ISSN 2355-7079
E-ISSN 2406-8195
538/AU3/P2MI-LIPI/06/2013

Indonesian Journal of Forestry Research

Vol. 2 No. 2, October 2015

Ministry of Environment and Forestry
Research, Development and Innovation Agency
Indonesia

Indonesian Journal of Forestry Research

Vol. 2 No. 2, October 2015

Annals of the Indonesian Journal of Forestry Research

Indonesian Journal of Forestry Research (IJFR) was first published as Journal of Forestry Research (JFR) on November 2004 (ISSN 0216-0919). The last issue of JFR was Volume 10 Number 2 published on December 2013. The Journal of Forestry Research has been accredited by the Indonesian Institute of Sciences since 2008. The last accreditation was on 21 June 2013 (accreditation number: 538/AU3/P2MI-LIPI/06/2013) which will be valid until 2016. IJFR will be issued in one volume every year including two issues which will be delivered every April and October. This Journal is published by Research, Development and Innovation Agency (FORDA), Ministry of Environment and Forestry, formerly known as Forestry Research and Development Agency, the Ministry of Forestry Republic of Indonesia. The name of publisher has been changed due to the amalgamation of the Ministry of Forestry with the Ministry of Environment into the Ministry of Environment and Forestry, Republic of Indonesia *(Perpres No. 16/2015)*. Consequently, the Forestry Research and Development Agency was transformed into Research Development and Innovation Agency for Forestry and Environment. The logo of the ministry was reformed, accordingly.

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Telephone : (0251) - 7521671
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E-mail : ijfr.forda@gmail.com
Website : http://ejournal.forda-mof.org

Printed in Indonesia

Accredited by the Indonesian Institute of Science

No. 538/AU3/P2MI-LIPI/06/2013

Acknowledgement

The Indonesian Journal of Forestry Research expresses sincere appreciation to all reviewers for selflessly contributing their expertise and time to the reviewing process, which is crucial to ensure the quality and substantive impact of the journal. The journal's editors and authors are collectively grateful for the reviewers' efforts in evaluating and assessing the articles submitted for consideration of publication, regardless of the outcome (acceptance or rejection).

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Indonesian Journal of Forestry Research

ABSTRACTS

ISSN 2355-7079

Vol. 2 No.2, October 2015

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UDC/ODC 630* 176.1:160.2

Arif Nirsatmanto, Teguh Setyaji, Sri Sunarti and Dwi Kartikaningtyas

GENETIC GAIN AND PROJECTED INCREASE IN STAND VOLUME FROM TWO CYCLES BREEDING PROGRAM OF *Acacia mangium*

(PERBAIKAN GENETIK DAN PROYEKSI PENINGKATAN PRODUKTIVITAS VOLUME TEGAKAN DARI DUA GENERASI SIKLUS PEMULIAAN *Acacia mangium)*

Dua generasi dalam siklus pemuliaan Acacia mangium telah dilakukan oleh Balai Besar Penelitian Bioteknologi dan Pemuliaan Tanaman Hutan. Tulisan ini mempelajari tingkat perbaikan genetik aktual dan proyeksi produktivitas volume tegakan sampai akhir daur., serta implikasinya pada produktivitas hutan tanaman dan kelestarian hutan di Indonesia. Benih unggul pemuliaan generasi pertama dan kedua diuji bersama dengan benih biasa (tidak dimuliakan) di dalam plot uji perbaikan genetik di Jawa Barat dengan jarak tanam operasional 3 x 3 m. Tinggi total, dbh dan volume batang diukur sampai tegakan umur 3 tahun. Perbaikan genetik aktual dihitung sebagai persentase peningkatan pertumbuhan tegakan dari benih unggul terhadap tegakan dari benih biasa. Secara umum, benih unggul menunjukkan pertumbuhan tegakan yang lebih baik dibandingkan benih biasa, perbaikan genetik berkisar 5-24% (tinggi), 3-44% (dbh) dan 11-90% (volume batang). Benih unggul pemuliaan generasi ke-dua menunjukkan produktivitas yang lebih tinggi dibandingkan benih unggul pemuliaan generasi pertama, berkisar 6-16% (tinggi), 3-26% (dbh) dan 20-53% (volume batang). Tingkat perbaikan genetik sifat tinggi meningkat dengan bertambahnya umur tanaman, tetapi cenderung menurun pada sifat dbh dan volume batang. Proyeksi produktivitas volume tegakan dari benih unggul (daur 8 tahun) mencapai 290-324 m3/ha atau terjadi peningkatan sebesar 30-50%. Penggunaan benih unggul dengan pola silvikulur yang baik akan mampu meningkatkan produktivitas hutan tanaman untuk kelestarian hutan di Indonesia.

Kata kunci: *Acacia mangium*, generasi kedua, volume tegakan, perbaikan genetik aktual, produktivitas

UDC/ODC 630*416.3

Hengki Siahaan and Agus Sumadi

SITE INDEX PREDICTION OF SMALLHOLDER PLANTATIONS OF KAYU BAWANG (*Disoxylum mollissimum* Blume) IN BENGKULU PROVINCE

(PENDUGAAN KUALITAS TEMPAT TUMBUH PADA HUTAN RAKYAT KAYU BAWANG (*Disoxylum mollissimum* Blume) SKALA KECIL DI PROVINSI BENGKULU)

Kayu bawang (*Dysoxylum mollissimum* Blume) telah ditanam pada hampir semua kabupaten di Provinsi Bengkulu, Indonesia, tetapi belum ada penelitian yang dilakukan untuk pendugaan kualitas tempat tumbuh jenis ini. Tulisan ini mempelajari penilaian terhadap kualitas tempat tumbuh penanaman kayu bawang skala kecil dengan membangun 32 petak ukur permanen yang terdistribusi pada 6 kabupaten di Provinsi Bengkulu dan diukur secara periodik dari tahun 2006 – 2012. Kualitas tempat tumbuh ditentukan dengan metode phytocentric menggunakan peninggi tegakan sebagai indikator. Hasil penelitian menunjukkan bahwa model yang akurat untuk menduga pertumbuhan peninggi kayu bawang adalah model Schumacer dengan persamaan Ln Ho = (3,06 + ai) – 2,05/A (R^2 = 96,5%, AMRES = 0,82 dan APD =5,03%). Persamaan kualitas tempat tumbuh, yang diformulasikan dari model pertumbuhan peninggi adalah Ln Si = Ln H0 – 2,05 (1/12-1/A) dengan umur indeks 12 tahun. Berdasarkan persamaan ini, tempat tumbuh kayu bawang diklasifikasikan ke dalam 5 kelas dengan interval kelas 3 m, yaitu SI < 16 m; 16 m ≤ SI < 19 m; 19 m ≤ SI < 22 m; 22 m ≤ SI < 25 m; and SI ≥ 25 untuk kelas tapak I, II, III, IV, dan V yang secara berturut-turut merepresentasikan produktifitas paling rendah hingga yang tertinggi. Kualitas tempat tumbuh I yang mempunyai kualitas terendah umumnya ditemukan pada dataran tinggi dengan ketinggian > 850 m dpl dengan jenis tanah andosol, sebaliknya kualitas tanah V (kualitas terbaik) dijumpai pada dataran rendah dengan ketinggian tempat < 300 m dpl yang berasal dari jenis tanah ultisol.

Kata kunci: *Dysoxylum mollissimum*, penanaman skala kecil, pertumbuhan, indeks tapak

UDC/ODC 630*238

Relawan Kuswandi and Agustinus Murdjoko

POPULATION STRUCTURES OF FOUR TREE SPECIES IN LOGGED-OVER TROPICAL FOREST IN SOUTH PAPUA, INDONESIA: AN INTEGRAL PROJECTION MODEL APPROACH

(STRUKTUR POPULASI DARI EMPAT SPESIES POHON DI HUTAN BEKAS TEBANGAN, PAPUA SELATAN, INDONESIA: SEBUAH PENDEKATAN DARI INTEGRAL PROJECTION MODEL)

Penebangan hutan masih berlangsung di Papua, namun informasi mengenai struktur tegakan masih belum banyak. Tulisan ini mempelajari struktur populasi dari tegakan pada hutan bekas tebangan di daerah Papua Selatan. Empat jenis yang tumbuh dalam Petak Ukur Permanen (PUP) diamati adalah *Vatica rassak*, *Syzygium* sp., *Litsea timoriana* dan *Canarium asperum*. PUP berlokasi di PT Tunas Sawerma, Asiki, Boven Digul, Papua. Dataset diperoleh dari pengukuran tahun 2005 dan 2012 yang terdiri dari jenis, jumlah individu dan diameter. Selanjutnya, Intergral Projection Models digunakan untuk menganalisis struktur tegakan dengan menggunakan mortality, pertumbuhan, recruitment dan fecundity ke dalam persamaan. Hasil simulasi model menunjukan bahwa model struktur tegakan dari keempat species adalah sama dimana banyak individu yang berada pada pohon dengan diameter kecil dibandingkan dengan jumlah individu pada pohon yang berdiameter besar. Secara umum, bentuk distribusi dari individu-individu dari kempat jenis tersebut adalah J terbalik. Selanjutnya, *Syzygium* sp. adalah species yang memiliki individu yang lebih banyak dibandingkan dengan ketiga species lainnya. Struktur populasi tegakan dari keempat species tersebut bergerak tumbuh setelah penebangan dimana ditunjukkan oleh nilai population growth rate (λ) di atas satu. Oleh karena itu, hutan bekas tebangan ini memiliki kemampuan untuk kembali pulih dan bisa mencapai fase klimaks.

Kata kunci: Petak ukur permanen, laju pertumbuhan populasi, kegiatan penebangan

UDC/ODC 630*31:561

Asep Ayat and Hesti L. Tata

DIVERSITY OF BIRDS ACROSS LAND USE AND HABITAT GRADIENTS IN FORESTS, RUBBER AGROFORESTS AND RUBBER PLANTATIONS OF NORTH SUMATRA

(KERAGAMAN JENIS BURUNG PADA BERBAGAI PEMANFAATAN LAHAN DAN GRADASI DI HUTAN, AGROFOREST KARET DAN PERKEBUNAN KARET DI SUMATERA UTARA)

Burung berperan penting dalam ekosistem, namun pada ekosistem yang terganggu peran mereka menjadi terbatas akibat perubahan habitat. Studi komunitas burung di berbagai tipe habitat, pada hutan, agroforest karet, monokultur karet dan daerah pemukiman telah dilakukan di Kabupaten Simalungun dan Asahan, Provinsi Sumatra Utara. Burung diamati dengan melakukan survei deskriptif dengan metode survei cepat biodiversitas, dengan mengkoleksi data pada transek sepanjang 1 km. Hasil studi di keempat tipe habitat menjumpai 142 jenis burung dari 42 suku. Burung yang dijumpai di hutan memiliki tingkat keragaman jenis tertinggi, selanjutnya habitat karet agroforest, daerah pemukiman dan karet monokultur, memiliki tingkat keragaman jenis yang lebih rendah, dengan index Shannon-Wiener secara berturut-turut 3,8, 3,6, 3,0 dan 2,9. Tercatat 12 jenis burung dengan status kelangkaan terancam punah dan dua species dengan status rentan, menurut red-list IUCN. Berdasarkan kategori CITES, tercatat satu jenis burung yang termasuk Appendix I, 12 jenis burung yang termasuk Appendix II, dan 26 jenis burung yang dilindungi berdasarkan peraturan perundang-undangan di Indonesia. Perubahan struktur dan komposisi vegetasi di hutan yang terganggu dan lahan terbuka menentukan kekayaan jenis burung. Perbedaan komposisi jenis pohon di keempat habitat di sekitar perkebunan karet monokultur mempengaruhi jumlah, keragaman dan komposisi jenis burung.

Kata kunci: Komposisi jenis, konservasi, CITES, relung pakan

UDC/ODC 630*182.21

Rospita O.P. Situmorang, Alfonsus H. Harianja and Johansen Silalahi

KARO'S LOCAL WISDOM: THE USE OF WOODY PLANTS FOR TRADITIONAL DIABETIC MEDICINES

(KEARIFAN LOKAL MASYARAKAT KARO: PENGGUNAAN TANAMAN BERKAYU UNTUK OBAT TRADISONAL PENYAKIT DIABETES)

Tulisan ini mengidentifikasi jenis-jenis tanaman yang digunakan oleh masyarakat Karo secara tradisional di Sumatara Utara, Indonesia, untuk mengobati diabetes. Jenis-jenis tanaman tersebut dianalisis indeks kepentingan budayanya (ICS) dan diklarifikasi kandungan fitokimianya. Metode survey digunakan dengan responden terpilih (n-54) berdasarkan pengetahuan mereka dalam memanfaatkan obat-obat tradisional untuk diabetes. Indeks kepentingan budaya (ICS) dari masing-masing tanaman diukur menggunakan metode yang dipakai oleh Turner. Hasil penelitian menunjukkan terdapat 12 jenis tanaman berkayu untuk mengobati diabetes: loning (*Psychotria* sp.), kacihe (*Prunus accuminta* Hook), kayu afrika (*Maesopsis eminii* Engl), jati belanda (*Guazuma ulmifolia* Lamk), cepcepan (*Villebrunea subescens* Blume), pirdot/cepcepan lembu (*Saurauia vulcani* Korth), raru (*Cotylelobium melanoxylo*), sukun (*Artocarpus altilis*), salam (*Syzygium polyanthum* Wight), mahoni (*Swietenia mahagoni* (L.) Jacq), kulit manis (*Cinnamomum burmanni*), dan bambu kuning (*Bambusa vulgaris* Schrad). Lima jenis tanaman: loning, kayu afrika, jati belanda, raru dan salam memiliki tingkat kepetingan budaya tertinggi yang dibutuhkan dalam jumlah yang banyak dibandingkan tanaman yang lain sehingga ketersediaannya di hutan perlu diperhatikan. Tanaman-tanaman yang dipakai oleh masyarakat tersebut mengandung alkaloid, flavonoid, fenolik dan terpenoid yang mampu menurunkan kadar gula darah.

Kata kunci: Etnobotani, Masyarakat Karo, obat diabetes, indeks kepentingan budaya (ICS), fitokimia

UDC/ODC 630*111.83:116

Wawan Halwany and Susy Andriani

THE SOIL AND WATER MICROORGANISM DIVERSITY OF MANGROVE FOREST OF TELUK KELUMPANG, SELAT LAUT AND SELAT SEBUKU NATURAL RESERVE

(KEANEKARAGAMAN MIKROORGANISME TANAH DAN AIR HUTAN MANGROVE CAGAR ALAM TELUK KELUMPANG, SELAT LAUT DAN SELAT SEBUKU)

Mangrove adalah suatu ekosistem unik yang memiliki komponen biotik dan abiotik yang komplek. Komponen mikroorganisme tanah dan air berfungsi sebagai dekomposer dalam ekosistem mangrove. Tulisan ini mempelajari keanekaragaman mikroorganisme tanah dan air, potensi dan fungsinya dalam ekosistem, dan parameter lingkungan di kawasan mangrove Cagar Alam Teluk Kelumpang, Selat Laut, dan Selat Sebuku (Cagar Alam Kelautku). Data mikroorganisme tanah dan air diambil dengan cara pengambilan contoh tanah dan air kemudian dianalisis di laboratorium. Hasil penelitian menunjukkan bahwa Selat Sebuku memiliki indeks keanekaragaman benthos tertinggi. Salah satu kelimpahan bentos yang banyak ditemukan di Selat Sebuku adalah *Anadara granosa*. Berlawanan dengan kelimpahan benthos kelimpahan plankton terendah di Selat Sebuku. Hal ini diduga gelombang laut lebih besar di Selat Sebuku dan kepadatan pemukiman lebih banyak di Teluk Kelumpang dan Selat Laut yang menyebabkan adanya input limbah rumah tangga ke dalam perairan sekitarnya. Cyanophyta yang hanya ditemukan di Teluk Kelumpang dan Selat Laut dari genera Oscillatoria menunjukkan toleransi yang tinggi terhadap kondisi perairan

Kata kunci: Keanekaragaman, mikroorganisme tanah dan air, hutan mangrove, Cagar Alam Kelautku

GENETIC GAIN AND PROJECTED INCREASE IN STAND VOLUME FROM TWO CYCLES BREEDING PROGRAM OF *Acacia mangium*

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Received: 23 October 2013, Revised: 5 May 2015, Accepted: 11 May 2015

GENETIC GAIN AND PROJECTED INCREASE IN STAND VOLUME FROM TWO CYCLES BREEDING PROGRAM OF *Acacia mangium*. Two cycles breeding program of *Acacia mangium* has been practiced by the Forest Biotechnology and Tree Improvement Research Center in Indonesia. Although improved seeds from the breeding program have been used in operational plantation, the real gains in productivity were not verified yet. This paper observes realized genetic gain and projected increase in stand volume from the two breeding cycles of *A. mangium*, and to discuss the implications on plantation productivity and sustainable forestry in Indonesia. Improved seeds from the first and second-generation seed orchards were tested together with an unimproved seed in genetic gain trial in West Java, with spacing of 3 x 3 m. Measurements were taken yearly until three years age for height, dbh, and stem volume. Realized genetic gain was calculated as the percentage increase of improved seed over the unimproved one. Results showed that the improved seeds performed better than the unimproved ones with realized gains of 5-24% (height), 3-44% (dbh) and 11-90% (stem volume). Improved seeds from the second-generation outperformed the one from the first-generation, with an improvement of 6-16% (height), 3-26% (dbh) and 20-53% (stem volume). Genetic gains increased with increasing ages for height, but it tended to decrease for dbh and stem volume. At a given site and silvicultural practices, projected increase in stand volume at 8 years rotation reached 290-325 m^3 ha^{-1}, which is equal to 30-50% gain. The use of high genetically improved seeds, in combination with better silvicultural practices would provide significant impacts on plantation productivity and sustainable forestry in Indonesia.

Keywords: *Acacia mangium*, second-generation, stand volume, realized genetic gain, productivity

PERBAIKAN GENETIK DAN PROYEKSI PENINGKATAN PRODUKTIVITAS VOLUME TEGAKAN DARI DUA GENERASI SIKLUS PEMULIAAN Acacia mangium. *Dua generasi dalam siklus pemuliaan Acacia mangium telah dilakukan oleh Balai Besar Penelitian Bioteknologi dan Pemuliaan Tanaman Hutan. Tulisan ini mempelajari tingkat perbaikan genetik aktual dan proyeksi produktivitas volume tegakan sampai akhir daur, serta implikasinya pada produktivitas hutan tanaman dan kelestarian hutan di Indonesia. Benih unggul pemuliaan generasi pertama dan kedua diuji bersama dengan benih biasa (tidak dimuliakan) di dalam plot uji perbaikan genetik di Jawa Barat dengan jarak tanam operasional 3 x 3 m. Tinggi total, dbh dan volume batang diukur sampai tegakan umur 3 tahun. Perbaikan genetik aktual dihitung sebagai persentase peningkatan pertumbuhan tegakan dari benih unggul terhadap tegakan dari benih biasa. Secara umum, benih unggul menunjukkan pertumbuhan tegakan yang lebih baik dibandingkan benih biasa, perbaikan genetik berkisar 5-24% (tinggi), 3-44% (dbh) dan 11-90% (volume batang). Benih unggul pemuliaan generasi ke-dua menunjukkan produktivitas yang lebih tinggi dibandingkan benih unggul pemuliaan generasi pertama, berkisar 6-16% (tinggi), 3-26% (dbh) dan 20-53% (volume batang). Tingkat perbaikan genetik sifat tinggi meningkat dengan bertambahnya umur tanaman, tetapi cenderung menurun pada sifat dbh dan volume batang. Proyeksi produktivitas volume tegakan dari benih unggul (daur 8 tahun) mencapai 290-324* m^3*/ha atau terjadi peningkatan sebesar 30-50%. Penggunaan benih unggul dengan pola silvikulur yang baik akan mampu meningkatkan produktivitas hutan tanaman untuk kelestarian hutan di Indonesia.*

Kata kunci: Acacia mangium, generasi ke-dua, volume tegakan, perbaikan genetik aktual, produktivitas

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I. INTRODUCTION

Acacia mangium is the most commonly planted species in Industrial Plantation Forest in Indonesia. This species shows high growth rates and produce high-quality wood for pulp and timber products in short rotation. Currently more than 1,000,000 hectares of *A. mangium* have been planted by several forest companies and has made a significant contribution to the Indonesian economy (Ministry of Forestry, 2010).

Indonesian government has targeted a total production of approximately 67 million m^3 of wood per year for producing 16 million ton of pulp by 2020 (Manurung et al., 2007). The increased wood demand for pulp industries has stimulated a growing importance of expanding the large scale plantations of the high productive *A. mangium*. It is well known that tree improvement in combination with better silvicultural practices had proved to be one of the major contributors to the increase of the forest plantation productivity (Zobel & Talbert, 1984).

Since 1993 the Center for Forest Biotechnology and Tree Improvement (CFBTI) has started a comprehensive tree improvement program for *A. mangium*. The program was implemented through establishing the first-generation seedling seed orchards, which was continued through the second-generation in 2000, in several regions such as Sumatra, Kalimantan and Java (Hashimoto, Kurinobu, & Suhaendi, 1996; Kurinobu & Rimbawanto, 2002). The two cycles of breeding programs had been completed and are now starting the third breeding cycle.

Realized gain from the first breeding cycle of *A. mangium* accounted around 13-30% for stand volume productivity which is equal to the production of around 250-290 m^3 ha^{-1} (Kurinobu, Arisman, Leksono, & Hardiyanto, 2006). Based on the results of progeny trial, the second cycle breeding was estimated to produce approximately 5% more productivity than the first-cycle (Setyaji, 2011). Although improved seeds from the breeding program have been used in operational plantations, the total real amount of gains in terms of productivity from the two breeding cycles was not verified yet based on a common genetic gain trial. This paper observes the realized genetic gain and the projected increase in stand volume from the two breeding cycles of *A. mangium*, as well as its implications on plantation productivity and sustainable forestry in Indonesia.

II. MATERIAL AND METHOD

A. Tested Materials

Four improved stands of *A. mangium* were tested in this study which were derived from two seedling seed orchards originating from Papua New Guinea (PNG) provenances and two seedling seed orchards originating from Far North Queensland-Australia (FNQ) provenances. The two orchards in each provenance consisted of the first-generation and the second-generation orchards. Sub-line system was practiced in the seedling seed orchard establishment, and therefore the second-generation orchards were established using seeds from plus trees selected in the respective first-generation orchard and some additions from natural forest selections of the same provenances. As a comparison, unimproved stand was derived from local seed stand of Subanjeriji, which is genetically less productive than the improved stands, and was also used in this study. The seeds were collected from the respective seed sources, namely: four seedling seed orchards and one seed stand were then used for establishing the genetic gain trial.

B. Genetic Gain Trial

The genetic gain trial was established in 2009 in BKPH Jonggol, KPH Bogor, West Java (Figure 1), which is located at latitude of 6°28'3" South, longitude of 107°2'59" East, and altitude of 438 m above sea level. The climate type is A according to Schmidt and Ferguson's classification with an average temperature of 25°C, and annual rainfall of 2,500 mm. The predominant soil type is Grumusol and the topography is moderately sloping of around 5 %.

The gain trial was arranged in randomized complete block design with four replications. In each replication, five set of bulk seeds collected from the five seed sources: two of the first-generation, two of the second-generation orchards, and one seed stand, were planted at spacing of 3 x 3 m. Within each plot, trees were planted in square grid pattern with a 10 x 10 tree square.

The previous vegetation in the trial area was dominated by *A. mangium* stand. During site preparation, the area was cultivated manually through land clearing, followed by slashing and burning without plowing. The following years after planting, fertilizer was applied twice per year using 150 gram per tree of NPK (15:15:15) until 2 years of age. During the first year after planting weed control was carried out manually every four month in order to eliminate the competition of the weeds with the trees planted. The frequency of weeding was then reduced to two times per year for the second and third year due to canopy closure which inhibited the development of grassy weeds (Hardiyanto, 2004).

C. Measurement and data analysis

To get an accurate observation, only the inner 36 trees (6 x 6 trees) in each square plot were measured to simulate the competition that would occur between individual trees of the same seed source. During the first three years, trees planted in the trial were measured periodically once per year on two traits (height and diameter at breast height). Data on height and diameter were then used to calculate individual stem volume (v) using the volume equation (Inose, Saridi, & Nakamura, 1992) :

$$v = 0.000058806 \times D^{1.71772} \times H^{1.0809} \text{ ....(1)}$$

Realized genetic gain was calculated as the percentage increase of improved seed from the two breeding cycles over the unimproved one. In this purpose of study, single factor analysis of variance was then made to test the effects of each treatment separately: three generations, two populations and five seed sources.

Projected increase in stand volume at the rotation age (8 years age) were estimated from the three years height gains using the methods described by Kurinobu et al., (2006). Briefly, superiorities in height growth of improved stand over the unimproved stand were converted to the increase in site index (SI) with the equation as follows:

$$H_T = h_1(t_i) + [SI - h_1(8)] \times h_2(t_i)/h_2(8) \text{ ....(2)}$$

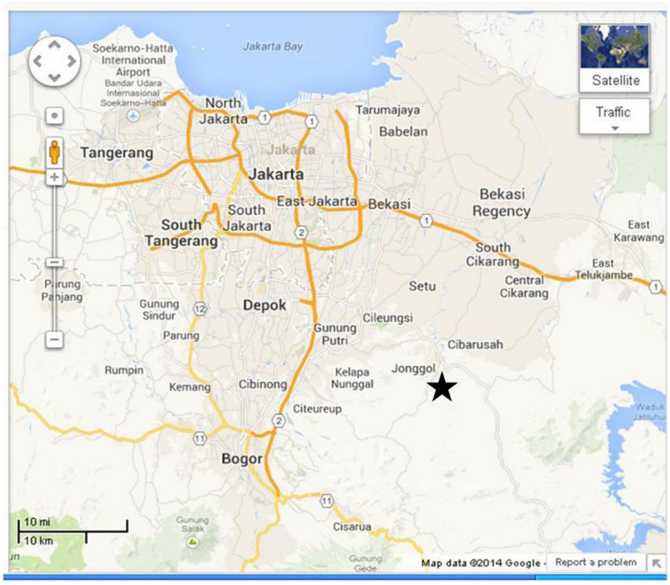

Figure 1. Site map of the location of *Acacia mangium* genetic gain trial in Jonggol, West Java
Source : google map

Where *h*(t_i) and *h*(8) were the height of the guide curve at age *ti* and the height at the reference age (= 8 years) in this study.

The site index values were then used with the growth model described by Nirsatmanto, Kurinobu, and Hardiyanto (2003) to estimate the expected increase in stand volume at rotation age.

