Mapping Distribution of *Dipterocarpus* in East Kalimantan, Indonesia

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Abstract

Dipterocarps (*Dipterocarpaceae*) is a dominant tree family of tropical rainforest in Southeast Asia. Dipterocarps have been exploited for its timber and disappearing fast in East Kalimantan. In this study, we predicted the distribution of *dipterocarpus*, one of the main dipterocarps genera, by evaluating its habitat suitability using logistic regression analysis with specimen collection points and environmental factors from GIS data. Current distribution of *dipterocarpus* was generated by combining the habitat suitability classes with an updated forest cover map. Rainfall, soil type, followed by elevation was the main factors that influence the distribution of *dipterocarpus* in East Kalimantan. *Dipterocarpus* can be found in a quarter of the current forest cover, which is highly suitable as habitat of *Dipterocarpus*.

Key Words: *Dipterocarpaceae*, habitat suitability, logistic regression analysis, geographical information system

Introduction

Tropical forests are being destroyed at an alarming rate, threatening more than half of the planet's biodiversity with extinction (Sayers and Whitmore 1991). Tropical rainforest in Southeast Asia has been threatened by deforestation (Achard et al. 2002). The key factors of deforestation/ forest degradation in Indonesia include commercial logging, illegal logging and encroachment, plantation, coal mining and forest fire. The deforestation rate in each decade seemed to be slowing down but deforestation will continue to cause further decline of the forest cover (FAO 2010). Hence, biodiversity will also be affected by the ongoing deforestation.

Borneo is also the center of diversity for many plant families including the important commercial timber tree family,

the *Dipterocarpaceae*, with at least 267 species (Ashton 1982). This key stone family is a target of commercial practice logging and threatened by conversion of forest to other land uses. Therefore, the need to know the current distribution of dipterocarps is of upmost importance. Although the ecological modelling approach employing Dipterocarp growth simulation model have been developed (Huth and Ditzer 2000), it is only applicable to stand level. To evaluate distribution of *dipterocarpus* in the landscape scale, more macroscopic approach should be applied. Probabilistic or predictive mapping using GIS has variously been used to identify areas for conservation, such as for conservation of owl through identification of its breeding site (Isaac et al. 2008). Logistic regression has been shown of its usefulness such as in evaluating habitat of Javan Hawk Eagle (Syartinilia and Tsuyuki 2008).

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In this paper, we applied the logistic regression approach for evaluating the habitat suitability and predicting the current distribution of *dipterocarpus* using GIS. Also using *dipterocarpus* as example, we demonstrated how herbarium specimen can be instrumental in mapping the distribution of the important tree family.

Materials and Methods

Study area

Borneo Island is the third largest island in the world. It is shared by three countries i.e. Indonesia, Malaysia and Brunei. Borneo is the center of distribution of dipterocarps. Indonesian part of Borneo is called Kalimantan. Our study area, East Kalimantan Province, is located at the eastern part of Borneo Island. East Kalimantan covers 198,440 km² of land area and ranges from 113°50' E to 118°59' E, 4°24' N to 2°25' S (Fig. 1). As shown in Fig. 1, the north-western part is mountainous with a maximum elevation of 2,185 m. According to the statistical report of Provincial Development and Planning Agency 2010, total population of East Kalimantan is about 3,164,800. Annual rainfall is

1,500-4,500 mm and temperature fluctuates from 21 to 34°C. There are at least 267 dipterocarps in Borneo and more than 90% can be found in East Kalimantan (Ashton 1982).

Dipterocarpus data

Dipterocarpus data were collected from August 1, 2011 to September 17, 2011 at Herbarium Wanariset, Balikpapan as well as Herbarium LIPI, Bogor. It was a manual work of browsing through all the collection of *Dipterocarpaceae* and recording into a computer the details of the specimen. Most important information was the collection point. Recent collection points have coordinates from GPS but older specimen only contained locality name or description. We carefully examined the name and description of locality to ensure the collection points can be digitized with 1-minute resolution. Only 49 specimens were used in the analysis.

We collected ground truth data at four areas; Sungai Wain Protection Forest, Forest concession area of Balikpapan Forest Industry, Bukit Bangkirai and Kutai National Park. Presence of dipterocarps at species level was collected in the field with the assistance of a field ranger, a botanist and a lecturer of Universitas Mulawarman. Coordinate of each location was determined by averaging with a handheld Garmin GPS receiver.

