiera macrophylla* Wall. ex Kurz
206	Malvaceae	*Mansonia gagei* Drumm.
207	Malvaceae	*Neesia altissima* (Blume) Blume
208	Malvaceae	*Pterospermum grandiflorum* Craib
209	Malvaceae	*Pterospermum littorale* Craib var. *littorale*
210	Malvaceae	*Pterospermum littorale* Craib var. *venustrum* (Craib) Phengklai
211	Malvaceae	*Reevesia pubescens* Mast. var. *pubescens*
212	Malvaceae	*Reevesia pubescens* Mast. var. *siamensis* (Craib) Anthony
213	Malvaceae	*Schoutenia glomerata* King subsp. *peregrina* (Craib) Roekm.
214	Malvaceae	*Sterculia cordata* Blume
215	Malvaceae	*Sterculia gilva* Miq.
216	Melastomataceae	*Pternandra tuberculata* (Korth) M. P. Nayar
217	Meliaceae	*Aglaia chittagonga* Miq.
218	Meliaceae	*Aglaia perviridis* Hiern
219	Moraceae	*Artocarpus thailandica* C.C.Berg
220	Myristicaceae	*Horsfieldia amygdalina* (Wall.) Warb. var. *amygdalina*
221	Myristicaceae	*Knema andamanica* (Warb.) W.J.de Wilde subsp. *peninsularis* W.J.de Wilde
222	Myristicaceae	*Knema austrosiamensis* W.J.de Wilde
223	Myristicaceae	*Knema conica* W.J.de Wilde
224	Myristicaceae	*Knema globulatericia* W.J.de Wilde
225	Myristicaceae	*Knema tenuinervia* W.J.de Wilde subsp. *kanburiensis* W.J.de Wilde
226	Myrtaceae	*Syzygium aksornii* Chantar. & J.Parn.
227	Myrtaceae	*Syzygium antisepticum* (Blume) Merr. & L.M.Perry
228	Myrtaceae	*Syzygium boisianum* (Gagnep.) Merr. & L.M.Perry subsp. *longifolium* Chantar. & J.Parn.
229	Myrtaceae	*Syzygium cacuminis* (Craib) Chantar. & J.Parn subsp. *cacuminis*
230	Myrtaceae	*Syzygium cacuminis* (Craib) Chantar. & J.Parn subsp. *inthanonense* P.Chan. & J.Parn
231	Myrtaceae	*Syzygium craibii* Chantar. & J.Paran.
232	Myrtaceae	*Syzygium fuscescens* (Craib) Chantar. & J.Parn.
233	Myrtaceae	*Syzygium hemsleyanum* (King) Chantar. & J.Parn subsp. *paucinervium* Chantar. & J.Parn
234	Myrtaceae	*Syzygium ixoroides* Chantar.& J.Parn
235	Myrtaceae	*Syzygium kerrii* Chantar. & J.Parn.
236	Myrtaceae	*Syzygium khaoyaiensis* (Chanthar. & J.Parn.) Craven & Briffin
237	Myrtaceae	*Syzygium lakshrakarae* Chantar.& J.Parn
238	Myrtaceae	*Syzygium myrtifolium* Walp.
239	Myrtaceae	*Syzygium nitrasirirakii* Chantar & J.Parn.
240	Myrtaceae	*Syzygium phengklaii* (Chantar. & J.Parn.) Craven & Biffin
241	Myrtaceae	*Syzygium prainianum* (King) Chantar & J.Parn. subsp. *minor* Chantar & J.Parn.
242	Myrtaceae	*Syzygium putii* Chantar.& J.Parn
243	Myrtaceae	*Syzygium refertum* (Craib) Chantar & J.Parn.
244	Myrtaceae	*Syzygium rigens* (Craib) Chantar. & J. Parn.
245	Myrtaceae	*Syzygium samarangense* (Blume) Merr. & L.M.Perry
246	Myrtaceae	*Syzygium thumra* (Roxb.) Merr. & L.M.Perry subsp. *punctifolium* (Ridl.) Chantar& J.Parn.

No.	Family	Botanical name
247	Olacaceae	*Schoepfia fragrans* Wall.
248	Olacaceae	*Scorodocarpus borneensis* (Baill.) Becc.
249	Oleaceae	*Chionanthus amblirrhinus* P.S.Green
250	Oleaceae	*Chionanthus decipiens* P.S.Green
251	Oleaceae	*Chionanthus eriorachis* (Kerr) P.S.Green
252	Oleaceae	*Chionanthus maxwelli* P.S.Green
253	Oleaceae	*Chionanthus sutepensis* (Kerr) P.S.Green
254	Oleaceae	*Chionanthus velutinus* (Kerr) P.S.Green
255	Oleaceae	*Fraxinus floribunda* Wall.
256	Oleaceae	*Schrebera swietenoides* Roxb.
257	Oxalidaceae	*Sarcotheca laxa* (Ridl.) Kunth
258	Pentaphylacaceae	*Adinandra oblonga* Craib
259	Phyllanthaceae	*Antidesma bunius* (L.) Spreng. var. *pubescens* Petra Hoffm.
260	Phyllanthaceae	*Antidesma forbesii* Pax & K.Hoffm.
261	Phyllanthaceae	*Aporosa duthieana* King ex Pax & K.Hoffim.
262	Phyllanthaceae	*Aporosa globifera* Hook.f.
263	Phyllanthaceae	*Baccaurea sumatrana* (Miq.) Müll.Arg.
264	Phyllanthaceae	*Cleistanthus glandulosa* Jabl.
265	Phyllanthaceae	*Cleistanthus hirsutopetalus* Gage
266	Phyllanthaceae	*Cleistanthus laurinum* Airy Shaw
267	Phyllanthaceae	*Glochidion santisukii* Airy Saw
268	Phyllanthaceae	*Phyllanthus angkorensis* Beille
269	Picrodendraceae	*Austrobuxus nitidus* Miq.
270	Podocarpaceae	*Dacrycapus imbricatus* (Blume) de Laub.
271	Podocarpaceae	*Dacrydium elatum* (Roxb.) Wall. ex Hook.
272	Podocarpaceae	*Nageia motleyi* (Presl) de Laub.
273	Podocarpaceae	*Nageia wallichiana* (C.Presl) Kuntze
274	Podocarpaceae	*Podocarpus neriifolius* D.Don
275	Podocarpaceae	*Podocarpus pilgerri* Foxw.
276	Podocarpaceae	*Podocarpus polystachyus* R. Br. ex Endl.
277	Primulaceae	*Ardisia confusa* K.Larsen & C.M.Hu
278	Primulaceae	*Ardisia ionantha* K.Larsen & C.M.Hu
279	Primulaceae	*Ardisia montana* King & Gamble
280	Primulaceae	*Ardisia multipunctata* H.R.Fletcher
281	Primulaceae	*Ardisia nervosa* H.R.Fletcher
282	Primulaceae	*Ardisia puberula* H.R.Fletcher
283	Primulaceae	*Ardisia sanguinolenta* Blume var. *paralleloneura* K.Larsen & C. M.Hu) K.Larsen & C. M. Hu
284	Primulaceae	*Maesa glomerata* K.Larsen & C.M.Hu
285	Proteaceae	*Helicia vestita* W.W.Sm.
286	Putranjivaceae	*Drypetes curtisii* (Hook.f.) Pax & K.Hoffm
287	Putranjivaceae	*Drypetes dasycarpa* (Airy Show) Phuph. & Chayamarit
288	Putranjivaceae	*Drypetes harmandii* Pierre ex Gagnep.
289	Putranjivaceae	*Drypetes helferi* (Hook.f.) Pax & K.Hoffm.
290	Putranjivaceae	*Drypetes ochrothrix* Airy Saw
291	Putranjivaceae	*Drypetes pendula* Ridl.
292	Putranjivaceae	*Drypetes subsessile* (Kurz) Pax & K.Hoffm.
293	Putranjivaceae	*Drypetes viridis* Airy Saw
294	Rubiaceae	*Brachytome scortechinii* King & Gamble
295	Rubiaceae	*Ceriscoides kerrii* Azmi
296	Rubiaceae	*Ceriscoides mamillata* (Craib) Tirveng.
297	Rubiaceae	*Fosbergia thailandica* Tirveng. & Sastre
298	Rubiaceae	*Gardenia thailandica* Tirveng.

No.	Family	Botanical name
299	Rubiaceae	*Gardenia truncata* Craib
300	Rubiaceae	*Gardiniopsis longifolia* Miq.
301	Rubiaceae	*Pertusadina malaccensis* Ridsdale
302	Rubiaceae	*Pitardelia poilanei* Tirveng.
303	Rubiaceae	*Porterandia scortechinii* (King & Gamble) Ridl.
304	Rubiaceae	*Rothmannia sootepensis* (Craib) Bremek.
305	Rubiaceae	*Timonius corneri* K.M.Wong var. *penangianus* (Ridl.) K.M.Wong
306	Rubiaceae	*Vidalasia fusca* (Craib) Tirveng.
307	Rubiaceae	*Vidalasia murina* (Criab) Tirveng.
308	Rubiaceae	*Vidalasia pubescens* (Tirveng. & Sastre) Tirveng.
309	Rutaceae	*Citrus halimii* B.C.Stone
310	Salicaceae	*Homalium grandiflorum* Benth.
311	Salicaceae	*Homalium longifolium* Benth.
312	Salicaceae	*Homalium peninsulare* Sleum.
313	Santalaceae	*Scleropyrum pentandrum* (Dennst.) Mabb.
314	Sapindaceae	*Acer calcaratum* Gagnep.
315	Sapindaceae	*Acer chiangdaoense* Santisuk
316	Sapindaceae	*Acer pseudowilsonii* Y.S.Chen
317	Sapindaceae	*Acer sterculiaceum* Wall. subsp. *thomsonii* (Miq.) A.E.Murray
318	Sapindaceae	*Lepisanthes amoena* (Hassk.) Leenh.
319	Sapindaceae	*Nephelium maingayi* Hiern
320	Sapindaceae	*Nephelium melliferum* Gagnep.
321	Sapotaceae	*Diploknema siamensis* H.R.Fletcher
322	Sapotaceae	*Madhuca chai-ananiae* Chantar.
323	Sapotaceae	*Madhuca chiangmaiensis* Chantar.
324	Sapotaceae	*Madhuca esculenta* H.R.Fletcher
325	Sapotaceae	*Madhuca floribunda* (Pierre ex Dubard) H.J.Lam
326	Sapotaceae	*Madhuca klackenbergii* Chantar.
327	Sapotaceae	*Madhuca krabiensis* Chantar.
328	Sapotaceae	*Madhuca punctata* H.R.Fletcher
329	Sapotaceae	*Madhuca smitinandii* Chantar.
330	Sapotaceae	*Madhuca stipulacea* H.R.Fletcher
331	Sapotaceae	*Madhuca takensis* Aubrév.
332	Sapotaceae	*Palaquium garrettii* H.R.Fletcher
333	Sapotaceae	*Palaquium hansenii* Chantar.
334	Sapotaceae	*Payena maingayi* C.B.Clarke
335	Sapotaceae	*Weinmannia fraxinea* (D.Don) Miq.
336	Sapotaceae	*Xantolis siamensis* (H.R.Fletcher) P.Royen
337	Schisandraceae	*Illicium peninsulare* A.C.Sm.
338	Schisandraceae	*Illicium tenuifolium* (Ridl.) A.C.Sm.
339	Symplocaceae	*Symplocos hensehelii* (Moritzi) Benth. ex C.B.Clarke subsp. *magnifica* (H.R.Fletcher) Noot.
340	Theaceae	*Camellia connata* (Craib) Craib
341	Theaceae	*Gordonia axillaris* (Roxb. ex Ker Gawl) Endl.
342	Theaceae	*Gordonia dalglieshiana* Craib
343	Theaceae	*Pyrenaria diospyricarpa* Kurz var. *diospyricarpa*
344	Thymelaeaceae	*Aquilaria crassna* Pierre ex Lecomte
345	Thymelaeaceae	*Aquilaria hirta* Ridl.
346	Thymelaeaceae	*Aquilaria malaccensis* Lam.
347	Thymelaeaceae	*Gonystylus confusus* Airy Shaw
348	Thymelaeaceae	*Gyrinops vidalii* P.H.Hô
349	Urticaceae	*Sebregeasia wallichiana* (Wedd.) Wedd.

Table A2 List of tree species mentioned in Rare Plants of Thailand (Pooma 2008)

No.	Family	Botanical name
1	Actinidiaceae	*Saurauia leprosa* Korth.
2	Akaniaceae	*Bretschneidera sinensis* Hemsl.
3	Altingiaceae	*Altingia excelsa* Noranha
4	Anacardiaceae	*Buchanania siamensis* Miq.
5	Annonaceae	*Alphonsea gaudichaudiana* (Baill.) Finet & Gagnep.
6	Annonaceae	*Goniothalamus cheliensis* Hu
7	Annonaceae	*Goniothalamus giganteus* Wall. ex Hook.f. &Thomson
8	Annonaceae	*Mitrephora keithii* Ridl.
9	Annonaceae	*Mitrephora sirikitiae* Weeras., Chalermglin & R.M.K.Saunders
10	Annonaceae	*Mitrephora wangii* Hu
11	Annonaceae	*Mitrephora winitii* Craib
12	Annonaceae	*Monoon membranifolium* (J.Sinclair) B. Xue & R.M.K.Saunders
13	Annonaceae	*Polyalthia cauliflora* Hook.f. & Thomson var. *wrayi* (Hemsl.) J.Sinclair
14	Annonaceae	*Polyalthia stenopetala* (Hook & Thomson) Finet. & Gagnep.
15	Annonaceae	*Pseuduvaria macrophylla* (Oliv.) Merr. var. *sessilicarpa* J.Sinclair
16	Apocynaceae	*Alstonia spatulata* Blume
17	Apocynaceae	*Dyera costulata* (Miq.) Hook.f.
18	Apocynaceae	*Kopsia arborea* Blume
19	Apocynaceae	*Kopsia rosea* D.J.Middleton
20	Apocynaceae	*Ochrosia oppositifolia* (Lam.) K.Schum.
21	Apocynaceae	*Rauvolfia sumatrana* Jack
22	Apocynaceae	*Tabernaemontana macrocarpa* Jack
23	Apocynaceae	*Wrightia coccinea* (Roxb.) Sims
24	Apocynaceae	*Wrightia viridiflora* Kerr
25	Asteraceae	*Gochnatia decora* (Kurz) Cabrera
26	Asteraceae	*Vernonia arborea* Buch.-Ham.
27	Bignoniaceae	*Markhamia stipulata* Seem. var. *kerrii* Sprague
28	Bignoniaceae	*Pauldopia ghorta* (Buch.-Ham. ex G.Don) Steenis
29	Bignoniaceae	*Radermachera boniana* Dop
30	Bignoniaceae	*Radermachera eberhardtii* Dop
31	Bignoniaceae	*Radermachera hainanensis* Merr.
32	Bignoniaceae	*Radermachera peninsularis* Steenis
33	Bignoniaceae	*Santisukia kerrii* (Barnett & Sandwith) Brummitt
34	Boraginaceae	*Cordia subcordata* Lam.
35	Burseraceae	*Canarium denticulatum* Blume
36	Burseraceae	*Canarium euphyllum* Kurz.
37	Burseraceae	*Canarium littorale* Blume
38	Burseraceae	*Canarium strictum* Roxb.
39	Burseraceae	*Dacryodes kingii* (Engl.) Kalkman
40	Cephalotaxaceae	*Cephalotaxus mannii* Hook.f.
41	Cunoniaceae	*Weinmannia fraxinea* (D.Don) Miq.
42	Dilleniaceae	*Dillenia reticulata* King
43	Dipterocarpaceae	*Anisoptera laevis* Ridl.
44	Dipterocarpaceae	*Anisoptera scaphula* (Roxb.) Kurz
45	Dipterocarpaceae	*Dipterocarpus acutangulus* Vesque
46	Dipterocarpaceae	*Hopea oblongifolia* Dyer
47	Dipterocarpaceae	*Hopea thorelii* Pierre

No.	Family	Botanical name
48	Dipterocarpaceae	*Neobalanocarpus heimii* (King) P.S.Ashton
49	Dipterocarpaceae	*Parashorea densiflora* Slooten & Symington subsp. *kerrii* (Tardieu) R.Pooma
50	Dipterocarpaceae	*Shorea macroptera* Dyer
51	Dipterocarpaceae	*Vatica bella* Slooten
52	Dipterocarpaceae	*Vatica mangachapoi* subsp. *obtusifolia* (Elmer) P.S.Ashton
53	Dipterocarpaceae	*Vatica philastreana* Pierre
54	Ebenaceae	*Diospyros cauliflora* Blume
55	Ebenaceae	*Diospyros confertiflora* (Hiern) Bakh.
56	Ebenaceae	*Diospyros dasyphylla* Kurz
57	Ebenaceae	*Diospyros dumetorum* W.W.Sm.
58	Ebenaceae	*Diospyros filipendula* Pierre ex Lecomte
59	Ebenaceae	*Diospyros kerrii* Craib
60	Ebenaceae	*Diospyros latisepala* Ridl.
61	Ebenaceae	*Diospyros winitii* H.R.Fletcher
62	Elaeocarpaceae	*Sloanea tomentosa* (Benth.) Rehder & E. H.Wilson
63	Ericaceae	*Diplycosia heterophylla* Blume var. *latifolia* (Blume) Sleum.
64	Ericaceae	*Rhododendron delavayi* Franch.
65	Ericaceae	*Rhododendron moulmainense* Hook.
66	Ericaceae	*Rhododendron simsii* Planch.
67	Ericaceae	*Styphelia malayana* (Jack) Spring
68	Escalloniaceae	*Polyosma integrifolia* Blume
69	Euphorbiaceae	*Chondrostylis kunstleri* (King ex Hook.f.) Thwaites
70	Euphorbiaceae	*Chorisandrachne diplosperma* Airy Shaw
71	Euphorbiaceae	*Croton poomae* Esser
72	Euphorbiaceae	*Dimorphocalyx malayanus* Hook.f.
73	Euphorbiaceae	*Dimorphocalyx muricatus* (Hook.f.) Airy Shaw
74	Euphorbiaceae	*Epiprinus malayanus* Griff.
75	Fabaceae	*Crudia chrysantha* (Pierre) K.Schum.
76	Fabaceae	*Dialium indum* L.
77	Fabaceae	*Maniltoa polyandra* (Roxb.) Harms.
78	Fabaceae	*Saraca declinata* (Jack) Miq.
79	Fagaceae	*Lithocarpus pattaniensis* Barnett
80	Fagaceae	*Quercus rex* Hemsl.
81	Fagaceae	*Trigonobalanus doichangensis* (A.Camus) Forman
82	Gentianaceae	*Fagraea racemosa* Jack
83	Hamamelidaceae	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.
84	Hamamelidaceae	*Rhodoleia championii* Hook.f.
85	Hypericaceae	*Cratoxylum arborescens* (Vahl) Blume
86	Lamiaceae	*Gmelina racemosa* (Lour.) Merr.
87	Lamiaceae	*Vitex longisepala* King & Gamble
88	Lamiaceae	*Vitex siamica* F.N.Williams
89	Lythraceae	*Pemphis acidula* J.R. Forst & G.Forst.
90	Magnoliaceae	*Magnolia garrettii* (Craib) V.S.Kumar
91	Magnoliaceae	*Magnolia liliifera* (L.) Baill
92	Magnoliaceae	*Magnolia praecalva* (Dandy) Figlar & Noot.
93	Magnoliaceae	*Magnolia sirindhorniae* Noot. & Chalermglin
94	Malvaceae	*Burretiodendron esquirolii* (Lév.) Rehder
95	Malvaceae	*Reevesia pubescens* Mast. var. *siamensis* (Craib) Anthony
96	Malvaceae	*Trichospermum javanicum* Blume
97	Myristicaceae	Myristica elliptica Wall. ex Hook.f. & Thomson
98	Olacaceae	*Scorodocarpus borneensis* (Baill.) Becc.
99	Oleaceae	*Osmanthus fragrans* Lour.

No.	Family	Botanical name
100	Oxalidaceae	*Sarcotheca laxa* (Ridl.) Kunth
101	Paulowniaceae	*Wightia speciosissima* (D.Don) Merr.
102	Rhizophoraceae	*Gynotroches axillaris* Blume
103	Rosaceae	*Photinia arguta* Lindl. var. *salicifolia* (Decne.) Vidal
104	Rosaceae	*Prunus cerasoides* D.Don
105	Rubiaceae	*Fosbergia thailandica* Tirveng. & Sastre
106	Rubiaceae	*Gardenia sootepensis* Hutch.
107	Rubiaceae	*Pertusadina malaccensis* Ridsdale
108	Rubiaceae	*Rennellia morindiformis* (Korth.) Ridl.
109	Rubiaceae	*Timonius corneri* K.M.Wong
110	Rubiaceae	*Vidalasia fusca* (Craib) Tirveng.
111	Rutaceae	*Citrus halimii* B.C.Stone
112	Sapindaceae	*Acer calcaratum* Gagnep.
113	Sapindaceae	*Acer chiangdaoense* Santisuk
114	Sapindaceae	*Acer pseudowilsonii* Y.S.Chen
115	Sapindaceae	*Aesculus assamica* Griff.
116	Sauraulaceae	*Saurauia pentapetala* (Jack) Hoogland
117	Schisandraceae	*Illicium tenuifolium* (Ridl.) A.C.Sm.
118	Thymelaeaceae	*Gyrinops vidalii* P.H.Hô
119	Torricelliaceae	*Aralidium pinnatifidum* (Jungh. & de Vriese) Miq.

Table A3 List of tree species mentioned in Forest of Thailand 2006 (Santisuk et. al. 2006)

No.	Family	Botanical name
1	Acanthaceae	*Avicennia marina* (Forssk.) Vierh.
2	Achariaceae	*Hydnocarpus castanea* Hook.f.& Thomson
3	Achariaceae	*Hydnocarpus ilicifolia* King
4	Actinidiaceae	*Saurauia napaulensis* DC.
5	Actinidiaceae	*Saurauia roxburghii* Wall.
6	Alangiaceae	*Alangium salviifolium* (L.f.) Wangerin subsp. *hexapetalum* (Lam.) Wangerin
7	Altingiaceae	*Altingia excelsa* Noranha
8	Anacardiaceae	*Bouea oppositifolia* (Roxb.) Meisn.
9	Anacardiaceae	*Buchanania lanzan* Spreng.
10	Anacardiaceae	*Buchanania siamensis* Miq.
11	Anacardiaceae	*Campnosperma coriaceum* (Jack) Hall.f. ex Steenis
12	Anacardiaceae	*Choerospondias axillaris* (Roxb.) B.L. Burtt & Hill
13	Anacardiaceae	*Dracontomelon dao* (Blanco) Merr. & Rolfe
14	Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou
15	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.
16	Anacardiaceae	*Mangifera gedebe* Miq.
17	Anacardiaceae	*Mangifera sylvatica* Roxb.
18	Anacardiaceae	*Parishia insignis* Hook.f.
19	Anacardiaceae	*Pentaspadon velutinus* Hook.f.
20	Anacardiaceae	*Rhus succedanea* L.
21	Anacardiaceae	*Semecarpus cochinchinensis* Engl.
22	Anacardiaceae	*Semecarpus curtisii* King

No.	Family	Botanical name
23	Anacardiaceae	*Spondias bipinnata* Airy Shaw & Forman
24	Anacardiaceae	*Spondias lakonensis* Pierre
25	Anacardiaceae	*Spondias pinnata* (L.f.) Kurz
26	Anacardiaceae	*Swintonia floribunda* Griff.
27	Annonaceae	*Canaga brandisiana* (Pierre) I.M.Turner
28	Annonaceae	*Cyathocalyx martabanicus* Hook.f. & Thomson var.*harmandii* Finet & Gagnep.
29	Annonaceae	*Goniothalamus giganteus* Wall. ex Hook.f. &Thomson
30	Annonaceae	*Miliusa velutina* (Dunal) Hook.f. & Thomson
31	Annonaceae	*Mitrephora maingayi* Hook.f. & Thomson
32	Annonaceae	*Mitrephora winitii* Craib
33	Annonaceae	*Monoon lateriflorum* Blume
34	Annonaceae	*Monoon sclerophyllum* (Hook.f. &Thomson) B.Xue & R.M.K. Saunders
35	Annonaceae	*Polyalthia suberosa* (Roxb.) Thwaites
36	Annonaceae	*Xylopia ferruginea* (Hook.f. & Thomson) Hook.f. & Thomson
37	Apocynaceae	*Alstonia macrophylla* Wall. ex G.Don
38	Apocynaceae	*Alstonia scholaris* (L.) R.Br.
39	Apocynaceae	*Alstonia spatulata* Blume
40	Apocynaceae	*Dyera costulata* (Miq.) Hook.f.
41	Apocynaceae	*Holarrhena pubescens* Wall. ex G.Don
42	Apocynaceae	*Wrightia arborea* (Dennst.) Mabb.
43	Aquifoliaceae	*Ilex triflora* Blume
44	Aquifoliaceae	*Ilex umbellulata* (Wall.) Loes.
45	Araliaceae	*Macropanax dispermus* (Blume) Kuntze
46	Araliaceae	*Schefflera subintegra* (Craib) C.B. Shang
47	Berberidaceae	*Mahonia duclouxiana* Gagnep.
48	Betulaceae	*Betula alnoides* Buch.-Ham. ex G.Don
49	Betulaceae	*Carpinus viminea* Wall. ex Lindl.
50	Bignoniaceae	*Dolichandrone serrulata* (Wall. ex D.C.) Seem
51	Bignoniaceae	*Dolichandrone spathacea* (L.f.) K. Schum.
52	Bignoniaceae	*Fernandoa adenophylla* (Wall. ex G. Don) Steenis
53	Bignoniaceae	*Heterophragma sulfureum* Kurz
54	Bignoniaceae	*Markhamia stipulata* Seem. var. *kerrii* Sprague
55	Bignoniaceae	*Mayodendron igneum* (Kurz) Kurz
56	Bignoniaceae	*Millingtonia hortensis* L.f.
57	Bignoniaceae	*Radermachera hainanensis* Merr.
58	Bignoniaceae	*Stereospermum fimbriatum* (Wall. ex G. Don) A.DC.
59	Bignoniaceae	*Stereospermum neuranthum* Kurz
60	Bignoniaceae	*Stereospermum tetragonum* DC.
61	Bombacaceae	*Bombax anceps* Pierre var. *anceps*
62	Bombacaceae	*Bombax ceiba* L.
63	Bonnetiaceae	*Ploiarium alternifolium* (Vahl) Melchior
64	Boraginaceae	*Cordia subcordata* Lam.
65	Boraginaceae	*Heliotropium foertherianum* Diane & Hilger
66	Burseraceae	*Canarium subulatum* Guillaumin

