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Original Article

Potential impact of climatic change on medicinal plants used in the Karen women's health care in northern Thailand

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Abstract

Global climate change can be expected to drive losses in plant diversity. To exemplifying this issue, the potential impact of climate change on nine medicinal plants relating to Karen women's healthcare in northern Thailand was investigated using species distribution models. Climatic and non-climatic variables were used to develop the distribution models. The greenhouse gas emissions scenarios, A1B (medium-high emission) and A2 (high emission) were used to examine the potential future species distribution for year 2050 and 2080. It was shown that a combination of climatic and non-climatic factors had strong effects on the distribution of medicinal plant species. Eight plant species were predicted to reduce suitable area in northern Thailand whereas one species is predicted to increase suitable area. Following IUCN Red List criteria, seven of the studied plant species were categorized as critically endangered under A1B or A2 scenarios by 2080. The importance of planning for climate change effects on the availability of wild-collected plant for rural populations was pointed out.

Keywords: ethnobotany, global warming, rural livelihoods, species distribution modeling, tropical forest

1. Introduction

Anthropogenic climate change has already marked effects on species ranges and ecological communities around the world (Thomas *et al.*, 2004). The Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2013) reported that world temperature had become higher at the Earth's surface than any preceding decade since 1850. These changes are likely to affect plant ecology via direct (e.g., drought and heat wave effects on photosynthesis, respiration, transpiration and phenology) and indirect (e.g., fire regime, parasites and diseases, litter quality and decomposition) effects (Barbosa *et al.*, 2012; IPCC, 20013; Sandel and Svenning, 2013) and likely to increase plant mortality and extinction risk in many areas (IPCC, 2013).

Wild plants provide a huge diversity of valued products for human livelihood particular for food, medicine, building materials, or financial income (Oldfield and Jenkins, 2012). Karen is the largest hill tribe in Thailand constituting 48% of the total hill tribe population (Department of Social Development and Welfare, 2002). Wild plants from the forests play an important role for their subsistence, especially as food and medicine (Trisonthi and Trisonthi, 2009). Most Karen villagers maintain traditional knowledge of medicinal plants that they use for first aid remedies (Tangjitman *et al.*, 2013). For Karen women, reproductive health problems are

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mostly functional disorders (e.g., postpartum recovery, amenorrhea) rather than infectious or surgical emergencies for which Thai health care facilities are available. However, as a result of ongoing climate change, many plant species are predicted to respond by shifting their ranges (Skov and Svenning, 2004) or extinct in near future (Dullinger *et al.*, 2012). Therefore, medicinal plants used for Karen's women's healthcare may be vulnerable to loss their suitable areas and even extinct due to the present and impending climate change. This severe situation may lead to the local and perhaps regional disappearance of a number of medicinal plants that provide important herbal medicine for the Karen.

This study was aimed to assess the potential effect of future climate change on medicinal plants used by the Karen in northern Thailand, particularly medicinal plants for woman's healthcare. Species distribution modeling (SDM) was used to identify the potential distribution of medicinal plants under current and future climate as well as evaluate the vulnerability of medicinal plants under future climatic change. SDM is widely used in many ecological applications (Guisan and Thuiller, 2005) such as predicting suitable habitat for a species estimating potential effects of climatic change on plant species and guiding for conservation planning (Wang *et al.*, 2009; Babar *et al.*, 2012).

2. Methods

2.1 Selection of medicinal plant species

Medicinal plants related to Karen women's healthcare were selected by using the culturally important index (CI) index, an efficient tool for highlighting species for which there is high agreement of its use among the surveyed cultures, thereby recognizing the shared knowledge of these people (Tardío and Pardo-De-Santayana, 2008). Base on a previous study of culturally important medicinal plant species used by the Karen (Tangjitman *et al.*, 2013), nine plant species with high CI value were selected (Table 1).

2.2 Species occurrences and study area

Since the Karen in Thailand have settled mainly in northern Thailand (Department of Social Development and Welfare, 2002), it was therefore selected as the study area. It is between latitudes 14° 56' 13" to 20° 28' 43" N and longitudes 97° 20' 53" to 101° 47' 53" E comprising 17 provinces and covers an area of 172,277 km^2 or 30% of the total geographic area of Thailand (Figure 1). Forests in this study area are broadly classified into dry dipterocarp and mixed deciduous forest where are found in low-moderate altitudes (0-900 meter above mean sea level (a.m.s.l.)), while coniferous forest, hill evergreen forest and tropical montane cloud forest are dominant in higher altitudes (1,000-2,000 a.m.s.l.) (Asavachaichan S., 2010; Santisuk, 2013).

