FINAL REPORT for APN PROJECT
Project Reference: ARCP2010-02CMY-Phua

Integrated Prediction of Dipterocarp Species Distribution in Borneo for Supporting Sustainable Use and Conservation Policy Adaptation

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

Borneo is known as a mega-biodiversity hotspot, also famous because of the unprecedented rate of deforestation. Sarawak, the Malaysian state in Borneo, recorded an average annual deforestation rate higher than 0.6% during the period of 1990-2009. Although no conclusive deforestation rate for East Kalimantan, it is believed that the deforestation rate is higher than Sarawak. Deforestation occurred mainly on intact forest and peat swamp forest. With a good collection of herbarium specimen, distributions of dipterocarps at species level can be predicted. Meanwhile, the distributions of dipterocarps in East Kalimantan were predicted at genus level.

It was further demonstrated that the species distribution maps can be analyzed in terms of conservation gaps at landscape level. Such information can be useful to sustainable forest management and conservation planning at state or province level. We evaluated the potential of REDD+ programs at West Kutai of East Kalimantan and found that most REDD+ activities supported by national programs were weak to strongly positive based on emission reduction, biodiversity conservation, and poverty alleviation. Protected forest management was found only weakly positive among the local people in East Kalimantan. In Sarawak, the local people showed their acceptance to REDD+ provided compensation in form of rubber plantation scheme.

Objectives

The main objectives of the project were:

a. To assess and predict the distribution of dipterocarp species distribution at landscape scale in Borneo.
b. To quantify and examine the land cover changes between 1990 and 2009 in Borneo.
c. To identify conservation gap in relation to the existing protected areas.
d. To evaluate REDD+ program and acceptance of local people in Borneo.

The focus areas of Borneo were Sarawak, Malaysia and East Kalimantan, Indonesia. Evaluation of REDD+ issues were implemented either in Sarawak or East Kalimantan due to financial and time constraints.

Amount received and number years supported

The Grant awarded to this project was:
Year 1: US$ 35,350
Year 2: US$ 39,650

Activity undertaken

Date/ Venue	Main Activity
16-17 Sept 2010/ Kota Kinabalu, Sabah, Malaysia	Project progress meeting/ Occasional seminar
20-28 October 2010/ Utsunomiya and Tokyo, Japan	Kanto-Japanese Forest Conference and Project Progress Meeting
30 July-6 August 2011/ Samarinda, East Kalimantan, Indonesia	Data Collection and Project Progress Meeting
7 March 2012/Kota Kinabalu, Sabah, Malaysia	Seminar on Challenges in Safeguarding Biodiversity against Deforestation and Degradation in Borneo

Results

Relevance to the APN Goals, Science Agenda and to Policy Processes

i. Science Agenda

This project focuses on prediction of dipterocarps, which is crucial in conservation planning and sustainable forest management in Borneo. The project supported the testing and development of an approach using herbarium specimen with GIS data for predicting the dipterocarps distributions. This approach helps scientists to reduce field work for constructing a prediction model.

ii. Policy Agenda

The results of this project will be beneficial to all researchers working in Borneo and the region, to resource managers, to policy makers, and to NGOs. Forestry instituions in the region urgently need scientifically sound inputs for planning and management of rapidly decreasing forest resources. We produced distribution maps and conservation gaps of dipterocarps and that are useful to the forestry institutions in the regions to review the existing forest policies.

iii. Institutional Agenda

The partners of this project are from institutions of Malaysia, Indonesia and The University of Tokyo, the top university in Japan. Under this project, partners were able to meet and conduct the necessary works together. The project has successfully strengthened the linkages between universities involved. In fact, a lecturer from Mulawarman University, East Kalimantan, recently enrolled to The University of Tokyo for PhD study.

Self evaluation

The primary goal of the project is to develop an integrated approach to predict dipterocarps, the most important timber family in Southeast Asia, for supporting conservation of the dipterocarps in Borneo. Given the number of species and size of the area involved, there have not been any studies that predicted the distribution of dipterocarps in Borneo. Despite of differences between Indonesian and Malaysia parts of Borneo, this has been generally achieved by the project team. The integration of herbarium database with GIS data has enabled prediction at species level for Sarawak and genus level for East Kalimantan. The current distribution maps of the dipterocarps can be instrumental in conservation planning of the tree family that is important to forestry as well as fighting against global warming. The project demonstrated the approaches and results at the seminar of the project to academics, government agencies and NGOs that deal with conservation. With the continued support from APN, this project aspires to bridge the gap in science-policy interface i.e. between scientists and policy makers. Scientists supply scientifically valid information to decision makers for policy adaptation.

Potential for further work

This project focused mainly on prediction of dipterocarps, which is the main timber species that store most of the above-ground biomass or carbon. An ideal REDD+ activity would be to conserve both carbon and biodiversity at the same time. Since it is possible to predict species, it presents an opportunity to look into producing these biodiversity and carbon information to decision making process in Malaysia, Indonesia or other countries.

Publications

Stephen Teo, Mui-How Phua. *in press*. Modeling the Natural Occurrence of Selected Dipterocarp Genera in Sarawak, Malaysia. *Journal of Forest Science*.

Kota Aoyagi, Satoshi Tsuyuki, Mui-How Phua, Stephen Teo. *in press*. Mapping of Distribution of Dipterocarpus in East Kalimantan, Indonesia. *Journal of Forest Science*.

Kamlisa Uni kamlun, Mia How Goh, Stephen Teo, Mui-How Phua. *in press*. Monitoring of Deforestation and Fragmentation in Sarawak, Malaysia between 1990 and 2009 using Landsat and SPOT Images. *Journal of Forest Science*.

Makoto Inoue. *in press*. Simple Prior Evaluation Method of National REDD-plus Programs for the Local Stakeholders. *Journal of Forest Science*.

Mustofa A. Sardjono. *in press*. Local Community Perspectives of Forest Policies Related to REDD+ in Indonesia. *Journal of Forest Science*.

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TECHNICAL REPORT

Preface

Lowland rain forest dominated by dipterocarps, the main timber species, has been rapidly disappearing in Borneo. Researchers of the Asia-Pacific region had developed an integrated approach that combines GIS, remote sensing and herbarium data for predicting the dipterocarps distribution at a landscape scale. Deforestation was analyzed against occurrence models of diterocarps and conservation gaps were identified. Perspectives of local people on REDD+ program and their acceptance were evaluated. Addressing the scientific information of the species distribution and social perspectives of REDD+ would no doubt fill the information gaps and assist in sustainable forest management and conservation of dipterocarps in Borneo.

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1.0 Introduction

Dipterocarpaceae is the dominant tree family in the rain forests of Southeast Asia and have its centre of diversity in Borneo. They are keystone species and at the same time economically important timber species of the rain forest. About 50 percent of dipterocarp species worldwide are found in Borneo, which also represents a significant proportion of endemic dipterocarps species (Ashton, 2004). Dipterocarps have been the subject of taxonomic and systematics studies (Ashton, 1982; 2004). However, information on the habitat loss and species distribution is rather meager. Borneo's lowland rain forest dominated by dipterocarps species has been subject to exploitations under different policy regimes leading to degradation and deforestation. Nevertheless, crucial information on the species distribution in both regimes are seriously lacking for sustainable management and conservation efforts.

This project aimed at producing significant impacts towards biodiversity conservation in Borneo, dipterocarps in particular. Conservation of dipterocarps is particularly important because it is the main commercial timber species besides being the keystone and dominant taxa as well as structurally the most important tree family in Borneo.

The main objectives of the project were:

a. To assess and predict the distribution of dipterocarp species distribution at a landscape scale in Borneo (Sarawak and East Kalimantan).
b. To quantify and examine the land cover changes between 1990 and recent year (around 2009) in the study area.
c. To identify conservation gap in relation to existing protected areas.
d. To evaluate REDD+ issues related to its implementation.

2.0 Methodology

2.1 Project's Approach

The project embarks on an integrated approach in deriving critical information on deforestation, distribution and conservation gaps on the major commercial timber species of dipterocarp in Borneo. Our study areas were Sarawak, Malaysia and East Kalimantan, Indonesia (Figure 1). To address such a vast land area, the most technically sound methodology is based on the use of satellite remote sensing and GIS coupling with herbarium data. Figure 2 shows the overall approach adopted in this project. Deforestation will be analyzed in the using supervised classification approach on multitemporal satellite data of sufficient resolution (e.g. Landsat and SPOT). The dipterocarps specimens from herbarium with georeferenced information and existing plant census data provide groundtruths on diversity and endemism of the dipterocarps. This is especially useful to the development of species occurrence model of dipterocarps using GIS data. The model output of the species occurrence will be ground checked and the conservation gaps will be identified with GIS based multicriteria assessment.

Figure 1. The study areas

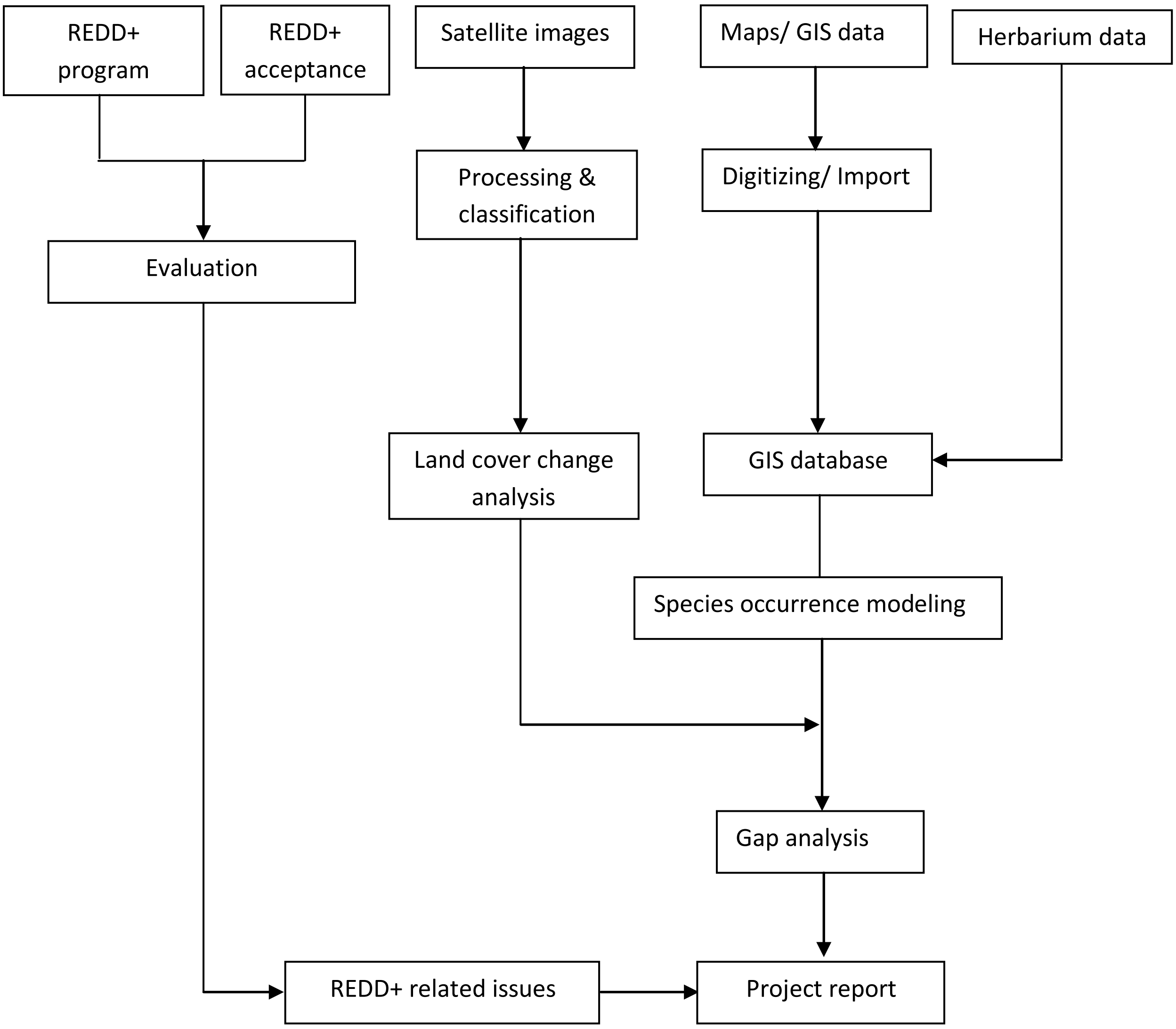


Figure 2. The project's approach

2.2 Land Cover Classification

Change detection approach, can be accomplised by either a post-classification comparison or spectral change detection (Lunetta, 1999). Spectral change detection analyzes changes in spectral value against certain threshold to detect the increase or decrease of certain land cover. The post-classification comparison is straightforward approach that compares land cover maps derived from multitemporal satellite images.