No.	Family	Botanical name
67	Burseraceae	*Dacryodes incurvata* (Engl.) H.J. Lam
68	Burseraceae	*Garuga pinnata* Roxb.
69	Burseraceae	*Protium serratum* Engl.
70	Calophyllaceae	*Calophyllum inophyllum* L.
71	Calophyllaceae	*Calophyllum pisiferum* Planch. & Triana
72	Calophyllaceae	*Calophyllum teysmannii* Miq.
73	Calophyllaceae	*Mammea harmandii* Kosterm.
74	Cannabaceae	*Gironniera nervosa* Planch
75	Capparaceae	*Maerua siamensis* (Kurz) Pax
76	Casuarinaceae	*Casuarina equisetifolia* L.
77	Celastraceae	*Siphonodon celastrineus* Griff.
78	Cephalotaxaceae	*Cephalotaxus mannii* Hook.f.
79	Chrysobalanaceae	*Parinari annamense* Hance
80	Clusiaceae	*Garcinia hanburyi* Hook.f.
81	Clusiaceae	*Garcinia merguensis* Wight
82	Clusiaceae	*Garcinia schomburgkiana* Pierre
83	Combretaceae	*Anogeissus acuminata* (Roxb. ex DC.) Guill. & Perr.
84	Combretaceae	*Combretum quadrangulare* Kurz
85	Combretaceae	*Terminalia alata* B.Heyne ex Roth
86	Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.
87	Combretaceae	*Terminalia catappa* L.
88	Combretaceae	*Terminalia chebula* Retz. var. *chebula*
89	Combretaceae	*Terminalia mucronata* Craib & Hutch.
90	Combretaceae	*Terminalia nigrovenulosa* Pierre
91	Combretaceae	*Terminalia pierrei* Gagnep.
92	Connaraceae	*Ellipanthus tomentosus* Kurz var. *tomentosus*
93	Cornaceae	*Cornus oblonga* Wall.
94	Cornaceae	*Mastixia euonymoides* Prain
95	Cornaceae	*Nyssa javanica* (Blume) Wangerin
96	Crypteroniaceae	*Crypteronia paniculata* Blume
97	Cupressaceae	*Calocedrus macrolepis* Kurz
98	Cycadaceae	*Cycas pectinata* Buch.-Ham.
99	Dilleniaceae	*Dillenia aurea* Sm.
100	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland
101	Dilleniaceae	*Dillenia ovata* Wall. ex Hook.f. & Thomson
102	Dilleniaceae	*Dillenia pentagyna* Roxb.
103	Dilleniaceae	*Dillenia pulchella* (Jack) Gilg
104	Dipterocarpaceae	*Anisoptera costata* Korth.
105	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King
106	Dipterocarpaceae	*Anisoptera scaphula* (Roxb.) Kurz
107	Dipterocarpaceae	*Cotylelobium lanceolatum* Craib
108	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don
109	Dipterocarpaceae	*Dipterocarpus baudii* Korth.
110	Dipterocarpaceae	*Dipterocarpus chartaceus* Symington
111	Dipterocarpaceae	*Dipterocarpus costatus* C.F.Gaertn.

No.	Family	Botanical name
112	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.
113	Dipterocarpaceae	*Dipterocarpus gracilis* Blume
114	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco
115	Dipterocarpaceae	*Dipterocarpus hasseltii* Blume
116	Dipterocarpaceae	*Dipterocarpus intricatus* Dyer
117	Dipterocarpaceae	*Dipterocarpus kerrii* King
118	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.
119	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.
120	Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.
121	Dipterocarpaceae	*Hopea ferrea* Laness.
122	Dipterocarpaceae	*Hopea latifolia* Symington
123	Dipterocarpaceae	*Hopea odorata* Roxb.
124	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington
125	Dipterocarpaceae	*Hopea pierrei* Hance
126	Dipterocarpaceae	*Hopea recopei* Pierre ex Laness.
127	Dipterocarpaceae	*Hopea sangal* Korth.
128	Dipterocarpaceae	*Neobalanocarpus heimii* (King) P.S.Ashton
129	Dipterocarpaceae	*Parashorea stellata* Kurz
130	Dipterocarpaceae	*Shorea curtisii* Dyer ex King
131	Dipterocarpaceae	*Shorea dasyphylla* Foxw.
132	Dipterocarpaceae	*Shorea faguetiana* F.Heim
133	Dipterocarpaceae	*Shorea glauca* King
134	Dipterocarpaceae	*Shorea gratissima* (Wall. ex Kurz) Dyer
135	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume
136	Dipterocarpaceae	*Shorea henryana* Pierre
137	Dipterocarpaceae	*Shorea hypochra* Hance
138	Dipterocarpaceae	*Shorea laevis* Ridl.
139	Dipterocarpaceae	*Shorea leprosula* Miq.
140	Dipterocarpaceae	*Shorea macroptera* Dyer
141	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume
142	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*
143	Dipterocarpaceae	*Shorea roxburghii* G.Don
144	Dipterocarpaceae	*Shorea siamensis* Miq.
145	Dipterocarpaceae	*Shorea singkawang* (Miq.) Miq.
146	Dipterocarpaceae	*Vatica diospyroides* Symington
147	Dipterocarpaceae	*Vatica harmandiana* Pierre
148	Dipterocarpaceae	*Vatica lowii* King
149	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington
150	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume
151	Ebenaceae	*Diospyros ehretioides* Wall. ex G.Don
152	Ebenaceae	*Diospyros glandulosa* Lace
153	Ebenaceae	*Diospyros malabarica* (Desr.) Kostel. var. *malabarica*
154	Ebenaceae	*Diospyros montana* Roxb.
155	Ebenaceae	*Diospyros rhodocalyx* Kurz
156	Ebenaceae	*Diospyros variegata* Kurz

No.	Family	Botanical name
157	Elaeocarpaceae	*Elaeocarpus floribundus* Blume
158	Elaeocarpaceae	*Elaeocarpus braceanus* Watt ex C.B. Clarke
159	Elaeocarpaceae	*Elaeocarpus griffithii* (Wight) A. Gray
160	Elaeocarpaceae	*Elaeocarpus macrocerus* (Turcz.) Merr.
161	Elaeocarpaceae	*Elaeocarpus prunifolius* Wall ex Mull. Berol
162	Elaeocarpaceae	*Sloanea sigun* (Blume) K. Schum.
163	Elaeocarpaceae	*Sloanea tomentosa* (Benth.) Rehder & E. H.Wilson
164	Ericaceae	*Craibiodendron stellatum* (Pierre) W.W. Sm.
165	Ericaceae	*Rhododendron delavayi* Franch.
166	Ericaceae	*Rhododendron ludwigianum* Hosseus
167	Euphorbiaceae	*Balakata baccata* (Roxb.) Esser
168	Euphorbiaceae	*Blumeodendron kurzii* (Hook.f.) Sm.
169	Euphorbiaceae	*Cleidion javanicum* Blume
170	Euphorbiaceae	*Croton persimilis* Müll. Arg.
171	Euphorbiaceae	*Elateriospermum tapos* Blume
172	Euphorbiaceae	*Excoecaria agallocha* L.
173	Euphorbiaceae	*Falconeria insignis* Royle
174	Euphorbiaceae	*Macaranga pruinosa* (Miq.) Mull.Arg.
175	Euphorbiaceae	*Mallotus philippensis* (Lam.) Mull.Arg.
176	Euphorbiaceae	*Shirakiopsis indica* (Willd.) Esser
177	Euphorbiaceae	*Suregada multiflorum* (A. Juss.) Baill.
178	Fabaceae	*Acacia harmandiana* (Pierre) Gagnep.
179	Fabaceae	*Acacia leucophloea* (Roxb.) Willd.
180	Fabaceae	*Acacia tomentosa* Willd.
181	Fabaceae	*Acrocarpus fraxinifolius* Wight ex Arn.
182	Fabaceae	*Adenanthera pavonina* L.
183	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib
184	Fabaceae	*Albizia chinensis* (Osbeck) Merr.
185	Fabaceae	*Albizia lebbeck* (L.) Benth.
186	Fabaceae	*Albizia lebbeckoides* (DC.) Benth.
187	Fabaceae	*Albizia lucidior* (Steud.) I.C.Nielsen
188	Fabaceae	*Albizia odoratissima* (L.f.) Benth.
189	Fabaceae	*Albizia procera* (Roxb.) Benth.
190	Fabaceae	*Archidendron jiringa* (Jack) I.C.Nielsen
191	Fabaceae	*Archidendron quocense* (Pierre) I.C.Nielsen
192	Fabaceae	*Bauhinia malabarica* Roxb.
193	Fabaceae	*Bauhinia variegata* L.
194	Fabaceae	*Butea monosperma* (Lam.) Taub.
195	Fabaceae	*Callerya atropurpurea* (Wall.) Schot
196	Fabaceae	*Cassia bakeriana* Craib
197	Fabaceae	*Cassia fistula* L.
198	Fabaceae	*Cathormion umbellatum* (Vahl) Kosterm.
199	Fabaceae	*Cynometra malaccensis* Meeuwen
200	Fabaceae	*Cynometra ramiflora* L.
201	Fabaceae	*Dalbergia cultrata* Graham. ex Benth.

No.	Family	Botanical name
202	Fabaceae	*Dialium cochinchinense* Pierre
203	Fabaceae	*Dialium indum* L.
204	Fabaceae	*Dialium patens* Baker
205	Fabaceae	*Dialium platysepalum* Baker
206	Fabaceae	*Erythrina subumbrans* (Hassk.) Merr.
207	Fabaceae	*Intsia bijuga* (Colebr.) Kuntze
208	Fabaceae	*Intsia palembanica* Miq.
209	Fabaceae	*Koompassia excelsa* (Becc.) Taub.
210	Fabaceae	*Koompassia malaccensis* Maingay ex Benth.
211	Fabaceae	*Parkia leiophylla* Kurz
212	Fabaceae	*Parkia speciosa* Hassk.
213	Fabaceae	*Parkia sumatrana* Miq. subsp. *sterptocarpa* (Hance) H.C.Hopkins
214	Fabaceae	*Parkia timoriana* (DC.) Merr.
215	Fabaceae	*Pterocarpus macrocarpus* Kurz
216	Fabaceae	*Saraca declinata* (Jack) Miq.
217	Fabaceae	*Saraca indica* L.
218	Fabaceae	*Saraca thaipingensis* Cantley ex Prain
219	Fabaceae	*Senna garrettiana* (Craib) H.S.Irwin & Barneby
220	Fabaceae	*Sindora echinocalyx* Prain
221	Fabaceae	*Sindora siamensis* Teijsm. & Miq. var. *maritima* (Pierre) K. Larsen & S.S. Larsen
222	Fabaceae	*Sindora siamensis* Teijsm. ex Miq. var. *siamensis*
223	Fabaceae	*Xylia xylocarpa* (Roxb.) W. Theob. var. *kerrii* (Craib & Hutch.) I. C. Nielsen
224	Fagaceae	*Castanopsis acuminatissima* (Blume) A.DC.
225	Fagaceae	*Castanopsis argyrophylla* King ex Hook.f.
226	Fagaceae	*Castanopsis armata* (Roxb.) Spach
227	Fagaceae	*Castanopsis calathiformis* (Skan) Rehder & E.H. Wilson
228	Fagaceae	*Castanopsis diversifolia* (Kurz) King ex Hook.f.
229	Fagaceae	*Castanopsis echinocarpa* Miq.
230	Fagaceae	*Castanopsis ferox* (Roxb.) Spach
231	Fagaceae	*Castanopsis fissa* (Champ. ex Benth.) Rehder & E.H.Wilson
232	Fagaceae	*Castanopsis hystrix* Hook.f. & Thomson ex A. DC.
233	Fagaceae	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.
234	Fagaceae	*Castanopsis piriformis* Hickel & A.Camus
235	Fagaceae	*Castanopsis purpurea* Barnett
236	Fagaceae	*Castanopsis rhamnifolia* (Miq.) A. DC.
237	Fagaceae	*Castanopsis tribuloides (*Sm.) A. DC.
238	Fagaceae	*Castanopsis wallichii* King ex Hook.f.
239	Fagaceae	*Lithocarpus aggregatus* Barnett
240	Fagaceae	*Lithocarpus auriculatus* (Hickel & A. Camus) Barnett
241	Fagaceae	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder
242	Fagaceae	*Lithocarpus elegans* (Blume) Hatus ex Soepadmo
243	Fagaceae	*Lithocarpus fenestratus* (Roxb.) Rehder
244	Fagaceae	*Lithocarpus garrettianus* (Craib) A. Camus

No.	Family	Botanical name
245	Fagaceae	*Lithocarpus lindleyanus* (Wall. ex A. DC.) A. Camus
246	Fagaceae	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehder
247	Fagaceae	*Lithocarpus recurvatus* Barnett
248	Fagaceae	*Lithocarpus sootepensis* (Craib) A. Camus
249	Fagaceae	*Lithocarpus thomsonii* (Miq.) Rehder
250	Fagaceae	*Lithocarpus trachycarpus* (Hickel & A. Camus) A. Camus
251	Fagaceae	*Lithocarpus truncatus* (King ex. Hook.f.) Rehder
252	Fagaceae	*Quercus aliena* Blume subsp. *aliena*
253	Fagaceae	*Quercus brandisiana* Kurz
254	Fagaceae	*Quercus chapensis* lineata Blume
255	Fagaceae	*Quercus eumorpha* Kurz
256	Fagaceae	*Quercus franchetii* Skan
257	Fagaceae	*Quercus helferiana* A. DC
258	Fagaceae	*Quercus kerrii* Craib
259	Fagaceae	*Quercus kingiana* Craib
260	Fagaceae	*Quercus lamellosa* Sm.
261	Fagaceae	*Quercus lanata* Sm.
262	Fagaceae	*Quercus lenticellata* Barnett
263	Fagaceae	*Quercus mespilifolia* Wall. ex A. DC
264	Fagaceae	*Quercus myrsinaefolia* Blume
265	Fagaceae	*Quercus oidocarpa* Korth.
266	Fagaceae	*Quercus poilanei* Hick. & A. Camus
267	Fagaceae	*Quercus ramsbottomii* A. Camus
268	Fagaceae	*Quercus semecarpifolia* Sm.
269	Fagaceae	*Quercus semiserrata* Roxb.
270	Fagaceae	*Quercus vestita* Griff.
271	Gentianaceae	*Fagraea fragrans* Roxb.
272	Hamamelidaceae	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.
273	Hernandiaceae	*Hernandia nymphaeifolia* (J.Presl) Kubitzki
274	Icacinaceae	*Pittosporopsis kerrii* Craib
275	Icacinaceae	*Stemonurus secundiflorus* Blume
276	Irvingiaceae	*Irvingia malayana* Oliv. ex A.W. Benn.
277	Juglandaceae	*Engelhardtia spicata* Lechen ex Blume var. *spicata*
278	Lamiaceae	*Gmelina arborea* Roxb.
279	Lamiaceae	*Premna tomentosa* Willd.
280	Lamiaceae	*Tectona grandis* L.f.
281	Lamiaceae	*Vitex canescens* Kurz
282	Lamiaceae	*Vitex limonifolia* Wall. ex Walp.
283	Lamiaceae	*Vitex peduncularis* Wall. ex Schauer
284	Lamiaceae	*Vitex pinnata* L.
285	Lamiaceae	*Vitex quinata* (Lour.) F.N. Williams
286	Lamiaceae	*Volkameria inermis* L.
287	Lauraceae	*Actinodaphne henryi* Gamble
288	Lauraceae	*Beilschmiedia gammieana* King ex Hook.f.
289	Lauraceae	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet

No.	Family	Botanical name
290	Lauraceae	*Cinnamomum glaucescens* (Nees) Hand.-Mazz
291	Lauraceae	*Cinnamomum ilicioides* A. Chev.
292	Lauraceae	*Cinnamomum iners* Reinw. ex Blume
293	Lauraceae	*Cinnamomum subavenium* Miq.
294	Lauraceae	*Cinnamomum tamala* (Buch.-Ham) T. Nee & Eberm.
295	Lauraceae	*Litsea beusekomii* Kosterm.
296	Lauraceae	*Litsea martabarnica* (Kurz) Hook.f.
297	Lauraceae	*Litsea monopetala* (Roxb.) Pers.
298	Lauraceae	*Litsea semecarpifolia* (Wall ex Nees) Hook
299	Lauraceae	*Neocinnamomum caudatum* (Nees) Merrs.
300	Lauraceae	*Persea gamblei* (Hook.f.) Kosterm.
301	Lauraceae	*Phoebe lanceolata* (Nees) Nees
302	Lauraceae	*Phoebe paniculata* (Nees) Nees
303	Lauraceae	*Phoebe tavoyana* (Meisn.) Hook.f.
304	Lecythidaceae	*Barringtonia asiatica* (L.) Kurz
305	Lecythidaceae	*Barringtonia racemosa* (L.) Spreng.
306	Lecythidaceae	*Careya arborea* Roxb.
307	Loganiaceae	*Strychnos nux-vomica* L.
308	Loganiaceae	*Styrax benzoides* Craib
309	Lythraceae	*Lagerstroemia calyculata* Kurz
310	Lythraceae	*Lagerstroemia cochinchinensis* Pierre
311	Lythraceae	*Lagerstroemia macrocarpa* Wall. ex Kurz
312	Lythraceae	*Lagerstroemia speciosa* (L.) Pers.
313	Lythraceae	*Lagerstroemia tomentosa* C. Presl
314	Lythraceae	*Lagerstroemia venusta* Wall. ex C.B.Clarke
315	Lythraceae	*Lagerstroemia villosa* Wall. ex Kurz
316	Lythraceae	*Pemphis acidula* J.R. Forst. & G. Forst.
317	Lythraceae	*Sonneratia alba* Sm.
318	Lythraceae	*Sonneratia caseolaris* (L.) Engl.
319	Lythraceae	*Sonneratia griffithii* Kurz
320	Magnoliaceae	*Magnolia baillonii* Pierre
321	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*
322	Magnoliaceae	*Magnolia floribunda* (Finet & Gagnep.) Figlar
323	Magnoliaceae	*Magnolia garrettii* (Craib) V.S.Kumar
324	Magnoliaceae	*Magnolia henryi* Dunn
325	Magnoliaceae	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng
326	Magnoliaceae	*Magnolia liliifera* (L.) Baill
327	Magnoliaceae	*Magnolia rajaniana* (Craib) Figlar
328	Malvaceae	*Berrya cordifolia* (Willd.) Burret
329	Malvaceae	*Berrya mollis* Wall. ex Kurz
330	Malvaceae	*Bombax anceps* Pierre
331	Malvaceae	*Colona flagrocarpa* (C.B. Clarke) Craib
332	Malvaceae	*Durio griffithii* (Mast.) Bakh.
333	Malvaceae	*Durio lowianus* Scort. ex King
334	Malvaceae	*Firmiana colorata* (Roxb.) R.Br.

No.	Family	Botanical name
335	Malvaceae	*Heritiera javanica* (Blume) Kosterm.
336	Malvaceae	*Heritiera littoralis* Aiton
337	Malvaceae	*Heritiera sumatrana* (Miq.) Kosterm.
338	Malvaceae	*Kydia calycina* Roxb.
339	Malvaceae	*Neesia altissima* (Blume) Blume
340	Malvaceae	*Neesia malayana* Bakh.
341	Malvaceae	*Pterocymbium tinctorium* (Blanco) Merr.
342	Malvaceae	*Pterygota alata* (Roxb.) R.Br.
343	Malvaceae	*Scaphium linearicarpum* (Mast.) Pierre
344	Malvaceae	*Scaphium scaphigerum* (Wall. ex G.Don) G.Planch.
345	Malvaceae	*Sterculia foetida* L.
346	Malvaceae	*Sterculia pexa* Pierre
347	Malvaceae	*Sterculia villosa* Roxb.
348	Malvaceae	*Thespesia lampas* (Cav.) Dalzell & A. Gibson var. *lampas*
349	Malvaceae	*Thespesia populnea* (L.) Soland. ex Corr.
350	Melastomataceae	*Memecylon scutellatum* (Lour.) Hook. & Arn. var. *scutellatum*
351	Meliaceae	*Aglaia chittagonga* Miq.
352	Meliaceae	*Aglaia rubiginosa* (Hiern) Pannell
353	Meliaceae	*Aglaia silvestris* (M.Roem.) Merr.
354	Meliaceae	*Aphanamixis polystachya* (Wall.) R. Parker
355	Meliaceae	*Azadirachta indica* A.Juss
356	Meliaceae	*Chisocheton patens* Blume
357	Meliaceae	*Chukrasia tabularis* A.Juss.
358	Meliaceae	*Melia azedarach* L.
359	Meliaceae	*Sandoricum koetjape* (Burm.f.) Merr.
360	Meliaceae	*Sandoricum beccarianum* Baill.
361	Meliaceae	*Toona ciliata* M. Roem.
362	Meliaceae	*Walsura robusta* Roxb.
363	Meliaceae	*Walsura trichostemon* Miq.
364	Meliaceae	*Xylocarpus moluccensis* (Lam.) M. Roem.
365	Meliaceae	*Xylocarpus granatum* J. Koenig
366	Meliaceae	*Xylocarpus rumphii* (Kostel.) Mabb.
367	Moraceae	*Artocarpus dadah* Miq.
368	Moraceae	*Artocarpus elasticus* Reinw. ex Blume
369	Moraceae	*Artocarpus lacucha* Buch.-Ham.
370	Moraceae	*Artocarpus lanceifolius* Roxb.
371	Moraceae	*Artocarpus rigidus* Blume
372	Moraceae	*Ficus albipila* (Miq.) King
373	Moraceae	*Ficus racemosa* Linn.
374	Moraceae	*Streblus asper* Lour.
375	Moraceae	*Streblus ilicifolius* (S.Vidal) Corner
376	Myricaceae	*Myrica esculenta* Buch-Ham ex D.Don
377	Myristicaceae	*Horsfieldia amygdalina* (Wall.) Warb. var. *amygdalina*
378	Myristicaceae	*Horsfieldia crassifolia* (Hook.f.et.Th.) Warb.
379	Myristicaceae	*Horsfieldia irya* (Gaertn.) Warb.

No.	Family	Botanical name
380	Myristicaceae	*Myristica elliptica* Wall. ex Hook.f. & Thomson
381	Myristicaceae	*Myristica iners* Blume
382	Myrtaceae	*Baeckea frutescens* L.
383	Myrtaceae	*Melaleuca cajuputi* Powell
384	Myrtaceae	*Syzygium angkae* (Craib) Chantar. & J.Parn subsp. *Angkae*
385	Myrtaceae	*Syzygium antisepticum* (Blume) Merr. & L. M. Perry
386	Myrtaceae	*Syzygium cumini* (L.) Skeels
387	Myrtaceae	*Syzygium grande* (Wight) Walp. var. *grande*
388	Myrtaceae	*Syzygium megacarpum* (Craib) Rathakr. & N.C. Nair
389	Myrtaceae	*Syzygium oblatum* (Roxb.) Wall. ex A.M. Cowan & Cowan var. *oblatum*
390	Myrtaceae	*Tristaniopsis burmanica* (Griff.) Peter G. Wilson & J.T. Waterh. var. *rufescens* (Hance) J. Parn.& Nic Lughadha
391	Ochnaceae	*Ochna integerrima* (Lour.) Merr.
392	Oleaceae	*Fraxinus floribunda* Wall.
393	Oleaceae	*Olea salicifolia* Wall. ex G. Don
394	Oleaceae	*Schrebera swietenioides* Roxb.
395	Opiliaceae	*Melientha suavis* Pierre
396	Paulowniaceae	*Wightia speciosissima* (D. Don) Merr.
397	Pentaphylacaceae	*Adinandra integerrima* T. Anderson ex Dyer
398	Pentaphylacaceae	*Anneslea fragrans* Wall.
399	Pentaphylacaceae	*Eurya acuminata* DC. var. *acuminata*
400	Pentaphylacaceae	*Eurya nitida* Korth.
401	Pentaphylacaceae	*Ternstroemia gymnanthera* (Wight & Arn.) Bedd.
402	Peraceae	*Chaetocarpus castanocarpus* (Roxb.) Thwaites
403	Phyllanthaceae	*Antidesma acidum* Retz.
404	Phyllanthaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.
405	Phyllanthaceae	*Baccaurea bracteata* Mull. Arg.
406	phyllanthaceae	*Baccaurea ramiflora* Lour.
407	Phyllanthaceae	*Bischofia javanica* Blume
408	Phyllanthaceae	*Hymenocardia punctata* Wall. ex Lindl.
409	Phyllanthaceae	*Phyllanthus emblic*a L.
410	Phyllanthaceae	*Phyllanthus reticulatus* Poir.
411	Pinaceae	*Pinus kesiya* Royle ex Gordon
412	Pinaceae	*Pinus merkusii* Jungh. & de Vriese
413	Podocarpaceae	*Dacrydium elatum* (Roxb.) Wall. ex Hook.
414	Podocarpaceae	*Nageia motleyi* (C.Presl) de Laub.
415	Podocarpaceae	*Nageia wallichiana* (C.Presl) Kuntze
416	Podocarpaceae	*Podocarpus motleyi* (Parl.) Dummer
417	Podocarpaceae	*Podocarpus neriifolius* D.Don
418	Podocarpaceae	*Podocarpus polystachyus* R. Br. ex Endl.
419	Polygalaceae	*Xanthophyllum lanceatum* J.J.Sm.
420	Polygalaceae	*Xanthophyllum virens* Roxb.
421	Proteaceae	*Helicia formosana* Hemsl. var. *oblanceolata* Sleumer
422	Proteaceae	*Helicia nilagirica* Bedd.

