# CHAPTER 3

# Materials and methods

## 3.1 Study area

The study areas are located in Chiang Mai province, northern Thailand (Figure 15). 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 dry dipterocarp and mixed deciduous forest in low and moderate altitudes, while coniferous forest, hill evergreen forest and tropical montane cloud forest are dominant in higher altitudes.

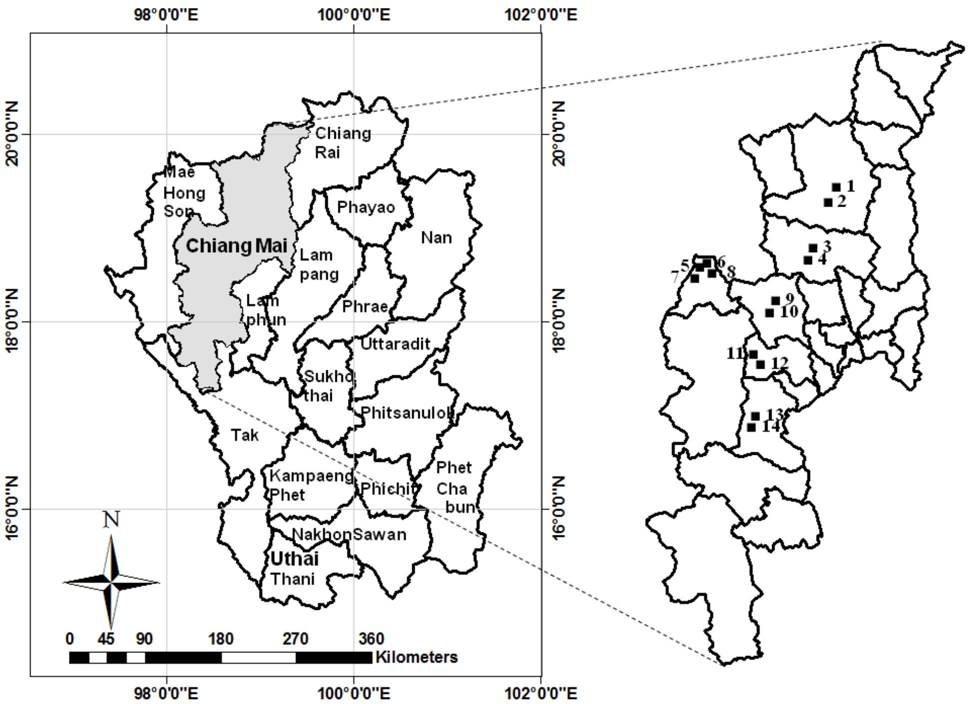


Figure 15 Location of study area. Fourteen Karen villages in Chiang Mai province in northern Thailand where medicinal plants were studied: (1) Yang Poo To; (2) Yang Tung Pong; (3) Mae Lod Tai; (4) Pa Taek; (5) Huay Bong; (6) Huay Hom; (7) Kew Pong; (8) San Muang; (9) Mai Lan Kam; (10) Huay Hea; (11) Huay Tong; (12) Tung Luang; (13) Huay Pu Ling; and (14) Mai Sa Wan.

### 3.2 Study of medicinal plants used by the Karen

Regard to Karen population in Chiang Mai province, more than 80% of the total population is Sgaw Karen (Perve, 2006). Therefore, this study was investigated the traditional medicinal plants only from the Sgaw Karen in Chiang Mai province. Medicinal plants data in this study were gathered from 2 data sources; 1) previous reports on Karen's medicinal plants knowledge in the Chiang Mai province, 2) field study.

#### 3.2.1 Reports on Karen's medicinal plants knowledge in Chiang Mai province

The data for medicinal plants used by the Karen in Chiang Mai province were selected from previous ethnobotanical reports which were showed in Table 3. Moreover, the precise locations of selected study sites from previous reports were shown in Figure 15 and Table 4.

#### 3.2.2 Field study

Field study was conducted in Mai Lan Kam and Huay Hea villages in Samoeng district, Chiang Mai province, between October 2010 - August 2011. The information of these villages were shown in Table 4.