The postclassification comparison approach was used for both Sarawak and East Kalimantan for examining the land cover change in terms of deforestation over time. We used supervised classification because we had good knowledge about the land cover classes in the study areas. 5x5 majority filtering was applied to reduce the salt and pepper effect in the classified images.

As all the satellite images were acquired in the past and the area is large and inaccessible in many places, training data for classification had to depend on available data. Reference points for accuracy assessment were generated from historical land use maps and quick-looks of high-resolution satellite images in Google Earth that partially covered some parts of the study areas. Groundtruth points using GPS were also collected but limited to accessible roads.

For Sarawak, nine scenes of Landsat were needed to cover the whole state. For 1990, one Landsat5-TM image was downloaded for each scene area while three Landsat7-ETM+ images were acquired for the missing line correction. All the free Landsat data were georeferenced so the missing line correction that involve overlaying and mosaic the images of the same scene area can readily be carried out. Simple mosaic of three ETM+ images with priority of best image quality on top was adopted. Three scenes of SPOT 4-HRVIR taken in 2010 were also used to fill in the 2009 images that were heavily affected by clouds.

In the case of East Kalimantan, cloud was the major problem for investigating land cover changes and deforestation because the province is very large. Province of East Kalimantan occupies about 28% of Borneo. 16 scenes of satellite images were needed to cover the province. So, getting cloud or haze free image was not possible. In fact, frequent covers of cloud and haze prevented us to gather satellite images for 1990. We only managed to gather Landsat ETM+ images of 2000 and 2009 with different degrees of cloud and haze covers. Cloud and haze affected about 20% and 10% of the East Kalimantan area for years 2000 and 2009, respectively.

2.3 Modeling and Mapping of Dipterocaprs Distribution

2.3.1 Data

Sarawak

Species occurrence data for all dipterocarps were digitized from the Sarawak Forest Herbarium's collection. The herbarium has an extensive collection of Bornean dipterocarp specimens including most of the type of specimens. These data were complimented with pseudoabsence data obtained from botanical literature as well as local and field knowledge for all the dipterocarps. For Sarawak, comprehensive ecological information accounts for all dipterocarps in Borneo are found in the Tree Flora of Sabah and Sarawak (Ashton 2004).

Environmental variables used for the binary logistic regression included bioclimatic parameters including El Nino Southern Oscillation (ENSO), topography and edaphic or soil factors. Bioclimatic data (19 parameters from 1950-2000) were downloaded from www.worldclim.org and complimented by the rainfall map (mean annual rainfall) that was generated by means of interpolation using ordinary kriging in ArcGis 9.4 as it is comparatively more accurate and representative than other interpolation methods (Nour et al. 2006; Earls 2007; Ayanlade and Odekunle 2009). The impact of ENSO were obtained from the relative average annual difference in "Normalized Difference Vegetation Index (NDVI)" between months of a severe ENSO (07/1982-06/1983) and a non-ENSO (07/1981-06/82) and the NDVIs were downloaded from ftp://ftp.glcf.umiacs.umd.edu/glcf/GIMMS/Geographics/. Edaphic factor maps were obtained from the Harmonized World Soil Map (HWSD) from FAO/IIASA/ISRIC/ISSCAS/JRC (2009) while topography map were obtained from the Land and Survey Department, Sarawak. Only soil properties relevant to Sarawak were used in the study. All data used were resampled to 1 arc second (*ca.* 30 m) resolution.

East Kalimantan

Dipterocarpus data of East Kalimantan were collected from August 1, 2011 to September 17, 2011. *Dipterocarpus* specimen data was collected at Herbarium Wanariset, Balikpapan as well as Herbarium LIPI, Bogor. It was a manual work of browsing through all the collection of Dipterocarpaceae and record 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. Specimen at species level was too few thus species occurrence modeling was carried out for *diterocarpus* at genus level. There were 179 specimens of *dipterocarpus* were useful to species occurrence modeling.

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, botanist and lecturer of Universitas Mulawarman. Coordinate of each location was determined by averaging with a handheld Garmin receiver.

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 were some other typical environmental factors; only a few of them were available for whole East Kalimantan that is large in area. For the factor of elevation, we used Shuttle Radar Topography Mission (SRTM; DTED-1, NASA), which was sampled at 3-arcsecond (approx. 90m). SRTM data can be downloaded from USGS website (http://dds.cr.usgs.gov/srtm/). Subsequently, slope was calculated from the SRTM data in TNTmips software by Microimages. Soil type and Rainfall were obtained from Provincial Development and Planning Agency of East Kalimantan, Indonesia. 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.

2.3.2 Dipterocarps Distribution Modeling

Sarawak

We examine GIS-based approaches using the extensive herbarium database coupling with GIS data for modeling the distribution of dipterocarps in Sarawak. We compare the use of global and local modeling methods for modeling species of selected genera of dipterocarps in Sarawak. Since we had a reasonably large set of dipterocarps occurrence data from herbarium, we decided to test two modeling techniques i.e. logistic regression and inverse distance weighting (IDW) methods. The species occurrence data were divided into two halves: one half to construct the model and the other half to be used for validation or accuracy assessment as employed by von Wehrden et al. (2009) and Jantakat et al. (2010).

Statistical modeling especially logistic regression is often used to model the presence or absence of a species in relation to environmental or habitat variables. Based on the correlation test, only eleven environmental factors were used in logistic regression. For soil parameters, Availability of Water holding Capacity (subsoil texture-USDA), Drainage (topsoil sand composition, topsoil clay composition, topsoil organic carbon, subsoil organic carbon, toposoil CEC, topsoil clay CEC, Topsoil TEB, topsoil texture-USDA), topsoil C:N ratio (topsoil % Nitrogen content and topsoil pH) and Base Saturation were used. On top of that, altitude, gradient of slope and El Nino Southern Oscillation (ENSO) factors were also added. The species occurrence point data were overlaid with the environmental factors to obtain the various environmental data for each dipterocarp species. The data of eleven environmental factors were analyzed with binomial logistic regression in SPSS for possible species occurrence models (SOMs) of the species. The resulted SOMs were implemented in ArcGIS for producing the occurrence probability maps for the species.

For the IDW method, the georeferenced species occurrence data were directly interpolated to construct the species occurrence map for each of the species. IDW is a method of interpolation whereby the value of the unknown point is a weighted sum of the values of N known points. All the species occurrence maps resulted were reclassified into three classes using mean and standard deviation: absence (0 to mean – 1 standard deviation) and presence (mean + 1 standard deviation to 1). The prediction accuracies of the models were assessed using the other half of species occurrence data.

East Kalimantan

Because of limited herbarium specimen for dipterocarps in East Kalimantan, we can only focused on modeling the distribution of dipterocarpus. We carried out logistic regression analysis with the presence and pseudo-absence data to estimate the probability of occurrence of *dipterocarpus*. 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 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 or natural occurrence 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 current distribution of *dipterocarpus* by overlaying an updated forest cover map and habitat suitability class map.

2.4 Conservation Gap Analysis

Conservation gap analysis was carried out only for Sarawak because it necessitates the availability of SOMs of all dipterocarps. Lacking of herbarium specimen in East Kalimantan had resulted species occurrence modeling for only one genus i.e. dipterocarpus.

Species occurrence models were generated for all 247 species of dipterocarps in Sarawak. SOMs of species belonging to the respective category [Non-endemic species, endemic (Borneo), Endemic (Sarawak) and each species belonging to the nine genus] were overlaid in ARCGIS 9.0. The resulting species occurrence density maps were then reclassified into 4 equal-interval classes in percent for each category, i.e. (0-25%, 26-50%, 51-75% and 76-100%). Hotspots of diversity and endemism were then identified from the density maps.

Overall species occurrence density map for all species was generated by overlaying the SOMs of all dipterocarp species. Similarly, overlay of SOMs of all endemic dipterocarp species generated the occurrence density map of endemic species. The species occurrence density maps were analyzed with forest cover from the land cover map of 2009 and protected area map for identifying conservation gaps in Sarawak.

2.5 Evaluation of REDD+ Programs and Acceptance of Local People

Relevant laws and regulations issued by the government of Indonesia and local ordinances issued by West Kutai district were collected and described, with special attention to their purposes and implementing agencies. Then the programs were evaluated from the viewpoint of expectations for achieving 'triple-benefit' which is relevant to 'effectiveness' and 'equity' of the governance, and 'feasibility' when the programs would be practiced on the ground. Evaluation was done as a result of discussion on December 6, 2010 at Center for Social Forestry (CSF), Mulawarman University. Participants of the discussion for evaluation are Dr. Fadjar Pambudhi, or a Director of CSF, Dr. Ndan Imang, or a vice Director of CSF, and Mr. Martinus Nanang, a staff of CSF, who know very well the real situation in West Kutai District of East Kalimantan.

The 'triple-benefit' comprises (1) emission reduction from mitigating deforestation and forest degradation, which is the main purpose of the REDD-plus mechanism, (2) biodiversity conservation, which is accordant to the Convention on Biodiversity, and (3) poverty alleviation, which is in accordance with United Nations Millennium Development Goals. It makes sense for the government to achieve the "triple-benefit" to abide by international agreements. Evaluation results were assigned numerical scores for the expected achievement of the "triple-benefit": "+2" for a strong positive effect on each aspect, "+1" for a weak positive effect, "-1" for a weak negative effect, and "-2" for a strong negative effect.

In addition, contingent valuation method was used to elicit willingness to accept (WTA) as value and acceptance of the local people on REDD+ against their existing livelihood activities. This study was only implemented at Sarawak. We carried out questionnaire survey at seven long house villages, included Nanga Ukom Ulu, Menggilir A, Menggilir B, Ng Tutong, Belok, Mengkak and Spanga in December 2009 and July 2010 (Figure 2). The respondents were selected through convenient sampling method. As the longhouse villages can only be reached by boat and relatively far between one and another, we had to interview any adult representative of the households who were present during the visit. The questionnaire consisted of three sections: 1) socio-economic characteristics, 2) forest dependency of the local people, and 3) WTA of REDD+ and preferred form of compensation. We used the open-ended approach for identifying the range of WTA values before estimating the central tendency in their value expressions. Respondents were asked to state the maximum monthly compensation for them to forgo the right of conducting their traditional cultivation and forest use. As for form of compensation, they were asked to choose between cash, agroforestry and rubber plantation. We analysed the WTA against the income, cost of living and other factors of the local people.