To characterize more fully the environmental niche of the nine plant species, occurrence records for the medicinal plants studied were obtained not just from northern Thailand, but also from Myanmar, Laos People's Democratic Republic, Vietnam, Cambodia, Malaysia, Indonesia, Philippines, Taiwan and southern China, within the area between latitude 10° 58' 43" S to 31° 01' 13" N and longitude 90° 45' 40" to 142° 00' 00" E. Occurrence records were derived from three sources: (1) field survey data (data collected during 1993-2011); (2) records of wild population from literatures and (3) the Global Biodiversity Information Facility (http://www.gbif.org/). A total of 306 occurrence records were put in the database (Figure 1)

2.3 Environmental variables

A combination of climatic and non-climatic environmental predictors was used for modeling suitable areas for the nine medicinal plants. Climatic variables were extracted from the WorldClim data base (Table 2) (Hijmans *et al.*, 2005) at 1 km-resolution for the period 1950–2000 (http://www.worldclim.org/). Moreover, some climatic variables from WorldClim are highly correlated and could make the results of inaccurate prediction (Hijmans *et al.*, 2005; Mbatudde *et al.*, 2012). Therefore, Pearson correlation was calculated to explore the relationships between all the WorldClim climatic variables for the South-East Asian region. To avoid the inclusion of pairs of variables with Pearson correlation, $r>|0.9|$, a total of ten variables were ultimately selected for modeling (Table 2; Appendix Table). The correlation analysis was done with the SPSS 17.0 software package for Windows.

Three non-climatic variables that may also influence plant species distribution were also included: soil type, slope, and human influence index (HII). The soil layer was downloaded from the Harmonized World Soil Database (HWSD) version 1.2 (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012). Soil type was defined by HWSD according to the composition of soil units and the characterization of selected soil parameters (organic carbon, pH, water storage capacity, soil depth, cation exchange capacity, clay fraction, total exchangeable nutrients, salinity, textural class and granulometry). Slope was downloaded from the Hydro1K GTOPO30 (EROS, 1996). The value represents the maximum change in elevations between each cell and their neighbors. The human influence index (HII) was obtained from the Socioeconomic Data and Applications Center (SEDAC). It was produced through incorporating four data types as proxies for human influence: human settlement, land transformation (land use and land cover), accessibility (road, railroads, major rivers and coastline) and electrical power infrastructure (night time lights) (Sanderson *et al.*, 2002). ArcGIS 10.0 was used to create all spatial data layers. The categorical data were re-sampled to a grid cell resolution of 1×1 km.

2.4 Future climate scenarios

Future climate forecasts from Hadley Centre Coupled Model, version 3 (HADCM3) was used for this study. This

Table 1. Medicinal plant species related to Karen women's healthcare.

Scientific name	Family	Karen name	Application	CI	Habit	Ecology	Altitude(a.m.s.l.)	References
Blumea balsamifera (L.) DC.	Asteraceae	Por pa ka la	amenorrhea, postpartum recovery	0.93	shrub	MDF-DF	0-2,000	Aguilar, 1999
Caesalpinia sappan L.	Caesalpiniaceae	Se kwaw	dysmenorrhea, haemotonic	0.56	tree	DF-LS	200-1,000	Zerrudo, 1991
Cleidion javanicum Blume	Euphorbiaceae	Na por jaw	amenorrhea, tonic	0.51	tree	EF-MDF-DF	30-1,200	Kulju and Welzen, 2005
Clerodendrum serratum (L.) Moon	Lamiaceae	Kwee do jaw	amenorrhea, muscular pain	0.60	shrub	MDF-DF	500-1,000	Nanakorn, 1995b
Croton roxburghii N. P. Balakr.	Euphorbiaceae	Sa ko wa pa do	amenorrhea, dizziness, postpartum recovery	0.71	tree	MDF-DF	10-950	Chayamarit and Welzen, 2005
Inula cappa (Buch.-Ham. ex D. Don) DC.	Asteraceae	Paw pa ka la	amenorrhea, dizziness, muscular pain postpartum recovery	0.71	herb	MDF-DF	800-1,600	Nanakorn, 1995a
Mussaenda sanderiana Ridl.	Rubiaceae	Por tae	amenorrhea	0.32	scandent shrub	MDF	400-1,300	Nanakorn, 1995a
Phlogacanthus curviflorus Nees	Acanthaceae	Jor to ko	amenorrhea, postpartum recover	0.54	shrub	MDF	500-1,200	Nanakorn, 1995b
Schefflera leucantha R.Vig.	Araliaceae	Pi jue ya	amenorrhea, postpartum recovery, muscular pain	0.52	shrub	MDF-HEF	500-2,500	Tap and Sosef, 1999

DF, deciduous forest; EF, evergreen forest; HEF, hill evergreen forest; LS, limestone; MDF, mixed deciduous forest

