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Plant species vulnerability to climate change in Peninsular Thailand

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A B S T R A C T

The objective of this research study was to evaluate the consequences of climate change on shifts in distributions of plant species and the vulnerability of the species in Peninsular Thailand. A sub-scene of the predicted climate in the year 2100, under the B2a scenario of the Hadley Centre Coupled Model, version 3 (HadCM3), was extracted and calibrated with topographic variables. A machine learning algorithm based on the maximum entropy theory (Maxent) was employed to generate ecological niche models of 66 forest plant species from 22 families. The results of the study showed that altitude was a significant factor for calibrating all 19 bioclimatic variables. According to the global climate data, the temperature in Peninsular Thailand will increase from 26.6 °C in 2008 to 28.7 °C in 2100, while the annual precipitation will decrease from 2253 mm to 2075 mm during the same period. Currently, nine species have suitable distribution ranges in more than 15% of the region, 20 species have suitable ecological niches in less than 10% while the ecological niches of many *Dipterocarpus* species cover less than 1% of the region. The number of trees gaining or losing climatically suitable areas is quite similar. However, 10 species have a turnover rate greater than 30% of the current distribution range and the status of several species will in 2100 be listed as threatened. Species hotspots are mainly located in large, intact protected forest complexes. However, several landscape indices indicated that the integrity of species hotspots in 2100 will deteriorate significantly due to the predicted climate change.

Introduction

Thailand has a species-rich and complex biodiversity that differs in various parts of the country (Wikramanayake et al., 2002). The Kingdom harbours one of the 25 global biodiversity hotspots (Myers, Mittermeier, Mittermeier, & Kent, 2000), supporting approximately 7–10% of the world's plant, bird, mammal, reptile, and amphibian species (ONEP, 2006). Biodiversity provides both direct and indirect benefits to people, especially the rural poor (Millennium Assessment, 2005). In addition, it has been considered an important resource base for socio-economic development in Thailand (National Economic and Social Development Board, 2007). Unfortunately, the biodiversity of Thailand is under severe threat, especially from deforestation (Stibig et al., 2007). The results from the monitoring in the last four decades show that the rate is considered to be one of the fastest rates of deforestation in the tropics (Middleton, 2003). Besides deforestation, climate change has also become a global threat to biodiversity. Changes in climate have the potential to affect both the geographic location of ecological systems and the mix of species that they contain (Secretariat of the Convention on Biological Diversity, 2003).

In recent years, a number of GIS-based modeling methods of species distributions have been developed for assessing the potential impacts of climate change, especially when detailed information about the natural history of the species is lacking (Anderson, Laverde, & Peterson, 2002; Peralvo, 2004). Species-distribution models (SDMs) are based on the assumption that the relationship between a given pattern of interest (e.g. species abundance or presence/absence) and a set of factors assumed to control it can be quantified (Anderson, Lew, & Peterson, 2003; Anderson & Martinez-Meyer, 2004; Guisan & Zimmermann, 2000; Raxworthy et al., 2003;). Therefore, this methodology allows us to predict the potential distribution of a species even for areas that suffer from incomplete and biased samplings, or for areas where no collections have been made (Araujo & Guisan, 2006; Elith et al., 2006).

Miles, Grainger, and Phillips (2004) used spatial distribution models to predict current and future species distributions in the Amazonia. The results indicated that up to 43% of a sample of species in the region could become non-viable by 2095. In addition, approximately 59% of plant and 37% of bird species in the Northern Tropical Andes will become extinct or classified as critically endangered

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species by the year 2080 as a result of the A2 climate change scenario (Cuest-Comocho, Ganzenmuller, Peralvo, Novoa, & Riofrio, 2006). Habitats of many species will move poleward or upward. The climatic zones suitable for temperate and boreal plant species may be displaced 200–1200 km poleward. Parolo and Rossi (2008) compared historical records (1954–1958) with results from recent plant surveys (2003–2005) from alpine to aquatic ecosystems in the Rhaetian Alps, northern Italy and reported an increase in species richness from 153 to 166 species in higher altitudes. In addition, Trivedi, Morecroft, Berry, and Dawson (2008) indicated that Arctic-alpine communities in protected areas could undergo substantial species turnover, even under the lower climate change scenario for the 2080s.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicated that the mean temperature in Thailand will raise by 2.0–5.5 °C by 2100 under the regionally-oriented economic development scenario of the Hadley Centre Coupled Model, version 3 (HadCM3 A2) (IPCC, 2007). Boonpragob and Santisirisomboon (1996) predicted that the temperature in Thailand will increase by 1.5–2.0 °C and annual rainfall in the south will increase by 40% by 2100. These changes would cause effects on Thai forests. The area of the subtropical life zone would decline from about 50% to 12–20% of the total cover, whereas the tropical life zone would expand its cover from 45% to 80%.