3.0 Results and Discussion

3.1 Land Cover Change and Deforestation

Sarawak

The overall accuracy of land cover classification of 1990 was 86% and only slightly lower at 80% for the land cover classification of 2009. We also calculated the more robust kappa accuracy for each of the land cover classifications. The land cover classification of 1990 remained high at 0.84 while the kappa accuracy for the land cover classification 2009 was lower at 0.75. The missing line errors in Landsat7-ETM data was likely the cause of lower accuracy in the land cover classification of 2009.

The intact forest, with more than 6 million ha, was the largest land cover type in 1990 (Figure 3). Even though in 2009 the intact forest is still the largest land cover type but it had shrunken more than 550,000 ha. Most of the deforestation of intact forest occurred in the inland areas (Figure 4). The intact forest was cleared mainly for agricultural development. The forests of Sarawak have been pressured for large-scale expansion of oil palm development by agricultural sectors (Tsuyuki et al. 2011). The oil palm plantation is the fastest growing agriculture sector in Sarawak. About 70% oil palm plantation increases annually from 1990 to 2008 (MPOB 2009). Our results indicate an annual increment of 77.4% for oil palm plantation. The state government targeted that since 2007 to have about 1 million ha of oil palm plantation in 2010 (MPOB 2007). The land cover classification of 2009 also showed that there were about 1 million ha of oil palm plantation (Figure 4). These recent oil palm plantations mainly took place in the peat swamp forest at coastal divisions of Sibu, Mukah, Bintulu and Miri were classified as bareland in the land cover classification of 2009 (Figure 4).

Sarawak had a deforestation rate of more than 0.6% per year between 1990 and 2009. The rate seemed very low compared to the average deforestation rate of Borneo, which was 1.7% per annum between 2002 and 2005, reported in Langner et al. (2007). However, the Borneo's rate was computed from a much shorter and recent time compared to our rate. IF we were to calculate the rate in the last few years, the deforestation rate could be much higher because of large-scale conversion of peat swamp forest to oil palm plantation. In addition, the Borneo's rate was derived from relatively coarse resolution satellite data (MODIS) that over-estimation may be inevitable. On the other hand,

Peat swamp forest in Sarawak is probably the forest that has been deforested at an unprecedented rate. According to Wong (1991), there was about 1.6 million ha of peat swamp forest in Sarawak in 1980. Our land cover classification results indicated that only about 1 million ha of the peat swamp forest was found in 1990 and almost half a million ha was further cleared in the last two decades. This means the annual deforestation rate of peat swamp forest between 1990 and 2009 was 2.6%. Sarawak's peat swamp forest was depleting faster than the average rate of Borneo, which was 2.2% per year, reported by Langner et al. (2007). Agricultural plantation establishment that drain out water from the peat could result in irreversible impacts to the hydrological system of peat swamp forest. Oil palm planters favor peatland for planting oil palm because the fruit's production is high (Phillips 1998). In addition, planting oil palm on a flat plain is also relatively easy to manage and harvest.

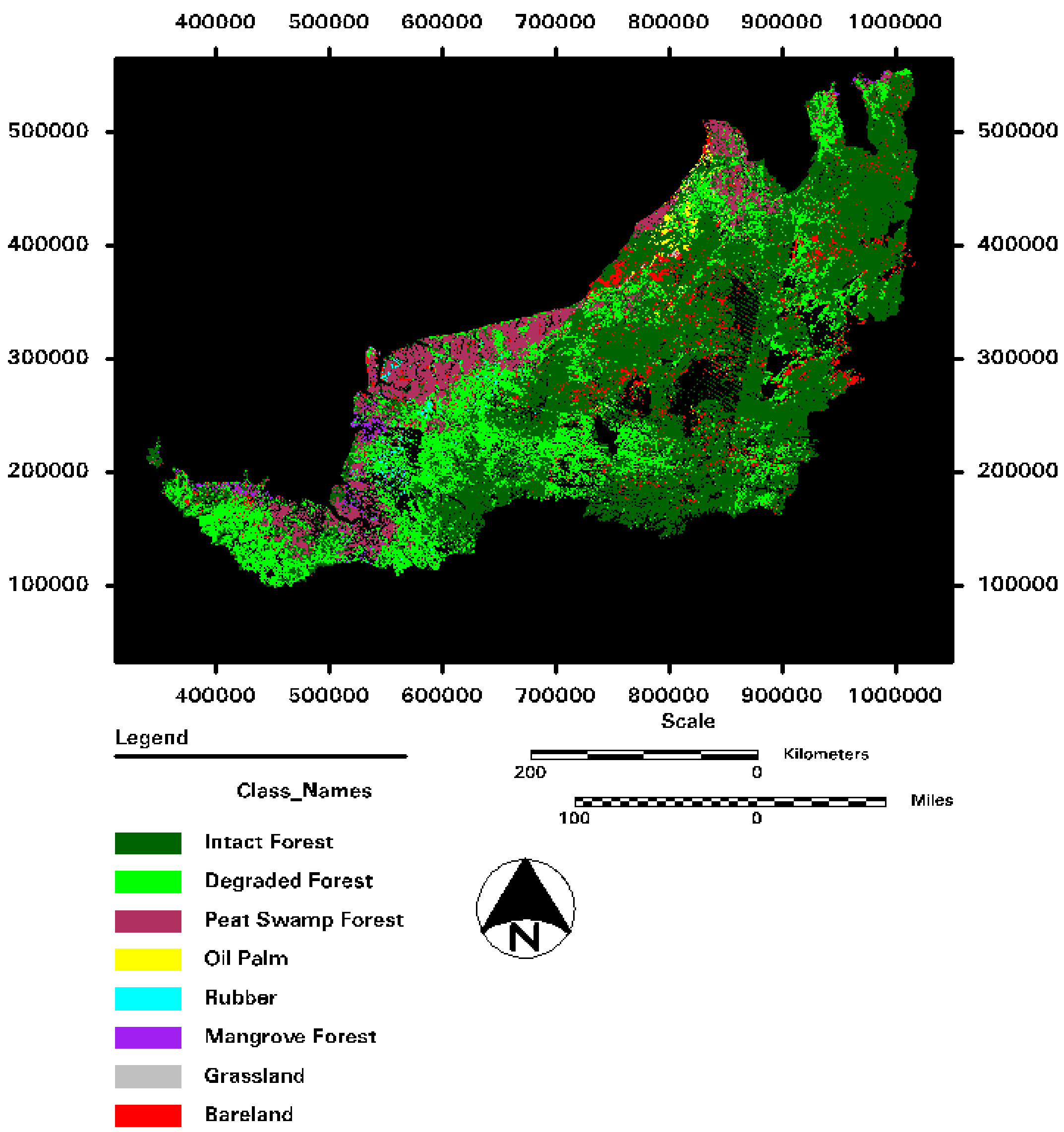


Figure 3. Land cover classification of Sarawak (1990)

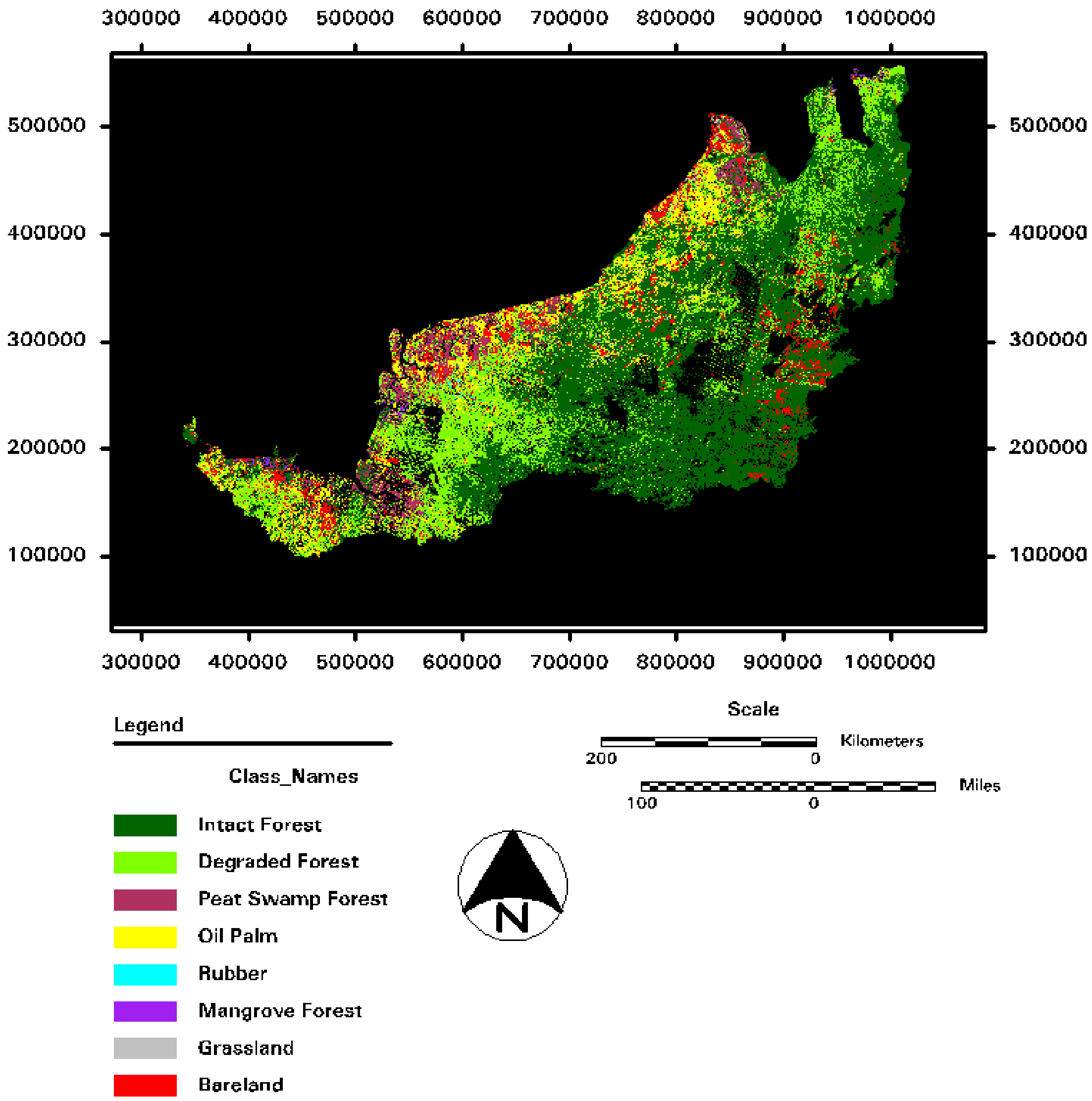


Figure 4. Land cover classification of Sarawak (2009)

