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Full Length Research Paper

Projecting forest tree distributions and adaptation to climate change in northern Thailand

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Climate change is a global threat to biodiversity because it has the potential to cause significant impacts on the distribution of species and the composition of habitats. The objective of this research is to evaluate the consequence of climate change in distribution of forest tree species, both deciduous and evergreen species. We extracted the HadCM3 A2 climate change scenario (regionally-oriented economic development) for the year 2050 in northern Thailand. A machine learning algorithm based on maximum entropy theory (MAXENT) was employed to generate ecological niche models of forest plants. Six evergreen species and 16 deciduous species were selected using the criteria developed by the Asia Pacific Forest Genetic Resources Programme (APFORGEN) for genetic resources conservation and management. Species occurrences were obtained from the Department of National Park, Wildlife and Plant Conservation. The accuracy of each ecological niche model was assessed using the area under curve of a receiver operating characteristic (ROC) curve. The results show that the total extent of occurrence of all selected plant species is not substantially different between current and predicted climate change conditions. However, their spatial configuration and turnover rate are high, especially evergreen tree species. Ten plant species will loss their ecological niches (suitable locations) ranging from 2 - 13%, while the remaining 12 species will gain substantial suitable habitats. The assemblages of evergreen species or species richness are likely to shift toward the north where low temperature is anticipated for year 2050. In contrast, the deciduous species will expand their distribution ranges. Based on the IUCN Red List criteria, 10 plant species will be categorized as near threatened (NT) and 12 species will be listed as concerned status. An important point is that species distribution models were found to depend significantly on extreme climate variables such as minimum temperature of coldest months, and precipitation of driest and coldest quarters.

Key words: Northern Thailand, climate change, forest tree species distribution model.

INTRODUCTION

Forest cover in Thailand had declined from 53% of the country area in 1961 to approximately 25% in 1998, which was an annual loss of between 1.5 and 2% on average (Charuphat, 2000). The impacts of deforestation have been recognized as critical threats to species loss (Fox and Vogler, 2005). Not only does it cause habitat loss but also habitat fragmentation, diminishing patch size and core area and isolation of suitable habitats (MacDonald, 2003). However, the recent trends indicate that the deforestation rate in Thailand, including other tropical countries is decreasing due to most of remaining forest cover is located in protected areas and rugged terrain which are strongly restricted by laws and not easy to access, respectively (RFD, 2007).

Several studies indicate that climate change has become a global threat to biodiversity in recent years and in the future (Young et al., 2002; Miles et al., 2004; Cuesta-Camach et al., 2006) because climatic variables are important environmental factors that determine ecological niches of tree species and their patterns of distribution (Avise, 2000; IPCC, 2001). By using species -distribution models (SDMs) and predicted global climate data, Miles et al. (2004) indicated that up to 43% of a sample of tree species in Amazonia could become non-viable by 2095.

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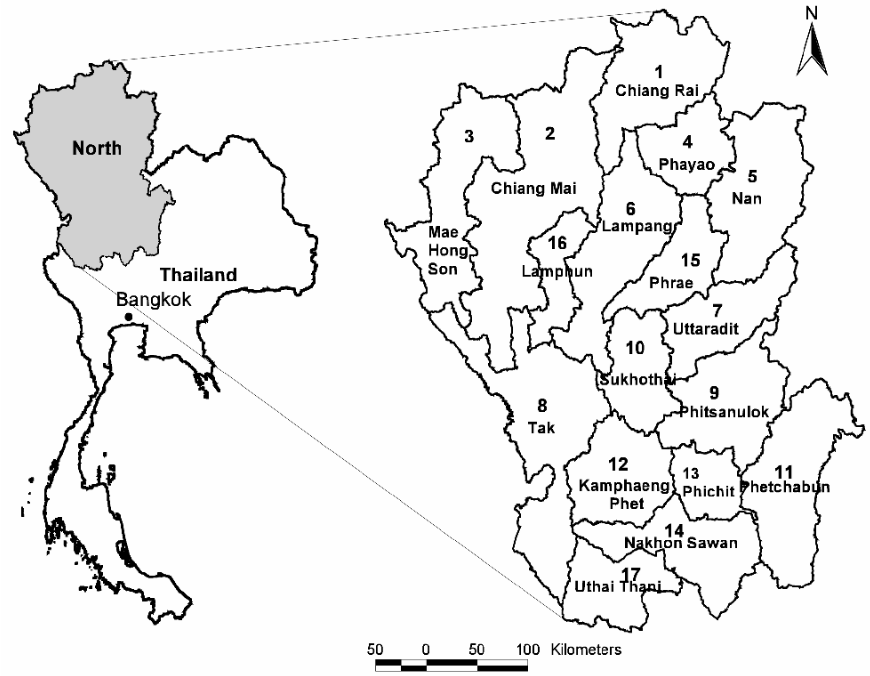