Initially, contacts were made to village headmen to explain the purpose and techniques of the proposed research. Subsequently, the headmen explained the study to the villagers who gave their informed consents. One key informant in each village was selected for his/her reputation as a specialist with medicinal plant knowledge. The information on traditional knowledge of medicinal plants was gathered through free listing interview and guided tours in homegardens, cultivated fields and nearby forests. During the survey, vernacular names of each medicinal plant and which part of the plant, which mode of preparation, and which routes of administration were noted. Each species was photographed, and voucher specimens were collected and subsequently deposited in the herbarium of the Ethnobotany and Northern Thai Flora Research Section, Department of Biology, Faculty of Science, Chiang Mai University and Queen Sirikit Botanic Garden Herbarium (QBG), Chiang Mai, Thailand.

Table 3 Reports on Karen's medicinal plants knowledge in Chiang Mai province

| Collector | Collecting period | Villages | District | Number of medicinal plants | Source |
|---|---|---|---|---|---|
| Piyawan Winijchaiyanan | June 1993 - May 1995 | Tung Luang | Mae Wang | 36 | Winijchaiyanan (1995) |
| | | Huay Tong | Mae Wang | 34 | |
| | | Pa Tak | Mae Tang | 36 | |
| | | Mae Lod Tai | Mae Tang | 86 | |
| Wittaya Pongamornkul | November 2002 - February 2003 | Yang Poo To | Chiang Dao | 36 | Pongamornkul (2003) |
| | | Yang Tung Pong | Chiang Dao | 28 | |
| Treetip Sukkho | June 2006 - December 2007 | Kew Pong | Kallayaniwattana | 90 | Sukkho (2008) |
| | | Huay Bong | Kallayaniwattana | 59 | |
| | | San Muang | Kallayaniwattana | 58 | |
| | | Huay Hom | Kallayaniwattana | 63 | |
| Kaweesin Kamwong | January 2007 - December 2008 | Mai Sa Wan | Chom Thong | 134 | Kamwong (2009) |
| | | Huay Poo Ling | Chom Thong | 106 | |

Table 4 Basic information for fourteen Karen villages in Chiang Mai province where medicinal plants data were gathered.

| Village name | Coordinates | Altitude (MSL) | Vegetation | Age of community (years of existance) | Households | Inhabitants | Presence of public health center | Presence of school |
|---|---|---|---|---|---|---|---|---|
| Yang Poo To | 19°21'45.01" 98°55'27.26" | 500 | MDF | <30 | 16 | 57 | No | No |
| Yang Tung Pong | 19°19'58.16" 98°55'41.15" | 413 | MDF | <30 | 5 | 20 | No | No |
| Huay Hea | 18°45'38.46" 98°42'36.30" | 746 | MDF | >100 | 14 | 68 | No | No |
| Mai Lan Kam | 18°46'37.26" 98°41'55.44" | 692 | MDF | <30 | 45 | 135 | Yes | Yes |
| Huay Tong | 18°42'21.06" 98°33'5.46" | 992 | MDF | 56 | 72 | 329 | Yes | Yes |
| Tung Luang | 18°43'10.20" 98°34'10.98" | 913 | MDF | >100 | 54 | 382 | No | No |
| Pa Taek | 19° 4'38.19" 98°45'59.46" | 682 | MDF | >100 | 45 | 281 | No | No |
| Mae Lod Tai | 19° 5'38.15" 98°46'39.22" | 690 | MDF | >100 | 34 | 136 | No | No |

Vegetation types: MDF, mixed deciduous forest; CF, coniferous forest; HE, hill evergreen forest.

Table 4 (continued)

| Village name | Coordinates | Altitude (MSL) | Vegetation | Age of community (years of existance) | Households | Inhabitants | Presence of public health center | Presence of school |
|---|---|---|---|---|---|---|---|---|
| Kew Pong | 19° 2'27.55" 98°16'30.46" | 1010 | CF/ MDF | <30 | 49 | 257 | No | No |
| Huay Bong | 19° 3'18.21" 98°16'13.25" | 1027 | CF/ MDF | <30 | 74 | 266 | No | Yes |
| San Muang | 19° 6'44.28" 98°18'6.84" | 1050 | CF/ MDF | <30 | 51 | 202 | Yes | No |
| Huay Hom | 19° 7'12.72" 98°17'36.66" | 1046 | CF/ MDF | <30 | 41 | 185 | No | No |
| Mai Sa Wan | 18°30'14.20" 98°26'39.71" | 1190 | HE/ MDF | 31 | 18 | 102 | No | No |
| Huay Poo Ling | 18°30'5.23" 98°25'49.87" | 1050 | HE/ MDF | >100 | 32 | 144 | No | No |

Vegetation types: MDF, mixed deciduous forest; CF, coniferous forest; HE, hill evergreen forest.

