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ABSTRACTS

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Emi Roslinda and Yuliantini

THE ECONOMIC VALUE OF HYDROLOGICAL SERVICES IN MENDALAM SUB WATERSHED, KAPUAS HULU REGENCY, WEST KALIMANTAN, INDONESIA

(NILAI EKONOMI JASA HIDROLOGIS HUTAN DI SUB DAS MENDALAM, KABUPATEN KAPUAS HULU, KALIMANTAN BARAT, INDONESIA)

Ekosistem hutan mampu memenuhi hampir seluruh kebutuhan manusia melalui kontribusi nilai-nilai yang bersifat *tangible* dan *intangible* yang dimilikinya. Namun, nilai *intangible* yang dimiliki hutan kurang mendapat perhatian dibanding nilai *tangible* hutan. Hal ini berakibat pada estimasi yang rendah terhadap nilai total yang dimiliki ekosistem hutan sehingga menyebabkan terjadinya konversi ekosistem hutan kepada penggunaan lain yang dianggap lebih menguntungkan dan terjadi kesalahan dalam pengelolaan ekosistem hutan. Salah satu nilai *intangible* hutan yang penting adalah nilai hidrologis. Sampai saat ini, nilai jasa hidrologis hutan sulit untuk dihitung. Dalam penelitian ini nilai *intangible* dari air untuk kebutuhan rumah tangga, transportasi, pertanian dan perikanan di Sub DAS Mendalam telah dilakukan. Nilai ekonomi dihitung menggunakan metode nilai pasar, biaya kesempatan dan surplus konsumen. Hasil penilaian menunjukkan berdasarkan biaya kesempatan nilai hidrologi adalah Rp 8.043.706.237,50 per tahun. Sementara nilai hidrologi berdasar surplus konsumen adalah Rp 8.031.351.664,60 per tahun, berarti lebih rendah dibanding metode biaya kesempatan. Penelitian ini menunjukkan bahwa nilai ekonomi jasa hidrologi hutan sangat tinggi, yang mana belum dimasukkan dalam perhitungan nilai ekonomi ekosistem hutan sehingga menimbulkan salah pengelolaan ekosistem hutan. Namun, perlu diingat bahwa tanpa adanya pohon tidak akan ada ekosistem hutan dan semua nilai ekonomi hutan yang terkandung di dalamnya. Konsekuensinya adalah, pengelolaan hutan saat ini dan masa mendatang perlu perhatian lebih lanjut mengenai ekosistem hutan.

Kata Kunci: Nilai *intangible*, jasa hidrologis, ekosistem hutan, DAS Mendalam

UDC/ODC 630*913

Gun Gun Hidayat and Hiroaki Kakizawa

DEVELOPMENT PROCESS OF WATERSHED PARTNERSHIP: A CASE STUDY OF LIMBOTO WATERSHED - GORONTALO, INDONESIA

(PROSES PERKEMBANGAN KEMITRAAN DAS: STUDI KASUS DAS LIMBOTO – GORONTALO, INDONESIA)

Pembentukan Kemitraan DAS diperlukan untuk mencapai Pengelolaan DAS Terpadu di Indonesia. Dengan mengambil Kemitraan DAS Limboto sebagai studi kasus, studi ini bermaksud menggali proses pembentukan kemitraan DAS, status dan perannya di dalam sebuah DAS. Sejumlah data dan informasi telah dikumpulkan melalui proses wawancara, diskusi kelompok dan survey kuesioner. Hasil studi menunjukkan bahwa pada tahap awal kemitraan, dengan proses persiapan yang baik maka kemitraan meraih perhatian dan dukungan dari pemangku kepentingan. Proses yang dilakukan secara informal, terbuka dan sukarela yang diadopsi oleh koordinator kemitraaan pada saat pembentukan dan tahap awal operasi sehingga kemitraan mengalami situasi yang inklusif dan aktif, dipandang sebagai sebuah kesuksesan. Namun demikian, pada tahap berikutnya, kemitraan tidak mampu mengatasi isu formalisasi sebagaimana tuntutan desentralisasi, dimana kemitraan menjadi sebuah struktur baru yang tidak memiliki institusi penanggung jawab, sekretariat dan sumber pendanaan yang jelas, sebagai akibat rendahnya perhatian dan kemauan mengambil alih tanggung jawab dari lembaga pemerintah lokal yang diharapkan. Formalisasi menyebabkan kemitraan tidak dapat berfungsi. Meski begitu, banyak anggota kemitraan memandang bahwa kemitraan memiliki peran positif khususnya terkait pertukaran informasi dan peningkatan kepedulian masyarakat Kemitraan ini tidak berfungsi bagi pengembangan pengelolaan DAS terpadu, namun lebih kepada mendidik dan menginspirasi masyarakat atas pelestarian DAS melalui aktifitas berbasis proyek.

Kata Kunci: Proses persiapan, informal, formalisasi, pemerintah daerah, disfungsi

UDC/ODC 630*232.2

Arif Nirsatmanto, Teguh Setyaji and Reny Setyo Wahyunigtyas

REALIZED GENETIC GAIN AND SEED SOURCE X SITE INTERACTION ON STAND VOLUME PRODUCTIVITY OF *ACACIA MANGIUM*

(PERBAIKAN GENETIK AKTUAL DAN INTERAKSI SUMBER BENIH X TAPAK TERHADAP PRODUKTIVITAS VOLUME TEGAKAN *ACACIA MANGIUM*)

Studi ini bertujuan untuk mengetahui besarnya perbaikan genetik aktual terhadap produktifitas volume tegakan dan interaksi sumber benih x lokasi pertanaman. Benih unggul *A. mangium* dari lima kebun benih diuji bersama benih dari tegakan benih di plot uji perbaikan genetik di Kalimantan Selatan dan Jawa Tengah. Hasil penelitian menunjukkan bahwa benih unggul dari kebun benih memilikii produktivitas volume tegakan yang lebih tinggi dibandingkan benih kontrol dari tegakan benih. Tingkat perbaikan genetik aktual di Kalimantan Selatan mencapai 66% umur dua tahun dan 59% umur empat tahun, sedangkan di Jawa Tengah mencapai 136% umur dua tahun dan 81% umur empat tahun. Interaksi sumber benih x lokasi tidak menunjukkan pengaruh yang nyata dan superioritas benih unggul stabil dikedua lokasi. Benih unggul dari lima kebun benih yang diuji dapat digunakan untuk pembangunan pertanaman di Kalimantan Selatan dan Jawa Tengah tanpa ada penurunan superioritas terhadap produktifitas volume tegakan yang dihasilkan.

Kata Kunci : *Acacia mangium*, uji perbaikan genetik, perbaikan genetik riil, sumber benih, tegakan benih, volume tegakan

UDC/ODC 630*93

Cecep Handoko

SOME PROBLEMS IN MAINTAINING SUSTAINABILITY OF INDONESIA'S FORESTS: DESCRIPTIVE STUDY (SOME PROBLEMS IN MAINTAINING SUSTAINABILITY OF INDONESIA'S FORESTS: DESCRIPTIVE STUDY)

(BEBERAPA MASALAH DALAM MEMPERTAHANKAN KELESTARIAN HUTAN INDONESIA: KAJIAN DESKRIPTIF)

Hutan Indonesia memiliki manfaat secara ekonomi, sosial, dan lingkungan. Beberapa upaya nasional, begitu pula dukungan dari komunitas global untuk mempertahankan pembangunan hutan Indonesia telah dilakukan. Namun, beberapa masalah masih mengemuka selama pembangunan hutan tersebut. Analisis menyeluruh diperlukan untuk merumuskan akar dari masalah-masalah tersebut, dan mendapatkan solusi/dukungan bagi pembangunan hutan yang berkelanjutan. Analisis deskriptif digunakan dalam penelitian ini. Hasil penelitian menunjukkan bahwa pembangunan hutan yang berkelanjutan di Indonesia masih dihadapkan pada masalah-masalah berupa ketidakpastiaan pengelolaan, rendahnya kapasitas pengelolaan dan rendahnya penegakan hukum. Kondisi tersebut ditandai oleh tingginya konflik kepentingan serta rendahnya dukungan para pihak, rendahnya tindakan-tindakan pengelolaan di tingkat tapak dan tingginya kerusakan hutan. Untuk mengatasi permasalahan pembangunan hutan, pengelolaan hutan nasional perlu membuka ruang yang lebih luas bagi komunikasi, keterbukaan, pembelajaran dan kolaborasi dalam mengatasi konflik-konflik hutan, serta menentukan arah ke depan terhadap tujuan kelestarian dari pengelolaan hutan yang dilakukannya.

Kata kunci: Indonesia, hutan, pembangunan berkelanjutan

UDC/ODC 630*524

Nunung Puji Nugroho

DEVELOPING SITE-SPECIFIC ALLOMETRIC EQUATIONS FOR ABOVE-GROUND BIOMASS ESTIMATION IN PEAT SWAMP FORESTS OF ROKAN HILIR DISTRICT, RIAU PROVINCE, INDONESIA

(PENGEMBANGAN PERSAMAAN-PERSAMAAN ALOMETRIK SPESIFIK TAPAK UNTUK PENDUGAAN BIOMASSA ATAS PERMUKAAN PADA HUTAN RAWA GAMBUT DI KABUPATEN ROKAN HILIR, PROVINSI RIAU, INDONESIA)

Dalam kajian-kajian penaksiran biomassa hutan, pemilihan atau pengembangan persamaan-persamaan alometrik biomassa yang dapat diandalkan merupakan langkah penting yang sangat menentukan ketepatan dari dugaan biomassa yang dihasilkan. Sayangnya, hanya sedikit kajian-kajian tentang persamaan alometrik biomassa yang dilakukan di hutan rawa gambut dan hasil-hasilnya biasanya tidak dapat diakses secara umum atau terdokumentasi dengan baik. Jadi, kajian ini bertujuan untuk mengembangkan persamaan-persamaan alometrik spesifik tapak untuk pendugaan biomassa atas permukaan di hutan rawa gambut di Indonesia. Persamaan-persamaan tersebut dikembangkan berdasarkan 51 pohon contoh yang ditebang. Hasil dari kajian ini menunjukkan bahwa persamaan-persamaan alometrik yang dikembangkan mempunyai koefisien determinasi lebih dari 95% dengan rentang nilai mulai dari 97,0% sampai dengan 98,7%. Dalam hal ini, koefisien determinasi yang paling rendah dihasilkan oleh persamaan alometrik yang paling sederhana dengan satu peubah, yaitu diameter setinggi dada (Model 1). Model 5 yang menggunakan tiga peubah (diameter setinggi dada, tinggi total dan kerapatan kayu) menghasilkan dugaan biomassa atas permukaan yang paling baik di wilayah kajian. Oleh karena itu, selama data peubah tersebut tersedia, maka Model 5 direkomendasikan dalam pendugaan biomassa atas permukaan di hutan rawa gambut. Ketepatan dan penerapan dari persamaan-persamaan alometrik ini dapat ditingkatkan dengan menambahkan pohon contoh dari jenis lain dan/atau dengan rentang diameter setinggi dada yang lebih besar. Mempertimbangkan pentingnya kerapatan kayu dalam pendugaan biomassa dan kurangnya informasi ini untuk jenis-jenis pohon di hutan rawa gambut, maka penelitian perlu dilakukan untuk menganalisis kerapatan kayu untuk jenis-jenis dominan yang menyumbang kerapatan biomassa terbesar pada wilayah kajian.

Kata kunci: spesifik tapak, persamaan alometrik, biomassa atas permukaan, hutan rawa gambut, Riau

UDC/ODC 667.28.099.72:630

Asep Hidayat and Sanro Tachibana

DECOLORIZATION OF AZO DYES AND MINERALIZATION OF PHENANTHRENE BY *TRAMETES* SP. AS03 ISOLATED FROM INDONESIAN MANGROVE FOREST

(DEKOLORASI PEWARNA AZO DAN PROSES MINERALISASI PHENANTREN OLEH JAMUR *TRAMETES* SP. AS03 YANG DIISOLASI DARI HUTAN MANGROVE INDONESIA)

Sekitar 40% zat pewarna tekstil telah menyebabkan pencemaran pada air buangan. Polycyclic aromatic hydrocarbons (PAHs), seperti phenanthrene, adalah kelompok senyawa organik yang memiliki dua atau lebih cincin benzena dan keberadaanya sangat sulit terurai baik yang berada di udara, air dan tanah. Organik polutan seperti zat pewarna dan PAHs mempunyai efek negatif terhadap rantai makanan, dan berpotensi untuk menjadi toksik, mutagenik, karsinogenik di lingkungan. Penelitian ini bertujuan untuk melakukan skrening dan mengevaluasi potensi jamur yang berasal dari hutan mangrove sebagai agen pengurai zat pewarna dan phenanthrene. Dalam penelitian ini, tubuh buah jamur dikumpulkan dari Hutan Mangrove di Provinsi Riau-Indonesia. Jamur *Trametes* sp. AS03 berhasil diisolasi dan memiliki kemampuan untuk mengurai zat pewarna Remazol Brilliant Blue R (RBBR). Kemampuan *Trametes* sp. AS03 untuk mengurai empat (4) tipe zat pewarna, Remazol B. Violet (V5), Levafix Orange E3GA (Or64), Levafix B. Red E-6BA (R159), dan Sumifix S. Scarlet 2GF (R222), dievaluasi dalam penelitian ini. Hasilnya menunjukkan bahwa *Trametes* sp. AS03 mampu mendegradasi 91, 60, 48, dan 31% masing-masing untuk V5, R222, R159, and Or64 selama 3 hari masa inkubasi. Dari kemampuannya ini, *Trametes* sp. AS03 juga dicobakan untuk mengurai phenanthrene. Jamur AS03 mampu mendegradasi lebih dari 70% phenanthrene selama 15 hari masa inkubasi.