Figure 1. Location of provinces in northern Thailand.

In addition, approximately 59% of plant and 37% of bird species in the Northern Tropical Andes will become extinct or classified as critically endangered species by the year 2080 (Peralvo, 2004).

The Fourth Inter-governmental Panel on Climate Change (IPCC) Assessment Report indicated that mean temperature in Thailand will raise by 2.0 - 5.5°C under the HadCM3 A2 scenario (regionally-oriented economic development) (IPCC, 2007). It is expected that the predicted climate change will have potential impacts on the distribution of tree species in Thailand. The objectives of this research are to predict forest tree distributions in northern Thailand, and assess the spatial patterns of their distribution changes and species loss under the predicted climate change.

MATERIALS AND METHODS

Study area

Northern Thailand is situated between latitudes 14° 56' 17" - 20° 27' 5" N and longitudes 97° 20' 38" - 101° 47' 31" E. It covers 17 provinces and encompasses an area of 172,277 km^2 or 30% of the country's land area (Figure 1). The dominant topography is mountainous oriented north-south. The average annual temperature ranges from 20 - 34°C depending on location. Similarly, the average annual rainfall varies between 600 and 1,000 mm in low areas to more than 1,000 mm in mountainous areas. The rainy season is from May to October.

Northern Thailand was formerly covered by dense forest. Dominant vegetation includes dry dipterocarp and mixed deciduous forests in low and moderate altitudes, while pine forest, hill evergreen forest and tropical montane cloud forest are dominant in high altitudes (Santisuk, 1988). Forest fires occur across the region in the dry season and contribute to the degradation of hill evergreen forest (Saipunkaew et al., 2007). According to Charuphat (2000), forest cover in northern Thailand declined from 68% in 1961 to 43% in 1998. In addition, eight percent of the forest cover was removed between 1982 and1998, which was the highest deforestation rate in Thailand.

Data on land use, socio-economic and biophysical factors

A set of environmental variables for plants that may directly or indirectly affect the patterns of abundance and distribution in northern Thailand were created. These variables were four topographic factors (altitude, slope, aspect and proximity to stream), bio-climate variables, three anthropogenic factors or threats to species loss (population density, distance to villages, and distance to roads), two biotic factors (vegetation type and patch size), and three soil characteristics (texture, drainage and depth). In addition, we assumed that environmental variable were stable, except climatic variables.

Altitude, aspect and slope were extracted and interpolated from 20 m interval contour lines. Distance to main road and distance to streams and rivers were digitized and buffered from topographic maps at scale 1:50,000. Current climate variables were generated from data recorded from weather stations across the north. Population data and a soil map at scale 1:100,000 were obtained from the Local Administration Department and Land Development Department, respectively.

The predicted monthly temperature and rainfall values of TYN SC 2.0 climate datasets in 2050 generated at a spatial resolution of 0.5° (approximately 45 km) (Mitchell et al., 2004) were converted to ESRI ASCII grids (*.asc). Then, we resampled the coarse resolution climatic variables to a resolution of 500 m using spline interpolation method (ESRI, 1996). The 500 m resolution was chosen as an appropriate size for regional assessment. In addition, it was relevant to general vegetation classification and topographic variation. These data were calibrated with latitude, longitude and digital elevation model (DEM) in the model because temperature and rainfall are often highly correlated with topographic variables (Hutchinson, 1995). Later the adjusted monthly temperature and rainfall grids were used to generate 19 biological climate variables (bioclim) which were more biologically meaningful variables. The bioclimate variables represent annual trends, seasonality and extreme or limiting environmental factors (see details in http://cre.anu.

edu.au/outputs/ anuclim/doc/bioclim.html). Meanwhile, vegetation types were derived from a 1: 50,000 land use map for 2002 (Land Development Department, 2003).