III. RESULT AND DISCUSSION

3.1. Growth and Realized Genetic Gain

In this study the growth of *A. mangium* planted in the trial established in West Java, above 9 meter for height and 12 cm for dbh at three years of age (Table 1), was generally comparable with the growth of the same species planted in one of the representative plantation areas of *A. mangium* in South Sumatera as reported by Hastanto (2009). The trial site was located in the concession area managed by Perhutani which has allocated it for *A. mangium* plantations. Thus, the site trial was suitable for the purpose of study.

Improved stand planted using seeds obtained from the two breeding cycles of *A. mangium* showed substantially better growth than the unimproved stand (Table 1). The growth rates of stand derived from the second-generation seedling seed orchards were higher than those derived from the first-generation. Over all, the realized genetic gain ranged from 5-24% for height, 3-44% for dbh and 11-90% for stem volume. The gain of the second-generation was substantially higher than that of the first-generation. By considering the fact that stem volume is the function of height and diameter, the stem volume has provided the highest genetic gain compared with the other two growth traits.

Improved stand derived from seedling seed orchard which has originated from PNG provenances tended to give a slightly slower growth than those originated from FNQ (Table 1). This result was not in agreement with previous reports of provenance trial (Harwood & Williams, 1991; Kari, Otsamo, Kuusipalo, Vuikko, & Nikles, 1996) and genetic gain trial of first-generation improvement (Kurinobu et al., 2006), where PNG generally performed better in growth than the ones from FNQ. This is probably due to the damage by wind, broken tops that has occurred in some trees of PNG plot after two years which then affected the growth rates.

Regarding the progress from the two breeding cycles, the realized genetic gain of the second-generation over the first-generation ranged from 6 to 16% for height, 3 to 26 % for dbh, and 20 to 53% for stem volume (Table 1). Stem volume provided the highest additional genetic gain compared to height and dbh. In general and despite the growth was slightly lower, the additional gain of the second generation over the first-generation was slightly higher for PNG than that for FNQ.

The significant difference level in the growth traits among the three generations breeding: unimproved, first-generation and second-generation, increased with increasing age (Table 2). All of the traits showed highly significant differences at three years of age. This indicated that the growth superiority resulted from the successive generation breeding was evident as the tree was getting older, with stem volume as the trait was substantially improved.

Among the two populations: unimproved and improved (first and second-generation seedling seed orchards) and among the five seed sources: seed stand (unimproved), two seedling seed orchards of PNG and two seedling seed orchards of FNQ, the significant difference level showed a similar trend among generations (Table 2). This indicated that gain from the two breeding cycles as described in preceding paragraphs was evident in the genetic gain trial. Therefore some improvement could be potentially obtained from utilizing the genetically improved seeds which were collected from the seed sources coming from the breeding program.

Basically, the realized gains achieved by the second-generation consisted of the accumulated total gains produced by the first-generation and

Table 1. Mean and realized genetic gains (%) of the first and the second-generation seedling seed orchards originating from Papua New Guinea (PNG) and Far North Queensland (FNQ) provenances

Traits / year	Unimproved	Improved									
		First-generation				Second-generation					
		PNG		FNQ		PNG			FNQ		
	Mean	Mean	Gain[a]	Mean	Gain[a]	Mean	Gain[a]	Gain[b]	Mean	Gain[a]	Gain[b]
Height-1 (m)	2.3	2.4	5.5	2.5	9.1	2.6	15.0	9.1	2.6	15.7	6.0
Height-2 (m)	7.0	8.0	13.4	7.6	8.0	8.6	22.5	8.0	8.1	15.0	6.4
Height-3 (m)	9.7	10.4	6.9	10.9	11.7	12.1	24.2	16.2	11.8	21.5	8.8
Dbh-1 (cm)	1.9	1.9	3.6	2.2	17.3	2.5	31.2	26.7	2.7	44.2	23.0
Dbh-2 (cm)	8.9	9.6	7.2	10.2	13.6	10.4	16.5	8.6	11.0	23.0	8.3
Dbh-3 (cm)	12.5	13.3	6.9	13.7	9.5	13.8	10.2	3.1	14.6	17.0	6.9
Volume-1 (x10^{-3} m^3)	0.6	0.7	11.3		35.1	1.07	71.3	53.9	1.2	90.8	41.2
Volume-2 (x10^{-3} m^3)	19.6	25.6	30.4	25.3	28.7	32.3	64.5	26.2	30.6	55.5	20.8
Volume-3 (x10^{-3} m^3)	47.7	56.1	17.8	63.0	32.1	76.6	60.7	36.5	78.6	64.8	24.7

Remarks : a gains (%) over unimproved stand
b gains (%) over first-generation

Table 2. Observed significance associated with the analysis of variance for three years measurements of height, dbh and stem volume

Source of Variance	df	p-value								
		height / year			dbh / year			stem volume / year		
		1	2	3	1	2	3	1	2	3
Generation	2	0.336^{ns}	0.068^{ns}	0.008**	0.138^{ns}	0.022*	0.008**	0.078^{ns}	0.037*	0.002**
Population	1	0.226^{ns}	0.066^{ns}	0.034*	0.212^{ns}	0.022*	0.007**	0.147^{ns}	0.052^{ns}	0.020*
Seed Source	4	0.711^{ns}	0.195^{ns}	0.047*	0.375^{ns}	0.074^{ns}	0.017*	0.271^{ns}	0.178^{ns}	0.022*

Remarks: ** significant at the level 1%, * significant at the level 5%, ns : not significant

the additional gain from the second-generation. The accumulative gains from the two successive generations of breeding cycles could be clearly observed in this study as presented in Figure 2. The amount of total gains produced by the second-generation, which was calculated directly from the percentage superiority of the second-generation over the unimproved stand, were similar to the sum of the total gains from the first-generation and the additional gains of the second-generation over the first-generation, except for stem volume which was slightly higher. Thus it confirmed that by subtracting the total gain of the first-generation seedling seed orchards, the second-generation seedling seed orchards produced additional gain ranging from 6 to 17% for height, 3 to 27% for dbh, and 26 to 60% for stem volume. These gains were similar to the gains calculated directly as the percentage superiority of the second-generation over the first-generation (Table 1). The accumulated gains from the second-generation seedling seed orchards as observed in this study indicated that the improvement work through the two breeding cycles had been done properly and their impacts on the stand productivity were verified well in the genetic gain trial.

Genetic gain slightly increased with increased age for height, but it tended to decrease for dbh and stem volume (Figure 3), despite the trend of significant difference level between populations: improved and unimproved, increased with age (Table 2). The decrease in gains were probably due to the effect of increasing inter-tree competition from more rapid stand development, either due to improved stand or productive site quality, which then tended to reduce the amount of genetic gain. Eldridge (1982) has reported a small genetic gain in productive site indicating decreasing genetic gains with increasing stand development and competition. In addition, diameter and stem volume are the traits which are sensitive to inter-tree competition (Clutter, Fortson, Pienaar, Britster, & Bailey, 1983).

3.2. Projected increase in stand volume

The projected increase in stand volume at the rotation age (8 years) was estimated from the three-year's age of height gains. The results of the average stand volume projection of stand derived from the two breeding cycles are presented in Figure 4. At given site and silvicultural practice, volume of unimproved stand derived from seed stand as a control was estimated at approximately 217 m^3 ha^{-1} at eight years of age, and it was similar to the volume of the same genetic resource reported previously in other gain trial in South Kalimantan (Kurinobu et al., 2006). Whereas the stand volume of improved stand derived from the two breeding cycles reached 290–325 m^3 ha^{-1}, with the average of each generation was around 278 m^3 ha^{-1} for the first-generation seedling seed orchard and 314 m^3 ha^{-1} for the second-generation.

Superiority of improved stand over the unimproved one resulted in genetic gains for stand volume at 8 years rotation age ranging from 27 to 44% (Figure 4). Subsequently, the second-generation seedling seed orchards produced additional 13% stand volume gain over the first-generation seedling seed orchard. By assuming the current national plantation productivity baseline of around 200 m^3 ha^{-1} (Manurung et al., 2007), utilizing the genetically improved seeds, which are collected from the seed sources resulting from the two breeding cycles program, one could be expecting to increase the productivity in stand volume by 30 to 50%.

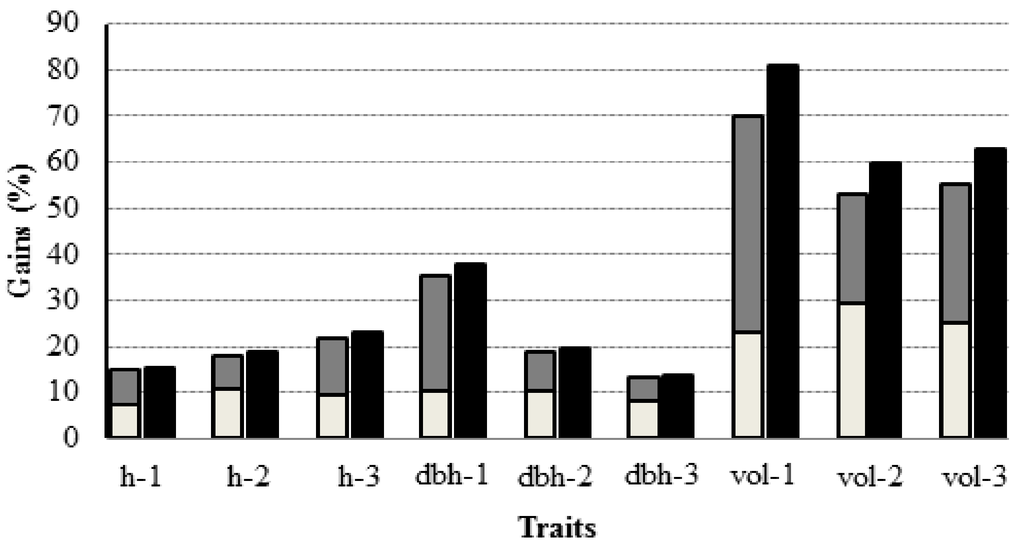

Figure 2. Average realized gains (%) of PNG and FNQ in the first-generation (white) and the second-generation seedling seed orchards (black) over unimproved stand, and gains of the second-generation over the first-generation (grey) for three year's measurements of height (h-1, h-2, h-3), dbh (dbh-1, dbh-2, dbh-3) and stem volume (vol-1, vol-2, vol-3)

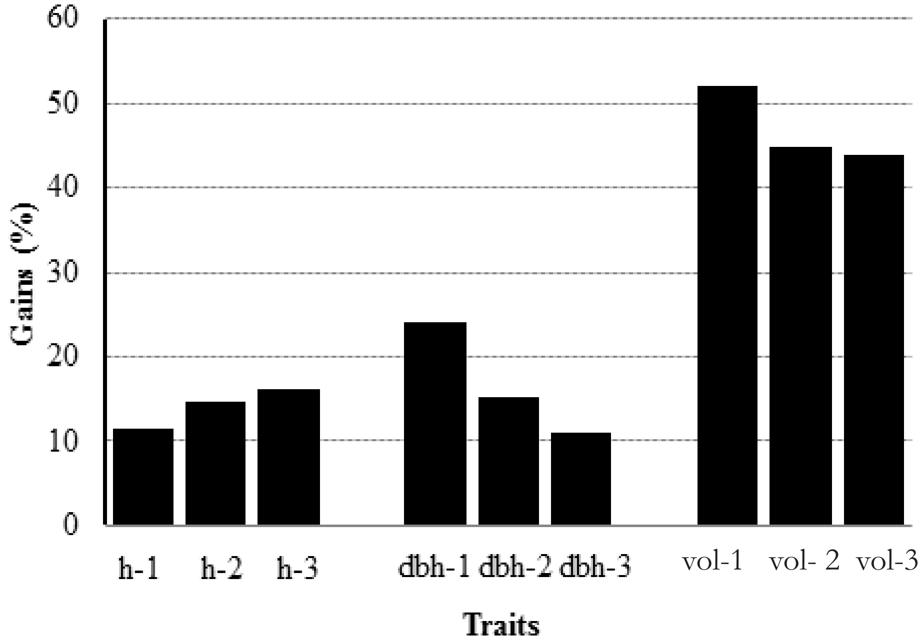

Figure 3. The average gains (%) across the two breeding cycles (the first and the second-generation seedling seed orchards) over unimproved stand for three year's measurements of height (h-1, h-2, h-3), dbh (dbh-1, dbh-2, dbh-3) and stem volume (vol-1, vol-2, vol-3)

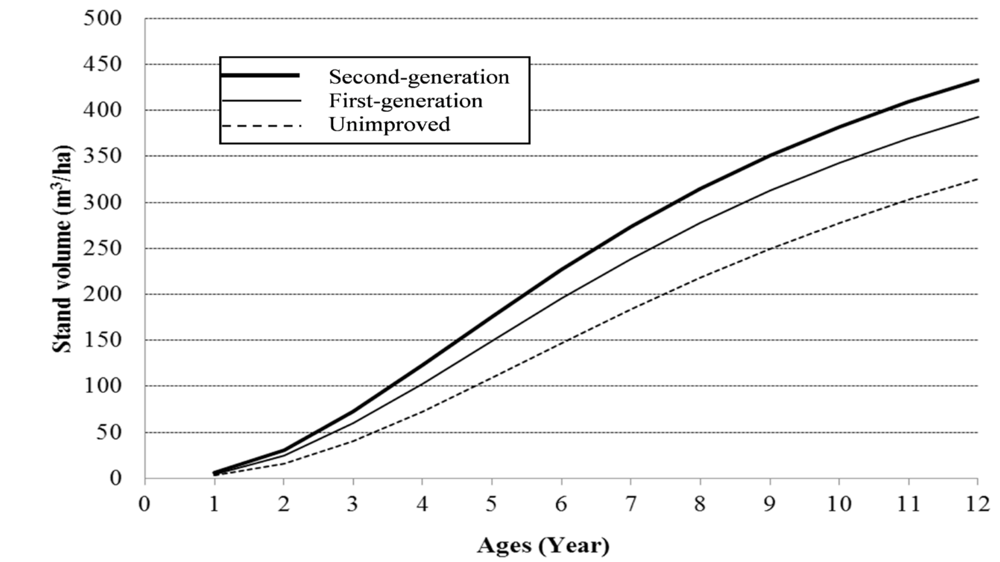

Figure 4. A projected increase in the average stand volume (m^3/ha) for the improved stand derived from two cycles breeding compared to unimproved stand

3.3. Implications on plantation productivity and sustainable forestry

The increased target for pulpwood production of up to 67 million m^3 per year will result a deficiency in supply of pulpwood of around 50% with current plantation productivity baseline (200 m^3 ha^{-1}). However, according to the high gains resulted in this study, which is around 30-50% more stand volume at the harvesting age over the baseline, it suggests that the impacts of tree improvement on plantation forest productivity would be substantial from the two cycles breeding of *A. mangium*. Using the genetically improved seeds from the breeding program it could be possible to increase the plantation productivity ranging from 278–314 m^3 ha^{-1}. Furthermore, by considering the annual plantation capacity of around 200,000 hectares as mentioned in preceding paragraph, it is estimated that a total of 55– 63 million m^3 of pulpwood would be produced from these improved *A. mangium*. Although the estimated wood production would be slightly less than the targeted production (67 million m^3), additional improvement from wood quality traits could be expected to be other source to increase pulp yield production through reducing wood consumption per ton pulp.

Considering the continued high target of pulp industries with the probable limitation of availability of productive commercial land, and the anticipation of probable impacts of climate change, stand volume productivity must be increased simultaneously. According to the results of this study, tree improvement program combined with best silvicultural practices had proved to be one of the most effective way to meet the future increased demand of high stand productivity. The impact of using wood from high productive plantation of *A. mangium* will significantly reduce the logging pressure on natural forests. This is because the wood demand for the industries could be fully supplied by wood harvested from improved plantations. Regarding these facts, it was revealed that the available genetically improved seed of *A. mangium* from the two cycles breeding could be the potential to provide a significant contribution for increasing plantation productivity and sustainable forestry in Indonesia. However, to achieve the target quantity of improved seeds, further multiplying of the seedling seed orchards from these two breeding cycles in mass scale (up to 100 hectares) should be undertaken to meet the demand for the targeted plantation establishment. In addition, the improvement of wood properties should also be included in the next breeding program to complete the improvement of growth traits. In the future, to increase the utility of the improved seed for another locally end product of *A. mangium* such as solid wood, it is necessary also to examine the productivity of the improved seed over the available local stand volume tables.

IV. CONCLUSION

The substantial realized genetic gain from the two breeding cycles of *A. mangium* was verified in genetic gain trial, with approximately 30-50% more production in stand volume (m^3/ha) over the current national plantation productivity baseline. This result indicated that the tree improvement work for *A. mangium* had been done properly and their impact on stand productivity was evident. By utilizing the highly productive genetically improved seeds for plantation forest establishment, that will provide a significant impact to reduce logging pressure on natural forest and to maintain the sustainability of forestry in Indonesia. Therefore, it is recommended to multiply the seedling seed orchards resulted from this two cycles breeding in mass scale to meet the demand of genetically improved seeds for the targeted plantations.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to PERUM PERHUTANI, on whose land the trial was established, for establishing and maintaining the trials. Without this support the study would not have been possible. We thank Mr. Surip and Mr. Sumaryana for all the fieldwork and data collection.

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SITE INDEX PREDICTION OF SMALLHOLDER PLANTATIONS OF KAYU BAWANG (*Disoxylum mollissimum* Blume) IN BENGKULU PROVINCE

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Received: 13 November 2013, Revised: 10 September 2015, Accepted: 12 September 2015

SITE INDEX PREDICTION OF SMALLHOLDER PLANTATIONS OF KAYU BAWANG (*Disoxylum mollissimum* Blume) IN BENGKULU PROVINCE. Kayu bawang (*Dysoxylum mollissimum* Blume) has been planted almost in all districts of Bengkulu Province, Indonesia, but yet no study has been conducted to analyze the site quality of this species. This paper studies the site quality of *Dysoxylum mollissimum* Blume of smallholder plantations by establishing 32 permanent sample plots (PSPs) distributed in six districts of Bengkulu Province and measured periodically from 2006 to 2012. Site quality was determined by phytocentric method which used stand dominant height as a indicator. The result shows that the best model for dominant height growth of *Dysoxylum mollissimum* Blume in Bengkulu Province was the Schumacher model expressed by the equation: Ln Ho = (3.06 + ai) – 2.05/A (R2 = 96.5%, Absolute Mean Residual (AMRES) = 0.82 and Average Percentage Difference (APD) =5.03%). The relevant site equation for this species derived from the dominant height growth model was: Ln Si = Ln H0 – 2.05 (1/12-1/A) for an index age of 12 years. Based on this equation, the sites were classified into 5 classes having an equal range of 3 m i.e. SI < 16 m; 16 m ≤ SI < 19 m; 19 m ≤ SI < 22 m; 22 m ≤ SI < 25 m; and SI ≥ 25 m: for site classes I, II, III, IV, and V representing from the lowest to the highest productivity respectively. Site class I, the poorest site, was found on the upland areas with an altitude of > 850 m above sea level on andosol soil type. Adversely, the best site (site class V) was found at lowland areas with an altitude of < 300 m above sea level and on ultisol soil type.

Keywords: *Dysoxylum mollissimum,* smallholder plantation, growth, and site index

PENDUGAAN KUALITAS TEMPAT TUMBUH PADA HUTAN RAKYAT KAYU BAWANG (Disoxylum mollissimum Blume) SKALA KECIL DI PROVINSI BENGKULU. Kayu bawang (Dysoxylum mollissimum Blume) telah ditanam pada hampir semua kabupaten di Provinsi Bengkulu, Indonesia, tetapi belum ada penelitian yang dilakukan untuk pendugaan kualitas tempat tumbuh jenis ini. Tulisan ini mempelajari kualitas tempat tumbuh penanaman kayu bawang skala kecil dengan membangun 32 petak ukur permanen yang terdistribusi pada 6 kabupaten di Provinsi Bengkulu dan diukur secara periodik dari tahun 2006 – 2012. Kualitas tempat tumbuh ditentukan dengan metode phytocentric menggunakan peninggi tegakan sebagai indikator. Hasil penelitian menunjukkan bahwa model yang akurat untuk menduga pertumbuhan peninggi kayu bawang adalah model Schumacer dengan persamaan Ln Ho = (3,06 + ai) – 2,05/A (R2 = 96,5%, AMRES = 0,82 dan APD =5,03%). Persamaan kualitas tempat tumbuh, yang diformulasikan dari model pertumbuhan peninggi adalah Ln Si = Ln H0 – 2,05 (1/12-1/A) dengan umur indeks 12 tahun. Berdasarkan persamaan ini, tempat tumbuh kayu bawang diklasifikasikan ke dalam 5 kelas dengan interval kelas 3 m, yaitu SI < 16 m; 16 m ≤ SI < 19 m; 19 m ≤ SI < 22 m; 22 m ≤ SI < 25 m; and SI ≥ 25 untuk kelas tapak I, II, III, IV, dan V yang secara berturut-turut merepresentasikan produktifitas paling rendah hingga yang tertinggi. Kualitas tempat tumbuh I yang mempunyai kualitas terendah umumnya ditemukan pada dataran tinggi dengan ketinggian > 850 m dpl dengan jenis tanah andosol, sebaliknya kualitas tanah V (kualitas terbaik) dijumpai pada dataran rendah dengan ketinggian tempat < 300 m dpl yang berasal dari jenis tanah ultisol.

Kata kunci: Dysoxylum mollissimum, penanaman skala kecil, pertumbuhan, dan indeks tapak

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I. INTRODUCTION

Kayu bawang (*Disoxylum mollissimum* Blume) is a local tree species of Meliaceae family and grow naturally in Bengkulu Province especially in North Bengkulu District. Since 1990, it has been planted by smallholder farmers in Bengkulu Province as a timber tree. This tree species can grow well in various sites and climatic conditions. It is well adapted to a wide range of rainfall, from 500 to 3500 mm year^{-1} and altitude from 0 to 1000 m above sea level (Forest District of Bengkulu, 2003). Farmers use kayu bawang as a timber source for construction material and furniture.

Smallholder plantations have specific characteristics reflecting various site management practices. The tree is grown usually in a small scale plantation comprising of a few hundred trees per household (Vanclay, Baynes, & Cedarnon, 2008). Despite grown in small scale plantations, kayu bawang has grown almost in all districts of Bengkulu Province. The farmers usually grow kayu bawang in agroforestry system with coffee and/or cacao (Siahaan, Suhendang, Rusolono, & Sumadi, 2011) as shown in Figure 1. Silvicultural practices applied for kayu bawang plantations vary considerably among the farmers, such as stand density (spacing), tending, and thinning regimes. Stand density varied from 150 to 1250 stems ha^{-1} (Siahaan et al., 2011).

Although kayu bawang has been planted almost in all districts of Bengkulu Province, research regarding site quality and its distribution is very limited. The effective management of forest plantations can be hindered if information on growth and yield of the tree plantations is limited (Krisnawati, 2007). Research on growth and yield of kayu bawang has been conducted by establishing permanent sample plots (PSPs) in Bengkulu Province, starting in 2006. Several publications on growth and yield of kayu bawang are available, including growth of monoculture plantations in North Bengkulu (Apriyanto, 2003), growth models for various planting patterns in Bengkulu Province (Siahaan et al, 2011) and tree volume estimation model (Sumadi & Siahaan, 2010); however up to present there is no quantitative information about its site quality.

Site quality can be defined as the potential of a site to produce timber or forest biomass for a particular tree species and forest type (Clutter, Pienar, Brister, & Bailey, 1983; Skovsgaard & Vanclay, 2008). Conceptually, site quality is considered as an inherent property of plots of land, whether or not trees are being grown at the time of interest (Beaulieu, Raulier, Pregent, & Bousquet, 2011). Site quality is commonly expressed by the site index, defined as the dominant height of a stand at a reference age (Avery & Burkhart, 2002). Dominant height is a good indicator of site quality of a particular site because it almost entirely insensitive to stand

Figure 1. Agroforestry kayu bawang + coffee (left) and kayu bawang + cacao (right) smallholder plantations of kayu bawang in Bengkulu Province

density and thinning regimes (Alder, 1980). In order to facilitate the application of site index model to a broader range of situation, some researcher incorporated climatic, edaphic, and physiographical aspects in the model development (Ovideo, Tome, Bravo, Montero, & del Rio, 2008; Beulieu et al., 2011; Khouri, Alvarez, Lopez, Prendes, & Obregon, 2011; Sharma, Brunner, & Eid, 2012; and Scolforo, Maesti, Filho, de Mello, de Oliveira, & de Assis, 2013).

Information on site quality is an important prerequisite for forest management planning (Sharma et al., 2012). For kayu bawang tree species, this information is required by the government (District Forestry Agency), the farmers and the other relevant forestry stakeholders. The government use the information of site quality to select the site where plantations will be established, while the farmer or landowner use it to implement the optimum management planning under certain conditions of demand, productivity, cost of silviculture and harvesting (Scolforo et al., 2013). This paper describes quantification of site quality of smallholder plantations of kayu bawang in Bengkulu Province to fill the information gap concerning growth of this species. Climatic and edaphic conditions are described for each site class in order to increase its application for management planning of this tree species.

II. MATERIAL AND METHOD

A. Data Description

Research was conducted from 2006 to 2012 on smallholder plantations of kayu bawang by establishing 32 permanent sample plots (PSPs) in a square shape of 30 m x 30 m, distributed over six districts of Bengkulu Province. The PSPs were located in North Bengkulu (11 PSPs), Central Bengkulu (7 PSPs), Rejang Lebong (6 PSPs), Kepahiang (1 PSP), Seluma (3 PSPs), and South Bengkulu (4 PSPs) Districts (Table 1, Figure 2). Almost all plots were initially planted in agroforestry system with coffee. Only 2 plots in Talang IV, Central Bengkulu and 1 plot in Kampung Delima, Rejang Lebong were in an agroforestry system with cacao.