### 3.3 Cultural important medicinal plant study

To determine the prevalence of medicinal plant knowledge, questionnaire interviews were carried out among the Karen villagers.

#### 3.3.1 Interviews of the culturally important medicinal plants

Questionnaire interviews were with 438 additional informants concerning traditional knowledge and actual uses of medicinal plants. In total, 206 females and 232 males were randomly selected in six stratified age groups (Table 5). In each village, all medicinal plant species data obtained from key informant who resides in that village were prepared for the semi-structure interview. During the interview, plant pictures and the Karen plant name were shown to the informants. The questions were asked individually concerning their actual medicinal use together with questions about what plant parts were used, modes of preparation, and route of administration. The semi-structured interviews were conducted in Thai with the presence of a translator when the informants could not communicate in Thai.

#### 3.3.2 Calculating cultural important index (CI)

Based on the data from the questionnaire interviews, species that were culturally important as medicines were identified using the cultural important index (CI) of Tardío and Pardo-De-Santayana (2008). This index considers diversity of uses along with the consensus of informant, and it is calculated as:



$$\sum_{u=1}^{NC}\sum_{i=1}^{N}\frac{URui}{N}$$

where *NC* is the total number of different use-categories (for species *i*), *UR* is the total number of use reports for species *i*, and *N* is the total number of informants. Hence, the CI index is the sum of the proportion of informants that mention each of the use-categories for a given species. The maximum value of the index equals the total number of different use-categories (NC), which would occur if all informants mentioned the use of a species in all different use categories. The highest CI value would be 22 in this study.

Table 5 Number of informants for questionnaire interview in the fourteen Karen villages where ethnobotanical study was conducted

| Village name | Number of informants for the questionnaires | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total (percent of the inhabitants) | Number of informants in each age range (males/females) | | | | | |
| | | 13-19 | 20-29 | 30-39 | 40-49 | 50-59 | >60 |
| Yang Poo To | 23 (40%) | 3 (1/2) | 3 (1/2) | 6 (3/3) | 4 (1/3) | 3 (1/2) | 4 (3/1) |
| Yang Tung Pong | 11 (55%) | 1 (0/1) | 1 (0/1) | 2 (1/1) | 4 (1/3) | 2 (1/1) | 1 (0/1) |
| Huay Hea | 35 (51%) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (2/4) | 5 (3/2) | 6 (3/3) |
| Mai Lan Kam | 36 (27%) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (3/3) |
| Huay Tong | 54 (16%) | 9 (5/4) | 9 (4/5) | 9 (5/4) | 9 (5/4) | 9 (4/5) | 9 (5/4) |
| Tung Luang | 48 (13%) | 8 (4/4) | 9 (5/4) | 7 (3/4) | 7 (4/3) | 9 (4/5) | 8 (4/4) |
| Pa Taek | 36 (13%) | 5 (2/3) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 7 (4/3) |
| Mae Lod Tai | 36 (26%) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (3/3) | 6 (2/4) | 6 (3/3) |

Table 5 (continued)

| Village name | Number of informants for the questionnaires | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total (percent of the inhabitants) | Number of informants in each age range (males/females) | | | | | |
| | | 13-19 | 20-29 | 30-39 | 40-49 | 50-59 | >60 |
| Kew Pong | 28 (11%) | 5 (2/3) | 4 (2/2) | 5 (3/2) | 5 (3/2) | 5 (2/3) | 4 (2/2) |
| Huay Bong | 27 (10%) | 3 (1/2) | 4 (1/3) | 6 (1/5) | 6 (3/3) | 5 (2/3) | 3 (1/2) |
| San Muang | 30 (13%) | 5 (2/3) | 5 (2/3) | 5 (3/2) | 6 (3/3) | 4 (2/2) | 5 (2/3) |
| Huay Hom | 31 (17%) | 5 (3/2) | 5 (3/2) | 6 (3/3) | 5 (3/2) | 5 (3/2) | 5 (2/3) |
| Mai Sa Wan | 21 (21%) | 3 (1/2) | 4 (2/2) | 3 (1/2) | 4 (1/3) | 3 (2/1) | 4 (2/2) |
| Huay Poo Ling | 22 (15%) | 2 (0/2) | 3 (1/2) | 5 (2/3) | 4 (1/3) | 3 (2/1) | 5 (2/3) |