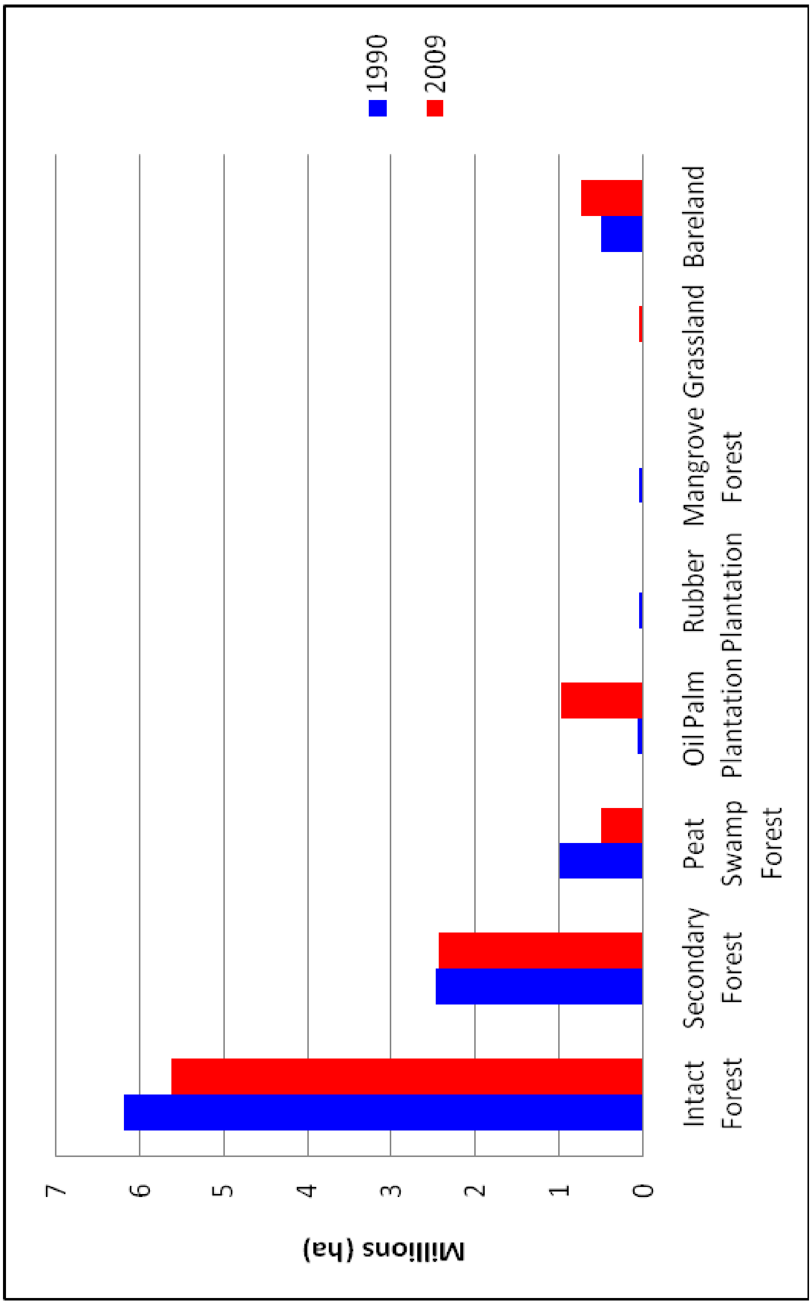


Figure 5. Land cover change in Sarawak between 1990 and 2009

East Kalimantan

The satellite images covering East Kalimantan were analyzed for land cover change and deforestation using the post-classification comparison approach. The land cover classification was conducted using supervised classification approach with maximum likelihood algorithm. However, the accuracies of the land cover classifications were not satisfactory. Overall accuracy of land cover classification of 2000 ranged between 51% and 86%, with an average of 66% (Table 1). The average overall accuracy for land cover classification of 2009 was much lower, at 59%. Half of the images had accuracies lower than the average overall accuracy for both years of 2000 and 2009. Many satellite images were adversely affected by cloud and haze. As a result, the maximum likelihood classifier wrongly classified many pixels in these images. To avoid producing unreliable results, we did not proceed with land cover change analysis for East Kalimantan.

Table 1. Accuracy Assessment for the land cover classification

PATH/ROW	Overall accuracy (%)	
	2000	2009
115/59	75.00	62.35
116/58	70.41	58.49
116/59	59.70	62.71
116/60	58.45	70.70
116/61	51.35	64.41
116/62	62.96	47.06
117/57	62.50	58.90
117/58	64.71	81.61
117/59	82.98	54.41
117/60	63.89	68.63
117/61	86.00	74.51
117/62	66.67	52.94
118/57	61.13	56.40
118/58	65.15	60.42
118/59	68.57	54.05
118/60	61.11	20.56
Average	66.29	59.26

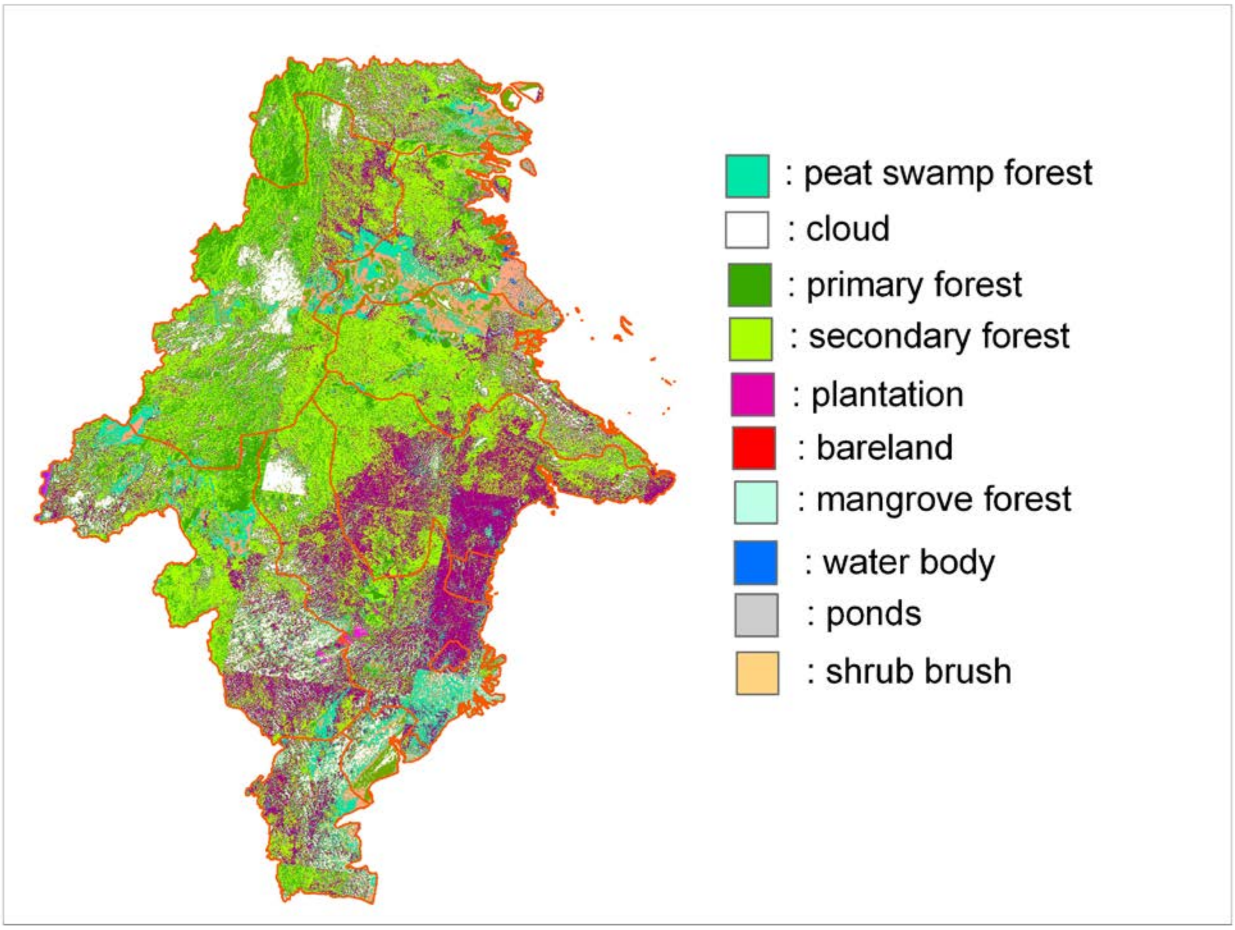


Figure 6. Land cover classification of East Kalimantan (2000)

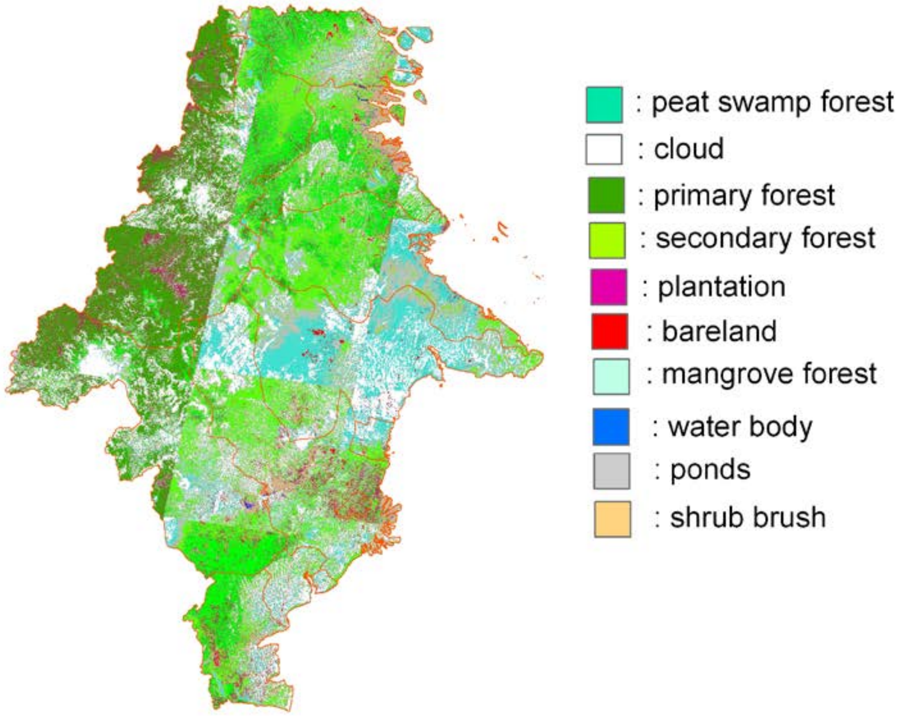


Figure 7. Land cover classification of East Kalimantan (2009)

3.2 Modeling the Distribution of Dipterocarps

Sarawak

Firstly, the IDW was compared against logistic regression for modeling of species occurrence. The species occurrence model from IDW displayed a reasonable distributional range for each of the dipterocarp species. For instance, the peat swamp species of *Dryobalanops rappa* Becc. (Figure 9) and *Anisoptera marginata* Korth (Figure 11) were generally found in coastal peat swamp areas and absent from the inland mountainous areas along the Sarawak-Kalimantan border. Similarly, non-peat swamp species such as *Dryobalanops aromatica* Gaertn.*f.* (Figure 8), were not predicted at peat swamp area, particularly in the coastal area. However, it should be noted that sometimes non-peat swamp species range can extend to the coastal areas as there are isolated hills in the coastal areas among the peat swamp. *Upuna borneensis* Symington which is found mainly in the coastal areas as well as inland area of Sarawak but absent from peat swamp area (Figure 10) were correctly portrayed in the species occurrence model.