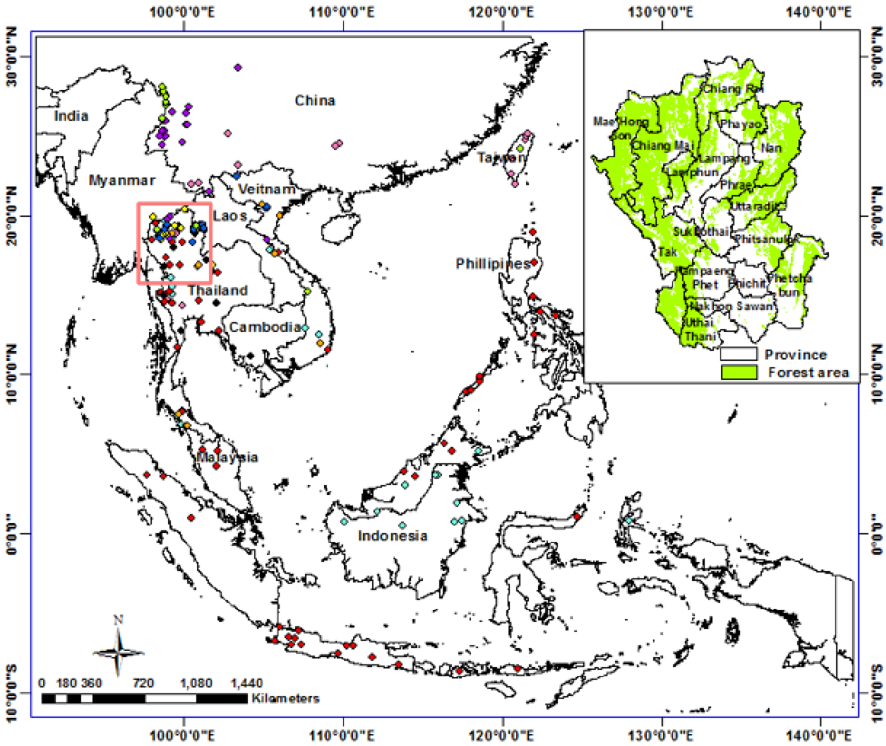

Figure 1. Study area in northern Thailand and occurrence records of nine medicinal plant species in South-east Asia region. Dots represent species occurrence records of nine medicinal plants: light blue = *Blumea balsamifera*, pink = *Caesalpinia sappan*, red = *Cleidion javanicum*, orange = *Clerodendrum serratum*, black = *Croton roxburghii*, purple = *Inula cappa*, yellow = *Mussaenda sanderianna*, dark blue = *Phlogacanthus curviflorus*, green = *Schefflera leucantha*.

Table 2. Predictor variables used for building species distribution models for the nine species of medicinal plants.

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 period (°C)
bio7	Temperature annual range (°C)
bio12	Annual precipitation (mm)
bio14	Precipitation of the driest period (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 types

model has been commonly used in the ecological studies (IPCC, 2007) and reported to provide good median results compared with other models (Jaramillo *et al.*, 2011). The time interval 2050 and 2080 was selected to make a future prediction in this study. The future data was provided by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (http://www.ccafs-climate.org/statistical downscaling_delta/).

Based on the IPCC (2007) on green-house gas emissions scenarios (SRES), scenario A1B and A2 were analyzed for potential impact of climate change in this study. The A1B is considered a medium warming scenario and assume as a world with continuously increasing global population, very rapid economic growth and maximum energy requirements that are balanced across all energy sources. The A2 scenario - often described as a business-as-usual scenario - describes a world with continued population growth, slow economic growth, and slow advances in technological solutions.

2.5 Species distribution modeling

Maxent (Phillips *et al.*, 2006) was used to predict potential distributions of the studied species under current and future climates. Maxent is a machine learning method that estimates a species distribution across a study area by calculating the probability distribution of maximum entropy (Phillips *et al.*, 2006). Maxent method is among the best modeling approaches for presence-only occurrence data (Elith *et al.*, 2006). Maxent version 3.3.3k, downloaded from http://www.cs.princeton.edu/, was used in this study.

Maxent was run using a convergence threshold of 10 with 1,000 iterations as upper limit for each run. For each species, occurrence data was randomly divided into two datasets. Seventy percent of the sample point data was used to generate species distribution models, while the remaining 30% was kept as independent data to test the accuracy of each model. Area under the curve (AUC) of the Receiver Operating Characteristic (ROC) curve was used to assess overall model performance, where AUC score of 0.5 indicates a random prediction and a score of 1 indicated a perfect prediction (Hosmer and Stanley, 2000). Moreover, the Jackknife procedure was used to assess the importance of variables (Yang *et al.*, 2013). Maxent output format was the continuous probability of the occurrence (0.0-1.0) where higher values mean better suitability and lower values mean poorer suitability. The procedure transformed values into a binary prediction of presence-absence using the logistic threshold at maximum training sensitivity plus specificity. This threshold value has been shown to be efficient as a more robust approach for predicting species distributions (Hu and Jiang, 2011). If the probability value was equal or greater than this threshold value, it was classified as presence, otherwise absence.

2.6 Species vulnerability

Based on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List criteria 2001 (Baillie *et al.*, 2004), six quantitative criteria have been developed to evaluate the status of threatened species. Criterion A3(c) was used 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.

3. Results

3.1 Model performance

The predictive accuracy as measured by AUC values for all species distribution models revealed good performance (Table 3). AUC values for the training data were > 0.900 for all species. For the test data, seven species (*Caesalpinia sappan*, *Croton roxburghii*, *Inula cappa*, *Mussaenda sanderianna*, *Phlogacanthus curviflorus* and *Schefflera leucantha*) had AUC > 0.900 whereas *Blumea balsamifera*, *Clerodendrum serratum* and *Cleidion javanicum* had AUC 0.806, 0.844 and 0.878, respectively.