Species distribution modeling

The processes for mapping species niche distributions include three main steps: (a) selection of species; (b) collection of plant presence points; and (c) generation of species distribution models.

Selection of species: We used the criteria and justification developed by the Asia Pacific Forest Genetic Resources Programme (APFOR GEN) to select vascular plant priorities for genetic resources conservation and management (Sumantakul, 2004) as proxy indicators of the northern region. These priority species are ecologically and economically important and are listed as high risk of extinction. The predicted climate change will escalate disappearances of these species.

Collection of plant presence data: We collected species presence points from two datasets sources. Plant occurrence points (geo-referenced and species name) were obtained from the Forest Resource Inventory Project and the Preparatory Studies to Install a Continuous Monitoring System for the Sustainable Management of Thailand's Forest Resources (RFD/ITTO, 2002). Both projects established a uniform fixed grid of 10 x 10 km and 20 x 20 km, respectively over the entire country for gathering plant species.

Out of these databases, only tree species with a minimum quantity of 30 records were chosen, so their distributions could be properly predictted using the spatial distribution model in the next steps.

Generation of species distribution models: The species distribution maps were developed using a niche-based model or the maximum entropy method (MAXENT) (Peterson et al., 2001). The models operate by establishing a relationship between a species known range and climatic variables within that region and then use this relationship to identify other regions the species may inhabit or to project potential range shifts under future climates. The advantages of MAXENT include the following: 1) it requires only presence data and environmental information, 2) it can utilize both continuous and categorical variables, and 3) efficient deterministic algorithms have been developed that are guaranteed to converge to the optimal probability distribution (Philips et al., 2006).

We ran MAXENT using a convergence threshold of 10 with 1,000 iterations as an upper limit for each run. For each species, occurrence data was divided into two datasets. Seventy-five percent of the sample point data was used to generate species distribution models, while the remaining 25% was kept as independent data to test the accuracy of each model. We used the area under curve (AUC) of a receiver operating characteristic (ROC) curve to assess the accuracy of each model (Hosmer and Stanley, 2000).

Assessment of impacts of climate change

We assessed the spatial patterns of species distribution changes and species loss under the predicted climate change.

Species turnover: The outputs of MAXENT model were the continuous probability of the occurrence (0.0 -1.0) where higher values mean better suitability and lower values mean poorer suitability. We transformed the predicted values into a binary prediction. The predicted values equal to or greater than 0.5 were assigned as present. On the other hand, values less than 0.5 were assigned as absent. Thus for each pixel of 500 m resolution, we could estimate individual species and the number of species predicted both under current and future climate conditions. Later, the number and percentage of species gain (new arrival) and species loss (no longer exists in the future) were quantified. The calculation of species turnover rate was modified from ß diversity metrics proposed by Cuesta-Camocho et al. (2006) as shown below:

$$T = 100 \times \frac{(G + L)}{(SR + G)}$$

Where, T = species turnover rate; G = species gain; L = species loss, and SR = current species distribution. A turnover rate of 0 indicates that the species assemblage does not change, whereas a turnover rate of 100 indicates that they are completely different from previous conditions.

Species vulnerability: Based on the IUCN Red List criteria 2001 (IUCN, 2004), six quantitative criteria have been developed to evaluate the status of threatened species. In this study, we used criterion A3(c) as follows: Extinct (EX) is a species with a projected suitable habitat loss of 100% in 50 years; Critically endangered (CR) has projected loss of 80 to 100%; Endangered (EN) has projected loss of 50 to 80%; Vulnerable (VU) has projected loss of 30 to 50%; Near threatened (NT) has projected loss <30%, and least concerned (LC) has no projected loss.