Validation using the second set of data shows very satisfactory level of overall accuracy for all species predicted with the IDW method. The average overall accuracy was about 85% (Table 2). In contrast, the performance of logistic regression was not satisfactory. Average accuracy for Binary Logistic Regression methods was not calculated because some species had no solutions. In addition, the species occurrence models from the IDW method were also more consistent (less variation in accuracy) among the species as compared with the logistic regression method (Table 2).

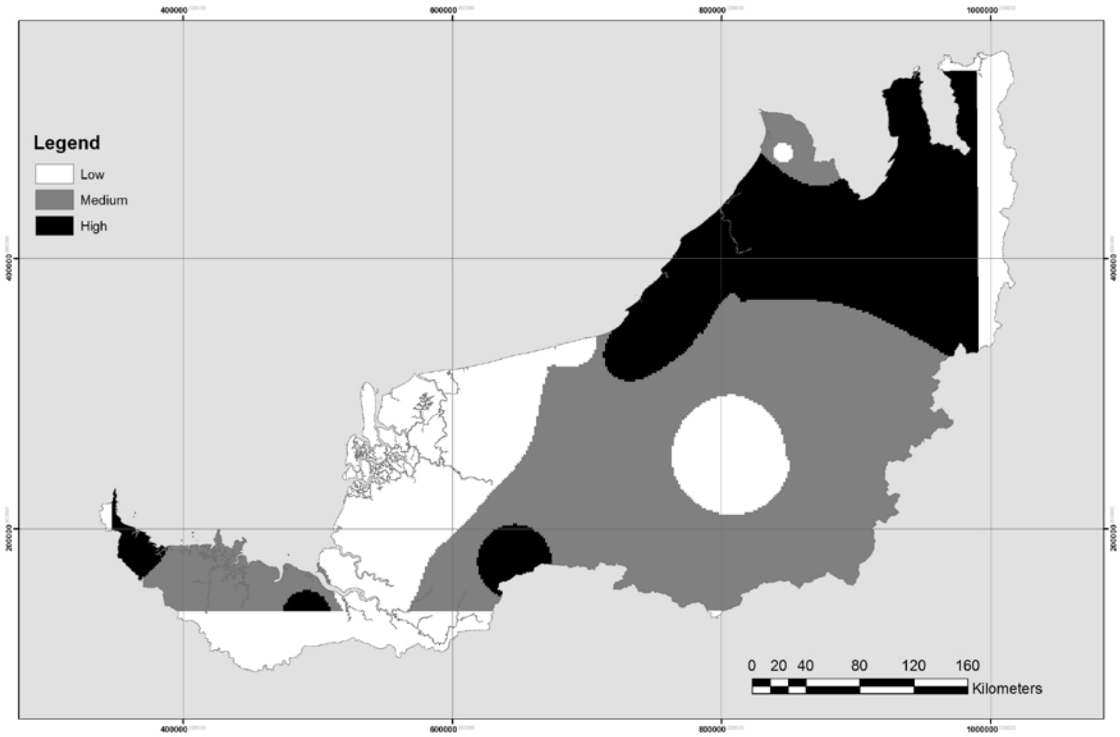


Figure 8. Dryobalanops aromatica Gaertn. f. distribution model using IDW method.

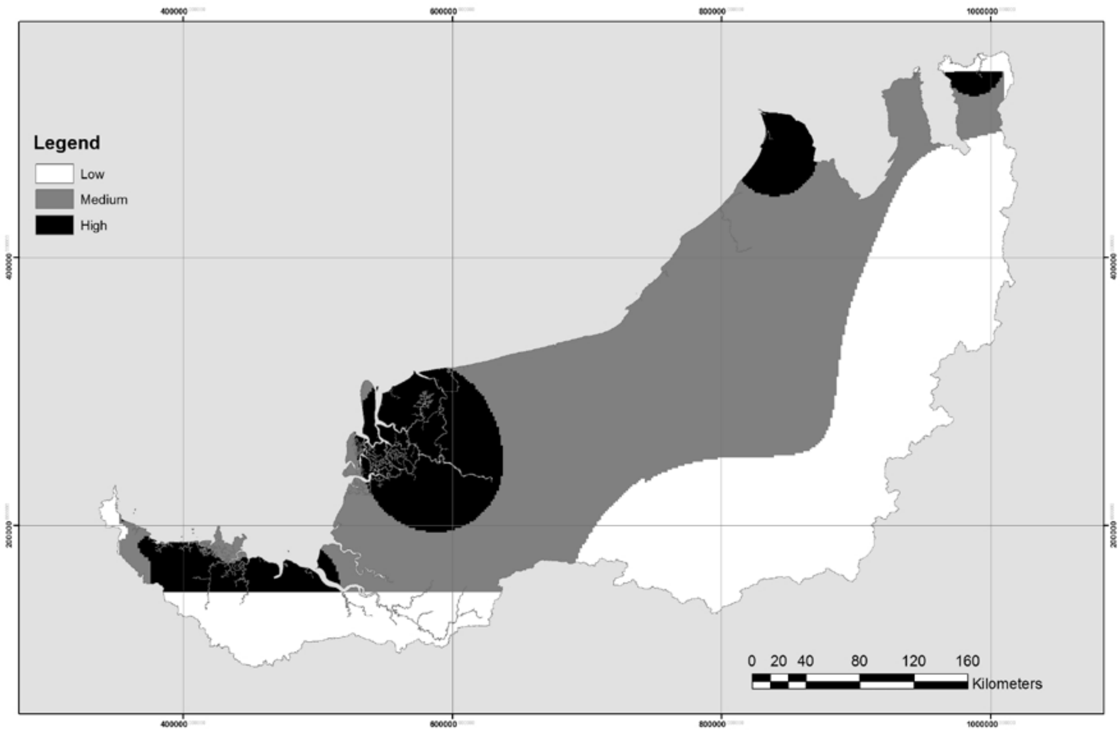


Figure 9. Dryobalanops rappa Becc. distribution model using IDW method.

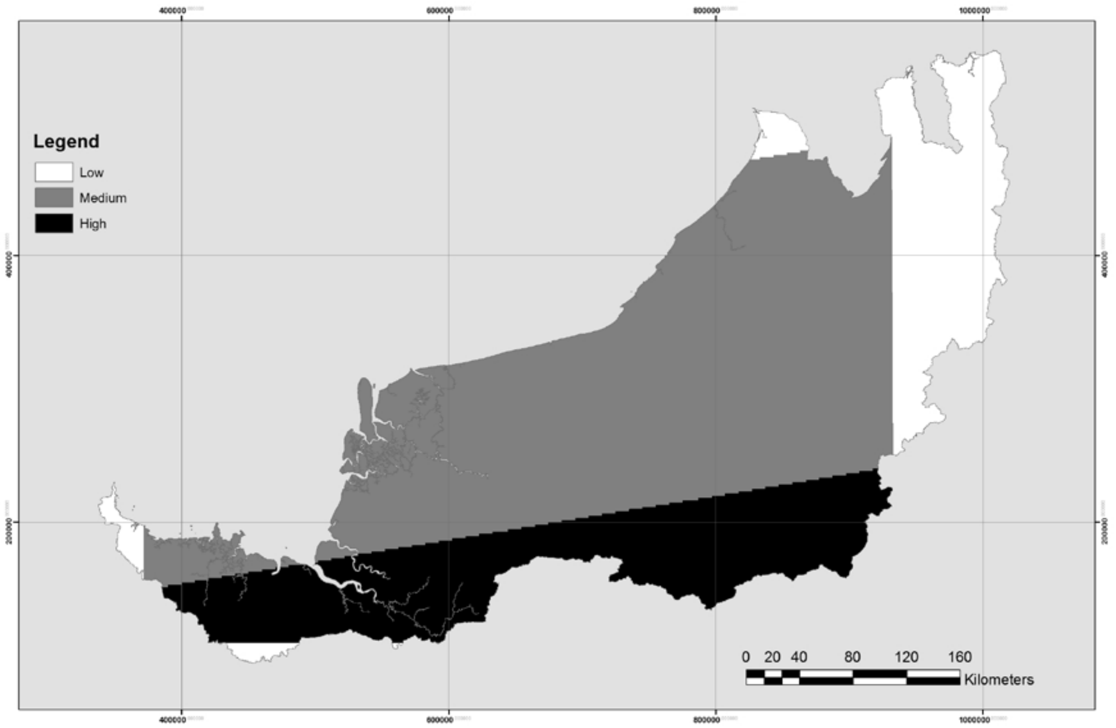


Figure 10**.** Upuna borneensis Symington distribution model using IDW method.

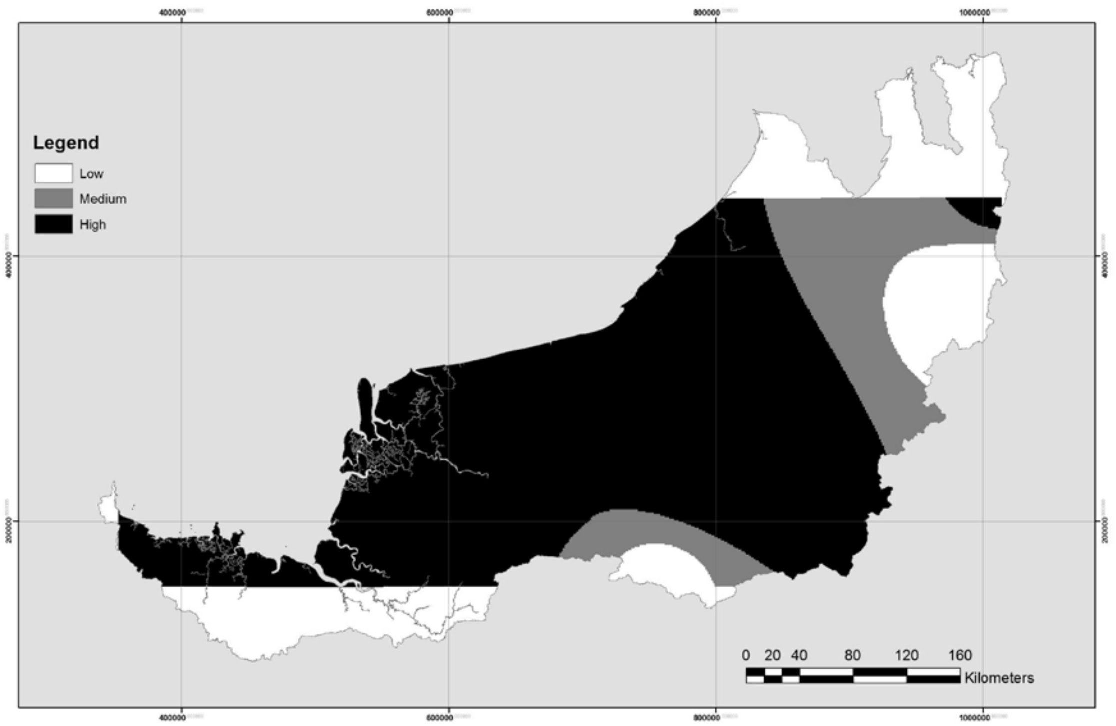


Figure 11**.** Species occurrence model for peat swamp species *Anisoptera marginata* Korth using IDW.