3.2 Current predicted distributions

Suitable areas of most medicinal plant species were in the west and central to the north of northern Thailand (Figure 2). Moreover, it was also indicated that only three (*Inula cappa*, *Mussaenda sanderiana* and *Schefflera leucantha*) species have suitable distribution ranges covering less than 50% of the northern Thailand (Table 3).

Relationships to the climatic and non-climatic factors varied from species to species. Soil type and slope were the most important contributors for four (*Blumea balsamifera*, *Cleidion javanicum*, *Clerodendrum serratum* and *Phlogacanthus curviflorus*) and two species (*Inula cappa* and *Schefflera leucantha*), respectively. Temperature diurnal range (bio2), temperature seasonality (bio4) and precipitation of the hottest quarter (bio18) were the most important climatic contributors for three plant species (*Mussaenda sanderiana, Caesalpinia sappan, Croton roxburghii*, respectively). Human influence index was among the three most important variables only for *Caesalpinia sappan*.

3.3 Forecasted suitable areas under climate change

The forecasted future climatic change under the A1B and A2 scenarios caused predicted reductions in suitable ranges for eight plant species (*Blumea balsamifera*, *Caesalpinia sappan*, *Clerodendrum serratum*, *Croton roxburghii*, *Inula cappa*, *Mussaenda sanderiana*, *Phlogacanthus curviflorus* and *Schefflera leucantha*) whereas *Cleidion javanicum* was predicted to gain more suitable areas by year 2050 and 2080 (Table 3, Figure 2). However, there was no significant difference between the reductions in suitable range under A1B and A2 scenario by year 2050 (t-test: p = 0.867) and 2080 (t-test: p = 0.721).

3.4 Predicted species status

Based on the IUCN Red List criteria 2001 (Baillie, 2004), four plant species (*Caesalpinia sappan*, *Cleidion javanicum*, *Clerodendrum serratum* and *Inula cappa*) should be categorized the same IUCN status under both A1B and

Table 3. Species distribution models of nine Karen women's healthcare medicinal plant species. Predictor variable contributions, predictive power (AUC), suitable area and change at present, 2050 and 2080 caused by climate change under A1B and A2 scenarios.

Plant species	Important variables (% contribution)	AUC		Predicted percentage of suitable area within northern Thailand								
		Training	Testing	current	Future							
					A1B				A2			
				2000	2050	2080	%change (2080)	IUCN status (2080)	2050	2080	%change (2080)	IUCN status (2080)
Blumea balsamifera	soil (29) slope(28) bio18(18)	0.934	0.806	67.6	38.5	12.6	-81.3	CR	38.4	30.8	-54.4	EN
Caesalpinia sappen	bio4(44) bio14(13) HII (12)	0.983	0.904	58.4	19.9	1.5	-97.4	CR	25.8	6.0	-90.5	CR
Cleidion javanicum	soil (35) bio18(28) bio4(12)	0.916	0.878	86.9	94.7	92.9	+6.9	LC	91.3	97.0	+11.6	LC
Clerodendrum serratum	soil (25) slope(18) bio14(17)	0.977	0.844	62.5	24.5	6.9	-89.0	CR	26.6	6.6	-89.4	CR
Croton roxburghii	bio18(24) bio2(20) soil (17)	0.988	0.993	72.3	36.4	8.2	-88.6	CR	48.6	33.9	-53.1	EN
Inula cappa	slope(27) bio2(23) bio4(20)	0.962	0.948	32.5	13.2	0.4	-89.8	CR	14.2	1.6	-90.1	CR
Mussaenda sanderiana	bio2(38) bio18(16) soil (15)	0.995	0.988	47.2	14.1	4.5	-90.4	CR	15.6	16.1	-65.8	EN
Phlogacanthus curviflorus	soil (33) bio6(28) bio12(22)	0.978	0.992	56.7	22.4	17.6	-68.9	EN	26.6	6.7	-88.2	CR
Schefflera leucantha	slope(42) bio3(11) soil (9)	0.997	0.944	16.8	15.8	15.1	-10.2	NT	10.6	6.5	-61.0	EN

CR=Critically endangered, EN=Endangered, NT=Near threatened, LC=Least concerned.

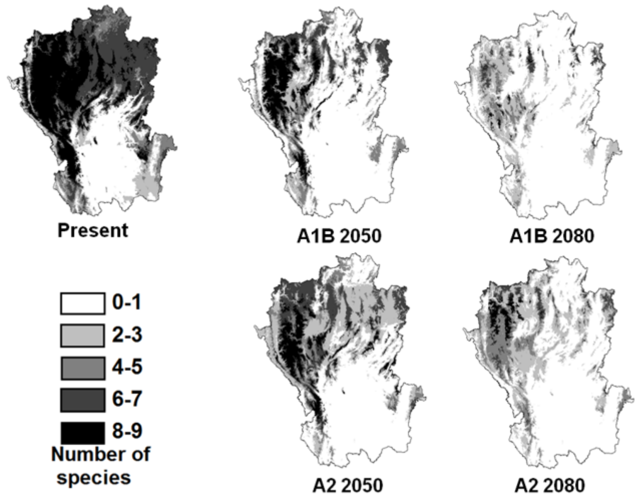

Figure 2. Spatial pattern in the suitable area for nine women's healthcare medicinal plant species at present, in 2050 and 2080.