Trisurat, Alkemade, and Arets (2009) used a species distribution model and fine resolution (1 km) climate data to generate ecological niches of forest plant species in northern Thailand. The results showed high turnover rates, especially for evergreen tree species. The assemblages of evergreen species or species richness are likely to shift toward the north, where lower temperatures are anticipated for year 2050. In contrast, the deciduous species will expand their distribution ranges. A similar study was conducted by Zonneveld, Van, Koskela, Vinceti, and Jarvis (2009) to estimate the potential occurrence of *Pinus kesiya* Royle ex Gordon and *Pinus merkusii* Jungh. & De Vriese in Southeast Asia. The results revealed that lowland *P. merkusii* stands in Cambodia and Thailand are expected to be threatened mostly by climate alterations. This is due to maximum temperatures in the warmest month in 2050 predicted to be above 36 °C will increase beyond the tolerance range of *P. merkusii* and will kill adult trees of this species (Hijmans et al., 2005) and work against recruitment success at the stand and site scales, but not at the regional scale (Zimmer & Baker, 2008).

Peninsular Thailand covers a major floristic and climatic transition zone with both wet tropical rainforests as well as seasonal evergreen tropical forests of the Indo-Sundaic region. However, studies of effects of climate change on the geographical species' distribution at present and in the future are lacking. Baltzer, Davies, Nursupardi, Abul Rahman, and La Frankie (2007) and Baltzer, Gregoire, Bunyavejchewin, Noor and Davies (2008) investigated the mechanisms constraining local and regional tree species distributions in the Kanger–Pattani Line in the Indo-Malay region. The results showed that inherent differences in physiological traits were contributing to drought tolerance and are associated with differences in tropical tree species distributions in relation to rainfall seasonality. These results strongly implicate climate as a determinant of tree species distributions around the Kanger–Pattani Line. Hence, the objective of this research study is to evaluate the consequences of climate change on species shifts in distributions, and species vulnerability in the Peninsular Thailand.

Methods

Study area

Peninsular or Southern Thailand is situated between 5°37′ - 11°42′ North latitudes and 98° 22′ - 102° 05′ East longitudes. It covers 14 provinces and encompasses an area of approximately 70,700 km^2 or 14% of the country's land area (Fig. 1). Currently, protected areas cover approximately 14.8% of the region. Peninsular Thailand varies in width from roughly 50–22 km, and a mountainous backbone runs its full range oriented north–south. The average annual temperature is 26.6 °C. Annual precipitation is over 2000 mm for most of the area and exceeds 3000 mm in some parts. Rainfall increases southward as the length of the dry season and the magnitude of pre-monsoon drought stress declines. The southern mountain ranges receive rain from both the northeast and southwest monsoons.

According to World Wild Fund for Nature (2008), Peninsular Thailand encompasses the southern portion of the Tenasserim–South Thailand semi-evergreen rain forests eco-region. It is mainly influenced by Malaysian flora in the south and Burmese flora in the northern part (Raes & Van Welzen, 2009). Santisuk et al. (1991) classified forest types in the Peninsular Thailand into 2 categories, i.e. Peninsular Wet Seasonal Evergreen Forest and Malayan Mixed Dipterocarp Forest. Peninsular Wet Seasonal Evergreen Forest encompasses Chumpon Province to the north boundary of the Kangar–Pattani Line, while the Malayan Mixed Dipterocarp Forest covers parts of the Kangar–Pattani Line. Tropical rainforest trees in the family Dipterocarpaceae dominate forests throughout the peninsular region but species change both with elevation and latitude.

Forest cover in Peninsular Thailand declined from 42% in 1961 (Charuphat, 2000) to 30% in 2008 (Land Development Department, 2008), which was the second highest deforestation rate after northern Thailand. The main threat is encroachment for rubber and oil palm plantations.

Data on land use, socio-economic and biophysical factors

A set of environmental variables that may directly or indirectly affect the patterns of tree distribution were created. These variables included biotic and physical factors. Remaining forest cover (biotic factor) was extracted from a 1:50,000 land use map of 2008 (Land Development Department, 2008). It should be noted that the scope of this study covers only terrestrial ecosystems, thus mangrove forests and wetlands are not included. In addition, we treated environmental variables as stable, except climatic variables because our research study emphasized the consequences of future climate change on plant distributions.

The physical factors were made up of four topographic inputs (altitude, slope, aspect and proximity to stream), as well as soil texture, and bio-climate variables (http://cres.anu.edu.au/outputs/anuclim/doc/bioclim.html) Contour lines (20-m intervals) were digitized from topographic maps at a scale of 1:50,000 (Royal Thai Survey Department, 1992). Then, digital elevation models of altitude, aspect and slope were interpolated from contour lines. In addition, a soil map at scale 1:100,000 was obtained from the Land Development Department.

The present (year 2000) and future world climate dataset predicted for 2100 and generated by the HadCM3 B2a climate change scenario (local sustainability and social equity) was obtained from the TYN SC 2.0 dataset (Mitchell, Carter, Jones, Hulme, & New, 2004). The original monthly temperature and rainfall values of TYN SC 2.0 climate datasets generated at a spatial resolution of 0.5° (approximately 45 km) were converted to Raster ASCII grids (*.asc). Then, the coarse resolution climatic variables were re-sampled to a resolution of 1 km using the interpolation method (Theobald, 2005). The 1-km resolution was chosen as an appropriate size for regional assessment and an intermediate point between the high resolution of digital elevation model (DEM) generated from the 20-m interval contour line, and the coarse resolution of the climatic variables. In addition, the world climate data of year 2000 were calibrated with local climate data recorded from weather stations