RESULTS

Species occurrence points and model performance

We developed species distribution models for 22 plant species that were found more than 30 locations. Six species are the name of selected species in evergreen species for modeling, including *P. kesiya, P. merkusii, Hopea ordorata, Diptercarp alatus, Mangifera* spp. and *Chukrasia* spp. The remaining 16 species are the selected deciduous species. All together, there were 2,215 occurrence records. The minimum number of records was 33 points for *A. xylocarpa* and *Tetrameles nudiflora* and the maximum number reached 280 unique records for *Pterocarpus macrocarpus*.

The relative contributions of environmental factors for the spatial distribution models (MAXENT) for plant assembles are shown in Table 1. Among the 19 bioclimatic variables, 9 variables are correlated with the occurrence of 22 selected plant species. The models indicate that the contribution of vegetation type is the highest among environmental factors followed by elevation, longitude and slope. Minimum temperature of coldest month (BIO6), precipitation of driest month (BIO14) and precipitation of coldest quarter (BIO19) show moderate contribution whereas mean temperature of coldest quarter (BIO11) shows the lowest contribution. Among the 9 bioclimate factors precipitation of driest month (BIO14) shows the highest dispersion. Anthropogenic factors such as distant to road and distant to village are also important and negatively correlated to the appearance of selected tree species. Geographical location (latitude) and soil properties (texture, drainage and depth) are moderate contribution factors. Meanwhile, contributions of environmental factors vary from species to species. For instance, slope factors contribute approximately 25% for *Gmerlina arborea* occurrence and 18% for *Dalbergia oliveri.* However, its relative contribution for *P. kesiya* is less than 1%.

The accuracies of ecological niche models are moderate to high. For instance, the predictive models are high for *D. cochinchinnensis* and *P. macrocarpus* (AUC 0.8 - 0.9), moderate for *Mangifera* spp. and *Xylia xylocarpa var. kerrii* (AUC 0.7 - 0.8). Basically, levels of accuracy for plants derived from the test points are relatively be-hind the training data. The disagreement may have occu-

Table 1. The contributions of environmental variables for plants distribution models.

Variable	Minimum	Maximum	Range	Mean	Median
Latitude	0.1	23.2	23.1	4.7	3.1
Longitude	0.3	29.0	28.7	8.6	7.2
Elevation	0.8	16.0	15.2	8.4	9.1
Aspect	0.2	7.1	6.9	2.9	2.3
Slope	0.7	25.3	24.6	8.1	6.8
Soil depth	0.1	21.0	20.9	5.8	3.4
Soil texture	0.5	20.1	19.6	6.5	2.4
Soil drainage	0.9	31.7	30.8	6.8	3.8
Vegetation type	2.4	29.0	26.6	12.1	12.8
Population	0.5	18.7	18.2	5.1	2.2
Distance to village	0.1	17.1	17.0	5.1	3.9
Distance to stream	0.7	27.8	27.1	5.9	4.4
Distance to road	0.3	21.6	21.3	5.8	3.8
Isothermality (BIO3)	0.2	21.7	21.5	4.3	2.0
Max temperature of warmest month (BIO5)	0.2	10.4	10.2	2.8	1.8
Min temperature of coldest month (BIO6)	0.1	12.4	12.3	4.4	5.0
Temperature annual range (BIO7)	0.2	9.4	9.2	2.2	1.1
Mean temperature of driest quarter (BIO9)	0.1	12.9	12.8	3.8	1.8
Mean temperature of coldest quarter (BIO11)	0.2	2.5	2.3	0.9	0.6
Precipitation of driest month (BIO14)	0.1	17.2	17.1	2.9	2.3
Precipitation of warmest quarter (BIO18)	0.3	6.4	6.1	2.4	2.0
Precipitation of coldest quarter (BIO19)	0.1	14.0	13.9	5.1	3.9

rred because there were fewer test points for plant species and they were randomly distributed

Spatial pattern distribution and change

The total extent of occurrence under current conditions and under predicted climate change conditions in 2050 is not substantially different for most plant species, except *H. ordorata* (Table 2). Ten plant species would loose suitable ecological niches under the predicted climate conditions. These species are *A. xylocarpa, C.* spp., *Dipterocarpus obtusifolius, D. tuberculatus*, *G. arborea*, *M. spp* (wild species), *P. macrocarpus*, *Shorea obtuse, Tectona grandis* and *Tetrameles nudiflora*. Substantial changes are found for *A. xylocarpa* and *Mangifera* spp, which would loss 13 and 10% from the current extent of their distributions, respectively.