A2 scenario by 2080 whereas five plant species (*Blumea balsamifera*, *Croton roxburghii*, *Mussaenda sanderiana, Phlogacanthus curviflorus* and *Schefflera leucantha*) should be categorized to varying IUCN statuses (Table 3).

4. Discussion

The Maxent models showed the average high level of predictive power when compared to random prediction (where the AUC would be 0.5). This result indicated that the Maxent model is suitable for evaluating the potential distribution of these medicinal plant species. The Jack-knife evaluation results indicated contributions of climatic and non-climatic factors which varied from species to species (Table 3). Soil was the most important factor for four species (*Blumea balsamifera, Cleidion javanicum, Clerodendrum serratum* and *Phlogacanthus curviflorus*). Tuomisto *et al.* (1995) stated that the spatial distributions of many tropical plant species show strong associations with edaphic conditions. Soil properties are likely to influence nutrient uptake and tropical trees functioning (ter Steege *et al.*, 2006). They might be important factors for shaping species boundaries or species absence (Thuiller, 2013). Slope was the most important factors for the distribution of *Inula cappa* and *Schefflera leucantha*. Slope and elevation had been demonstrated to be useful surrogates for the spatial and temporal distribution of factors such as radiation, precipitation and temperature that influence species composition and productivity (Stage and Salas, 2007). Among ten climatic variables, temperature diurnal range (bio2), temperature seasonality (bio4), mean minimum temperature of the coldest period (bio6), precipitation of the driest period (bio14) and precipitation of the hottest quarter (bio18) were important factors influencing the distribution of most medicinal plant species. However, our finding also showed that the distribution of most plant species was controlled mainly by a combination of climatic and non-climatic predictors. Some studies have showed that at continental scale (>10^5 km^2), climatic variables are strong environmental control of plant distribution (Willis and Whittaker, 2002; Trivedi *et al.*, 2008), whereas the combination of climatic and non-climatic factors showed strong response of plant distribution at regional scale (Blach-Overgaard *et al.*, 2010).

Human influence index has a much lower impact compared with other predictor variables in this study. Sandel and Svenning (2013) stated that human impacts are strongest on flat terrain whereas steep areas are less affected by human activities. Consequently, steep mountains areas act as refuges for forests and their plant species. The Maxent modeling in this study predicted suitable distribution at present of most of the study medicinal plants in the mountainous areas of northern Thailand (Figure 1 and 2), suggesting relatively good changes of suitable habitat remaining for the species here in the future.

4.1 Extinction risk from climate change

Prediction of species extinction risk of nine medicinal plant species varies with emission scenario (Table 3). *Cleidion javanicum* was categorized to have no extinction risk due to the prediction to gain more suitable area in northern Thailand. Regarding the ecology of *Cleidion javanicum*, it could be grown in different forest types (evergreen, mixed-deciduous and deciduous forest) and also different altitude gradients from 30-1,200 a.m.s.l. (Kulju and Welzen, 2005) (Table 1). These would make this plant has a good adaptation to environmental constraints and high survival rate in future climatic change. Moreover, according to the occurrence data in this study, *Cleidion javanicum* has a higher record in southern region of South-East Asia particular Malaysia and Indonesia compared with other plant species (Figure 1). Besides, Kulju and Welzen (2005) revealed that *high populations of Cleidion javanicum* could be found from Malaysia to Australia (Queensland). Due to global warming, plant species might suffer with climate constraints. They were predicted to shift their distribution pole ward to find the suitable climate condition (Skov and Svenning, 2004; Feeley *et al.*, 2013). Therefore, *Cleidion javanicum* was predicted to shift northward and make northern Thailand having more population of this species.

Seven species (*Blumea balsamifera*, *Caesalpinia sappan, Clerodendrum serratum*, *Croton roxburghii*, *Inula cappa*, *Mussaenda sanderiana* and *Phlogacanthus curviflorus*) would be listed as high extinction risk (critically endangered) due to the over 80% predicted loss of their suitable areas under A1B or A2 scenarios by 2080 (Table 3). Several studies revealed that plant which had narrow climatic tolerances or restricted to specific ecology were especially threatened with extinction in future climate change (Thuiller *et al.*, 2005; Feeley *et al.*, 2013; Lenoir and Svenning, 2013). Obviously, *Caesalpinia sappan* which has the highest extinction risk in this study grows in specific environment in mountainous areas with clayey soil and calcareous rocks (Zerrudo, 1991). This might make this plant has low ability to adapt to new environmental condition and has the lowest survival rate in future climatic change compare with other species. *Schefflera leucantha* would be categorized as endangered under A2 scenario. However, this medicinal plant species was also predicted to have high risk of extinction due to their suitable range areas in northern Thailand was less than 7%. Therefore, it was shown that eight of nine medicinal plant species were predicted to experience critical situation under the impending climate change. This situation might strongly affect Karen livelihood particularly women's reproductive health problems by reducing suitable ranges and availabilities of their important medicinal plants.