Permanent sample plots were established by selecting smallholder plantations with relative equal frequency of various site quality, stand density and age class. Based on these criteria, PSPs were established on sites with altitude

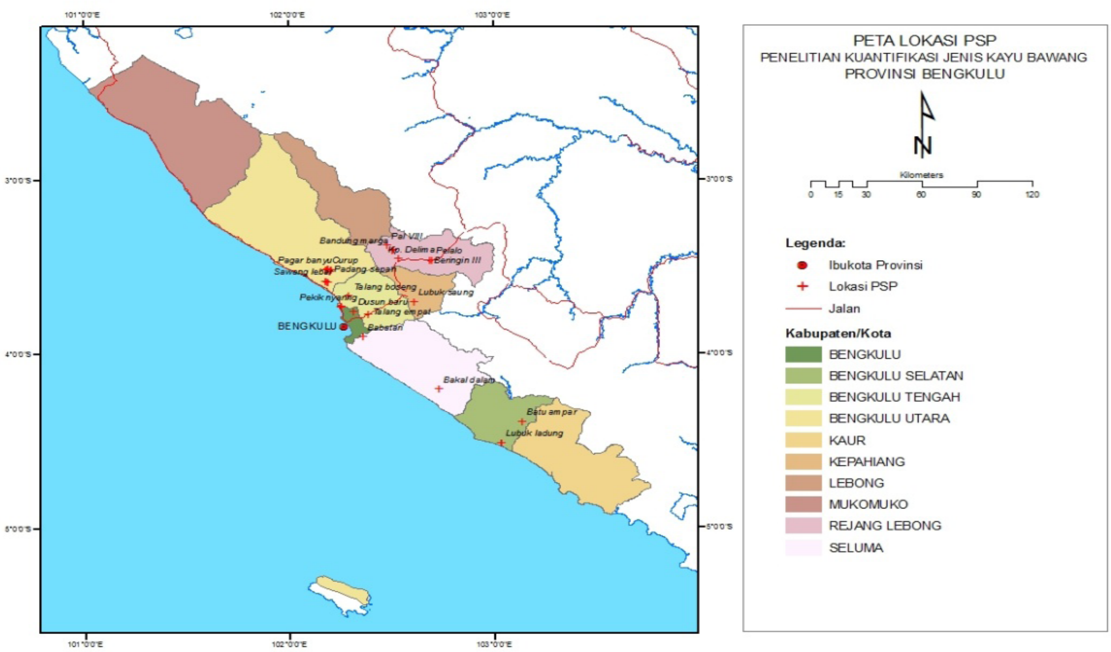

Figure 2. Map of permanent sample plots (PSPs) for site quantification of kayu bawang in Bengkulu Province

Table 1. List of PSPs locations for Kayu bawang Site Quantification in Bengkulu Province

No.	District	Village (number of plot)	Geographycal coordinate	Altitude(m)
1.	North Bengkulu	Sawang Lebar (4)	102° 10' 49" E; 03°35'07" S	46-56
		Dusun Curup (2)	102° 11' 20" E; 03°30'54" S	86-88
		Genting Perangkap (2)	102° 10' 50" E; 03°31'16" S	91-95
		Padang Sepan (1)	102° 11' 53" E; 03°31'50" S	86
		Pagar Banyu (2)	102° 12' 07" E; 03°31'08" S	106
2.	Central Bengkulu	Pasar Pedati (2)	102°14'35"E; 03°43'11" S	24
		Pekik Nyaring (2)	102° 15' 10" E; 03°43'59" S	8
		Talang Boseng (1)	102.29185°E; 03.66858°S	52
		Dusun Baru (1)	102.31565°E; 03.76000°S	80
		Talang Empat (1)	102.38407°E; 03.77526°S	59
3.	South Bengkulu	Batu Ampar (1)	103.13814°E; 04.39450°S	277
		Lubuk Ladung (2)	103.03434° E; 04.51560°S	96
		Pagar Dewa (1)	102°53'52" E; 4°26'11" S	25
4.	Seluma	Bakal Dalam (1)	102.73258°E; 04.20771°S	43
		Taba (1)	102.73261°E; 04.20766°S	33
		Babatan (1)	102.35807° E; 03.90380° S	8
5.	Kepahiang	Lubuk Saung (1)	102.60946° E; 03.70277° S	529
6.	Rejang Lebong	Bandung Marga (2)	102.50582° E; 03.40670° S	885-891
		Pal VIII (1)	102.47994°E; 03.37851°S	923
		Kp. Delima (1)	102. 53171°E; 03.45536° S	694
		Pelalo (1)	102.69809° E; 03.46332°S	873
		Beringin III (1)	102.68678° E; 03.46524° S	974

Remark: Map of these geographical coordinates is presented in Figure 2

ranging from 8 to 974 m above sea level, rainfall from 2002 to 3956 mm/year, stand density from 150 to 1389 trees/ha, and stand age ranged from 2 to 13 years. Data from 32 PSPs consisted of 184 measurements which were divided into two parts for fitting and validation models. Fitting model used data from 20 PSPs consisting of 121 measurements and the remaining 12 PSPs (63 measurements) were used for validation. Statistical description of fitting and validation data regarding dominant height is shown in Table 2. Each PSP was generally measured periodically once a year from 2006 to 2012 so each plot was measured seven times but several PSPs were cut during the measurement period.

B. Soil Sampling and Climatic Data Collection

Soil samples were collected from each plot using two methods. The first method was collecting soil samples from four sides of the soil profiles at a depth of 0-30 cm and 30-60 cm. The samples from the same depth were pooled as a composite sample from each plot. The second method was collecting soil samples by using a ring sample at the same depth as the first method. The properties of the soil samples were analyzed in the soil laboratory. The samples collected by the first method were analyzed to get information on texture, pH, organic matter, nutrient content (N, P, K, Ca,

Table 2. Statistic description of fitting and validation data models for dominant height growth of kayu bawang in Bengkulu Province

Age (year)	Fitting data					Validation data				
	n	Mean (m)	SD (m)	Min (m)	Max (m)	n	Mean (m)	SD (m)	Min (m)	Max (m)
2	12	8.15	1.82	4.3	11.1	6	10.32	1.37	8.7	11.9
3	4	10.38	2.37	7.1	12.4	4	11.38	2.43	8.0	13.5
4	8	12.75	2.40	8.7	15.5	4	14.68	2.67	11.7	18.2
5	8	13.82	3.12	6.9	16.6	4	14.22	1.81	11.9	15.9
6	9	16.28	3.62	8.3	20.4	5	18.52	2.32	14.5	20.5
7	5	16.82	4.22	10.5	22.2	4	20.13	3.59	16.5	23.6
8	13	16.65	2.86	11.4	23.4	8	18.65	3.19	11.2	21.4
9	14	17.62	3.08	11.9	23.6	8	20.59	3.54	14.0	25.8
10	18	19.27	2.45	14.1	23.9	8	23.20	4.10	14.5	26.9
11	14	20.31	2.92	14.2	25.2	6	23.10	4.59	14.9	28.3
12	9	21.01	3.82	14.6	26.2	6	22.40	5.77	15.3	28.5
13	7	21.29	3.81	14.6	27.9					
Total	121					63				

Table 3. Statistic description of fitting and validation data models for dominant height growth of kayu bawang in Bengkulu Province

Equation	a_0	b	R^2 (%)	AMRES	APD (%)
$\ln H_0 = (3.06 + a_i) - 2.05/A$	3.06	-2.05	96.5	0.82	5.03
$H_0 = (1.92 + a_i) + 7.18 \ln A$	1.92	7.18	96.0	0.95	32.48

Mg), and cation exchange capacity. The samples collected by the second method were analyzed to get information on bulk density. Rainfall data were collected from the Indonesian Agency for Meteorology, Climatology and Geophysics.

C. Procedure for Developing Site Index Model

Site index model was developed by establishing a 100 m x 100 m PSP. Dominant height is defined as the average of the 100 highest trees or the average height of the 100 largest DBH trees per hectare. The latter definition has been used by Krisnawati, Wang, Ades, and Wild (2009) to model site index of Acacia mangium plantations in South Sumatra. Due to the small area of smallholder plantations of kayu bawang in the study sites, quantification of site quality of kayu bawang was conducted through establishing square PSPs of 30 m x 30 m. For each PSP, heights of the 10 dominant trees were measured with a laser dendrometer. The average heght of the 10 dominant trees was used as dominant height (Ho) and as an indicator of the site quality.

Site quality is expressed in an equation as a relationship of dominant height over stand age. The site index equation was developed by the guide curve method. The guide curve method is used to generate a set of anamorphic site index curves. Two non linear models were selected as candidates for the base equation. These were the Schumacher model (used by Alder, 1980) and the model used by Avery and Burkhart (1994). These two models and its derivative models were commonly used to model site index for some forest plantations in Indonesia (e.g. Harbagung (1991); Puspasari & Achmad (2000) for *Acacia mangium* and Darwo, Suhendang, Jaya, and Purnomo (2012) for Eucalyptus. The two models are:

Ln Ho = a + b/A (Schumacer, 1937).................(1)

Ho = a + b (Ln A) (Avery and Burkhart, 1994)...(2)

Where:
Ho = dominant height (m), A = stand age (year), a, and b = coefficients

Data from each PSP were analyzed by applying a nested regression to differentiate the site quality difference of each plot. The difference of site quality between plots is expressed by different intercept as shown in equation 3 and 4 as:

Ln Ho = (a0 + ai) + b/A ....(3)

Ho = (a0 + ai) + b (Ln A) ....(4)

Where:
A = stand age (year), a0= intercept for plot 1, ai= differential intercept for the-i plot; (i = 2, 3,…32)
Site quality index is the dominant height at a reference age called the index age. For kayu bawang, an index age of 12 year was selected, which is approximately its rotation age. If the age of a stand is below the reference age, site index is estimated by the following equation:

Ln Si = Ln H0 + b (1/Ai-1/A) ....(5)

SI = H0 + b (ln Ai – ln A) ....(6)

Where:
SI = site index, Ho = dominant height (m), A = stand age (year), and Ai = index age

D. Model Evaluation

Besides biological or logical consideration of kayu bawang's height growth, model evaluation was conducted based on both model's fitting and validation statistics. There are several statistical fitting models which are usually used for model evaluation such as asymptotic t-statistic, adjusted coefficient of determination (R^2_{adj}), root mean square error, and residual analysis (Krisnawati et al., 2009). Darwo et al. (2012) used a coefficient of determination (R^2) and variance analysis (F-test). For this evaluation purpose, the fit statistic used was the coefficient of determination (R^2), because evaluation of regression analysis based on R^2 as a single criteria has the same result as the evaluation that included other statistical criteria simultaneously. It can be proven that other statistical tests like mean square error (MSE) and F-value can be derived from the value of R^2.

Model validation is aimed to see if the quality of the fit reflects the quality of the predictions. Several validation statistics recommended by Huang, Yang, and Wang (2003) and used by Krisnawati et al. (2009) for *Acacia mangium* plantations in South Sumatra are: mean residual (MRES), absolute mean residual (AMRES), root mean square error (RMSE), and the adjusted model efficiency (MEF adj). Husch et al. (1963) recommended aggregate difference (AD) and average percentage deviation (APD) as used by Harbagung (1991). For this evaluation, two validation statistics, the mean residual (MRES) and the average percentage deviation (APD) were used and calculated by the following formula:

$$AMRES = \frac{\sum \left| Y_i - \hat{Y} \right|}{n}$$

$$APD = \frac{\sum \frac{\left| Y_i - \hat{Y}_i \right|}{Yi}}{n} x100\%$$

III. RESULT AND DISCUSSION

A. Dominant Height Growth

Dominant height growth model was developed based on 32 PSPs of kayu bawang by applying the nested regression method. Results of analysis are expressed in equations (1) and (2). The coefficients of regression a0, ai, and

Table 4. Value of differential coefficient ai and intercept for the two models of kayu bawang dominant height growth in Bengkulu Province

No Plot	Model 1			Model 2		
	a_0	a_i	$a = a_{0} + a_{i}$	a_0	a_i	$a = a_{0} + a_{i}$
1.	3.06	-	3.06	1.92	-	1.92
2.	3.06	-0.05	3.01	1.92	-0.75	1.17
3.	3.06	0.08	3.14	1.92	0.69	2.61
4.	3.06	0.14	3.20	1.92	1.59	3.51
5.	3.06	0.04	3.11	1.92	0.95	2.87
6.	3.06	-0.12	2.94	1.92	-0.92	1.0
7.	3.06	-0.11	2.95	1.92	-2.71	-0.79
8.	3.06	0.12	3.18	1.92	1.55	3.48
9.	3.06	-0.11	2.95	1.92	-2.02	-0.10
10.	3.06	0.09	3.15	1.92	0.55	2.47
11.	3.06	0.12	3.18	1.92	1.09	3.02
12.	3.06	-0.58	2.48	1.92	-6.14	-4.22
13.	3.06	0.08	3.15	1.92	0.57	2.49
14.	3.06	-0.31	2.76	1.92	-3.26	-1.34
15.	3.06	0.17	3.24	1.92	3.12	5.04
16.	3.06	0.33	3.39	1.92	6.24	8.17
17.	3.06	0.35	3.42	1.92	5.05	6.97
18.	3.06	0.20	3.27	1.92	2.64	4.57
19.	3.06	0.24	3.31	1.92	3.34	5.27
20.	3.06	0.36	3.42	1.92	5.04	6.96
21.	3.06	0.10	3.17	1.92	1.40	3.32
22.	3.06	0.13	3.19	1.92	2.68	4.60
23.	3.06	0.26	3.32	1.92	4.98	6.90
24.	3.06	0.23	3.29	1.92	4.21	6.13
25.	3.06	0.23	3.29	1.92	4.05	5.97
26.	3.06	0.22	3.29	1.92	3.32	5.24
27.	3.06	0.27	3.34	1.92	3.99	5.91
28.	3.06	0.19	3.26	1.92	3.44	5.36
29.	3.06	0.07	3.13	1.92	1.82	3.74
30.	3.06	0.07	3.13	1.92	1.76	3.69
31.	3.06	0.13	3.19	1.92	1.66	3.59
32.	3.06	0.12	3.19	1.92	1.78	3.71

b for each equation are shown in Table 3. The coefficients ai for model 1 ranges from -0.58 to 0.36 and for model 2 from -6.14 to 6.24 (Table 4). The difference of coefficient ai shows that there is a difference in site quality among the plots. The lowest coefficient indicates the poorest site quality of the plot and adversely to the highest coefficient.

When the accuracy of the models was compared, both models performed reasonably well with high coefficient of determination (R^2>95%). However, model 1 (Ln H0 = (3.06 + ai) – 2.05/A) compared to model 2 (H0 = (1.92 + ai) + 7.18 ln A) is the better model for dominant height growth of kayu bawang because it has the lower deviation both AMRES

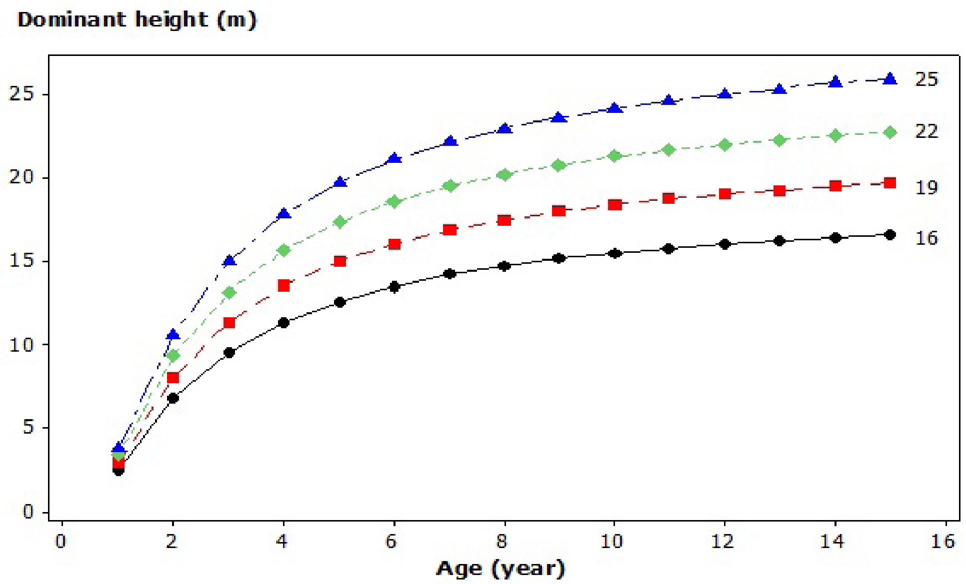

Figure 3. Dominant height curve of kayu bawang at Bengkulu Province for site indices 16, 19, 22, and 25

Table 5. The location of five site classes of kayu bawang stands in Bengkulu Province

No.	Site classes (m)	Plot location (village)
1.	< 16	Beringin III and Pelalo (Rejang Lebong)
2.	16 ≤ SI < 19	Pasar Pedati, Pekik Nyaring, Dusun Baru (Centre Bengkulu); and Bandung Marga (Rejang Lebong)
3.	19 ≤ SI < 22	Talang IV, Talang Boseng (Centre Bengkulu); Sukaraja, Taba (Seluma); Kp Delima, Pal VIII, Bandung Marga (Rejang Lebong); Lubuk Saung (Kepahiang), Sawang Lebar, Padang Sepan, and Genting Perangkap (North Bengkulu).
4.	22 ≤ SI < 25	Lubuk Ladung (South Bengkulu); Dusun Curup, Genting Perangkap, and Pagar Banyu (North Bengkulu)
5.	> 25	Batu Ampar, Pagar Dewa (South Bengkulu), and Bakal Dalam (Seluma).

and APD (Tabel 4). Model 1 was also used by Darwo (2012) to quantify site quality of Eucalyptus plantations in North Sumatra, but 10 based logarithms was used in the model. He used both equations of log OH = 1.48 – 0.69/A and log S = log OH + 0.69 (1/A – 1/8) to predict dominant height growth and site index of Eucalyptus in South Sumatra. Puspasari and Achmad (2000) also used the same model to predict site index for Acacia mangium in Riau Province. The model used is anamorphic model i.e. log H = 1.59 – 0.94/A and log SI = log H – 1.59 (1/A – 1/8). All the results of these studies showed that site classification by stand dominant height growth has become the most common and suitable practice for forest plantations in Indonesia, including smallholder plantations.

In selecting the most appropriate model, a compromise between biological and statistical

Table 6. Correlation between site characteristics and site indices of kayu bawang in Bengkulu Province

Site characteristics	SI	Alt	RF	BD	Nt	P	K	Snd
Alt	-0.541							
RF	0.014	-0.076						
BD	0.568	-0.699	0.390					
Nt	-0.313	0.836	-0.244	-0.790				
P	0.396	-0.099	0.377	0.247	-0.130			
K	0.037	0.161	0.091	0.052	0.018	0.044		
Snd	-0.056	0.550	-0.176	-0.295	0.595	-0.241	-0.172	
Cly	0.190	-0.747	0.083	0.366	-0.713	0.183	-0.063	-0.854

Remarks: SI = site index, Alt = altitude (m asl.), RF = rainfall (mm/year), BD = bulk density (g/cm3), pH = soil acidity, Nt = N total (%), P = phosphor (ppm), K = Kalium (me/100 g), Snd = sand (%), Cly = clay (%)

considerations have been made, rather than a pure statistical inference (Krisnawati, 2007). Model 2, although it has a high coefficient of determination and small AMRES, produces an unrealistic prediction, the negative value of dominant height at younger ages for plots that have differential intercept ai < -1.92. For example, if ai = -2. 92 at age (A) = 1 year, based on model 2, H0 = (1.92 - 2.92 + 7.18 ln (1) = -1. Negative value of a dominant height is unrealistic; therefore, logically model 2 was not preferred.

B. Site Index and Site Class

Based on model 1 with the selected reference age of 12 years, the site index equation for kayu bawang was determined as: Ln Si = Ln H0 – 2.05 (1/12-1/A). Substituting differential intercept ai in the site index equation, then the site index of kayu bawang ranges between 10.09 and 28.50 meter. For site classification purposes, site indices were divided into 5 classes, with an equal range of 3 meters intervals. The following site classes were established: SI < 16 m, 16 m ≤ SI < 19 m; 19 m ≤ SI < 22 m; 22 m ≤ SI < 25 m; and SI ≥ 25 m for site classes I, II, III, IV, and V respectively from the lowest to the highest productivity. Site classes can be expressed by a curve that shows the growth of the dominant height at one point of the site index. The five different site indices of 16, 19, 22, and 25 meters (Figure 3) are anamorphic curves, which consist of proportional site index curves. The curves are produced by five equations with different intercept (a) but with the same slope (b).

Based on this site classification, growth of kayu bawang in Bengkulu Province was divided into 5 site classes. The distribution of the location of each site class is shown in Table 5. Site class I (SI < 16 m) was found only in Rejang Lebong District that constitutes of two PSPs in Beringin III and Pelalo villages. Site index II was found in Rejang Lebong and Centre Bengkulu District. The site that was categorized as the medium site class (Site index III) is located almost in all districts of Bengkulu Province, with the exception of South Bengkulu District. Site indices IV and V were found in South Bengkulu, North Bengkulu and Seluma District.

Site classification can be related to the physical environment variables such as altitude, rainfall, and soil characteristics (Table 6). Based on the coefficient of correlation as shown in Table 6, two environmental variables, altitude and soil bulk density, have significant effect on the site index of kayu bawang. Altitude has

Table 7. The range of site characteristics for each site class of kayu bawang in Bengkulu Province

Site characteristic	Site index (number of locations)				
	I (2)	II (4)	III (8)	IV (3)	V (3)
Alt	873-974 924	9-885 238	8-923 405	86-115 105	12-277 111
RF	2668- 3528 2974	2782-3089 2993	2333-3876 2965	2500-3079 2886	2002-3956 3168
BD	0.73-0.80 0.77	0.60-1.15 0.96	0.67-1.36 1.02	0.93-1.49 1.29	1.07-1.33 1.24
Nt	0.39-0.41 0.40	0.15-0.61 0.29	0.17-0.54 0.32	0.17-0.31 0.24	0.17-0.38 0.25
P	7.05-9.30 8.18	2.25-14.1 7.50	4.65-13.35 8.44	5.55-6.75 6.30	13.6-58.7 31.43
K	0.19-0.38 0.29	0.13-0.96 0.46	0.19-1.28 0.45	0.26-0.32 0.28	0.19-0.58 0.34
Snd	61.84-63.97 62.91	39.67-71.68 53.56	37.67-80.73 55.42	58.78-65.58 62.11	36.48-83.75 57.90
Cly	7.66-8.17 7.92	7.96-31.59 24.26	7.76-36.59 20.21	11.5-14.2 13.14	7.61-32.6 20.88

Remarks: SI = site index, Alt = altitude (m asl.), RF = rainfall (mm year^{-1}), BD = bulk density (g cm$^{3\ -1}$), pH = soil acidity, Nt = N total (%), P = phosphor (ppm), K = Kalium (me/100 g), Snd = sand (%), Cly = clay (%)

negative effect on the site index, so the higher the altitude the poorer is the site index for kayu bawang. In line with this fact, both locations of site class I, the poorest site, was found on the upland areas at an altitude of > 850 m above sea level on andosol soil type. Adversely, the best site (site classes IV and V) were found on lowland areas with altitude < 300 m above sea level on ultisol soil type (Table 7).

The other physical characteristic that has significant correlation with site quality is bulk density. A positive correlation between site index and soil bulk density with r = 0,568 (Table 6) is caused by the fact that at low altitude, the location with the higher site index, the bulk density tended to increase until 1,49 gr cm$^{3\ -1}$, so it seems that the increase in bulk density has positive effect on the site index. It was found that at the upland site soil bulk density was less than 0.9 gr cm$^{3\ -1}$ and adversely at the lower sites it was higher than 0.9 gr cm$^{3\ -1}$. Although the soil with low bulk density derived from amorphous or volcanic material (Hardjowigeno, 2003; Sutanto, 2005; Rachim & Arifin, 2011) was a fertile soil, the upland site of the soil caused some negative effect on site quality. On the upland site in Rejang Lebong it was found that the soil had low proportion of clay and adversely high proportion of sand. Usta, Yilmaz, and Altun (2013) confirms the negative correlation between altitude and clay content of the soil. The decrease of clay ratio on the upland site can be explained by the decrease in temperature. Although humidity (moisture) conditions were sufficient, the insufficient temperature level negatively affected the disintegration and thus, the amount of clay per unit volume of soil was found to be at low levels (Usta et al., 2013).

IV. CONCLUSION

Site index equation based on the dominant height-age relationship as proposed by Schumacher was selected as the best model for classifying site quality of smallholder plantations of kayu bawang in Bengkulu Province.

The site quality of kayu bawang is classified into five classes with an equal range of 3 m, i.e. SI < 16 m; 16 m ≤ SI < 19 m; 19 m ≤ SI < 22 m; 22 m ≤ SI < 25 m; and SI ≥ 25 m for site classes I, II, III, IV, and V, respectively from the poorest to the highest site productivity.

Site class I, the poorest site, was found on the upland site with an altitude of > 850 m above sea level on andosol soil type, adversely, the best site (site class V) was found on lowland areas with an altitude of < 300 m above sea level on ultisol soil type

ACKNOWLEDGEMENT

We thank Mr. Darwis for field assistance, and Mrs Anik Sriwahyuni SPKP, MSi for giving access to established PSP on her land. We also thank Mr. Kisno, SP, MSi and Efratenta, S.Hut., MSi, lecturers of Bengkulu University, for providing guidance in determining soil characteristic.

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POPULATION STRUCTURES OF FOUR TREE SPECIES IN LOGGED-OVER TROPICAL FOREST IN SOUTH PAPUA, INDONESIA: AN INTEGRAL PROJECTION MODEL APPROACH

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Received: 20 December 2013, Revised: 19 October 2015, Accepted: 21 October 2015

POPULATION STRUCTURES OF FOUR TREE SPECIES IN LOGGED-OVER TROPICAL FOREST IN SOUTH PAPUA, INDONESIA: AN INTEGRAL PROJECTION MODEL APPROACH. Selective logging has been taking place in Papua for several decades. In contrast, very little is known about the stand structure in post-logged forest. Hence, this paper investigates stand structures in logged-over area of tropical forest in South Papua. Four species were selected in three one-hectare permanent sample plots (PSPs): *Vatica rassak*, *Syzygium* sp, *Litsea timoriana* and *Canarium asperum*. PSPs were located in the forest concession area of PT. Tunas Sawaerma in Assiki, Boven Digul, in South Papua. Data sets comprised measurements made in 2005 and 2012 consisting of species, diameter at breast height (DBH), mortality and number of tree of each species. Integral Projection Models (IPMs) were developed, taking into account mortality, growth, recruitment and fecundity. Results show the pattern of stand structures of the four species were more or less similar, i.e. more individual trees were present in the small diameter classes than in the larger diameter classes. The general pattern of the individual distribution of the four species is the typical reverse-J shape. *Syzygium* sp. has a greater number of individuals in the small diameter classes than the other three species. Population growth rates (λ) are above one, indicating that the stand structures of the population dynamics of the four species are recuperating. Conclusively, these results suggest that species composition and population structure in these logged-over forests are recovering increasingly.