No.	Family	Botanical name
423	Proteaceae	*Helicia vestita* W.W. Sm.
424	Proteaceae	*Heliciopsis terminalis* (Kurz) Sleumer
425	Putranjivaceae	*Putranjiva roxburghii* Wall.
426	Rhizophoraceae	*Bruguiera parviflora* (Roxb.) Wight & Arn. ex Griff.
427	Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.
428	Rhizophoraceae	*Rhizophora apiculata* Blume
429	Rhizophoraceae	*Rhizophora mucronata* Poir.
430	Rosaceae	*Eriobotrya bengalensis* (Roxb.) Hook.f.
431	Rosaceae	*Prunus cerasoides* D.Don
432	Rosaceae	*Sorbus corymbifera* (Miq.) T. H. Nguyen & Yakovlev
433	Rubiaceae	*Aidia parvifolia* (King & Gamble) K.M. Wong
434	Rubiaceae	*Catunaregam tomentosa* (Blume ex DC.) Tirveng.
435	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz
436	Rubiaceae	*Gardenia saxatilis* Geddes
437	Rubiaceae	*Gardenia sootepensis* Hutch.
438	Rubiaceae	*Guettarda speciosa* L.
439	Rubiaceae	*Haldina cordifolia* (Roxb.) Ridsdale
440	Rubiaceae	*Hymenodictyon orixense* (Roxb.) Mabb.
441	Rubiaceae	*Ixora grandifolia* Zoll. & Moritzi
442	Rubiaceae	*Luculia gratissima* (Wall.) Sweet var. *glabra* Fukuoka
443	Rubiaceae	*Mitragyna diversifolia* (Wall. ex G. Don) Havil
444	Rubiaceae	*Mitragyna hirsuta* Havil
445	Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze
446	Rubiaceae	*Nauclea orientalis* (L.) L.
447	Rubiaceae	*Nauclea subdita* (Korth.) Steud.
448	Rubiaceae	*Neolamarckia cadamba* (Roxb.) Bosser
449	Rubiaceae	*Ochreinauclea maingayi* (Hook.f.) Ridsdale
450	Rubiaceae	*Psydrax dicoccos* Gaertn.
451	Rubiaceae	*Wendlandia tinctoria* (Roxb.) DC.
452	Rutaceae	*Atalantia monophylla* (L.) DC.
453	Rutaceae	*Feroniella lucida* (Scheff.) Swingle
454	Rutaceae	*Naringi crenulata* (Roxb.) Nicolson
455	Sabiaceae	*Meliosma pinnata* (Roxb.) Maxim. subsp. *barbulata* (Cufod.) Welzen
456	Salicaceae	*Flacourtia indica* (Burm.f.) Merr.
457	Salicaceae	*Homalium ceylanicum* (Gardner) Benth.
458	Salicaceae	*Homalium foetidum* (Roxb.) Benth.
459	Salicaceae	*Homalium grandiflorum* Benth.
460	Salicaceae	*Homalium tomentosum* (Vent.) Benth.
461	Salicaceae	*Salix tetrasperma* Roxb.
462	Santalaceae	*Scleropyrum pentandrum* (Dennst.) Mabb.
463	Sapindaceae	*Acer calcaratum* Gagnep.
464	Sapindaceae	*Acer laurinum* Hassk.
465	Sapindaceae	*Acer oblongum* Wall. ex DC.
466	Sapindaceae	*Aesculus assamica* Griff.

No.	Family	Botanical name
467	Sapindaceae	*Arfeuillea arborescens* Pierre ex Radlk.
468	Sapindaceae	*Dimocarpus longan* Lour. var. *longan*
469	Sapindaceae	*Nephelium hypoleucum* Kurz
470	Sapindaceae	*Nephelium maingayi* Hiern
471	Sapindaceae	*Nephelium melliferum* Gagnep.
472	Sapindaceae	*Paranephelium xestophyllum* Miq.
473	Sapindaceae	*Pometia pinnata* J.R. & G. Forst.
474	Sapindaceae	*Sapindus rarak* DC.
475	Sapindaceae	*Schleichera oleosa* (Lour) Merr.
476	Sapindaceae	*Sisyrolepis muricata* (Pierre) Leenh.
477	Sapindaceae	*Zollingeria dongnaiensis* Pierre
478	Sapotaceae	*Madhuca motleyana* (de Vriese) J. F. Macbr.
479	Sapotaceae	*Manilkara hexandra* (Roxb.) Dubard
480	Sapotaceae	*Palaquium obovatum* (Griff.) Engl.
481	Sapotaceae	*Pouteria obovata* (R.Br.) Baehni
482	Simaroubaceae	*Ailanthus triphysa* (Dennst.) Alston
483	Simaroubaceae	*Picrasma javanica* Blume
484	Staphyleaceae	*Turpinia cochinchinensis* (Lour.) Merr.
485	Stemonuraceae	*Stemonurus secundiflorus* Blume
486	Symplocaceae	*Symplocos cochinchinensis* (Lour.) S. Moore var. *cochinchinensis*
487	Symplocaceae	*Symplocos dryophila* C.B. Clarke
488	Symplocaceae	*Symplocos racemosa* Roxb.
489	Symplocaceae	*Symplocos sumuntia* Buch.-Ham. ex D. Don
490	Tetramelaceae	*Tetrameles nudiflora* R.Br.
491	Theaceae	*Camellia connata* (Craib) Craib
492	Theaceae	*Camellia oleifera* C.Abel. var. *confusa* (Craib) Sealy
493	Theaceae	*Gordonia dalglieshiana* Craib
494	Theaceae	*Pyrenaria diospyricarpa* Kurz var. *camelliflora* (Kurz) S.X.Yang
495	Theaceae	*Pyrenaria diospyricarpa* Kurz var. *diospyricarpa*
496	Theaceae	*Schima wallichii* (DC.) Korth.
497	Thymelaeaceae	*Aquilaria malaccensis* Lam.
498	Ulmaceae	*Holoptelea integrifolia* Planch.
499	Ulmaceae	*Ulmus lancifolia* Roxb. ex Wall
500	Zingiberaceae	*Kaempferia rotunda* L.

Table A4 List of tree species of 5 families: Magnoliaceae, Dipterocarpaceae, Fagaceae, Fabaceae (or Leguminosae) and Ebenaceae

No.	Family	Botanical name
1	Dipterocarpaceae	*Anisoptera costata* Korth.
2	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King
3	Dipterocarpaceae	*Anisoptera laevis* Ridl.
4	Dipterocarpaceae	*Anisoptera scaphula* (Roxb.) Kurz
5	Dipterocarpaceae	*Cotylelobium lanceolatum* Craib
6	Dipterocarpaceae	*Dipterocarpus acutangulus* Vesque
7	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don
8	Dipterocarpaceae	*Dipterocarpus baudii* Korth.
9	Dipterocarpaceae	*Dipterocarpus chartaceus* Symington
10	Dipterocarpaceae	*Dipterocarpus costatus* C.F.Gaertn.
11	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.
12	Dipterocarpaceae	*Dipterocarpus gracilis* Blume
13	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco
14	Dipterocarpaceae	*Dipterocarpus grandifolius* Teijsm. ex Miq.
15	Dipterocarpaceae	*Dipterocarpus hasseltii* Blume
16	Dipterocarpaceae	*Dipterocarpus intricatus* Dyer
17	Dipterocarpaceae	*Dipterocarpus kerrii* King
18	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.
19	Dipterocarpaceae	*Dipterocarpus retusus* Blume
20	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.
21	Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.
22	Dipterocarpaceae	*Hopea beccariana* Burck
23	Dipterocarpaceae	*Hopea ferrea* Laness.
24	Dipterocarpaceae	*Hopea griffithii* Kurz
25	Dipterocarpaceae	*Hopea helferi* (Dyer) Brandis
26	Dipterocarpaceae	*Hopea latifolia* Symington
27	Dipterocarpaceae	*Hopea oblongifolia* Dyer
28	Dipterocarpaceae	*Hopea odorata* Roxb.
29	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington
30	Dipterocarpaceae	*Hopea pierrei* Hance
31	Dipterocarpaceae	*Hopea recopei* Pierre ex Laness.
32	Dipterocarpaceae	*Hopea sangal* Korth.
33	Dipterocarpaceae	*Hopea sublanceolata* Symington
34	Dipterocarpaceae	*Hopea thorelii* Pierre
35	Dipterocarpaceae	*Neobalanocarpus heimii* (King) P.S.Ashton
36	Dipterocarpaceae	*Parashorea densiflora* Slooten & Symington subsp. *kerrii* (Tardieu) R.Pooma
37	Dipterocarpaceae	*Parashorea stellata* Kurz
38	Dipterocarpaceae	*Shorea assamica* Dyer
39	Dipterocarpaceae	*Shorea assamica* Dyer subsp. *globifera* (Ridl.) Y.K.Yang & J.K.Wu
40	Dipterocarpaceae	*Shorea bracteolata* Dyer
41	Dipterocarpaceae	*Shorea curtisii* Dyer ex King
42	Dipterocarpaceae	*Shorea faguetiana* F.Heim
43	Dipterocarpaceae	*Shorea farinosa* C.E.C.Fisch.
44	Dipterocarpaceae	*Shorea glauca* King
45	Dipterocarpaceae	*Shorea gratissima* (Wall. ex Kurz) Dyer
46	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume
47	Dipterocarpaceae	*Shorea henryana* Pierre
48	Dipterocarpaceae	*Shorea hypochra* Hance

No.	Family	Botanical name
49	Dipterocarpaceae	*Shorea laevis* Ridl.
50	Dipterocarpaceae	*Shorea leprosula* Miq.
51	Dipterocarpaceae	*Shorea macroptera* Dyer
52	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume
53	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*
54	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *velutinata* P.S.Ashton
55	Dipterocarpaceae	*Shorea roxburghii* G.Don
56	Dipterocarpaceae	*Shorea siamensis* Miq.
57	Dipterocarpaceae	*Shorea singkawang* (Miq.) Miq.
58	Dipterocarpaceae	*Shorea sumatrana* (Slooten ex Thorenaar) Symington ex Desch
59	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.
60	Dipterocarpaceae	*Vatica bella* Slooten
61	Dipterocarpaceae	*Vatica diospyroides* Symington
62	Dipterocarpaceae	*Vatica harmandiana* Pierre
63	Dipterocarpaceae	*Vatica mangachapoi* subsp. *obtusifolia* (Elmer) P.S.Ashton
64	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington
65	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume
66	Dipterocarpaceae	*Vatica philastreana* Pierre
67	Dipterocarpaceae	*Vatica stapfiana* (King) Slooten
68	Dipterocarpaceae	*Vatica umbonata* (Hook.f.) Burck
69	Ebenaceae	*Diospyros andamanica* (Kurz) Bakh.
70	Ebenaceae	*Diospyros apiculata* Hiern
71	Ebenaceae	*Diospyros areolata* King & Gamble
72	Ebenaceae	*Diospyros bambuseti* H.R.Fletcher
73	Ebenaceae	*Diospyros bejaudii* Lecomte
74	Ebenaceae	*Diospyros buxifolia* (Blume) Hiern
75	Ebenaceae	*Diospyros castanea* (Craib) H.R.Fletcher
76	Ebenaceae	*Diospyros cauliflora* Blume
77	Ebenaceae	*Diospyros coaetanea* H.R.Fletcher
78	Ebenaceae	*Diospyros collinsae* Craib
79	Ebenaceae	*Diospyros confertiflora* (Hiern) Bakh.
80	Ebenaceae	*Diospyros curranii* Merr.
81	Ebenaceae	*Diospyros dasyphylla* Kurz
82	Ebenaceae	*Diospyros defectrix* H.R.Fletcher
83	Ebenaceae	*Diospyros dictyoneura* Hiern
84	Ebenaceae	*Diospyros diepenhorstii* Miq.
85	Ebenaceae	*Diospyros dumetorum* W.W.Sm.
86	Ebenaceae	*Diospyros ehretioides* Wall. ex G.Don
87	Ebenaceae	*Diospyros filipendula* Pierre ex Lecomte
88	Ebenaceae	*Diospyros frutescens* Blume
89	Ebenaceae	*Diospyros fulvopilosa* H.R.Fletcher
90	Ebenaceae	*Diospyros glandulosa* Lace
91	Ebenaceae	*Diospyros gracilis* H.R.Fletcher
92	Ebenaceae	*Diospyros hasseltii* Zoll.
93	Ebenaceae	*Diospyros insidiosa* Bakh.
94	Ebenaceae	*Diospyros kerrii* Craib
95	Ebenaceae	*Diospyros kurzii* Hiern.
96	Ebenaceae	*Diospyros lanceifolia* Roxb.
97	Ebenaceae	*Diospyros latisepala* Ridl.
98	Ebenaceae	*Diospyros longipilosa* Phengklai
99	Ebenaceae	*Diospyros malabarica* (Desv.) Kostel.
100	Ebenaceae	*Diospyros mollis* Griff.

No.	Family	Botanical name
101	Ebenaceae	*Diospyros montana* Roxb.
102	Ebenaceae	*Diospyros oblonga* Wall ex G.Don
103	Ebenaceae	*Diospyros pilosanthera* Blanco
104	Ebenaceae	*Diospyros pilosiuscula* G.Don
105	Ebenaceae	*Diospyros pilosula* (A.DC.) Hiern.
106	Ebenaceae	*Diospyros racemosa* Roxb.
107	Ebenaceae	*Diospyros rdefectrix* H.R.Fletcher
108	Ebenaceae	*Diospyros rhodocalyx* Kurz
109	Ebenaceae	*Diospyros scalariformis* H.R.Fletcher
110	Ebenaceae	*Diospyros scortechinii* King & Gamble
111	Ebenaceae	*Diospyros sumatrana* Miq.
112	Ebenaceae	*Diospyros thaiensis* Phengklai
113	Ebenaceae	*Diospyros transitoria* Bakh.
114	Ebenaceae	*Diospyros trianthos* Phengklai
115	Ebenaceae	*Diospyros undulata* Wall. ex G. Don
116	Ebenaceae	*Diospyros variegata* Kurz
117	Ebenaceae	*Diospyros venosa* Wall. ex A.DC.
118	Ebenaceae	*Diospyros vera* (Lour.) A. Chev.
119	Ebenaceae	*Diospyros wallichii* King & Gamble
120	Ebenaceae	*Diospyros winitii* H.R.Fletcher
121	Fabaceae	*Acacia harmandiana* (Pierre) Gagnep.
122	Fabaceae	*Acacia leucophloea* (Roxb.) Willd.
123	Fabaceae	*Acacia mangium* Willd.
124	Fabaceae	*Acacia meanrsii* De Wild.
125	Fabaceae	*Acacia tomentosa* Willd.
126	Fabaceae	*Acrocarpus fraxinifolius* Wight ex Arn.
127	Fabaceae	*Adenanthera pavonina* L.
128	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib
129	Fabaceae	*Albizia attopeuensis* (Pierre) I.C.Nielsen
130	Fabaceae	*Albizia chinensis* (Osb.) Merr.
131	Fabaceae	*Albizia garrettii* I.C.Nielsen
132	Fabaceae	*Albizia lebbeck* (L.) Benth.
133	Fabaceae	*Albizia lebbeckoides* (DC.) Benth.
134	Fabaceae	*Albizia lucidior* (Steud.) I.C.Nielsen
135	Fabaceae	*Albizia odoratissima* (L.f.) Benth.
136	Fabaceae	*Albizia procera* (Roxb.) Benth.
137	Fabaceae	*Albizia vialeana* Pierre
138	Fabaceae	*Antheroporum glaucum* Z. Wei
139	Fabaceae	*Archidendron bubalinum* (Jack) I.C.Nielsen
140	Fabaceae	*Archidendron clypearia* (Jack) I.C.Nielsen
141	Fabaceae	*Archidendron conspicuum* (Craib) I.C.Nielsen
142	Fabaceae	*Archidendron contortum* (Mart.) I.C.Nielsen
143	Fabaceae	*Archidendron ellipticum* (Blume) I.C.Nielsen
144	Fabaceae	*Archidendron jiringa* (Jack) I.C.Nielsen
145	Fabaceae	*Archidendron lucidum* (Benth.) I.C.Nielsen
146	Fabaceae	*Archidendron quocense* (Pierre) I.C.Nielsen
147	Fabaceae	*Bauhinia malabarica* Roxb.
148	Fabaceae	*Bauhinia saccocalyx* Pierre
149	Fabaceae	*Bauhinia variegata* L.
150	Fabaceae	*Butea monosperma* (Lam.) Taub.
151	Fabaceae	*Callerya atropurpurea* (Wall.) Schot
152	Fabaceae	*Cassia bakeriana* Craib
153	Fabaceae	*Cassia fistula* L.

No.	Family	Botanical name
154	Fabaceae	*Castanopsis fissa* (Champ. ex Benth.) Rehder & E.H.Wilson
155	Fabaceae	*Castanopsis hystrix* Hook.f. & Thomson ex A. DC.
156	Fabaceae	*Castanopsis megacarpa* Gamble
157	Fabaceae	*Castanopsis rhamnifolia* (Miq.) A. DC.
158	Fabaceae	*Cathormion umbellatum* (Vahl) Kosterm.
159	Fabaceae	*Crudia caudata* Prain ex King
160	Fabaceae	*Crudia gracilis* Prain
161	Fabaceae	*Crudia lanceolatum* Ridl.
162	Fabaceae	*Crudia speciosa* Prain
163	Fabaceae	*Cynometra malaccensis* Meeuwen
164	Fabaceae	*Cynometra craibii* Gagnep.
165	Fabaceae	*Dalbergia cana* Graham. ex Kurz var. *kurzii* (Prain) Niyomdham
166	Fabaceae	*Dalbergia cochinchinensis* Pierre
167	Fabaceae	*Dalbergia cultrata* Graham. ex Benth.
168	Fabaceae	*Dalbergia lanceolaria* L.f.
169	Fabaceae	*Dalbergia nigrescens* Kurz
170	Fabaceae	*Dalbergia oliveri* Gamble ex Prain
171	Fabaceae	*Dalbergia velutina* Benth. var. *velutina*
172	Fabaceae	*Derris indica* (Lam.) Bennet
173	Fabaceae	*Dialium cochinchinense* Pierre
174	Fabaceae	*Erythrina stricta* Roxb. var. *stricta*
175	Fabaceae	*Erythrina subumbrans* (Hassk.) Merr.
176	Fabaceae	*Gymnocladus burmanicus* C.E. Parkinson
177	Fabaceae	*Intsia palembanica* Miq.
178	Fabaceae	*Koompassia excelsa* (Becc.) Taub.
179	Fabaceae	*Lithocarpus echinops* Hjelmq.
180	Fabaceae	*Lithocarpus siamensis* A. Camus
181	Fabaceae	*Lithocarpus xylocarpus* (Kurz) Markgr.
182	Fabaceae	*Millettia brandisiana* Kurz
183	Fabaceae	*Millettia leucantha* Kurz var. *leucantha*
184	Fabaceae	*Ormosia sumatrana* (Miq.) Prain
185	Fabaceae	*Parkia leiophylla* Kurz
186	Fabaceae	*Parkia speciosa* Hassk.
187	Fabaceae	*Parkia sumatrana* Miq. subsp. *sterptocarpa* (Hance) H.C.Hopkins
188	Fabaceae	*Parkia timoriana* (DC.) Merr.
189	Fabaceae	*Peltophorum dasyrrhachis* (Miq.) Kurz
190	Fabaceae	*Pterocarpus indicus* Willd.
191	Fabaceae	*Pterocarpus macrocarpus* Kurz
192	Fabaceae	*Quercus aliena* Blume subsp. *aliena*
193	Fabaceae	*Quercus eumorpha* Kurz
194	Fabaceae	*Quercus franchetii* Skan
195	Fabaceae	*Quercus lamellosa* Sm.
196	Fabaceae	*Quercus lanata* Sm.
197	Fabaceae	*Quercus lenticellatus* Barnett
198	Fabaceae	*Quercus lineatus* Blume var. *lailderbrandii* King
199	Fabaceae	*Quercus mespilifolia* Wall ex A. DC var. *mespilifoli*
200	Fabaceae	*Quercus poilanei* Hick. & A. Camus
201	Fabaceae	*Quercus semecarpifolia* Sm.
202	Fabaceae	*Quercus semiserrata* Roxb.
203	Fabaceae	*Quercus vestita* Griff.
204	Fabaceae	*Saraca thaipingensis* Cantley ex Prain

No.	Family	Botanical name
205	Fabaceae	*Saraca declinata* (Jack) Miq.
206	Fabaceae	*Saraca indica* L.
207	Fabaceae	*Senna garrettiana* (Craib) H.S.Irwin & Barneby
208	Fabaceae	*Senna siamea* (Lam.) H.S.Irwin & Barneby
209	Fabaceae	*Sindora echinocalyx* Prain
210	Fabaceae	*Sindora siamensis* Teijsm. Ex Miq.
211	Fabaceae	*Sindora siamensis* Teijsm. ex Miq. var. *siamensis*
212	Fabaceae	*Trigonobalanus doichangensis* (A. Camus) Forman
213	Fabaceae	*Xylia xylocarpa* (Roxb.) W. Theob. var. *kerrii* (Craib & Hutch.) I. C. Nielsen
214	Fabaceae	*Xylia xylocarpa* (Roxb.) W. Theob. var. *xylocarpa*
215	Fagaceae	*Castanopsis acuminatissima* (Blume) A.DC.
216	Fagaceae	*Castanopsis argentea* (Blume) A.DC.
217	Fagaceae	*Castanopsis argyrophylla* King ex Hook.f.
218	Fagaceae	*Castanopsis armata* (Roxb.) Spach
219	Fagaceae	*Castanopsis calathiformis* (Skan) Rehder & E.H. Wilson
220	Fagaceae	*Castanopsis cerebrina* (Hickel & A.Camus) Barnett
221	Fagaceae	*Castanopsis costata* (Blume) A.DC.
222	Fagaceae	*Castanopsis crassifolia* Hickel & A. Camus
223	Fagaceae	*Castanopsis diversifolia* (Kurz) King ex Hook.f.
224	Fagaceae	*Castanopsis echinocarpa* Miq.
225	Fagaceae	*Castanopsis ferox* (Roxb.) Spach
226	Fagaceae	*Castanopsis fissa* (Champ. ex Benth.) Rehder & E.H.Wilson
227	Fagaceae	*Castanopsis hystrix* Hook.f. & Thomson ex A. DC.
228	Fagaceae	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.
229	Fagaceae	*Castanopsis inermis* (Lindl.) Benth. & Hook.f.
230	Fagaceae	*Castanopsis megacarpa* Gamble
231	Fagaceae	*Castanopsis nephelioides* King ex Hook.f.
232	Fagaceae	*Castanopsis pierrei* Hance
233	Fagaceae	*Castanopsis piriformis* Hickel & A.Camus
234	Fagaceae	*Castanopsis pseudo-hystrix* Phengklai
235	Fagaceae	*Castanopsis purpurea* Barnett
236	Fagaceae	*Castanopsis rhamnifolia* (Miq.) A.DC.
237	Fagaceae	*Castanopsis tribuloides (*Sm.) A. DC.
238	Fagaceae	*Castanopsis wallichii* King ex Hook.f.
239	Fagaceae	*Lithocarpus aggregatus* Barnett
240	Fagaceae	*Lithocarpus cantleyanus* (King ex Hook.f.) Rehder
241	Fagaceae	*Lithocarpus clementianus* (King) A. Camus
242	Fagaceae	*Lithocarpus craibianus* Barnett
243	Fagaceae	*Lithocarpus curtisii* (King ex Hoof. f.) A.camus
244	Fagaceae	*Lithocarpus cyclocarpus* (Endl.) A.Camus
245	Fagaceae	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder
246	Fagaceae	*Lithocarpus echinop* Hjelmq.
247	Fagaceae	Lithocarpus echinophorus (Hickle & A. Camus) A.Camus
248	Fagaceae	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo
249	Fagaceae	*Lithocarpus eucalyptifolius* (Hickel & A. Camus) A. Camus
250	Fagaceae	*Lithocarpus falconeri* (Kurz) Rehder
251	Fagaceae	*Lithocarpus fenestratus* (Roxb.) Rehder
252	Fagaceae	*Lithocarpus garrettianus* (Craib) A. Camus
253	Fagaceae	*Lithocarpus harmandii* (Hickel & A. Camus) A. Camus
254	Fagaceae	*Lithocarpus lindleyanus* (Wall. ex A. DC.) A. Camus
255	Fagaceae	*Lithocarpus lucidus* (Roxb.) Rehder

