Predicting Vulnerability of Medicinal Plants Used by Karen People in Chiang Mai Province to Climatic Change

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Abstract

Anthropogenic climate change has already had an impact on plant diversity and mortality around the world. To exemplify this issue, vulnerability of medicinal plants used by the Karen in Chiang Mai Province to climatic change was investigated using species distribution model (SDM). A total of 244 medicinal plants species were evaluated. The greenhouse gas emissions scenarios, A1B (medium-high emissions) and A2 (high emissions) were used to examine the potential future species distribution under climatic changes for the years 2050 and 2080. It was found that more than 60% of the plants were predicted to suffer significant losses in their suitable ranges by the years 2050 and 2080, respectively. Following the International Union for Conservation of Nature and Natural Resources (IUCN) Red List criteria, four plant species were predicted to become extinct due to climate change in Chiang Mai Province under A1B or A2 scenarios by 2080. Raising the climate change awareness of the Karen people and supporting the sustainable use of medicinal plants will be crucial in preserving the medicinal plants. Cultivating threatened medicinal plants in the home-gardens of the Karen people is also recommended in order to decrease the effects of climate change on these plants.

Keywords: diversity loss / extinction / conservation / ethnobotany / Maxent

1. Introduction

Humans have relied profoundly on natural resources, especially on plants, for their ways of life. Plants provide, directly and indirectly, for the four human basic needs which are food, clothing, medicine, and shelter. In particular, an enormous amount of traditional medicinal plant knowledge, which is considered among the most important knowledge, has accumulated and has been passed on through the generations. Moreover, in the 21st century, 80% of the world inhabitants and 88% of the inhabitants of developing countries still use medicinal plants for curing many illnesses especially in China, Mexico, Nigeria, and Thailand (Balick and Cox, 1997). Besides, Ullah and Rashid (2014) state that medicinal plants in the higher altitude are important because people living in remote far from urban areas are mainly dependent on plants and plants products for their livelihood and curing of different ailments.

In Thailand, the Karen is the largest hill tribe who settled mainly in remote areas (Department of Social Development and Welfare, 2002). They still practice their own way of living and rely on natural ecosystems. Particularly, they have used medicinal plants for primary health care to cure various disorders from times immemorial (Lewis and Lewis, 2004). As a result of residing in the forest, they are able to gather valuable medicinal plants around their village and have accumulated traditional knowledge of medicinal plants (Trisonthi and Trisonthi, 2009).

The Intergovernmental Panel on Climate Change (IPCC) predicts that global temperature would probably increase a further 1.0-7.8 °C during the 21st century (IPCC, 2014). Moreover, land surface temperature have risen averagely 0.74˚C (0.56˚C-0.92˚C) in the last 100 years (1906-2005), and this risen has accelerated since the 1970s (IPCC, 2013). Moreover, IPCC also revealed that climate change will likely increase plant mortality and extinction risk in many areas (IPCC, 2013). On this basis, medicinal plants have also been predicted to confront with severity effects in the coming decades (Yang et al., 2013). Thus, the Karen's traditional medicinal plants are vulnerable and have a high risk for extinction during the present and impending climate change. This dire situation may lead to the decreasing of a number of medicinal plants which provide herbal supplements and medicine for the Karen.

We here aim to estimate the potential effect of future climatic change on medicinal plants used by the Karen in Chiang Mai province using species distribution model (SDM). It is widely used in many ecological applications (Guisan and Thuiller, 2005) such as identifying suitable areas for plants species, which can be valuable for conservation planning. We also aim to evaluate the vulnerability and define the conservation implications for these medicinal plants.

2. Methodology

2.1 Study area

Chiang Mai province, northern Thailand was selected to be the study area in this study (Figure 1). It is between latitudes 18° 47' 25" N and longitudes 98° 57' 38" E and covers an area of 20,107 km^2 (Asavachaichan, 2010). The forests in this study area are broadly classified into mixed deciduous forest, dry dipterocarp forest, hill evergreen forest and pine forest.