Kata kunci: *Trametes* sp. AS03, zat pewarna, phenanthrene, biodegradasi, pengurai warna

THE ECONOMIC VALUE OF HYDROLOGICAL SERVICES IN MENDALAM SUB WATERSHED, KAPUAS HULU REGENCY, WEST KALIMANTAN, INDONESIA

Emi Roslinda[1*] and Yuliantini[1]

Received : 13 August 2012, Accepted : 4 December 2013

ABSTRACT

Forest ecosystem supports almost all of the needs of human being through its contribution of tangible and intangible values. Currently, the intangible values have gained less attention than the tangible values that cause underestimation of the total value of the forest conversion into other more tangibly profitable usages, and miss-management of the forest. One of the important intangible values is the hydrological value that has been hardly calculated until now. This research the intangible values of water for household, transportation, agriculture and fishing in Mendalam Sub Watershed, Kalimantan. The economic values calculated based on market prices, opportunity costs and consumer's surplus methods. The results showed that based on the opportunity cost method the economic values of the hydrological services was about Rp 8,043,706,237.50 per year. Meanwhile, the economic values of the hydrological services based on the consumer's surplus method gave lower value than the former method, i.e. Rp 8,031,351,664.60 per year. This study showed that the economic value of the hydrological services was very high, which has not been included in the calculation yet. However, without trees there would be no forest and all other values included water value would not exist. Consequently, current forest management should put forest ecosystem as important to consider.

Keywords: Intangible value, hydrological services, forest ecosystem, Mendalam, sub watershed

ABSTRAK

Ekosistem hutan mampu memenuhi hampir seluruh kebutuhan manusia melalui kontribusi nilai-nilai yang bersifat tangible dan intangible yang dimilikinya. Namun, nilai intangible yang dimiliki hutan kurang mendapat perhatian dibanding nilai tangible hutan. Hal ini berakibat pada estimasi yang rendah terhadap nilai total yang dimiliki ekosistem hutan sehingga menyebabkan terjadinya konversi ekosistem hutan kepada penggunaan lain yang dianggap lebih menguntungkan dan terjadi kesalahan dalam pengelolaan ekosistem hutan. Salah satu nilai intangible hutan yang penting adalah nilai hidrologis. Sampai saat ini, nilai jasa hidrologis hutan sulit untuk dihitung. Dalam penelitian ini nilai intangible dari air untuk kebutuhan rumah tangga, transportasi, pertanian dan perikanan di Sub DAS Mendalam telah dilakukan. Nilai ekonomi dihitung menggunakan metode nilai pasar, biaya kesempatan dan surplus konsumen. Hasil penilaian menunjukkan berdasarkan biaya kesempatan nilai hidrologi adalah Rp 8.043.706.237,50 per tahun. Sementara nilai hidrologi berdasar surplus konsumen adalah Rp 8.031.351.664,60 per tahun, berarti lebih rendah dibanding metode biaya kesempatan. Penelitian ini menunjukkan bahwa nilai ekonomi jasa hidrologi hutan sangat tinggi, yang mana belum dimasukkan dalam perhitungan nilai ekonomi ekosistem hutan sehingga menimbulkan salah pengelolaan ekosistem hutan. Namun, perlu diingat bahwa tanpa adanya pohon tidak akan ada ekosistem hutan dan semua nilai ekonomi hutan yang terkandung di dalamnya. Konsekuensinya adalah, pengelolaan hutan saat ini dan masa mendatang perlu perhatian lebih lanjut mengenai ekosistem hutan.

Kata kunci: Nilai intangible, jasa hidrologis, ekosistem hutan, Medalam, sub DAS

[1] Faculty of Forestry, Tanjungpura University, Jl. Ahmad Yani Pontianak, West Kalimantan - Indonesia
[*] Corresponding Author : eroslinda71@gmail.com

I. INTRODUCTION

Forest has a variety of biophysical components; ecological functions that can provide environmental services; cultural and social functions and economic values for the people living around the forest. So far, the economic value of the forest is generally assessed from the value of timber production only, while the value of the environmental services of the forest (for example: water) is underestimated or not estimated at all because it is considered as public goods. Environmental services of the forest are non-tangible benefits which are difficult to quantify and giving rise to externalities. According to Hartwick and Oliver (1998), public externalities occur when public goods are consumed without proper payment. To suppress these externalities there is a need to make a valuation of forest values.

Economic valuation can be defined as the attempt to assign quantitative values to the goods and services provided by the ecosystem. The economic value of any goods or services is generally measured in terms of what we are willing to pay for the commodity less what it costs to supply it. Where an environmental resource simply exists and provides us with products and services at no cost, then it is our willingness to pay alone that describes the value of the resource in providing such commodities, whether or not we actually make any payment.

Environmental services are supplied by the ecosystem, one of which is the function of the hydrology, which provide benefits for humans.

Hydrological services are one of the economic values of the forests which until now have not been taken into account because there is no market price for these services. It is necessary to make an economic valuation of the environmental services generated by the forest. Economic valuation is required as a means for decision making in forest management (Bahruni, 2008; Syaukani, 2005; Widada, 2004; Barbier *et al.,* 1997; Munasinghe *et al.,* 1994).

However, valuation is only one element in the effort to improve forest management and services. Economic valuation may help to inform management decisions, but only if decision-makers do understand the overall objectives and limitations of the valuation. The objective of the valuation of ecosystem services is to indicate generally the overall economic efficiency of the various competing uses of the functions of a particular ecosystem. The underlying assumption is that ecosystem resources should be allocated to those uses that yield an overall net gain to the society, as measured through valuation in terms of the economic benefit of each use adjusted by its costs (Kumar and Kumar, 2008). The objectives of this study are to determine the economic value of the hydrological services in Mendalam Sub Watershed.

II. METHODOLOGY

The research was conducted by using the survey method. Mendalam Sub Watershed was purposely selected comprising of 3 valleys and 9 hamlets. A total number of 120 respondents, 40 families in each valley, from small local communities were randomly selected. Collection of data and information was done by using the questionnaire interview technique.

The economic values were calculated based on market prices, opportunity costs and consumer's surplus methods (Pearce and Moran, 1994). Market price method uses the prices of goods and services that are bought and sold on the commercial markets to determine the value of an ecosystem service. This method only takes into account use-values and marketed goods or services that have an actual price. In this research opportunity costs method is based on the productivity method. The productivity method measures the contribution of a non-market ecosystem service that has on a marketed commodity. This method is most useful in cases where a resource is a perfect substitute for another input for production and in cases where the producers are the only ones to benefit from changes in quantity or quality of the resource, and consumers are not affected. Consumer's surplus method is based on the demand function from goods and services by measuring the consumer's surplus after the application of a change in the production or price, the value can be determined.

This research is intended to illustrate the

Table 1. Forest types in *Mendalam* Sub Watershed

No.	Forest Types	Area (Ha)
1.	Shrub swamp (*Belukar rawa*)	18,185
2.	Mixed upland forest (*Hutan lahan kering campuran*)	127,364
3.	Secondary upland forest(*Hutan lahan kering sekunder*)	37,750
4.	Secondary swamp forest (*Hutan rawa sekunder*)	-
5.	Settlement (*Pemukiman*)	-
6.	Mix dryland farming (*Pertanian lahan kering campur*)	55
7.	Shrub (*Semak/Belukar*)	-
8.	Water (*Tubuh air*)	518

intangible values from the forest especially the hydrological ones that could give a lot of benefits for the communities, i.e.: for household, agriculture, fishing and transportation. The benefits depend on the presence of the existing watershed. If the watershed is in good condition, the benefits will be felt by the surrounding communities and downstream areas.

III. RESULT AND DISCUSSION

Table 1 presents the forest types of Mendalam Sub Watershed, one of the units belongs to the hydrological system of Betung Kerihun National Park.

Along the Mendalam Sub Watershed, there are 9 hamlets in 3 valley administrations; the composition of the communities can be seen in Table 2. There are 4 tribes living together, i.e: Kayaan Mendalam, Ariung Mendalam (Taman semangkok), Melayu Sambus and Bukat. All of the communities use water from the river for their every day's needs.

In the everyday's life the people practice shifting cultivation in the drylands. In the wetlands the ethnic Malays, Taman and Kayaan undertake gardening activities, while ethnic Bukat still follow the tradition of shifting cultivation of dry land farming and very rarely plant vegetables so it is unlikely that they will buy vegetables from wealthier farms of the tribal villages downstream Bukat. The Bukat more frequently hunt animals in the

Table 2. Name of hamlets and the number of inhabitants in *Mendalam* Sub Watershed

No	Valley/hamlet	Number of people	Number of household
1.	Datah diaan valley		
	Nanga hovat	144	35
	Uma' suling	280	64
	Pagung	376	106
2.	Padua mendalam valley		
	Teluk telaga	706	152
	Tanjung karang	222	57
	Lung miting	311	74
3.	Tanjung jati valley		
	Semangkok	342	73
	Nanga sambus	714	175
	Tanjung jati	1702	143
	Total	4770	883

forest. Taman tribal's women, in addition to farming activities, also known for their skills as craftsmen (handicrafts). In other activities, at the Putussibau market they often sell products from growing crops in the field or vegetables and fruits which they collect from the forest. This farming and gardening system are two elements in the society of Taman and Kayaan as a result of their interaction with the surrounding nature which they have done for generations.

This interaction has gradually formed a legacy of tradition that is believed to have noble values . As an example every year a form of cultural/customary tradition is still being held to give due thanks to the Almighty for the crops they earn. The event is known as "Dange" or "Pamole 'Beo" (Tamambaloh Dayak language) and also is commonly known by the whole Dayak tribe in West Kalimantan under the name "Naik Dango" (in the Dayak language Kanayant). In this activity their culture is visible presented in specific forms such as: dance, repertoire of oral literature, the splendour of the motive shield/karawit and tattoos, accessories of custom clothing, the uniqueness of the motive mask "Hudo" and the ceremonial procession, all of it is loaded with the meaning of the life.

The benefits of the ecosystem services from the forests were identified as the water obtained by the people for their household in Mendalam Sub Watershed, the water for agriculture, the water for fishing and the water for transport. In Mendalam Sub Watershed the following variables affect the water consumption: number of family members (X2) and education level (X5). Using the method of Marshall the demand curve equation will be as follows:

Y = 390.88 – 7.83 X1 + 1.815 X2 – 1.265 X3 – 24.845 X4 + 179.260 X5 – 1.191 X6

Determination of economic value of watershed services that include the total willingness to pay, expenses, and consumer's surplus is based on the willingness of consumers to sacrifice to consume the goods or services obtained from watershed services. Determination of the economic value of water was done by using the demand curve of Marshall with the following stages:

1. Model

   Y = 390.88 – 7.83 (X1) + 1.815 (X2) – 1.265 (X3) – 24.845 (X4) + 179.260 (X5) – 1.191 (X6)

2. Intercept (β0)

   Y = 390.88 – 7.83 (X1) + 1.815 (1.4) – 1.265 (43.10000) – 24.845 (2.6750) + 179.260 (5.7083) – 1.191 (70.0000)

   Y = 390.88 – 7.83 (X1) + 2.541 – 54.5215 – 66.460 + 1023.269 – 83.37

   Y = 390.88 – 7.83 X1 + 821.4585

   Y = 121.3385 – 7.83 X1

3. Infers

   Y = 1212.3385– 7.83 X1

   $$X_1 = \frac{1212.3385 - Y}{7.8}$$

   X1 = 154.838 – 0.1277 Y

4. Willingness to pay

(1) $U = \int_O^Y f(Y)\delta Y$

(2) $U = \int_O^Y f(154.838 - 0.1277)\delta \mathrm{Y}$

(3) $U = 154.838Y - \frac{0.1277}{2} Y^2 \Big]_0^{1198.3284}$

(4) U = 185546.7728 - (0.06385 x 1435990.954)

(5) U = 185546.7728 - 91688.02243

(6) U = 93858.75037

5. X1 at Y

   X1 = 154.838 – 0.1277 Y

   X1 = 154.838 – 0.1277 (1198.3284)

   X1 = 154.838 – 153.0265

   X1 = 1.8115

Table 3. Economic value of water for household needs

Economic value	Sample (Rp/people/year)	Population (people)	Total (Rp/year)
Willingness to pay	93,858.75	4,770	447,706,237.50
Value of sacrifice	2,170.77	4,770	10,354,572.90
Consumers' surplus	91,687.98	4,770	437,351,664.60

Table 4. Economic valuie of agriculture

No	Subject	Calculation	Total
1.	Economic value of agriculture per year	(number of household x (number of harvest per year x price of rice) – (number of household x production cost) (1,584 x 300 x Rp 10,000,-) – (1,584 x Rp 2,000,000)	Rp 1,584,000,000

6. The value of sacrifice (NA)
   NA = X1 x Y
   NA = 1.8115 x 1198.3284
   NA = 2170.771897

7. Consumer's Surplus
   Consumer's surplus = Willingness to pay – value of sacrifice
   = 93858.75 – 2170.77
   = 91687.98

8. Economic Value

Summary of calculation of total economic value of water use of households is presented in Table 3 below. Calculation was based on the value of the total willingness to sacrifice, value of the sacrifice, and value of the consumer's surplus to the needs of water users of the entire population of all households. It was done by extrapolating the values with the population of Mendalam Sub-basin which is consisting of 4,770 people.