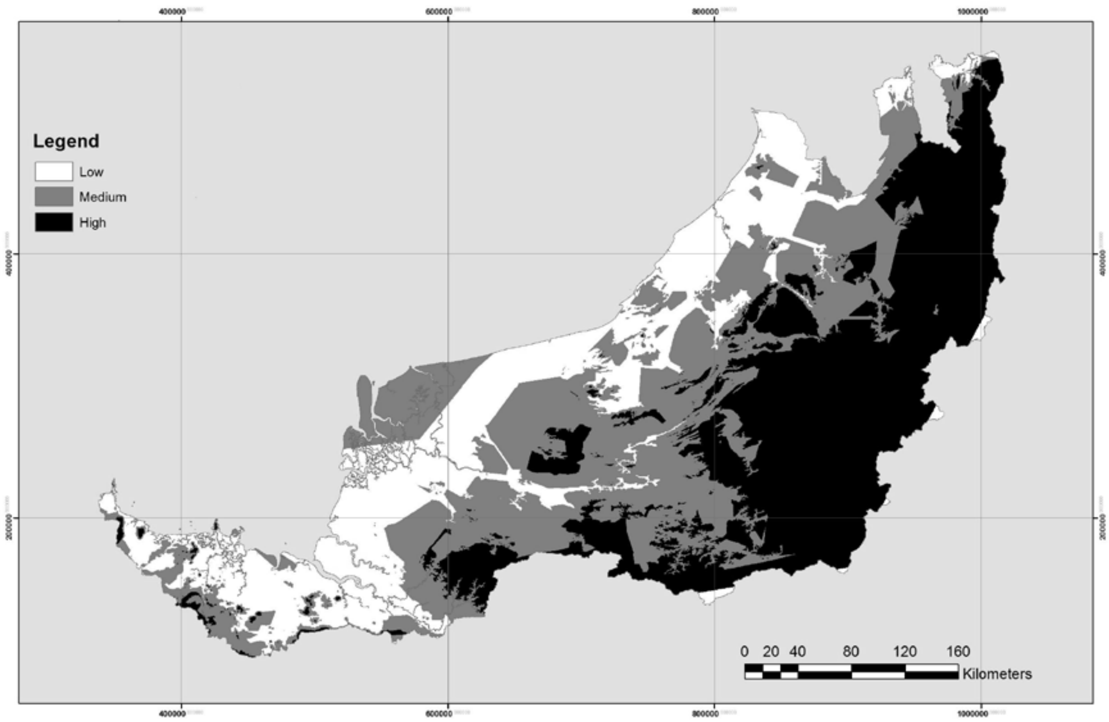


Figure 12. Species occurrence model for peat swamp species *Anisoptera marginata* Korth using binary logistic regression.

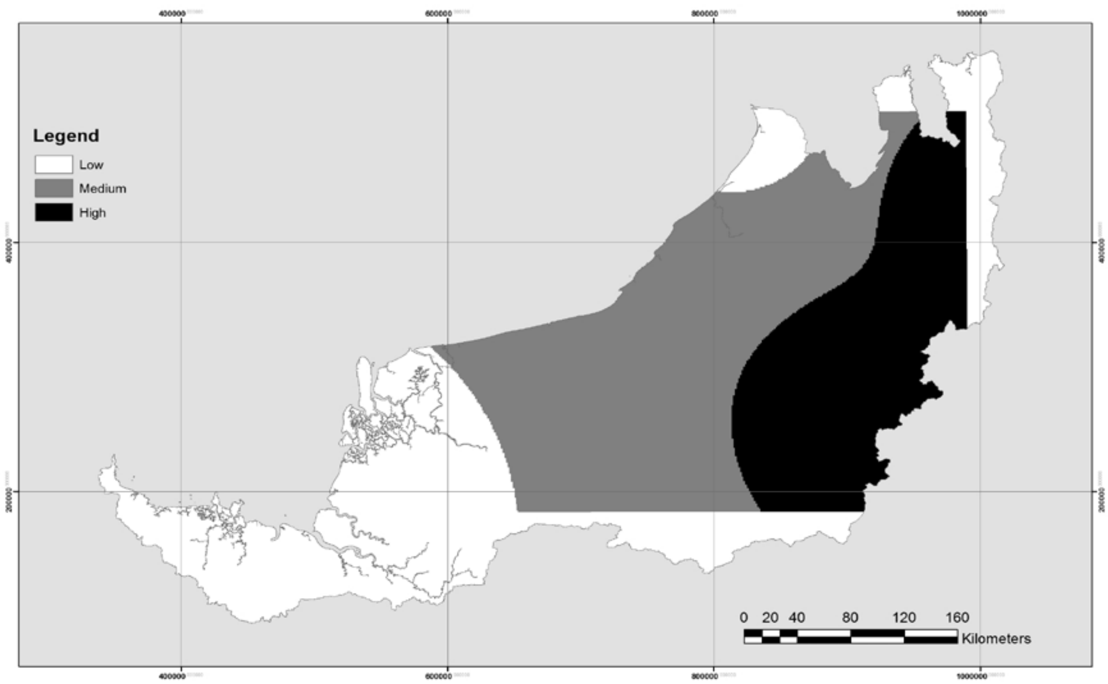


Figure 13. Species occurrence Model for *Anisoptera reticulata* P.S. Ashton using IDW. No solution for binary logistic regression.

Table 2. Accuracy comparison between the logistic regression and IDW methods.

	Binary Logistic Regression		IDW	
	Correct (%)	Incorrect (%)	Correct (%)	Incorrect (%)
Anisoptera costata korth.	0%	100%	100%	0%
Anisoptera grossinervia Slooten	n.a.	n.a.	73.3%	26.7%
Anisoptera laevis Ridl.	n.a.	n.a.	83.3%	16.7%
Anisoptera marginata korth.	29.4%	70.6%	69.2%	30.8%
Anisoptera reticulate P.S. Ashton	n.a.	n.a.	60%	40%
Dryobalanops aromatica Gaertn.f.	n.a.	n.a.	61.1%	38.9%
Dryobalanops beccariana Dyer	0%	100%	61%	39%
Dryobalanops fusca Slooten	0%	100%	83.3%	26.7%
Dryobalanops lanceolata Burck	0%	100%	85%	15%
Dryobalanops oblongifolia Dyer	0%	100%	92.9%	7.2%
Dryobalanops rappa Becc.	n.a.	n.a.	92.8%	7.2%
Upuna borneensis Symington	42.8%	57.2%	84.6%	15.4%
Average	-	-	78.9%	21.1%

East Kalimantan

The occurrence data of dipterocarpus were analyzed against the environmental factors using logistic regression method. Table 3 shows the result of logistic regression analysis. *P*-value indicates significance of each variable in the logistic regression model. 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.

Table 3. Summary of logistic regression analysis

Independent Variable	Coefficient	*p*-Value	*Sig.*
Elevation	-1.92	7.0×10^{-4}	**
Slope	-8.78×10^{-1}	4.2×10^{-1}	
Soil type	4.95	3.2×10^{-6}	**
Rainfall	5.60	3.5×10^{-3}	**

We thus decided to estimate the occurrence probability of *dipterocarpus* (P_i) with all the variables as follows,

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

where,

x_{elv}: elevation

x_{slp}: slope

x_s: soil type

x_{rf}: rainfall

Habitat suitability or occurrence map of *dipterocarpus* was generated by assigning the coefficient values on the environmental factors. Figure 14 shows the occurrence probability of *dipterocarpus* obtained by applying the logistic model. 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 (n=179), *dipterocarpus* was found in wet area but less than 3500mm. The western part of East Kalimantan (dark brown in Figure 14) was the wettest area. Dipterocarps are usually 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 (Figure 14).

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*. As the reason why slope was only marginally important in the logistic model, a possible explanation is because of the smoothing effect of resampling of the SRTM elevation data from 90m to 1.8 km. Slope calculated from the resampled elevation data may not be the nearest representation of the actual slope of the land surface.

The habitat suitability or occurrence map only depicted the natural habitat of *dipterocarpus*. By overlaying the habitat suitability classes and current forest cover area, we obtained the distribution of *dipterocarpus* (Figure 15). 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*. We used the land cover map produced by the Ministry of Forestry of Indonesia because the land cover classification of 2009 was badly affected by clouds and haze. 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 coastal area of East Kalimantan. Although the number of ground truth points was limited, all points with *dipterocarpus* occurrence were located in the highly suitable area (Figure 15).

Table 4 shows the cross-tabulation between habitat suitability class and forest/non-forest classes. The forest area 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 4 also shows that almost 20,000 km^2 of non-forest area 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.