GIS data

Dipterocarp species have been shown to have habitat associations with both topography and edaphic factors in a number of studies (Kettle 2010). Trisurat et al. (2009) used topographic factors, bio-climate factors, anthropogenic factors, biotic factors and soil characteristics to build tropical tree species distribution in Thailand. Raes et al. (2009) used altitude, temperature, precipitation and soil characteristics for mapping botanical richness in Borneo. In this study, four basic environmental factors were chosen as dependent variables; elevation, slope, soil type and rainfall. These factors were fundamental habitat factors of tree species including *dipterocarpus*. There are some other typical environmental factors shown above; only a few of them were available for whole East Kalimantan that is large in area. To estimate natural habitat of *dipterocarpus*, anthropogenic factors were not considered in this study. Current distribution was estimated by overlaying current forest cov-

Fig. 1. Study site (East Kalimantan Province shown by red shaded area, presence data shown by green dot).

er area, which include anthropogenic effect, to the natural habitat map.

For the factor of elevation, we used Shuttle Radar Topography Mission (SRTM; DTED-1, NASA), which was sampled at 3-arc second (approx. 90 m). SRTM data can be downloaded from USGS web site (<http://dds.cr.usgs.gov/srtm/>). Elevation was reclassified into 3 classes; 0-200 m, 200-400 m and over 400 m. Subsequently, slope was calculated from the SRTM data in TNTmips version 7.7 software by Microimages. Slope was also reclassified into 3 classes; 0-4 degrees, 5-8 degrees and 9-12 degrees. Soil type and annual rainfall were obtained from Provincial Development and Planning Agency of East Kalimantan, Indonesia. There were 13 classes included in the soil type map, and they were reclassified to 2 classes. Annual rainfall ranged from 0 to over 4,000 mm by 6 classes, it was reclassified into 3 classes; under 2,500 mm, 2,500-3,500 mm and over 3,500 mm. For the current forest cover, a land cover map produced by Ministry of Forestry, Indonesia in 2007 was used to overlay with the habitat suitability map for determining the current distribution of *dipterocarpus*.

All the factors were resampled to a pixel resolution of 1.8 km (approx. 1 minute resolution) to compensate uncertainty in the location of *dipterocarpus* from herbarium's specimen.

Logistic regression analysis

Logistic regression analysis is often used to determine factors of occurrence of certain event and the resulted model predicts probability of occurrence of an event. Dependent variable is described binary, such as presence (1) /absence (0) (Syartinilia and Tsuyuki 2008). The probability of *dipterocarpus* occurrence at pixel i , P_i , is written as follows,

$$P_i = \frac{1}{1 + \exp[-(\beta_0 + \sum_{j=1}^k \beta_j x_{ji})]} \quad (1)$$

where,

P_i = probability of *dipterocarpus* occurrence at pixel i

β_0 = constant

x_{ji} = habitat factors at pixel i

β_j = coefficients for x_j

k = number of variables

In order to carry out the logistic regression analysis, presence data and absence data of *dipterocarpus* are needed. We used the collection point of *dipterocarpus* specimen from herbarium as presence data. Herbarium specimen is the

evidence that *dipterocarpus* tree existed at the collection point. Absence data is the evidence that the tree cannot grow in a particular place. However, it is difficult to acquire such data because even if there is no *dipterocarpus* tree found at a particular place, it is difficult to be certain whether 'the absence' is actually attributed to unsuitable habitat or anthropogenic activities that have removed the trees. Therefore, we can only determine "pseudo-absence" data from randomly generated point data in East Kalimantan by setting the absent conditions based on the environmental factors except slope. Finally, 130 points were selected as pseud-absence data.

We carried out logistic regression analysis with the presence and pseudo-absence data to estimate the probability of occurrence of *dipterocarpus*. The occurrence probability value ranged between from 0 to 1; unsuitable and most suitable for *dipterocarpus*. Therefore, the occurrence probability was also the habitat suitability model for *dipterocarpus*. The resulted habitat suitability map was equally divided into four classes, unsuitable, low-suitable, middle-suitable and high-suitable. Finally, we generated the distribution of *dipterocarpus* by overlaying an current forest cover map and habitat suitability class map.

Results and Discussion

Habitat suitability modeling using logistic regression

Table 1 shows the result of logistic regression analysis. p-value indicates significance of each variable in the logistic regression model. The smaller the p-value, the more strongly the test rejects the null hypothesis, that is, the hypothesis being tested. In this analysis, excluding slope, the p-values of all other variables were significant at 1% level. However, the log likelihood ratio with all variables was better than excluding the slope factor. We thus decided to esti-

Table 1. Summary of logistic regression analysis

Independent variable	Coefficient	p-value	Significance at 1% level **
Elevation	-1.92	7.0×10^{-4}	**
Slope	-8.78×10^{-1}	4.2×10^{-1}	
Soil type	4.95	3.2×10^{-6}	**
Annual rainfall	5.60	3.5×10^{-3}	**

mate the occurrence probability of *dipterocarpus* (P_i) with all the variables as follows,

$$P_i = \frac{1}{1 + \exp[-3.88 - 1.92x_{elv} - 0.88x_{slp} + 4.95x_s + 5.60x_{rf}]} \quad (2)$$

where,

x_{elv} : elevation

x_{slp} : slope

x_s : soil type

x_{rf} : rainfall

Fig. 2. Habitat suitability model of *dipterocarpus*.