Keywords: Permanent sample plots, population growth rate, harvest activity

STRUKTUR POPULASI DARI EMPAT SPESIES POHON DI HUTAN BEKAS TEBANGAN, PAPUA SELATAN, INDONESIA: SEBUAH PENDEKATAN DARI INTEGRAL PROJECTION MODEL. Penebangan hutan masih berlangsung di Papua, namun informasi mengenai struktur tegakan masih belum banyak. Tulisan ini mempelajari struktur populasi dari tegakan pada hutan bekas tebangan di daerah Papua Selatan. Empat species yang tumbuh dalam Petak Ukur Permanen (PUP) diamati adalah Vatica rassak*,* Syzygium sp.*,* Litsea timoriana *dan* Canarium asperum. *PUP berlokasi di PT Tunas Sawerma, Asiki, Boven Digul, Papua. Dataset diperoleh dari pengukuran tahun 2005 dan 2012 yang terdiri dari jenis, jumlah individu dan diameter. Selanjutnya, Intergral Projection Models digunakan untuk menganalisis struktur tegakan dengan menggunakan mortality, pertumbuhan, recruitment dan fecundity ke dalam persamaan. Hasil simulasi model menunjukan bahwa model struktur tegakan dari keempat species adalah sama dimana banyak individu yang berada pada pohon dengan diameter kecil dibandingkan dengan jumlah individu pada pohon yang berdiameter besar. Secara umum, bentuk distribusi dari individu-individu dari kempat jenis tersebut adalah J terbalik. Selanjutnya,* Syzygium sp. *adalah species yang memiliki individu yang lebih banyak dibandingkan dengan ketiga species lainnya. Struktur populasi tegakan dari keempat species tersebut bergerak tumbuh setelah penebangan dimana ditunjukkan oleh nilai population growth rate (λ) di atas satu. Oleh karena itu, hutan bekas tebangan ini memiliki kemampuan untuk kembali pulih dan bisa mencapai fase klimaks.*

Kata kunci: Petak ukur permanen, population growth rate, kegiatan penebangan

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I. INTRODUCTION

Indonesia's natural forests are globally significant, for both their ecosystem service and commercial wood production values (FAO, 2011). Indonesia has also been experiencing significant loss and degradation of its primary forests (Margono et al., 2014). These pressures mean that it is more important than ever to apply proper forest management in natural tropical forests managed for production (Putz & Romero, 2015). This include the implementation of the Annual Allowable Cut (AAC) principles which, if applied correctly, will allow sustainable harvests over time (Vanclay, 1996). There are also various other considerations in ensuring sustainable production, such as appropriate silvicultural management through selective harvesting, retention of a specified number of remaining trees, specification of a minimum cutting diameter (MCD) and certain cutting cycle, and post-harvest tending. The period of cutting cycle needs to be determined with both economic and ecological considerations in mind. As an example, Indonesia has a 40 year cutting cycle with a timber volume of about 67 m^3 ha^{-1}, which is economically profitable (Sist, Picard, & Gourlet-Fleury, 2003). As another example, in Brazil's natural forests, the total volume of commercial species can increase after logging and good management; the tree growth rates and tree density below the minimum cutting diameter play an important role in the productivity of the second cycle (Dauber, Fredericksen, & Pena, 2005). Moreover, growth rate of trees after logging will increase when silvicultural treatments are applied (Krisnawati & Wahjono, 2010; Murdjoko, 2013). Therefore, in order to understand and monitor the post-logging recovery process and forest dynamics, continuous inventory is needed both before and after harvesting (Vanclay, 1996).

Dynamic models are now increasingly being developed to facilitate this understanding and monitoring. The forest is modeled as a system that contains interrelated elements to simulate cause-effect relationships and to predict future population of forest (Vanclay, 1994). The models need periodical measurement data, which can be obtained from annual measurements of tree diameter and analysis of tree ring growth. Such data have already been used to carry out studies in forest modeling. For instance, in Bolivia sustaining timber yields for emergent species can be reached by applying silvicultural treatments based on the simulation of forest dynamics (e.g. Brienen & Zuidema, 2006). As another example, the structure of the stand can be modeled by forming a transition matrix to represent the growth of stands, including recruitment, fecundity and mortality (e.g. Rusolono, Parthama, & Rosmatika, 1997; Krisnawati, Suhendang, & Parthama, 2008).

Indonesia is one of the main producers of topical timber. Production forests covering about 61% of total forest area (Ministry of Forestry, 2010). One of the regions with a large area of tropical moist forests is Papua, with a forest extent of 41 million ha. These forests consist of 27 million ha of primary forest, 5 million ha of secondary forest, and 9 million ha of other forest. In primary forest, most part of the forests is used for production and conservation. (Forestry Department, 2007). Based on data from Indonesian Ministry of Forestry (2010), there are eight forest utilization companies that have been given permission to operate in Papua. Therefore, this level of harvesting means that it is important to monitor the recovery of logged-over forests in Papua.

However, valid information on how stand structures of populations are formed after logging is not generally completely. Therefore, this research has analyzed the periodic data-set of four species obtained from permanent sample plots in logged-over forests, using Integral Projection Models (IPMs) (Zuidema, Jongejans, Pham, During, & Schieving, 2010). IPMs are developed from estimated matrix models and still provide the same output as the matrix models (Easterling, Ellner, & Dixon, 2000; Zuidema et al., 2010). Furthermore, IPMs provide two advantages compared to the matrix model. Firstly, the IPMs take vital stand parameters (population growth, sensitivity, elasticity and age estimates) into account. Secondly, variations among individuals are integrated, while matrix models produce large variation (Zuidema et al., 2010). The IPMs are appropriate to describe long-term growth of trees (Zuidema, Brienen, During, & Guneralp, 2009; Zuidema et al., 2010; Zuidema, Vlam, & Chien, 2011). One output of IPMs is a stable population of individuals that can be used to describe stand structure. The purpose of the study is to predict stand structure of population in logged-over area in tropical forests in South Papua using IPMs.

II. MATERIAL AND METHOD

A. Study Area

This study was located in a forest concession area of PT. Tunas Sawaerma in Assiki, Boven Digul, Southern Part of Papua, where forest has been selectively harvested in 2004 (Figure 1).

The AAC in 2004 was 88.247 m^3 yr^{-1}. After logging, three hectares of the logged forest area were set aside for permanent sample plots (PSPs) of one ha each. The distance between plots was 100 m. Coordinates of this location was 6°37'14.0" South 140°39'43.6" East using datum WGS 84. In each PSP, 4 tree species were studied, as described below. The diameter of the trees was measured in 2005 and 2012, and the mortality and recruitment were recorded for the same years. To get an overview of the condition of this forest, all trees in PSPs were also measured to describe stand density, using basal area as presented in Table 1.

In PSPs, there is no enrichment planting, in order to allow remaining trees grow naturally. Multi layers in the canopy forming strata characterize this forest. Understories comprise shrubs, herb layers and associates with seedlings from trees along with epiphytes, ferny plants and climbing plants. The soil is primarily alluvial, and climatic conditions are characterized by a mean annual rainfall ranging from 3000 to 4000 mm and mean annual temperature of 32°C. Elevation is approximately 30 m above sea-level (PT Tunas Sawaerma, 2009).

B. Study Species

According to the report of PT Tunas Sawaerma (2009), the principal commercial species are meranti species including resak (*Vatica rassak*), kenari (*Canarium aspermum*), rimba campuran (*Syzigium* sp.) and medang

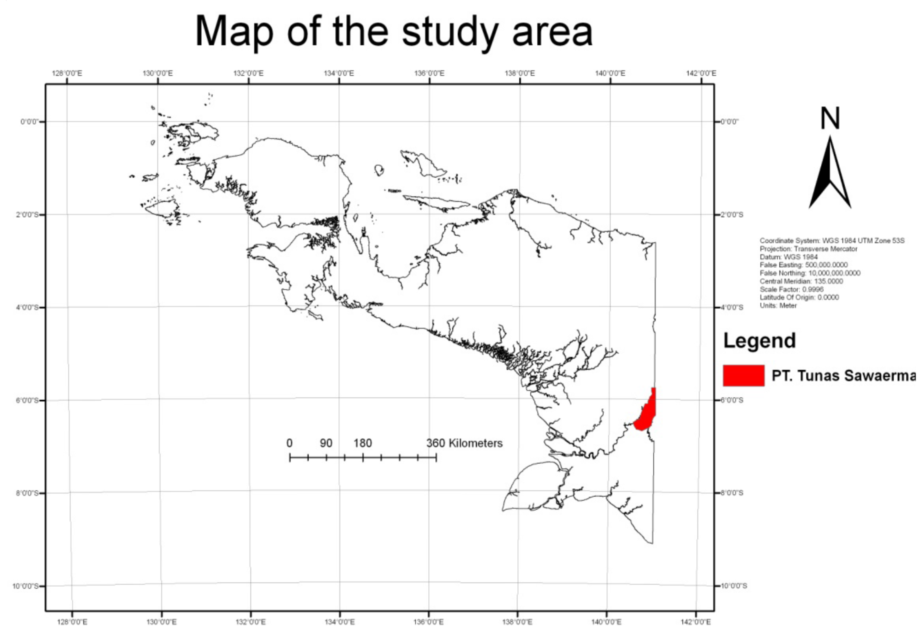

Figure 1. Map of the study area in PT. Tunas Sawaerma, Boven Digul, Papua

Table 1. Basal area of trees in PSPs based on diameter class and year

No.	Diameter Classes (cm)	Basal area (m^2 ha^{-1})		Standard deviation	
		2005	2012	2005	2012
1	10-19	4.21	6.93	0.55	0.09
2	20-29	4.62	7.43	0.41	0.35
3	30-39	4.46	5.71	0.38	1.41
4	40-49	2.92	3.53	1.26	0.77
5	50 +	4.73	5.33	3.83	3.94

(*Litsea timoriana*). The principal non-commercial species are *Actinodapne nitida*, *Beiscmedia* sp, *Blumeodendron amboinicum*, *Linociera macrophylla*, *Meduchantera* sp and *Pimeliodendron amboinicum*. The four dominant commercial species were selected for analysis in this study in Table 2.

C. Data

The data measured in 2005 and 2012 consisted of species, diameter at breast height (DBH), mortality and number of tree of each species. The minimum diameter of measured trees was 10 cm with an accuracy of measurement was 0.1 cm. DBH of the tree was measured to analyze growth. Mortality of the trees was recorded by counting number of dead trees in 2012. Recruitment was recorded by the number of trees that entered diameter class 10 cm in 2012.

D. Integral Projection Models

Integral Projection Model (IPMs) were developed to analyze populations of trees in the logged forest. To build IPMs, equations of survival probability, growth, variance of growth, and mean number of new individuals of trees were prepared. Easterling et al. (2000) demonstrated that the projection matrix is replaced by a projection by Kernel $K_{(y,x)} = P_{(y,x)} + F_{(y,x)}$. P is survival and growth from state x (*time t*) to state y (*time t+1*) and F is the production of state y of new individual

$$n_{(y,t+1)} = \int_L^U K_{(y,x)} n_{(x,t)} dx$$

trees. The Kernel function is written as:
where (L, U) is the range of possible sizes, $n_{(x,t)}$ is the distribution function n in time t, $n_{(y,t+1)}$ is the distribution function n in time t+1, K is Kernel which is a non-negative surface as a possible transition from size x (*time 1*) to size y (*time t+1*) and describes survival, growth and fecundity.

The mesh points are defined by dividing the interval (L, U) equally into m size classes and setting xi, at the midpoint of the i class :
Where h= (U-L)/m. The midpoint rule

$x_i = L + (i\text{-}0.5)h$,
$i = 1,2,....m$,

approximation to first equation above is:
Then, the multiplication of matrix is:

$$n_{(xi,\,t+1)} = h \sum_{j=1}^{m} k_{(xi,\,xj)}\, n_{(x,\,j,\,t)}$$

Where K is the matrix whose $(i,j)^{th}$ entry is

$n_{(t+1)} = Kn_{(t)}$

$hK_{(xi,xj)}$ and $n_{(t)}$ is the vector whose i^{th} entry is $n_{(xi,\,t)}$ (Ellner & Rees, 2006).

Stand structures of population were built when lambda (λ) was stable, where n as width of matrix was tested using 50, 100 and 500. IPMs were run using R version 2.13.2. (R Development Core Team. 2005). The stand structures describe the proportional distribution of individual trees based on groups of diameter at breast height (DBH) as discrete data. Then, IPMs computation were able to produce continuous data.

E. Estimation versus observation result

Horvitz and Schemske (1995) have proposed a proportional similarity index as one of the methods to validate the results obtained from model with observed data. Results of IPMs were compared with observed data in 2005 and 2012 using the proportional similarity index.
where in n stages and ai is the proportion

$$PS = \sum_{n}^{i-1} \min(a_i, b_i) \times 100$$

of individuals in the i^{th} stage of stable-stage distribution and bi is the proportion of individuals in the ith stage of the observed stage distribution. If Proportional Similarity Index (%) is close to 100%, it means that similarity is strong, and vice versa.

III. RESULT AND DISCUSSION

A. Stand structures of population

Figure 2 shows the distribution of individual trees of stands of each species proportionally over diameter.

In general, the distribution pattern of stand structures of the four species are more or less similar, where the number of trees declines as the diameter increases. The figure above shows the general pattern of individual distribution of trees which is characteristic of tropical forest (Fayolle et al., 2014). Moreover, in each population of each species, there is a greater number of individuals with diameter below 20 cm, and fewer individuals are present in diameter classes larger than 20 cm. Of the four species, *Syzigium* sp. has the largest number of small individuals, about 12 % of the population of this species; whereas for the other species, less than 8 % of the total individuals of the population is comprised of small individual trees. Further, the individuals of *Syzigium* sp have the widest diameter distribution. It can be seen from Figure 2 that their diameter is ranging from 10 cm to about 100 cm, while those of the three other species, namely *Canarium* sp., *Litsea timoriana* and *Vatica rassak*, have a diameter range of up to 50 cm only. There are also similar patterns in the stand structures of the

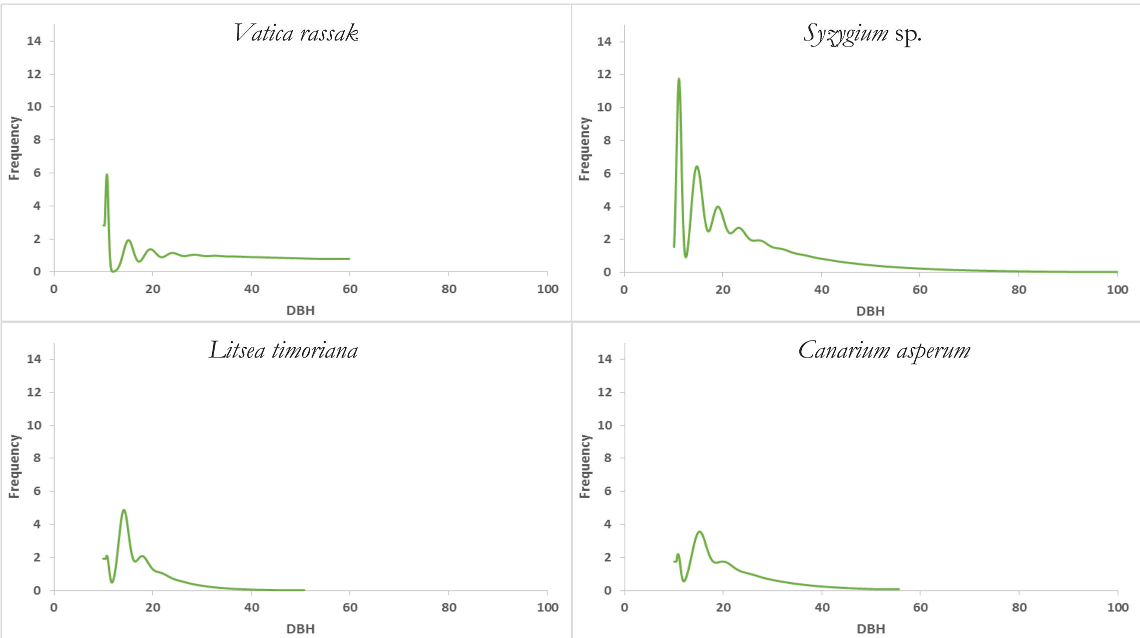

Figure 2. Stand structures with stable population of four species in logged forest. The stand structures were illustrated by plotting frequencies of individual trees over each diameter (cm) and n=500 number of matrices in simulation of IPMs when λ was stable

four species, where the number of individuals in diameter class just above 10 cm declines, and then increases. Finally, the number of individuals is reduced somewhat as the diameter of the individuals increases.

Besides the stand structures of the population, we also ran simulations to obtain population growth rate (λ). The population growth rates indicate how the stand structures of the population alters over time. In this study, we found that the population growth rates of the four species are greater than 1: 1.007, 1.28, 1.74 and 1.457 for *Vatica rassak*, *Syzygium* sp., *Litsea timoriana* and *Canarium asperum*, respectively. This indicates that stand structures of the population dynamics are increasing over time, and the pattern of population in the stand structures will be stable as displayed in Figure 2 where individuals of small diameter trees are more abundant than individuals of large diameter trees. The stand structures would probably change if disturbances such as windstorm or forest fire occurred in this area.

In this study, we were able to see how well the stand structures of each species predicted from IPMs compared to observed data in 2005 and 2012. In Figure 3, stand structures are illustrated as bar charts where each bar chart displays bar of IPM results and observed results (2005 and 2012). The bar charts were set by plotting relative frequencies against diameter classes with an interval of 5 cm.

The Proportional Similarity Index (%) of four species is presented in Table 3.

B. Stand dynamics after logging

The four tree species have similarities in the population shape of the stand structure, with individuals with small diameters more abundant than individuals with larger diameters. This phenomenon usually occurs in primary forest as a process of natural regeneration where a large tree produces many seeds. Then, the seeds germinate on the forest floor, producing seedlings which will grow and survive (Gorchov, Comejo, Ascorna, & Jaramillo, 1993; Plumptre, 1995). Then, the seedlings will possibly enter the next class as new individuals of trees.

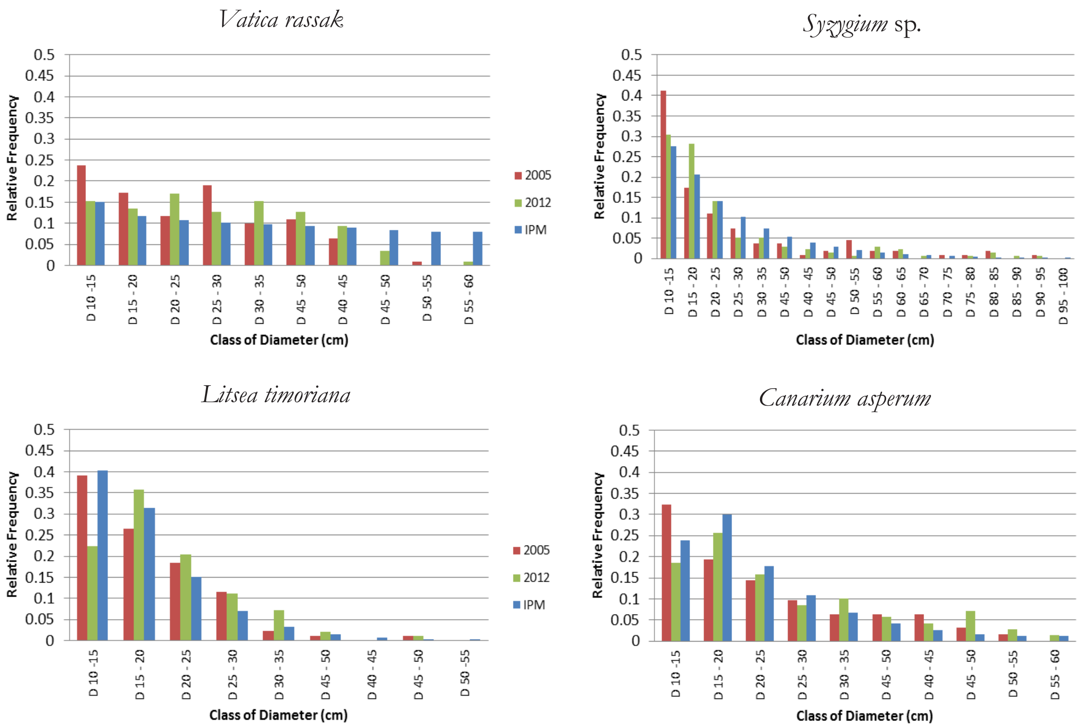

Figure 3. Comparison of stand structures of four species between observed results and results of IPM models

Table 3. Proportional Similarity Index (%) comparing stand structures between IPM and observed results

Name of tree species	Proportional Similarity Index (%)	
	(IPM results vs. observed results in 2005)	(IPM results vs. observed results in 2012)
Vatica rassak	73.97	79.80
Syzygium sp	79.84	84.65
Litsea timoriana	91.51	81.15
Canarium asperum	83.47	86.02

In this logged forest, not all large trees are harvested during logging activity. Therefore, the remaining trees are available to contribute producing new individuals (Kuswandi, 2014). Further, the forest canopy is more open as a result of tree cutting. This condition will allow more sunlight to reach forest floor in which seedlings are growing, and then understory can grow faster (Kennard, 2002; Edwards & Mason, 2006; Duah-Gyamfi, Swaine, Adam, Pinard, & Swaine, 2014). The increased number of seedlings is usually correlated with the extent of forest fragmentation (Cusack & McCleery, 2014). Further, Soil Organic Matter (SOM) can be more available for growth of understory in forest gaps (Throckmorton, Bird, Monte, Doane, Firestone, & Horwath, 2015).

Syzygium sp. has large number of small individuals compared to those of the three other species. This may be due to the larger number of individuals in larger diameters results contributing to regeneration. According to Kammesheidt, Kohler, and Huth (2001), different species growing in the same area have differences in the speed of succession. It seems from these results that the succession ability of Syzygium sp is higher than that of the three other species.

In terms of the population dynamics of stand structures of the four species, the total population increased over the period 2005 to 2012, subsequent to logging. The increase of population is by reason of increase of growth rate as a response to individuals receiving more light. The light can hit forest floor because of the gaps in the canopy are more open as an impact of logging activity (Villegas et al., 2009; Sist & Nguyen-The, 2002; Toledo et al., 2012). In addition, growth rate of individual trees specifically occur for individuals with small diameters. Therefore, growth rate and recruitment of new individuals have significant contribution in the increase of population of the four species. That can be seen from the population growth rate (λ) of the four species above (Lieberman, Lieberman, Peralta, & Hartshom, 1985).

The stand structures of the population of the four species from 2005 and 2012 are very dynamic because forest stands have been changing for several years owing to fast growth and recruitment. This can be seen from the Proportional Similarity Index (%) in 2005 and 2012, where the results of IPMs of *Syzygium* sp. and Litsea timoriana were more similar to stand structures in 2005 rather than stand structures in 2012, while for *Vatica rassak* and *Canarium asperum* were more close to stand structure in 2012. This means that secondary succession is taking place in logged forest.

The competition of trees after harvest is an indicator that forest is able to grow after harvesting. As stated by MacPhersona, Schulzec, Cartera, & Vidala (2010), the seedlings can grow to be mature, if determining factors such as light are available. Even though stand structures of forest changed as a result of logging, the stand structures are able to recover through natural process. The data here suggest that species composition in logged forest will not alter, because of the four species which are dominant are predicted to regain their dominance. Ultimately, this process will support the sustainability of the forest (Sist & Ferreira, 2007; Huth & Ditzer, 2001)

IV. CONCLUSION

Patterns of stand structures of four species assessed are more or less similar, with more individuals of small diameter rather than large diameter present. *Syzygium* sp. has a greater number of individuals of small diameter compared to the three other species (i.e *Vatica rassak*, *Litsea timoriana* and *Canarium asperum*). The stand structures of population of the four species are increasing after harvest activity. Therefore, it seems that logged forest in this area would be able to recuperate and eventually return to pre-logging status.

IPMs have not been widely used in Indonesian tropical forest research. This research suggests that these model can be used to describe stand structures of forest, because the results of IPMs are close to observed results for the stands assessed.

ACKNOWLEDGEMENT

We are grateful to PT. Tunas Sawaerma in Assiki for using facilities and to anonymous reviewers for useful comments on this manuscript.

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DIVERSITY OF BIRDS ACROSS LAND USE AND HABITAT GRADIENTS IN FORESTS, RUBBER AGROFORESTS AND RUBBER PLANTATIONS OF NORTH SUMATRA

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Received: 31 March 2014, Revised: 10 May 2014, Accepted: 11 October 2015

DIVERSITY OF BIRDS ACROSS LAND USE AND HABITAT GRADIENTS IN FORESTS, RUBBER AGROFORESTS AND RUBBER PLANTATIONS OF NORTH SUMATRA. Birds play a pivotal role in the ecosystem, but in disturbed areas their roles may be limited due to the changes of their natural habitats. This paper studies the birds' habitats in Simalungun and Asahan Districts, North Sumatra. The study was conducted in four habitats: natural forest, rubber agroforests, rubber monoculture plantations and emplacement areas. The birds were observed using descriptive survey methods by implementing a quick biodiversity survey, data were collected along one km transect. The results showed that in total, 142 species of birds from 42 families were observed in the four habitats. Natural forests had the highest diversity of bird species, followed by rubber agroforests, emplacement areas and rubber plantations, with a Shannon-Wiener index of 3.8, 3.6, 3.0 and 2.9, respectively. Regarding the IUCN red list species, 12 bird species of near-threatened status and 2 species of vulnerable status were recorded. Based on CITES categories, one species was listed in the Appendix I, 12 species were classified in Appendix II and 26 bird species were protected under Indonesian regulations. Changes in the structure and composition of the vegetation in disturbed forests and cleared land determined the richness of the bird species. The different tree compositions in the four habitats of the rubber estate plantations and surrounding areas influenced the number of bird species, bird diversity and species composition.

Keywords: Species composition, conservation, CITES, guild type

KERAGAMAN JENIS BURUNG PADA BERBAGAI PEMANFAATAN LAHAN DAN GRADASI DI HUTAN, AGROFOREST KARET DAN PERKEBUNAN KARET DI SUMATERA UTARA. Burung berperan penting dalam ekosistem, namun pada ekosistem yang terganggu peran mereka menjadi terbatas akibat perubahan habitat. Studi komunitas burung di berbagai tipe habitat, pada hutan, agroforest karet, monokultur karet dan daerah pemukiman telah dilakukan di Kabupaten Simalungun dan Asahan, Provinsi Sumatra Utara. Burung diamati dengan melakukan survei deskriptif dengan metode survei cepat biodiversitas, dengan mengkoleksi data pada transek sepanjang 1 km. Hasil studi di keempat tipe habitat menjumpai 142 jenis burung dari 42 suku. Burung yang dijumpai di hutan memiliki tingkat keragaman jenis tertinggi, selanjutnya habitat karet agroforest, daerah pemukiman dan karet monokultur, memiliki tingkat keragaman jenis yang lebih rendah, dengan index Shannon-Wiener secara berturut-turut 3,8, 3,6, 3,0 dan 2,9. Tercatat 12 jenis burung dengan status kelangkaan terancam punah dan dua species dengan status rentan, menurut red-list IUCN. Berdasarkan kategori CITES, tercatat satu jenis burung yang termasuk Appendix I, 12 jenis burung yang termasuk Appendix II, dan 26 jenis burung yang dilindungi berdasarkan peraturan perundang-undangan di Indonesia. Perubahan struktur dan komposisi vegetasi di hutan yang terganggu dan lahan terbuka menentukan kekayaan jenis burung. Perbedaan komposisi jenis pohon di keempat habitat di sekitar perkebunan karet monokultur mempengaruhi jumlah, keragaman, dan komposisi jenis burung.