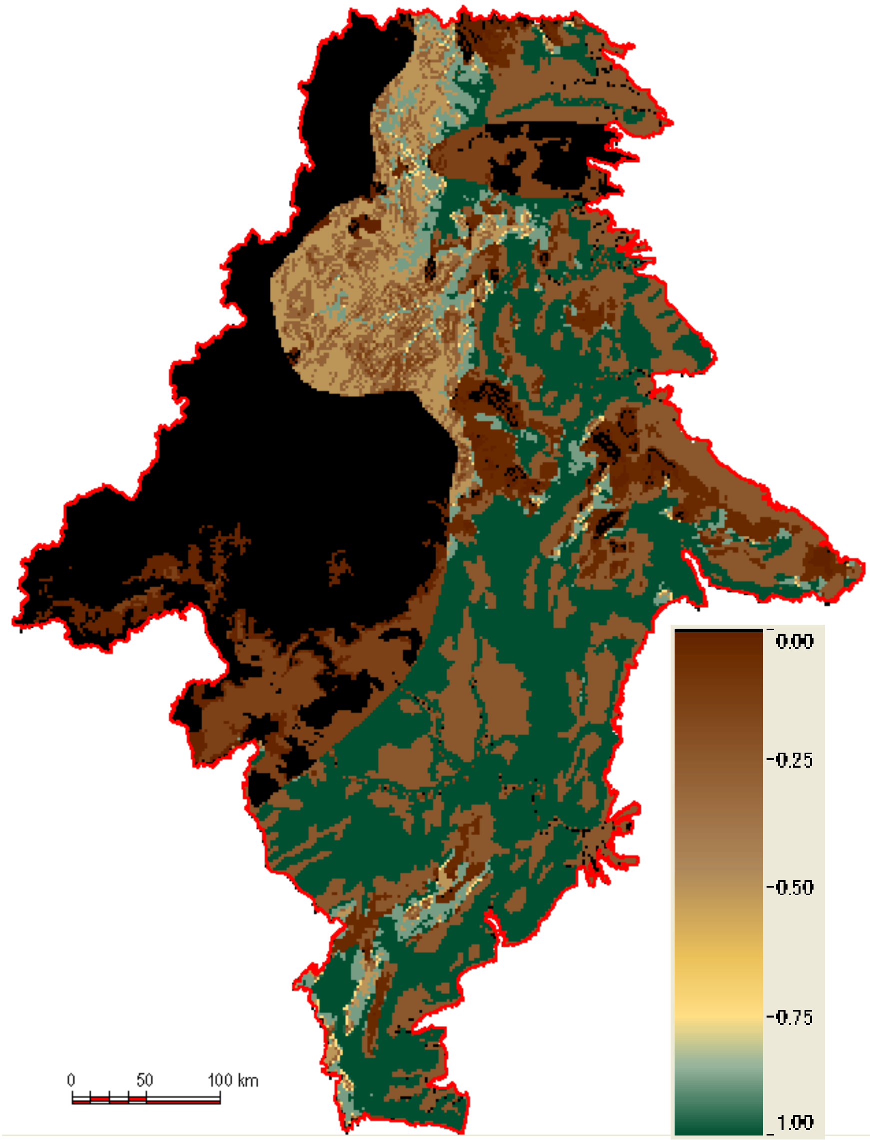


Figure 14. Habitat suitability or occurrence model of *dipterocarpus*

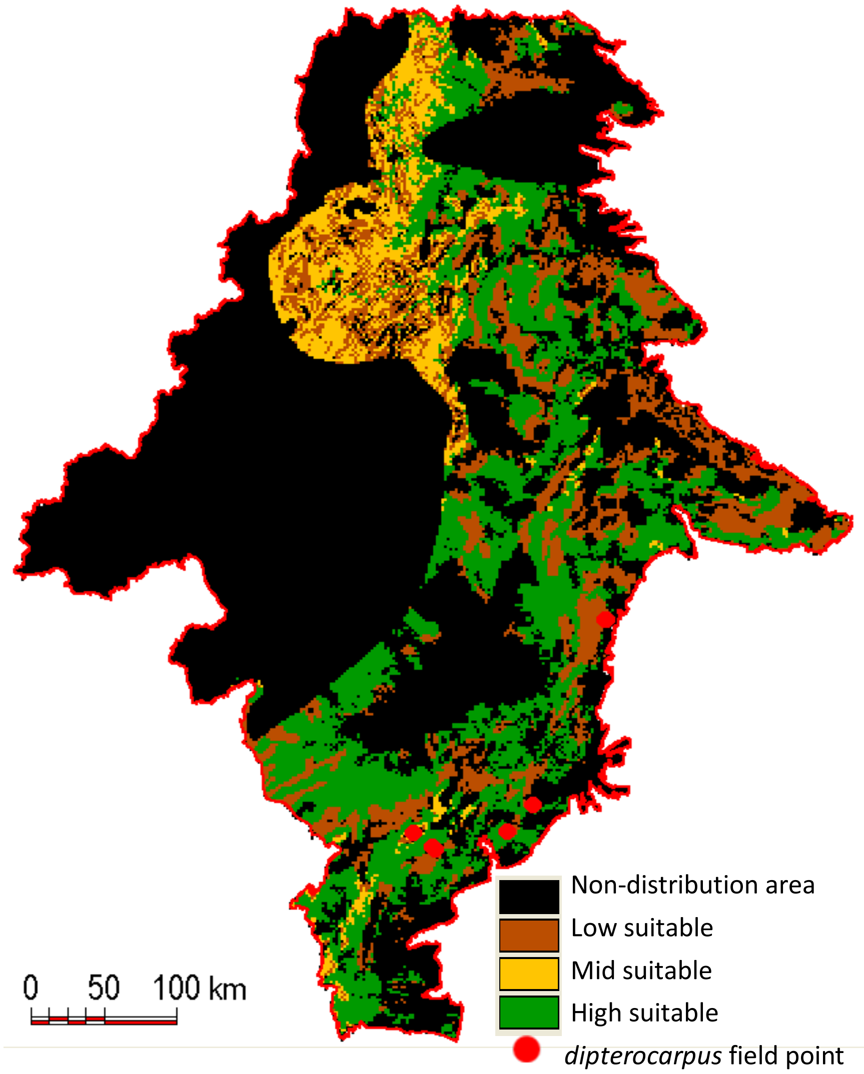


Figure 15. Distribution of *dipterocarpus* based on habitat suitability class and current forest cover

Table 4. Habitat suitability class by forest and non-forest areas

Suitability class	Non-forest Area (km^2)	Forest area (km^2)
Unsuitable	7,944.3	76,621.3
Low suitable	15,342.1	26,463.9
Mid suitable	164.0	11,068.4
High suitable	18,566.0	39,219.4
Total	42,016.4	153,373.0

Conservation gap analysis of dipterocaprs was not conducted for East Kalimantan because only the distribution of genus of *dipterocarpus* was predicted.

3.3 Conservation Gap of Dipterocarps in Sarawak

3.3.1 Overall

Overall, only a mere 2% of the area with high diversity (those with species density >75 % of the total dipterocarp species) are inside the protected areas while the majority (98 %) are outside the protected areas with only 29% that are still with primary forest (Table 5 & Figure 16).

Table 5. Area size (sq km) under the different land categories for the respective percentage of total species class.

SOM Density class	Area inside protected areas (km^2)	Area outside protected areas (km^2)	Area outside protected areas with primary forest (km^2)
0 – 25%	331	7048	41901
26 – 50%	1433	28465	9788
51 – 75%	1357	39106	13614
76-100%	1767	43763	18052

Note: SOM: species occurrence model

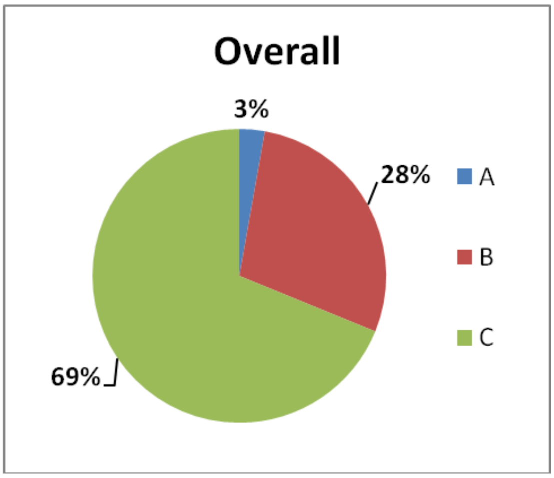
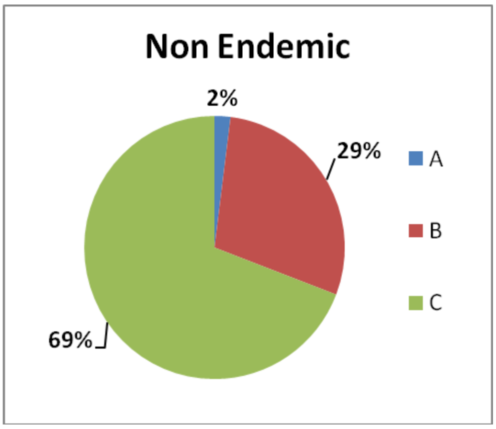


Figure 16. Percentage of hotspot area (>75% species density)

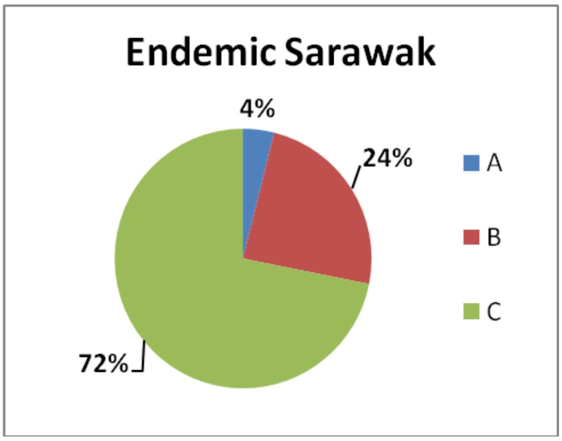
Note: Inside protected area (A), area outside protected area with primary forest cover (B) and area outside protected area without primary forest cover (C).

3.3.2. Endemic/non-endemic

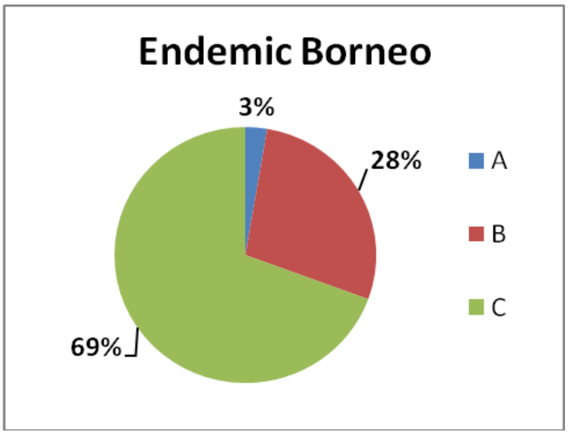
For Borneo's and Sarawak's endemic dipterocarp species, only about 3 % and 4% of the total area of Sarawak (with species density >75% of the total endemic species) are inside protected areas respectively. For area outside the protected areas, about 69 % and 72 % are still with intact natural forest for area of high species density (>75%) for Borneo's and Sarawak's endemic respectively (Figure 17).



(a)



(b)



(c)

Figure 17. Percentage of hotspot area (>75% of the total species) for (a) Non Endemic , (b) Endemic Sarawak and (c) Endemic Borneo

Note: Inside protected area (A), area outside protected area with primary forest cover (B) and area outside protected area without primary forest cover (C).

3.4 REDD+ Related Questionnaire Studies

3.4.1 Evaluation of REDD+ Related Programs

Table 6 indicates the results of our evaluation of activities supported by national programs.

Most activities are considered to have strong or weak positive effects (scores: +1, or +2) on emission reduction, biodiversity conservation, and poverty alleviation.

- Plantation forest management for timber utilization by private companies, however, would have a weak negative effect (score: -1) on biodiversity conservation due to large-scale monoculture, and a weak negative effect (score: -1) on poverty alleviation due to the tendency to expropriate land cultivated by local people.
- Feasibility of protection forest management on the ground is considered to be low (score: +1) because of conflicts with local people.
- Restored forest ecosystem management for timber utilization and management of Individual forest on privately owned lands are also regarded as having low feasibility (score: +1) because we could not find any examples in East Kalimantan at the time.

The evaluation indicated promising selected activities for each stakeholder, if supported by national policy, in terms of achieving 'triple-benefit' as well as feasibility on the ground. Even though we saw various types of customary forest management in West Kutai district, we were unable to find instances of formal Customary Forest (*Hutan Adat*) management supported by the government, because a minister's decree has not yet been issued to guide the formalities for approval. It is, then, evident that promising selected activities in West Kutai district, the Province of East Kalimantan are;

- Management of forests for specific purposes such as research and education is promising for the government.
- Natural Forest Management for timber utilization is advisable for private companies (sponsors and project initiators).
- Plantation forest management by villagers' groups (*Hutan Tanaman Rakyat: HTR*) for timber utilization, management of Village Forests (*Hutan Desa*) by village organizations, and management of Community Forests (*Hutan Kemasyarakatan*) by groups of local people are preferable for local communities.

3.4.2 Evaluation of Acceptance of REDD+ of Local People

Approximately 90% of respondents were farmers who practised shifting cultivation, hunting, fishing and gathering forest products for their livelihoods. Their main agricultural crops were hill paddy, vegetables, fruits and pepper. The period of cultivation varied between six months and more than three years, depending on soil fertility. Once soil is no longer fertile, they will shift to another location. Due to recent encouraging rubber price, some returned to rubber tapping, which had earlier been temporarily abandoned. Approximately 87% of the local people still rely on forest products for their daily life for a variety of uses such as firewood, food (wild fruits, vegetables and meat), building materials for house and boat, and herbs for medicines. In sum, the longhouse dwellers have a strong dependence on forest products for their subsistence needs.