### 3.4 Species distribution modeling (SDM)

The potential distribution for medicinal plant species based on ecological niche models generated by Maxent software version 3.3.3k (downloaded from portal http://www.cs.princeton.edu/). In order to make the prediction, Maxent needs predictor variables and species occurrences data which are in term of geographic coordinate, as input data (Figure 16). Maxent then estimates species distributions based on presence-only occurrence data by finding the distribution of maximum entropy, subject to the constraint that the expected value of each environmental variable under this estimated distribution should match its empirical average (Phillips et al., 2006). The obtained model reveals the relative probability of a species distribution over all grid cells in the defined geographical space, in which a high probability-value associated to a particular grid cell indicates the likehood of this cell having suitable environmental conditions for the modeled species (Figure 16) (Urbina-Cardona and Loyola, 2008). Moreover, Maxent has many advantages include the following (Phillips et al., 2006): (1) It requires only presence data, together with environmental information for the whole study area. (2) It is possible to run models with small numbers (≥5) of sample localities. (3) It can utilize both continuous and categorical data, and can incorporate interactions between different variables. (4) Efficient deterministic algorithms have been developed that are guaranteed to converge to the optimal (maximum entropy) probability distribution. (5) The Maxent probability distribution has a concise mathematical definition, and is therefore amenable to analysis. (6) The output is continuous, allowing fine distinctions to be made between the modeled suitability of different areas. If binary predictions are desired, this allows great flexibility in the choice of threshold.

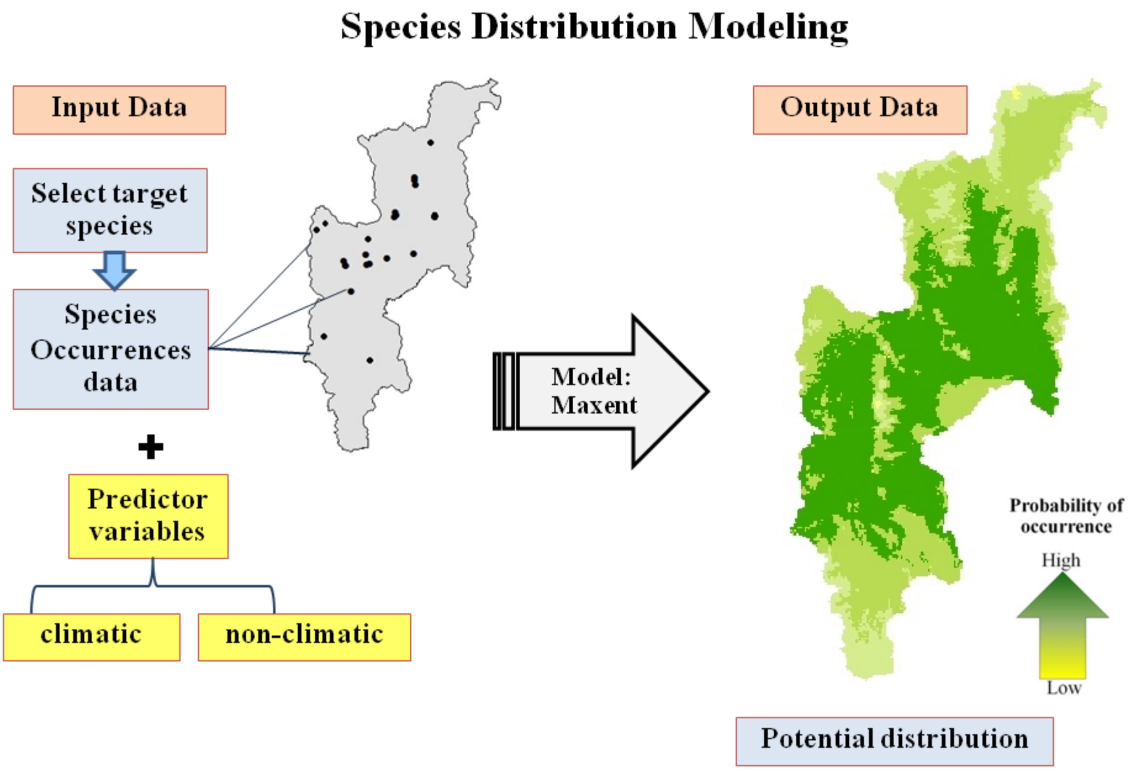


Figure 16 Method of species distribution modeling

### 3.4.1 Selection of medicinal plant for modeling work

Medicinal plants used by the Karen were selected for evaluating in SDM based on the following criteria