The results showed that value of the average willingness to pay, the value of the sacrifice, and the consumer's surplus was Rp 93,858.75/people/year, Rp 2,170.77/people/year and Rp 91,687.98/people/year, respectively. The value of water was higher when compared with the results of research in Gunung Halimun National Park (Widada, 2004), where willingness to pay was Rp 23,774.8/people/year, value of sacrifice was Rp 5,294.7/people/year and consumers' surplus was Rp 18,480.1/people/year. But it was far smaller if compared with the results of the research in Gunung Walat Educational Park (Roslinda, 2002), where the value for willingness to sacrifice was Rp 295,679.25/people/year, value of sacrifice was Rp 2,196.81/people/year and consumer's surplus was Rp 293,482.49/people/year. This may have happened because the need of water for households are different from place to place.

Economic value of agriculture (especialy from ladang) was calculated using the market price method. The shifting cultivation area was used free by farmers. In the calculation of production costs land was included and all the activities carried out during the process of farming were included i.e. clearing, cutting, slashing, burning, clean up burning, planting, removing grass, crop, save and rice rotation (mengisar padi). All activities are carried out during 6-7 months and people worked together.

One hectare of land is usually farmed by a family of 4-5. If one assumes a fruit farm with an area of 1 hectare, farmed by 5 people, than if one hectare of land is valued at Rp 1,000,000. the operational cost for working in 10 phases is calculated at Rp 20,000 per person per phase of labor, then it would require a fee of Rp 1,000,000 + (Rp 20,000 x 5 x 10) = Rp 2,000,000 per-ha/household/year. Based on this assumption, the value of agriculture is shown in Table 4.

Table 5. Economic value of fisheries

No	Subject	Calculation	Total
1.	Economic value of fishing per year	(number of household x amount of fish/day x number of day per year x fish price) (1,584x1xRp 10,000 x 335)–(Rp 200,000 x 1,584)	Rp 4,989,600,000

Table 6. Economic value of transportation

No	Subject	Calculation	Total
1.	Economic value of transportation	(number of people x number of day per year x ticket price x number of transport) – (cost of premium) (40x365xRp 20,000 x 7) – (40xRp 10,000 x 365 x 7)	Rp 1,022,000,000

Table 7. Summary of calculations of the hydrological value based on the willingness of sacrifice (opportunity cost) and consumer's surplus

No	Hydrological value	Total value (Rp/year)	
		Opportunity Cost	Consumer's Surplus
1.	Household	447,706,237.50	437,351,664.60
2.	Agriculture	1,584,000,000.00	1,584,000,000.00
3.	Fishing	4,990,100,000.00	4,990,100,000.00
4.	Transportation	1,022,000,000.00	1,022,000,000.00
Total		8,043,706,237.50	8,031,351,664.60

Economic value of fishing was also calculated with the market price method. Communities in Mendalam Sub Watershed generally catch fish every day to meet their daily food needs.

The types of fish frequently caught are: semah, jelawat, tengadak and rock fish.

From interviews we gathered that the number of fish they can catch vary, depending on luck and natural factors. In general, fishing activities are conducted to meet the needs of sehar-day. The average person of a household is able to catch 1-2 kg of each type of fish every day. The fish is usually caught not for sale but for home consumption only.

Calculation of the economic value of fishing was done by using the fish type that had the lowest value among the fish types. The fish used in the calculation was a type of rock fish at Rp 10.000/kg.

The value of income has to be reduced by capital and other costs (equipment such as: net Rp 200,000/lifetime of 4 years; trawl Rp 50,000/lifetime of one year; rope nets Rp 10,000 per roll; rope trawl USD 10,000 per roll; rock netting Rp 3,000 per piece). Two rolls per year are needed to rope nets; to rope trawl also requires 2 rolls per year. Rope trawl and nets are usually used to patch up broken straps. Usually 20 pieces of stone nets are needed each year. Capital and equipment costs per year are Rp 200,000/family/year. Based on above assumptions the economic value of fishing can be seen in Table 5.

Economic value of transportation was calculated using market prices. Almost all communities in Mendalam Sub Watershed use river transportation, though there are regular public transportation in Pagung, Uma' Suling, and Teluk Telaga hamlets. Besides communities in Mendalam Sub Watershed commonly have a speed boat for their own transportation to go to other valley. Based on assumptions and data, economic value of transportation can be seen in Table 6.

In summary the economic value of water used by communities in Mendalam Sub-Watershed can be seen in Table 7.

Water used by communities is originating from the Betung Kerihun National Park, which among other functions serves as a protector and guardian of the water system. The consumer's surplus from the use of water was calculated at Rp 437,351,664.60 per year, and the sacrifice value for the society to get this water is estimated at Rp 10,354,572 per year. The value of consumer's surplus is the value of the benefits from the forest ecosystem services that is still often ignored so that the value of forests is often estimated much lower than the true value of what it can generate.

Based on the values that were calculated, it became obvious that the value of the environmental services generated by the forest ecosystem is not often counted, so that the applied forest management does not pay attention to this aspect. As a result, the value of the forest ecosystem is lower than its actual value. Furthermore, forest ecosystem is mismanaged and forest ecosystem was converted to other ecosystem which was considered providing a higher value.

Environmental services are benefits that people obtain from the ecosystem; Paruelo (2012) concluded that ecosystem services are an anthropogenic concept, in the absence of people there are no services (Bennett *et al.,* 2009). Therefore local stakeholders' perception is critical for assessment and management of ecosystem services (Kijazi and Kant, 2010; Vihervaara *et al.,* 2012).

The economic valuation studies are giving the potential values that can be derived from the environmental services of the forests which are intangible benefits. Nurrochmat *et al.* (2010) states that the environmental services of forests are a function of the water and carbon sinks, which are likely to be recognized in the near future. The function of the water (hydrological) can be of economic value through incentive mechanisms upstream and downstream (Nugroho and Kartodihardjo, 2009; Nurfatriani, 2008). Therefore hydrological values obtained from this research may be even greater if the mechanism can be applied.

The economic value of hydrological services was very high; it was derived from the forest; however, without trees there will be no forests and thus all other values included water value may not exist. Forests have long been recognized as the main ecological construction and restoration means for their multiple ecosystem services (Deal *et al.,* 2012). These services have different spatial–temporal scale characteristics and corresponding different stakeholders. Consequently, the management of the forest ecosystem needs further consideration to make rational management decisions, depending on local conditions, needs and underpinning ecosystem processes.

IV. CONCLUSION

The results showed that based on the opportunity costs the economic values of hydrological services was estimated at Rp 8,043,706,237.50 per year. Meanwhile, the economic values of hydrological services based on the calculation of consumer's surplus method gave a somewhat less value than the former calculation, i.e. Rp 8,031,351,664.60 per year.

The economic value of hydrological services was very high; it was derived from the forest; however, without trees there will be no forest and all other values included water value may be non-existing. Based on the values that were calculated, it became obvious that the value of the environmental services generated by the forest ecosystem is not often counted, so that the selected forest management does not pay attention to this aspect. As a result, the value of the forest ecosystem is lower than its actual value. Consequently, forest ecosystem is mismanaged and forest ecosystem was converted to other ecosystem which was considered providing a higher value. It is necessary that the current management of the forest ecosystem needs further consideration to make rational management decisions, depending on local conditions, needs, and underpinning ecosystem processes.

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DEVELOPMENT PROCESS OF WATERSHED PARTNERSHIP : A CASE STUDY OF LIMBOTO WATERSHED - GORONTALO, INDONESIA

Gun Gun Hidayat[1,2] and Hiroaki Kakizawa[1]

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ABSTRACT

Establishment of watershed partnership is required to achieve integrated watershed management in Indonesia. Taking "partnership of Limboto watershed" as a case study, this study aimed to explore the development process of watershed partnership and its state and role in a watershed. Data and information were collected through interviews, group discussions and questionnaire survey. The results showed that in the early stages, through a good preparation process, the partnership gained recognition and support from stakeholders. Informal, open, and voluntary processes were adopted by the Coordinator of the partnership for the establishment and initial operation phases which gave the partnership the experience of being inclusive and an active period which was considered as a good success. However, in the next phase, the partnership was unable to cope with the formalization of the watershed partnership as demanded by the decentralized institution by having a new structure without a definite and responsible institution, secretariat and budget source due to lack of interest of the expected local government to take on the responsibility. Formalization resulted in the disfunction of the partnership. Though, many participants considered the partnership had a positive role, especially concerning exchange of information and improvement of concern about the community. This partnership did not yet function for integrated watershed management, but more to educate and inspire people on watershed conservation through project-based activities.

Keywords: Preparation process, informal, formalization, local government, disfunction, positive role

ABSTRAK

Pembentukan Kemitraan DAS diperlukan untuk mencapai Pengelolaan DAS Terpadu di Indonesia. Dengan mengambil Kemitraan DAS Limboto sebagai studi kasus, studi ini bermaksud menggali proses pembentukan kemitraan DAS, status dan perannya di dalam sebuah DAS. Sejumlah data dan informasi telah dikumpulkan melalui proses wawancara, diskusi kelompok dan survey kuesioner. Hasil studi menunjukkan bahwa pada tahap awal kemitraan, dengan proses persiapan yang baik maka kemitraan meraih perhatian dan dukungan dari pemangku kepentingan. Proses yang dilakukan secara informal, terbuka dan sukarela yang diadopsi oleh Koordinator kemitraaan pada saat pembentukan dan tahap awal operasi sehingga kemitraan mengalami situasi yang inklusif dan aktif, dipandang sebagai sebuah kesuksesan. Namun demikian, pada tahap berikutnya, kemitraan tidak mampu mengatasi isu formalisasi sebagaimana tuntutan desentralisasi, dimana kemitraan menjadi sebuah struktur baru yang tidak memiliki institusi penanggung jawab, sekretariat dan sumber pendanaan yang jelas, sebagai akibat rendahnya perhatian dan kemauan mengambil alih tanggung jawab dari lembaga pemerintah lokal yang diharapkan. Formalisasi menyebabkan kemitraan tidak dapat berfungsi. Meski begitu, banyak anggota kemitraan memandang bahwa kemitraan memiliki peran positif khususnya terkait pertukaran informasi dan peningkatan kepedulian masyarakat Kemitraan ini tidak berfungsi bagi pengembangan pengelolaan DAS terpadu, namun lebih kepada mendidik dan menginspirasi masyarakat atas pelestarian DAS melalui aktifitas berbasis proyek.

Keywords: Proses persiapan, informal, formalisasi, pemerintah daerah, disfungsi

[1] Graduate School of Agriculture, Hokkaido University, Hokkaido Japan

[*] Corresponding author: Email: hgun354@yahoo.com

I. INTRODUCTION

Watershed management has become a focal point for integrated natural resource management. The challenge is that the watershed is managed by conventional agencies whose works are based on sector or commodity such as forestry, agriculture, mining and fishery. It could also be pointed out that watershed issues involve various stakeholders, including communities and NGO (Sabatier *et.al.*, 2005; Leach and Pelkey, 2001), often with different views, positions and interests in the management of the watershed. Watershed partnership requires networking of stakeholders which periodically convene to discuss or negotiate issues associated with the management of the watershed (Leach and Pelkey, 2001). However, instead of replacing, watershed partnership is expected to complement and transform the conventional agencies (Sabatier *et.al.,* 2005).

In Indonesia, watershed management became an important resource management approach in pursuing sustainable development. The Ministry of Forestry (MoFor) is one of the important line ministries responsible for the development and implementation of the watershed management policy. In 2001 the MoFor issued the Decree "Guidance for Watershed Administration", which encourages the establishment of integrated watershed management, with watershed partnership as an essential approach. It is stated that "Policy on watershed management, which include planning, programming, controlling, and budgeting, implemented by a team in the form of Watershed Board or Forum".

Until 2009, 23 watershed partnerships were established. Considering that there are 458 watersheds throughout Indonesia, establishment of only 23 watershed partnerships are still not sufficient. In the mean time, the assessment of good watershed conditions carried out by MoFor showed that 282 of 458 watersheds, or equal to 30 million hectares, are still in critical and very critical conditions3. In this sense, establishment and development of watershed partnership is strongly required in Indonesia.

In this study, the development process of the watershed partnership for Limboto Watershed was elaborated as a case study. The study mainly focuses on the institutional arrangement of the partnership, management of the partnership, and perception of members of the partnership. With this research, the central government (MoFor) is intended to acquire more knowledge and understanding concerning development of watershed partnership for a better future promotion and facilitation. This research finding will also provide the stakeholders and the local government of Limboto watershed with an important lesson learned.

II. METHODS

A. Study site: Limboto Watershed

Limboto watershed is located on Sulawesi Island. In Indonesia, there are two levels of local

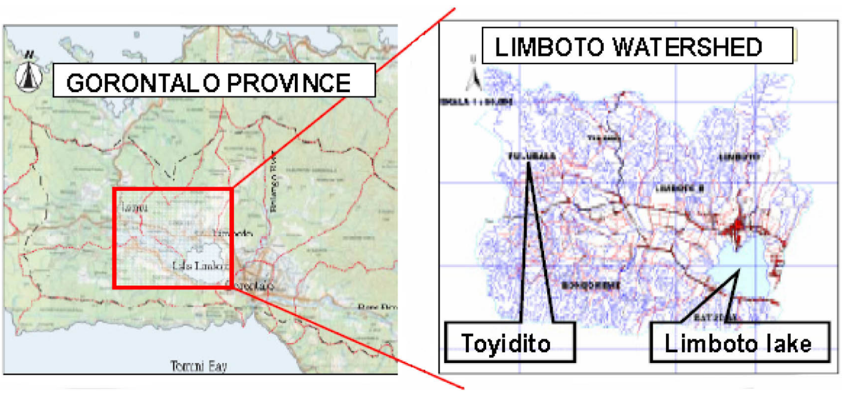


Figure 1. Location of study area

government i.e. province and district. Limboto watershed is located in Gorontalo province, Gorontalo district, and Gorontalo city as district level. The area of Limboto Watershed is 91,004 ha with 177,632 inhabitants (BPDAS-BB, 2004). Gorontalo district administrates 95.66% of the area (or 87,053 ha) including the largest part of Limboto Lake.