Climate change is predicted to accelerate over current and coming centuries (Feeley *et al.*, 2013). Tropical plants are likely sensitive to these climate changes (Svenning and Condit, 2008). Feeley *et al.* (2013) revealed that tropical plants will not be able to continue to keep pace with future climate change and thus their persistence in the face of climate change will depend on successful migrations. However, many plants have limited dispersal (Svenning and Skov, 2004). Many of them, particular tree species have delayed response due to their long life span, and are not able to rapidly colonize at newly suitable climatic areas (Lenoir and Svenning, 2013). Under warming climate, plant species will move upward to retain their thermal niche (Feeley *et al.*, 2013). As mountains usually have conical shapes, plants which are unsuccessful upward shifted might experience in range loss and even mountain-top extinctions (Dullinger *et al.*, 2012). Therefore, tropical mountain plants which have low tolerance to climate change and slow migration rate may be at relatively high risk of extinction from future climate change (Feeley *et al.*, 2013).

4.2 Implications for plant conservation and rural livelihoods

Conservation of threatened medicinal plants in the higher altitude is important because people living in isolated and far from urban areas are completely dependent on plants and plants products for their livelihood and curing different ailments (Ullah and Rashid, 2014). Therefore, it is necessary to carry out concrete steps for the conservation of women healthcare medicinal plants in northern Thailand to ensure their availability to the Karen communities in the future, also in the face of climate change. Raising awareness of climate change to the Karen by focusing on local or regional impacts is a crucial step in order to engage their attention and inspire individual and community action. Furthermore, conservation of medicinal plant population in their native habitat is also an important issue. To achieve this, extending existing protected areas particularly near the Karen community settlements is needed to be done by government authorities to prevent losing in suitable ranges of medicinal plant species. However, *ex-situ* conservation might also be considered to provide insurance against catastrophic loss and to facilitate for reintroduction. In addition, legislation and monitoring will be a key importance for conservation and sustainable use of threatened medicinal plants species.

5. Conclusions

The recent rapid climate changes are already affecting a wide variety of organisms, including many plant species. In this study, the potential effects of future climate change on nine medicinal plants that are important to Karen women healthcare were evaluated. Species distribution modeling was used to forecast potential climate change effects on these species by year 2050 and 2080. It was shown that one species was predicted to gain more suitable areas while eight species were predicted to experience strong reductions in the suitable areas. In an extreme case, six plant species will be categorized as critically endangered due to more than 80% loss in their suitable areas. This situation may reduce the availability of medicinal plants in northern Thailand in near future and provide negative effect on Karen livelihoods, particular women's reproductive health problems. Raising climate change awareness and supporting the sustainable use of medicinal plants to Karen people will be crucial for preserving these medicinal plants, as will *in-situ* conservation in protected areas with suitable habitats. However, *ex-situ* conservation might also be needed to reduce the negative impacts of climate change on these and other culturally important medicinal plants.

References

Aguilar, N.O. 1999. *Blumea balsamifera* (L.) DC. In Plant Resources of South-East Asia No. 19: Essential-oil plants, L.P.A. Oyen and X.D. Nguyen, editors. Backhuys Publisher, Leiden, Netherlands, pp. 68-70.

Asavachaichan, S. 2010. Chiang Mai, Sarakadee Press, Bangkok, Thailand, pp. 1-20.

Barbosa, J.P.R.A.D., Rambal, S., Soares, A.M., Mouillot, F., Nogueira, J.M.P. and Martins, G.A. 2012. Plant physiological ecology and the global changes. Ciência e Agrotecnologia. 36, 253-269.

Babar, S., Amarnath, G., Reddy, C. S., Jentsch, A. and Sudhakar, S. 2012. Species distribution models: ecological explanation and prediction of an endemic and endangered plant species (*Pterocarpus santalinus* L.f.). Current Science. 102, 1157-1165.

Baillie, J.E.M., Hilton-Taylor, C. and Stuart, S.N. 2004. IUCN Red List of Threatened Species: A Global Species Assessment, IUCN, Gland, Switzerland and Cambridge, U.K., pp.140.

Blach-Overgaard, A., Svenning, J.-C., Dransfield, J., Greve, M. and Balslev, H. 2010. Determinants of palm species distributions across Africa: The relative roles of climate, non-climatic environmental factors, and spatial constraints. Ecography. 33, 380-391.

Chayamarit, K. and Welzen, P.C. 2005. Flora of Thailand vol. 8 part 1. The Forest Herbarium, Royal Forest Department, Prachachon Company Limited, Bangkok, Thailand, pp. 303.

Department of Social Development and Welfare (DSDW), Ministry of Social Development and Human Security of Thailand and UNICEF. 2002. Highland Communities within 20 Provinces of Thailand, Naetikulkarnpim, Bangkok, Thailand, pp. 250.