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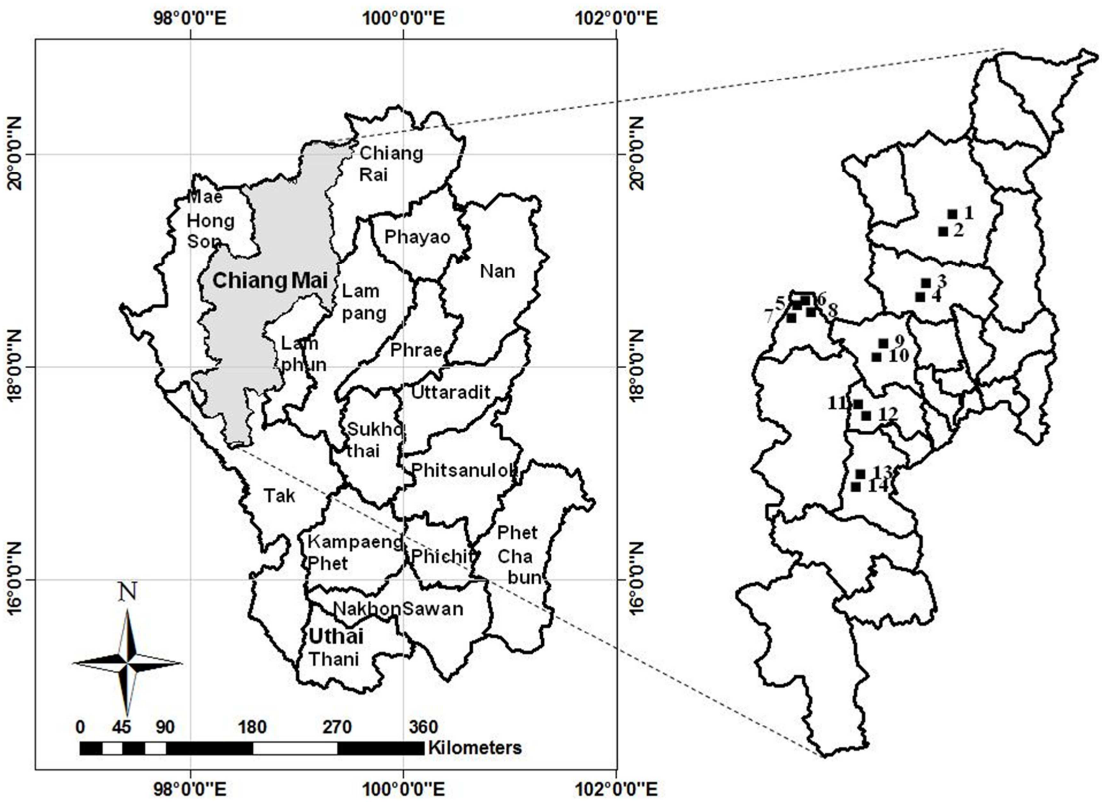

Figure 1: Location of study area. Fourteen Karen villages in Chiang Mai province in northern Thailand where medicinal plants were studied.

2.2 Selection of medicinal plants for modeling work

Based on a previous study of medicinal plant used by the Karen in Chiang Mai province (Tangjitman et al., 2013), 244 species were selected for evaluation in SDM.

2.3 Species occurrences data

In order to characterize more fully the environmental niche of medicinal plant species, the occurrence records for the medicinal plants were obtained not just from Chiang Mai province, but also from a whole Thailand, Myanmar, Laos People's Democratic Republic, Vietnam, Cambodia, Malaysia, Indonesia, Philippines and southern China. Overall occurrence ranges cover the area between latitude -10° 58' 43" S - 31° 01' 13" N and longitude 90° 45' 40"- 142° 00' 00" E. Moreover, the occurrence records were gathered from three sources: 1) Records of wild population from literature, 2) Field survey data (data collected during 1993-2011), and 3) The Global Biodiversity Information Facility (http://www.gbif.org/).