Since 54.65% of watershed land is dominated by hilly and mountainous area, while rate of rainfall is high and the soil layer is young-shallow, the condition of watershed is fragile and easy to erode (BPDAS-BB, 2004). Combination of those characteristics with traditional system of land use such as shifting cultivation or low intensive agriculture system resulted in high level of soil erosion. Erosion in Limboto Watershed is recorded at about 9,902,588.12 tons/year of which 39,864.60 tons/year are accumulated in Limboto Lake as sediment (BPDAS-BB, 2004). Siltation, nitrification, depletion of biodiversity and shrinkage of Limboto lake indicate degradation of the lake (BPDASBB, 2004; KKPDLBM, 2004; BALITBANGPEDALDA, 2006).

Three levels of government agency (national, provincial and district) from various sectors have relation to the watershed on several issues. Agencies which have strong relation to the soil, land, and forest conservation issues are the forestry service and the agriculture service, including the regional office of Ministry of Forestry i.e. the Watershed Management Office - Bone Bolango Section (herein after referred as BPDAS-BB). Public works service and environmental management agency, both at district and provincial level deal with water issues i.e. flood and lake management. Planning Agency of provincial government and district government has role to coordinate budgeting and planning aspects of the activities related to the watershed.

Formal coordination for local development was organized by the Planning Agency through hierarchical annual meeting known as "Regional Development Planning Meeting" (or MUSRENBANGDA in Bahasa Indonesia), from village, ward, district to provincial level. Still, development perspective of the government is based on sectors and economics, viewing natural resource as a commodity rather than as a stock or service (Kartodihardjo *et.al.*, 2004).

B. Collection of Data and Information

The study was conducted from September to October 2006 and February to August 2007. Adopting qualitative approach (Silverman, 2005), this study conducted interviews as well as observation of actions and interactions of partnership's members and other key players, regarding their involvement in the development of the partnership.

Open-ended and semi-structured interviews were conducted. Respondents were asked regarding the activities and developments of the partnership, participants' roles and activities, communication patterns, and perceptions of the partnership. Thirty one person were interviewed of which 28 persons were members and ex-members of the partnership, while 3 persons were not member of the partnership i.e. from Ministry of Forestry, JICA Forestry Program Advisor Office. The questions asked were about their knowledge of as well as their role or involvement in the partnership.

Questionnaire forms were distributed to only members and ex-members of the partnership to find out their perceptions. Twenty eight persons were participating in this survey. Questions were divided into 3 groups: 1) assessment of the situation or background of the decision to join the partnership, 2) assessment of the situation experienced in the partnership, 3) assessment of the situation outside of but surrounding the partnership.

To explore the linkage between the partnership and its project, a field site-level study was conducted of the partnership's collaboration project: Toyidito Social Forestry Project (hereinafter referred as TSFP). For this purpose, interviewees were also added consisting of farmer group leaders, farmers, informal leaders, and field facilitators of TSFP.

Field observation was also conducted to have a better understanding of the situation of the site. In total, 36 persons were involved in this study as source of information. Relevant formal and informal documents including statistics, minute of meetings, and other source of data/ information were also collected.

C. Data Analysis

Data analysis in qualitative research generally comprises of three activities which might simultaneously and interactively take place, namely data reduction, data display, and drawing of conclusion/verification (Miles and Huberman, 1994).

Data reduction covered activities in form of (re)defining conceptual framework and research problems, summarizing, coding and making memos. Data analysis was continued by displaying the reduced data in "Exploring and Describing" format. As the data was reduced and displayed firmly, conclusion was then drawn preceded by the verification process.

III. RESULT AND DISCUSSION

Development process was divided into two phases. The first phase was the establishment and development of the partnership from the end of 2002 to the end of 2005. The second phase was formalization of the partnership, changed from voluntary-based to local government decree-based partnership, from year 2005 to 2007.

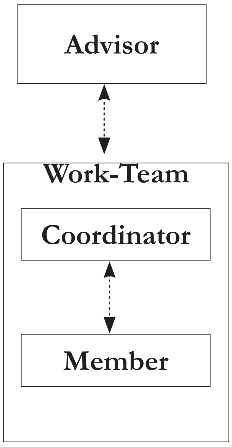
A. First Phase: Establishment and Initial Operation of Partnership

The establishment of partnership of the Limboto watershed was initiated by BPDAS-BB at the end of 2002. This initiative was closely related to the assignment of BPDAS as a newly transformed office (from old structure of BRLKT; Land Rehabilitation and Soil Conservation Office) to promote the watershed management framework, rather than to only deal with soil conservation and land rehabilitation. The Provincial Forest Service (herein after referred as DISHUTPROP) together with a forestry-concerned NGO "Lembaga Pengkajian Pembangunan Provinsi Gorontalo (hereinafter referred as LP2G), and BPDAS-BB started to discuss environmental issues under watershed framework, which was believed to be able to call concern and collaboration from various stakeholders.

These three initiators decided to hold series of multi-stakeholders meetings, as a medium to update environmental and management status of Limboto watershed, build common consciousness and understanding, and find prospective solution which would be conducted under a multi-stakeholder process. Meanwhile, discussions and small meetings were continued by the initiators to invite several other key stakeholders to join, such as Provincial Agency for Research and Development, Environmental Impact Management (herein after referred as BALITBANGPEDALDA), Forest Service of Gorontalo District, and University of Gorontalo.

Multi-stakeholder workshop (MSW) was held on January 29th 2003, joined by about 93 participants from various fields such as community leaders, academicians, government officers, NGOs, and others. The MSW shared information on environmental problems faced as well as current and potential counter measures from the watershed perspective was presented by the representatives from government offices, which was continued with open discussions. The MSW resulted in a common understanding on the status of the environment and identified causal factors of the problem. One of the recommendations of this workshop was the establishment of the watershed partnership.

Village discussions (VDs) were organized, based on parts of the watershed i.e. upstream, midstream, and downstream areas. These VDs were held respectively on February 4th, 15th, and 20th, 2003, and was attended by local communities from each part of the watershed. About 30 persons consisting of informal and formal leaders of communities attended each



Membership
1. Vice Governor (Advisor)
2. Head of Provincial Forestry Service (Advisor)
3. Head of BPDAS-BB (Advisor)
4. Head of District Forestry Service (Advisor)
5. Director of NGO-LP2G (Coordinator)
6. Representative of BPDAS-BB (Member)
7. Representative of BPDAS-BB (Member)
8. Representative of Provincial Forestry Service (Member)
9. Representative of NGO-Jappesda (Member)
10. Representative of District Forestry (Meber)
11. Representative of Prov. Land Agency (Member)
12. Representative of Gorontalo University (Member)
13. Representative of Provincial Agriculture Service (Member)
14. Representative of NGO-LP2G (Member)
15. Representative of BPDAS-BB (Member)
16. I Representative of District Public Work (Member)

Figure 2. Structure of KKPDLBM
Source: LP2G (2003)

meeting, representing villages. In VDs, initiators shared results from MSW and facilitated discussions of the problems and potential solutions based on community participation. On the other hand villages' representatives shared the information about the behavior of watershed users and the emerging impact, as well as recommendations in building a watershed management model.

In March 2003, based on recommendations from the MSW and VDs, the initiators formulated the watershed partnership namely "Kelompok Kerja Pengelolaan DAS Limboto berbasis Multi-pihak" (known as KKPDLBM) or Working Group for Multi stakeholders-based Management of Limboto Watershed. Formal decree to legalize this partnership was not made, and the partnership was organized as informal and voluntary based. Structure of the partnership was simple as shown in Figure 2.

The structure simply consisted of two tiers, advisory group and members, with one person as the Coordinator. The advisors were top-ranked officers who have authorization in resources and policies in each related office. Members of the partnership were mid-ranked officers and staff from related institutions and NGO activists, selected by the initiators based on informal commitment. Director of LP2G was appointed as the Coordinator by the initiators, as he had already facilitated the partnership since the beginning.

Even though the structure consisted of two tiers i.e. advisor and members, there were no separate meeting among advisors, coordinator, and members, instead they were sitting together in regular meetings. In daily practice, the Coordinator and members conducted technical and non-technical activities of the partnership. Secretariat which managed the partnership was in the LP2G office, even though BPDAS-BB provided an office space.

In its early period, activities of KKPDLBM were mostly meetings to consolidate the partnership and build a common understanding as well as the spirit on function and role of the partnership. The partnership moved forward to establish priority issues of the partnership i.e. 1) fundamental strategy of the partnership, 2) publication and outreach to both other offices and public, and 3) implementation of watershed conservation program.

The partnership also elaborated the results from MSW and VDs in the document "Mapping the Results of Multi-stakeholders Workshop and Village Discussion for Limboto Watershed Management" (in short called as the map), and "Matrix Plan of Strategic Program and Form of Activity for each watershed part of Limboto Watershed" (in short called as the matrix plan).

"The map" contains a long list of factors contributing to degradation, type of counter measures, expected actors, and priority programs. For example, "traditional land cultivation system" which was identified as a contributing factor to degradation at upstream area, was planned to be encountered by developing demo-plot of conservation system, with local government such as Forestry Service and Agriculture Service as expected actors.

"The matrix plan" was formulated in four columns: strategic problems, programs, form of activities, and responsible parties. To encounter forest encroachment and land cultivation, for example, community forestry program was planned to consist of activities such as designing area model, replanting activity, and community-based protection and utilization of forest. Several parties were also identified and expected to be as responsible parties for the community forestry program, i.e. Forest Service, Agriculture Service Industry Service both of provincial and district government, and BPDAS-BB.

Public awareness building regarding the condition of Limboto watershed became the priority of the partnership to be conducted. Several public discussions, educative advertisings and partnership activities were disseminated through the radio station (the SELEBES 100.2 FM), newspaper (Gorontalo Post) and bulletin "Watershed Forum".

Another priority was to carry out the project in the field. The Coordinator believed that real work in the field was important as it answered to the motto of the partnership i.e. "Today is meeting, tomorrow is time to implement". This motto was important to avoid an image of the partnership to spend time only for meetings and discussions. The first project agreed to be implemented was the TSFP, generated from "the map" and "the matrix plan".

The TSFP which was firstly proposed by LP2G, was aimed to encounter strategic problems of forest encroachment and land cultivation at upper-stream. TSFP tried to implement land rehabilitation and expected not only just to replant but also improve the capacity of the communities to protect and utilize the land for their livelihood. It proposed 25 hectares of critical land to be managed sustainably and effectively by groups of farmers including preparation and planting with certain tree species (which produce wood or fruit) combined with horticulture plant species.

TSFP was considered as a "success story" and a "good image" for the partnership in terms of process as well as output. TSFP enabled to promote the process of collective action among involved parties to share contribution with the so called "cost sharing mechanism". Through meetings and informal

Table 1. Sharing of members of partnership on TSFP members

	Contribution
BPDAS-BB	Provide 200,000 trees; conduct land conservation model of 10 ha; cover news of TSFP in bulletin "Forum DAS"
JICA-FPA	Finance procurement of materials for capacity building, training, facilitation, monitoring and evaluation
Forest Service(Prov. & District)	Provide technical assistance for fertilizer "Bokashi" production; provide 25,000 plants for reforestation
Prov. Agriculture Service	Conduct training for pepper commodity
District Planning Agency	Facilitate village to get project for road improvement
Gorontalo Univ.	Provide facilitators for training
Gorontalo Post	Upload the state or activities of TSFP to newspaper
LP2G	Provide material, field facilitation and training facilitator.

Source: KKPDLBM, (2004); LWF, (2006)

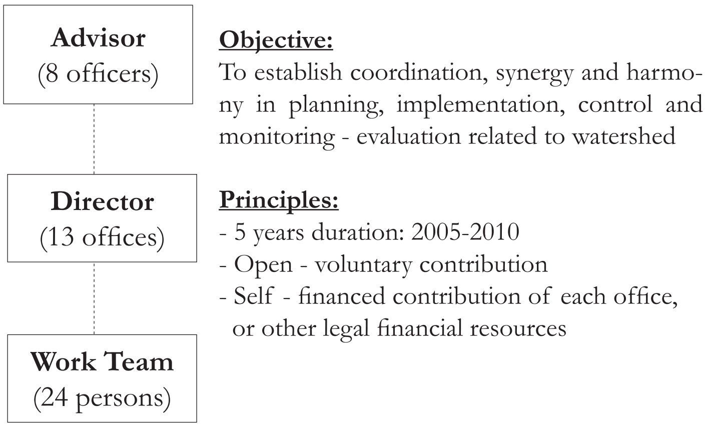


Figure 3. Structure and Objective of FDL

communications, the Coordinator arranged involvement of members of the partnership based on their expertise and capacity to give contribution and support. In reforestation activity members from the forestry sectors, for instance, Forestry Service and BPDAS-BB provided 225,000 seedlings while in the agriculture activity, such as "pepper farming", Agriculture Service provided the trainer and training facility. "Cost-sharing mechanism" was applied by the Coordinator through acquiring commitment from farmers to procure local resource/material for proposed activities, while support from partnership and donor would be complementary and as a subsidy. Table 1 below shows the sharing of members of partnership on TSFP.