1) Plants should be wild species which the Karen collected them from forest. Nabout et al. (2012) stated that cultivated species are strongly influenced by several factors usually not included as model predictors, such as biotechnical resources, irrigation, soil types and fertilization, as well as other local factors. Therefore, cultivated species would be excluded and wild species would be used in this SDM study. Moreover, *Senna alata*, which originated in South-America (Mabberley, 1997), was introduced and cultivated in Thailand for many years ago. However, at the present, this plant grows in forest. Therfore, this plant was categorized as wild species in this study.

2) Plants should be identified to the species level. Owing to plants which are unidentified to the species level have limit availability data and ambiguity of the occurrences, therefore, those plants would be excluded from the SDM.

3) Plants need to have more than 5 occurrences recorded in the study area. Hernandez et al. (2008) were investigated how many number of species' occurrence records which were suitable for modeling work. The result revealted that good predictive performances were found in models which had equal or above 5 occurrence recorded. Therefore, plants which had occurrence records less than 5 would be excluded in this study.

Regard medicinal plants used by the Karen in this study, 244 species were selected are wild species, 68 species were cultivated species, 64 species are not identified to the species level (Figure 17, Appendix A) and 3 species (*Alstonia glaucescens*, *Flemingia ferruginea*, *Zingiber latifolium*) have their occurrence recorded in the study area less than 5. Therefore, total of 244 plant species were selected to evaluate in modeling work.

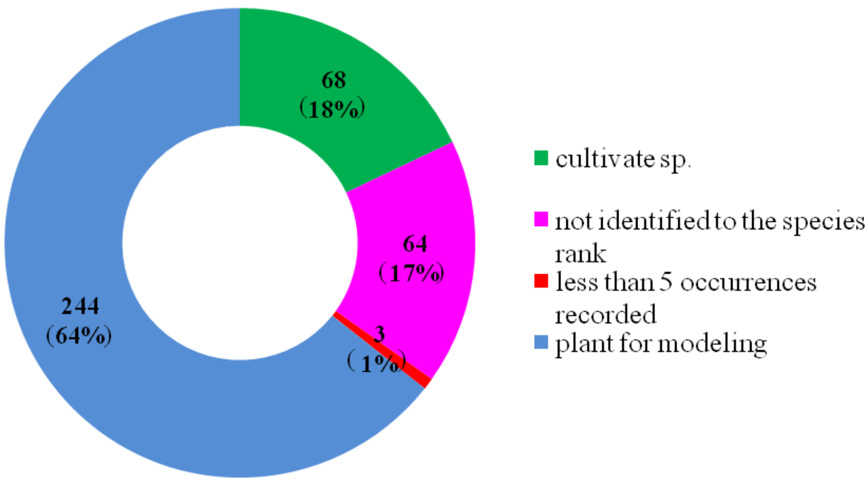


Figure 17 Number of medicinal plants for modeling work

### 3.4.2 Species occurrences data

Owing to medicinal plants have difference species range, some species have small ranges but some species have the large ranges (Appendix B) which cover throughout South-East Asia and China. Therefore, occurrence records for the medicinal plants studied were obtained not just from Chiang Mai province, but also from a whole Thailand and Myanmar, Laos People's Democratic Republic, Vietnam, Cambodia, Malaysia, Indonesia, Philippines, Taiwan and southern China, within the area between latitude -10° 58' 43" S - 31° 01' 13" N and longitude 90° 45' 40"- 142° 00' 00" E in order to characterize more fully the environmental niche of plant species. The occurrence records were derived from three sources:

1) Field survey data (data collected during 1993-2011)

2) Records of wild population from literatures

3) The Global Biodiversity Information Facility (http://www.gbif.org/).