2.4 Environmental variables

We used a combination of non-climatic and climatic environmental predictors previously proven useful for SDM studies in Thailand (Trisurat et al., 2009; Tovaranonte et al., 2013). The non-climatic variables were soil types, slopes, and human influence index (HII). Data on soil layer was downloaded from the Harmonized World Soil Database (HWSD) version 1.2 (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012). Slope data were downloaded from the Hydro1K GTOPO30 (EROS, 1996). The HII was obtained from the Socioeconomic Data and Applications Center (SEDAC). It was created through integrating four data types which were represented the human influence: land transformation (land use and land cover), accessibility (major rivers, coastline, road and railroads), electrical power infrastructure (night time lights) and human settlement (Sanderson et al., 2002). HII values vary from 0 to 64, corresponding to low or high human influence on habitat.

The climatic variables were downloaded from the World Clim database (Hijmans et al., 2005). However, there were high correlations between climatic variables (Mbatudde et al., 2012). Therefore, Pearson correlation was calculated to explore the relationships between all the World Clim climatic variables for the South-East Asian region. To avoid the inclusion of pairs of variables with Pearson correlation, $r > |0.9|$ was analyzed with SPSS for Windows (version17.0). A total of 10 climatic variables were ultimately selected for modeling (Table 1; detailed list is available from the first author).ArcGIS 10.0 was used to create all spatial data layers. Analyses were conducted at grid cell resolution of 1 × 1 km.

Table 1 Predictor variables used for building SDM.

Code	Parameter (units)
bio1	Annual mean temperature (°C)
bio2	Temperature diurnal range (°C)
bio3	Isothermality (°C) (bio2/bio7)
bio4	Temperature seasonality (standard deviation *100, %)
bio6	Mean minimum temperature of the coldest month (°C)
bio7	Temperature annual range (°C)
bio12	Annual precipitation (mm)
bio14	Precipitation of the driest month (mm)
bio18	Precipitation of the hottest quarter (mm)
bio19	Precipitation of the coldest quarter (mm)
Slope	Maximum range in elevation (meters)
HII	Human influence index
Soil	Soil type

2.5 Species distribution modeling

The potential distributions of medicinal plant species were evaluated by Maxent program (Phillips et al., 2006). This software is known to perform the best modeling approaches for presence-only model with a small sample sizes (Elith et al., 2006). The freely available Maxent software, version 3.3.3k was downloaded from http://www.cs.princeton.edu/. To calculate the predictive accuracy of SDM, occurrence data was randomly divided into training and test data sets. The model is calibrated with the training data and its predictive power assessed using the test data (Tovaranonte et al., 2013). Seventy percent of the randomly occurrence data was used to generate training data, while the residue 30% was used for test data.

To validate model predictions, the Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve was calculated. Thuiller et al. (2003) have established a scale to enable interpretation of AUC values and for model validation: 0.90-1.00 = excellent; 0.80-0.90 = good; 0.70-0.80 = average; 0.60-0.70 = poor; 0.50-0.60 = insufficient. Moreover, the Jackknife procedure was used to assess the importance of variables (Yang et al., 2013). Maxent generates the probability of the occurrence that varies from 0 to 1, where lower values mean poorer probability and higher values mean better probability.

2.6 Future climate scenarios

Future climate data was derived from the U.K. Meteorological Centre's Hadley Centre Coupled Model version 3 (HADCM3) for the time intervals 2050 and 2080, under two emission scenarios of the IPCC Special Report on Emissions Scenarios (SRES): scenario A1B (medium-high greenhouse gases emissions), A2A (high greenhouse gases emission). The future data were downloaded from the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (http://www.ccafs-climate.org/statistical downscaling_delta/).