In terms of output and outcome, TSFP had resulted in improvement of environmental conditions and change of behavior of the community. Hundred thousands of seedlings had been self-produced and planted throughout the village. The community had furthermore improved in organizing themselves into several groups based on similar interests such as banana planter group, paddy field farmer group, and housing credit circle.

JICA-FPA continued its financial support for the following years, since the partnership was running and gained participation from its members. During the first phase, the partnership experienced an inclusive and active period which was considered as a good success. Watershed issues were brought to and being noticed by wider stakeholders through inclusive meetings as well as in a collaborative conservation project such as TSFP.

1. Good preparation process

The preparation process to develop partnership which was expressed through series of stakeholder meetings had built social capital of stakeholders who then became members of the partnership. Successful identification and socialization of status and problems in the watershed through series of meetings and discussions enabled to share expectations, optimism, and interest in the partnership as a prospective approach, as it was reflected from the questionnaire survey.

Response to the question "what factors facilitated them to join the partnership" showed that 60% of the members believed and strongly believed that trustworthiness of other members was an important factor, while the other 40% showed moderate response, without any negative responses. Matching mechanism, idea, and program offered by the partnership meeting their interests was selected by 65% of the members. About 48% of the members felt and strongly felt that other stakeholders would question their commitment to the environment if not joining the partnership. Those results indicated the appropriate preparation process which enabled to provide information and convinced prospective members to join.

2. Voluntary and open process

Voluntary and open process adopted by the partnership and intentionally implemented and sounded by the Coordinator made the situation in the partnership more flexible and the communication among members easier. Through informal approach an active discussion was arranged in a flexible way for the sake of fruitful result actions.

3. Project contribution: actual implementation process

Willingness of stakeholders to meet and having discussions is somehow a step forward for the partnership. However, there is a stigma that any partnership is usually wasting time in discussions rather than doing real actions. It is why the Coordinator shared and emphasized the principle "Today is meeting, tomorrow is time to implement". TSFP functioned as the actual implementation body rather than for discussions only. "Cost sharing mechanism" which was also promoted to some extent has tested the real contribution of the members and the sense of belonging to the community as well. These approaches showed an effective work to deal with bureaucratic and time consuming administrative system of government offices for establishing a project.

B. Second Phase: Formalization of The Partnership

The first phase was considered as a success story of the partnership. However, the following issues started to appear at the end of the first phase.

Firstly, the open and voluntary process impacted in difficulties to maintain and control the process in the partnership, while the operative and success story made "formality of partnership" to a low priority. The approach was unable to make correction of the partnership when the partnership seemed to focus mainly on specific field activities i.e. TSFP. The dominance of the Coordinator also became one consequence due to the absence of a working mechanism while workload increased (Parker *et.al.,* 2010). Claim to improve the partnership was sounded by other members of the partnership especially from NGO.

Secondly, the partnership was requested by JICA-FPA and MoFor to become an independent and self-sufficient body since JICA-FPA was expected to terminate its support in October 2006. JICA-FPA and MoFor wanted to pave the way to a functional partnership by improvement of management and legal aspect of the partnership toward a better and sustainable organization which was capable to find financial support from various sources.

Thirdly, under the decentralization policy, BPDAS-BB as a central government office was urged to transfer facilitative and secretarial functions to the local government. BPDAS-BB had duty to only facilitate establishment of the partnership model while the full implementation was expected to be made by local stakeholders including the government office. BALITBANGPEDALDA had the characteristics to be the suitable responsible institution.

On October 2005, MoFor, BPDAS-BB and JICA-FPA urged the Coordinator to formalize KKPDLBM and it was targeted to be launched at the occasion of the "Watershed Forums Meeting for Sulawesi Region", which was planned to be held at Gorontalo in December 2005. On the other hand, the Coordinator still believed in the informal approach and had reluctance on "formalization of partnership". It was thought by the Coordinator that, the formalization would result in only formality and ceremony and having expiration characteristic. Expiration of the partnership was worrying to become a critical point and reduce the spirit of involvement of the members of the partnership. In November 2005, the formalization process of KKPDLBM had just started. Intention to broaden the scope and share experience by enlisting stakeholders of adjacent and concurrent watersheds had to face a tight deadline to launch the new form of the partnership in December 2005. Under such a situation, the Coordinator was unable to perform the appropriate arrangements such as discussions to formulate the new structure or to confirm with proposed members.

Unfortunately BALITBANGPEDALDA, which was expected to be the lead agency for the new form of the partnership, did not show interest in the watershed partnership concept. The structural constraint was that budget of BALITBANGPEDALDA was more focused to the lake part of the Limboto watershed, while the perception of the top officer of BALITBANGPEDALDA was that "partnership" should be organized only by government agencies, with special budget for a certain period. BALITBANGPEDALDA only assigned several staff to be involved in the partnership.

The new form of the partnership was named Forum DAS Limboto (FDL or Limboto Watershed Forum) and was signed by the Vice Governor and inaugurated at the occasion of the "Watershed Forums Meeting for Sulawesi Region", on December 8th 2005. The occasion also functioned to assist FDL by formulating working mechanism, logical framework, and working agenda for partnership in discussion groups. Unfortunately, the targeted formulation could not be accomplished, due to time shortage.

Organization of the FDL was quite big, with a rigid structure, and low involvement of members. The new structure looked big consisting of 43 members, or three times more compared to the previous one, the KKPDLBM. Rigid structure is indicated by the three tiers of group which was mixed between (top) officers and institutions (offices) without definite secretariat, coordinator, job descriptions, and working mechanism, as it is indicated by this study with the dotted line. The new structure also did not clarify or appointed certain responsible institution to facilitate the daily operations of FDL. Furthermore, position of the coordinator was deleted to give equal position to all members.

However, this structure was not used and did not work. The document of FDL decree was kept by the ex-coordinator and was not distributed to listed members. The ex-coordinator continued to organize, based on previous structure, added with some members listed in the new structure. Support from the local government to the partnership was very limited. There was no commitment from the local government to become the responsible institution and to establish secretariat for the partnership. Members of the partnership were passive and did not show concern on the crisis situation of the partnership, since they had been used to wait for the arrangement from the ex-coordinator. Furthermore, in fact there were some members who were not confirmed regarding their appointment as members of the partnership.

In that regard, the ex-coordinator went back to the forestry institution i.e. BPDASBB concerning its role as initiator of the partnership and its responsibility to promote conservation of the watershed. Activities of and discussions in the partnership was more focused on forestry issues even more than before the formalization. The partnership was utilized to become the facilitation medium for projects or activities such as the government's project (National Movement on Land and Forest Rehabilitation or GNRHL).

Concerning the objective of FDL to become the coordination medium for stakeholders of the watershed, the situation explained above indicates that the partnership did not play its role appropriately.

Evaluation of the Formalization of the Partnership: key factors contributing to the disfunction of partnership

Formalization under the decentralized institution so far has failed. BPDAS-BB could not appropriately organize the responsible local government agency. The partnership was unable to acquire commitment from coordinative-profile of the local government to be the secretariat and facilitate the partnership. In this regard, both the initiator of the formalization and the expected local government had contributed to the failure.

The initiator did not establish an agenda and roadmap to transfer the partnership initiative to local government in an appropriate process. Daily operation of partnership did not indicate plan in that direction. Local government, especially the expected office, BALITBANGPEDALDA, did not show an interest to become the responsible institution of the partnership, due to differences in priority of action and concept of partnership, while budget also became a significant constrain. Involvement of JICA-FPA and MoFor contributed to the disfunction of the partnership.

Intervention of JICA-FPA and MoFor to support the partnership somehow resulted in two ways. While it has clearly facilitated the operation of the partnership, the image embedded in the partnership was then narrowed to forestry coordinating. This situation was not a conducive environment for the partnership, especially when JICA-FPA and MoFor required formal commitment from the local government through formalization of the partnership. Preparation to establish an effective partnership then has not appropriately taken place.

Though formalization was not a success, many of the participants considered the role of the partnership still as positive, especially concerning the exchange of information and improvement of concern of the community. Most of the members of the partnership still showed positive responses and respect to the partnership, as shown in Table 2.

In general, positive responses showed by the members were related to the experience of participating in the activities of the partnership such as meetings and field activities. Improvement of creativity and concern of members about the village community were also indicated by initiative from members which had tried to implement social forestry in adjacent area or other locations. The disfunction was accepted by members as the ebb part of the partnership.

With that they still had hoped that the partnership would someday and somewhat be active again

In that sense, this partnership has not yet functioned for an integrated watershed management, but more to educate and inspire people to pay more concern to the conservation of the watershed through project-based activities.

IV. CONCLUSION

Through good preparation process, partnership for Limboto watershed gained recognition and support from stakeholders. Informal, open, and voluntary processes adopted by the partnership in the early development stages enabled to gain collective actions of members to contribute to the partnership. Willingness of stakeholders to gather and having discussions was somehow a step forward for the partnership. TSFP as a collaborative project was actually an implementation work with involvement of members of the partnership. At this first phase, the partnership has acquired active participation which was considered as a good success.

However, such a kind of approach made the partnership unable to cope with the formalization under a decentralized institution, as demanded by JICA-FPA and Ministry of Forestry. Formalization resulted in disfunction of the partnership, when the partnership was unable to acquire commitment from expected

Table 2. Perception of members regarding changes in the partnership

Aspect	Response
Other members willing to share more resource	68.19% agree and strongly agree
Improvement of member’s creativity	54.55% strongly agree
Improvement of member’s concern on village community	63.64% agree and strongly agree

and suitable local government to be the responsible institution and secretariat. Both the initiator of formalization and the expected local government had contributed to the failure.

Though formalization was not a success, many of the participants considered the role of the partnership was still positive, especially concerning the exchange of information and improvement of concern regarding the community. In that sense, this partnership did not yet function for integrated watershed management, but more to educate and inspire people to pay more concern to the conservation of the watershed through project-based activities.

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REALIZED GENETIC GAIN AND SEED SOURCE X SITE INTERACTION ON STAND VOLUME PRODUCTIVITY OF *Acacia mangium*

Arif Nirsatmanto[1*], Teguh Setyaji[1] and Reny Setyo Wahyuningtyas[2]

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ABSTRACT

Following the results of the comprehensive tree improvement programs for *Acacia mangium*, it is necessary to estimate the real amount of genetic improvement and to develop an improved seed deployment strategy. This study was aimed to verify realized genetic gain on stand volume productivity attained by the first-generation Seedling Seed Orchards (SSO) of *A. mangium* and to identify the magnitude of seed sources x site interaction as a basis for improved seed deployment. Seeds from five SSOs were tested together with seeds from seed stand in genetic gain trials which were established in South Kalimantan and Central Java. Realized gains were calculated from the percentage improvement of respective SSOs compared with seed stand at two and four years of age. Seed source x site interaction was investigated through analysis across the two sites. Results of the study showed that trees derived from the five SSOs produced better stand volume than those from seed stand. At four years of age, stand volume of the best SSO reached around 127 m^3/ha in South Kalimantan and 84 m^3/ha in Central Java. Realized genetic gain were around 66% at two years and 59% at four years in South Kalimantan, and around 136% at two years and 81% at four years in Central Java. Seed source x site interaction was not significantly different indicating superiority of improved seed were consistent across the two sites with the average realized gain ranging from 18% to 79% and 24% to 62% at two and four years, respectively. The best three SSOs were SSO-1 located in Pleihari-South Kalimantan, SSO-2 in Pendopo-South Sumatra and SSO-5 in Wonogiri-Central Java, all of which originated from Papua New Guinea provenances. Improved seed from the orchards could be used at plantation sites without any significant change of the order in their superiority for stand volume productivity.

Keywords: *Acacia mangium*, genetic gain trial, realized genetic gain, seedling seed orchard, stand volume

ABSTRAK

Studi ini bertujuan untuk mengetahui besarnya perbaikan genetik aktual terhadap produktifitas volume tegakan dan interaksi sumber benih x lokasi pertanaman. Benih unggul *A. mangium* dari lima kebun benih diuji bersama benih dari tegakan benih di plot uji perbaikan genetik di Kalimantan Selatan dan Jawa Tengah. Hasil penelitian menunjukkan bahwa benih unggul dari kebun benih memiliki produktivitas volume tegakan yang lebih tinggi dibandingkan benih kontrol dari tegakan benih. Tingkat perbaikan genetik aktual di Kalimantan Selatan mencapai 66% umur dua tahun dan 59% umur empat tahun, sedangkan di Jawa Tengah mencapai 136% umur dua tahun dan 81% umur empat tahun. Interaksi sumber benih x lokasi tidak menunjukkan pengaruh yang nyata dan superioritas benih unggul stabil dikedua lokasi. Benih unggul dari lima kebun benih yang diuji dapat digunakan untuk pembangunan pertanaman di Kalimantan Selatan dan Jawa Tengah tanpa ada penurunan superioritas terhadap produktifitas volume tegakan yang dihasilkan.

Kata kunci: *Acacia mangium*, uji perbaikan genetik, perbaikan genetik riil, kebun benih, volume tegakan

[1]Center for Forest Biotechnology and Tree Improvement, Jl. Palagan Tentara Pelajar Km. 15, Purwobinangun, Yogyakarta 55582 - Indonesia

[2]Banjarbaru Forestry Research Institute, Jl Ahmad Yani Km.28,7 Landasan Ulin, Banjarbaru, South Kalimantan 70721 - Indonesia

[*]Corresponding Author: arif_nirz@yahoo.com

I. INTRODUCTION

Establishment of *Acacia mangium* plantations in Indonesia in the early years had been using seeds collected from seed stand. The oldest seed stand of *A. mangium* in Indonesia was established in 1979 at Subanjeriji, South Sumatra, and used combination of bulk seeds from Queensland and Indonesian provenances (Werren, 1991). This seed stand is well known as the land race of Subanjeriji, and its seed production had been widely used in the establishment of the first rotation *A. mangium* plantations. The use of seeds collected from such kind of seed source was commonly practiced in the beginning of the plantation programs before permanent seed orchards became available (Zobel and Talbert, 1984).