Table 6. Evaluation of activities supported by national programs

Stake-holder	Rights/ programs	Evaluation in terms of 'triple-benefit'				Evaluation of 'feasibility' (Y)	Score
		Emission reduction	Biodiversity conservation	Poverty Alleviation	Total (X)		(XxY)
Gov.	FM for specific purposes	+2	+2	+1	+5	+2	+10
	Protection FM	+2	+2	+1	+5	+1 *	+5
Sponsor/ initiator	Natural FM	+2	+2	+1	+5	+2	+10
	Plantation FM	+1	- 1 *	- 1 *	- 1	+3	- 3
	Restored F ecosystem M	+2	+2	+1	+5	+1 *	+5
	Activities as FM Unit	Impossible to evaluate because of not being formed					
Local Com.	M of Individual Forest	+2	+2	+2	+6	+1 *	+6
	M of Customary Forest	+2	+2	+1	+5	+2	+10
	Plantation FM by people	+1	+1	+2	+4	+3	+12
	M of Community Forest	+2	+2	+1	+5	+2	+10
	M of Village Forest	+2	+2	+2	+6	+2	+12

Note: FM Forest Management; M: Management

Majority of the local people of Batang Ai area showed their readiness to accept the REDD+ mechanism. The majority (86.1%) of the respondents were willing to accept the REDD+ provided there is some form of compensation. The remaining local people declined to accept because they did not want to leave their ancestral lands. The three most preferred compensation scheme by the local people was the rubber scheme (69%), followed by rubber/others scheme (10%) and rubber/agroforestry scheme (8%). The high price of rubber in recent years may explain the dominant preference of the local people.

The annual mean of WTA of the local people was RM 463.2 per month while the median WTA was at RM 400.00 per month. The highest WTA of the local people was RM 2,000 and the lowest was merely RM 65. The annual mean WTA of the local people was US$1790.4 9 per year per household. Van Beukering et al. (2009) revealed that the annual mean of WTA of local people in Cambodia was US$656 while Hanley *et al*. (2010) estimated the annual mean of WTA for the case of Uganda at US$417. The annual mean of WTA elicited in the Batang Ai area was at least 2.5 times and 4 times higher than the annual means of WTA for Cambodia and Uganda, respectively. This disparity may be attributed to the differences in living standard between these countries. Gross National Income (GNI) per capita for Malaysia, Cambodia and Uganda are US$13,530, US$1,850 and US$1,190 respectively (World Bank, 2010). Similarly, the annual mean of WTA of Malaysia was the highest, followed by Cambodia and Uganda.

Among the five socioeconomic variables tested, only compensation type was not significantly correlated with the WTA (Table 7). There was a relatively strong, positive correlation between WTA and household expenses, which was statistically significant (r_s = 0.49, P = .000). The correlation strength of household expenses was much stronger than the household income which could be due to difficulty of the respondents in assessing the income from forest produce collection. In contrast, household expenses were a more accurate measure of the household financial stance because it represented cash payment in exchange of manufactured goods and services. These variables imply the local people who either earned or spent more tend to expect higher compensation from REDD's implementation.

Table 7. Correlations between the WTA and socioeconomic variables

		WTA	Age	Compensation Type	Cultivation period	Income	Expenses
WTA	Correlation Coefficient	1.000	.271**	.181	.299**	.337**	.490**
	Sig. (2-tailed)	.	.007	.073	.003	.001	.000
Age	Correlation Coefficient	.271**	1.000	.201*	-.003	.267**	.221*
	Sig. (2-tailed)	.007	.	.046	.975	.007	.030
Compensation Type	Correlation Coefficient	.181	.201*	1.000	.030	-.108	-.104
	Sig. (2-tailed)	.073	.046	.	.768	.287	.314
Cultivation period	Correlation Coefficient	.299**	-.003	.030	1.000	.234*	.376**
	Sig. (2-tailed)	.003	.975	.768	.	.020	.000
Income	Correlation Coefficient	.337**	.267**	-.108	.234*	1.000	.387**
	Sig. (2-tailed)	.001	.007	.287	.020	.	.000
Expenses	Correlation Coefficient	.490**	.221*	-.104	.376**	.387**	1.000
	Sig. (2-tailed)	.000	.030	.314	.000	.000	.

4.0 Conclusions

Borneo's lowland rain forest dominated by dipterocarps has been subject to exploitations for its timber resources and leading to unprecedented deforestation. Dipterocarps is important in terms of commercial value as well as global warming because of its massive storage of carbon. Nevertheless, crucial information on the species distribution in Borneo are seriously lacking for sustainable management and conservation efforts. APN funded the collaborative works of researchers of Asia-Pacific region to fill the gap of missing information about the dipterocarp species distribution and conservation gap at a landscape scale through an integrated approach that combines remote sensing, GIS and herbarium data.

The dipterocarps specimens from herbarium and groundtruths on diversity and endemism of the dipterocarps were used with environmental factors from GIS for modeling the distribution of the dipterocarps. Although herbarium specimen of dipterocarps was lacking, we were able to predict the distribution of dipterocarps at genus level for *Dipterocarpus* in East Kalimantan. For Sarawak, we were able to predict most of the dipterocarps using the inverse distance method with average prediction accuracy higher than 80%. The species occurrence maps were then used in conservation gap analysis. And we found that only about 3% of the dipterocarps hotspot areas are inside the existing protected areas of Sarawak. Similarly, only about 3-4% of the hotspot areas of dipterocarps that are endemic to Sarawak and Borneo were inside the existing protected areas. This means conservation effort to ensure sustainable forest resources in future is seriously lacking in Sarawak and the state government must establish more protected areas to conserve dipterocarps for future resource use.

Land cover changes were analyzed using supervised classification approach on multitemporal satellite data. The free Landsat dataset of 1990 and 2009 were the base data to this project. Only deforestation rate of Sarawak was assessed because of cloud and haze problem over the satellite images of East Kalimantan province. At a deforestation rate higher than 0.6% per annum, the deforestation rate of Sarawak was lower than reported rate of Borneo. However, it became clear that the peat swamp forest was significantly reduced. We expect the deforestation to be accelerating in next few years because the state government had decided to convert the peat swamp forest to oil palm plantation. Endemic dipterocarps confined to peat swamp habitat will be disappearing in the agricultural development.

For exploring the potential of REDD+ implementation, perspectives of local people were evaluated towards REDD+ activities that were supported by national program in East Kalimantan, Indonesia. All the activities were evaluated as weak to strongly positive based on the criteria of emission reduction, biodiversity conservation and poverty alleviation. Protected forest management was found only weakly positive among the local people in East Kalimantan. In Sarawak, the local people showed their acceptance to REDD+ provided compensation in form of rubber plantation scheme.

All the findings including the modeling and conservation gap analysis approaches and evaluation of REDD+ activities were presented in a project's seminar held in Kota Kinabalu, Sabah, Malaysia. Beside of academics and researchers, representatives from relevant authorities, forest managers and NGOs attended the seminar. The audience was shown the appropriateness of the approach and how will the results be useful to support policy adaptation to better deal with dipterocarp conservation gaps and REDD+.

5.0 Future Directions

This project focused mainly on prediction of dipterocarps, which is the main timber species that store most of the above-ground biomass or carbon. REDD+ mechanism has been criticized for not seriously include biodiversity in the monetary mechanism. It is thus important for us to look into both carbon and biodiversity at the same time. We had demonstrated the prediction of the dipterocarps, keystone species of lowland rain forest. And we should further research and develop an approach to consider both biodiversity and carbon simultaneously in a decision making process.

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Appendix

1. Conferences/Symposia/Workshops

SEMINAR ON CHALLENGES IN SAFEGUARDING BIODIVERSITY AGAINST DEFORESTATION AND DEGRADATION IN BORNEO

7th March 2012

Novotel, 1 Borneo, Kota Kinabalu, Sabah

PROGRAM

8.00 am	Registration of participants
8.30 am	Arrival of invited guests
8.40 am	Arrival of the Vice-Chancellor of UMS
9.00 am	Welcoming address by Dean of School of International Tropical Forestry
9.15 am	Opening speech by the Vice-Chancellor of UMS
9.30 am	TEA BREAK
10.00 am	Keynote address: Incorporating spatial and non-spatial data in GIS for biodiversity conservation *Mui-How Phua, School of International Tropical Forestry (SITF), UMS, Malaysia*
10.25 am	Multi-sensor approach for monitoring deforestation and forest degradation in Borneo *Andreas Langner, Forestry & Forest Products Research Institute, Japan*
10.50 am	Land cover changes and deforestation in Sarawak, Malaysia Using Landsat and SPOT images *Kamlisa Uni kamlun, Calvin Goh, Stephen Teo, Mui-How Phua, SITF, UMS, Malaysia*
11.15 am	Monitoring of Deforestation and degradation in Sabah using multitemporal Landsat images *Razis Osman, Kamlisa Uni Kamlun, Zia Ying Ling, SITF, UMS, Malaysia*
11.40 am	Mapping of natural distribution of dipterocarps in East Kalimantan *Kota Aoyagi, Satoshi Tsuyuki, The University of Tokyo, Japan*
12.05 pm	Spatial distribution of endemic dipterocarps in Sabah *Colin Maycock & John Sugau, Sabah Forestry Department, Malaysia*
12.30 pm	LUNCH
2.00 pm	Modeling the natural occurrence of dipterocarps in Sarawak: The potential of spatial interpolation technique *Stephen Teo, Sarawak Forestry Department, Malaysia*
2.25 pm	Assessment of the livelihood and acceptance of Ibans in Batang Ai, Sarawak for REDD+ *Wilson Wong, Julius Kodoh, Mui-How Phua, SITF, UMS, Malaysia*
2.50 pm	Local Community Perspectives of Forest Policies Related to REDD+ in Indonesia *Mustofa Agung Sardjono, Universitas Mulawarman, Indonesia*
3.15 pm	TEA BREAK
3.45 pm	Simple Method to Evaluate National REDD+ Programs for Local Stakeholders *Makoto Inoue, The University of Tokyo, Japan*
4.10 pm	Local Community's Perspective on Forest Conservation: A Case Study of Community at Gana Resettlement and Intergrated Development Project, (GRID), Sabah *Hardawati Yahya, Roszehan Mohd. Idrus, Hamimah Talib, Eunice Fong, SITF, UMS, Malaysia*
4.35 pm	Panel Discussion
5.15 pm	Closing Ceremony

2. Funding sources outside the APN

i. Universiti Malaysia Sabah (In-kind and fund)
ii. The University of Tokyo, Japan (In-kind and fund)
iii. GIZ, Germany (Fund)
iv. Universitas Mulawarman (In-kind)
v. Sarawak Forestry Department, Malaysia (In-kind)
vi. National Coordinating Agency for Surveying and Mapping, Indonesia (In-kind)

3. List of Young Scientists

i. Dr. Arief Darmawan, Universitas Lampung, Indonesia.
ii. Kota Aoyagi, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Japan.
iii. Wilson Wong, School of International Tropical Forestry, Universiti Malaysia Sabah, Malaysia.
iv. Kamlisa Uni Kamlun, School of International Tropical Forestry, Universiti Malaysia Sabah, Malaysia.
v. Julius Kodoh, School of International Tropical Forestry, Universiti Malaysia Sabah, Malaysia.
vi. Mea How Goh, School of International Tropical Forestry, Universiti Malaysia Sabah, Malaysia.