2.7 Species extinction risk

The extinction risk of plant species was determined by using the International Union for Conservation of Nature and Natural Resources (IUCN) Red List criteria 2001 (Baillie et al., 2004). Criterion A3(c) was used as follows: suitable habitat has been predicted loss of 100% in 50 years = extinct (EX); loss of 80 to 100% = critically endangered (CR); loss of 50 to 80% = endangered (EN); loss of 30 to 50% = vulnerable (VN); loss <30% = near threatened (NE); and 0% loss = least concerned (LC).

3. Results

3.1 Species distribution model

A model with AUC values approaching 1.0 is usually determined as excellence model, while AUC values are lower than 0.5 are determined poor predictive model (Wang et al., 2009). In this study, AUC values ranged 0.713 to 0.998 (mean 0.935), indicating average to excellence predictive power.

3.2 Current predicted distributions

The suitable areas of most medicinal plant species were in the west and south of Chiang Mai province (Figure 2). Moreover, it was also indicated that 223 plant species (91%) had suitable ranges more than 50% of total area in Chiang Mai province (detailed list is available from the first author).

Regard to 13 variables which were used in this study, the relationships to the climatic and non-climatic factors varied from species to species (detailed list is available from the first author). Soil type was the most important contributor for 65 species whereas annual mean temperature (bio1) was the least important variable (Figure 3).

3.3 Forecasted spatial patterns of changes

The potential impacts of forecasted climate scenarios reveal a profound change in the spatial patterns of medicinal plants in study area. In 2050, 60% and 61% of total plant species were predicted to loss their suitable range in Chiang Mai province under A1B and A2 respectively whereas 22% and 20% of total plant species were predicted to gain their suitable range and 18% and 17% of total plant species were predicted to have no change in their suitable area under A1B under A2 scenario respectively (detailed list is available from the first author) (Figure 4).

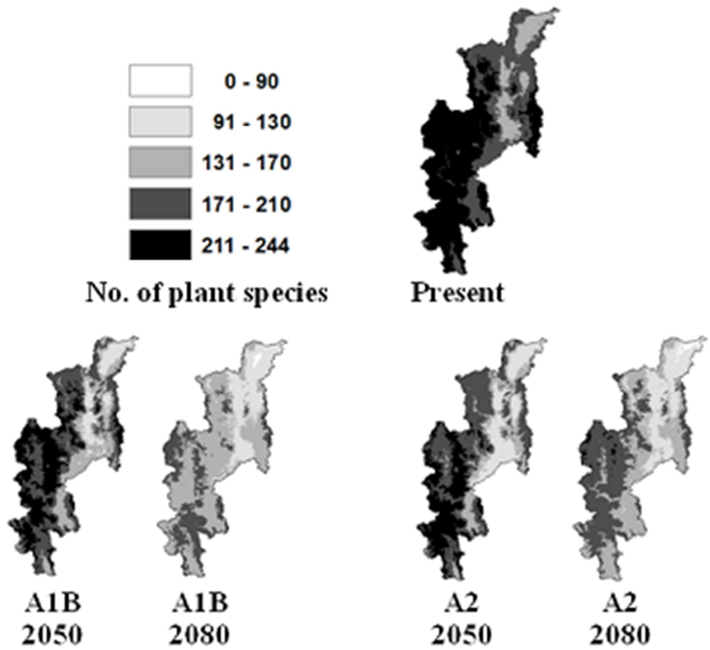

Figure 2: Modeled pattern of medicinal plant species richness at present, in 2050 and 2080 in Chiang Mai province under A1B and A2 greenhouse gases emission scenario.