Due to the growing importance of *A. mangium* in large scale plantation programs, the demand of genetically improved seeds of this species was increasing to improve the productivity of the plantations. In order to fulfill the demand, first-generation seedling seed orchards of *A. mangium* were established in some regions in Indonesia under a comprehensive tree improvement program, such as in South Kalimantan, South Sumatra, West Kalimantan and Central Java (Hashimoto *et al.,* 1996). The seedling seed orchard was initially established as a progeny test using families collected from superior provenances in Papua New Guinea and Far North Queensland. In 2000, the selection procedures have completely finished, and the orchards were in the stage of production of improved seeds ready for plantation.

Studies designed specifically to estimate realized genetic gain will allow the tree breeder to show what has actually been achieved through selection and breeding (Zobel and Talbert, 1984). Such studies can be implemented by establishing genetic gain trials, where the improved seeds are tested against the unimproved seeds in a plot trial with the same silvicultural practices. Establishing genetic gain trials will be required if we want to be able to confidently obtain realized genetic gain from improved plantation (St. Clair, 1993).

Genetic gain trials can be established and replicated in several plantation locations, and thus it will be useful to identify the magnitude of seed source x site interaction which is important for the development of a genetically improved seed deployment strategy. This is needed because often a strong genotype x environment interaction for growth traits restricts the possible gains when one population is destined for use over wide areas of plantation (Zobel and Talbert, 1984). In addition, genetic gain is better to be presented as an expected amount of improvement in the form of volume productivity per unit area. This is because single tree volume is not always a good indicator to measure the potential of improvement in volume productivity.

Studies on realized genetic gains by first-generation tree improvement in forest tree species have been done for several pine species, for example, 16%-18% increase in stand volume at 10 years age (Matziris, 1974) and 7%-12% at rotation age (Li *et al.,* 2000) for loblolly pine; 32% increase in individual stem volume for black pine (Matziris, 2005). In the case of tropical forest species, Luangviriyasaeng and Pinyopusarerk (2002) reported outstanding growth and form trait of improved families of *A. auriculiformis* at 36-40 months. With regard to *A. mangium*, although Nirsatmanto *et al.* (2004) has reported the realized genetic gain based on the one year age data observed in second-generation of seed orchard: increased around 3%, 5 % and 4 % for height, diamater and stem straightness respectively, the realized genetic gain was not yet verified in genetic gain trial. Therefore, the objective of this study is to verify the realized genetic gain for stand volume productivity attained by the first-generation seedling seed orchards of *A. mangium* in two genetic gain trials located in Central Java and South Kalimantan. As a basis to develop an improved seed deployment strategy, the effect and the magnitude of seed sources x site interaction were also investigated.

II. MATERIAL AND METHOD

A. Genetic Gain Trials

Following a comprehensive tree improvement program for *A. mangium*, three genetic gain trials were established in Central Java (7°32'S and 110°41'E), South Sumatra (3°15'S and 103°50'E), and South Kalimantan (3°30'S and 115°0'E) (see Table 1). The last two locations represent the regions with large scale operational plantations of *A. mangium* in Indonesia. The design of all genetic gain trials was similar using a randomized complete block design which was laid out as 100 trees in square plots (10×10 trees) of 4 - 5 replications with a spacing of 4×2 m. High mortality occurred in the trial in South Sumatera due to fire, thus this trial was excluded from the analysis. At four years of age, two replications in the trial in South Kalimantan was also destroyed by fire, thus at this age only three out of five replications from this trial were used for the analysis.

Basically, the genetic gain trials consisted of the same set of a mix open pollinated seeds collected from eight seed sources. However, for the purpose of this study, only six of the seed sources were used for the analysis: five seedling seed orchards (SSO) and one seed stand as the control (Table 2). The five seedling seed orchards (referred to as SSO-1, SSO-2, SSO-3, SSO-4, SSO-5) were established using family originating from Papua New Guinea and Queensland-Australia provenances as part of a comprehensive breeding program for *A. mangium* (Hashimoto *et al.,* 1996). While one control was the seed stand from the local land race of Subanjeriji (Werren, 1991).

B. Measurement and Statistical Analysis

Investigation was done by analyzing stand volume productivity at two and four years of age. Individual stem volume was derived from the volume equation (Inose *et al.,* 1992) using height and diameter at breast height (dbh):

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

To get an accurate observation, only the inner 64 trees (8 x 8 trees) in each square plot were measured to stimulate the competition that would occur between individual trees of the same seed source. The stand volume on each plot was calculated by summing up the individual stem volumes of all surviving trees in each plot, which was then expressed as stand volume productivity per hectare (m^3/ha) using the following equation:

$$\text{Stand Volume per Hectare} = \frac{\text{stand volume on plot}}{\text{area of plot in square meter}} \times 10000 \quad \text{.................(2)}$$

Analysis of variance was made at each site as well as across the two sites with the following linear equations (Hai *et.al.*, 2008):

$$Y_{ij} = \mu + B_i + S_j + e_{ij} \quad (\text{for each site}) \quad \text{............(3)}$$

$$Y_{ijk} = \mu + L_i + B/L_{ij} + S_k + S*L_{ik} + e_{ijk} \quad (\text{for across sites}) \quad \text{...........(4)}$$

Where, μ = population mean, B_i = *the ith replication effect*, S_j = *the jth seed source effect*, L_i = *the ith site effect*, B/L_{ij} = *the jth replication effect in the ith site*, S_k = *the kth seed source effect*, $S*L_{ik}$ = *the effect of seed source×site interaction, eijand eijk = experimental error associated with yij and yijk*, respectively.

The realized genetic gains were calculated as differences between the respective seedling seed orchard and the seed stand, all of which were the least square estimates of the linear model given in Equations 3 and 4. Then the relative gain was calculated as a percentage rate of the gain to the average seed stand.

III. RESULT AND DISCUSSION

A. Survival Rate and Stand Volume

The average number of surviving trees varied slightly among seed sources as indicated by the different average number of observations per plot (Table 3). Except SSO-4 in genetic gain trial in Central Java, which had the smallest number of observation (survival rate around 70 %), the average number of surviving trees per plot in each seed source at both ages and sites were more than 51 (survival rate was ranging from 80% to 97%). Difference in survival by seed sources over the two ages was small (less than 3%). In South Kalimantan, the data used for analysis at four years was only from three out of five replications (two damaged replications with low survival rates were excluded). As a result, the average number of trees per plot at four years increased from that at the two years age. The high survival rate would be sufficient to ensure an accurate comparison among the tested seed sources to examine the realized genetic gain and seed source x site interactions for stand volume productivity in genetic gain trial.

Stand volume productivity of genetic gain trial in South Kalimantan was much better than that in Central Java. The average stand volume in South Kalimantan was 18.62 m^3/ha at two years and 108.43 m^3/ha at four years, while the corresponding stand volume in Central Java was 6.76 m^3/ha at two years age and 72.53 m^3/ha at four years age (Table 3). The differences observed here are possibly associated with climatic characteristic, whereby rainfall in Central Java is lower than in South Kalimantan: 1,878 mm in Central Java and 2,043 mm in South Kalimantan (see Table 1). The natural distribution of this species can be found in areas with a range of rainfall from 1446 mm to 2970 mm and can tolerate a minimum annual rainfall of 1000 mm. *A. mangium* has performed well in site with higher annual rainfall. In addition, the growth seems to slow or cease in response to the combination of low rainfall and temperature (Mackey, 1996). Another reason might be due to the differences in the geographic coordinates of the sites, where the latitude of test plantations decreases from 7°32' S in Central Java to 3°30'S in South Kalimantan. The same trend of faster early growth with decreasing latitude for *A. mangium* was also observed in trials and operational plantations in Vietnam (Kha, 2011) and in provenance trial in many tropical countries (Harwood and Williams, 1991). Besides the climate factor in general, soils property is also another important factor of plantation productivity. Despite *A. mangium* tolerates to the soil with low fertility, its growth more pronounced in a site with red and well drained soil properties such as Podzols, the similar type of soil as in the site of South Kalimantan in this study (Table. 1). Moreover, most of *A. mangium* plantation in Indonesia were also established in the regions dominated by the type soil of Podzols (Hardiyanto and Wicaksono, 2008; Golani *et.al.*, 2009).

Trees planted using seed sources from five seedling seed orchards outperformed those from seed stand (Table 3). Stand volume from the five orchards in genetic gain trial in Central Java exceeded 5 m^3/ha and 60 m^3/ha at two and four years respectively, and those in South Kalimantan exceeded 15 m^3/ha and 90 m^3/ha at two and four years respectively. While the corresponding stand volume of the control seed source from seed stand at respective ages and sites were less than the observed values from the seedling seed orchards. Except at two years in Central Java, analysis of variance

Table 1. Site location and experimental design of the genetic gain trail

Site location (Latitude, Longitude)	Altitude (m)	Mean annual rainfall (mm)	Temp. Max./Min. (°C)	Soil type	Planting	Design
Central Java (7°32′S and 110°41′E)	141	1,878	33.23/21.9	Vertisols	2002	RCBD/4 replications
South Sumatra (3°15′S and 103°50′E)	130	2,781	33 / 24	Podzolls	2002	RCBD/4 replications
South Kalimantan (3°30′S and 115°0′E)	150	2,043	33.7 / 26.2	Podzolls	2002	RCBD/5 replications

RCBD= Randomized Complete Block Design

Table 2. Six seed sources with different genetic levels and original provenances tested in genetic gain trial

No.	Seed source	Location	Latitude, Longitude, (Elevation)	Location of original provenance
1.	SSO-1	Pleihari- South Kalimantan	3°58'S and 114°37'E (15 m)	Dimissisi, PNG Derideri E Morehead, PNG Gubam NE Morehead, PNG Bimadebun, PNG Arufi Village, PNG Boite NE Morehead, PNG
2.	SSO-2	Pendopo- South Sumatra	3°31'S and 103°48'E (80 m)	Oriomo, PNG Wipim, PNG Kini, PNG
3.	SSO-3	Pleihari- South Kalimantan	3°58'S and 114°37'E (15 m)	Claudie River, FNQ 135K N, FNQ
4.	SSO-4	Pendopo- South Sumatra	3°31'S and 103°48'E (80 m)	Pascoe River, FNQ Claudie River, FNQ Cassowary CK, FNQ
5.	SSO-5	Wonogiri- Central Java	7°32'S and 110°41'E (141 m)	PNG(*), FNQ(**)
6.	Seed Stand	Subanjeriji- South Sumatra	3°05'S and 104°25'E (80 m)	Queensland (bulk) IND (bulk)

PNG=Papua New Guinea; FNQ=Far North Queensland; IND=Indonesia
SSO=Seedling Seed Orchard
*) same as in seed source no.1, 2
**) same as in seed source no. 3, 4

Table 3. Average stand volume (m^3/ha) and realized genetic gain (%) at two ages of measurements in genetic gain trial of *Acacia mangium*

Seed source [a]	2 years age				4 years age			
	Central Java		South Kalimantan		Central Java		South Kalimantan	
	N	Volume	N [b]	Volume	N	Volume	N [c]	Volume
SSO-1	55	7.29 (+83)	59	19.92 (+46)	55	74.36 (+57)	62	127.79 (+59)
SSO-2	58	9.42 (+136)	58	22.61 (+66)	56	85.89 (+81)	60	118.41 (+47)
SSO-3	55	6.80 (+71)	59	18.40 (+35)	55	78.24 (+65)	61	111.80 (+39)
SSO-4	48	5.70 (+43)	56	15.36 (+13)	46	64.48 (+36)	60	92.01 (+14)
SSO-5	55	7.39 (+86)	59	21.76 (+59)	54	84.88 (+80)	60	120.02 (+49)
Seed Stand	53	3.98	55	13.65	51	47.34	57	80.57
Grand Mean	54	6.76	57	18.62	52	72.53	60	108.43

N=average number of observation per plot
a) Seed sources as described in Table 2.
b) number of observation based on five replications
c) number of observation based on three replications only or excluding two damaged replications
Value in parenthesis is realized genetic gain (%)

revealed that stand volume among seed sources were significantly different at both ages and sites (Table 4). Separation the means showed that the significant differences among seed sources were mainly a result of differences between the improved seeds from seedling seed orchards and the unimproved seeds from seed stand (Table 3). This result indicated that

Table 4. Degree of freedom and mean square values for each component of stand volume at two ages of measurements in genetic gain trial of *Acacia mangium* analyzed in each site using Equation(3).

Source of variation	2 years volume		4 years volume	
	df	Mean square	*df*	Mean square
Central Java				
Replication	3	22.8797	3	284.9613
Seed source	5	13.2633ns	5	853.0961 **
Error	15	4.7358	15	173.0243
South Kalimantan				
Replication	4	58.2914	2	1614.3415
Seed source	5	62.8200 **	5	999.2511**
Error	20	14.0269	10	172.7574

**Significant at the 1% level, ns not significant

Table 5. Degree of freedom and mean square values for each component of stand volume at two ages of measurements in genetic gain trial of *Acacia mangium* analyzed across the two sites using Equation(4).