Kata kunci: Komposisi jenis, konservasi, CITES, relung pakan

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I. INTRODUCTION

Sumatra has the lowest number of endemic bird species in Indonesia. This is related to its geological history of separation from the plains of Asia. Sumatra has about 306 bird species that are also found in Borneo, 345 species that can be found in the Malayan Peninsula and 211 species that also live in Java (MacKinnon & Phillips, 1993). A total of 583 recorded species inhabit the island of Sumatra and 438 species are breeding in Sumatra (Andrew, 1992). These numbers increase to 602 and 450 species, respectively when we include the small islands along the coast of Sumatra. There are 12 endemic bird species in the lowlands of Sumatra (Marle & Marle, 1988).

North Sumatra is covered by natural forests including Batang Gadis, Bohorok, Batang Toru and other forested areas, although most of these forests are fragmented and under considerable pressure from land-use changes (MacKinnon, Phillips, & van Balen, 1998; Sirait, 2007). Human activities change natural environments, such as turning forest into agricultural land, plantations and infrastructure for industrial activities. Forest areas of Sumatra remained at about 30% (13 million ha) of the total area of Sumatra in 2007 (Laumonier et al., 2010)). Forest losses cause loss of bird habitat and decrease the number of bird species (Danielsen & Heegard, 1995; O'Brien & Kinnaird, 1996; Lane et al., 2011). Besides hunting and trade, deforestation and habitat destruction are the most dominant drivers in reducing the number of bird species and their possible extinction.

Agroforestry may reconcile ecological and economic objectives, balancing the need to generate income along with protecting the environment (Nair & Garrity, 2012). In 2005, agroforests covered about 16.3 million ha, or 8% of the total area of Indonesia (ICRAF, 2011). Rubber agroforests (RAFs) are part of Sumatra's man-made ecosystem and have been used by farmers for many decades. Farmers with limited resources plant rubber trees within the agroforestry system and manage the farm extensively. Rubber agroforests include a mixture of trees, lianas, shrubs and herbaceous plants. Monoculture rubber plantations are managed by companies and farmers with greater resources. The basal area of rubber monocultures is lower than that in the natural forest, because there are no large trees in the plantations (van Noordwijk, Tata, Xu, Dewi, & Minang, 2012; Tata, van Noordwijk, & Werger, 2008).

In conservation, it is important to analyse the response of birds to habitat fragmentation and the diversity found in a fragmented habitat, such as rubber monocultures. Bird conservation activities tend to be focused on protected natural forests (NF) and emphasise threatened species faced with extinction, but most of the remaining forest in Sumatra is secondary (Ekadinata & Vincent, 2011). Currently little attention is given to common species or species that inhabit secondary forests and agro-ecosystems, such as rubber agroforests (RAF) and rubber monocultures (RMP). This paper studies at Simalungun and Asahan Districts, North Sumatra, Indonesia bird richness and diversity, the composition of bird communities and their roles in secondary and primary forests, RAF systems, rubber monoculture (RMP) and emplacement areas (EA) of RMP.

II. MATERIAL AND METHOD

A. Study Area

The study was conducted from December 2010 to January 2011 in four habitat types: NF, RMP, RAF, and EA, in the Districts of Simalungun and Asahan in North Sumatra Province, Indonesia (02°43'4"N and 98°56'25"E) (Figure 1). The EA was located inside the rubber plantations. The RMPs have been intensively managed for many years with regular fertilisation, weeding and tapping, which affected the condition of the vegetation. The rubber stands in the RMP were grouped based on ages: 2-6 years, 12-15 years, and 22-25 years after planting. Two RAF plots were located in the surroundings of the RMPs. RAF plots were managed with less fertilisation and weeding. Other trees were allowed to grow on these farms, creating mixed vegetation of

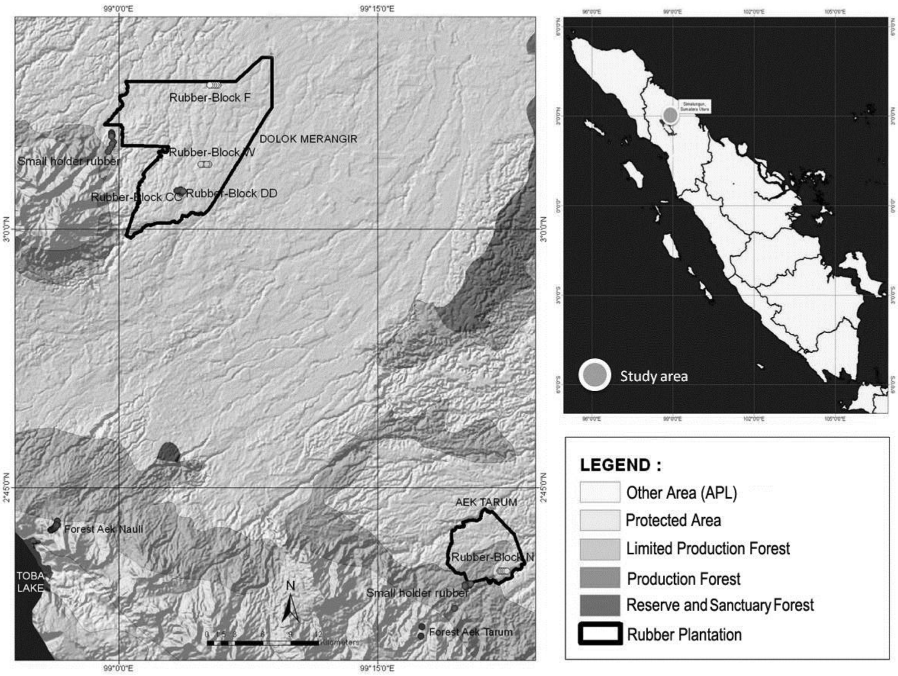

Figure 1. Study sites in Dolok Merangir (Simalungun District) and Aek Tarum (Asahan District), North Sumatra.

simple agroforestry system.

Forest plots were located in two sites: Aek Nauli (Bartong) forest research area in Dolok Merangir, Simalungun District and Aek Tarum forest in Asahan District. The elevation of the forest plots ranged from 1200 m to 1300 m above sea level (asl). The size of the Aek Tarum study area was 79,944.5 ha, and the Dolok Merangir study area was 139,353.93 ha. Each study site included RAFs, RMPs and EAs.

B. Data Collection

The birds were observed by descriptive survey methods using a quick biodiversity survey (QBSur) for birds (Tata et al., 2013), where data were collected along a 1 km transect, in total 12 transects; and from the list of 20 MacKinnon's bird species (MacKinnon & Phillips, 1993) simultaneously in four habitat types (e.g. NF, RMP, RAF, EA). The survey was completed within two weeks. The MacKinnon's list is an established method used to record and verify species and to calculate bird densities. Data was tabulated and birds were identified using this nomenclature (Sukmantoro et al., 2007). Composition of guilds, which are defined as a group of species using the same resource in the same way, was adapted from Wiens (1989), the threat of fragmentation of bird species refers to Lambert and Collar (Lambert & Collar, 2002), while IUCN status refers to the IUCN Red List (IUCN, 2012).

C. Data Analysis

Comparison of abundance was calculated from the percentage ratio of the individual numbers of a species compared to the total individual number that was caught. Diversity was calculated using the Shannon-Wiener index (Magurran, 1988).

The Shannon-Wiener index was used to determine the diversity of mammal species on each transect (Krebs, 1999) and is described by the following equation:

$$H' = \sum_{i=1}^{n} -(pi \ln pi)$$

where,
H' = Shannon-Wiener diversity index
pi = Probability of species (relative density)
n = Number of species

Evenness index (E') was used to estimate the evenness of the species distribution of the birds (Krebs, 1999) and is described by the following equation:

$$E' = \frac{H}{\ln s}$$

where,
H'= Shannon-Wiener diversity index
S = Number of species

Each bird species found in the study area was recorded in a list containing the names of the first 20 species encountered, after which a new list of the recording began. This list was used to generate a curve of bird species' richness among different sites. Observations were made twice a day, in the morning from 06:00 to 11:00 and in the afternoon from 15:00 to 17:30 (except on rainy days). Tools used in this activity were binoculars (Bushnell 10 x 25), GPS Garmin Oregon 300, a digital voice recorder (Olympus WS-560M) and a Nikon D80 (70–300 mm Tele Lens). Two field identification guides were used (King, Woodcock, & Dickinson, 1975; MacKinnnon & Phillips, 1993).

III. RESULT AND DISCUSSION

A. Bird Richness and Diversity

In total, 142 species of birds from 42 families were recorded across all the areas (Appendix 1). From the total bird species recorded, 122 species were found in the NF, 30 in the RMP, 39 in the EA and 46 in the RAF. A total of 728 individual birds were observed across different habitats. Encountered species richness, abundance, diversity and density are summarized in Table 1 and Figure 2. NF was the most diverse in bird species, indicated by a Shannon-Wiener index of 3.8, followed by RAF (3.6), EA (3.0) and RMP (2.9). All bird species were distributed evenly in every types of habitat, as shown by the evenness index value of almost 1 (ranged 0.87–0.94).

In general, the richness of bird species in North Sumatra was high. Of the 1,589 bird species found in Indonesia, 583 were found in Sumatra (Andrew, 1992). Rubber plantations and surrounding areas in the two Districts of North Sumatra have 124 of the total bird species of Sumatra or 8.9% of the whole of Indonesia.

The species' richness in Simalungun and Asahan area (142 species) was close to the richness of bird species encountered in Batang Toru (Jihad, 2009). RAF in Bungo, Jambi Province had even higher species richness (167 bird species) (Joshi et al., 2002). For comparison, in the forest habitat of Bukit Barisan Selatan National Park (Jambi-Sumatra), 276 bird species were found (O'Brien & Kinnaird, 1996).

The highest bird species' richness occurs in NF habitat (122 species), followed by RAF (46 species), EA (39 species) and RMP (30 species). Bird species were more diverse at the two NF sites than those in RAFs and RMPs. Although Aek Nauli was categorised as disturbed forest, bird composition was similar to that of the natural forest of Aek Tarum. Bird species richness in the three habitats decreased sharply from 122 species in the forest to 46 species in RAF to only 18 species in RMP (see Table 1).

The number of species in the RMP was the lowest, except along river banks, which have more diverse vegetation. RAF had greater richness of species compared with EA and RMP. Many food trees and trees suitable for nesting were still available in the RAF, such as durian (*Durio zybethinus*), candle nuts (*Aleurites mollucana*) and other fruit trees. RAF provides a compatible bird habitat, with mixed vegetation composed of fruit trees, such as durian (*Durio zibethinus*), duku (*Lansium domesticum*), jengkol (*Pithecellobium lobatum*), mangosteen (*Garcinia mangostana*) and cacao (*Theobroma cacao*). The mixed vegetations attract birds searching for food and nesting materials. In addition, RAFs provide a comfortable habitat, especially for the Helmeted Hornbill (*Rhinoplax vigil*). The bird species in the EA were fewer than those in RAF, although there were some food trees for birds, such as Ficus and other fruit trees.

Bird diversity at a given site may also

Table 1. Statistical summary of birds in the study areas of Simalungun and Asahan Districts, North Sumatra

Habitat Types	Abundance	Species Number	H'	E'
NF	267	122	3.8	0.94
RMP	147	30	2.9	0.88
2–6 yr	49	15	2.5	0.91
12–15 yr	37	18	2.7	0.95
22–25 yr	56	20	2.6	0.87
RAF	103	46	3.6	0.94
EA	211	39	3.0	0.84

Remarks : H'= Shannon-Wiener index, E'=Evenness index
NF=natural forests at a protected forest area in Aek Tarum and a research forest area in Aek Nauli
Rubber Agroforest (RAF)= mixed rubber trees with other valuable trees to form simple agroforestry system
Rubber Monoculture Plantation (RMP)=Young rubber plantation (2–6 years), medium rubber plantation (12–15 years) and older rubber plantation (22–25 years)
Emplacement Area (EA)=Settlement area of a rubber plantation with mixed fruit trees

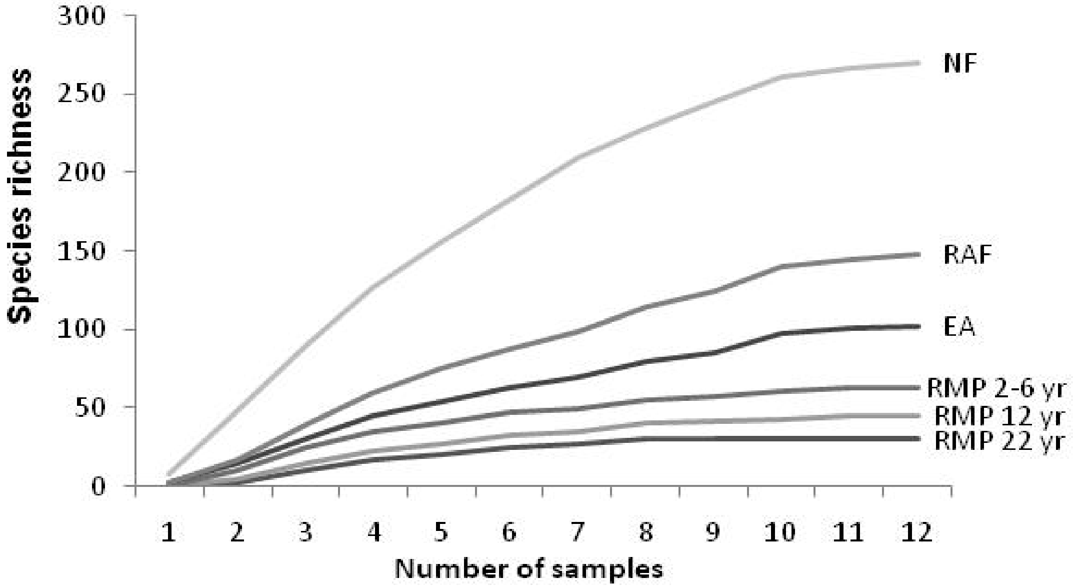

Figure 2. Species accumulation curves by habitat types (Natural Forests=NF, Rubber Agroforests=RAF, Emplacement Areas=EA and 3 differently aged Rubber Monoculture Plantations=RMP)

reflect a high biodiversity of other wildlife in the ecosystem (McNeely, 1988; Yoza, 2000). Bird species diversity in North Sumatra varied between 3.8 in forests to 2.9 in RMP areas. The diversity of bird species depends on environmental conditions. Species diversity decreased in the land use gradient from NF to RMP, which relates to a decrease in environmental factors, such as structure and composition of the vegetation. Among the four habitats, the basal area of vegetation in RMP was the lowest owing to fewer large trees growing in monocultures. Bird diversity in RMP was categorised as 'middle value', based on the Shannon-Wienner index. Environmental factors, such as canopy height, diversity of tree species, and crop coverage, determine the diversity of bird species (Welty, 1982). The decline in bird diversity is related to the decline of carrying capacity.

B. Bird Composition

The birds in the ecosystem were classified according to their roles. There were 17 guilds represented: arboreal frugivore (AF), arboreal foliage gleaning insectivore (AFGI), arboreal foliage gleaning insectivore-frugivore (AFGIF), arboreal frugivore-predator (AFP), aerial insectivore (AL), bark gleaning insectivore (BGI), miscellaneous insectivore-piscivore (MIP), nectarivore (N), nocturnal predator (NP), nectarivore-insectivore-frugivore (NIF), piscivore (P), raptor (R), sallying insectivore (SI), sallying substrate gleaning insectivore (SSGI), terrestrial frugivore (TF), terrestrial insectivore (TI) and terrestrial insectivore-frugivore (TIF) (Figure 3).

The guilds were further categorised, based on feeding habits, into eight groups, namely frugivore, insectivore, nectarivore, nocturnal predator, insectivore-frugivore, piscivore, raptor and omnivore (Figure 4). Bird species composition in the rubber plantation was different from the three other habitats; two feeding groups of birds, i.e. omnivores and nectarivores, were not found. Aratrakorn et al. (2006) also found different bird composition and guild types in forest compared with oil palm and rubber plantation. Nectarivores birds are not found in oil palm and rubber plantations in southern Thailand.

The differences in the guild composition of the open-canopy areas (RMP) and closed-canopy areas (forest) indicated that the RAF

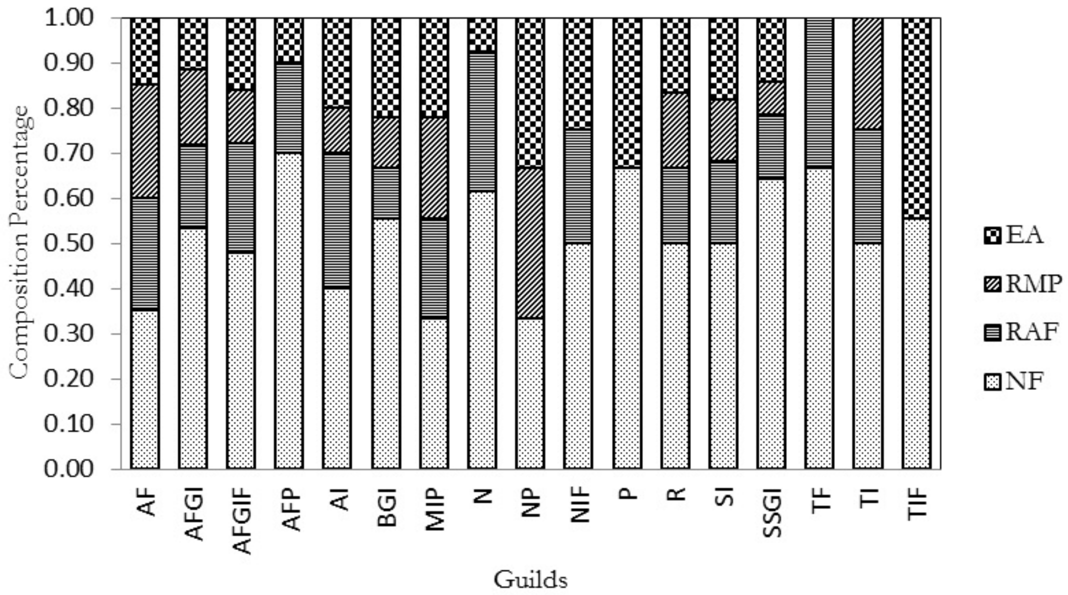

Figure 3. Bird composition guilds according to their roles in four habitats in Simalungun and Asahan Districts, North Sumatra. AF = arboreal frugivore; AFGI = arboreal foliage gleaning insectivore; AFGIF = arboreal foliage gleaning insectivore-frugivore; AFP = arboreal frugivore-predator; AI = aerial insectivore; BGI = bark gleaning insectivore; MIP = miscellaneous insectivore-piscivore; N = nectarivore; NP = nocturnal predator; NIF = nectarivore-insectivore-frugivore; P = pinsivore; R = raptor; SI = sallying insectivore; SSGI = sallying substrate gleaning insectivore; TF = terrestrial frugivore; TI = terrestrial insectivore; and TIF = terrestrial insectivore-frugivore

areas were transition areas between forest and RMP, making rubber agroforest the second choice after forests as habitat for bird nesting, foraging, and breeding (Figure 4).

Species that were absent from bird communities in different habitats (forests, RAF, RMP and EA) allowed comparison of habitat function. In general, species composition was dominated by insect-eaters (insectivores) and seed or fruit-eaters (frugivores). Each type of forest, e.g. primary forest at Aek Tarum and secondary forest at Aek Nauli education-forest, contained similar bird species. While RAFs and RMPs held different species compared to both the primary and secondary forests. Groups of insectivores, which were not found in RMPs, play the role as pollinators, as they feed on nectar and transfer pollen at the same time. However, rubber is not pollinated by birds, but usually through controlled pollination by insects (Warmke, 1952). Rubber monocultures do not provide a suitable environment for specific bird species with particular roles.

The difference in guild composition between open-canopy areas (such as rubber plantations) and closed-canopy areas (such as natural forest) indicate that RAF and smallholder rubber plantations provide a transition area between forests and RMP. Insectivores, frugivores, and nectarivores were commonly found in secondary forests and the more open forest fringes, whereas arboreal frugivores, terrestrial frugivores and bark gleaning insectivores prefer to live in the middle of the forest.

Bird species in North Sumatra as shown in Figure 4 are dominated by the Nectariniidae and Pycnonotidae families. These birds prefer to live in secondary forests, forest edges and settlements (MacKinnon et al., 1998), where insects and nectar are available. Other studies

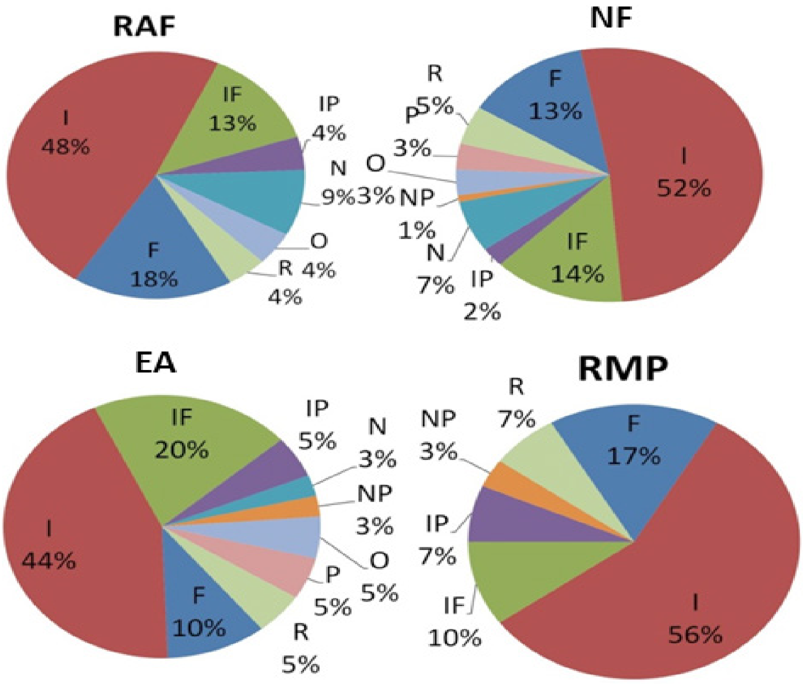

Figure 4. Bird composition guilds based on feeding habitat in four habitat types in Simalungun and Asahan Districts, North Sumatra

Remarks : F = frugivore (AF, AFGI, AFGIF, AFP, TF); I = insectivore (AI, BGI, MIP, SI, SSG, TI); N = nectarivore; NP = nocturnal predator; IF = insectivore-frugivore; (TIF), P = piscivore; R = raptor; and O = Omnivore (NIF) show that bird communities are usually dominated by a few specific types, which have a high relative abundance, and most other species are much rarer (Karr, Schemske, & Brokaw, 1983; Prawiradilaga, Astuti, Marakarmah, Wijayamukti, & Kundarmasno, 2002).

Based on the guild feeding groups, species' compositions in forests and RAF were relatively similar, dominated by the insectivores and frugivores, and followed by nectarivores, piscivores, raptor and granivores. Bird communities in the study area clearly showed a mix of the species that prefer the central parts of forests (*Picidae*, *Capitonidae*, *Trogonidae*, *Pittidae*) and forest edges (such as *Pycnonotidae*, *Nectariniidae*, *Sylviidae*, *Laniidae*, *Timaliidae*). In the forests, we found frugivores (*Bucerotidae*, *Capitonidae*, *Columbidae*, *Pycnonotidae*, *Decidae* and *Chloropsidae*) suggesting the presence of fruit trees. Fruit trees create a good ecosystem for many species, providing refuge, perches and food.

Rubber monoculture plantations where food is depleted, has less support on birdlife. Therefore, an ecotone such as riparian and emplacement, is important as an intermediary region between two adjacent ecosystems. An ecotone allows various types of life which are better adapted to changes in the environment (Fitri & Ford, 2003). The diversity of bird species in an ecotone is a combination of species from the surrounding areas. Hence, bird species diversity in an ecotone is usually higher than that of the surrounding area (Odum, 1971; Baker, French, & Whelan, 2002).

Bird composition in rubber plantations was clearly different from bird composition in RAF. Only four guild groups of birds were found in RMP: insectivores, frugivores, piscivores and raptors. The other four groups found in the forests were not encountered in RMP. Bird compositions in the three differently aged stands of rubber trees were not significantly different. Bird types were dominated by Alcedinidae, Pycnonotidae, Strigidae, Apodidae, Sylviidae, Cuculidae and Columbiae. Insectivorous groups comprised large percentage in plantation areas and were present in large numbers in all habitat types. We observed insectivore birds, such as Yellow-vented Bulbul (*Pycnonotus goiavier*), Common Tailorbird (*Orthotomus sutorius*), Ashy Tailorbird (*Orthotomus ruficeps*) and Yellow-browed Warbler (*Phylloscopus inornatus*). Various insectivore-piscivore species were abundant in the plantations, like White-throated Kingfisher (*Halcyon smyrnensis*) and Collared Kingfisher (*Halcyon chloris*). There were also groups of nocturnal predators, which play an important role in maintaining the biological balance, such as the Buffy Fish-Owl (*Ketupa ketupu*).

Birds play a role in controlling insect populations, consuming up to one third of their body weight (Hernowo, Soekmadi, & Ekaelawan, 1991) daily. Of the 494 bird species found in Java, 331 (67 %) are insectivorous, with 24 percent of these being primary insectivores, and 76 % secondary insect eaters (Andrew, 1992). Some insects such as Orthoptera (grasshoppers, crickets), Homoptera (leafhoppers, mites) and Heteroptera (ladybugs) are pests on plants, and therefore the insectivore birds play an important biological control in the ecosystem.

Frugivorous birds act as a dispersal agent for plants (Welty, 1982). Nectarivores birds act as polinators (MacKinnon & Phillips, 1993). Birds also help nitrogen and phosphorus cycles (Odum, 1971). High numbers of large arboreal frugivores were encountered in the rubber plantation, such as Spotted Dove (*Streptopelia chinensis*) and Zebra Dove (*Geopelia striata*). In addition, two groups of birds were found in the ground-cover of the rubber plantation in all stand-ages, namely sallying insectivores and arboreal foliage gleaning-insectivores, such as the Tiger Shrike (*Lanius tigrinus*) and Hill Prinia (*Prinia atrogularis*). Velvet bean (*Mucuna*) as a cover crop provided insect food for these two species.