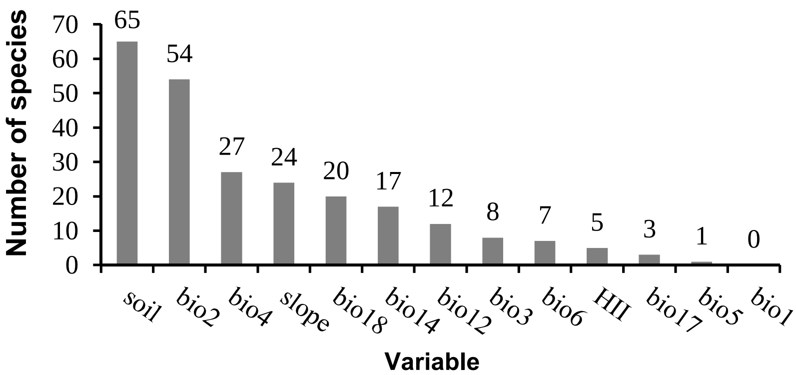

Figure 3: The most important variables of 244 plant species

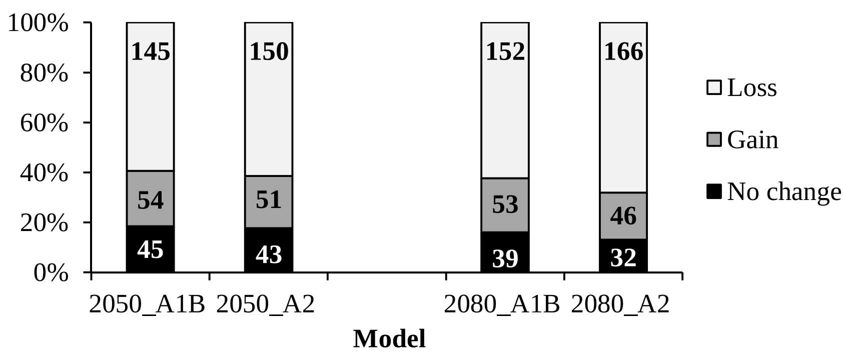

Figure 4 Proportion of predicted suitable area changes of medicinal plant species in Chiang Mai province under A1B and A2 scenario by 2050 and 2080. Number on bar indicated number of species based on the change categories

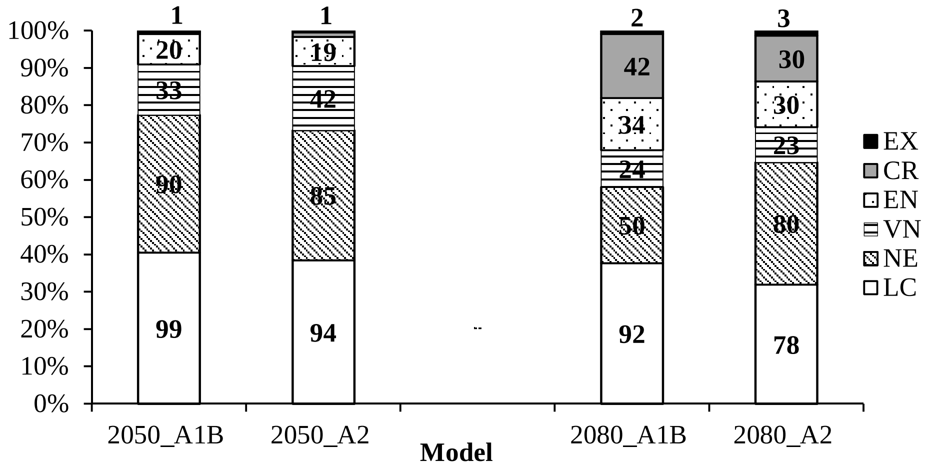

Figure 5 Proportion of medicinal plant species classified based on the IUCN Red List under A1B and A2 scenario by 2050 and 2080. Number on bar indicated number of species in each IUCN status. EX= Extinct; CR= Critically endangered; EN= Endangered; VN= Vulnerable; NE= Near threatened and LC=Least concerned.

Table 2 The top 20 most predicted vulnerable medicinal plant species, percentage of area change and IUCN status under A1B and A2 scenario by 2050 and 2080.