Source of variation	2 years volume		4 years volume	
	df	Mean square	*df*	Mean square
Site	1	1873.2697 **	1	13257.7816 **
Replication (site)	7	43.1150 **	5	816.7134 **
Seed Source	5	67.9251 **	5	1714.5543 **
Seed source x Site	5	8.1583 ns	5	137.7930 ns
Error	35	15.5567	25	172.9175

**Significant at the 1% level, ns not significant

the improved seeds performed better than the control from unimproved seed regarding stand volume. Less inter-trees competition due to a slower growth in Central Java at two years probably reduced the magnitude of variance in seed sources level. As a result, stand volume among seed sources in such situation tends not to be significantly different.

Among the five seedling seed orchards, SSO-2 was ranked first for stand volume in Central Java at both ages (9.42 m^3/ha and 85.89 m^3/ha at two and four years, respectively), followed by the second ranked SSO-5 (7.39 m^3/ha and 84.88 m^3/ha at two and four years, respectively), while SSO-3 and SSO-1 was an intermediate. In South Kalimantan, SSO-2 was also ranked first at two years (22.61 m^3/ha), but it was replaced by SSO-1 at four years (127.79 m^3/ha). The superiority of SSO-1 over SSO-2 at four years in South Kalimantan is probably due to the effect of the distance between seed source location and planting site. SSO-1 was located close to the trial site in South Kalimantan (50 km away) with probably more adaptive stand development at the trial site condition, while SSO-2 was located in South Sumatra (Table 2). The same as in Central Java, SSO-5 was second ranked at both ages (21.76 m^3/ha and 120.02 m^3/ha). While SSO-4 performed poorest in stand volume productivity over both sites and

Table 6. Average stand volume across the two sites of genetic gain trial of *Acacia mangium* at two ages of measurements, followed by the ranking order

Seed source	2 years volume		4 years volume	
	Average (m^3/ha)	Rank	Average (m^3/ha)	Rank
SSO-1	14.30 *abc*	3	97.26 *ab*	3
SSO-2	16.75 *a*	1	99.83 *ab*	2
SSO-3	13.25 *bc*	4	92.62 *ab*	4
SSO-4	11.07 *cd*	5	76.28 *b*	5
SSO-5	15.38 *ab*	2	99.94 *a*	1
Seed Stand	9.35 *d*	6	61.58 *c*	6

Averages with the same letter in respective year indicate they are not significantly different at the 1% level

ages.

The superiority of SSO-1, SSO-2 and SSO-5 over SSO-3 and SSO-4 might be mainly due to the effect of provenances. This is because the first three superior seedling seed orchards as described above mostly consisted of families from Papua New Guinea (PNG) provenances, while the other two seedling seed orchards consisted of families from Far North Queensland (FNQ)-Australia (Table 1). The superiority of PNG provenances as resulted in this study was in agreement with the report of previous provenance trials (Harwood and William, 1991; Kari *et al.,* 1996).

Absolute stand volume productivity in this study seemed lower as compared to the study reported by Otsamo *et al.,* (1996). In a previous study, mean annual increment (MAI) of stand volume at 41 months age in South Kalimantan reached around 39 m^3/ha/yr and 28 m^3/ha/yr for PNG and FNQ provenances, respectively. The corresponding MAI in the present study at 4 years was around 30 m^3/ha/yr and 25 m^3/ha/yr for PNG and FNQ, respectively. This discrepancy is probably due to the differences in site preparation and the practices of singling multi-stemmed trees. In a previous study, the trial plots were plowed twice which was recognized as the best method to support the initial growth in *Imperata cylindrica* grassland area (Otsamo, *et al.,* 1995), while in the present study the preparation of the trial site was made manually, that is clear-felling followed by burning. The singling practiced in the present study was also a source for reducing the stand volume. Otsamo *et al.* (1996) has reported a statistical difference between singling and control (no singling), in which MAI of the singled tree population was only 71% of that of the control.

B. Realized Genetic Gain

Superiority of the five seedling seed orchards over the seed stands resulted realized genetic gains for stand volume in the two sites which ranged from 13% to 136% at two years of age and 14% to 81% at four years of age (Table 3). In general, realized genetic gain in Central Java was higher than in South Kalimantan. Among both ages, the realized genetic gain at two years was generally higher than that at four years. These trends were probably due to the effect of increasing inter-tree competition from more rapid stand development, either attributable to good site quality or older age, which then tend to reduce the amount of genetic gain. Site in Central Java was less productive as compared to South Kalimantan, as shown by the slower growth of the trees (Table 3), which then indicated that the inter-tree competition in Central Java was less intense compared to South

Kalimantan. Eldridge (1982) has reported a small genetic gain in productive site indicating the decreasing genetic gains with increasing stand development and competition.

Consistent with the superiority in absolute stand volume, realized genetic gain of seedling seed orchards originating mostly from PNG (SSO-1, SSO-2, SSO-5) were higher than those from FNQ provenances (SSO-3, SSO-4). At two years, realized genetic gains ranged from 35% to 136% for the orchards of PNG provenances, and from 13% to 71% for the orchards of FNQ, while at four years the gains ranged from 39% to 81% and from 14% to 65% for the PNG and FNQ, respectively. SSO-2 which consisted of Oriomo, Wipim and Kini region of PNG provenances (see Table 1) showed the highest realized genetic gain in Central Java: 136% increase at two years age and 66% at four years. *A. mangium* from Oriomo region was recognized as the most productive of the PNG provenances (Harwood and Williams, 1991, Kari *et al.,* 1996). While in South Kalimantan, the gain of SSO-2 was the highest at two years (81%), but it was replaced by SSO-1 at four years (59%). Similar to the absolute stand volume, SSO-4 has produced the poorest realized genetic gain among the seedling seed orchards at both ages and sites, which ranged only from 36% to 43% in Central Java and 13% to 14% in South Kalimantan. However, the data used in this study was collected at half rotation age (rotation age assumed to be 8 years) and the actual genetic gain might become smaller amount when the stand is getting older. This is because the amount genetic gain tends to be reduced as the stand development is progressing (Zobel and Talbert, 1984).

By considering the fact that the stand volume is a function of height, diameter and stem form, the amount of realized genetic gains in this study seemed to be greater than the gain confirmed in 1 year's measurement of second-generation seedling seed orchards as reported by Nirsatmanto *et al.* (2004). In a previous study, the realized gain which was calculated as percentage increase of family from selected plus trees in the first-generation orchards to the newly added infused family were around 3%, 5%, and 4% for height, dbh, and stem straightness, respectively. This discrepancy might be mostly due to additional gain from the selected provenance that was accumulated in the amount of gain calculated in the present study. The gain by selected provenance of Papua New Guinea and Queensland-Australia for *A. mangium* was reported to be ranging from around 20% to 40 % for stand volume

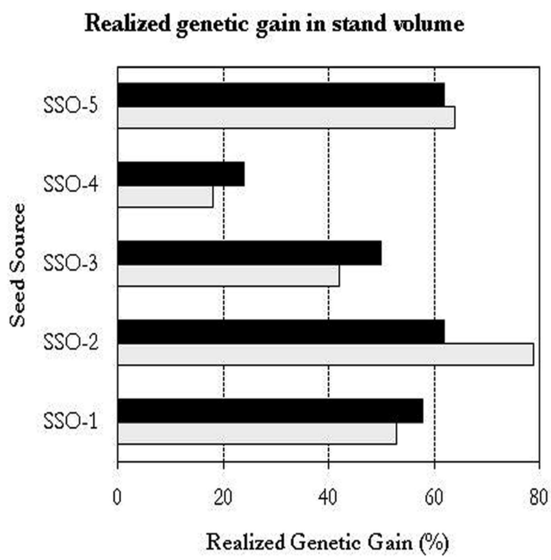

Figure 1. Realized genetic gain (%) for stand volume across the two sites of genetic gain trial of Acacia mangium at two years age (white bar) and four years age (dark bar)

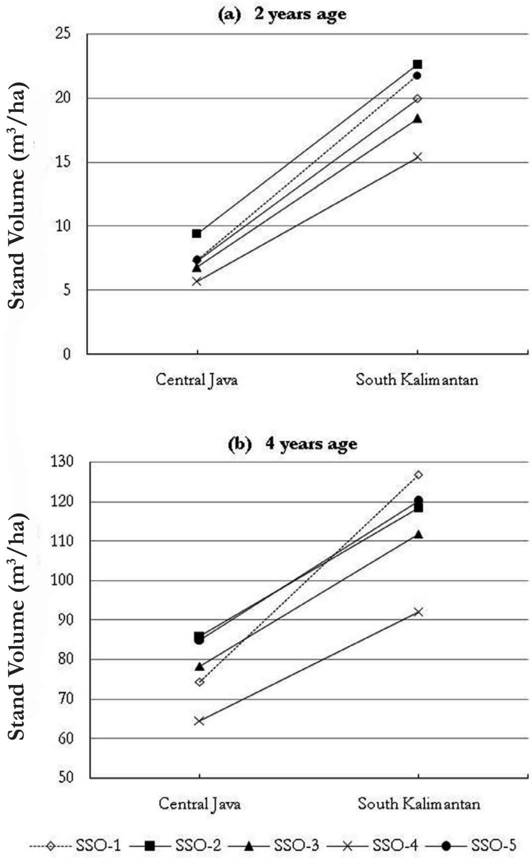

Figure 2. Ranking order of five seedling seed orchard (SSO) between two sites (Central Java and South Kalimantan) for stand volume observed at 2 years age (a) and 4 years age (b)

(Hardiyanto *et al.,* 2000; Nirsatmanto *et al.,* 2003). Total realized genetic gain by the first-generation seed orchard as confirmed by this study was also higher as compared to other studies in pines species, e.g. 16%-18% increase in stand volume at 10 years age (Matziris, 1974) and 7%-12% at rotation age (Li *et al.,* 2000) for loblolly pine; 32% increase in individual stem volume for black pine (Matziris, 2005).

Selection of the productive provenance has become an important step for the success of the tree improvement of *A. mangium*. Butcher *et al.* (1998) has reported major differences in the level of genetic diversity of *A. mangium* in populations from the south of the species range (Daintree, Queensland) compared to levels in populations from Papua New Guinea using RFLPs. Higher level of genetic diversity, as shown by the population of Papua New Guinea (He=0.16-0.21), tended to produce superior growth in field trial.

C. Seed Source x Site Interaction

Analysis of variance across the two sites showed that differences among seed sources were statistically significant for stand volume (Table 5). The average of pooled stand volume from the two sites by seed sources ranged from 9.35 m^3/ha to 16.75 m^3/ha and from 61.58 m^3/ha to 99.83 m^3/ha for two years and four years respectively, with the average values of control (seed stand) were always the lowest (Table 6). Therefore, the realized genetic gain based on across site analysis ranged from 18% to 79% at two years, and from 24% to 62% at four years (Figure 1). SSO-1, SSO-2 and SSO-5 which originated from PNG provenances were consistently found at the top three highest realized genetic gain with a slight change in the ranking order among them between the two sites at four years (Figure 2b). The positive realized genetic gain from all of the five orchards through two types of analysis, single analysis (Table 3) and across site analysis (Table 6), suggested that the superiority of the five seedling seed orchards were evident for stand volume productivity.

Despite the fact that both sites were considerably different in climate and geographic coordinates, seed source x site interaction was not significantly different (Table 5), indicating there was not a strong GxE interaction among the two sites at seed source level. It means that at half rotation age, superiority of the five seedling seed orchards were consistent across the two sites of genetic gain trial for stand volume. This result supports our previously reported study where GxE interaction between South Sumatra and South Kalimantan was not strong to cause any apparent reduction in genetic gain (Nirsatmanto *et al.,* 2004). Thus, improved seed produced from the five seedling seed sources could be deployed into two tested sites of plantations without any serious change of order in their superiority.

The seed source x site interaction was slightly lower at two years than at four years, as demonstrated by the difference in changing of the ranking order (Figure 2a and Figure 2b). At two years, all five seeding seed orchards performance was relatively stable across the two sites, while at four years there was one seed source (SSO-1), which most responsive to the site difference. However this interactive effect was not so strong to appear as a significant seed source x site interaction. SSO-1 which is located in close distance from the trial site in South Kalimantan tended to be more productive for stand volume at older age when planted in a site that pronounced a similar environment, while SSO-2 and SSO-5 was relatively stable across the diverse environment.

The non significance of GxE interaction at the level of seed sources as resulted in this study was not in agreement with the report of previous GxE interaction study at the level of family (Setyaji, 2011). In the previous study, high significance of family x site interaction for growth traits were observed using data from second-generation of progeny test of *A. mangium* in South Sumatra and South Kalimantan. This discrepancy might be due to the difference in magnitude of variations, where the increases of genetic variation tend to reduce the strength of GxE interaction. The five seedling seed orchards in this study were converted from progeny trials which were established using grouped sub-line system based on the original of natural population distribution. It is well known that genetic variation between populations for *A. mangium* was larger than the variation among individuals (family) within the population (Butcher *et al.,* 2000). Among some GxE interaction studies summarized by King (1964) it was also concluded that as the genetic diversity of material increases, the relative magnitude of the interaction decreases.

Result in this study through analysis in realized genetic gain and seed source x site interaction as described above suggested that genetic improvement in stand volume of *A. mangium* has been achieved through first-generation seedling seed orchards. Selection of productive provenance proved to be an essential factor to bring some amount of improvement from first-generation breeding program for *A. mangium*. This study revealed that seed orchards which were established using family originating from superior provenances of PNG and FNQ consistently produced higher productive stand as compared to the unimproved material.