No.	Family	Botanical name
256	Fagaceae	*Lithocarpus magnificus* (Brandis) Barnett
257	Fagaceae	*Lithocarpus pattaniensis* Barnett
258	Fagaceae	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehder
259	Fagaceae	*Lithocarpus rassa* (Miq.) Rehd.
260	Fagaceae	*Lithocarpus reinwardtii* (Korth.) A.Camus
261	Fagaceae	*Lithocarpus siamensis* A.Camus
262	Fagaceae	*Lithocarpus sootepensis* (Craib) A. Camus
263	Fagaceae	*Lithocarpus sundaicus* (Blume) Rehder
264	Fagaceae	*Lithocarpus thomsonii* (Miq.) Rehder
265	Fagaceae	*Lithocarpus trachycarpus* (Hickel & A. Camus) A. Camus
266	Fagaceae	*Lithocarpus truncatus* (King ex. Hook.f.) Rehder
267	Fagaceae	*Lithocarpus tubulosus* (Hickel & A.Camus) A.Camus
268	Fagaceae	*Lithocarpus wrayi* (King) A.Camus
269	Fagaceae	*Lithocarpus xylocarpus* (Kurz) Markgr.
270	Fagaceae	*Quercus aliena* Blume subsp. *aliena*
271	Fagaceae	*Quercus angustinii* Skan
272	Fagaceae	*Quercus auricoma* A. Camus
273	Fagaceae	*Quercus brandisiana* Kurz
274	Fagaceae	*Quercus eumorpha* Kurz
275	Fagaceae	*Quercus franchetii* Skan
276	Fagaceae	*Quercus helferiana* A.DC.
277	Fagaceae	*Quercus kerrii* Craib
278	Fagaceae	*Quercus kingiana* Craib
279	Fagaceae	*Quercus lamellosa* Sm.
280	Fagaceae	*Quercus lanata* Sm.
281	Fagaceae	*Quercus lenticellata* Barnett
282	Fagaceae	*Quercus lineata* Blume
283	Fagaceae	*Quercus mespilifolia* Wall ex A. DC var. *mespilifolia*
284	Fagaceae	*Quercus mespilifolia* Wall. ex A. DC. var. *pubescens* Barnett ex Smitinand & Phengklai
285	Fagaceae	*Quercus myrsinaefolia* Blume
286	Fagaceae	*Quercus oidocarpa* Korth.
287	Fagaceae	*Quercus quangtriensis* Hickel & A. Camus
288	Fagaceae	*Quercus ramsbottomii* A. Camus
289	Fagaceae	*Quercus rex* Hemsl.
290	Magnoliaceae	*Magnolia* × *alba* (DC.) Figlar
291	Magnoliaceae	*Magnolia baillonii* Pierre
292	Magnoliaceae	*Magnolia betongensis* (Craib) H.Keng
293	Magnoliaceae	*Magnolia carsonii* Dandy ex Noot. var. *drymifolia* Noot.
294	Magnoliaceae	*Magnolia cathcartii* (Hook.f. &Thomson) Noot.
295	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*
296	Magnoliaceae	*Magnolia champaca* var. *pubinervia* (Blume) Figlar & Noot.
297	Magnoliaceae	*Magnolia citrata* Noot. & Chalermglin
298	Magnoliaceae	*Magnolia duperreana* Pierre
299	Magnoliaceae	*Magnolia elegans* (Blume) H.Keng
300	Magnoliaceae	*Magnolia floribunda* (Finet & Gagnep.) Figlar
301	Magnoliaceae	*Magnolia garrettii* (Craib) V.S.Kumar
302	Magnoliaceae	*Magnolia gustavii* King
303	Magnoliaceae	*Magnolia henryi* Dunn
304	Magnoliaceae	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng
305	Magnoliaceae	*Magnolia insignis* Wall.
306	Magnoliaceae	*Magnolia koordersiana* (Noot.) Figlar

No.	Family	Botanical name
307	Magnoliaceae	*Magnolia liliifera* (L.) Baill
308	Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar
309	Magnoliaceae	*Magnolia praecalva* (Dandy) Figlar & Noot.
310	Magnoliaceae	*Magnolia rajaniana* (Craib) Figlar
311	Magnoliaceae	*Magnolia siamensis* (Dandy) H.Keng
312	Magnoliaceae	*Magnolia sirindhorniae* Noot. & Chalermglin
313	Magnoliaceae	*Magnolia thailandica* Noot. & Chalermglin

Table A5 List of tree species in the royal decree on restricted logging trees 1987 of Thailand

No.	Family	Botanical name
1	Ulmaceae	*Holoptelea integrifolia* Planch.
2	Lecythidaceae	*Careya arborea* Roxb.
3	Fabaceae	*Acacia harmandiana* (Pierre) Gagnep.
	Fabaceae	*Acacia tomentosa* Willd.
	Fabaceae	*Acacia leucophloea* (Roxb.) Willd.
4	Meliaceae	*Sandoricum koetjape* (Burm. f.) Merr.
5	Elaeocarpaceae	*Elaeocarpus* spp.
6	Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze
7	Irvingiaceae	*Irvingia malayana* Oliv. ex A.W. Benn.
8	Dipterocarpaceae	*Anisoptera scaphula* (Roxb.) Kurz
9	Dipterocarpaceae	*Shorea farinosa* C. E. C. Fisch.
10	Achariaceae	*Hydnocarpus ilicifolia* King
11	Fagaceae	*Castanopsis* spp.
	Fagaceae	*Lithocarpus* spp.
	Fagaceae	*Quercus* spp.
12	Annonaceae	*Hubera cerasoides* (Roxb.) Chaowasku
13	Calophyllaceae	*Calophyllum inophyllum* L.
14	Meliaceae	*Walsura* spp.
15	Gentianaceae	*Fagraea fragrans* Roxb.
16	Anacardiaceae	*Swintonia schwenckii* (Teijsm. & Binn.) Teijsm. & Binn.
17	Rubiaceae	*Nauclea orientalis* (L.) L.
	Rubiaceae	*Nauclea officinalis* (Pierre ex Pit.) Merr. & Chun
18	Dipterocarpaceae	*Shorea faguetiana* F.Heim
19	Betulaceae	*Betula alnoides* Buch.-Ham. ex G. Don
20	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.
21	Olacaceae	*Scorodocarpus borneensis* (Baill.) Becc.
22	Sapotaceae	*Manilkara hexandra* (Roxb.) Dubard
23	Sapindaceae	*Xerospermum* spp.
24	Rubiaceae	*Haldina cordifolia* (Roxb.) Ridsdale
	Rubiaceae	*Metadina trichotoma* (Zoll. & Moritzi) Bakh. f.
25	Moraceae	*Maclura cochinchinensis* (Lour.) Corner
26	Rhizophoraceae	*Rhizophora* spp.
27	Erythroxylaceae	*Erythroxylum cuneatum* (Miq.) Kurz
28	Malvaceae	*Pterospermum* spp.

No.	Family	Botanical name
29	Moraceae	*Artocarpus altissimus* (Miq.) J. J. Sm.
	Moraceae	*Artocarpus chama* Buch.-Ham.
	Moraceae	*Artocarpus elasticus* Reinw. ex Blume
	Moraceae	*Artocarpus gomezianus* Wall. ex Trécul
	Moraceae	*Artocarpus kemando* Miq.
	Moraceae	*Artocarpus lacucha* Roxb. ex Buch.-Ham.
	Moraceae	*Artocarpus lanceifolius* Roxb.
	Moraceae	*Artocarpus nitidus* Trécul
	Moraceae	*Artocarpus rigidus* Blume
	Moraceae	*Artocarpus thailandicus* C. C. Berg
30	Dipterocarpaceae	*Parashorea* spp.
31	Fabaceae	*Millettia leucantha* Kurz var. *leucantha*
	Fabaceae	*Millettia leucantha* Kurz var. *buteoides* (Gagnep.) P. K. Lôc
	Fabaceae	*Millettia xylocarpa* Miq.
32	Ulmaceae	*Ulmus lancifolia* Roxb. ex Wall
33	Fabaceae	*Senna garrettiana* (Craib) Irwin & Barneby
34	Fabaceae	*Dialium cochinchinense* Pierre
35	Juglandaceae	*Engelhardtia* spp.
36	Fabaceae	*Albizia lebbeck* (L.) Benth.
	Fabaceae	*Albizia lebbekoides* (DC.) Benth.
	Fabaceae	*Albizia lucidior* (Steud.) I. C. Nielsen
	Fabaceae	*Albizia odoratissima* (L. f.) Benth.
	Fabaceae	*Albizia procera* (Roxb.) Benth.
37	Meliaceae	*Aglaia edulis* (Roxb.) Wall.
38	Fabaceae	*Cassia fistula* L.
39	Dipterocarpaceae	*Cotylelobium lanceolatum* Craib
40	Dipterocarpaceae	*Shorea henryana* Pierre
41	Bignoniaceae	*Stereospermum tetragonum* DC.
42	Sapindaceae	*Nephelium* spp.
43	Myristicaceae	*Myristica* spp.
44	Oleaceae	*Fraxinus floribunda* Wall.
45	Magnoliaceae	*Magnolia* × *alba* (DC.) Figlar
	Magnoliaceae	*Magnolia baillonii* Pierre
	Magnoliaceae	*Magnolia cathcartii* (Hook.f. & Thomson) Noot.
	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*
	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *pubinervia* (Blume) Figlar & Noot.
	Magnoliaceae	*Magnolia citrata* Noot. & Chalermglin
	Magnoliaceae	*Magnolia duperreana* Pierre
	Magnoliaceae	*Magnolia elegans* (Blume) H. Keng
	Magnoliaceae	*Magnolia floribunda* (Finet & Gagnep.) Figlar
	Magnoliaceae	*Magnolia gustavii* King
	Magnoliaceae	*Magnolia henryi* Dunn
	Magnoliaceae	*Magnolia hodgsonii* (Hook.f. & Thomson) H. Keng
	Magnoliaceae	*Magnolia koordersiana* (Noot.) Figlar

No.	Family	Botanical name
	Magnoliaceae	*Magnolia lacei* (W.W.Sm.) Figlar
	Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar
	Magnoliaceae	*Magnolia philippinensis* P. Parm.
	Magnoliaceae	*Magnolia rajaniana* (Craib) Figlar
	Magnoliaceae	*Magnolia siamensis* (Dandy) H. Keng
	Magnoliaceae	*Magnolia sirindhorniae* Noot. & Chalermglin
	Magnoliaceae	*Magnolia thailandica* Noot. & Chalermglin
	Magnoliaceae	*Magnolia utilis* (Dandy) V. S. Kumar
46	Sapotaceae	*Palaquium garrettii* H. R. Fletcher
	Sapotaceae	*Palaquium hispidum* H. J. Lam
	Sapotaceae	*Palaquium maingayi* (C. B. Clarke) Engl.
	Sapotaceae	*Palaquium obovatum* (Griff.) Engl.
	Sapotaceae	*Palaquium ottolanderi* Koord. & Valeton
47	Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.
48	Rosaceae	*Prunus arborea* (Blume) Kalkman var. *montana* Kalkman
49	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.
50	Dipterocarpaceae	*Hopea* spp.
51	Malvaceae	*Durio griffithii* (Mast.) Bakh.
	Malvaceae	*Durio lowianus* Scort. ex King
	Malvaceae	*Durio mansonii* (Gamble) Bakh.
52	Malvaceae	*Neesia* spp.
53	Fabaceae	*Dalbergia assamica* Benth.
	Fabaceae	*Dalbergia cana* Graham ex Kurz var. *cana*
	Fabaceae	*Dalbergia cana* Graham ex Kurz var. *kurzii* (Prain) Niyomdham
	Fabaceae	*Dalbergia cochinchinensis* Pierre
	Fabaceae	*Dalbergia cultrata* Graham ex Benth.
	Fabaceae	*Dalbergia nigrescens* Kurz
	Fabaceae	*Dalbergia oliveri* Gamble ex Prain
	Fabaceae	*Dalbergia suthepensis* Niyomdham
	Fabaceae	*Dalbergia errans* Craib
54	Malvaceae	*Heritiera* spp.
55	Polygalaceae	*Xanthophyllum* spp.
56	Lamiaceae	*Gmelina arborea* Roxb.
57	Fabaceae	*Erythrophleum* spp.
58	Fabaceae	*Xylia* spp.
59	Fabaceae	*Acrocarpus fraxinifolius* Wight ex Arn.
60	Malvaceae	*Schoutenia ovata* Korth.
61	Sapindaceae	*Schleichera oleosa* (Lour) Merr.
62	Burseraceae	*Garuga pinnata* Roxb.
63	Dipterocarpaceae	*Neobalanocarpus heimii* (King) P. S. Ashton
64	Dipterocarpaceae	*Shorea gratissima* (Wall. ex Kurz) Dyer
	Dipterocarpaceae	*Shorea laevis* Ridl.
65	Combretaceae	*Anogeissus acuminata* (Roxb. ex DC.) Guill. & Perr.
66	Meliaceae	*Xylocarpus* spp.
67	Lythraceae	*Lagerstroemia calyculata* Kurz

No.	Family	Botanical name
	Lythraceae	*Lagerstroemia cochinchinensis* Pierre.
	Lythraceae	*Lagerstroemia crispa* Pierre
	Lythraceae	*Lagerstroemia duperreana* Pierre ex Gagnep. var. *duperreana*
	Lythraceae	*Lagerstroemia duperreana* Pierre ex Gagnep. var. *saxatilis* W. J. de Wilde & Duyfjes
	Lythraceae	*Lagerstroemia floribunda* Jack var. *floribunda*
	Lythraceae	*Lagerstroemia floribunda* Jack var. *cuspidata* C. B. Clarke
	Lythraceae	*Lagerstroemia loudonii* Teijsm. & Binn.
	Lythraceae	*Lagerstroemia macrocarpa* Wall. ex Kurz
	Lythraceae	*Lagerstroemia ovalifolia* Teijsm. & Binn.
	Lythraceae	*Lagerstroemia speciosa* (L.) Pers.
	Lythraceae	*Lagerstroemia tomentosa* C. Presl
	Lythraceae	*Lagerstroemia venusta* Wall. ex C. B. Clarke
68	Combretaceae	Terminalia foetidissima Griff.
69	Meliaceae	*Aglaia cucullata* (Roxb.) Pellegr.
70	Sapotaceae	*Planchonella obovata* (R. Br.) Pierre
71	Hypericaceae	*Cratoxylum* spp.
72	Lamiaceae	*Vitex canescens* Kurz
	Lamiaceae	*Vitex limonifolia* Wall. ex Walp.
	Lamiaceae	*Vitex peduncularis* Wall. ex Schauer
	Lamiaceae	*Vitex pinnata* L.
73	Apocynaceae	*Alstonia scholaris* (L.) R. Br.
74	Lythraceae	*Duabanga grandiflora* (DC.) Walp.
75	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume
	Dipterocarpaceae	*Shorea siamensis* Miq.
76	Anacardiaceae	*Pentaspadon velutinus* Hook.f.
77	Phyllanthaceae	*Bischofia javanica* Blume
78	Sapotaceae	*Madhuca motleyana* (de Vriese) J. F. Macbr.
79	Fabaceae	*Koompassia* spp.
80	Lauraceae	*Litsea elliptica* Blume
	Lauraceae	*Litsea glutinosa* (Lour.) C. B. Rob.
	Lauraceae	*Litsea grandis* (Nees) Hook.f.
	Lauraceae	*Litsea laeta* (Nees) Hook.f.
	Lauraceae	*Litsea mollis* Hemsl.
	Lauraceae	*Litsea monopetala* (Roxb.) Pers.
	Lauraceae	*Litsea myristicifolia* (Nees) Hook.f.
81	Lauraceae	*Cinnamomum parthenoxylon* (Jack) Meisn.
	Lauraceae	*Cinnamomum ilicioides* A. Chev.
82	Fabaceae	*Peltophorum* spp.
83	Moraceae	*Antiaris toxicaria* Lesch.
84	Annonaceae	*Platymitra siamensis* Craib
	Annonaceae	*Cyathocalyx martabanicus* Hook.f. & Thomson var.*harmandii* Finet & Gagnep.
85	Lauraceae	*Persea kurzii* Kosterm.
86	Calophyllaceae	*Mesua* spp.
87	Fabaceae	*Pterocarpus macrocarpus* Kurz

No.	Family	Botanical name
88	Rhizophoraceae	*Bruguiera* spp.
89	Cornaceae	*Alangium salviifolium* (L. f.) Wang. subsp. *hexapetalum* (Lam.) Wangerin
90	Malvaceae	*Kydia calycina* Roxb.
91	Malvaceae	*Brownlowia helferiana* Pierre
92	Rhizophoraceae	*Ceriops decandra* (Griff.) W. Theob.
93	Annonaceae	*Cananga brandisiana* (Pierre) I. M. Turner
94	Euphorbiaceae	*Endospermum diadenum* (Miq.) Airy Shaw
95	Combretaceae	*Lumnitzera* spp.
96	Podocarpus	*Podocarpus neriifolius* D. Don
97	Dipterocarpaceae	*Shorea hypochra* Hance
98	Proteaceae	*Helicia excelsa* (Roxb.) Blume
	Proteaceae	*Helicia nilagirica* Bedd.
	Proteaceae	*Helicia petiolaris* Benn.
	Proteaceae	*Helicia robusta* (Roxb.) R. Br. ex Blume
99	Anacardiaceae	*Dracontomelon dao* (Blanco) Merr. & Rolfe
100	Dipterocarpaceae	*Dipterocarpus intricatus Dyer*
	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.
	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.
101	Melastomataceae	*Memecylon ovatum* Sm.
102	Ebenaceae	*Diospyros* spp.
103	Dipterocarpaceae	*Shorea roxburghii* G. Don
104	Clusiaceae	*Garcinia* spp.
105	Dipterocarpaceae	*Vatica cuspidata* (Ridl.) Symington
	Dipterocarpaceae	*Vatica diospyroides* Symington
	Dipterocarpaceae	*Vatica harmandiana* Pierre
	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington
	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume
106	Theaceae	*Schima wallichii* (DC.) Korth.
107	Sapotaceae	*Mimusops elengi* L.
	Sapotaceae	Payena spp.
108	Loganiaceae	*Gardenia sootepensis* Hutch.
	Loganiaceae	*Gardenia philastrei* Pierre ex Pit.
	Loganiaceae	*Gardenia obtusifolia* Roxb. ex Hook.f.
	Loganiaceae	*Gardenia carinata* Wall. ex Roxb.
	Loganiaceae	*Gardenia collinsiae* Craib
109	Fabaceae	*Adenanthera pavonina L.*
110	Burseraceae	*Canarium subulatum* Guillaumin
111	Fabaceae	*Sindora siamensis* Teijsm. ex Miq. var. *siamensis*
	Fabaceae	*Sindora siamensis* Teijsm. ex Miq. var. *maritima* (Pierre) K. Larsen & S. S. Larsen
112	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib
113	Putranjivaceae	*Drypetes hoaensis* Gagnep.
114	Sapotaceae	*Madhuca dongnaiensis* (Pierre) Baehni
	Sapotaceae	*Madhuca esculenta* H. R. Fletcher
115	Burseraceae	*Protium serratum* Engl.

No.	Family	Botanical name
116	Anacardiaceae	*Mangifera* spp.
117	Fabaceae	*Cynometra ramiflora* L.
118	Crypteroniaceae	*Crypteronia paniculata* Blume
119	Apocynaceae	*Wrightia tomentosa* (Roxb.) Roem. & Schult.
120	Apocynaceae	*Holarrhena antidysenterica* Wall.
121	Meliaceae	*Toona* spp.
122	Meliaceae	*Chukrasia tabularis* A. Juss.
123	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco
124	Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou
125	Anacardiaceae	*Semecarpus curtisii* King
126	Celastraceae	*Kokoona* spp.
127	Annonaceae	*Goniothalamus macrophyllus* (Blume) Hook.f. & Thomson
128	Dipterocarpaceae	*Shorea curtisii* Dyer ex King
129	Lauraceae	*Dehaasia kurzii* King ex Hook.f.
130	Malvaceae	*Berrya* spp.
131	Meliaceae	*Melia azedarach* L.
132	Myristicaceae	*Knema furfuracea* (Hook.f. & Thomson) Warb.
	Myristicaceae	*Knema globularia* (Lam.) Warb.
133	Lamiaceae	*Peronema canescens* Jack
134	Pinaceae	*Pinus* spp.
135	Podocarpaceae	*Dacrydium elatum* (Roxb.) Wall. ex Hook.
136	Altingiaceae	*Altingia excelsa* Noronha
137	Tetramelaceae	*Tetrameles nudiflora* R.Br.
138	Dipterocarpaceae	*Shorea leprosula* Miq.
	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*
	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *velutinata* P.S.Ashton
139	Celastraceae	*Lophopetalum duperreanum* Pierre
140	Meliaceae	*Azadirachta indica* A.Juss
141	Lauraceae	*Phoebe lanceolata* (Nees) Nees
	Lauraceae	*Phoebe paniculata* (Nees) Nees
142	Lamiaceae	*Premna tomentosa* Willd.
	Lamiaceae	*Premna pyramidata* Wall.
143	Dilleniaceae	*Dillenia* spp.
144	Sapindaceae	*Pometia* spp.
145	Calophyllaceae	*Mammea* spp.
146	Malvaceae	*Pentace* spp.
147	Salicaceae	*Casearia grewiifolia* Vent.
148	Chrysobalanaceae	*Parinari annamense* Hance
149	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume
150	Fabaceae	*Intsia* spp.
151	Myrtaceae	*Eugenia* spp.
152	Sapotaceae	*Chrysophyllum roxburghii* G. Don
153	Anacardiaceae	*Buchanania lanzan* Spreng.
154	Fabaceae	*Parkia* spp.
155	Lauraceae	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet

No.	Family	Botanical name
	Lauraceae	*Cinnamomum iners* Reinw. ex Blume
156	Lauraceae	*Neolitsea zeylanica* (Nees & T.Nees) Merr.
157	Dipterocarpaceae	*Shorea glauca* King
158	Salicaceae	*Homalium grandiflorum* Benth.
	Salicaceae	*Homalium tomentosum* (Vent.) Benth.

Table A6 List of 35 priority species for Thailand (Sumantakul et al. 2004)

No.	Family	Botanical name
1	Anacardiaceae	*Mangifera gedebe* Miq.
2	Apocynaceae	*Alstonia scholaris* (L.) R.Br.
3	Apocynaceae	*Wrightia arborea* (Dennst.) Mabb.
4	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don
5	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.
6	Dipterocarpaceae	*Hopea ferrea* Laness.
7	Dipterocarpaceae	*Hopea odorata* Roxb.
8	Dipterocarpaceae	*Parashorea stellata* Kurz
9	Dipterocarpaceae	*Shorea henryana* Pierre
10	Dipterocarpaceae	*Shorea roxburghii* G.Don
11	Dipterocarpaceae	*Cotylelobium melanoxylon* (Hook.f) Pierre
12	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib
13	Fabaceae	*Dalbergia cochinchinensis* Pierre
14	Fabaceae	*Dalbergia oliveri* Gamble ex Prain
15	Fabaceae	*Intsia palembanica* Miq.
16	Fabaceae	*Parkia speciosa* Hassk.
17	Fabaceae	*Pterocarpus macrocarpus* Kurz
18	Fabaceae	*Xylia xylocarpa* (Roxb.) W. Theob. var. *kerrii* (Craib & Hutch.) I. C. Nielsen
19	Fabaceae	*Millettia kangensis* Craib
20	Gentianaceae	*Fagraea fragrans* Roxb.
21	Lamiaceae	*Gmelina arborea* Roxb.
22	Lamiaceae	*Tectona grandis* L.f.
23	Magnoliaceae	*Magnolia garrettii* (Craib) V.S.Kumar
24	Malvaceae	*Durio mansoni* (Gamble) Bakh.
25	Malvaceae	*Mansonia gagei* J. R. Drumm. ex Prain
26	Meliaceae	*Azadirachta excelsa* (Jack) Jacobs
27	Meliaceae	*Azadirachta indica* A.Juss
28	Meliaceae	*Chukrasia* spp.
29	Meliaceae	*Toona ciliata* M. Roem.
30	Opiliaceae	*Melientha suavis* Pierre
31	Pinaceae	*Pinus kesiya* Royle ex Gordon
32	Pinaceae	*Pinus merkusii* Jungh. & de Vriese
33	Tetramelaceae	*Tetrameles nudiflora* R.Br.
34	Thymelaeaceae	*Aquilaria crassna* Pierre ex Lecomte
35	Ulmaceae	*Holoptelea integrifolia* Planch.