Species	Application	2050				2080			
		A1B		A2		A1B		A2	
		%change	IUCN status	%change	IUCN status	%change	IUCN status	%change	IUCN status
Lycopodium cernuum	muscular pain, cold	-100.00	EX	-100.00	EX	-100.00	EX	-100.00	EX
Vitex trifolia	dizziness	-20.23	NE	-82.77	CR	-93.02	CR	-100.00	EX
Lilium primulinum	muscular pain, cough	56.25	LC	39.46	LC	-48.38	VN	-100.00	EX
Schima wallichii	cold, fever	-32.40	VN	-31.76	VN	-100.00	EX	-99.89	CR
Spondias pinnata	sore throat, fever	-59.10	EN	-20.41	NT	-99.21	CR	-99.18	CR
Drynaria quercifolia	diabetes, amenorrhea	-45.23	VN	-65.38	EN	-99.34	CR	-97.48	CR
Pothos scandens	muscular pain, tonic	-69.41	EN	-68.72	EN	-97.93	CR	-98.45	CR
Lygodium flexuosum	wound, haemostatic	-12.80	NE	-22.39	NE	-92.54	CR	-99.64	CR
Sambucus javanica	sprain, muscular pain	-71.14	EN	-39.14	VN	-94.42	CR	-97.75	CR
Senna alata	laxative, ringworm	-49.92	VN	-53.33	EN	-95.63	CR	-96.30	CR
Dipterocarpus obtusifolius	fever, cold	-76.34	EN	-65.16	EN	-97.08	CR	-92.93	CR
Inula cappa	postpartum recovery	-42.27	VN	-52.87	EN	-98.10	CR	-90.41	CR
Berchemia floribunda	muscular pain	-90.81	CR	-87.99	CR	-94.46	CR	-93.99	CR
Equisetum debile	urethral stones, dysuria	-32.18	VN	-33.96	VN	-96.82	CR	-90.78	CR
Acanthopanax trifoliatum	urethral stone	-52.80	EN	-53.86	EN	-97.31	CR	-89.35	CR
Eurycoma longifolia	fever, muscular pain	-58.31	EN	-59.12	EN	-95.28	CR	-91.35	CR
Thunbergia laurifolia	intoxication, snake bite	-15.98	NE	-18.43	NE	-95.19	CR	-91.06	CR
Litsea cubeba	fever	-63.40	EN	-71.91	EN	-99.22	CR	-84.07	CR
Viburnum sambucinum	diarrhea, sprain	-68.50	EN	-54.45	EN	-90.33	CR	-90.76	CR
Cissus bicolor	allergic to hairy worm	-52.60	EN	-60.52	EN	-89.27	CR	-91.10	CR

EX= Extinct; CR= Critically endangered; EN= Endangered; VN= Vulnerable; NE= Near threatened and LC=Least concerned

3.4 Species extinction risk

Based on the IUCN Red List criteria 2001 (Baillie et al., 2004), in 2050, Lycopodium cernuum were predicted as extinction to climate change in Chiang Mai province under A1B and A2 scenario. In 2080, Lycopodium cernuum and Schima wallichii were predicted as extinct under A1B scenario whereas Lilium primulinum, Lycopodium cernuum and Vitex trifolia were predicted as extinction in Chiang Mai province under A2 scenario (Table 2). Moreover, the projection of most of medicinal plant species revealed a 62 % (152 species) and 69% (166 species) loss of suitable ranges by year 2050 and 2080 respectively (detailed list is available from the first author) (Figure 4, Figure 5).

4. Discussion

4.1 Species distribution modeling

In this study, Maxent models showed the excellence predictive power (mean AUC=0.935) when compared to random prediction (AUC=0.5). This could be indicated that the Maxent model is suitable for evaluating the potential distribution of medicinal plant species used by the Karen in Chiang Mai province. High AUC values (>0.9) also indicates that a model precision is adequate for conservation decisions and management applications (Thuiller et al., 2005).