Different compositions of bird communities were found in the EA. Emplacement sites, which are located inside the RMP, were planted with a variety of large trees. Some trees, such as ficus, pine, palm, banana, mango, rambutan and cocoa and woody-tree species provide

Table 2. Status of birds according to IUCN, CITES and Indonesian law

Scientific Name	English Name	Status			Habitats			
		IUCN[1]	CITES[2]	UU/ PP RI[3]	NF	RMP	RAF	EA
Ardea alba	Great Egret			AB	#			
Egretta garzetta	Little Egret			AB	#			
Haliastur indus	Brahminy Kite		II	AB	#			
Haliaeetus leucogaster	White-bellied Sea Eagle		II	AB	#			
Ictinaetus malayensis	Black Eagle		II	AB	#		#	#
Spizaetus cirrhatus	Crested Hawk-Eagle		II	AB	#			#
Spizaetus alboniger	Blyth's Hawk-Eagle		II	AB	#			
Spilornis cheela	Crested Serpent Eagle		II	AB	#	#	#	
Accipiter virgatus	Besra		II	AB		#		
Argusianus argus	Great Argus	NT	II	AB	#			
Treron capellei	Large Green Pigeon	VU			#			
Loriculus galgulus	Blue-crowned Hanging Parrot		II		#		#	
Rhopodytes diardi	Black-bellied Malkoha	NT			#			
Tyto alba	Barn Owl		II					#
Ketupa ketupu	Buffy Fish-Owl		II			#		
Glaucidium brodiei	Collared Owlet		II		#			
Collocalia vulcanorum	Volcano Swiftlet	NT			#			
Harpactes kasumba	Red-naped Trogon	NT		AB	#			
Alcedo meninting	Blue-eared Kingfisher			AB	#			
Halcyon smyrnensis	White-throated Kingfisher			AB	#	#	#	#
Halcyon chloris	Collared Kingfisher			AB	#	#	#	#
Buceros rhinoceros	Rhinoceros Hornbill	NT	II	AB	#			
Rhyticeros undulatus	Wreathed Hornbill		II	AB	#			
Rhinoplax vigil J	Helmeted Hornbill	NT	I	AB	#			
Rhipidura javanica	Pied Fantail			AB	#			
Anthreptes simplex	Plain Sunbird			B	#			
Anthreptes singalensis	Ruby-cheeked Sunbird			AB	#		#	
Anthreptes malacensis	Brown-throated Sunbird			AB	#			
Cinnyris jugularis	Olive-backed Sunbird			AB	#		#	#
Arachnothera longirostra	Little Spiderhunter			AB	#			
Arachnothera affinis	Streaky-breasted Spiderhunter			B	#		#	
Anthreptes malacensis	Brown-throated Sunbird			AB	#		#	
Anthreptes rhodolaema	Red-throated Sunbird	NT		AB	#			
Padda oryzivora	Java Sparrow	VU	II					
Gracula religiosa	Common Hill Myna		II	AB	#	#		
Dicrurus sumatranus	Sumatran Drongo	NT			#		#	#

[1]Status based on IUCN; [2]CITES; [3]Indonesian laws: A = Republic of Indonesia of Act no. 5/1990; B = Regulation of Indonesian Government no. 7/1999

suitable sites for nesting, resting and foraging. The number of birds that like forest edges or open areas increased, such as mynas, barbets, sparrows, bulbuls, pigeons, cuckoos, doves, prinias, white-eyes, woodpeckers and raptors. Nonetheless, forest-edge is important as a buffer zone for bird diversity and as an area for the succession process of bird communities (Novarino & Salsabila, 2005).

In the EA, Ficus trees were the food source for the frugivores. A total of 23 species of birds from 11 families were recorded in three Ficus trees that grew in the emplacement, 17 of which were recorded eating fruit. Barbets and bulbuls were common on Ficus caulocarpa and Ficus microcarpa, which have relatively small fruits. Large frugivores, such as Imperial Pigeon and hornbills, were not observed in these trees, although they were frequently seen flying overhead. Frugivore birds in the emplacement of RMP in Dolok Merangir were lower than that found in lowland tropical forest in Kuala Lompat, Malaysia (Lambert & Marshall, 1991). Twenty nine bird species were reported as Ficus dispersal agents. Ficus forms an exclusive group within the subset of plants with bird-eaten fruit owing to the synchronized fruit ripening of each tree, the relatively short intervals between fruiting seasons, large crop sizes and different fruiting seasons in each population. These factors make Ficus an important keystone plant resource (Lambert & Collar, 2002).

Birds are one of the most important seed dispersal agents in tropical forests (Jordano et al., 2007). Plants are food sources for animals and effective seed dispersal may reduce competition between plants and their derivatives, as well as enabling the distribution of plant species to new locations. If there are no animals to disperse the seeds, the seeds will fall on the ground and will grow around the parent tree only, affecting plant regeneration.

C. Prominence of Protected Birds

Bird species encountered in the four habitats were grouped based on their status according to the International Union for Conservation of Nature and Natural Resources (IUCN). Twelve near-threatened (NT) species and 2 vulnerable (VU) species we recorded. Referring to the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), one species was listed in Appendix I, and 12 species were listed in Appendix II. Regarding Indonesian regulations, under Law no. 7/1999, we found that 26 species were listed as protected species (Table 2).

Nine species of the 24 restricted range species were found. A restricted range species is one with a known breeding area of less than 50,000 km^2 (Sujatnika, Soehartono, Crosby, & Mardiastuti, 1995) and, by virtue of its small range, is suitable for identifying areas for conservation. It was reported that there were five Important Bird Areas (IBA) in North Sumatra and 24 restricted range species (Holmes & Rombang, 2001).

Some noteworthy bird species that are protected under Indonesian law were encountered in North Sumatra, such as the Great Argus (*Argusianus argus*), Red-naped Trogon (*Harpactes kasumba*), Rhinoceros Hornbill (*Buceros rhinoceros*), Wreathed Hornbill (*Rhyticeros undulatus*), Blue-masked Leafbird (*Chloropsis venusta*), Java Sparrow (*Padda oryzivora*), Sumatran Drongo (*Dicrurus sumatranus*), Finsch's Bulbul (*Criniger finschii*), Large Green Pigeon (*Treron capellei*), Blue-crowned Hanging Parrot (*Loriculus galgulus*), Black-bellied Malkoha (*Rhopodytes diardi*), Volcano Swiftlet (*Collocalia vulcanorum*), Barn Owl (*Tyto alba*), Buffy Fish Owl (*Ketupa ketupu*), Collared Owlet (*Galucidium brodiei*), Helmeted Hornbill (*Rhinoplax vigil*), Buff-necked Woodpecker (*Meiglyptes tukki*), Green Broadbill (*Calyptomena viridis*) and the Common Hill Myna (*Gracula religiosa*).

A number of raptor species were also found in the area, such as the Brahminy Kite (*Haliastur indus*), White-bellied Sea Eagle (*Haliaeetus leucogaster*), Black Eagle (*Ictinaetus malayensis*), Crested Hawk-Eagle (*Spizaetus cirrhatus*), Blyth's Hawk-Eagle (*Spizaetus alboniger*) and the Crested Serpent Eagle (*Spilornis cheela*). All these raptors are protected under Indonesian law. Moreover, the high number of raptor birds in this area implies it is a part of their home range. Raptors are known to have a wide home range compared to other bird species. Their prey includes various mammals and reptiles, including squirrels, rats and lizards. The study

Table 3. Number of protected bird species in four habitat types

Habitats	Status		
	IUCN	CITES	UU/PP RI
NF	9	13	26
RAF	1	3	8
RMP	0	4	5
EA	1	3	5

[1]Status based on IUCN; [2]CITES; [3]Indonesian laws: A = Republic of Indonesia Act no. 5/1990; B = Regulation of Indonesian Government no. 7/1999.

area in North Sumatra may provide significant amounts of food. Some bird species (predator and raptor guild types) benefit to agriculture. Predators, like eagles (family: Accipitridae) and owls (family: Strigidae) prey rodents, which are pests to crops and tree crops, such as oil palm. However, there are very few studies of the potential relationship of birds in either natural or agricultural ecosystems.

Number of protected birds based on IUCN status, CITES, and Indonesian regulations are issummarized in Table 3. High number of protected bird species found in NF, consecutively followed by RAF, RMP and EA. Forests provide suitable habitat for protected bird species, which can not be replaced by any other habitats.

D. Implications for Conservation

Forest per se is not sufficient to protect bird diversity in a given habitat. Each species of birds occupies a particular habitat in accordance with its needs and plays a certain role in the environment (Mulyani, 1985).The diversity of bird species is affected by a decline in the carrying capacity of the habitat. Changes in vegetation structure and species composition in disturbed forests and cleared land affect on richness of bird species, thus altering composition of bird species. Habitats fragmentation in the study area consisted of patchy forest, RAFs and RMPs which are composed of different species. Forest has the highest index diversity compared with RAF and RMP (Ningsih, Rahayu, & Tata, 2011). Differences in tree composition in the three habitats of North Sumatra affected bird species richness, diversity and composition. Gonzalez-Oreja et al. (2012) reported there is a positive correlation between tree diversity and bird diversity.

Rapid land-use change and high deforestation are threatening the diversity and conservation status of birds (Rittenhouse et al., 2010). Forest cover in Aek Tarum study area has lost dramatically from 45 018 ha (56.03%) in 1970 to 10 220 ha (12.80%) in 2010 (Said, Ekadinata, & Widayati, 2011). Habitat fragmentation will cause the loss of specialist types (interior species) which includes terrestrial birds. Another consequence of the habitat fragmentation is the presence of edge effects. The area will be occupied by the edge of the bird species that are at risk of ecological disturbance or interference from outside. Degraded and fragmentation areas will impact on the dynamics and meta-population (Wiens, 1989; Lunberg & Moberg, 2003). Our observation showed that bird species in the study area have different tolerances of fragmentation and canopy openings. Some, such as hornbills and woodpeckers, were only encountered in forest habitat, being very sensitive to habitat change. Other species have a wider range of adaptive abilities, such as Pycnonotidae (bulbul), Columbidae (pigeon and dove) and Sylvidae (prinias and wabler), which were found across different land uses.

Implications of forest fragmentation caused three important processes, namely extinction, migration and colonization. Fragmented region will lead to solving the sub-sub-populations and reduces movement (migration) types among sub-populations thereby increasing the risk of extinction. Separation between sub-populations will decrease colonization opportunities for regeneration (Wiens, 1989; André, 1994). Birds with large territorial requirements, such as raptors, apparently are sensitive to habitat fragmentation.

Birds act as mobile conduits, transferring energy among ecosystems, and contribute to ecosystem functions and resilience with their foraging. Bird-plant interactions like pollination and seed dispersal have a high impact on ecosystems (Lunberg & Moberg, 2003). The pollination process of some tree species is assisted by birds. Nectarivore birds (family: Nectariniidae) that only consume nectar, pollinate some trees species and were encountered in both forests and RAF, but not found in RMP. Four species of nectarivore were found in both forest and RAF, namely *Anthreptes singalensis*, *Cinnyris jugularis*, *Arachnothera affinis* and *Anthreptes malacensis*.

Birds disperse seeds through fruit consumption. Frugivore birds (family: Columbidae and Sturnidae) that only consume fruit, were encountered in the four habitats. Birds disperse seeds of many woody plant species of value to humans for timber, medicine, food and other uses. A number of frugivore birds and those who combine frugivore with other food were encountered in forests, however far fewer frugivores were found in RAF and RMPs.

Large frugivore birds, such as Bucerotidae, were not found in RAF and RMP, as they are very susceptible to anthropogenic and environmental change. Larger fruits require larger birds to carry and disperse the fruit at a distance from the mother trees. A lower density of frugivores birds may result in seedlings being concentrated under the mother trees and not widely dispersed (Wenny et al., 2011), which in turn may decrease tree diversity in the ecosystems.

Birds also contribute to the nutrient cycling in the ecosystems. Aquatic and marine birds produce guano, which is a valuable phosphorous fertilizer (Wenny et al., 2011). Aquatic birds belonging to the piscivore type that consume fish were found in the forest only (*Ardea* spp. and *Egretta garzetta*). The landscape of the study area consisted of hilly mountains, valleys, and lowlands along the rivershed of Aek Tarum and Sigura-gura of North Sumatra. Forest area concentrated at the hilly mountains (Asahan and Bukit Barisan landscape) for birds' habitat of mountain species up to 700 m asl level such as Silver-breasted Broadbill (*Serilophus lunatus*), Long-tailed Broadbill (*Psarisomus dalhousiae*) and Fire-tufted Barbet (*Psilopogon pyrolophus*). Although piscivores are considered predators, they also contribute to nutrient cycling in their habitats. All birds contribute to maintaining the equilibrium of the food chain in the ecosystems.

When forest habitat is degraded, RAFs become an alternative sanctuary where birds can nest and forage. The vegetation in RAFs provides good carrying capacity for bird diversity. To improve biodiversity in the area it is recommended to preserve intermediary regions, such as along riverbanks and main roads in the RMPs. An intermediary region could be a corridor between one region and another along the border of the RMPs. In such places, planting rubber trees mixed with fruit trees, such as Ficus, that could provide habitat for birds is recommended.

IV. CONCLUSION

Natural forests have the highest bird diversity compared with RAFs, RMPs and EAs. Changing natural ecosystems to man-made ecosystems affected bird species' composition and numbers. Habitat loss reduced bird composition, and birds with specialist roles have the highest risk of extinction. Compared with RAFs, RMPs are less suitable for all bird species. Birds provide many ecosystem services, especially regulating and supporting services, which directly and indirectly benefit humans. Efforts to conserve habitats and bird populations will maintain the diverse services provided by ecosystems, thus contributing to human well-being.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Bridgestone Corporation and PT. Bridgestone Sumatra Rubber Estate (BSRE) for financial and logistical support during the research project "Towards biodiverse rubber plantations: a Quick biodiversity survey in Bridgestone Sumatra's Rubber Estate Plantation" to the World Agroforestry Centre (ICRAF) Southeast Asia Regional Office. The Forest Research Institute of Aek Nauli is acknowledged for giving permission to conduct our research in the forest research area. We thank Prof. Ani Mardiastuti and Dr. Jarwadi Hernowo for invaluable inputs and comments to the manuscript and one anonymous reviewer of language. We also thank Andrew J. Warner and Cassandra Graham for improving the language.

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Appendix 1. List of birds found in different habitat types in North Sumatra

Scientific Name[1]	English Name	Guild[2]	Status[3]			P	Habitat			
			IUCN	CITES[4]	UU/ PP RI[5]		NF	RMP	RAF	EA
Ardeidae										
Ardea cinerea	Grey Heron	P				s	#			#
Ardea purpurea	Purple Heron	P				s	#			#
Ardea alba	Great Egret	P			AB	s	#			
Egretta garzetta	Little Egret	P			AB	s	#			
Accipitridae										
Haliastur indus	Brahminy Kite	R		II	AB	s	#			
Haliaeetus leucogaster	White-bellied Sea Eagle	R		II	AB	s	#			
Ictinaetus malayensis	Black Eagle	R		II	AB	s	#		#	#
Spizaetus cirrhatus	Crested Hawk-Eagle	R		II	AB	s	#			#
Spizaetus alboniger	Blyth's Hawk-Eagle	R		II	AB	s	#			
Spilornis cheela	Crested Serpent Eagle	R		II	AB		#	#	#	
Accipiter virgatus	Besra	R		II	AB	s		#		
Phasianidae										
Lophura inornata	Salvadori's Pheasant	TIF				h+r	#			
Gallus gallus	Red Junglefowl	TIF				h+r	#			
Argusianus argus	Great Argus	TIF	NT	II	AB	h	#			
Turnicidae										
Turnix suscitator	Barred Buttonquail	TIF				s	#			
Rallidae										
Amaurornis phoenicurus	White-breasted Waterhen	TIF				s	#			
Columbidae										
Treron capellei	Large Green Pigeon	AF	VU			s	#			
Treron olax	Little Green Pigeon	AF				s	#			
Treron vernans	Pink-necked Green Pigeon	AF				s	#	#	#	#
Macropygia ruficeps	Little Cuckoo Dove	AF				s+h	#			
Streptopelia chinensis	Spotted Dove	AF				s+h	#	#	#	#
Geopelia striata	Zebra Dove	AF						#	#	
Psittacidae										
Loriculus galgulus	Blue-crowned Hanging Parrot	AF		II		s	#		#	
Cuculidae										
Cuculus saturatus	Oriental Cuckoo	AFGI				s		#		
Cacomantis sepulcralis	Rusty-breasted Cuckoo	AFGI				h				#
Surniculus lugubris	Asian Drongo-Cuckoo	AFGI				h	#	#		
Eudynamys scolopaceus	Asian Koel	AFGI				h	#			
Rhopodytes diardi	Black-bellied Malkoha	AFGI	NT			s	#			
Rhinortha chlorophaeus	Raffles's Malkoha	AFGI				s	#			
Centropus sinensis	Greater Coucal	TI				s+h	#			
Centropus bengalensis	Lesser Coucal	TI				h	#	#	#	
Tytonidae										
Tyto alba	Barn Owl	NP		II		s				#
Strigidae										
Ketupa ketupu	Buffy Fish-Owl	NP		II		s		#		
Glaucidium brodiei	Collared Owlet	NP		II		s	#			
Apodidae										
Collocalia vulcanorum	Volcano Swiftlet	AI	NT			s	#			
Collocalia fuciphagus	Edible-nest Swiftlet	AI				s				#
Collocalia esculenta	Glossy Swiftlet	AI				s	#	#	#	
Collocalia linchi	Cave Swiftlet	AI				s			#	
Hirundapus caudacutus	White-throated Needletail	AI				s	#			
Apus nipalensis	House Swift	AI				s	#		#	#
Hemiprocnidae										
Hemiprocne comata	Whiskered Treeswift	SI				s	#			#
Trogonidae										
Harpactes kasumba	Red-naped Trogon	SSGI	NT		AB	s+r	#			
Alcedinidae										
Alcedo meninting	Blue-eared Kingfisher	MIP			AB	s	#			
Halcyon smyrnensis	White-throated Kingfisher	MIP			AB	s	#	#	#	#
Halcyon chloris	Collared Kingfisher	MIP			AB	s	#	#	#	#
Meropidae										
Merops leschenaulti	Chestnut-headed Bee-eater	SI				s			#	
Merops viridis	Blue-throated Bee-eater	SI				s	#	#		#
Bucerotidae										
Buceros rhinoceros	Rhinoceros Hornbill	AFP	NT	II	AB	h	#			
Rhyticeros undulatus	Wreathed Hornbill	AFP		II	AB	s+h	#			
Rhinoplax vigil J	Helmeted Hornbill	AFP	NT	I	AB	h+r	#			
Capitonidae										
Psilopogon pyrolophus	Fire-tufted Barbet	AFP				s	#			
Megalaima chrysopogon	Golden-whiskered Barbet	AFP				s	#			
Megalaima oorti	Black-browed Barbet	AFP				s+h	#			
Megalaima haemacephala	Coppersmith Barbet	AFP				s+h	#		#	#
Calorhamphus fuliginosus	Brown Barbet	AFP				s			#	

Scientific Name[1]	English Name	Guild[2]	Status[3]			P	Habitat			
			IUCN	CITES[4]	UU/ PP RI[5]		NF	RMP	RAF	EA
Picidae										
Picumnus innominatus	Speckled Piculet	BGI				s				#
Picus flavinucha	Greater Yellownape	BGI				s	#			
Dinopium javanense	Common Goldenback	BGI				s	#			
Meiglyptes tukki	Buff-necked Woodpecker	BGI	NT			s	#			
Dendrocopos moluccensis	Sunda Pygmy Woodpecker	BGI				s	#	#	#	#
Reinwardtipicus validus	Orange-backed Woodpecker	BGI				s	#			
Eurylaimidae										
Serilophus lunatus	Silver-breasted Broadbill	SSGI				s	#			
Psarisomus dalhousiae	Long-tailed Broadbill	SSGI				h	#			
Calyptomena viridis	Green Broadbill	SSGI	NT			h	#			
Hirundinidae										
Delichon dasypus	Asian House Martin	AFGI				s	#	#	#	#
Campephagidae										
Pericrocotus divaricatus	Ashy Minivet	AFGI				s	#			
Pericrocotus flammeus	Scarlet Minivet	AFGI				s	#			
Hemipus picatus	Bar-winged Flycatcher-shrike	AFGI				s	#			
Aegithinidae										
Aegithina tiphia	Common Iora	AFGI				s+h	#		#	#
Chloropseidae										
Chloropsis venusta	Blue-masked Leafbird	NIF	NT			s	#			
Chloropsis sonnerati	Greater Green Leafbird	NIF				s	#			
Pycnonotidae										
Pycnonotus atriceps	Black-headed Bulbul	AFGIF				s	#			
Pycnonotus melanicterus	Black-crested Bulbul	AFGIF				s	#		#	
Pycnonotus aurigaster	Sooty-headed Bulbul	AFGIF				s	#	#	#	#
Pycnonotus bimaculatus	Orange-spotted Bulbul	AFGIF				s	#			
Pycnonotus goiavier	Yellow-vented Bulbul	AFGIF				s	#	#	#	#
Pycnonotus simplex	Cream-vented Bulbul	AFGIF				s	#		#	
Pycnonotus erythropthalmos	Spectacled Bulbul	AFGIF				s	#			
Criniger finschii	Finsch's Bulbul	AFGIF	NT			s	#			
Laniidae										
Lanius tigrinus	Tiger Shrike	SI				s	#	#		
Lanius cristatus	Brown Shrike	SI				s	#			
Lanius schach	Long-tailed Shrike	SI				s	#		#	#
Turdidae										
Brachypteryx montana	White-browed Shortwing	AFGI				h+s			#	
Copsychus saularis	Oriental Magpie-robin	AFGI				s	#	#	#	#
Copsychus malabaricus	White-rumped Shama	AFGI				h+s	#		#	
Timaliidae										
Malacocincla sepiarium	Horsfield's Babbler	AFGI				h	#			
Malacocincla abboti	Abbott's Babbler	AFGI				h	#			
Stachyris rufifrons	Rufous-fronted Babbler	AFGI				h	#			
Macronous gularis	Striped Tit-Babbler	AFGI				h	#			
Garrulax leucolophus	White-crested Laughingthrush	AFGI				h+r	#			
Garrulax lugubris	Black Laughingthrush	AFGI				h+r	#			
Sylviidae										
Cettia vulcania	Sunda Bush-warbler	AFGI				h	#		#	
Prinia atrogularis	Hill Prinia	AFGI				s	#	#	#	
Prinia familiaris	Bar-winged Prinia	AFGI				s	#		#	
Orthotomus cuculatus	Mountain Tailorbird	AFGI				s	#			
Orthotomus sutorius	Common Tailorbird	AFGI				s	#	#	#	
Orthotomus atrogularis	Dark-necked Tailorbird	AFGI				s	#			
Orthotomus sericeus	Rufous-tailed Tailorbird	AFGI				s	#			
Orthotomus ruficeps	Ashy Tailorbird	AFGI				s	#			#
Phylloscopus inornatus	Yellow-browed Warbler	AFGI				s	#	#	#	
Phylloscopus borealis	Arctic Warbler	AFGI				s	#	#		
Phylloscopus trivirgatus	Mountain Leaf Warbler	AFGI				s				
Seicercus grammiceps	Sunda Warbler	AFGI				s	#			
Abroscopus superciliaris	Yellow-bellied Warbler	AFGI				s	#		#	#
Muscicapidae										
Saxicola caprata	Pied Bush Chat	SI				s	#		#	
Muscicapa dauurica	Asian Brown Flycatcher	SI				s	#			
Ficedula hyperythra	Snowy-browed Flycatcher	SI				s	#			
Ficedula westermanni	Little Pied Flycatcher	SI				s	#		#	
Acanthizidae										
Gerygone sulphurea	Golden-bellied Geryone	SI				s+h	#	#		#
Rhipiduridae										
Rhipidura javanica	Pied Fantail	SI			AB	h	#			
Paridae										
Parus major	Great Tit	SI				s				
Dicaeidae										
Dicaeum sanguinolentum	Blood-breasted Flowerpecker	NIF				s	#			
Dicaeum cruentatum	Scarlet-backed Flowerpecker	NIF				s	#		#	
Dicaeum trochileum	Scarlet-headed Flowerpecker	NIF				s+h			#	#
Dicaeum trigonostigma	Orange-bellied Flowerpecker	NIF				s				#

Scientific Name[1]	English Name	Guild[2]	Status[3]			P	Habitat			
			IUCN	CITES[4]	UU/ PP RI[5]		NF	RMP	RAF	EA
Nectariniidae										
Anthreptes simplex	Plain Sunbird	N			B	s	#			
Anthreptes singalensis	Ruby-cheeked Sunbird	N			AB	s	#		#	
Anthreptes malacensis	Brown-throated Sunbird	N			AB		#			
Cinnyris jugularis	Olive-backed Sunbird	N			AB	s	#		#	#
Arachnothera longirostra	Little Spiderhunter	N			AB	s	#			
Arachnothera affinis	Streaky-breasted Spiderhunter	N			B	s	#		#	
Anthreptes rhodolaema	Red-throated Sunbird	N	NT		AB	s	#			
Zosteropidae										
Zosterops palpebrosus	Oriental White-eye	AFGI				s	#	#		#
Zosterops everetti	Everett's White-eye	AFGI				s	#			
Zosterops montanus	Mountain White-eye	AFGI				s	#	#		
Estrildidae										
Lonchura striata	White-rumped Munia	TF				s	#			#
Lonchura leucogastroides	Javan Munia	TF				s	#		#	#
Lonchura maja	White-headed Munia	TF				s				#
Padda oryzivora	Java Sparrow	TF	VU	II		s				
Ploceidae										
Passer montanus	Eurasian Tree Sparrow	TF				s				#
Sturnidae										
Acridotheres javanicus	White-vented Myna	AF				s		#	#	#
Gracula religiosa	Common Hill Myna	AF		II	AB	r	#	#		
Oriolidae										
Oriolus chinensis	Black-naped Oriole	AFGIF				s	#	#	#	#
Dicruridae										
Dicrurus macrocercus	Black Drongo	SSGI				s	#	#		
Dicrurus leucophaeus	Ashy Drongo	SSGI				s	#			
Dicrurus remifer	Lesser Racquet-tailed Drongo	SSGI				s+h	#		#	
Dicrurus sumatranus	Sumatran Drongo	SSGI	NT			s	#		#	#
Artamidae										
Artamus leucorynchus	White-breasted Woodswallow	SSGI				s	#			#
Corvidae										
Dendrocitta occipitalis	Sumatran Treepie	AFGIF				s	#			
Corvus enca	Slender-billed Crow	AFGIF				s	#			
Corvus macrorhynchos	Large-billed Crow	AFGIF				s	#		#	#
TOTAL							122	30	46	39

Remarks :

[1]Clasification name based on Sukmantoro et al. (2007)

[2]Clasification of guild composition based on Lambert and Collar (2002):AF=arboreal frugivore, AFGI=arboreal foliage gleaning insectivore, AFGIF= arboreal foliage gleaning insectivore-frugivore, AFP=arboreal frugivore-predator, AI=aerial insectivore, BGI=bark gleaning insectivore, MIP=miscellaneous insectivor-piscivore, N=nectarivore, NP=nocturnal predator, NIF=nectarivore-insectivore-frugivore, P=piscivore, R=raptivore, SI=sallying insectivore, SSGI=sallying substrate gleaning insctivore, TF=terrestrial frugivore, TI=terrestrial insectivore and TIF=terrestrial insectivore-frugivore. AI, N, NIF, SI, MIP, SSGI: Thisgroupof birds for age sin theair, whileflying. BGI: This group for ages in trees, by searching in ordisassemblingbark. TF, TI, TIF:This group for ages on the ground or the forest floor.