In contrast, the total suitable areas of the other twelve species will increase during this period. The forecasted climate reveals an extreme increase in the suitable location of *H. ordorata* from 19% of the northern region in 2002 to 29% in 2050 or increase of 50%. Relative increments (more than 10% of new suitable area) are also observed for *D. cochinchinnensis, P. kesiya, P. kerkusii,* and *Wrightia tomentosa.* Relative increments (more than 10% of new suitable area) are also observed for *P. kesiya, P. merkusii, Diptercarpus alatus, D. cochinchinnensis,* and *Mangifera. spp.* New arrival suitable pixels are mainly located in the northwest (Chiang Mai Province) (Figure 2).

Even though the percentage of suitable pixels for most plant species are not substantially increased, the spatial patterns of species distribution before and after climate change are considerably different for all species due to the different species-specific responses to climate change. The average turnover rate of all plant species is approximately 35%. Major shifts in distribution are predicted for *D. alatus, H. ordorata,* and *Mangifera spp.* Their turnover rates are approximately 81, 68 and 49%, respectively. For instance, *D. alatus* is expected to gain 28% new habitat, but it would lose approximately 75% of existing distribution range. In addition, *H. ordorata* is expected to gain new suitable habitat of approximately 90% but lose 39% of its current distribution range under the A2 2050 climate scenario. The remaining species have turnover rates of more than 21% (Table 2). The assemblages of 22 selected plant species are expected to lose approximately 19% of suitable habitat by current climate niches but their overall climate niche will increase approximately 24% in 2050. Major changes are observed in the west and in the north. On the other hand, forest tree species in the lower north and the east portions of the northern region are not predicted to be severely affected by climate change in the next 5 decades due to most areas have been permanently converted for intensive agriculture and human settlement (Charuphat, 2000; Trisurat et

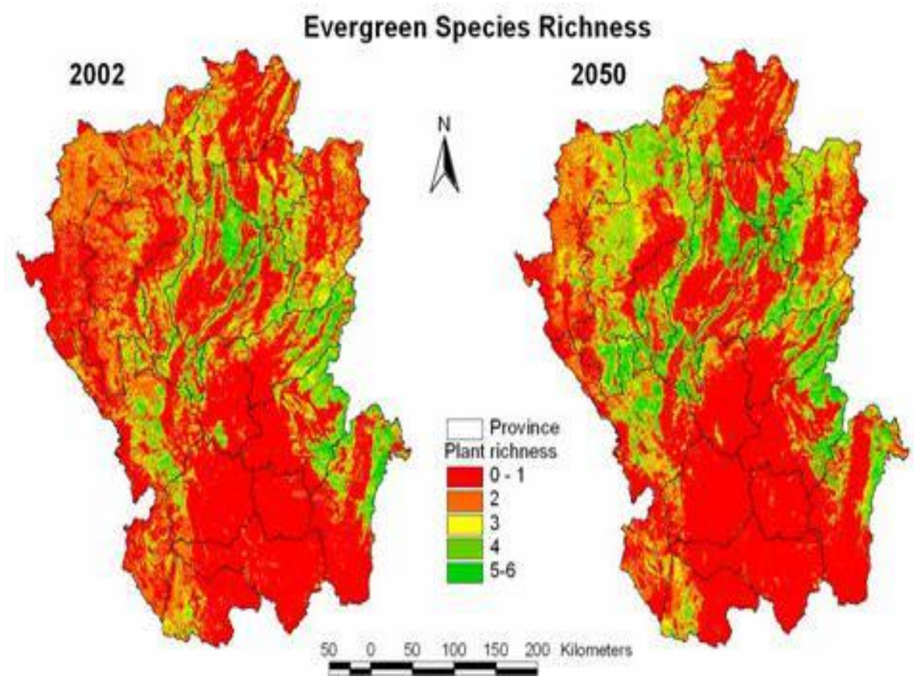

Figure 2a. Spatial pattern distribution of evergreen species in 2002 and 2050.