The Jack-knife evaluation results showed that most predictor variables were correlated with the occurrence of medicinal plants species. The distributions of the medicinal plants were largely affected by soil type, which was the most important contributor for 65 species (Figure 3). Tuomisto et al. (1995) stated the distribution of many tropical plant species have profoundly relied with soil condition. This variable, likely influences nutrient uptake and the life functions of tropical trees (Steege et al., 2006). It may also be important factor for shaping the species boundaries or in addressing species absence (Thuiller, 2013). Moreover, Eiserhardt et al. (2011) revealed that soil type was an important factor that affected plant species distribution on local to regional scales (10^1-10^5 km^2). Several plant species restrict and respond in their distribution to the specific soil conditions such as nutrient concentrations and aluminium content.

The human influence index revealed that humans had a relatively low impact compared with other predictor variables in this study. Sandel and Svenning (2013) stated that human impacts are strongest on flat terrain, whereas topographic slope areas experience low levels of human stress influences. Owing to the fact that flat areas benefit more from human activities, forests, however, are easily threatened from deforestation, grazing, clearing for agricultural uses and other human influences. On the other hand, sloped areas are more difficult to occupy by humans. Consequently, steep mountains experience low levels of human influence and this factor may serve as a redeeming quality for forests.

4.2 Potential impact of climate change on medicinal plants

Temperature under future climate change in Chiang Mai province is predicted to increase more than 2 °C during 21st Century (Chula Unisearch and Southeast Asia START Regional Center, 2012). The warmest period will extend up to 2-3 months. More extreme weather is also predicted for the near future, with more frequent heavy precipitation events. This situation might be a strong effect on the distribution change and plants species composition in this region.

Regard to prediction results, more than 60% of medicinal plants could potentially be confronted with a decline in population and species extinction in northern Thailand under future climatic change. This situation might strongly affect Karen livelihood, particularly health care problems by reducing suitable ranges and availabilities of their important medicinal plants. Moreover, Svenning and Skov (2004) stated that many plants have a limited dispersal range.

Many of them, particularly tree species, have shown delayed responses due to their long life span, and are not able to speedy move in newly suitable climatic areas (Lenoir and Svenning, 2013). Therefore, medicinal plants, which have a low tolerance to climate change and a slow migration rate, might have a relatively high risk of extinction from future climate change trends (Feeley et al., 2013).

According to the IPCC Special Report on Emission Scenarios (SERS), the A2 scenario is expected to be warmer than the A1B scenario (IPCC, 2000). However, Chula Unisearch and Southeast Asia START Regional Center (2012) revealed that the mean temperatures during the next 60 years were predicted to be higher than the present at the same rate (>2 °C) under A1B and A2 scenarios throughout Chiang Mai Province and northern Thailand. Therefore, this might be a cause of no significance in prediction results under A1B and A2 scenario in this study.

However, it should be noted that there were some limitations in this study. This SDM study was aimed to investigate on a local scale in Chiang Mai Province. However, the results showed that the potential distribution of most medicinal plants was not only found to be limited to Chiang Mai Province, but were also found throughout northern Thailand (detailed list is available from the first author). For example, *Lilium primulinum*, *Schima wallichii* and *Vitex trifolia* which were categorized as extinct in Chiang Mai province could be found in other areas in northern Thailand. Therefore, an incorporation of the changes in spatial patterns in Chiang Mai Province and northern Thailand is suggested in future studies in order to fully investigate the potential distribution of medicinal plants in the future.

Moreover, this study evaluated SDM with the same model predictors for all 244 plant species. However, some medicinal plants need different environmental conditions. Therefore, researchers in the future should elaborate on plant natural environmental conditions. They also recommend investigating SDM with the same group of plants such as plant family or habitat.

4.3 Vulnerability of medicinal plants

Based on the IUCN Red List assessment rang-loss criterion (Baillie et al., 2004), the prediction of the species vulnerability of the medicinal plant species varies with the emission scenario. In pessimistic situations, one (*Lycopodium cernuum*) and four (*Lilium primulinum*, *Lycopodium cernuum*, *Schima wallichii* and *Vitex trifolia*) species were predicted to become extinct through the influences of climate change in Chiang Mai in 2050 and 2080, respectively. This indicates that the magnitude of climate change on Karen's medicinal plants is relatively higher than previous SDM study (Trisurat et al., 2009) in northern Thailand.