A total of 4,888 occurenes recorded for 244 plant species were selected from ten countries in South-East Asia and southern of China (Figure 18, Table 6). The highest number of occurences recored were found in Thailand (50.8%) follow by China (20.7%), Indonesia (11.7%), Vietnam (6.9%), Laos (2.8%), Malaysia (2.2%), the Phillippines (1.9%), Taiwan (1.7%), Cambodia (1.4%) and Myanmar (0.2%). Regard to occurences recorded, the potential species distribution was investigated not only for Chiang Mai province but also throughout ten countries in South-East Asia and southern of China.

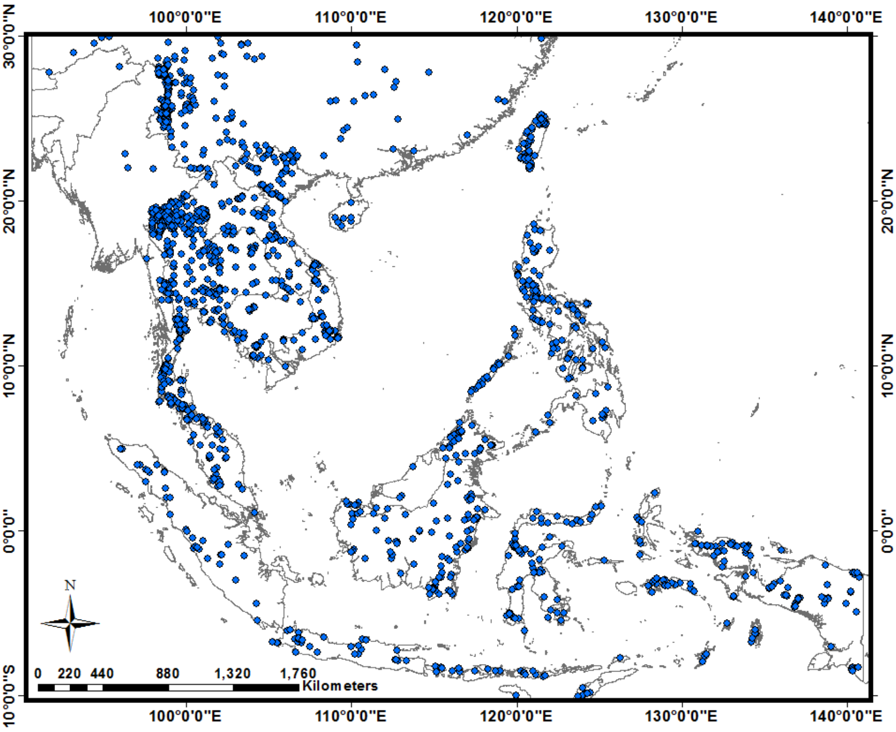


Figure 18 Occurrences recorded of medicinal plant species in South-east Asia region.

Table 6 Number of surveyed occurrences recorded in South-east Asia countries.

| Country | Number of occurrence recorded |
|---|---|
| Thailand | 2326 |
| China | 947 |
| Indonesia | 535 |
| Viet Nam | 314 |
| Laos | 128 |
| Malaysia | 99 |
| Phillippines | 86 |
| Taiwan | 75 |
| Cambodia | 63 |
| Myanmar | 7 |
| Total | 4888 |

### 3.4.3 Environmental variables

A combination of non-climatic and climatic environmental predictors was used for modeling suitable areas for the medicinal plants used by the Karen.

1) Non-climatic variables

Three non-climatic variables that may also influence plant species distribution were also included: soil types, slopes, and human influence index (HII). 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.

1.1) Soil-layer data

Data on soil layer was downloaded from the Harmonized World Soil Database (HWSD) version 1.2 (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012). Soil types were 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, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry).

1.2) Slope data

Slope data were downloaded from the Hydro1K GTOPO30 (EROS 1996). The Hydro1K GTOPO30 data were derived from several raster and vector sources of topographic information at the US Geological Survey Center for Earth Resources Observation and Science.

1.3) Human influence index (HII)

The 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). Data values range from 0 to 64, corresponding to no or maximum human influence on habitat.

2) Climatic variables

The climatic variables were extracted from the WorldClim data base (Table 7) (Hijmans et al., 2005) at 1 km resolution for the period of 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, 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, $r > |0.9|$ was done with the SPSS 17.0 software package for Windows. However, some climatic variables including bio1 and bio5 were selected due to the previous reports (Trisurat et al., 2009; Garcia et al., 2013) revealed that they were the important predictor variables for plant species distribution in northern Thailand and tropical regions.