Table A7 List of tree species of each selected tree species group that were considered in the research

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
1	Acanthaceae	*Avicennia marina* (Forssk.) Vierh.	-	/	-	-
2	Achariaceae	*Hydnocarpus castanea* Hook.f.& Thomson	-	/	-	-
3	Achariaceae	*Hydnocarpus ilicifolia* King	-	/	/	-
4	Actinidiaceae	*Saurauia napaulensis* DC.	-	/	-	-
5	Actinidiaceae	*Saurauia roxburghii* Wall.	-	/	-	-
6	Akaniaceae	*Bretschneidera sinensis* Hemsl.	/	-	-	-
7	Alangiaceae	*Alangium salviifolium* (L.f.) Wangerin subsp. *hexapetalum* (Lam.) Wangerin	-	/	/	-
8	Altingiaceae	*Altingia excelsa* Noranha	/	/	/	-
9	Anacardiaceae	*Bouea oppositifolia* (Roxb.) Meisn.	-	/	-	-
10	Anacardiaceae	*Buchanania lanzan* Spreng.	-	/	/	-
11	Anacardiaceae	*Buchanania siamensis* Miq.	/	/	-	-
12	Anacardiaceae	*Campnosperma coriaceum* (Jack) Hall.f. ex Steenis	-	/	-	-
13	Anacardiaceae	*Choerospondias axillaris* (Roxb.) B.L. Burtt & Hill	-	/	-	-
14	Anacardiaceae	*Dracontomelon dao* (Blanco) Merr. & Rolfe	-	/	/	-
15	Anacardiaceae	*Gluta obovata* Craib	/	-	-	-
16	Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou	-	/	/	-
17	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.	-	/	/	-
18	Anacardiaceae	*Mangifera gedebe* Miq.	-	/	/	/
19	Anacardiaceae	*Parishia insignis* Hook.f.	-	/	-	-
20	Anacardiaceae	*Pentaspadon velutinus* Hook.f.	-	/	/	-
21	Anacardiaceae	*Rhus succedanea* L.	-	/	-	-
22	Anacardiaceae	*Semecarpus cochinchinensis* Engl.	-	/	-	-
23	Anacardiaceae	*Semecarpus curtisii* King	-	/	/	-
24	Anacardiaceae	*Spondias bipinnata* Airy Shaw & Forman	/	/	-	-
25	Anacardiaceae	*Spondias lakonensis* Pierre	-	/	-	-
26	Anacardiaceae	*Spondias pinnata* (L.f.) Kurz	-	/	-	-
27	Anacardiaceae	*Swintonia floribunda* Griff.	-	/	-	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
28	Annonaceae	*Alphonsea gaudichaudiana* (Baill.) Finet & Gagnep.	/	-	-	-
29	Annonaceae	*Cananga brandisiana* (Pierre) I. M. Turner	-	/	/	-
30	Annonaceae	*Cyathocalyx martabanicus* Hook.f. & Thomson var.*harmandii* Finet & Gagnep.	-	/	/	-
31	Annonaceae	*Goniothalamus cheliensis* Hu	/	-	-	-
32	Annonaceae	*Goniothalamus giganteus* Wall. ex Hook.f. & Thomson	/	/	-	-
33	Annonaceae	*Miliusa velutina* (Dunal) Hook.f. & Thomson	-	/	-	-
34	Annonaceae	*Mitrephora keithii* Ridl.	/	-	-	-
35	Annonaceae	*Mitrephora maingayi* Hook.f. & Thomson	-	/	-	-
36	Annonaceae	*Mitrephora sirikitiae* Weeras., Chalermglin & R.M.K.Saunders	/	-	-	-
37	Annonaceae	*Mitrephora wangii* Hu	/	-	-	-
38	Annonaceae	*Mitrephora winitii* Craib	/	/	-	-
39	Annonaceae	*Monocarpia maingayi* (Hook.f. & Thomson) I.M.Turner	/	-	-	-
40	Annonaceae	*Monoon lateriflorum* Blume	-	/	-	-
41	Annonaceae	*Monoon membranifolium* (J.Sinclair) B. Xue & R.M.K.Saunders	/	-	-	-
42	Annonaceae	*Monoon sclerophyllum* (Hook.f. &Thomson) B.Xue & R.M.K. Saunders	-	/	-	-
43	Annonaceae	*Orophea kerrii* Kessler	/	-	-	-
44	Annonaceae	*Platymitra siamensis* Craib	-	-	/	-
45	Annonaceae	*Polyalthia cauliflora* Hook.f. & Thomson var. *wrayi* (Hemsl.) J.Sinclair	/	-	-	-
46	Annonaceae	*Polyalthia lateritia* J.Sincl.	/	-	-	-
47	Annonaceae	*Polyalthia stenopetala* (Hook & Thomson) Finet. & Gagnep.	/	-	-	-
48	Annonaceae	*Polyalthia suberosa* (Roxb.) Thwaites	-	/	-	-
49	Annonaceae	*Pseuduvaria macrophylla* (Oliv.) Merr. var. *sessilicarpa* J.Sinclair	/	-	-	-
50	Annonaceae	*Trivalvaria macrophylla* Miq.	/	-	-	-
51	Annonaceae	*Xylopia ferruginea* (Hook.f. & Thomson) Hook.f. & Thomson	-	/	-	-
52	Apocynaceae	*Alstonia macrophylla* Wall. ex G.Don	-	/	-	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
53	Apocynaceae	*Alstonia scholaris* (L.) R.Br.	-	/	/	/
54	Apocynaceae	*Alstonia spatulata* Blume	/	/	-	-
55	Apocynaceae	*Dyera costulata* (Miq.) Hook.f.	/	/	-	-
56	Apocynaceae	*Holarrhena pubescens* Wall. ex G. Don	-	/	-	-
57	Apocynaceae	*Kopsia angustipetala* Kerr	/	-	-	-
58	Apocynaceae	*Kopsia rosea* D.J.Middleton	/	-	-	-
59	Apocynaceae	*Tabernaemontana macrocarpa* Jack	/	-	-	-
60	Apocynaceae	*Wrightia arborea* (Dennst.) Mabb.	-	/	-	/
61	Apocynaceae	*Wrightia coccinea* (Roxb.) Sims	/	-	-	-
62	Apocynaceae	*Wrightia sirikitiae* D.J.Middleton & Santisuk	/	-	-	-
63	Apocynaceae	*Wrightia viridiflora* Kerr	/	-	-	-
64	Aquifoliaceae	*Ilex triflora* Blume	-	/	-	-
65	Araliaceae	*Schefflera siamensis* W.W.Sm. ex Craib	/	-	-	-
66	Berberidaceae	*Mahonia duclouxiana* Gagnep.	-	/	-	-
67	Betulaceae	*Betula alnoides* Buch.-Ham. ex G. Don	-	/	/	-
68	Betulaceae	*Carpinus viminea* Wall. ex Lindl.	-	/	-	-
69	Bignoniaceae	*Dolichandrone serrulata* (Wall. ex D.C.) Seem	-	/	-	-
70	Bignoniaceae	*Fernandoa adenophylla* (Wall. ex G. Don) Steenis	-	/	-	-
71	Bignoniaceae	*Fernandoa collignonii* (P.Dop) Steenis	/	-	-	-
72	Bignoniaceae	*Heterophragma sulfureum* Kurz	-	/	-	-
73	Bignoniaceae	*Markhamia stipulata* Seem. var. *kerrii* Sprague	/	/	-	-
74	Bignoniaceae	*Mayodendron igneum* (Kurz) Kurz	-	/	-	-
75	Bignoniaceae	*Pauldopia ghorta* (Buch.-Ham. ex G.Don) Steenis	/	-	-	-
76	Bignoniaceae	*Radermachera boniana* Dop	/	-	-	-
77	Bignoniaceae	*Radermachera eberhardtii* Dop	/	-	-	-
78	Bignoniaceae	*Radermachera hainanensis* Merr.	/	/	-	-
79	Bignoniaceae	*Radermachera peninsularis* Steenis	/	-	-	-
80	Bignoniaceae	*Radermachera pinnata* (Blanco) Seem.	/	-	-	-
81	Bignoniaceae	*Santisukia kerrii* (Barnett & Sandwith) Brummitt	/	-	-	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
82	Bignoniaceae	*Stereospermum fimbriatum* (Wall. ex G. Don) A.DC.	-	/	-	-
83	Bignoniaceae	*Stereospermum neuranthum* Kurz	-	/	-	-
84	Bignoniaceae	*Stereospermum tetragonum* DC.	-	/	/	-
85	Bombacaceae	*Bombax anceps* Pierre var. *anceps*	-	/	-	-
86	Bombacaceae	*Bombax ceiba* L.	-	/	-	-
87	Boraginaceae	*Cordia mhaya* Kerr	/	-	-	-
88	Boraginaceae	*Cordia subcordata* Lam.	/	/	-	-
89	Burseraceae	*Canarium euphyllum* Kurz.	/	-	-	-
90	Burseraceae	*Canarium littorale* Blume	/	-	-	-
91	Burseraceae	*Canarium patentinervium* Miq.	/	-	-	-
92	Burseraceae	*Canarium pavum* Leenh.	/	-	-	-
93	Burseraceae	*Canarium pseudosumatranum* Leenh.	/	-	-	-
94	Burseraceae	*Canarium strictum* Roxb.	/	-	-	-
95	Burseraceae	*Canarium subulatum* Guillaumin	-	/	/	-
96	Burseraceae	*Canarium sumatranum* Boerl. & Koord.	/	-	-	-
97	Burseraceae	*Dacryodes kingii* (Engl.) Kalkman	/	-	-	-
98	Burseraceae	*Garuga floribunda* Decne. var. *gamblei* (King ex W.W.Sm) Kalkman	/	-	-	-
99	Burseraceae	*Garuga pinnata* Roxb.	-	/	/	-
100	Burseraceae	*Protium serratum* Engl.	-	/	/	-
101	Burseraceae	*Santiria laeviagata* Blume	/	-	-	-
102	Burseraceae	*Santiria rubiginosa* Blume	/	-	-	-
103	Burseraceae	*Santiria tomentosa* Blume	/	-	-	-
104	Calophyllaceae	*Calophyllum canum* Hook.f. ex T.Anderson	/	-	-	-
105	Calophyllaceae	*Calophyllum inophyllum* L.	-	/	/	-
106	Calophyllaceae	*Calophyllum pisiferum* Planch. & Triana	-	/	-	-
107	Calophyllaceae	*Calophyllum rupicolum* Ridl.	/	-	-	-
108	Calophyllaceae	*Calophyllum sclerophyllum* Vesgue	/	-	-	-
109	Calophyllaceae	*Calophyllum teysmannii* Miq.	/	/	-	-
110	Calophyllaceae	*Mammea harmandii* Kosterm.	-	/	/	-
111	Cannabaceae	*Gironniera nervosa* Planch	-	/	-	-
112	Capparaceae	*Maerua siamensis* (Kurz) Pax	-	/	-	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
113	Casuarinaceae	*Casuarina equisetifolia* L.	-	/	-	-
114	Celastraceae	*Glyptopetalum sclerocarpus* M.A.Lawson	/	-	-	-
115	Celastraceae	*Siphonodon celastrineus* Griff.	-	/	-	-
116	Cephalotaxaceae	*Cephalotaxus mannii* Hook.f.	/	/	-	-
117	Chrysobalanace	*Parinari annamense* Hance	-	/	/	-
118	Clusiaceae	*Garcinia hanburyi* Hook.f.	-	/	/	-
119	Clusiaceae	*Garcinia merguensis* Wight	-	/	/	-
120	Clusiaceae	*Garcinia schomburgkiana* Pierre	-	/	/	-
121	Combretaceae	*Anogeissus acuminata* (Roxb. ex DC.) Guill. & Perr.	-	/	/	-
122	Combretaceae	*Combretum quadrangulare* Kurz	-	/	-	-
123	Combretaceae	*Terminalia alata* B.Heyne ex Roth	-	/	-	-
124	Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	-	/	-	-
125	Combretaceae	*Terminalia catappa* L.	-	/	-	-
126	Combretaceae	*Terminalia chebula* Retz. var. *chebula*	-	/	-	-
127	Combretaceae	*Terminalia franchetii* Gagnep.	/	-	-	-
128	Combretaceae	*Terminalia mucronata* Craib & Hutch.	-	/	-	-
129	Combretaceae	*Terminalia myriocarpa* Heur & Muell.Arg. var. *hirsuta* Craib	/	-	-	-
130	Combretaceae	*Terminalia nigrovenulosa* Pierre	-	/	-	-
131	Compositae	*Gochnatia decora* (Kurz) Cabrera	/	-	-	-
132	Connaraceae	*Ellipanthus tomentosus* Kurz var. *tomentosus*	-	/	-	-
133	Cornaceae	*Cornus oblonga* Wall.	/	/	-	-
134	Cornaceae	*Mastixia euonymoides* Prain	-	/	-	-
135	Crypteroniaceae	*Crypteronia paniculata* Blume	-	/	/	-
136	Dilleniaceae	*Dillenia aurea* Sm.	-	/	/	-
137	Dilleniaceae	*Dillenia excelsa* (Jack) Martelli ex Gilg	/	-	/	-
138	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	-	/	/	-
139	Dilleniaceae	*Dillenia ovata* Wall. ex Hook.f. & Thomson	/	/	/	-
140	Dilleniaceae	*Dillenia pentagyna* Roxb.	-	/	/	-
141	Dilleniaceae	*Dillenia pulchella* (Jack) Gilg	-	/	/	-
142	Dilleniaceae	*Dillenia reticulata* King	/	-	/	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
143	Dilleniaceae	*Dillenia scabrella* (D.Don) Roxb. ex Wall.	/	-	/	-
144	Dipterocarpaceae	*Anisoptera costata* Korth.	-	/	-	-
145	Dipterocarpaceae	*Anisoptera curtisii* Dyer ex King	/	/	-	-
146	Dipterocarpaceae	*Anisoptera laevis* Ridl.	/	/	-	-
147	Dipterocarpaceae	*Anisoptera scaphula* (Roxb.) Kurz	/	/	/	-
148	Dipterocarpaceae	*Cotylelobium lanceolatum* Craib	/	/	/	-
149	Dipterocarpaceae	*Dipterocarpus acutangulus* Vesque	/	/	-	-
150	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G.Don	-	/	/	/
151	Dipterocarpaceae	*Dipterocarpus baudii* Korth.	-	/	-	-
152	Dipterocarpaceae	*Dipterocarpus chartaceus* Symington	-	/	-	-
153	Dipterocarpaceae	*Dipterocarpus costatus* C.F.Gaertn.	-	/	-	-
154	Dipterocarpaceae	*Dipterocarpus dyeri* Pierre ex Laness.	/	/	-	-
155	Dipterocarpaceae	*Dipterocarpus gracilis* Blume	-	/	-	-
156	Dipterocarpaceae	*Dipterocarpus grandiflorus* (Blanco) Blanco	-	/	/	-
157	Dipterocarpaceae	*Dipterocarpus hasseltii* Blume	/	/	-	-
158	Dipterocarpaceae	*Dipterocarpus intricatus* Dyer	-	/	/	-
159	Dipterocarpaceae	*Dipterocarpus kerrii* King	-	/	-	-
160	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	-	/	/	-
161	Dipterocarpaceae	*Dipterocarpus retusus* Blume	/	/	-	-
162	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	-	/	/	/
163	Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.	-	/	-	-
164	Dipterocarpaceae	*Hopea ferrea* Laness.	-	/	/	/
165	Dipterocarpaceae	*Hopea griffithii* Kurz	-	/	/	-
166	Dipterocarpaceae	*Hopea helferi* (Dyer) Brandis	/	/	/	-
167	Dipterocarpaceae	*Hopea latifolia* Symington	-	/	/	-
168	Dipterocarpaceae	*Hopea oblongifolia* Dyer	/	/	/	-
169	Dipterocarpaceae	*Hopea odorata* Roxb.	-	/	/	/
170	Dipterocarpaceae	*Hopea pedicellata* (Brandis) Symington	/	/	/	-
171	Dipterocarpaceae	*Hopea pierrei* Hance	/	/	/	-
172	Dipterocarpaceae	*Hopea recopei* Pierre ex Laness.	/	/	/	-
173	Dipterocarpaceae	*Hopea sangal* Korth.	/	/	/	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
174	Dipterocarpaceae	*Hopea sublanceolata* Symington	/	/	/	-
175	Dipterocarpaceae	*Hopea thorelii* Pierre	/	/	/	-
176	Dipterocarpaceae	*Neobalanocarpus heimii* (King) P.S.Ashton	/	/	/	-
177	Dipterocarpaceae	*Parashorea densiflora* Slooten & Symington subsp. *Kerrii* (Tardieu) R.Pooma	/	/	/	-
178	Dipterocarpaceae	*Parashorea stellata* Kurz	-	/	/	/
179	Dipterocarpaceae	*Shorea assamica* Dyer	-	/	-	-
180	Dipterocarpaceae	*Shorea assamica* Dyer subsp. *globifera* (Ridl.) Y.K.Yang & J.K.Wu	-	/	-	-
181	Dipterocarpaceae	*Shorea bracteolata* Dyer	/	/	-	-
182	Dipterocarpaceae	*Shorea curtisii* Dyer ex King	-	/	/	-
183	Dipterocarpaceae	*Shorea faguetiana* F.Heim	/	/	/	-
184	Dipterocarpaceae	*Shorea farinosa* C.E.C.Fisch.	/	/	/	-
185	Dipterocarpaceae	*Shorea glauca* King	-	/	/	-
186	Dipterocarpaceae	*Shorea gratissima* (Wall. ex Kurz) Dyer	-	/	/	-
187	Dipterocarpaceae	*Shorea guiso* (Blanco) Blume	/	/	/	-
188	Dipterocarpaceae	*Shorea henryana* Pierre	-	/	/	/
189	Dipterocarpaceae	*Shorea hypochra* Hance	-	/	/	-
190	Dipterocarpaceae	*Shorea leprosula* Miq.	-	/	/	-
191	Dipterocarpaceae	*Shorea macroptera* Dyer	/	/	-	-
192	Dipterocarpaceae	*Shorea obtusa* Wall. ex Blume	-	/	/	-
193	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *parvifolia*	-	/	/	-
194	Dipterocarpaceae	*Shorea parvifolia* Dyer subsp. *velutinata* P.S.Ashton	-	/	/	-
195	Dipterocarpaceae	*Shorea roxburghii* G.Don	-	/	/	/
196	Dipterocarpaceae	*Shorea siamensis* Miq.	-	/	/	-
197	Dipterocarpaceae	*Shorea singkawang* (Miq.) Miq.	/	/	-	-
198	Dipterocarpaceae	*Shorea thorelii* Pierre ex Laness.	/	/	/	-
199	Dipterocarpaceae	*Vatica bella* Slooten	/	/	-	-
200	Dipterocarpaceae	*Vatica diospyroides* Symington	/	/	/	-
201	Dipterocarpaceae	*Vatica harmandiana* Pierre	-	/	/	-
202	Dipterocarpaceae	*Vatica mangachapoi* subsp. *obtusifolia* (Elmer) P.S.Ashton	/	/	-	-

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203	Dipterocarpaceae	*Vatica odorata* (Griff.) Symington	-	/	/	-
204	Dipterocarpaceae	*Vatica pauciflora* (Korth.) Blume	-	/	/	-
205	Dipterocarpaceae	*Vatica philastreana* Pierre	/	/	-	-
206	Dipterocarpaceae	*Vatica stapfiana* (King) Slooten	/	/	-	-
207	Dipterocarpaceae	*Vatica umbonata* (Hook.f.) Burck	-	/	-	-
208	Ebenaceae	*Diospyros andamanica* (Kurz) Bakh.	/	/	/	-
209	Ebenaceae	*Diospyros apiculata* Hiern	-	/	/	-
210	Ebenaceae	*Diospyros areolata* King & Gamble	-	/	/	-
211	Ebenaceae	*Diospyros bambuseti* H.R.Fletcher	/	/	/	-
212	Ebenaceae	*Diospyros bejaudii* Lecomte	-	/	/	-
213	Ebenaceae	*Diospyros buxifolia* (Blume) Hiern	-	/	/	-
214	Ebenaceae	*Diospyros castanea* (Craib) H.R.Fletcher	-	/	/	-
215	Ebenaceae	*Diospyros cauliflora* Blume	/	/	/	-
216	Ebenaceae	*Diospyros coaetanea* H.R.Fletcher	/	/	/	-
217	Ebenaceae	*Diospyros collinsae* Craib	/	/	/	-
218	Ebenaceae	*Diospyros confertiflora* (Hiern) Bakh.	/	/	/	-
219	Ebenaceae	*Diospyros curranii* Merr.	-	/	/	-
220	Ebenaceae	*Diospyros dasyphylla* Kurz	/	/	/	-
221	Ebenaceae	*Diospyros defectrix* H.R.Fletcher	-	/	/	-
222	Ebenaceae	*Diospyros diepenhorstii* Miq.	-	/	/	-
223	Ebenaceae	*Diospyros dumetorum* W.W.Sm.	/	/	/	-
224	Ebenaceae	*Diospyros ehretioides* Wall. ex G.Don	-	/	/	-
225	Ebenaceae	*Diospyros filipendula* Pierre ex Lecomte	/	/	/	-
226	Ebenaceae	*Diospyros frutescens* Blume	-	/	/	-
227	Ebenaceae	*Diospyros fulvopilosa* H.R.Fletcher	-	/	/	-
228	Ebenaceae	*Diospyros glandulosa* Lace	-	/	/	-
229	Ebenaceae	*Diospyros gracilis* H.R.Fletcher	/	/	/	-
230	Ebenaceae	*Diospyros hasseltii* Zoll.	-	/	/	-
231	Ebenaceae	*Diospyros insidiosa* Bakh.	-	/	/	-
232	Ebenaceae	*Diospyros kerrii* Craib	/	/	/	-
233	Ebenaceae	*Diospyros kurzii* Hiern.	-	/	/	-
234	Ebenaceae	*Diospyros lanceifolia* Roxb.	-	/	/	-

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235	Ebenaceae	*Diospyros latisepala* Ridl.	/	/	/	-
236	Ebenaceae	*Diospyros malabarica* (Desr.) Kostel. var. *malabarica*	-	/	/	-
237	Ebenaceae	*Diospyros mollis* Griff.	-	/	/	-
238	Ebenaceae	*Diospyros montana* Roxb.	/	/	/	-
239	Ebenaceae	*Diospyros oblonga* Wall ex G.Don	-	/	/	-
240	Ebenaceae	*Diospyros pilosanthera* Blanco	-	/	/	-
241	Ebenaceae	*Diospyros pilosiuscula* G.Don	-	/	/	-
242	Ebenaceae	*Diospyros racemosa* Roxb.	-	/	/	-
243	Ebenaceae	*Diospyros rhodocalyx* Kurz	-	/	/	-
244	Ebenaceae	*Diospyros scalariformis* H.R.Fletcher	/	/	/	-
245	Ebenaceae	*Diospyros sumatrana* Miq.	-	/	/	-
246	Ebenaceae	*Diospyros thaiensis* Phengklai	/	/	/	-
247	Ebenaceae	*Diospyros trianthos* Phengklai	/	/	/	-
248	Ebenaceae	*Diospyros undulata* Wall. ex G. Don	-	/	/	-
249	Ebenaceae	*Diospyros venosa* Wall. ex A.DC.	-	/	/	-
250	Ebenaceae	*Diospyros vera* (Lour.) A. Chev.	-	/	/	-
251	Ebenaceae	*Diospyros wallichii* King & Gamble	-	/	/	-
252	Ebenaceae	*Diospyros winitii* H.R.Fletcher	/	/	/	-
253	Elaeocarpaceae	*Elaeocarpus braceanus* Watt ex C.B. Clarke	/	/	/	-
254	Elaeocarpaceae	*Elaeocarpus floribundus* Blume	-	/	/	-
255	Elaeocarpaceae	*Elaeocarpus griffithii* (Wight) A. Gray	-	/	/	-
256	Elaeocarpaceae	*Elaeocarpus macrocerus* (Turcz.) Merr.	-	/	/	-
257	Elaeocarpaceae	*Elaeocarpus prunifolius* Wall ex Mull. Berol	-	/	/	-
258	Elaeocarpaceae	*Sloanea sigun* (Blume) K. Schum.	-	/	-	-
259	Elaeocarpaceae	*Sloanea tomentosa* (Benth.) Rehder & E. H.Wilson	/	/	-	-
260	Ericaceae	*Craibiodendron stellatum* (Pierre) W.W. Sm.	-	/	-	-
261	Ericaceae	*Diplycosia heterophylla* Blume var. *latifolia* (Blume) Sleum.	/	-	-	-
262	Ericaceae	*Rhododendron delavayi* Franch.	/	/	-	-
263	Ericaceae	*Rhododendron longiflorum* Lindl.	/	-	-	-
264	Ericaceae	*Rhododendron ludwigianum* Hosseus	/	/	-	-