Dullinger, S., Gattringer, A., Thuiller, W., Moser, D., Zimmermann, N. E., Guisan, A., Willner, W., lutzar, C., Leitner, M., Mang, T., Caccianiga, M., Dirnböck, T., Ertl, S., Fischer, A., Lenoir, J., Svenning, J.-C., Psomas, A., Schmatz, D. R., Silc, U., Vittoz, P. and Hülber, K. 2012. Extinction debt of high-mountain plants under twenty-first-century climate change. Nature Climate Change. 2, 619-622.

Elith, J., Graham, C. H., Anderson, R. P., Dudik, M., Ferrier, S. and Guisan, A. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography. 29, 129-151.

EROS, 1996. Hydro 1k elevation derivative database. Earth Resources Observation and Science Center, U.S.A.

FAO/IIASA/ISRIC/ISSCAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.

Feeley, K.J., Hurtado, J., Saatchis, S., Silmank, M.R. and Clark, D.B. 2013. Compositional shifts in Costa Rican forests due to climate-driven species migrations. Global Change Biology. 19, 3472-3480.

Guisan, A. and Thuiller, W. 2005. Predicting species distribution: offering more than simple habitat models. Ecology Letters. 8, 993-1009.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. and Jarvis, A. 2005. Very high resolution interpolated climate surface for global land areas. International Journal of Climatology. 25, 1965-2198.

Hosmer, D.W. and Standley, L. 2000. Applied Logistic Regression (2nd edition), Chichester Wiley, New York, U.S.A., pp. 369.

Hu, J. and Jiang, Z. 2011. Climate change hastens the conservation urgency of an endangered ungulated. PLoS One. 6(8), e22873.

IPCC, 2007. Summary for Policymakers. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tigno, and H.L. Miller, editors. Cambridge University Press, Cambridge, U.K. and New York, U.S.A., pp. 104.

IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, editors. Cambridge University Press, Cambridge, U.K. and New York, U.S.A., pp. 1535.

Jaramillo, J., Muchugu, E., Vega, F.E., Davis, A.P. and Borgemeister, C. 2011. Some like it hot: the influence and implications of climate change on coffee berry borer (*Hypothenemus hampei*) and coffee production in East Africa. PLoS ONE. 6:e24528.

Kulju, K.K.M. and Welzen, P.C. 2005. Revision of the genus *Cleidion* (Euphorbiaceae) in Malesia. Blumea. 50, 197-219.

Lenoir, J. and Svenning, J.-C. 2013. Latitudinal and elevational range shifts under contemporary climate change. Encyclopedia of Biodiversity. 4, 599-611.

Mbatudde, M., Mwanjololo, M., Kakudidi, E.K. and Dalitz, H. 2012. Modelling the potential distribution of endangered *Prunus africana* (Hook.f.) Kalkm. in East Africa. African Journal of Ecology. 50, 393-403.

Nanakorn, W. 1995a. Queen Sirikit Botanical Garden No.1, O.S. Printing House, Bangkok, Thailand, pp. 112.

Nanakorn, W. 1995b. Queen Sirikit Botanical Garden No.2, O.S. Printing House, Bangkok, Thailand, pp. 153.

Oldfield, S. and Jenkins, M. 2012. Wild flora for improved rural livelihoods. Case studies from Brazil, China, India and Mexico. Botanic Garden Conservation International, Richmond, U.K., pp. 36.

Phillips, S.J., Anderson, R.P. and Schapire, R.E. 2006. Maximum entropy modeling of species geographic distribution. Ecological Modeling. 190, 231-259.

Sandel, B. and Svenning, J.-C. 2013. Human impacts drive a global topographic signature in tree cover. Nature Communications, 4, http://dx.doi.org/10.1038/ncomms 3474.

Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V. and Woolmer, G. 2002. The human footprint and the last of the wild. American Institute of Biological Sciences. 52, 891-904.

Santisuk, T. 2013. Forest of Thailand. Department of National Parks, Wildlife and Plant Conservation, Thailand, pp. 8-10.

Skov, F. and Svenning, J.-C. 2004. Potential impact of climatic change on the distribution of forest herbs in Europe. Ecography. 27, 366-380.

Stage, A.R. and Salas, C. 2007. Interactions of elevation, aspect, and slope in models of forest species composition and productivity. Forest Science. 53, 486-492.

Svenning, J.-C. and Condit, R. 2008. Biodiversity in a warmer world. Science. 322, 206-207.

Svenning, J.-C. and Skov, F. 2004. Limited filling of the potential range in European tree species. Ecology Letters. 7, 565-573.

Tap, N. and Sosef, M.S.M. 1999. Schefflera J.R. Forster and J.G. Forster. In Plant Resources of South-East Asia No. 12(1): Medicinal and poisonous plants 1, L.S. de

Padua, N. Bunyapraphatsara, and R.H.M.J. Lemmens, editors. Backhuys Publisher, Leiden, Netherlands, pp. 433-438.

Tangjitman, K., Wongsawad, C., Winijchaiyanan, P., Sukkho, T., Kamwong, K., Pongamornkul, W. and Trisonthi, C. 2013. Traditional knowledge on medicinal plant of the Karen in northern Thailand: A comparative study. Journal of Ethnopharmacology. 150, 232-243.