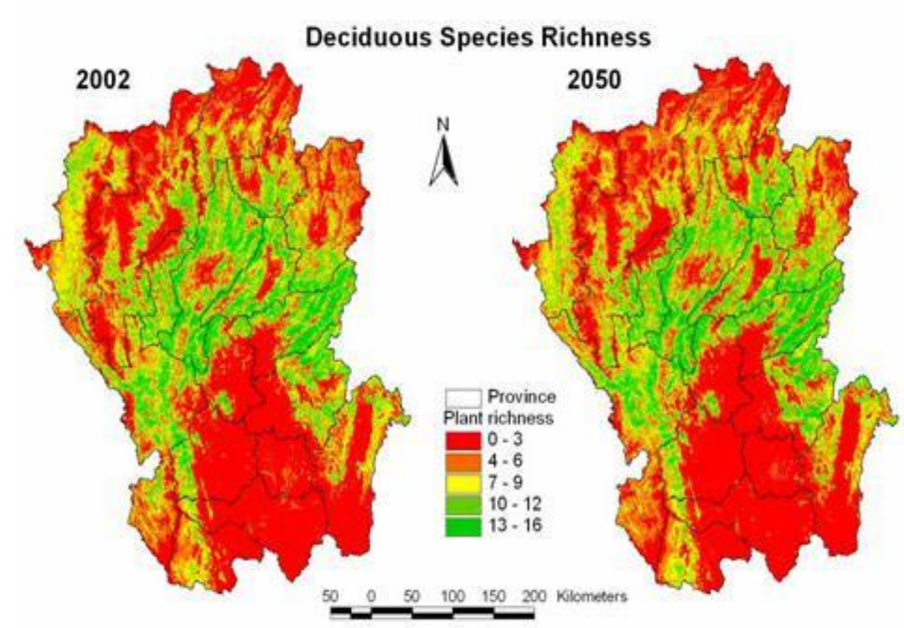

Figure 2b. Spatial pattern distribution of deciduous species in 2002 and 2050.

al., 2008).

Effects on evergreen and deciduous species

The results of spatial distribution models reveal that the evergreen species will be more severely affected by climate change than deciduous species. Table 2 shows that the medians of relative gain, relative loss and turnover rate for six evergreen species are approximately 28, 27 and 43% respectively, while they are approximately 17, 14 and 28% for deciduous species. The results also reveal that higher species composition is likely shifting towards the north which has lower temperature. In contrast, species richness of deciduous tress is likely to extend their occurrences due to raising temperature and long drought period (IPCC, 2007).

Predicted species status

Based on the IUCN Red List criteria 2001 (IUCN, 2004), there is no single selected species that will be categorized as extinct, critically endangered, endangered and vulnerable or threatened by year 2050. This is due to less than 30% of their current suitable niches being lost. Ten plant species will be listed as near threatened (Table 2) and twelve will be categorized as least concerned because they are predicted to gain more suitable ecological niches than lose. It is important to note that these projections are only based on climate change. In reality, there are more pressures created by human activities such as encroachment, forest fires, fuel wood collection, illegal logging and unforeseen factors that will diminish biodiversity.

DISCUSSION

Species distribution model

Our results reveal that the spatial distribution model, MAXENT, is able to predict climate niche for plants across the northern region by using present data only. It is one way to use the value of existing monitoring data for conservation planning. However, the accuracy of predictions from independent test data outside the extent of the training data show lower accuracy for all plant species compared to the training dataset. In addition, the Pearson's correlation coefficient between actual and adjusted temperature is moderate. There are a number of possible reasons that may also explain why species distributions may not match climate, including biotic interactions (Davis et al., 1998), dispersal limitation (Svenning and Skov, 2007) and data quality (Beale et al., 2008).

These problems occur due to the limited training dataset used to generate the ecological niche model. However, problems can be reduced by conducting more field surveys or adding presence point data from different herbaria to existing data gathered from systematic sampling plots. In addition, the bioclimatic variables are based on interpolations of global climate data of a 0.5 degree grid which have coarse-scale resolution. It is essential to explore other methods to see whether the finer-scale calibration can improve enough to be used in species modeling at local and regional scales. The thin plate smoothing splines using the ANUSPLIN licensed software might be a promising option (Hutchinson, 1995). These methods are also able to incorporate longitude, latitude and elevation, and generalized standard multivariate linear regression in which the parametric model is replaced by a suitable smooth non-parametric function. In addition, previous research indicated that they yield higher accuracy than normal regression statistic methods (Hutchinson, 2000).