[3]Status: IUCN=International Union Conservation of Nature, CITES=Convention on the International Trade in Endangered Flora and Fauna, A = Undang-undang RI No. 5/1990; B = Peraturan Pemerintah No. 7/1999

[4]Birds' presence in location survey (P): s=seen, h=heard, r=reported

[5]Habitat: NF (Natural Forest), RAF (Rubber Agroforest), RMP (Rubber Monoculture Plantation), EA (Emplacement Area)

KARO'S LOCAL WISDOM: THE USE OF WOODY PLANTS FOR TRADITIONAL DIABETIC MEDICINES

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Received: 13 August 2014, Revised: 9 July 2015, Accepted: 6 September 2015

KARO'S LOCAL WISDOM: THE USE OF WOODY PLANTS FOR TRADITIONAL DIABETIC MEDICINES. This paper identifies the plant species used traditionally by Karo people in North Sumatra, to cure diabetes, analyses the cultural significance index of those plants for the Karo, and clarifies phytochemical contents of the plants. Data were collected using survey method from selected respondents (n=54) based on their knowledge and practices in utilising medicinal plants to cure diabetic disease. Index of Cultural Significance (ICS) of plants was determined using the method proposed by Turner. Results showed that twelve woody plant species have been used to cure diabetes: loning leave (*Psychotria* sp.), kacihe leave (*Prunus accuminta* Hook), umbrella tree leave (*Maesopsis eminii* Engl), mutamba leave (*Guazuma ulmifolia* Lamk), cepcepan leave (*Villebrunea subescens* Blume), pirdot/cepcepan lembu leave (*Saurauia vulcani* Korth), raru bark (*Cotylelobium melanoxylo*), breadfruit leave (*Artocarpus altilis*), salam leave (*Syzygium polyanthum* Wight), mahogany seed (*Swietenia mahagoni* (L.) Jacq), cinnamon bark (*Cinnamomum burmani*), and yellow bamboo rod (B*ambusa vulgaris* Schrad). Five of those plants: loning, umbrella tree, mutamba, raru and salam have the highest cultural significance level. These five plants are highly needed in large quatities by the Karo people, so their availability in the forest should be securely conserved and protected. The plants used contained alkaloids, flavonoids, phenolics and terpenoids which can help to lower blood sugar level.

Keywords: Ethnobotany, Karo ethnic, diabetic medicines, Index of Cultural Significance (ICS), phytochemical

*KEARIFAN LOKAL MASYARAKAT KARO: PENGGUNAAN TANAMAN BERKAYU UNTUK OBAT TRADISONALPENYAKIT DIABETES. Tulisan ini mengidentifikasi jenis-jenis tanaman yang digunakan oleh masyarakat Karo secara tradisional di Sumatara Utara, Indonesia, untuk mengobati diabetes. Jenis-jenis tanaman tersebut dianalisis indeks kepentingan budayanya (ICS) dan diklarifikasi kandungan fitokimianya. Metode survey digunakan dengan responden terpilih (n-54) berdasarkan pengetahuan mereka dalam memanfaatkan obat-obat tradisional untuk diabetes. Indeks kepentingan budaya (ICS) dari masing-masing tanaman diukur menggunakan metode yang dipakai oleh Turner. Hasil penelitian menunjukkan terdapat 12 jenis tanaman berkayu untuk mengobati diabetes: loning (*Psychotria sp.*), kacihe (*Prunus accuminta Hook*), kayu afrika (*Maesopsis eminii *Engl), jati belanda (*Guazuma ulmifolia Lamk*), cepcepan (*Villebrunea subescens Blume*), pirdot/cepcepan lembu (*Saurauia vulcani Kort*h), raru (*Cotylelobium melanoxylo), sukun (Artocarpus altilis), salam (Syzygium polyanthum Wight), mahoni (Swietenia mahagoni (L.) Jacq*), kulit manis (*Cinnamomum burmanni*), dan bambu kuning (*Bambusa vulgaris Schrad*). Lima jenis tanaman: loning, kayu afrika, jati belanda, raru dan salam memiliki tingkat kepetingan budaya tertinggi yang dibutuhkan dalam jumlah yang banyak dibandingkan tanaman lain sehingga ketersediaannya di hutan harus dikonservasi dan dilindungi. Tanaman-tanaman yang dipakai oleh masyarakat tersebut mengandung alkaloid, flavonoid, fenolik dan terpenoid yang mampu menurunkan kadar gula darah.*

Kata kunci: Etnobotani, Masyarakat Karo, obat diabetes, indeks kepentingan budaya (ICS), fitokimia

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I. INTRODUCTION

Traditional communities have high dependency on a variety of plants as a source of food, medicine and for traditional ceremonial purposes (Winarti & Nurdjanah, 2005; Gerique, 2006; Das, Gupta, Nath, & Mustapha, 2013). Local knowledge of existing vegetation is developed based on experiences that has been tested for centuries and adapted to the local culture and environment (Martin, 1995; Waluyo, 2008; Hasibuan, 2011). This knowledge is known as local wisdom. Local wisdom is a basic knowledge gained from living in balance with nature. It is related to culture in the community which is accumulated and passed on from generation to generation. This wisdom can be both abstract and concrete, but the important characteristics come from experiences or evidences gained from life. The wisdom from real experiences integrates the body, the spirit and the environment (Mungmachon, 2012).

Karo people are spread in many regions of North Sumatra Province, Indonesia, but their origin are from the Karo Regency. They migrated to various places such as Medan City, Binjai, Deli Serdang, Langkat, and Simalungun Regency. The size of Karo regency is 2.97 % of the North Sumatra Province. Karonese population in North Sumatra in 2011 was about 913.000 people or 6.90 % of the total population of North Sumatra (North Sumatra Statistical Bureau, 2012; Karo Regency Statistical Bureau, 2012).

Karo people use various plant species for their daily life including for medicines. In terms of illness treatment, they have a philosophy "*lit bisa lit tawar*" which means that all diseases can be treated or cured. They strongly believe that the nature provides medicines to cure diseases. The use of natural resources as medicines for curing diseases including diabetes practiced by Karo as part of their culture since long time ago.

Widowati, Dzulkarnain, and Sa'roni (1997) stated that diabetes mellitus is a carbohydrate metabolism disorder characterised by high blood sugar level (hyperglycaemia) and the presence of glucose in urine (glucosuria). Complications of the disease can increase the risk of heart attack and stroke. This disease is also closely associated with the blood circulation if left untreated, diabetes can cause many complications like kidney's damage, eye problems, nerve cell damages, depressions, slow healing of skin diseases, gum and urinary tract infections (Widowati et al., 1997; Alexious & Demopoulos, 2010). Ministry of Health of Republic Indonesia (2012) stated that diabetes is the sixth fatal disease in Indonesia. Due to the seriousness of this disease, people with diabetes usually take many types of treatment including traditional medicine.

Ethnobotany research is conducted to explore the cultural heritage as well as elaborating the potential of existing plants in the forest and environment (Windadri, Rahayu, & Uji, & Rustiami, 2006; Waluyo, 2008). The study primarily aimed to discover chemical compounds which are useful in the manufacturing of modern medicines to cure dangerous diseases such as cancer, AIDS, and others. Many researchers, especially those from Europe, have been conducting ethnobotany researches to obtain new chemical material for modern medicine. In the last decade, they began to shift ethnobotany research to Asia. Indonesia is preferred by the ethnobotany researchers as one of the research sites because its biodiversity richness is the second largest to Brazil (Ministry of Forestry of Republic Indonesia, 2010).

Raw materials of traditional medicines are generally supplied from the forests. Harianja (2012) stated that traditional medicine entrepreneurs in Karo Regency still utilise the natural forest to obtain the raw materials for the medicine. Forest area in Karo Regency is about 125,536.50 ha and 78.58 % of the total forest area and it is a protected forest (Karo Regency Statistical Bureau, 2012). The forest area is dominated by local and exotic woody plants, such as *Pinus merkusii*, *Altingia exelsa*, *Schima wallichii*, *Podocarpus* sp., *Toona sureni*, local fruit plants such as durian (*Durio zibethinus*), dadap (*Erythrima subumbrans*), rambutan (*Niphelliun lappacium*), pulai (*Alstonia scholaris*), palm sugar (*Arenga pinnata*), and rattan (*Calamus caesius*)

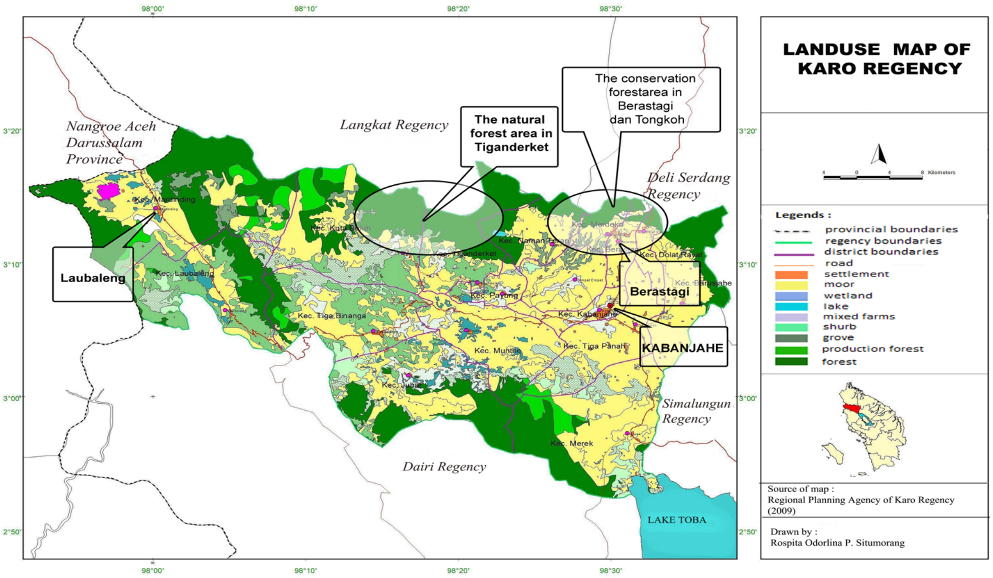

Figure 1. Research location in Karo Regency, North Sumatra, Indonesia

(Forestry Planning Agency, 2002).

Ethnobotanical research of medicinal plants is also important for conserving forests, endangered plant species, and cultural heritages; increasing the potential economic value of useful plants, and introducing natural drugs. Karo community is used to consume traditional medicines (Harianja, 2012), so they know the potential of various raw materials for ethnobotany study. Research on utilisation of plants for medicines has been done by many researchers (Bailey & Day, 1998; Batubara, Darusman, Mitsunaga, Rahminiwati, & Djauhari, 2010), but research on woody plants for treatment of diabetes is still limited. This paper aims to identify the woody plant species, parts of the plants used and processed by the Karo people for diabetes treatment, to assess the cultural significance value of those woody plants, and to analyse their phytochemical contents.

II. MATERIAL AND METHOD

A. Location and Time

The research was conducted in Karo Regency, North Sumatra Province, Indonesia, that is geographically located between 2050' – 3019' North and 97055' – 98038' East (Karo Regency Statistical Bureau, 2012). Survey on utilisation of various woody plants for traditional medicine was conducted at Kabanjahe (3° 5'52.70"N and 98°29'30.78"E), Berastagi (3°11'24.68"N and 98°30'34.94"E), Tongkoh (3°12'28.72"N and 98°32'15.41"E), Katepul (3° 5'55.64"N, 98°30'16.09"E), and Laubaleng Villages (3°11'9.62"N and 98° 2'34.01"E). Sample plants were collected from conservation forest in Tiganderket (3°10'56.35"N and 98°19'39.13"E), Berastagi and Tongkoh Villages (03001'10"-03019'37" N and 98012'16"-98041'00" E). The research was undertaken from April to November 2013.

B. Data Collection and Sampling Techniques

Primary data were gathered through observations and surveys. Respondents and informants were selected purposively comprising of 48 respondents of patients, farmers, local merchants, processors, and collectors, and 6 government officials as key informants. Sample trees used by the respondents to cure diabetes were collected from the conservation forest for identifying their scientific names according to a systematic plant classification in the Conservation and Rehabilitation Research and

Development Centre in Bogor. Parts of plants identified were leaves, flowers, barks, and fruits.

C. Determination of Index of Cultural Significance

Data of plants, parts of plant, processing methods and the application in diabetes treatment are presented in Table 1 tables and then analysed descriptively. While the level of respondents' preference in utilising this natural medicine is analysed by using the Index of Cultural Significance (ICS) with the following formula:

ICS $= \sum_{i=1}^{n} (q.i.e)ni$

ICS = Total utilisation of a plant (1,…,n)

n = utility values

q =quality values

i = intensity values

e = exclusivity values

The value of quality, intensity and exclusivity are scored using the scoring method proposed by Turner (1988) as cited by Sari (2009) as described below:

Quality value is estimated by scoring the value of plant species, which are: 5 = staple; 4 = secondary material/extra + primary material; 3 = other materials + secondary + medicinal plant material; 2 = ritual, mythology, recreation and so forth; 1 = unknown significance. Intensity value describes the intensity of utilisation of plant species, which are: 5 = very high intensity; 4 = high intensity ; 3 = moderate intensity; 2 = low (minimum), and 1 = very rarely use;

Exclusivity value describes the preference levels, which are: 2 = most preferred (the ultimate choice) and unchangeable; 1 = there are several substitutions to the original plants; and 0,5 = secondary source.

D. Phytochemical screening

Phytochemical screening is a qualitative analysis of the secondary metabolite compounds (Harborne, 1987). Bioactive substances tested usually contain tannins, alkaloids, carbohydrates, terpenoids, steroids and flavonoids. These compounds are synthesised by primary or rather secondary metabolism of living (Mann, 1987; Edoga, Okwu, & Mbaebie, 2005). The testing performed in this study was preliminary for testing the presence of the different chemical groups (Rajani & Kanaki, 2008).

Literature reviews of previous studies were used first to find out the chemical compounds of several medicinal plants used by Karo people and other plants and were tested using phytochemical screening method in the laboratory. This research conducted only a preliminary test of the chemical compounds. To find out more of the pharmacologically compounds, further testing is still required. Four samples were tested in the laboratory i.e. pirdot leaves, loning leaves, yellow bamboo, and umbrella tree leaves. The secondary metabolite compounds tested were alkaloids, steroids, flavonoids, tannins, terpenoids and saponins. The phytochemical analysis was conducted at the Phytochemistry Laboratory, Faculty of Pharmacy, North Sumatra University.

III. RESULT AND DISCUSSION

A. The species of woody plants used for diabetes treatment by the Karo.

There are 12 woody plant species from 11 families used by the Karo people in the treatment of diabetes. Most of the plants are dicotyledonous plants except bamboo which is monocotyledonous. Table 1 shows the scientific and local names of the plants, part of the plants used for diabetes treatment, and method of medicine preparation and suggested dosage/ consumption.

The plant samples were collected from the Karo forest areas at an altitude of about 850 – 1400 meters above sea level except raru barks which were taken from outside of Karo area. Raru (*Cotylelobium melanoxylon* Pierre and *Shorea balanocarpoides*) according to Pasaribu (2009), are grown in the Central Tapanuli and Simalungun Regency forests at an altitude of 100-800 meters above sea level.

Karo people commonly process medical plants into medical concoctions with a very simple technique through boiling the plant

Table 1. The woody plant species utilised by the Karo people to cure diabetes

No.	Scientific name/Family	Local name	Part used	Material preparation and dosage/consumption
1.	*Psychotria* sp./ Rubiaceae	Loning	Leaf	A handful of dried leaves are mixed with 2 liter of water and then boiled until the water is reduced to about one third of its original volume. The remaining water/liquid is consumed twice a day.
2.	*Prunus acuminta* Hook/ Rosaceae	Kacihe	Leaf	9-10 pieces of dried leaves are boiled in 1 liter water until approximately 1/2 part of water is remaining, and then consumed twice a day.
3.	*Maesopsis eminii* Engl/ Rhamnaceae	Umbrella tree/ Kayu Afrika	Leaf	Fresh leaves or dried leaves (5-8 pieces) are boiled in 1 liter water until 2/3 part is remaining and then consumed twice up to three times a day.
4.	*Guazuma ulmifolia* Lamk/ Sterculiaceae	Mutamba/ Jati belanda	Leaf	A handful of dried leaves are boiled in 2 liter of water until 1/3 part is remaining and then consumed twice a day.
5.	*Bambusa vulgaris* Schrad/ Gramnineae	Yellow bamboo	Rod	10-12 pieces of a 1 cm cubes from the rod are boiled in 2 liters of palm sap until ½ part is remaining and then consumed twice a day.
6.	*Saurauia vulcani* Korth/ Actinidiaceae	Pirdot, Cepcepan lembu	Leaf	Dried leaves (5-8 pieces) are boiled in 1 liter of water until half part is remaining and then consumed twice up to three times a day.
7.	*Cotylelobium melanoxylon* Pierre/ Dipterocarpaceae	Raru	Bark	The bark of 3-4 cm long and 1-2 cm width is cut into smaller sizes. Then they are boiled in 2 liters of water until half part is remaining and consumed twice a day
8.	*Shorea balanocarpoides* Symington/ Dipterocarpaceae	Raru	Bark	The bark of 3-4 cm long and 1-2 cm width is cut into smaller sizes. Then they are boiled in 2 liters of water until half of it is remaining. Then it is drunk twice a day.
9.	*Artocarpus altilis*/ Moraceae	Breadfruit	Leaf	The chopped dried leaves, approximately a half handheld quantity are taken and boiled in 2 liters of water until 1/3 part of the water is remaining and consumed twice a day.
10.	*Syzygium polyanthum* Wight/ Myrtaceae	Salam	Leaf	• 5-8 pieces dried leaves boiled in 2 liter of water until about 1/2 part of extract left and it is consumed 2-3 times a day. • A handful dried leaves mixed with dried cinnamon bark, the size of a finger pinkie. Materials are meshed to flour. A spoonful (approximately 1 gram) is brewed in a cup boiled water, then it is consumed 1-2 times a day.
11.	*Swietenia mahagoni* (L.) Jacq/ Meliaceae	Mahogany	Seed	Mahogany seeds are crushed to a finer size. A spoonful of mahogany fraction is boiled in 2 liters of water until ¾ of it is remaining. The extract is consumed once up to twice a day.
12.	*Cinnamomum burmanni*/ Lauraceae	Cinnamon	Bark	Bark size of 3 to 4 cm is boiled in 1 liter water until half of it is remaining, and then the extract is consumed 1-2 times a day.

parts at a certain dose and then drinking the remaining water. They believe that boiling is a simple way to separate the useful substances from the plants. Boiling aims to extract medicinal compounds that dissolve in the water (polar). Thus extraction using the boiling method can separate the chemical constituents from the plant tissue. Heating process can accelerate the extraction process because high temperature will soften plant tissue so that extraction becomes faster. The second method is flouring plant parts that are listed in Table 1 with other materials such as betel leaves, various palm (riman and pinang) roots, turmeric, ginger and lime. Karo people believe that this process can enrich and thus strengthen the efficacy of the medicinal plants.

Karo people gather medical plants from nearby forests, fields, home gardens or purchasing it from local vendors. The forests are spread over Mount Sinabung, Simpang Empat, Namanteran, Tiganderket, Payung, Laubaleng and Mardingding Districts, Bukit Barisan Mountain, Merek, and Forest Conservation Park in the Districts of Berastagi and Dolatrayat. The knowledge of traditional medicine among Karo people has been passed from generations to generations. These traditional medicines are widely known as "Karo medicines" which are easily found at traditional markets in Karo Regency and neighboring areas. The raw materials for the medicines such as leaves, stems, roots and dried fruits are also available at the traditional markets in Kabanjahe and other markets in Berastagi and Tigapanah.

B. The Level of Cultural Significance

The level of cultural significance of various woody plants used for the treatment of diabetes is listed based on intensity and exclusiveness of its utilisation. The value of cultural significance (ICS) of each plant is presented in Table 2.

Table 2 shows five highest ICS values are belonging to loning tree, umbrella tree, mutamba, raru and salam. Result show that these plants are the most preferred and utilised intensively by the Karo people for diabetic treatment that might will affect those plants' existence in the forest. In order to avoid the extinction of these medicinal plants in their habitats, they should be cultivated either in-situ or ex-situ. Cultivation techniques (silviculture) should be taught and disseminated to farmers. Some of those species such as raru (*Cotylelobium melanoxylon*) is listed as endangered species (IUCN, 2014) and mahogany (*Swietenia mahagoni* (L.) Jacq) is listed in APPENDIX II (CITES, 2012; lists species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled).

C. Chemical Compounds

Medical and pharmaceuticals technology in the world rely on the introduction of modern treatment and isolation of various chemical elements contained in the plant materials. One of the tests used to determine the chemical contents of a plant's material is through phytochemical screening which is described as a way to determine the qualitative content of the secondary metabolites of natural materials (Pasaribu, 2009).

Information of phytochemical contents of some woody plants that also are used by Karo people as diabetic medicines is gathered from literatures as presented in Table 3. Other woody plants tested in the laboratory with their results are presented in Table 4.

Tables 3 and 4 showed that alkaloids, flavonoids, phenolic (tannins) and terpenoids are present in pirdot leave, mutamba leave, cinnamon bark, loning leave, umbrella tree leave, salam leave, raru bark, breadfruit leave, and mahogany seed. While phytochemical screening of kacihe leaves (*Prunus acuminta* Hook) was not done in this study due to the very low level of usage of this species by the Karo community. This plant is less desirable in treatment of diabetes because it is considered less potent than other types so it had not been used lately.

According to previous research, those active compounds have hypoglycemic activity that decreases blood sugar level (Lumbanraja, Tabel 2. Index of Cultural Significance (ICS) of diabetic medicinal plants

No.	Family name	Scientific name	Local name	ICS value
1.	Rubiaceae	*Psychotria* sp.	Loning (Karo)	170
2.	Rhamnaceae	*Maesopsis eminii* Engl	Kayu afrika	125
3.	Sterculiaceae	*Guazuma ulmifolia* Lamk	Mutamba/ Jati belanda	103
4.	Dipterocarpaceae	*Cotylelobium melanoxylon* Pierre	Raru (Batak, Karo)	93
5.	Dipterocarpaceae	*Shorea balanocarpoides* Symington	Raru (Batak, Karo)	93
6.	Myrtaceae	*Syzygium polyanthum* Wight	Salam	83
7.	Actinidiaceae		Cepcepan lembu (Karo), Pirdot (Batak)	49
8.	Meliaceae	*Swietenia mahagoni* (L.) Jacq	Mahogany	48
9.	Moraceae	*Artocarpus altilis* (Park.) Fosberg	Breadfruit	41
10.	Lauraceae	*Cinnamomum burmanii*	Cinnamon	28
11.	Gramnineae	*Bambusa vulgaris* Schrad.	Yellow bamboo	25
12.	Rosaceae	*Prunus acuminata* Hook	Kacihe (Karo)	13

Remark: n = 48

2008; Pasaribu, 2009; Ngadiwiyana et al, 2011). Table 3 shows that mahogany seeds contain saponins, flavonoids and alkaloids. Lumbanraja (2008) stated that mahogany seeds extracted with ethanol would lower blood sugar levels. Raru wood extract contains flavonoids, tannins and saponins which are also lowering blood sugar levels through inhibition of the activity of α-glucosidace enzyme. This enzyme breaks polysaccharides into simple molecules that can be absorbed by the blood (Pasaribu, 2009). The most responsible chemical compounds for curing diabetes is belong to phenolic groups, namely cinnamaldehyde. Ngadiwiyana et al., 2011 stated that cinnamaldehyde isolated from cinnamon bark can inhibit the action of α-glucosidace enzyme, so it has the potential to decrease blood sugar level.

Based on above results, it can be concluded that indigenous knowledge of Karo people in identifying and utilising woody plants for traditional diabetic drugs is not contradicting to pharmacology. The varieties of the plants used by Karo people generally contain the active compounds that are studied in most researches (Table 3 and 4). A research conducted by Giri (2008) on the potency of salam leaf (Syzygium polyanthum Wight) to reduce the blood sugar level, concluded that the blood sugar level in the treated mice inducted with hyperglicea had significant effect on the decrease of the blood sugar level. However, to determine the most active compound that acts to degrade blood sugar level needs further tests on various types of pharmaceuticals that were not yet conducted in this study. The tests that should be done

Table 3. Phytochemical content of woody plants used by Karo people as diabetes medicine based on literature review

No.	Name/ part used	Chemical compounds: Alkaloids	Steroids	Flavonoids	Tannins	Saponin	Triterpenoids	Others	Literatures Source
1.	*Swietenia mahagoni* (L.) Jacq seed	+	-	+	-	+	-	-	Hariana, 2007; Lumbanraja, 2008.
2.	*Artocarpus altilis* (Park.) Fosberg / leaf	-	-	+	+	+	-	hydrocyanic acid, acetyl choline	Ministry of Health of Republic Indonesia, 1997
3.	*Cotylelobium melanoxylon* Pierre /bark	-	-	+	+	+	+	-	Pasaribu, 2009
4.	*Shorea balanocarpoides* Symington /bark	-	-	+	+	+	-	-	Pasaribu, 2009
5.	*Cinnamomum burmanii* /bark	+	-	+	+	+	+	-	Sufriadi, 2006
6.	*Guazuma ulmifolia* Lamk/Leaf	+	+	+	+	+	+	-	Dzulkarnaen & Widowati, 1996; Umar, 2008
7.	*Syzygium polyanthum* Wight /leaf	-	-	+	+	+	-	-	Sulistiyani et al., 2010; Oktavia, 2011

should include isolation of active compounds and test on extracts or isolates in experimental animals.

IV. CONCLUSION

The Karo people in North Sumatra possess local knowledge that has been transferred from generations to generations for using parts of 12 woody plants as diabetic medicines, i.e. loning leave (*Psychotria* sp.), kacihe leave (*Prunus accuminata* Hook), umbrella tree leave (*Maesopsis eminii* Engl), mutamba leave (*Guazuma ulmifolia* Lamk), cepcepan leave (*Villebrunea subescens* Blume), pirdot/cepcepan lembu leave (S*aurauia vulcani* Korth), raru bark (*Cotylelobium melanoxylon*), breadfruit leave (*Artocarpus altilis*), salam leave (*Syzygium polyanthum* Wight), mahogany seed (*Swietenia mahagoni* (L.) Jacq), cinnamon bark (*Cinnamomum burmanni*), and yellow bamboo rod (*Bambusa vulgaris* Schrad). Five plants have proved to be the most preferred and utilised intensively by the Karo people for diabetic treatment, i.e. loning tree, umbrella tree, mutamba, raru and salam, so they need to be conserved through in-situ or ex-situ techniques to avoid extinction.