Tardío, J. and Pardo-De-Santayana, M. 2008. Cultural importance indices: a comparative analysis based on the useful wild plants of southern Cantabria (northern Spain). Economic Botany. 62, 24-39.

ter Steege, H., Pitman, N.C. and Phillips, O.L. 2006. Continental-scale patterns of canopy tree composition and function across Amazonia. Nature. 443, 444-447.

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., de Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. and Williams, S.E. 2004. Extinction risk from climate change. Nature. 427, 145-148.

Thuiller, W., Lavorel, S., Araujo, M.B., Sykes, M.T. and Prentice, I.C. 2005. Climate change threats to plant diversity in Europe. PNAS. 23, 8245-8250.

Thuiller, W. 2013. On the importance of edaphic variables to predict plant species distributions – limits and prospects. Journal of Vegetation Science. 24, 591-592.

Trisonthi, C. and Trisonthi, P. 2009. Ethnobotanical study in Thailand, a case study in Khun Yuam District Maehongson Province. Thai Journal of Botany. 1, 1-23.

Trivedi, M., Berry, P.M., Morecroft, M.D. and Dawson, T.P. 2008. Spatial scale affects bioclimate model projections of climate change impacts on mountain plants. Global Change Biology. 14, 1089-1103.

Tuomisto, H., Ruokolainen, K., Kalliola, R., Linna, A., Danjoy, W. and Rodriguez, Z. 1995. Dissecting amazonian biodiversity. Science. 269, 63-66.

Ullah, A. and Rashid, A. 2014. Conservation status of threatened medicinal plants of Mankial Valley Hindukush Range, Pakistan. International Journal of Biodiversity and Conservation. 6, 59-70.

Wang, X. Y., Huang, X. L., Jiang L. Y. and Qiao, G. X. 2009. Predicting potential distribution of chestnut phylloxerid (Hemiptera: Phylloxeridae) based on GARP and Maxent ecological niche models. Journal of Applied Entomology. 134, 45-54.

Willis, K.J. and Whittaker, R.J. 2002. Species diversity – scale matters. Science. 295, 1245-1248.

Yang, X.Q., Kushwaha, S.P.S., Saran, S, Xu, J. and Roy, P.S. 2013. Maxent modeling for predicting the potential distribution of medicinal plant, *Justicia adhatoda* L. in Lesser Himalayan foothills. Ecological Engineering. 51, 83-87.

Zerrudo, J.V. 1991. *Caesalpinia sappan* L. In Plant Resources of South-East Asia No 3. Dye and tannin producing plants. Lemmens, R.H.M.J. and Wulijarni-Soetjipto, N., editors. Pudoc, Wageningen, Netherlands, pp. 60-62.

Appendix Table. Correlation between different climatic variables.

Variables	bio1	bio2	bio3	bio4	bio5	bio6	bio7	bio8	bio9	bio10	bio11	bio12	bio13	bio14	bio15	bio16	bio17	bio18	bio19
bio1	1	-.025	.313**	-.680**	.827**	.833**	-.206**	.877**	.961**	.934**	.964**	-.106	-.165**	-.050	.084	-.188**	-.034	-.607**	.032
bio2		1	-.509**	.272**	.481**	-.512**	.894**	-.064	-.125*	.109	-.120*	-.730**	-.542**	-.561**	.913**	-.518**	-.634**	-.406**	-.674**
bio3			1	-.777**	-.159**	.687**	-.823**	.093	.484**	.011	.501**	.493**	.151**	.528**	-.661**	.141*	.620**	-.026	.653**
bio4				1	-.327**	-.850**	.611**	-.324**	-.826**	-.381**	-.847**	-.188**	.023	-.196**	.238**	.043	-.257**	.481**	-.348**
bio5					1	.404**	.364**	.747**	.719**	.900**	.716**	-.510**	-.431**	-.364**	.459**	-.439**	-.407**	-.937**	-.376**
bio6						1	-.704**	.963**	.904**	.642**	.908**	.307**	.113*	.275**	-.303**	.084	.339**	-.350**	.434**
bio7							1	-.095	-.362**	.045	-.369**	-.708**	-.449**	-.563**	.665**	-.426**	-.661**	-.216**	-.734**
bio8								1	.755**	.936**	.745**	-.091	-.088	-.053	.090	-.114*	-.044	-.349**	-.026
bio9									1	.821**	.990**	-.018	-.143*	.033	-.029	-.166**	.066	-.620**	.164**
bio10										1	.813**	-.242**	-.219**	-.165**	.232**	-.238**	-.178**	-.567**	-.133*
bio11											1	-.008	-.126*	.032	-.021	-.150**	.065	-.618**	.149**
bio12												1	.827**	.660**	-.581**	.837**	.718**	.590**	.698**
bio13													1	.243**	-.080	.988**	.272**	.595**	.367**
bio14														1	-.845**	.244**	.969**	.345**	.703**
bio15															1	-.084	-.908**	-.324**	-.736**
bio16																1	.273**	.606**	.375**
bio17																	1	.376**	.762**
bio18																		1	.220**
bio19																			1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).