Sensitivity

All plant species show different responses to predicted climate change due to different species-specific requirements or ecological niches. Basically, the deciduous tree species are more resistant to climate change than evergreen tree species. It is predicted that these evergreen species will substantially lose current suitable habitat and the turnover rate are expected to be high. This is possibly due to deciduous species are recognized as being more drought-tolerant and have higher water use efficiency than evergreen species (Shuxia et al., 2006). They are able to adapt to environmental and climatic changes by losing their leaves during dry season in order to reduce water loss from transpiration. In contrast, evergreen species under higher temperatures may exceed their photosynthetic optimum more, thus having higher respiration and lower net carbon gain, thus less competitive. More research in laboratory and controlled sites is needed to prove this assumption. In addition, shifting in species distribution is high in the western portion of the region but it is quite constant in the eastern part. This is due to the western region being influenced by the south-west monsoon in the wet season, thus very high rainfall amounts is expected under the A2 scenario during the rainy season (IPCC, 2007).

Species extinction risk

Our results predict that selected plant species will be categorized as near threatened and least concerned in 2050. The magnitude of climate change impact in northern Thailand is significant behind the Northern Tropical Andes (Cuesta-Camach et al., 2006) and Amazonia (Miles et al., 2004). This may be due to more deciduous species were selected and the geographical location of this study is different. Future research should be conducted in lower latitude, especially Peninsular Thailand for comparison. However, direct interpretation of these results may be misleading to conservationists, decision-makers and the public. A critical point is that the outputs of analysis are only based on climate change (for plants). Thus, the impacts of future climate change over the northern landscape on biodiversity are absolutely underestimated since deforestation has been recognized as the greatest contribution factor to biodiversity loss in the northern landscape (Trisurat et al., 2008). In addition, the northern region shows the highest lost of forest cover in Thailand (Charuphat, 2000). Deforestation is mainly caused by commercial logging of primary forest, encroachment by farmers, and urban development, driven by ongoing population growth and market pressures encouraging commercial agriculture rather than subsistence (Fox and Vogler, 2005; Panayotou and Sungsuwan, 1989). During

Table 2. Potential distributions of plants and change between 2002 and 2050 caused by climate change.

	Species	Predicted percentage suitable area		% change	2050			
		2002	2050	2002 - 2050	Species gain	Species loss	Turnover	IUCN status
	Deciduous species	-	-	-	17	14	28	-
1	*Afzelia xylocarpa*	21.1	18.4	-13.2	13.2	14.3	24.3	NT
2	*Astonia scholaris*	28.2	29.1	3.0	21.2	11.3	26.8	LC
3	*Dalbergia cochinchinnensis*	7.2	8.4	16.5	26.4	10.0	28.8	LC
4	*Dalbergia oliveri*	41.8	41.9	0.3	19.0	18.7	31.6	LC
5	*Dipterocarpus obtusifolius*	39.1	37.3	-4.6	19.0	23.6	35.8	NT
6	*Diptercarpus tuberculatus*	34.6	33.2	-3.8	20.1	24.0	36.7	NT
7	*Gmelina arborea*	50.4	48.5	-3.9	10.6	14.4	22.6	NT
8	*Pterocarpus macrocarpus*	41.6	40.9	-1.6	11.2	12.8	21.6	NT
9	*Shorea obtusa*	50.5	49.3	-2.3	13.8	16.2	26.4	NT
10	*Shorea roxburghii*	45.3	49.5	9.1	22.6	13.5	29.5	LC
11	*Shorea siamensis*	45.7	47.0	3.0	17.1	14.0	26.6	LC
12	*Tectona grandis*	34.0	31.4	-7.5	15.7	23.3	33.7	NT
13	*Tetrameles nudiflora*	20.3	19.2	-5.7	13.8	19.5	29.2	NT
14	*Toona ciliata*	23.0	24.7	7.6	16.6	9.0	22.0	LC
15	*Wrightia tomentosa*	41.5	46.0	10.9	17.9	7.0	21.1	LC
16	*Xylia xylocarpa var. kerrii*	33.4	34.4	1.9	21.0	17.8	32.1	LC
	Evergreen species	-	-	-	28	27	43	-
1	*Chukrasia* spp.	37.7	36.5	-3.2	16.0	16.6	28.1	NT
2	*Dipterocarpus alatus*	9.3	9.6	3.2	27.7	75.5	80.8	LC
3	*Hopea ordorata*	19.3	29.1	50.7	89.8	39.2	68.0	LC
4	*Mangifera* spp. (wild species)	36.1	32.4	-10.4	25.3	35.6	48.6	NT
5	*Pinus kesiya*	36.3	40.3	10.9	30.4	19.5	38.3	LC
6	*Pinus merkusii*	22.2	25.1	12.8	28.9	16.1	34.9	LC
	Species richness in protected areas	10.1	10.4	13.2	21.7	15.0	30.1	-