According to statistic result (Table 8), ten climatic variables from Worldclim were selected (Table 9). Therefore, a total thirteen predictor variables (10 climatic variables and 3 non-climatic variables) were used to make SDM (Table 9).

Table 7 Climatic variables from WorldClim database

| Code | Parameter (unit) |
|---|---|
| bio1 | Annual mean temperature (°C) |
| bio2 | Temperature diurnal range (°C) |
| bio3 | Isothermality (°C) (quotient between parameters bio2/bio7) |
| bio4 | Temperature seasonality (coefficient of variation, %) |
| bio5 | Mean maximum temperature of the hottest month (°C) |
| bio6 | Mean minimum temperature of the coldest month (°C) |
| bio7 | Temperature annual range (°C) (quotient between parameters bio5-bio6) |
| bio8 | Mean temperature of the wettest quarter (°C) |
| bio9 | Mean temperature of the driest quarter (°C) |
| bio10 | Mean temperature of the hottest quarter (°C) |
| bio11 | Mean temperature of the coldest quarter (°C) |
| bio12 | Annual precipitation (mm) |
| bio13 | Precipitation of the wettest month (mm) |
| bio14 | Precipitation of the driest month (mm) |
| bio15 | Precipitation seasonality (coefficient of variation, %) |
| bio16 | Precipitation of the wettest quarter (mm) |
| bio17 | Precipitation of the driest quarter (mm) |
| bio18 | Precipitation of the hottest quarter (mm) |
| bio19 | Precipitation of the coldest quarter (mm) |

Table 8 Correlation between different Worldclim 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$^{**}$ | .613$^{**}$ | -.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$^{**}$ | -.737$^{**}$ | -.376$^{**}$ |
| bio6 | | | | | | 1 | -.704$^{**}$ | .663$^{**}$ | .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).

No significant

Table 9 Predictor variables used for building SDM.

| Code | Parameter (units) |
|---|---|
| bio1 | Annual mean temperature (°C) |
| bio 2 | Temperature diurnal range (°C) |
| bio 3 | Isothermality (°C)  (bio2/bio7) |
| bio 4 | Temperature seasonality (standard deviation *100, %) |
| bio 6 | Mean minimum temperature of the coldest month (°C) |
| bio 7 | Temperature annual range (°C) |
| bio 12 | Annual precipitation (mm) |
| bio 14 | Precipitation of the driest month (mm) |
| bio 18 | Precipitation of the hottest quarter (mm) |
| bio 19 | Precipitation of the coldest quarter (mm) |
| Slope | Maximum range in elevation (meters) |
| HII | Human influence index |
| Soil | Soil type |

### 3.4.4 Model building

Maxent was run using a convergence threshold of 10 with 1,000 iterations as upper limit for each run. To assess the predictive capacity of the Maxent models, 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. The accuracy of the Maxent models were evaluated from the Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve, 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 predicted was 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.

### 3.4.5 Future climate scenarios

Future climate forecasts from Hadley Centre Coupled Model, version 3 (HADCM3) were used for this study. This model has been commonly used in ecological studies (IPCC, 2007) and reported to provide good median results compared with other models (Jaramillo et al., 2011). Mean annual temperatures during 2010-2030 were forecasted not to change much (Chula Unisearch and Southeast Asia START Regional Center, 2012). For 2050-2080, the annual mean temperature was predicted to be 1-3 °C higher than the year 2000 depending on scenarios. Therefore, the time interval 2050 and 2080 was selected to make future predictions in this study. The future data were 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) data 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.

## 3.5 Climate change impact measurement



### 3.5.1 Spatial pattern

The impacts of climate change on the spatial patterns of individual species and on the species richness distribution changes were evaluated in this study. For each species the assessment was done in terms of the percentage of species gain (new arrival) and species loss (no longer exists in the future) under predicted climate change (Trisurat et al., 2011). The calculation of species turnover rate was shown below:

$$T = 100 \times \left[\frac{G + L}{SR + G}\right]$$

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.

### 3.5.2 Species extinction risk

Based on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List criteria 2001 (IUCN, 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 (VN) has projected loss of 30 to 50%; Near threatened (NE) has projected loss <30%, and least concerned (LC) has no projected loss.