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265	Ericaceae	*Rhododendron moulmainense* Hook.	/	-	-	-
266	Ericaceae	*Rhododendron simsii* Planch.	/	-	-	-
267	Erythroxylaceae	*Erythroxylum cuneatum* (Miq.) Kurz	-	-	/	-
268	Escalloniaceae	*Polyosma integrifolia* Blume	/	-	-	-
269	Euphorbiaceae	*Balakata baccata* (Roxb.) Esser	-	/	-	-
270	Euphorbiaceae	*Blumeodendron kurzii* (Hook.f.) Sm.	-	/	-	-
271	Euphorbiaceae	*Blumeodendron tokbrai* (Blume) J.J.Sm.	/	-	-	-
272	Euphorbiaceae	*Chorisandrachne diplosperma* Airy Shaw	/	-	-	-
273	Euphorbiaceae	*Claoxylon putii* Airy Shaw	/	-	-	-
274	Euphorbiaceae	*Cleidion javanicum* Blume	-	/	-	-
275	Euphorbiaceae	*Croton kongkandanus* Esser	/	-	-	-
276	Euphorbiaceae	*Croton poomae* Esser	/	-	-	-
277	Euphorbiaceae	*Dimorphocalyx muricatus* (Hook.f.) Airy Shaw	/	-	-	-
278	Euphorbiaceae	*Hancea kingii* (Hook.f.) S.E.C.Sierra, Kulju & Welzen	/	-	-	-
279	Euphorbiaceae	*Mallotus calocarpus* Airy Shaw	/	-	-	-
280	Euphorbiaceae	*Mallotus kongkandae* Welzen & Phattar.	/	-	-	-
281	Euphorbiaceae	*Mallotus pallidus* (Airy Shaw) Airy Shaw	/	-	-	-
282	Euphorbiaceae	*Mallotous resinosus* (Blanco) Merr.	/	-	-	-
283	Euphorbiaceae	*Ptychopyxis plagiocarpa* Airy Shaw	/	-	-	-
284	Euphorbiaceae	*Sauropus thyrsiflorus* Welzen	/	-	-	-
285	Euphorbiaceae	*Spathiostemon moniformis* Airy Shaw	/	-	-	-
286	Euphorbiaceae	*Suregada multiflorum* (A. Juss.) Baill.	-	/	-	-
287	Fabaceae	*Acacia harmandiana* (Pierre) Gagnep.	-	/	/	-
288	Fabaceae	*Acacia leucophloea* (Roxb.) Willd.	-	/	/	-
289	Fabaceae	*Acacia meanrsii* De Wild.	-	/	-	-
290	Fabaceae	*Acacia tomentosa* Willd.	-	/	/	-
291	Fabaceae	*Acrocarpus fraxinifolius* Wight ex Arn.	-	/	/	-
292	Fabaceae	*Adenanthera pavonina* L.	-	/	/	-
293	Fabaceae	*Afzelia xylocarpa* (Kurz) Craib	-	/	/	/

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294	Fabaceae	*Albizia attopeuensis* (Pierre) I.C.Nielsen	/	/	-	-
295	Fabaceae	*Albizia chinensis* (Osbeck) Merr.	-	/	-	-
296	Fabaceae	*Albizia garrettii* I.C.Nielsen	/	/	-	-
297	Fabaceae	*Albizia lebbeck* (L.) Benth.	-	/	/	-
298	Fabaceae	*Albizia lebbeckoides* (DC.) Benth.	-	/	/	-
299	Fabaceae	*Albizia lucidior* (Steud.) I.C.Nielsen	-	/	/	-
300	Fabaceae	*Albizia odoratissima* (L.f.) Benth.	-	/	/	-
301	Fabaceae	*Albizia procera* (Roxb.) Benth.	-	/	/	-
302	Fabaceae	*Albizia vialeana* Pierre	/	/	-	-
303	Fabaceae	*Antheroporum glaucum* Z. Wei	-	/	-	-
304	Fabaceae	*Archidendron bubalinum* (Jack) I.C.Nielsen	-	/	-	-
305	Fabaceae	*Archidendron clypearia* (Jack) I.C.Nielsen	-	/	-	-
306	Fabaceae	*Archidendron conspicuum* (Craib) I.C.Nielsen	/	/	-	-
307	Fabaceae	*Archidendron contortum* (Mart.) I.C.Nielsen	-	/	-	-
308	Fabaceae	*Archidendron ellipticum* (Blume) I.C.Nielsen	-	/	-	-
309	Fabaceae	*Archidendron jiringa* (Jack) I.C.Nielsen	-	/	-	-
310	Fabaceae	*Archidendron lucidum* (Benth.) I.C.Nielsen	-	/	-	-
311	Fabaceae	*Archidendron quocense* (Pierre) I.C.Nielsen	/	/	-	-
312	Fabaceae	*Bauhinia malabarica* Roxb.	-	/	-	-
313	Fabaceae	*Bauhinia saccocalyx* Pierre	-	/	-	-
314	Fabaceae	*Bauhinia variegata* L.	-	/	-	-
315	Fabaceae	*Butea monosperma* (Lam.) Taub.	-	/	-	-
316	Fabaceae	*Callerya atropurpurea* (Wall.) Schot	-	/	-	-
317	Fabaceae	*Cassia bakeriana* Craib	-	/	-	-
318	Fabaceae	*Cassia fistula* L.	-	/	/	-
319	Fabaceae	*Cathormion umbellatum* (Vahl) Kosterm.	-	/	-	-
320	Fabaceae	*Crudia caudata* Prain ex King	/	/	-	-
321	Fabaceae	*Crudia gracilis* Prain	/	/	-	-
322	Fabaceae	*Crudia lanceolatum* Ridl.	/	/	-	-
323	Fabaceae	*Crudia speciosa* Prain	/	/	-	-

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324	Fabaceae	*Cynometra craibii* Gagnep.	/	/	-	-
325	Fabaceae	*Cynometra malaccensis* Meeuwen	-	/	-	-
326	Fabaceae	*Dalbergia cana* Graham ex Kurz var. *kurzii* (Prain) Niyomdham	-	/	/	-
327	Fabaceae	*Dalbergia cochinchinensis* Pierre	-	/	/	/
328	Fabaceae	*Dalbergia cultrata* Graham ex Benth.	-	/	/	-
329	Fabaceae	*Dalbergia lanceolaria* L.f.	-	/	-	-
330	Fabaceae	*Dalbergia oliveri* Gamble ex Prain	-	/	/	/
331	Fabaceae	*Dalbergia velutina* Benth. var. *velutina*	-	/	-	-
332	Fabaceae	*Derris indica* (Lam.) Bennet	-	/	-	-
333	Fabaceae	*Dialium cochinchinense* Pierre	-	/	/	-
334	Fabaceae	*Erythrina stricta* Roxb. var. *stricta*	-	/	-	-
335	Fabaceae	*Erythrina subumbrans* (Hassk.) Merr.	-	/	-	-
336	Fabaceae	*Gymnocladus burmanicus* C.E. Parkinson	/	/	-	-
337	Fabaceae	*Intsia palembanica* Miq.	-	/	/	/
338	Fabaceae	*Koompassia excelsa* (Becc.) Taub.	-	/	/	-
339	Fabaceae	*Millettia brandisiana* Kurz	-	/	-	-
340	Fabaceae	*Millettia leucantha* Kurz var. *leucantha*	-	/	/	-
341	Fabaceae	*Ormosia sumatrana* (Miq.) Prain	-	/	-	-
342	Fabaceae	*Parkia leiophylla* Kurz	-	/	/	-
343	Fabaceae	*Parkia speciosa* Hassk.	-	/	/	/
344	Fabaceae	*Parkia sumatrana* Miq. subsp. *sterptocarpa* (Hance) H.C.Hopkins	-	/	/	-
345	Fabaceae	*Parkia timoriana* (DC.) Merr.	-	/	/	-
346	Fabaceae	*Peltophorum dasyrrhachis* (Miq.) Kurz	-	/	/	-
347	Fabaceae	*Pterocarpus indicus* Willd.	-	/	-	-
348	Fabaceae	*Pterocarpus macrocarpus* Kurz	-	/	/	/
349	Fabaceae	*Saraca declinata* (Jack) Miq.	/	/	-	-
350	Fabaceae	*Saraca indica* L.	-	/	-	-
351	Fabaceae	*Saraca thaipingensis* Cantley ex Prain	/	/	-	-
352	Fabaceae	*Senna garrettiana* (Craib) H.S.Irwin & Barneby	-	/	/	-
353	Fabaceae	*Senna siamea* (Lam.) H.S.Irwin & Barneby	-	/	-	-

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354	Fabaceae	*Sindora echinocalyx* Prain	-	/	-	-
355	Fabaceae	*Sindora siamensis* Teijsm. ex Miq. var. *siamensis*	-	/	/	-
356	Fabaceae	*Xylia xylocarpa* (Roxb.) W. Theob. var. *kerrii* (Craib & Hutch.) I. C. Nielsen	-	/	/	/
357	Fagaceae	*Castanopsis acuminatissima* (Blume) A.DC.	-	/	/	-
358	Fagaceae	*Castanopsis argentea* (Blume) A.DC.	-	/	/	-
359	Fagaceae	*Castanopsis argyrophylla* King ex Hook.f.	-	/	/	-
360	Fagaceae	*Castanopsis armata* (Roxb.) Spach	-	/	/	-
361	Fagaceae	*Castanopsis calathiformis* (Skan) Rehder & E.H. Wilson	-	/	/	-
362	Fagaceae	*Castanopsis cerebrina* (Hickel & A.Camus) Barnett	-	/	/	-
363	Fagaceae	*Castanopsis costata* (Blume) A.DC.	-	/	/	-
364	Fagaceae	*Castanopsis crassifolia* Hickel & A. Camus	-	/	/	-
365	Fagaceae	*Castanopsis diversifolia* (Kurz) King ex Hook.f.	-	/	/	-
366	Fagaceae	*Castanopsis echinocarpa* Miq.	-	/	/	-
367	Fagaceae	*Castanopsis ferox* (Roxb.) Spach	-	/	/	-
368	Fagaceae	*Castanopsis fissa* (Champ. ex Benth.) Rehder & E.H.Wilson	-	/	/	-
369	Fagaceae	*Castanopsis hystrix* Hook.f. & Thomson ex A. DC.	-	/	/	-
370	Fagaceae	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	-	/	/	-
371	Fagaceae	*Castanopsis inermis* (Lindl.) Benth. & Hook.f.	-	/	/	-
372	Fagaceae	*Castanopsis megacarpa* Gamble	/	/	/	-
373	Fagaceae	*Castanopsis nephelioides* King ex Hook.f.	-	/	/	-
374	Fagaceae	*Castanopsis pierrei* Hance	-	/	/	-
375	Fagaceae	*Castanopsis piriformis* Hickel & A.Camus	-	/	/	-
376	Fagaceae	*Castanopsis pseudo-hystrix* Phengklai	/	/	/	-
377	Fagaceae	*Castanopsis purpurea* Barnett	/	/	/	-
378	Fagaceae	*Castanopsis rhamnifolia* (Miq.) A. DC.	-	/	/	-
379	Fagaceae	*Castanopsis tribuloides (*Sm.) A. DC.	-	/	/	-

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380	Fagaceae	*Castanopsis wallichii* King ex Hook.f.	-	/	/	-
381	Fagaceae	*Lithocarpus aggregatus* Barnett	-	/	/	-
382	Fagaceae	*Lithocarpus cantleyanus* (King ex Hook.f.) Rehder	-	/	/	-
383	Fagaceae	*Lithocarpus clementianus* (King) A. Camus	-	/	/	-
384	Fagaceae	*Lithocarpus craibianus* Barnett	-	/	/	-
385	Fagaceae	*Lithocarpus curtisii* (King ex Hoof. f.) A. Camus	-	/	/	-
386	Fagaceae	*Lithocarpus cyclocarpus* (Endl.) A. Camus	-	/	/	-
387	Fagaceae	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder	-	/	/	-
388	Fagaceae	*Lithocarpus echinops* Hjelmq.	/	/	/	-
389	Fagaceae	*Lithocarpus echinophorus* (Hick & A.Camus) A. Camus	-	/	/	-
390	Fagaceae	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	-	/	/	-
391	Fagaceae	*Lithocarpus eucalyptifolius* (Hickel & A. Camus) A. Camus	-	/	/	-
392	Fagaceae	*Lithocarpus falconeri* (Kurz) Rehder	-	/	/	-
393	Fagaceae	*Lithocarpus fenestratus* (Roxb.) Rehder	-	/	/	-
394	Fagaceae	*Lithocarpus garrettianus* (Craib) A. Camus	-	/	/	-
395	Fagaceae	*Lithocarpus harmandii* (Hickel & A. Camus) A. Camus	-	/	/	-
396	Fagaceae	*Lithocarpus lindleyanus* (Wall. ex A. DC.) A. Camus	-	/	/	-
397	Fagaceae	*Lithocarpus lucidus* (Roxb.) Rehder	-	/	/	-
398	Fagaceae	*Lithocarpus magnificus* (Brandis) Barnett	-	/	/	-
399	Fagaceae	*Lithocarpus pattaniensis* Barnett	/	/	/	-
400	Fagaceae	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehder	-	/	/	-
401	Fagaceae	*Lithocarpus rassa* (Miq.) Rehd.	-	/	/	-
402	Fagaceae	*Lithocarpus reinwardtii* (Korth.) A. Camus	-	/	/	-
403	Fagaceae	*Lithocarpus siamensis* A. Camus	/	/	/	-
404	Fagaceae	*Lithocarpus sootepensis* (Craib) A. Camus	-	/	/	-
405	Fagaceae	*Lithocarpus sundaicus* (Blume) Rehder	-	/	/	-

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406	Fagaceae	*Lithocarpus thomsonii* (Miq.) Rehder	-	/	/	-
407	Fagaceae	*Lithocarpus trachycarpus* (Hickel & A. Camus) A. Camus	-	/	/	-
408	Fagaceae	*Lithocarpus truncatus* (King ex. Hook.f.) Rehder	-	/	/	-
409	Fagaceae	*Lithocarpus tubulosus* (Hickel & A. Camus) A. Camus	-	/	/	-
410	Fagaceae	*Lithocarpus wrayi* (King) A. Camus	-	/	/	-
411	Fagaceae	*Lithocarpus xylocarpus* (Kurz) Markgr.	/	/	/	-
412	Fagaceae	*Quercus aliena* Blume subsp. *aliena*	-	/	/	-
413	Fagaceae	*Quercus angustinii* Skan	-	/	/	-
414	Fagaceae	*Quercus auricoma* A. Camus	-	/	/	-
415	Fagaceae	*Quercus brandisiana* Kurz	-	/	/	-
416	Fagaceae	*Quercus eumorpha* Kurz	-	/	/	-
417	Fagaceae	*Quercus franchetii* Skan	-	/	/	-
418	Fagaceae	*Quercus helferiana* A. DC.	-	/	/	-
419	Fagaceae	*Quercus kerrii* Craib	-	/	/	-
420	Fagaceae	*Quercus kingiana* Craib	/	/	/	-
421	Fagaceae	*Quercus lamellosa* Sm.	/	/	/	-
422	Fagaceae	*Quercus lanata* Sm.	-	/	/	-
423	Fagaceae	*Quercus lenticellata* Barnett	/	/	/	-
424	Fagaceae	*Quercus lineata* Blume	-	/	/	-
425	Fagaceae	*Quercus mespilifolia* Wall ex A. DC var. *mespilifoli*	-	/	/	-
426	Fagaceae	*Quercus myrsinaefolia* Blume	-	/	/	-
427	Fagaceae	*Quercus oidocarpa* Korth.	-	/	/	-
428	Fagaceae	*Quercus poilanei* Hick. & A. Camus	-	/	/	-
429	Fagaceae	*Quercus quangtriensis* Hickel & A. Camus	-	/	/	-
430	Fagaceae	*Quercus ramsbottomii* A. Camus	-	/	/	-
431	Fagaceae	*Quercus rex* Hemsl.	/	/	/	-
432	Fagaceae	*Quercus semecarpifolia* Sm.	-	/	/	-
433	Fagaceae	*Quercus semiserrata* Roxb.	-	/	/	-
434	Fagaceae	*Quercus vestita* Griff.	-	/	/	-
435	Fagaceae	*Trigonobalanus doichangensis* (A. Camus) Forman	/	/	-	-

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436	Gentianaceae	*Fagraea fragrans* Roxb.	-	/	/	/
437	Hamamelidaceae	*Distylium annamicum* (Gagnep.) Airy Shaw	/	-	-	-
438	Hamamelidaceae	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.	/	/	-	-
439	Hamamelidaceae	*Loropetalum chinense* (R.Br.) Oliv. var. *chinense*	/	-	-	-
440	Hamamelidaceae	*Rhodoleia championii* Hook.f.	/	-	-	-
441	Hernandiaceae	*Hernandia nymphaeifolia* (J.Presl) Kubitzki	-	/	-	-
442	Hypericaceae	*Cratoxylum arborescens* (Vahl) Blume	/	-	/	-
443	Icacinaceae	*Pittosporopsis kerrii* Craib	-	/	-	-
444	Icacinaceae	*Stemonurus secundiflorus* Blume	-	/	-	-
445	Irvingiaceae	*Irvingia malayana* Oliv. ex A.W. Benn.	-	/	/	-
446	Juglandaceae	*Engelhardtia spicata* Lechen ex Blume var. *spicata*	-	/	/	-
447	Lamiaceae	*Gmelina arborea* Roxb.	-	/	/	/
448	Lamiaceae	*Gmelina racemosa* (Lour.) Merr.	/	-	-	-
449	Lamiaceae	*Peronema canescens* Jack	-	-	/	-
450	Lamiaceae	*Premna tomentosa* Willd.	-	/	/	-
451	Lamiaceae	*Tectona grandis* L.f.	-	/	/	/
452	Lamiaceae	*Vitex canescens* Kurz	-	/	/	-
453	Lamiaceae	*Vitex longisepala* King & Gamble	/	-	-	-
454	Lamiaceae	*Vitex peduncularis* Wall. ex Schauer	-	/	/	-
455	Lamiaceae	*Vitex pinnata* L.	-	/	/	-
456	Lamiaceae	*Vitex quinata* (Lour.) F.N. Williams	-	/	-	-
457	Lauraceae	*Actinodaphne henryi* Gamble	-	/	-	-
458	Lauraceae	*Beilschmiedia elegantissima* Kosterm.	/	-	-	-
459	Lauraceae	*Beilschmiedia gammieana* King ex Hook.f.	-	/	-	-
460	Lauraceae	*Beilschmiedia inconspicua* Kesterm.	/	-	-	-
461	Lauraceae	*Beilschmiedia velutinosa* Kosterm.	/	-	-	-
462	Lauraceae	*Beilschmiedia villosa* Kosterm.	/	-	-	-
463	Lauraceae	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	-	/	/	-
464	Lauraceae	*Cinnamomum glaucescens* (Nees) Hand.-Mazz	-	/	-	-

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465	Lauraceae	*Cinnamomum ilicioides* A. Chev.	-	/	/	-
466	Lauraceae	*Cinnamomum iners* Reinw. ex Blume	-	/	/	-
467	Lauraceae	*Cinnamomum parthenoxylon* (Jack) Meisn.	-	-	/	-
468	Lauraceae	*Cinnamomum tamala* (Buch.-Ham) T. Nee & Eberm.	-	/	-	-
469	Lauraceae	*Litsea beusekomii* Kosterm.	-	/	-	-
470	Lauraceae	*Litsea kerrii* Kosterm.	/	-	-	-
471	Lauraceae	*Litsea martabarnica* (Kurz) Hook.f.	-	/	-	-
472	Lauraceae	*Litsea membranifolia* Hook.f.	/	-	-	-
473	Lauraceae	*Litsea monopetala* (Roxb.) Pers.	-	/	/	-
474	Lauraceae	*Litsea pseudo-umbellata* Kosterm.	/	-	-	-
475	Lauraceae	*Litsea punctulata* Kosterm.	/	-	-	-
476	Lauraceae	*Litsea semecarpifolia* (Wall ex Nees) Hook	-	/	-	-
477	Lauraceae	*Neocinnamomum caudatum* (Nees) Merrs.	-	/	-	-
478	Lauraceae	*Neolitsea zeylanica* (Nees & T.Nees) Merr.	-	-	/	-
479	Lauraceae	*Persea gamblei* (Hook.f.) Kosterm.	-	/	-	-
480	Lauraceae	*Phoebe lanceolata* (Nees) Nees	-	/	/	-
481	Lauraceae	*Phoebe paniculata* (Nees) Nees	-	/	/	-
482	Lauraceae	*Phoebe tavoyana* (Meisn.) Hook.f.	-	/	-	-
483	Lecythidaceae	*Barringtonia asiatica* (L.) Kurz	/	/	-	-
484	Lecythidaceae	*Barringtonia racemosa* (L.) Spreng.	-	/	-	-
485	Lecythidaceae	*Careya arborea* Roxb.	-	/	/	-
486	Loganiaceae	*Strychnos nux-vomica* L.	-	/	-	-
487	Lythraceae	*Duabanga grandiflora* (DC.) Walp.	-	-	/	-
488	Lythraceae	*Lagerstroemia calyculata* Kurz	-	/	/	-
489	Lythraceae	*Lagerstroemia cochinchinensis* Pierre	-	/	/	-
490	Lythraceae	*Lagerstroemia macrocarpa* Wall. ex Kurz	-	/	/	-
491	Lythraceae	*Lagerstroemia speciosa* (L.) Pers.	-	/	/	-
492	Lythraceae	*Lagerstroemia tomentosa* C. Presl	-	/	/	-
493	Lythraceae	*Lagerstroemia venusta* Wall. ex C.B.Clarke	-	/	/	-
494	Lythraceae	*Lagerstroemia villosa* Wall. ex Kurz	-	/	-	-
495	Lythraceae	*Sonneratia alba* Sm.	-	/	-	-

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496	Lythraceae	*Sonneratia caseolaris* (L.) Engl.	-	/	-	-
497	Lythraceae	*Sonneratia griffithii* Kurz	-	/	-	-
498	Magnoliaceae	*Magnolia baillonii* Pierre	-	/	/	-
499	Magnoliaceae	*Magnolia betongensis* (Craib) H.Keng	-	/	-	-
500	Magnoliaceae	*Magnolia cathcartii* (Hook.f. &Thomson) Noot.	-	/	/	-
501	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *champaca*	-	/	/	-
502	Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre var. *pubinervia* (Blume) Figlar & Noot.	-	/	/	-
503	Magnoliaceae	*Magnolia citrata* Noot. & Chalermglin	-	/	/	-
504	Magnoliaceae	*Magnolia duperreana* Pierre	/	/	/	-
505	Magnoliaceae	*Magnolia elegans* (Blume) H.Keng	-	/	/	-
506	Magnoliaceae	*Magnolia floribunda* (Finet & Gagnep.) Figlar	-	/	/	-
507	Magnoliaceae	*Magnolia garrettii* (Craib) V.S.Kumar	/	/	-	/
508	Magnoliaceae	*Magnolia gustavii* King	-	/	/	-
509	Magnoliaceae	*Magnolia henryi* Dunn	-	/	/	-
510	Magnoliaceae	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng	-	/	/	-
511	Magnoliaceae	*Magnolia insignis* Wall.	-	/	-	-
512	Magnoliaceae	*Magnolia koordersiana* (Noot.) Figlar	-	/	/	-
513	Magnoliaceae	*Magnolia liliifera* (L.) Baill.	/	/	-	-
514	Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar	/	/	/	-
515	Magnoliaceae	*Magnolia praecalva* (Dandy) Figlar & Noot.	/	/	-	-
516	Magnoliaceae	*Magnolia rajaniana* (Craib) Figlar	/	/	/	-
517	Magnoliaceae	*Magnolia siamensis* (Dandy) H.Keng	-	/	/	-
518	Magnoliaceae	*Magnolia sirindhorniae* Noot. & Chalermglin	/	/	/	-
519	Magnoliaceae	*Magnolia thailandica* Noot. & Chalermglin	/	/	/	-
520	Malvaceae	*Berrya mollis* Wall. ex Kurz	-	/	/	-
521	Malvaceae	*Burretiodendron esquirolii* (Lév.) Rehder	/	-	-	-
522	Malvaceae	*Colona flagrocarpa* (C.B. Clarke) Craib	-	/	-	-

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523	Malvaceae	*Dicellostyles zizyphifolia* (Griff.) Phup.	/	-	-	-
524	Malvaceae	*Durio graveolens* Becc.	/	-	-	-
525	Malvaceae	*Durio griffithii* (Mast.) Bakh.	/	/	/	-
526	Malvaceae	*Durio lowianus* Scort. ex King	/	/	/	-
527	Malvaceae	*Durio mansoni* (Gamble) Bakh.	/	-	/	/
528	Malvaceae	*Firmiana colorata* (Roxb.) R.Br.	-	/	-	-
529	Malvaceae	*Firmiana kerrii* (Craib) Kosterm.	/	-	-	-
530	Malvaceae	*Heritiera javanica* (Blume) Kosterm.	-	/	/	-
531	Malvaceae	*Heritiera littoralis* Aiton	-	/	/	-
532	Malvaceae	*Kydia calycina* Roxb.	-	/	/	-
533	Malvaceae	*Neesia altissima* (Blume) Blume	/	/	/	-
534	Malvaceae	*Neesia malayana* Bakh.	-	/	/	-
535	Malvaceae	*Pterocymbium tinctorium* (Blanco) Merr.	-	/	-	-
536	Malvaceae	*Pterospermum grandiflorum* Craib	/	-	/	-
537	Malvaceae	*Pterygota alata* (Roxb.) R.Br.	-	/	-	-
538	Malvaceae	*Reevesia pubescens* Mast. var. *pubescens*	/	-	-	-
539	Malvaceae	*Reevesia pubescens* Mast. var. *siamensis* (Craib) Anthony	/	-	-	-
540	Malvaceae	*Scaphium linearicarpum* (Mast.) Pierre	-	/	-	-
541	Malvaceae	*Scaphium scaphigerum* (Wall. ex G.Don) G.Planch.	-	/	-	-
542	Malvaceae	*Sterculia foetida* L.	-	/	-	-
543	Malvaceae	*Sterculia gilva* Miq.	/	-	-	-
544	Malvaceae	*Sterculia pexa* Pierre	-	/	-	-
545	Malvaceae	*Sterculia villosa* Roxb.	-	/	-	-
546	Malvaceae	*Thespesia lampas* (Cav.) Dalzell & A. Gibson var. *lampas*	-	/	-	-
547	Malvaceae	*Thespesia populnea* (L.) Soland. ex Corr.	-	/	-	-
548	Melastomataceae	*Memecylon ovatum* Sm.	-	-	/	-
549	Melastomataceae	*Memecylon scutellatum* (Lour.) Hook. & Arn. var. *scutellatum*	-	/	-	-
550	Meliaceae	*Aglaia chittagonga* Miq.	/	/	-	-
551	Meliaceae	*Aglaia perviridis* Hiern	/	-	-	-
552	Meliaceae	*Aglaia rubiginosa* (Hiern) Pannell	-	/	-	-