Another factor that may accelerate plant extinction risk is overexploitation. Ullah and Rashid (2014) stated that over exploitation was the most important contributor (77.55%) threatening medicinal plant numbers following by habitat loss (35.55%), over grazing (28.88%) and deforestation (15.55%), respectively. Besides, Rai et al. (2000) also revealed the severe reduction of natural populations of some high therapeutic value medicinal plants in the Sikkim Himalayas due to over exploitation by intense commercialization, over-harvesting and the collecting methods of untrained and unskilled individuals

4.4 Implications for conservation

It is necessary to carry out concrete steps for the conservation of medicinal plants that are used by the Karen people in order to assure their availability for future Karen generations in the face of a changing climate.

Firstly, raising awareness of climate change to the Karen people is crucial because it will help them to plan an appropriate action for this change. In this step, it is suggested that scientists and local environmental authorities should educate the Karen people on the present situation and future effects of climate change on their livelihood. Moreover, an awareness of the vulnerabilities of the traditional medicinal plants used by the Karen people with regard to future climatic changes needs to be shown to the Karen people in order to inform them of the extinction risk that exists and to raise awareness of the conservation planning for these medicinal plants.

Secondly, an education in the sustainable use of these medicinal plants also needs to be promoted to Karen people. Additionally, the cultivation of species that are at high risk of extinct or are predicted to be critically endangered under future climatic change in the home-gardens or fields of the Karen people may be an effective strategy that would help to mitigate the effects of climate change on these medicinal plants. Srithi et al. (2012) revealed that home-gardens have also been important sites for the domestication of plant species especially for those of medicinal plants and these gardens make a valuable contribution to the conservation of rare, endangered, or overexploited species.

Overall, the conservation of the medicinal plants of the Karen people would not only benefit their livelihood, but would also provide certain advantages to all people who reside in Thailand by helping to maintain plant biodiversity, plant ecosystems, indigenous plant genetics and all regional forest resources.

5. Conclusions

The potential effects of the impending climatic changes on medicinal plants used by the Karen people by the years 2050 and 2080 were investigated using SDM. It was shown that the model evaluated the average high levels of performance and that a combination of climatic and non-climatic predictors controlled the distribution of the most plant species. It was predicted that more than 60% of the plants would suffer substantial losses of their suitable ranges by the years 2050 and 2080. In an extreme case, one (*Lycopodium cernuum*) and four species (*Lilium primulinum*, *Lycopodium cernuum*, *Schima wallichii* and *Vitex trifolia*) were predicted to extinct due to climate change in Chiang Mai by the years 2050 and 2080, respectively.

Moreover, it was predicted that a total 171 plant species would loss their suitable ranges and were categorized as being critically endangered (51 species), endangered (44 species), vulnerable (25 species) and near threatened (51 species), respectively, whereas 73 species were predicted to gain more ranges or to see no changes to their areas. This situation may reduce the availability of medicinal plants in study area in the near future and would likely have negative effects on Karen livelihoods, particularly in terms of traditional remedies for common health problems.

Raising climate change awareness, disseminating the vulnerabilities of medicinal plants under future climatic changes and supporting the sustainable use of plants of the Karen people will be crucial to engage their attention and to inspire individual and community action regarding these medicinal plants. It is also recommended that cultivating medicinal plants in the home-gardens of the Karen people might also be needed to decrease the impacts of climate change on these medicinal plant species.

6. Acknowledgements

We thank the Karen people of northern Thailand for their generosity, sharing valuable medicinal plant knowledge and permitting us to publish our findings. We wish to thank the Royal Project Foundation for transportation and accommodation during our field work. We would also like to thank the Office of the Higher Education Commission of Thailand for the funding of this PhD study.

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