Remarks: LC = Least concern; NT = near threatened.

2004 -2006, approximately 500,000 ha of rubber were planted in this region (OAE, 2007). The continuing rise of rubber price and a subsidy program are anticipated to be the driving factors to further increase rubber area as the cause of deforestation. Besides, forest fires occur across the region in the dry season and contribute to the degradation of hill evergreen forest (Saipunkaew et al., 2007).

Conservation planning

Currently, protected areas cover approximately 30% of the northern region. However, the results of spatial distribution models show that approximately 10.1 and 10.4% of selected species richness are in protected area network in year 2002 and 2050, respectively. If we use a comparison index (CI), which is calculated by dividing the proportion of protected areas in particular the extent of species distribution’s share of the region, as a mean to evaluate the effectiveness of protected areas Trisurat, 2007), we found that the selected plant species are not proportionally represented by protected areas. This is due to most reserves being located in high altitudes in the west and the north, while suitable ecological niches of selected plant species are situated in low altitude outside protected areas (except *Pinus* spp.). However, it is difficult to establish more national parks and wildlife sanctuaries to prevent climate change impact in northern Thailand due to the potential threat areas are either too small (less than 10 km^2) or isolated which are not compliance with IUCN criteria (IUCN, 1984). We recommend extending existing protected area coverage to include the threat areas. If they are isolated, other categories of *in-situ* conservation such as forest park or non-hunting area are recommended. Meanwhile, *ex-situ* conservation facilities such as seed bank and seed orchard are needed to store original genetic resources of tree species that have high turnover rate.

Conclusion

Global climate change is becoming additional threat to species loss because it has the potential to cause significant impacts on the distribution of species and the composition of habitats. In this study, we selected six evergreen species and 16 deciduous species for genetic resources conservation and management as candidate species to evaluate the impact of climate change on species distribution for the year 2050 in northern Thailand based on the HadCM3 A2 scenario.

The results derived from spatial distribution models show that the total extent of occurrence of all selected plant species is not substantially different between current and predicted climate change conditions. However, their spatial configuration and turnover rate will be moderate to high. Major changes are observed in the west and in the north. On the other hand, the lower north and the east portions are not substantially different? Due to the fact that most areas have been converted to agriculture and human settlement. Evergreen tree species are expected to be more affected than deciduous species. The assemblages of evergreen species are likely to shift toward the north where low temperature is anticipated for year 2050. In contrast, the deciduous species will expand their distribution ranges.

Based on the IUCN Red List criteria, 10 plant species will be categorized as near threatened and 12 species will be least concerned status. The expected impact de-rived from this study is substantially less than other stu-dies conducted in the Amazonia and the Tropical Andres. This may be due to the period of predicted climate change is approximately a half of those studies. In addi-tion, the results of this study should be interpreted with caution and should be viewed as identifying an additional threat to species loss rather than as accurate estimation of future species loss. A cautious approach is warranted because deforestation, over exploitation and forest fire are greater contributing pressures than global climate change. It is recommended that predicted land-use change should be added as another pressure indicator for next research.

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