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553	Meliaceae	*Aglaia silvestris* (M.Roem.) Merr.	-	/	-	-
554	Meliaceae	*Aphanamixis polystachya* (Wall.) R. Parker	-	/	-	-
555	Meliaceae	*Azadirachta excelsa* (Jack) Jacobs	-	-	-	/
556	Meliaceae	*Azadirachta indica* A.Juss	-	/	/	/
557	Meliaceae	*Chisocheton patens* Blume	-	/	-	-
558	Meliaceae	*Chukrasia tabularis* A.Juss.	-	/	/	/
559	Meliaceae	*Melia azedarach* L.	-	/	/	-
560	Meliaceae	*Sandoricum beccarianum* Baill.	-	/	-	-
561	Meliaceae	*Sandoricum koetjape* (Burm.f.) Merr.	-	/	/	-
562	Meliaceae	*Toona ciliata* M. Roem.	-	/	/	/
563	Meliaceae	*Walsura robusta* Roxb.	-	/	/	-
564	Meliaceae	*Walsura trichostemon* Miq.	-	/	/	-
565	Meliaceae	*Xylocarpus granatum* J. Koenig	-	/	/	-
566	Meliaceae	*Xylocarpus moluccensis* (Lam.) M. Roem.	-	/	/	-
567	Meliaceae	*Xylocarpus rumphii* (Kostel.) Mabb.	-	/	/	-
568	Moraceae	*Antiaris toxicaria* Leach.	-	-	/	-
569	Moraceae	*Artocarpus elasticus* Reinw. ex Blume	-	/	/	-
570	Moraceae	*Artocarpus lacucha* Roxb. ex Buch.-Ham.	-	/	/	-
571	Moraceae	*Artocarpus lanceifolius* Roxb.	-	/	/	-
572	Moraceae	*Artocarpus rigidus* Blume	-	/	/	-
573	Moraceae	*Artocarpus thailandicus* C. C. Berg	/	-	/	-
574	Moraceae	*Ficus racemosa* Linn.	-	/	-	-
575	Moraceae	*Streblus asper* Lour.	-	/	-	-
576	Moraceae	*Streblus ilicifolius* (S.Vidal) Corner	-	/	-	-
577	Myricaceae	*Myrica esculenta* Buch-Ham ex D.Don	-	/	-	-
578	Myristicaceae	*Horsfieldia amygdalina* (Wall.) Warb. var. *amygdalina*	/	/	-	-
579	Myristicaceae	*Horsfieldia crassifolia* (Hook.f.et.Th.) Warb.	-	/	-	-
580	Myristicaceae	*Horsfieldia irya* (Gaertn.) Warb.	-	/	-	-
581	Myristicaceae	*Knema andamanica* (Warb.) W.J.de Wilde subsp. *peninsularis* W.J.de Wilde	/	-	-	-

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582	Myristicaceae	*Knema austrosiamensis* W.J.de Wilde	/	-	-	-
583	Myristicaceae	*Knema globulatericia* W.J.de Wilde	/	-	-	-
584	Myristicaceae	*Knema tenuinervia* W.J.de Wilde subsp. *kanburiensis* W.J.de Wilde	/	-	-	-
585	Myristicaceae	*Myristica elliptica* Wall. ex Hook.f. & Thomson	-	/	/	-
586	Myristicaceae	*Myristica iners* Blume	-	/	/	-
587	Myrtaceae	*Baeckea frutescens* L.	-	/	-	-
588	Myrtaceae	*Melaleuca cajuputi* Powell	-	/	-	-
589	Myrtaceae	*Syzygium aksornii* Chantar. & J.Parn.	/	-	-	-
590	Myrtaceae	*Syzygium angkae* (Craib) Chantar. & J.Parn subsp. *Angkae*	-	/	-	-
591	Myrtaceae	*Syzygium antisepticum* (Blume) Merr. & L.M.Perry	/	/	-	-
592	Myrtaceae	*Syzygium cacuminis* (Craib) Chantar. & J.Parn subsp. *inthanonense* P.Chan. & J.Parn	/	-	-	-
593	Myrtaceae	*Syzygium cumini* (L.) Skeels	-	/	-	-
594	Myrtaceae	*Syzygium grande* (Wight) Walp. var. *grande*	-	/	-	-
595	Myrtaceae	*Syzygium hemsleyanum* (King) Chantar. & J.Parn subsp. *paucinervium* Chantar. & J.Parn	/	-	-	-
596	Myrtaceae	*Syzygium ixoroides* Chantar.& J.Parn	/	-	-	-
597	Myrtaceae	*Syzygium kerrii* Chantar. & J.Parn.	/	-	-	-
598	Myrtaceae	*Syzygium lakshrakarae* Chantar.& J.Parn	/	-	-	-
599	Myrtaceae	*Syzygium myrtifolium* Walp.	/	-	-	-
600	Myrtaceae	*Syzygium oblatum* (Roxb.) Wall. ex A.M. Cowan & Cowan var. *oblatum*	-	/	-	-
601	Myrtaceae	*Syzygium putii* Chantar.& J.Parn	/	-	-	-
602	Myrtaceae	*Syzygium rigens* (Craib) Chantar. & J. Parn.	/	-	-	-
603	Myrtaceae	*Syzygium samarangense* (Blume) Merr. & L.M.Perry	/	-	-	-
604	Myrtaceae	*Tristaniopsis burmanica* (Griff.) Peter G. Wilson & J.T. Waterh. var. *rufescens* (Hance) J. Parn.& Nic Lughadha	-	/	-	-
605	Ochnaceae	*Ochna integerrima* (Lour.) Merr.	-	/	-	-
606	Olacaceae	*Schoepfia fragrans* Wall.	/	-	-	-

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607	Olacaceae	*Scorodocarpus borneensis* (Baill.) Becc.	/	-	/	-
608	Oleaceae	*Chionanthus amblirrhinus* P.S.Green	/	-	-	-
609	Oleaceae	*Chionanthus decipiens* P.S.Green	/	-	-	-
610	Oleaceae	*Chionanthus eriorachis* (Kerr) P.S.Green	/	-	-	-
611	Oleaceae	*Chionanthus maxwelli* P.S.Green	/	-	-	-
612	Oleaceae	*Chionanthus sutepensis* (Kerr) P.S.Green	/	-	-	-
613	Oleaceae	*Chionanthus velutinus* (Kerr) P.S.Green	/	-	-	-
614	Oleaceae	*Fraxinus floribunda* Wall.	/	/	/	-
615	Opiliaceae	*Melientha suavis* Pierre	-	/	-	/
616	Oxalidaceae	*Sarcotheca laxa* (Ridl.) Kunth	/	-	-	-
617	Paulowniaceae	*Wightia speciosissima* (D.Don) Merr.	-	/	-	-
618	Pentaphylacaceae	*Adinandra integerrima* T. Anderson ex Dyer	-	/	-	-
619	Pentaphylacaceae	*Anneslea fragrans* Wall.	-	/	-	-
620	Pentaphylacaceae	*Eurya acuminata* DC. var. *acuminata*	-	/	-	-
621	Pentaphylacaceae	*Eurya nitida* Korth.	-	/	-	-
622	Pentaphylacaceae	*Ternstroemia gymnanthera* (Wight & Arn.) Bedd.	-	/	-	-
623	Phyllanthaceae	*Antidesma bunius* (L.) Spreng.	/	-	-	-
624	Phyllanthaceae	*Aporosa duthieana* King ex Pax & K. Hoffim.	/	-	-	-
625	Phyllanthaceae	*Aporosa globifera* Hook.f.	/	-	-	-
626	Phyllanthaceae	*Baccaurea bracteata* Mull. Arg.	-	/	-	-
627	Phyllanthaceae	*Baccaurea ramiflora* Lour.	-	/	-	-
628	Phyllanthaceae	*Baccaurea sumatrana* (Miq.) Müll.Arg.	/	-	-	-
629	Phyllanthaceae	*Bischofia javanica* Blume	-	/	/	-
630	Phyllanthaceae	*Cleistanthus hirsutopetalus* Gage	/	-	-	-
631	Phyllanthaceae	*Glochidion santisukii* Airy Saw	/	-	-	-
632	Phyllanthaceae	*Phyllanthus angkorensis* Beille	/	-	-	-
633	Picrodendraceae	*Austrobuxus nitidus* Miq.	/	-	-	-
634	Pinaceae	*Pinus kesiya* Royle ex Gordon	-	/	/	/
635	Pinaceae	*Pinus merkusii* Jungh. & de Vriese	-	/	/	/
636	Podocarpaceae	*Dacrycapus imbricatus* (Blume) de Laub.	/	-	-	-

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637	Podocarpaceae	*Dacrydium elatum* (Roxb.) Wall. ex Hook.	/	/	/	-
638	Podocarpaceae	*Nageia wallichiana* (C.Presl) Kuntze	/	/	-	-
639	Podocarpaceae	*Podocarpus neriifolius* D.Don	/	/	/	-
640	Podocarpaceae	*Podocarpus polystachyus* R. Br. ex Endl.	/	/	-	-
641	Polygalaceae	*Xanthophyllum lanceatum* J.J.Sm.	-	/	/	-
642	Polygalaceae	*Xanthophyllum virens* Roxb.	-	/	/	-
643	Primulaceae	*Ardisia nervosa* H.R.Fletcher	/	-	-	-
644	Proteaceae	*Helicia formosana* Hemsl. var. *oblanceolata* Sleumer	-	/	-	-
645	Proteaceae	*Helicia nilagirica* Bedd.	-	/	/	-
646	Proteaceae	*Helicia vestita* W.W. Sm.	/	/	-	-
647	Proteaceae	*Heliciopsis terminalis* (Kurz) Sleumer	-	/	-	-
648	Putranjivaceae	*Drypetes curtisii* (Hook.f.) Pax & K.Hoffm	/	-	-	-
649	Putranjivaceae	*Drypetes dasycarpa* (Airy Show) Phuph. & Chayamarit	/	-	-	-
650	Putranjivaceae	*Drypetes helferi* (Hook.f.) Pax & K.Hoffm.	/	-	-	-
651	Putranjivaceae	*Drypetes ochrothrix* Airy Saw	/	-	-	-
652	Putranjivaceae	*Drypetes pendula* Ridl.	/	-	-	-
653	Putranjivaceae	*Drypetes subsessile* (Kurz) Pax & K.Hoffm.	/	-	-	-
654	Putranjivaceae	*Drypetes viridis* Airy Saw	/	-	-	-
655	Rhizophoraceae	*Bruguiera parviflora* (Roxb.) Wight & Arn. ex Griff.	-	/	/	-
656	Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.	-	/	/	-
657	Rhizophoraceae	*Gynotroches axillaris* Blume	/	-	-	-
658	Rhizophoraceae	*Rhizophora apiculata* Blume	-	/	/	-
659	Rhizophoraceae	*Rhizophora mucronata* Poir.	-	/	/	-
660	Rosaceae	*Eriobotrya bengalensis* (Roxb.) Hook.f.	-	/	-	-
661	Rosaceae	*Photinia arguta* Lindl. var. *salicifolia* (Decne.) Vidal	/	-	-	-
662	Rosaceae	*Prunus cerasoides* D.Don	/	/	-	-
663	Rubiaceae	*Aidia parvifolia* (King & Gamble) K.M. Wong	-	/	-	-
664	Rubiaceae	*Ceriscoides kerrii* Azmi	/	-	-	-

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665	Rubiaceae	*Ceriscoides mamillata* (Craib) Tirveng.	/	-	-	-
666	Rubiaceae	*Fosbergia thailandica* Tirveng. & Sastre	/	-	-	-
667	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Hook.f.	-	/	/	-
668	Rubiaceae	*Gardenia sootepensis* Hutch.	/	/	/	-
669	Rubiaceae	*Gardenia thailandica* Tirveng.	/	-	-	-
670	Rubiaceae	*Gardiniopsis longifolia* Miq.	/	-	-	-
671	Rubiaceae	*Guettarda speciosa* L.	-	/	-	-
672	Rubiaceae	*Haldina cordifolia* (Roxb.) Ridsdale	-	/	/	-
673	Rubiaceae	*Ixora grandifolia* Zoll. & Moritzi	-	/	-	-
674	Rubiaceae	*Luculia gratissima* (Wall.) Sweet var. *glabra* Fukuoka	-	/	-	-
675	Rubiaceae	*Mitragyna diversifolia* (Wall. ex G. Don) Havil	-	/	-	-
676	Rubiaceae	*Mitragyna hirsuta* Havil	-	/	-	-
677	Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze	-	/	/	-
678	Rubiaceae	*Nauclea orientalis* (L.) L.	-	/	/	-
679	Rubiaceae	*Nauclea subdita* (Korth.) Steud.	-	/	-	-
680	Rubiaceae	*Neolamarckia cadamba* (Roxb.) Bosser	-	/	-	-
681	Rubiaceae	*Ochreinauclea maingayi* (Hook.f.) Ridsdale	-	/	-	-
682	Rubiaceae	*Pertusadina malaccensis* Ridsdale	/	-	-	-
683	Rubiaceae	*Pitardelia poilanei* Tirveng.	/	-	-	-
684	Rubiaceae	*Psydrax dicoccos* Gaertn.	-	/	-	-
685	Rubiaceae	*Rennellia morindiformis* (Korth.) Ridl.	/	-	-	-
686	Rubiaceae	*Rothmannia sootepensis* (Craib) Bremek.	/	-	-	-
687	Rubiaceae	*Vidalasia fusca* (Craib) Tirveng.	/	-	-	-
688	Rubiaceae	*Vidalasia murina* (Criab) Tirveng.	/	-	-	-
689	Rubiaceae	*Vidalasia pubescens* (Tirveng. & Sastre) Tirveng.	/	-	-	-
690	Rubiaceae	*Wendlandia tinctoria* (Roxb.) DC.	-	/	-	-
691	Rutaceae	*Atalantia monophylla* (L.) DC.	-	/	-	-
692	Rutaceae	*Citrus halimii* B.C.Stone	/	-	-	-
693	Rutaceae	*Naringi crenulata* (Roxb.) Nicolson	-	/	-	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
694	Sabiaceae	*Meliosma pinnata* (Roxb.) Maxim. subsp. *barbulata* (Cufod.) Welzen	-	/	-	-
695	Salicaceae	*Homalium ceylanicum* (Gardner) Benth.	-	/	-	-
696	Salicaceae	*Homalium foetidum* (Roxb.) Benth.	-	/	-	-
697	Salicaceae	*Homalium grandiflorum* Benth.	/	/	/	-
698	Salicaceae	*Homalium longifolium* Benth.	/	-	-	-
699	Salicaceae	*Homalium peninsulare* Sleum.	/	-	-	-
700	Salicaceae	*Homalium tomentosum* (Vent.) Benth.	-	/	/	-
701	Salicaceae	*Salix tetrasperma* Roxb.	-	/	-	-
702	Santalaceae	*Scleropyrum pentandrum* (Dennst.) Mabb.	/	/	-	-
703	Sapindaceae	*Acer calcaratum* Gagnep.	/	/	-	-
704	Sapindaceae	*Acer chiangdaoense* Santisuk	/	-	-	-
705	Sapindaceae	*Acer laurinum* Hassk.	-	/	-	-
706	Sapindaceae	*Acer pseudowilsonii* Y.S.Chen	/	-	-	-
707	Sapindaceae	*Aesculus assamica* Griff.	/	/	-	-
708	Sapindaceae	*Arfeuillea arborescens* Pierre ex Radlk.	-	/	-	-
709	Sapindaceae	*Dimocarpus longan* Lour. var. *longan*	-	/	-	-
710	Sapindaceae	*Nephelium hypoleucum* Kurz	-	/	/	-
711	Sapindaceae	*Nephelium maingayi* Hiern	/	/	/	-
712	Sapindaceae	*Nephelium melliferum* Gagnep.	/	/	/	-
713	Sapindaceae	*Paranephelium xestophyllum* Miq.	-	/	-	-
714	Sapindaceae	*Pometia pinnata* J.R. & G. Forst.	-	/	/	-
715	Sapindaceae	*Sapindus rarak* DC.	-	/	-	-
716	Sapindaceae	*Schleichera oleosa* (Lour) Merr.	-	/	/	-
717	Sapindaceae	*Zollingeria dongnaiensis* Pierre	-	/	-	-
718	Sapotaceae	*Diploknema siamensis* H.R.Fletcher	/	-	-	-
719	Sapotaceae	*Madhuca esculenta* H.R.Fletcher	/	-	/	-
720	Sapotaceae	*Madhuca klackenbergii* Chantar.	/	-	-	-
721	Sapotaceae	*Madhuca stipulacea* H.R.Fletcher	/	-	-	-
722	Sapotaceae	*Manilkara hexandra* (Roxb.) Dubard	-	/	/	-
723	Sapotaceae	*Palaquium obovatum* (Griff.) Engl.	-	/	/	-
724	Sapotaceae	*Payena maingayi* C.B.Clarke	/	-	/	-

No.	Family	Botanical name	Tree that are threatened with extinction	Trees that dominate the different forest types in Thailand	Trees that are of particular economic importance	Trees that are important to *in situ* genetic conservation
725	Sapotaceae	*Pouteria obovata* (R.Br.) Baehni	-	/	-	-
726	Sapotaceae	*Weinmannia fraxinea* (D.Don) Miq.	/	-	-	-
727	Sauraulaceae	*Saurauia pentapetala* (Jack) Hoogland	/	-	-	-
728	Schisandraceae	*Illicium peninsulare* A.C. Sm.	/	-	-	-
729	Schisandraceae	*Illicium tenuifolium* (Ridl.) A.C. Sm.	/	-	-	-
730	Simaroubaceae	*Ailanthus triphysa* (Dennst.) Alston	-	/	-	-
731	Simaroubaceae	*Picrasma javanica* Blume	-	/	-	-
732	Styracaceae	*Styrax benzoides* Craib	-	/	-	-
733	Symplocaceae	*Symplocos cochinchinensis* (Lour.) S. Moore var. *cochinchinensis*	-	/	-	-
734	Symplocaceae	*Symplocos racemosa* Roxb.	-	/	-	-
735	Symplocaceae	*Symplocos sumuntia* Buch.-Ham. ex D. Don	-	/	-	-
736	Tetramelaceae	*Tetrameles nudiflora* R.Br.	-	/	/	/
737	Theaceae	*Camellia connata* (Craib) Craib	/	/	-	-
738	Theaceae	*Camellia oleifera* C.Abel. var. *confusa* (Craib) Sealy	-	/	-	-
739	Theaceae	*Gordonia axillaris* (Roxb. ex Ker Gawl) Endl.	/	-	-	-
740	Theaceae	*Gordonia dalglieshiana* Craib	/	/	-	-
741	Theaceae	*Pyrenaria diospyricarpa* Kurz var. *camelliflora* (Kurz) S.X.Yang	-	/	-	-
742	Theaceae	*Pyrenaria diospyricarpa* Kurz var. *diospyricarpa*	/	/	-	-
743	Theaceae	*Schima wallichii* (DC.) Korth.	-	/	/	-
744	Thymelaeaceae	*Aquilaria crassna* Pierre ex Lecomte	/	-	-	/
745	Thymelaeaceae	*Aquilaria malaccensis* Lam.	/	/	-	-
746	Thymelaeaceae	*Gonystylus confusus* Airy Shaw	/	-	-	-
747	Thymelaeaceae	*Gyrinops vidalii* P.H.Hô	/	-	-	-
748	Ulmaceae	*Holoptelea integrifolia* Planch.	-	/	/	/
749	Ulmaceae	*Ulmus lancifolia* Roxb. ex Wall	-	/	/	-

Note: Each species can be in more than one group of tree. Symbol ‘ / ’ under each group of tree means that species belongs to that tree group, Symbol ‘ **-** ’ means that species does not belong to that tree group.

Appendix B: Maps of 22 layers analysed in ILWIS program

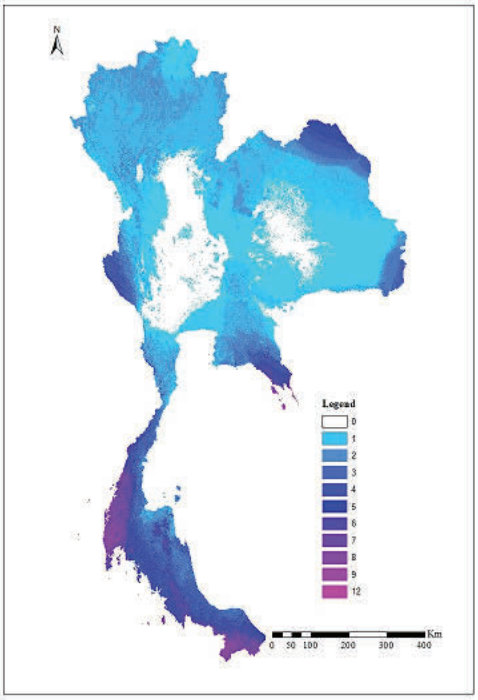

Figure B1 - Layer 1 Tree species richness
Note: the values are used to show the total number of all tree species present within each pixel

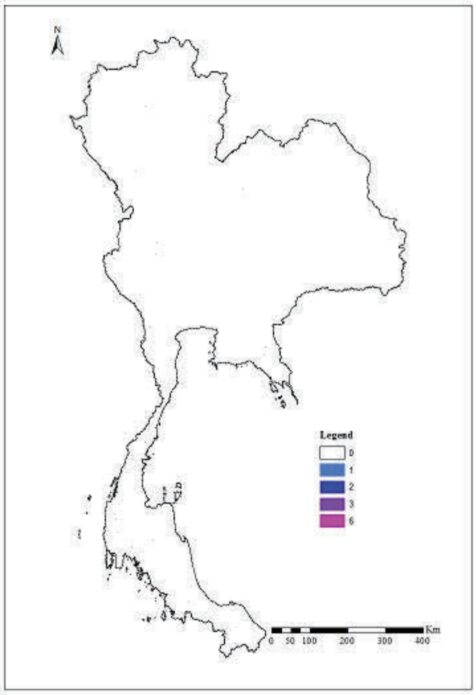

Figure B2 - Layer 2 Rare tree species
Note: the values are used to show the total number of all tree species present within each pixel

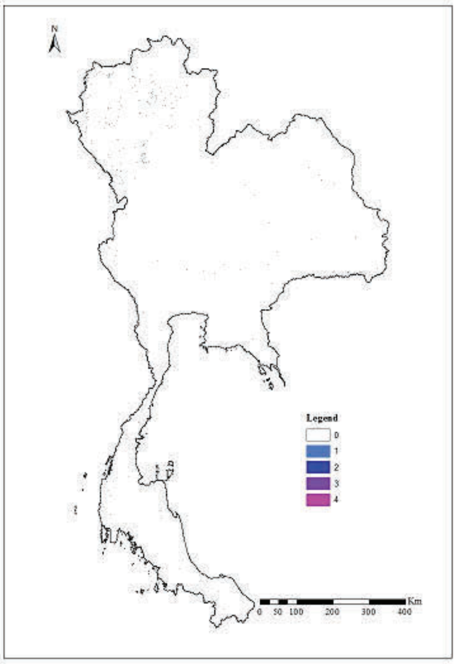

Figure B3 - Layer 3 Tree species of high genetic conservation value
Note: the values are used to show the total number of all tree species present within each pixel

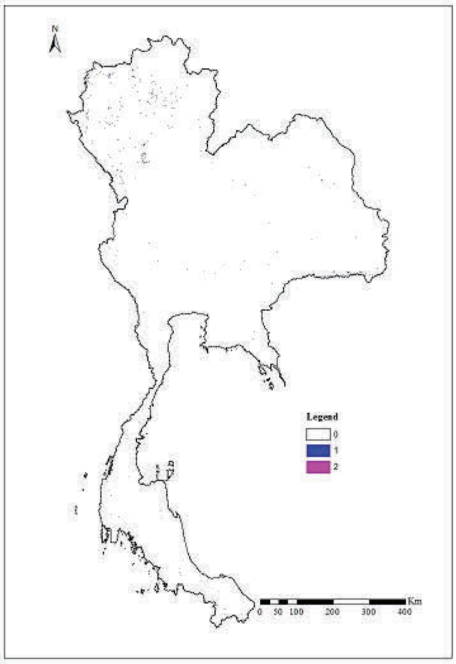

Figure B4 - Layer 4 Economically important tree species
Note: the values are used to show the total number of all tree species present within each pixel