Habitat suitability model of *dipterocarpus*

Habitat suitability model of *dipterocarpus* was generated by assigning the coefficient values on the environmental factors using TNTmips. Fig. 2 shows the occurrence probability of *dipterocarpus* obtained by applying the equation (2). Dark green and dark brown colors indicate the highest and lowest occurrence probability of *dipterocarpus*, respectively. Among the four environmental factors, rainfall and soil type were found the main factors that influenced the occurrence of *dipterocarpus* in East Kalimantan. Dipterocarps are mostly concentrated in aseasonally wet lowland evergreen forest (Ashton 1995). With a randomly collected specimen data used as presence data ($n=49$), *dipterocarpus* was found in wet area but less than 3,500 mm of annual rainfall. The western part of East Kalimantan (dark brown in Fig. 2) is the wettest area. Dipterocarps are found on well-drained soils (Ashton 1995). Soil type was also an important factor that influenced the occurrence of *dipterocarpus*. Occurrence probability of *dipterocarpus* was almost ignorable at poor soils of podsol and cambisol (Fig. 2).

Dipterocarps are often found at altitudes below 800 m (Ashton 1995). Only some ten dipterocarp species or less than 4% of all dipterocarp species in Borneo are confined to montane and submontane environments (Ashton 2004). Elevation was also a significant factor to the occurrence of *dipterocarpus*. On the other hand, slope was only marginally important in the logistic model. This is probably because of the smoothing effect of resampling of the SRTM elevation data from 90m to 1.8 km. Slope calculated from the re-sampled elevation data may not be the nearest representation of the actual slope of the land surface.

Table 2 shows the error matrix of the habitat suitability

Table 2. Accuracy assessment of the model

Training data	Habitat suitability model						
	Suitable				Non-suitable	Total	Producer's accuracy
	Total	High	Mid	Low			
Present	44	38	2	4	5	49	89.8%
Absent	17	0	5	12	113	130	86.9%
Total	61				118	179	87.7%
User's accuracy	72.1%				95.8%		

model. As the number of presence data was small, it was not possible to use independent evaluation dataset for accuracy assessment. By using 179 points of presence/absence dataset used to construct the model, the overall accuracy was 87.7%, with producer's accuracy of 89.8% and 86.9% for present and absent points, respectively, which were relatively high. On the other hand, user's accuracy for suitable class and non-suitable class were 72.1% and 95.8%, respectively, which non-suitable class had higher confidence.

Current distribution of *dipterocarpus*

The most suitable habitat depicts natural habitat of *dipterocarpus*. By overlaying the habitat suitability classes and current forest cover area, we obtained the current distribution of *dipterocarpus* (Fig. 3). Vegetation types of "Primary Forest", "Secondary Forest" and "Bush/shrub" in the land cover map were used as the current forest cover area. The highly suitable areas that are covered by forest were mainly located in flat to undulating inland area of East Kalimantan.

Fig. 3. Distribution of *dipterocarpus* based on habitat suitability class and forest cover.

Fig. 3 is also showing 18 *dipterocarpus* field points taken from four ground truth areas. As the time period assigned for ground truth trip was very limited, we could select only the areas easily accessible. So, 18 points of four areas fall only in five pixels but they were all current distribution pixel; three pixel of highly suitable class and two pixel of low suitable class.

Table 3 shows the cross-tabulation between habitat suitability classes and forest/non-forest classes. The forest cover in East Kalimantan was less than 80%. About a quarter of the forest area was the highly suitable habitat of *dipterocarpus* (occurrence probability > 0.75). In other words, we can expect to find *dipterocarpus* in about a quarter of the forest areas of East Kalimantan. Table 3 also shows that more than 18,000 km² of non-forest area was predicted as 'highly suitable' for *dipterocarpus*. These areas are natural habitat of *dipterocarpus* in terms of environmental conditions of elevation, soil type, rainfall and slope and may be prioritized in reforestation planning activities.

Conclusions

Dipterocarpaceae is an important timber family that is fast disappearing due to over-harvesting. We demonstrated the use of herbarium species occurrence data in GIS for evaluating the occurrence of *dipterocarpus*, one of the genera in *Dipterocarpaceae*. We predicted the current distribution of *dipterocarpus* in East Kalimantan as in areas of suitable habitat that is covered by forest. This approach is potentially useful to forest planners because it can greatly reduce the need of field work in forest management and conservation planning of Dipterocarpaceae as well as other important tree families.

Table 3. Habitat suitability class by forest and non-forest areas (Unit: km²)

Suitability class	Non-forest area	Forest area	Total
Unsuitable	7,944.3	76,621.3	84,565.6
Low suitable	15,342.1	26,463.9	41,896.0
High suitable	18,566.0	39,219.4	57,785.4
Total	42,016.4	153,373.0	195,479.4

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