Chemical compounds in those 12 woody plants have proven to decrease blood sugar level. It means that the traditional knowledge of Karo people in utilising woody plants as diabetic medicine complies with pharmacology, however further research is still needed on

Table 4. The phytochemical contents of several woody medicinal plants tested in laboratory

No.	Samples of plants	Alkaloids			Steroids	Tannins	Flavonoids	
		Meyer	Dragendrof	Bouchardar			Zn reagent	Mg reagent
1.	Pirdot leaves	+	+	+	+	+	+	+
2.	Loning leaves	+	+	+	+	-	+	+
3.	Yellow bamboo	+	+	+	+	+	+	+
4.	Umbrella tree leaves	+	+	+	+	-	+	+

Remarks : + = contain tested elements
- = does not contain tested elements

isolation of active compounds and testing them on experimental animals.

ACKNKOWLEDGEMENT

We would like to express our sincere gratitude to the Head of Aek Nauli Forestry Research Institute for facilitating of this research and to Forestry District officers of Karo Regency who had accompanied along the research. Without these supports, the study would not have been possible. We thank to our technicians Salman Zuhri and Andilo E. Siahaan for all the fieldworks and data collection.

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SOIL AND WATER MICROORGANISM DIVERSITY OF MANGROVE FOREST OF TELUK KELUMPANG, SELAT LAUT AND SELAT SEBUKU NATURAL RESERVE

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Received: 23 October 2013, Revised: 31 August 2015, Accepted: 7 September 2015

SOIL AND WATER MICROORGANISM DIVERSITY OF MANGROVE FOREST OF TELUK KELUMPANG, SELAT LAUT AND SELAT SEBUKU NATURAL RESERVE. Mangrove is a unique ecosystem that has complex biotic and abiotic components. Soil and water microorganisms have function as decomposer in mangrove forest ecosystem. This paper studies the soil and water microorganisms' diversity, their potential, function in ecosystem and their role as environmental parameters in mangrove area of Teluk Kelumpang, Selat Laut and Selat Sebuku Natural Reserve (Kelautku Natural Reserve). Data of soil and water microorganisms were recorded from soil and water samplings then analyzed in the laboratory. Results show that benthos in Selat Sebuku figure the highest diversity index. *Anadara granosa* is one of the common benthos found in Selat Sebuku. In contrary the phytoplankton in Selat Sebuku is the lowest value compared to the other two locations, due to the settlements in the locations and it was suspected that Selat Sebuku has a relatively larger wave exposure than the two other locations. In addition, input of organic matters from the settlements in Teluk Kelumpang and Selat Laut is also effected by the growth of phytoplankton. Cyanophyta found in Teluk Kelumpang and Selat Laut was genera of Oscillatoria that showed high tolerance genera to the environment conditions.

Keywords: Diversity, soil and water microorganism, mangrove forest, Kelautku Natural Reserve

KEANEKARAGAMAN MIKROORGANISME TANAH DAN AIR HUTAN MANGROVE CAGAR ALAM TELUK KELUMPANG, SELAT LAUT DAN SELAT SEBUKU. Mangrove adalah suatu ekosistem unik yang memiliki komponen biotik dan abiotik yang komplek. Komponen mikroorganisme tanah dan air berfungsi sebagai dekomposer dalam ekosistem mangrove. Tulisan ini mempelajari keanekaragaman mikroorganisme tanah dan air, potensi dan fungsinya dalam ekosistem, dan parameter lingkungan di kawasan mangrove Cagar Alam Teluk Kelumpang, Selat Laut, dan Selat Sebuku (Cagar Alam Kelautku). Data mikroorganisme tanah dan air diambil dengan cara pengambilan contoh uji tanah dan air kemudian dianalisis di laboratorium. Hasil penelitian menunjukkan bahwa Selat Sebuku memiliki indeks keanekaragaman benthos tertinggi. Salah satu kelimpahan bentos yang banyak ditemukan di Selat Sebuku adalah Anadara granosa. Berlawanan dengan kelimpahan benthos kelimpahan plankton terendah di Selat Sebuku. Hal ini diduga gelombang laut lebih besar di Selat Sebuku dan kepadatan pemukiman lebih banyak di Teluk Kelumpang dan Selat Laut yang menyebabkan adanya input dari limbah rumah tangga ke dalam perairan sekitarnya. Cyanophyta yang hanya ditemukan di Teluk Kelumpang dan Selat Laut merupakan genera Oscillatoria yang menunjukkan toleransi tinggi terhadap kondisi perairan

Kata kunci: Keanekaragaman, mikroorganisme tanah dan air, hutan mangrove, Cagar Alam Kelautku

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I. INTRODUCTION

Mangrove forest gives huge benefits to human life and produce economic services. Mangrove functions as coastline protection, food chains support, and carbon sequestration (Giesen, Wulffraat, Zieren, & Scholtren, 2006). Mangrove leaves are the biggest parts of the primary litter products and provide food for the consumers and contribute to the food chains in coastal areas by the fallen litter of the leaves (Ananda, Sridhar, Raviraja, & Barlocher, 2007). While the economic functions are many, e.g. to produce construction timber, industrial raw materials, firewood and charcoal, honey, and to support the breeding and cultivation of fish, milkfish, shrimp, clams, crabs, and also as a tourism object.

Domingues, Barbosam, & Galvao (2008) stated that some important ecological functions of Phytoplankton were as primary producer that directly and indirectly fuels the food webs, produce important impacts on water quality (e.g. by affecting turbidity and concentration of dissolved oxygen) and plays a number of other major roles in many ecosystem processes. In consequence, phytoplankton is usually employed as an indicator of change in nutrient loads and as a key element for assessing eutrophication in marine systems. The phytoplankton diversity is indirectly affected by temperature in the post-bloom phase through changing zooplankton composition and grazing activities (Lewandowska, Hilldebrand, Lengfellner, & Sommer, 2014)

South Kalimantan has mangrove forest conservation areas which are classified as a nature reserve. Teluk Kelumpang, Selat Laut, and Selat Sebuku Nature Reserve (Kelautku Natural Reserve) is a representative type of mangrove ecosystems and unique lowland forests that have many species of protected fauna and unique flora of mangrove and lowland forests of South Kalimantan. This area has a distinctive protected flora and fauna of mangroves, for example the proboscis monkey (Nasalis larvatus) which is also an icon animal of South Kalimantan.

Research in this area, especially regarding aquatic fauna and soil and water microorganisms of mangrove forest has not been done. Therefore this research is carried out to generate scientific information on the diversity of aquatic fauna and microorganisms in soil and water of the mangrove ecosystem. This scientific information is very important to be used as a base for further management action. Plankton and benthos data can be used as indicators of water nutrient pollution, because some species of plankton and bethos can only live or abundantly exist in a specific water condition.

II. MATERIAL AND METHOD

A. Research Location

The study was conducted in natural mangrove stands which were in good condition, in the Kelautku Natural Reserve, Kotabaru District, South Kalimantan. Kelautku Natural Reserve is located at coordinates 115°58'10 "- 116°24'00" E, 2°48'10"- 3°38'50" S. This area has a flat topography with an elevation of 0-15 m above sea level. Soils are alluvial, podzolic and a little muddy on the beach area with sedimentary alluvium rocks and coral reefs. The climate at Kelautku Natural Reserve is of type B (climate type of Schmidt and Ferguson) with an average rainfall of 2,500 mm/year, average humidity is 70% and an average temperature of 26°C. Research location was chosen based on the diversity of mangrove plants where these three locations had a higher number of mangrove species compared to other mangrove forests existing in South Kalimantan. These three locations faced different problems. Conversion of mangrove for palm plantation was the problem in Teluk Kelumpang Natural Reserve area. While in Selat Laut Natural Reserve, some parts of the area were converted to ponds and harbor at nearby settlements. In Selat Sebuku Natural Reserve, mangrove was converted to ponds which were located side by side with the iron mining area (BKSDA Kalimantan Selatan, 2013).

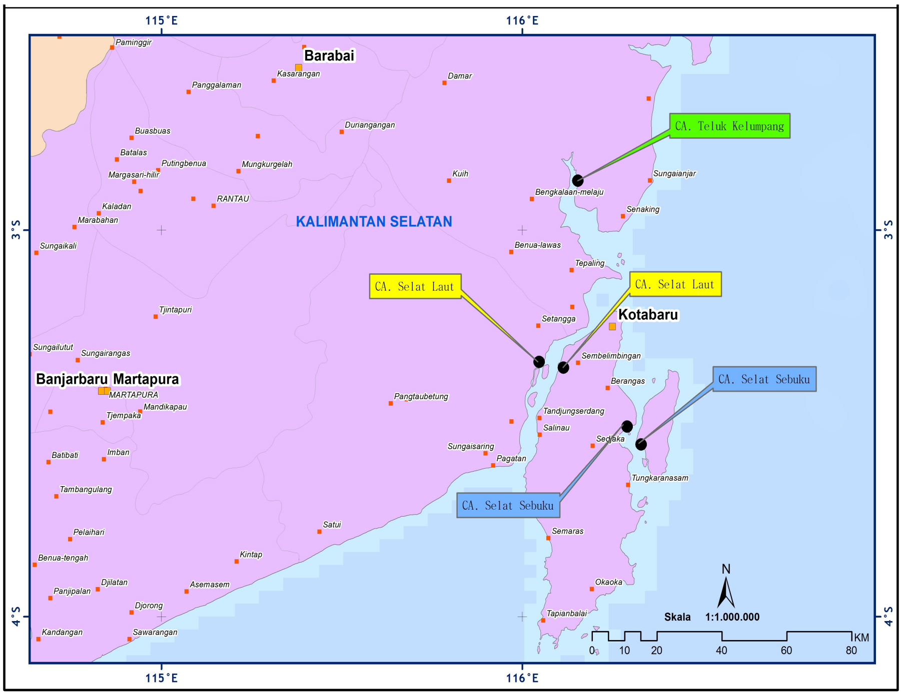

Figure 1. Research site map

B. Experimental Design

The research activity was carried out through observation/field observations on natural mangrove ecosystem with good conditions in Kelautku Natural Reserve, Kotabaru, South Kalimantan. Parameter observed includes water quality, benthos and plankton.

Water quality in aquatic ecosystems was observed in various parameters such as water temperature, pH, turbidity and salinity. Water temperature, salinity and pH were measured with a digital tool called conductivity. Its censor part was put into the sea water and soaked for two minutes then the numbers shown were read and recorded. Dissolved oxygen (DO) was measured using Winkler titration method, which was conducted directly in the field.

Turbidity is an optic character of water based on the number of light that was produced and absorbed by the particles in the water. Turbidity is caused by suspended and dissolved organic and inorganic materials. Turbidity influences light penetration into the water thus reduces phytoplankton productivity in the waters (APHA, 1989).

Benthos sampling was carried out on the floor of the mangrove forests using trap method. Trap was made of a plastic tube with holes on both ends with a length of 5 cm. Trap was embedded in the substrate (5 cm) and then the substrate in the trap was filtered using a sieve of 1 mm mesh size. Furthermore, the filtered benthos was put in plastic bottles and soaked in a solution of 5% formalin. Benthos sampling was done three times with three measuring points taken compositely around the river at each location.

Plankton was collected by using plankton net. Microorganisms data were retrieved by taking water samples and analyzed to determine the physical, chemical and laboratory content of microorganism at the Faculty of Fisheries laboratory of Lambung Mangkurat University, Banjarbaru, South Kalimantan. Plankton sampling was done three times with three measuring points taken compositely around river at each location.

Biological Index Analysis was used to determine species diversity level in spesific ecosystem as mentioned by Odum (1994).

III. RESULT AND DISCUSSION

A. Water Quality

Water quality is the limiting factor for aquatic fauna and microorganisms. Water quality of the three locations is shown below in Table 1.

Temperature range of the three locations is 28-29,4 °C. This range is normal for the tropical area. The difference of the lowest and the highest temperature was not significantly affected by the watershed metabolism (Garno, 2008). Water temperature measured, based on the Decree of Minister of Environment No. 51 year 2004, was within the normal limit, as 28-32°C is normal for water temperature in mangrove area.

Generally, sea water has a pH value above 7, while suitable pH value for water life is 7-8.5. The pH parameter in Selat Laut and Selat Sebuku was in the normal range (7-8.5). While pH parameter in Teluk Kelumpang location was below the normal limit. Low pH parameter in Teluk Kelumpang was caused by the dense settlement nearby where disposal of domestic litters mainly detergents resulted in degradation of pH parameter (Susana, 2009).

Similarly Dissolved Oxygen (DO) in Selat Laut and Selat Sebuku was in normal range, but DO in Teluk Kelumpang was below normal. Salinity of the three locations was within the normal range. The low value of dissolved oxygen was in the same rate as the low value of pH. This has confirmed that these waters had been polluted by domestic litter (Susana, 2009).

B. Benthos

Benthos found in the research locations are Mollusca and Annelida. Quantity and diversity of benthos are shown in Table 2.

In general, Table 2 shows the highest quantity of benthos was found in Selat Sebuku Nature Reserve. The lowest quantity of benthos abundance was in Selat Laut Nature Reserve. Shannon Wiener calculation indicated that Selat Sebuku Natural Reserve achieved the highest index of benthos.

The diversity index is affected by water conditions. Teluk Kelumpang and Selat Laut waters have more people accessing the area and fishing vessels than Selat Sebuku, therefore the water pollution in term of waste residues and motorboat fuel are more prevalent in Teluk Kelumpang and Selat Laut. This condition is similar with those stated by Odum (1994), that a healthy water (not contaminated) will show almost a balanced number of individuals of existing species. Otherwise in tainted water, distribution of the number of individuals is uneven and there are spesific species tend to dominate.

In addition, aquatic life can survive if there is a minimum dissolved oxygen of 5 mg/l, and the rest depends on the organism's fitness, degree of activity, the presence of contaminants, temperature, and vice versa (Sastrawijaya, 1991). Dissolved Oxygen (DO) in the waters of Selat Sebuku was higher than those in the other two locations. The DO of Selat Sebuku was about 6.73, while in Teluk Kelumpang and Selat Laut it was 4.13 and 5.53 respectively. The availability of dissolved oxygen was the most possible reason of larger quantity of benthos in the Selat Sebuku than in the other locations.

Eventhough the highest quantity species was recorded at Selat Sebuku Natural Reserve, fellen trees were also found in the area. Local residences mentioned that mangrove trees were

Table 1. Average physical and chemical values of water in Kelautku Natural Reserve

Parameter	T. Kelumpang	S. Laut	S. Sebuku	Mangrove Guide Standard
Temperature [^{o}C]	28.1	29	29.43	28-32^{o}C
pH	6.75	7.16	7.13	7-8.5
DO [mg/l]	4.13	5.53	6.73	>5
Salinity [‰]	21.67	24	20.67	s/d 34

Table 2. The quantity (individual/l), index of diversity and dominancy of benthos of the three locations in Kelautku Natural Reserve

Phyllum	Class	Genera	Teluk Kelumpang	Selat Laut	Selat Sebuku
Mollusca	Bivalvia	*Tellina* sp.	58.7	29.3	58.7
	Bivalvia	Donax	56.7	14.7	-
	Gastropoda	*Terebralia* sp.	-	-	14.7
	Gastropoda	Ceritium	-	-	14.7
	Bivalvia	Piniidae	-	-	58.7
	Bivalvia	Mactidae	-	-	220
	Bivalvia	*Anadara granosa*	-	-	234.7
	Gastropoda	Bullidae	-	-	73.3
	Gastropoda	Nerita	-	-	14.7
Annelida		Diplogasterodae	14.7	29.3	-
		Abundance [individual/l]	132	73.3	689
		Diversity index (Shannon Wiener)	0.79	0,69	0.89
		Dominancy	0.48	0.66	0.46

cut down to build the foundation of bagang (a hut in the sea for fishing). It Was predicted that the utilization of mangrove trees for bagang will damage the mangrove ecosystem.

One of benthos found in Selat Sebuku is *Anadara granosa*. Which is a bivalvae mollusca in the family of Arcidae, subfamily Anadarinae. Since *A. granosa* is a filter, feeding organism contamination of the highly productive mudflats with heavy metals tend to be accumulated in their body tissues. This could serve as an important environmental sink of heavy metals and provide an indication of river pollution (Alkarkhi, Ismail, & Easa, 2008). The quantity high of *Anadara granosa* indicates the concentration of organic matter in Selat Sebuku water is higher than the other two locations (Prasojo, 2012). Accumulated organic matter was considered coming from residues of illegal ponds activities in Selat Sebuku. The statistic of the Natural Resource Conservation Agency of South Kalimantan (2013) stated that 2,346 ha of illegal ponds existed in Selat Sebuku Natural Reserve. Besides that, the location of Selat Sebuku Natural Reserve was nearby iron mining. *Anadara granosa* is one of the food sources for fishermen which is high in protein. In addition, *Anadara granosa* (blood clams) is also an indicator of water condition due to its ability to accumulate the metal better than other aquatic animals because it settle and filter food (filter feeders) and moves slow to be able to escape the effects of pollution (Fauziah, 2012).

C. Plankton

1. Phytoplankton

In contrary to the abundance of benthos, the quantity of phytoplankton in Selat Sebuku showed the smallest value compared to the other two locations. It is probably caused by the smaller number of activities and fewer settlements compared to the other locations. In addition, the higher exposure to sea waves also caused lower abundance of phytoplankton in Selat Sebuku. Phytoplankton condition in research location can be seen in Table 3.

Lee (1978) in Zulkifli (2009) stated that if the water a diversity index value is smaller than

1, then the water is categorized as polluted. If the diversity index ranges from 1.5 to 2.0 then the water is in the lightly polluted category, and if it has diversity index of more than 2.0, then the water is categorized as not polluted. Diversity index in these three waters were more than 2, therefore the waters were not polluted.

The quality area of phytoplankton in Teluk Kelumpang was the highest compared to the other two locations. Teluk Kelumpang has the lowest level of turbidity compared to the other two locations. A condition of clear water allows better sunlight penetration, thus supporting the development and activity of phytoplankton photosynthesis. Another possible cause of the abundance of phytoplankton in Teluk Kelumpang and Selat Laut was the content of organic matter in the waste from settlement as nutrient inputs for phytoplankton. The settlements in Teluk Kelumpang and Selat Laut were denser than in Selat Sebuku. This was confirmed with a research of Barus, Sinaga, & Tarigan (2008) who stated that waters with settlements contributed to phytoplankton abundance by pollutants from domestic activities.

In Teluk Kelumpang and Selat Laut, it was found Cyanophyta, and was not in the waters of Selat Sebuku. Some Cyanophyta can bind nitrogen and act as pioneer plant in nutrient-poor areas such as sandy beaches. Cyanophyta's body is gas vacuoles that can float near the surface of the water, which has a high light intensity. Cyanophyta needs sunlight for photosynthesis. Selat Sebuku has a relatively dense mangrove stand, so that less sunlight reach the waters. Teluk Kelumpang and Selat Laut which more open sea. This was the cause of not finding Cyanophyta in Selat Sebuku. Cyanophyta is usually found in water polluted by phosphor and nitrogen nutrient. The existence of Cyanophyta confirmed the conclusion that the water was in eutrophic condition where Cyanophyta thrived by its adaptation ability to a high oxygen dissolved fluctuation (Garno, 2005).

Cyanophyta found in Teluk Kelumpang and Selat Laut was from the genera of Oscillatoria that showed that this species had a high tolerance to environment condition (Zulkifli, Husnah, Ridho, & Juanda, 2009). Bacillariophyceae in both locations tended to be more abundant than in Selat Sebuku. Bacillariophyceae group is a phytoplankton which is commonly found in Indonesian waters because of its ability to cope with extreme environmental conditions and high reproduction capability (Zulkifli et al., 2009; Nurfadillah, Damar, & Adiwilaga, 2012; Radiarta, 2013; Yuliana, Adiwilaga, Harris, & Pratiwi, 2012; Thoha & Amri, 2011). Basillariophyceae class is a diatom that is often found in Indonesian waters, such as Selat Alas, Sumbawa, NTB (Radiarta, 2013). Oscillatoria genus can be used as water bio-indicator to show that the water is moderately polluted (Zulkifli et al., 2009).

Chaetocerros was found in all three locations. Chaetocerros is a species that commonly found in tropical waters (Usman, Kusen, & Rimper, 2013; Sutomo, 2013; Sawestri & Farid, 2012; Samsidar, Kasim, & Salwiyah, 2013; Nurfadillah et al., 2012; Radiarta, 2013; Thoha & Amri, 2011). In the three locations, *Nitzchia* sp. was found at different rate of quantity. The highest was in two locations Teluk Kelumpang with 150 individuals/l and Selat Laut with 136.7 individuals/l. In Selat Sebuku it was only 10 individuals/l. Nitzchia is one of the species that will endanger other organisms if it exists in a high number (Garno, 2008).

2. Zooplankton

The quantity of zooplankton in Selat Sebuku showed the lowest value. Diversity of zooplankton is illustrated in Table 4. Selat Sebuku had the lowest zooplankton abundance compared to the other two locations. This was related to the number of existing phytoplankton in the water at this location. The high density of zooplankton is affected by high phytoplankton. Phytoplankton abundance in Selat Sebuku was low, so zooplankton abundance was low as well. Zooplankton abundance can be affected by several factors such as the abundance of

Table 3. Abundance (individual/l), index of diversity and dominancy of Phytoplankton at three locations in Kelautku Natural Reserve.

Phyllum	Genera	Teluk Kelumpang	Selat Laut	Selat Sebuku
Cyanophyta	Oscillatoria	63.3	56.7	-
Chlorophyta	Closterium	16.7	10	26.7
	Meugeotia	56.7	26.7	-
	Gonatozygon	23.3	30	-
	Steletonema	33.3	23.3	-
	Spirogyra	-	-	6.67
	Cosmocladium	-	-	93.3
	Cosmarium	-	-	16.7
	Staurastrum	-	-	60
	Eunotia	-	-	40
	Eunotia	-	-	30
	Pediastrum	-	-	83.3
	Docidium	-	-	13.3
Chrysophyta	Campylodiscus	-	-	6.67
	Coscinosira	40	-	-
	Cyclotella	16.7	-	6.7
	Frustulia	13.3	-	-
	Gomphonema	-	-	13.3
	Gyrosigma	156.7	116.7	110
	Laundria	96.7	73.3	-
	Rhabdonella	-	-	6.7
	Stephanodiscus	66.7	66.7	283.3
	Stephanopyxis	350	300	-
	Streptotheca	60	46.7	3.3
Bacillariophyceae	Bacteriastrum	216.7	193.3	-
	Chaetoceros	330	160	53.3
	Coscinodiscus	53,3	50	-
	Nitszchia	150	136.67	10
	Rhizosolenia	66.7	66.7	16.7
	Thallasiothrix	220	216.7	3.3
	Dytillium	20	30	-
	Triceratium	-	-	6.7
	Melosira	26.7	23.3	-
	Thallasiosira	56.7	40	-
	Surirella	23.3	-	-
	Diplnoeis	6.67	-	-
	Diatoma	83.3	43.3	16.7
	Biddhulpia	63.3	60	-
	Amphora	20		13.3
	Hemialus	16.7	20	-
Abundance [individual/l])		2346.7	1813.3	976.7
Diversity index (Shannon Wiener)		2.7	2,7	2
Dominancy index		0.1	0.1	0.2

phytoplankton, waves and predators (Nybakken, 1988).

At Selat Sebuku, only protozoa zooplankton was discovered, while in Teluk Kelumpang and Selat Laut also zooplankton of phylum crustaceans can be found. Crustascea found in Teluk Kelumpang and Selat laut were from the genera Diaphanosoma, Nauplius, and Diaptomus. The relationship between life expectancy and water temperature of *Diaphanosoma dubium* Manuilova was in the form of a parabola (Han, Juan, Xian, & Dumont,

Table 4. Abundance (individual/l), index of diversity and dominancy of Zooplankton at three locations in Kelautku Natural Reserve

Phyllum	Genera	Teluk Kelumpang	Selat Laut	Selat Sebuku
Protozoa	Tintinnopsis	23.3	23.3	-
	Peridinium	6.7	-	-
	Difflugia	6.7	-	-
	Parafavella	-	-	6.7
	Peridinium	-	-	6.7
	Gymnodinium	-	-	3.3
Crustacea	Diaphanosoma	10	10	-
	Nauplius	66.7	66.7	-
	Diaptomus	23.3	43.3	-
Abundance [individual/l]		136.7	143.3	16.7
Diversity index (Shannon Wiener)		1.4	1,1	0
Evenness index		0.8	0.9	0
Dominancy index		0.4	0.4	1

2011). It can be said that Diaphanosoma does not like too high temperatures. Among the three study sites, Selat Sebuku has the highest water temperature (29.43°C).

IV. CONCLUSION

Research the study shows that the quality of mangrove waters, directly or indirectly, was mostly affected by human activities such as settlements, mangrove conversion to ponds, agriculture, harbor and mining. Some areas of mangrove in Selat Sebuku Natural Reserve had been converted to ponds. Benthos at Selat Sebuku Natural Reserve has the highest diversity index. *Anadara granosa* is one of the common benthos found in Selat Sebuku. Contrary to the abundance of benthos, the abundance of phytoplankton in the Selat Sebuku showed the smallest value compared to the other two locations, due to many settlements at the two other locations and also it is suspected that Selat Sebuku has a relatively bigger wave exposure than the two other locations. In Teluk Kelumpang Natural Reserve, part of mangrove forest had been converted to ponds and angriculture activities. In Selat Laut Natural Reserve, mangrove forest was converted to ponds, settlements and mining harbor. In addition, input of organic matters from the settlements in Teluk Kelumpang and Selat Laut also affected the growth of phytoplankton. Cyanophyta found in Teluk Kelumpang and Selat Laut was from the genera of Oscillatoria that showed that this species had a high tolerance to environment condition. Good condition of mangrove will support a good aquatic environment condition as well. Mangrove protected area manager need to conserve mangrove and prevent mangrove conversion to other land uses. Beside that, routine control of mangrove water and surrounding areas is needed.

ACKNOWLEDGEMENT

A big thank to the Head of Banjarbaru Forestry Research Institute that facilitated this research. We also thank to our technicians Hendra Ambo Basiang and Arif Susianto who helped us doing the field work.

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Water is a necessary part of every reasons's diet and of all the nutrient a body needs to function, it requires more water each daya than any other nutrients a body needs to function, it requires more water each day than any other nutrient (Whitney & Rolfes, 2011)

Or

Whitney and Rolfes (2011) state the body requires many nutrients to function but highlight that water is of greater importance than any other nutrient.

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