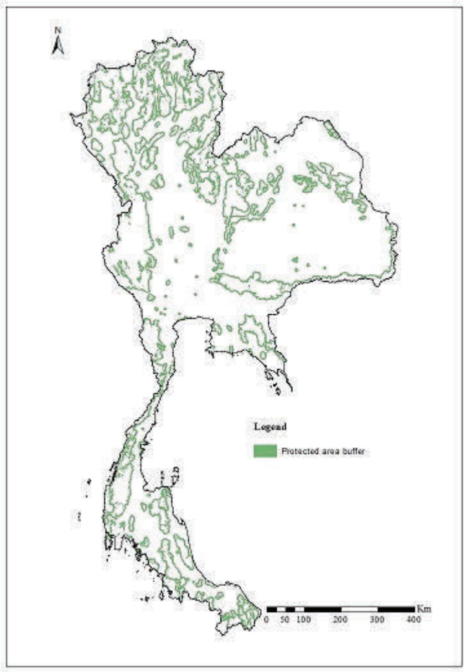

Figure B5 - Layer 5 Protected area buffer, that is a 4 km-buffer outside the PA boundaries

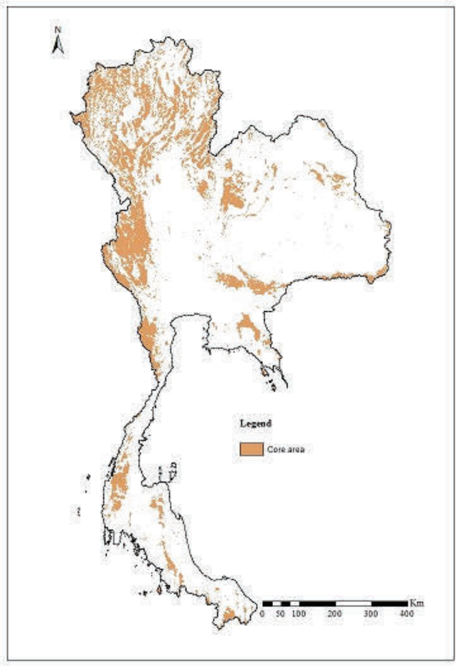

Figure B6 - Layer 6 Core area, that is areas inside forest patches after excluding 300 m from the forest edge

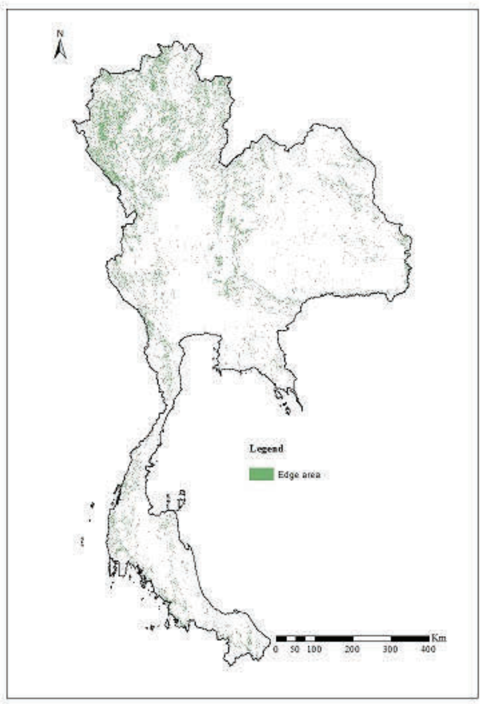

Figure B7 - Layer 7 Edge area, that is the 300 m-outer area of forest patches from forest edge to core area

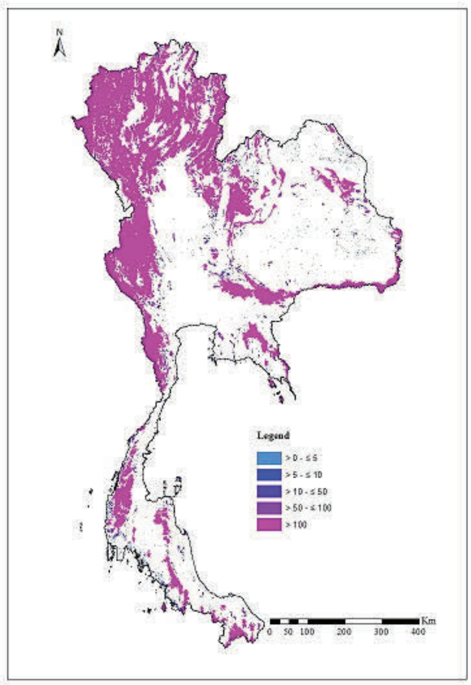

Figure B8 - Layer 8 Forest patch size

Note: the values are used to show size of forest patch present within each pixel in km^2. These are > 0 - ≤ 5 small patch size); > 5 - ≤ 10 = rather small patch size; > 10 - ≤ 50 = medium patch size; > 50 - ≤ 100 = rather large patch size; and > 100 = large patch size

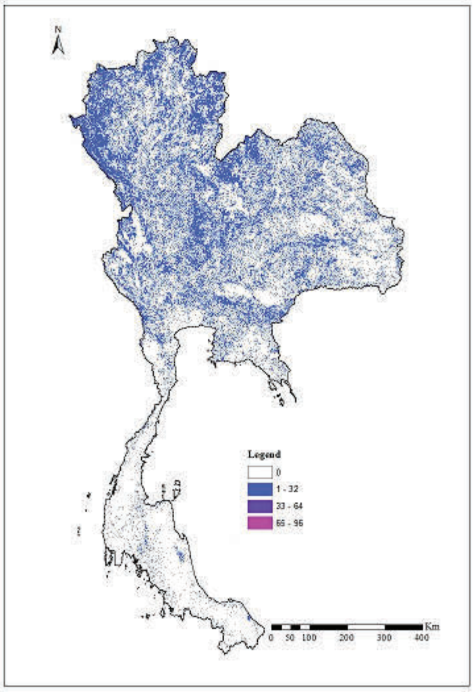

Figure B9 - Layer 9 Fire frequency
Note: the values are used to show the number of fire occurrences present within each pixel. These are 0 = no fire/pixel; 1 - 32 = low fire frequency; 33 - 64 = medium fire frequency; and 65 - 96 = high fire frequency

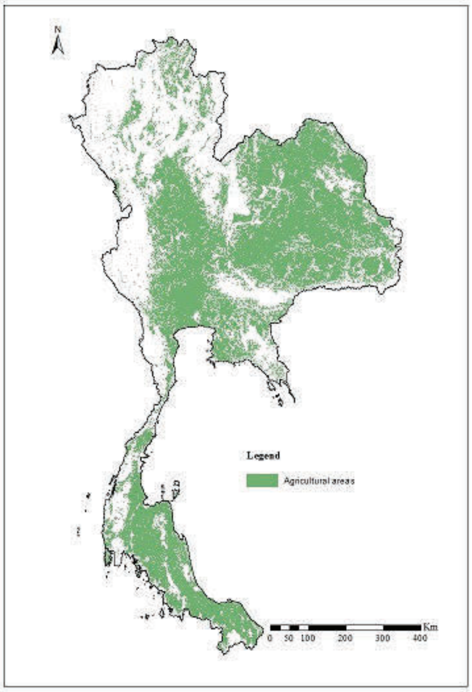

Figure B10 - Layer 10 Land conversion to agricultural areas

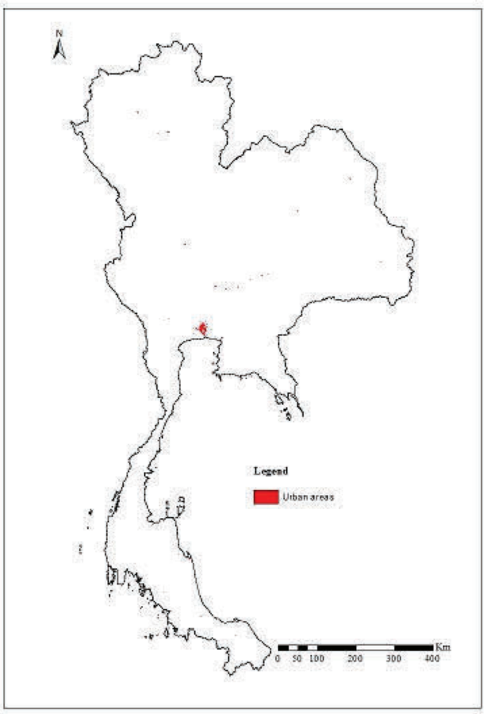

Figure B11 - Layer 11 Land conversion to urban areas

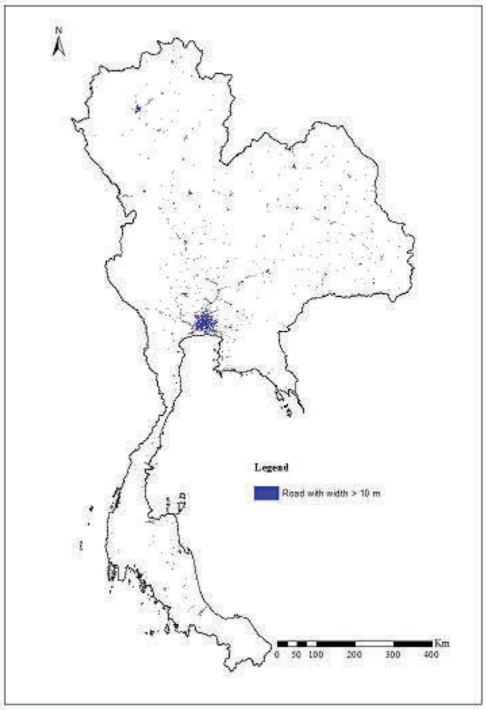

Figure B12 - Layer 12 Land conversion to roads, areas that were changed into roads with width > 10 m

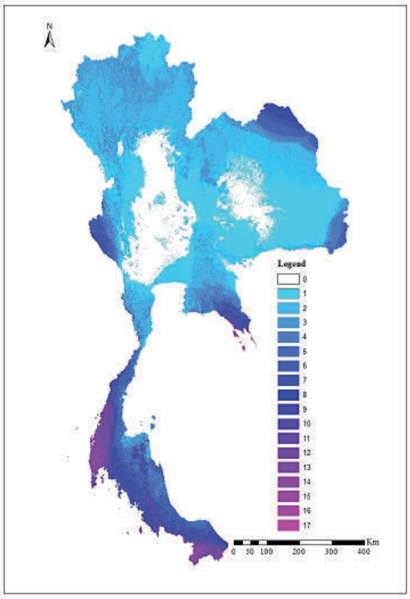

Figure B13 - Layer 13 Diversity of species habitat suitability
Note: the values are used to show the total number of all tree suitable habitats within each pixel

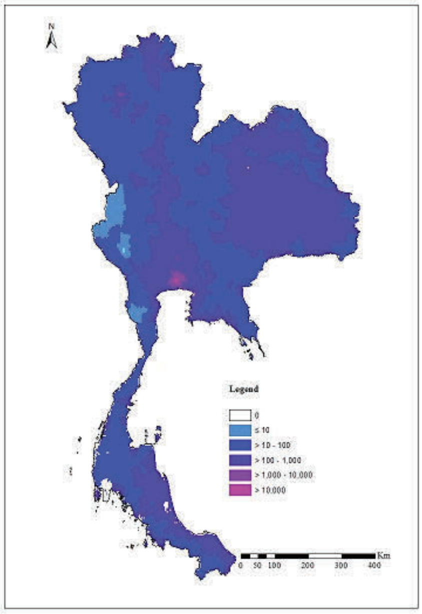

Figure B14 - Layer 14 Population density
Note: the values are used to show the number of population density present within each pixel (people km^{-2}). These are 0 = no people; ≤ 10 = low population density; > 10 - 100 = rather low population density; > 100 - 1,000 = medium population density; > 1,000 - 10,000 = rather high population density; and > 10,000 = high population density

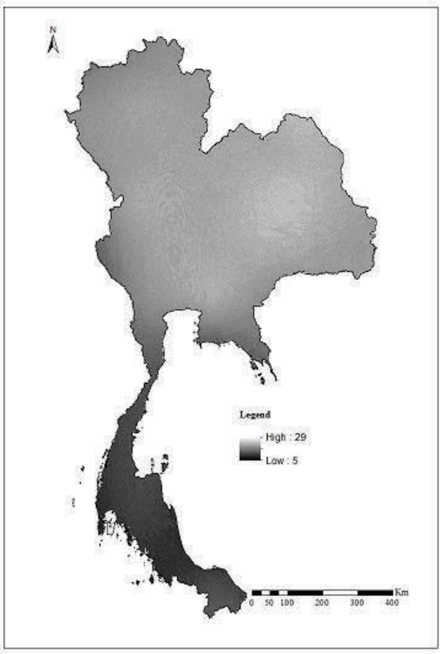

Figure B15 - Layer 15 Annual Mean Temperature (BIO 1)
Note: the values are used to show the difference of mean value between current (1950-2000) and predicted future (2050) climate in relation to BIO 1

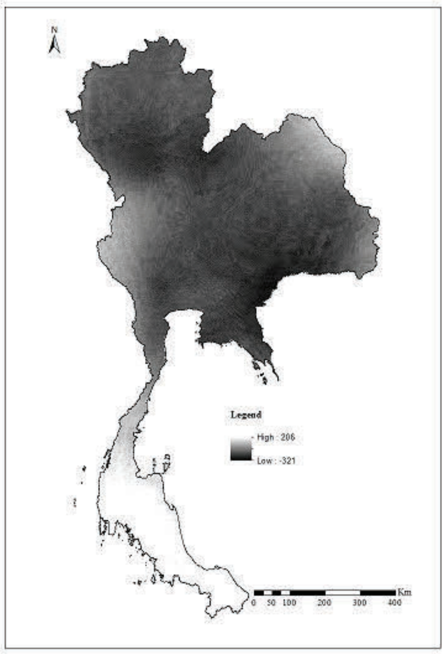

Figure B16 - Layer 16 Temperature Seasonality (standard deviation *100) (BIO 4)
Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 4

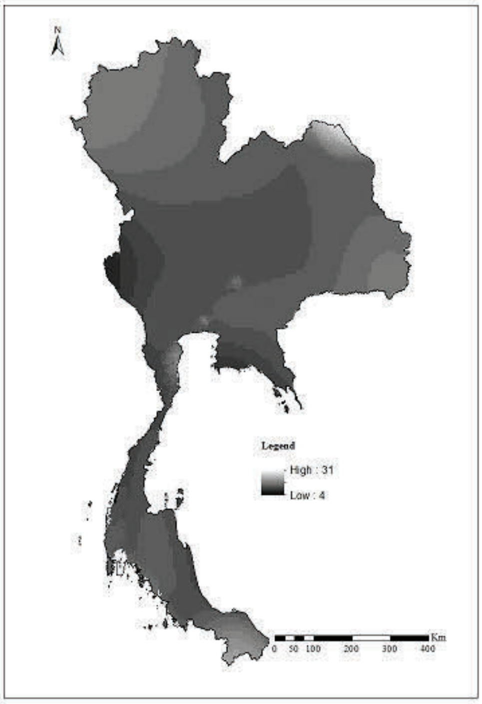

Figure B17 - Layer 17 Max. Temperature of Warmest Month (BIO 5)
Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 5

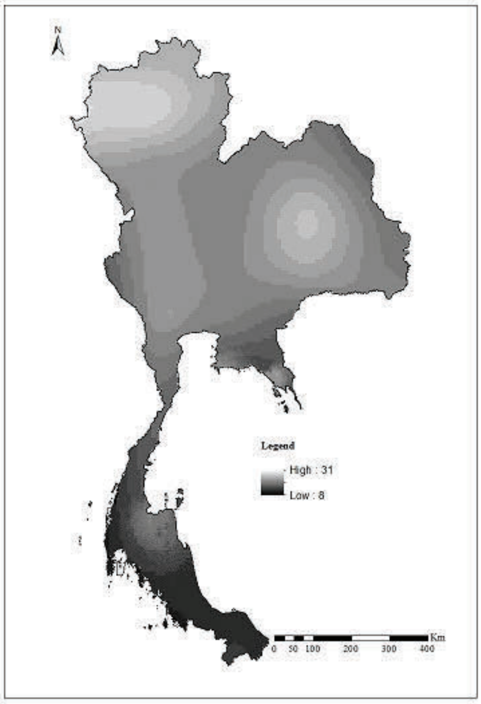

Figure B18 - Layer 18 Min. Temperature of Coldest Month (BIO 6)
Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 6

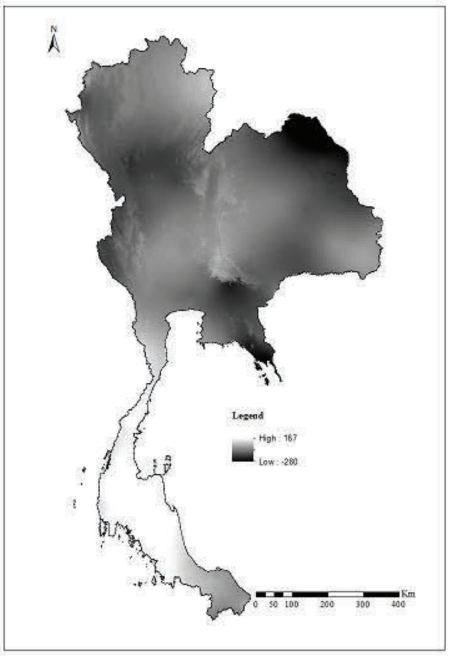

Figure B19 - Layer 19 Annual precipitation (BIO 12)
Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 12

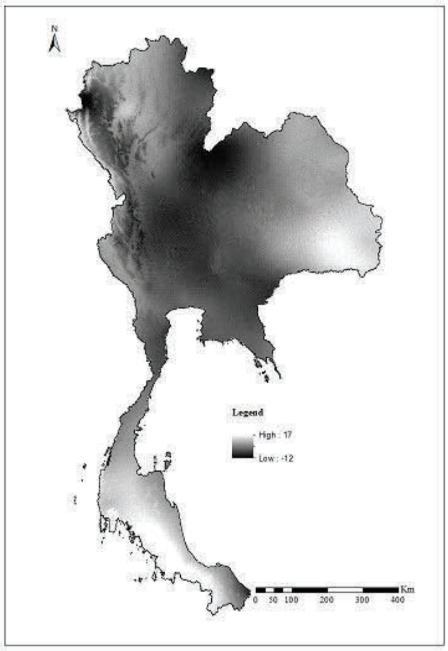

Figure B20 - Layer 20 Precipitation Seasonality (Coefficient of Variation) (BIO 15)
Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 15

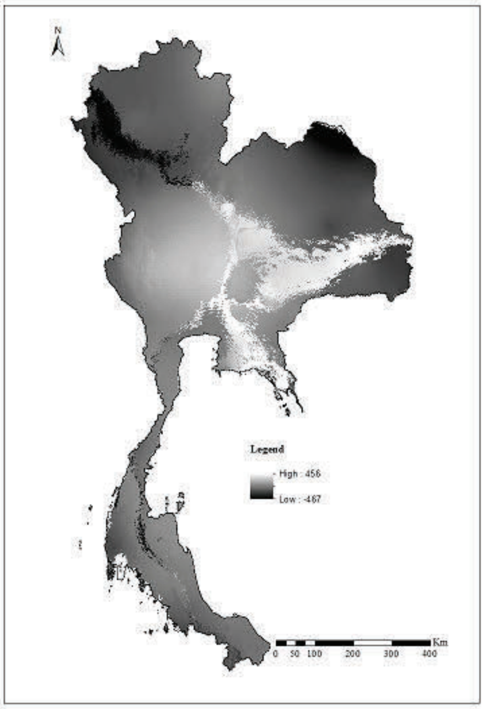

Figure B21 - Layer 21 Precipitation of Warmest Quarter (BIO 18)

Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 18

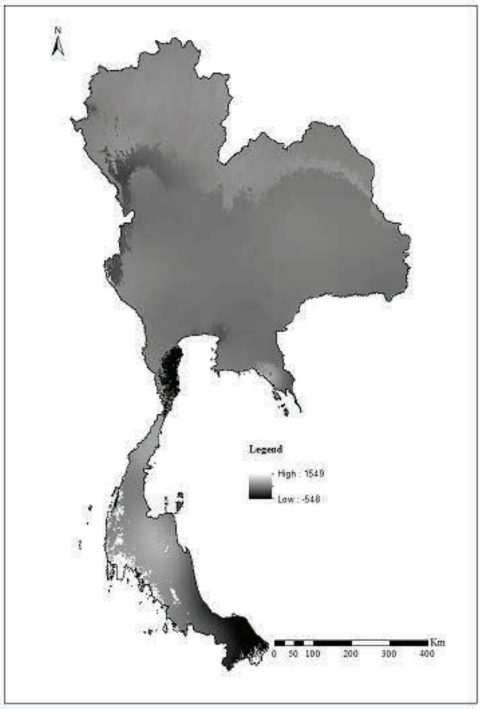

Figure B22 - Layer 22 Precipitation of Coldest Quarter (BIO 19)

Note: the values are used to show the difference of mean value between current (1950 - 2000) and predicted future (2050) climate in relation to BIO 19

Appendix C: Forest Complexes of Thailand

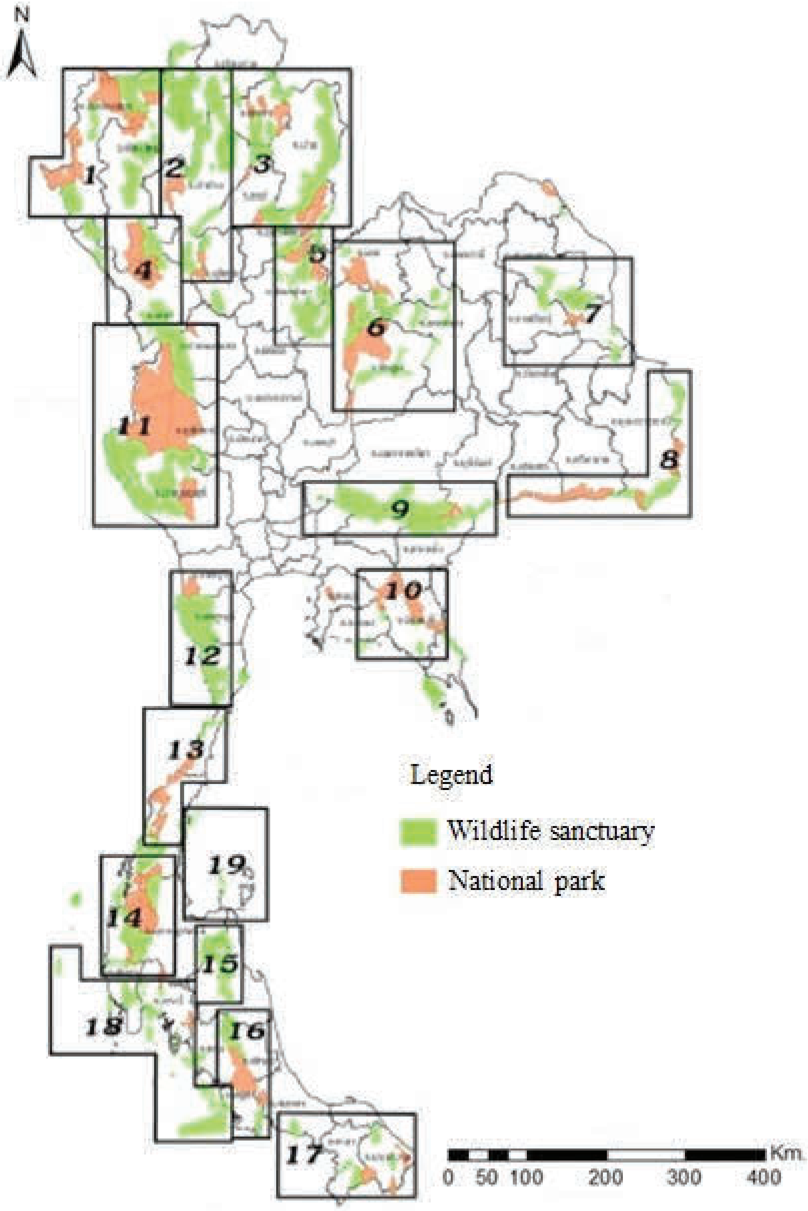

Figure C1 - Map of 19 Forest Complexes of Thailand (Modified from WCG 2009)

Note: Number are used to show the names of the Forest Complexes. 1 = Lum Nam Pai – Salween; 2 = Si Lanna - Khun Tan; 3 = Doi Phu Kha - Mae Yom; 4 = Mae Ping – Omkoi; 5 = Phu Miang – Phu Thong; 6 = Phu Khiao – Nam Nao; 7 = Phu Phan; 8 = Phanom Dong Rak - Pha Taem; 9 = Dong Phaya Yen – Khao Yai; 10 = Eastern; 11 = Western; 12 = Kaeng Krachan; 13 = Chumphon; 14 = Khlong Saeng - Khao Sok; 15 = Khao Luang; 16 = Khao Ban That; 17 = Hala – Bala; 18 = Similan - Phi Phi - Andaman islands; 19 = Ang Thong island – Gulf of Thailand.

Appendix D: Provinces of Thailand

Figure D1 - Map of provinces of Thailand (Whereig 2010)