IV. CONCLUSION

Realized genetic gains of five seedling seed orchards from first-generation breeding program of *A. mangium* were well verified at half rotation age in genetic gain trials established at two different sites. The genetic gains were high in relation to the stand volume productivity, although the magnitude varied depending on site quality and the age of the stand. Gain observed in poor site quality (Central Java) tended to be higher than that observed in high site quality (South Kalimantan). Across the two sites, the realized genetic gains were in the range of 18% –79% at two years of age and 24%-62% at four years of age. Seedling seed orchards consisting of family originating from superior provenance (PNG) showed higher genetic gain. The effect of interaction between seed sources and sites was also weak which indicated that the superiority of improved seed was consistent across the two different sites. The results of the study implied that the genetically improved seed would increase stand volume productivity of *A. mangium* plantations and it could be potentially deployed in wider range of environments without any serious change of order in their superiority.

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SOME PROBLEMS IN MAINTAINING SUSTAINABILITY OF INDONESIA'S FORESTS: DESCRIPTIVE STUDY

Cecep Handoko[1*]

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ABSTRACT

Indonesia's forests have economic, social, and environmental benefits. Some national efforts, as well as support from the global community for sustaining forest development in Indonesia have been done. However, some problems were still reported during the implementation of the forest development. Thorough analysis was needed to formulate the root of the problems, and to identify solutions/supports to the current forest development to achieve its sustainability. Descriptive analysis was used in this study. The results indicated that sustainable forest development in Indonesia was still faced with the problems of uncertainty of management, insufficient management capacity, and lack of law enforcement. These conditions were indicated by high conflict of interests as well as lack of support from stakeholders, not enough forest management actions at site-level, and high forest degradation. Aiming at overcoming problems of sustainable forest development and maintaining sustainability of Indonesia's forest, national forest management needs to embrace more space for communication, openness, mutual learning, collaboration in addressing forest conflicts, and determining the future direction of its sustainability goal of management.

Keywords: Indonesia, forest, sustainable development

ABSTRAK

Hutan Indonesia memiliki manfaat secara ekonomi, sosial, dan lingkungan. Beberapa upaya nasional, begitu pula dukungan dari komunitas global untuk mempertahankan pembangunan hutan Indonesia telah dilakukan. Namun, beberapa masalah masih mengemuka selama pembangunan hutan tersebut. Analisis menyeluruh diperlukan untuk merumuskan akar dari masalah-masalah tersebut, dan mendapatkan solusi / dukungan bagi pembangunan hutan yang berkelanjutan. Analisis deskriptif digunakan dalam penelitian ini. Hasil penelitian menunjukkan bahwa pembangunan hutan yang berkelanjutan di Indonesia masih dihadapkan pada masalah-masalah berupa ketidakpastiaan pengelolaan, rendahnya kapasitas pengelolaan dan rendahnya penegakan hukum. Kondisi tersebut ditandai oleh tingginya konflik kepentingan serta rendahnya dukungan para pihak, rendahnya tindakan-tindakan pengelolaan di tingkat tapak dan tingginya kerusakan hutan. Untuk mengatasi permasalahan pembangunan hutan, pengelolaan hutan nasional perlu membuka ruang yang lebih luas bagi komunikasi, keterbukaan, pembelajaran dan kolaborasi dalam mengatasi konflik-konflik hutan, serta menentukan arah ke depan terhadap tujuan kelestarian dari pengelolaan hutan yang dilakukannya.

Kata kunci : Indonesia, hutan, pembangunan berkelanjutan

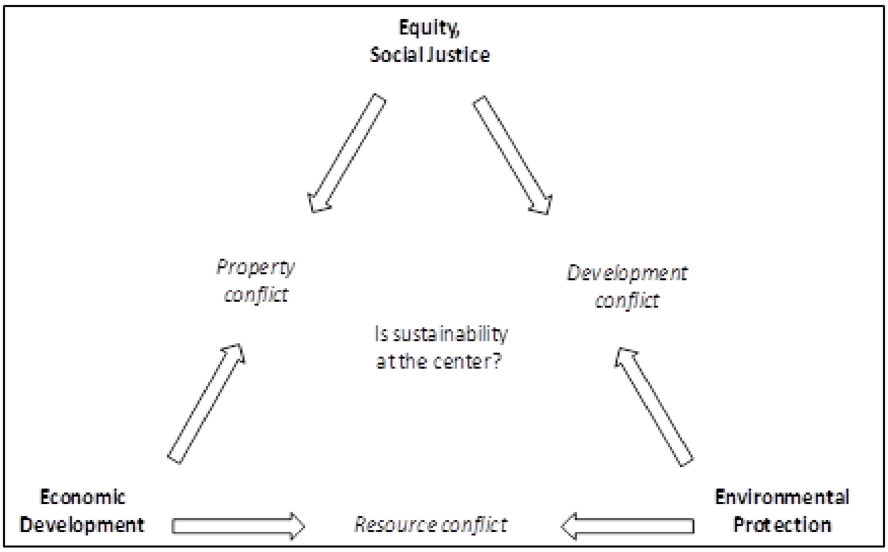
[1] Research Institute of Non Timber Forest Product Technology Jl. Dharma Bhakti No. 7 Po.Box. 1054, Ds. Langko Kec. Lingsar, Lombok Barat, NTB 83371. West Nusa Tenggara - Indonesia

[*]Corresponding Author: cecep_h@yahoo.com

I. INTRODUCTION

Forest is a national capital, which has tangible benefits in ecological, socio-cultural, and economic values (Law number 41 of 1999 on Forestry). As one of the determinants of life supporting systems, forests play important roles in hydrological functions, protection from flood, and erosion. Despite the important functions of the forests, however, Indonesia's forests have been dramatically degraded, as a result of large-scale forest exploitation (The World Bank, 2006b). Natural disasters, decline in forestry incomes, and declining capital for national development are linked to such degradation. Meanwhile, high greenhouse gas emissions caused by deforestation, forest fires, and degradation of peatland has attracted national and global attention because of its impact on global warming. Some of the major concerns in forest development in Indonesia are: illegal logging, land degradation, forest revenue enhancement, community development, and the revitalization function of the forest management unit (FMU) as well as forestry extension. Moreover, since global warming that leads to climate change has negative impact on the raising risks of hydrological-related disasters, including flood and drought, the government of Indonesia has stressed national involvement in climate change adaptation as well as mitigation.

On the other hand, accommodating the changes in the society as well as the requirements of decentralization in the autonomy era, some changes have been done related to the implementation of forestry policies (Subarudi and Dwiprabowo, 2007). Moreover, several local-community empowerment programs were introduced to overcome social conflicts. The programs included Community Forestry (Ministry of Forestry Regulation Number P.37/Menhut-II/2007), village forest (Ministry of Forestry Regulation Number P.49/Menhut-II/2008), and Forestry Partnership (Ministry of Forestry Regulation number: P.39/Menhut-II/2013). However, social conflicts were still emerging frequently. Social conflicts have been occurring within governmental bodies, multi-level governmental bodies, and governmental bodies with communities and customary groups. Moreover, the occurrence of claim to forest land highlighted conflict condition which has occurred for years. On the other hand, aiming at overcoming social conflict and improving effectiveness of management,



Source: Campbell, 1996

Figure 1. The triangle of conflicting goals for planning, and the three associated conflicts

including handling of forest land degradation, the establishment of FMU was hampered by lack of human resources and insufficient support from stakeholders (MoF, 2010).

Along with the efforts on sustaining forest development in Indonesia, many contrary reports of problems in forest development were produced. The reports could lead to the question on how Indonesia could achieve sustainability in its forests. Since a solution to forest sustainability in Indonesia should be obtained, a guidance to formulate sustainable forest development strategy as well as to know the root of the problems of development was needed. Campbell (1996) asserted that sustainable development should take into account three conflicting goals of development as well as their three associated conflicts. Sustainable development goals, including economy, social justice/equity, and environmental protection, while the three associated conflicts, include property conflict (economy-equity conflict), resource conflict (economy-environmental conflict), and development conflict (equity-environmental conflict). Sustainable development itself is ideally placed in the center of the triangle of those goals and conflicts (As it can be seen in Figure 1).

In practical term, the triangular model of planning can be used to operationalize long-term vision of sustainable development into a medium-term and short-term planning (Nur, 2010). Using this triangular model of planning, the goals as well as the associated conflicts of the development can be definitely determined, therefore the roots of the problems of sustainable development can be thoroughly analyzed. This results in arriving at the solutions to the development. By using the triangular model of planning, this study was aimed at finding the root of some of the problems of sustainable forest development in Indonesia, and proposing solutions as well as support to the current forest development to achieve its sustainability.

II. MATERIALS AND METHODS

A. Materials

This study used secondary data and information which were obtained from various publications, including news, reviews, reports and research publications.

B. Methods

This study was a desk study. Data were analyzed descriptively. The main data source was the forestry statistical report of Indonesia from the Ministry of Forestry (MoF). Some other supporting information was also used, including: 1. Some current forestry issues and case studies related to the subject; 2. The history of the development of the national forest to get an overall picture of the trends in forest development and the problems that are associated with it, and 3. The various stated solutions to the current problems of forestry development.

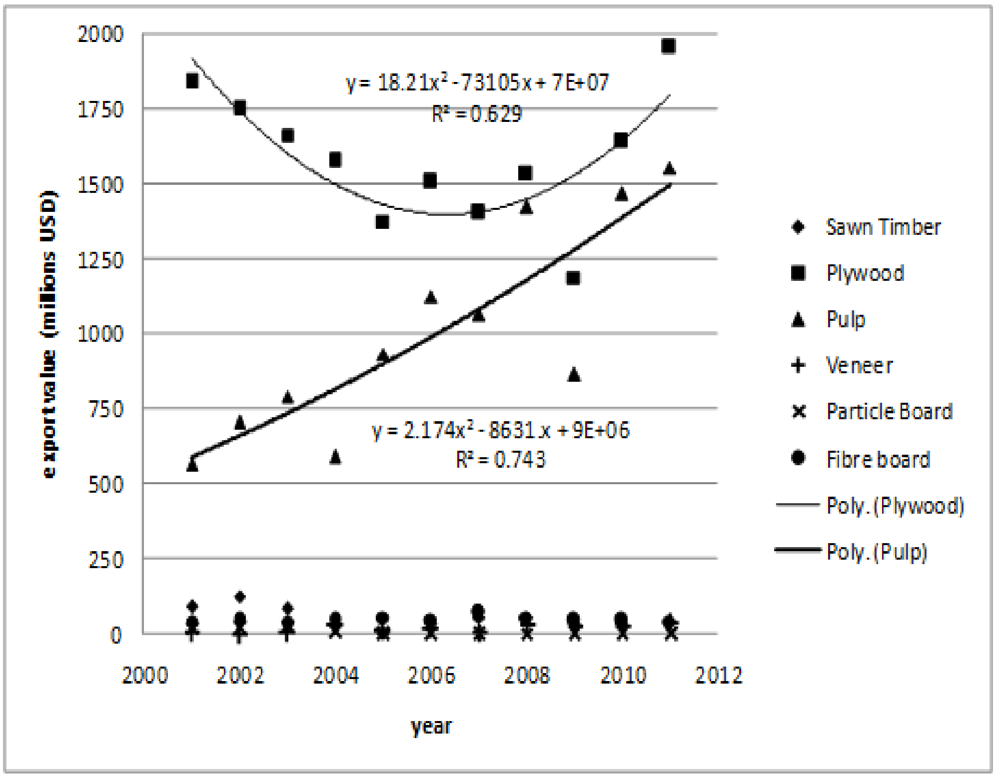
Steps of analysis included:

1. Collecting data and information to find out mainstream concerns or problems of forest development related to the objectives of forest development;
2. Grouping some mainstream concerns/problems by their sources of conflicts;
3. Overlaying divergent of interests of forest development (economy, social, and protection of environment) with the associated sources of conflicts (properties conflict, resources conflicts, and development conflicts) to obtain the roots of the forest development problems;
4. Finding possible solution or support in maintaining sustainability of forest development in Indonesia.

III. RESULTS AND DISCUSSION

A. Results

Until 2009, strategic efforts have been made for the successful development of the forests in Indonesia. Some of the efforts, including: (1) completion of 578 cases of illegal logging (18.75% of the total of 3,083



Source: MoF (2006), MoF (2008) and MoF (2012) (data processed)

Figure 2. Export values of processed timber during 2001 - 2011

cases) during 2005-2009; (2) rehabilitation of 906,969 hectares of forest area, and 1,102,912 hectares outside of forest area; (3) development of intensive silviculture system and industrial plantation forests (HTI) reaching a total investment of IDR 23.72 trillion; (4) construction of 227 units of wood processing industries capable of employing 205,300 people reaching a total investment of IDR 16.56 trillion; (5) development of 8,800 hectares of community forests (HKm), 22,860 hectares of private forests (HR), and 2,360 hectares of village forests; (6) distribution of investment funds to communities for establishment of HTI and private plantation forests (HTR) reaching an investment volume of IDR 4 trillion in 2008; (7) demarcation of 219,606 km forest boundaries (77.91% of the total length of 282,873 km); (8) establishment of forest management units (KPH); and (9) institutional and capacity strengthening of the forestry extension (Forestry Minister Regulation Number: P.08/Menhut-II/2010 on Forestry Ministry's Strategic Plan 2010-2014).

As it is known from the above efforts, illegal logging, land degradation, forest benefit enhancement, community development, and revitalization of the forest management unit as well as forestry extension were some of the major concerns of forest development in Indonesia until 2009. The concerns continued in the next development periode (2010-2014). Meanwhile, as important input for evaluating and obtaining suitable solutions to the current and the future development of the forests in Indonesia, some national or global problems/ issues were reported, as follows:

1. Problems in forest border demarcation and forest area determination

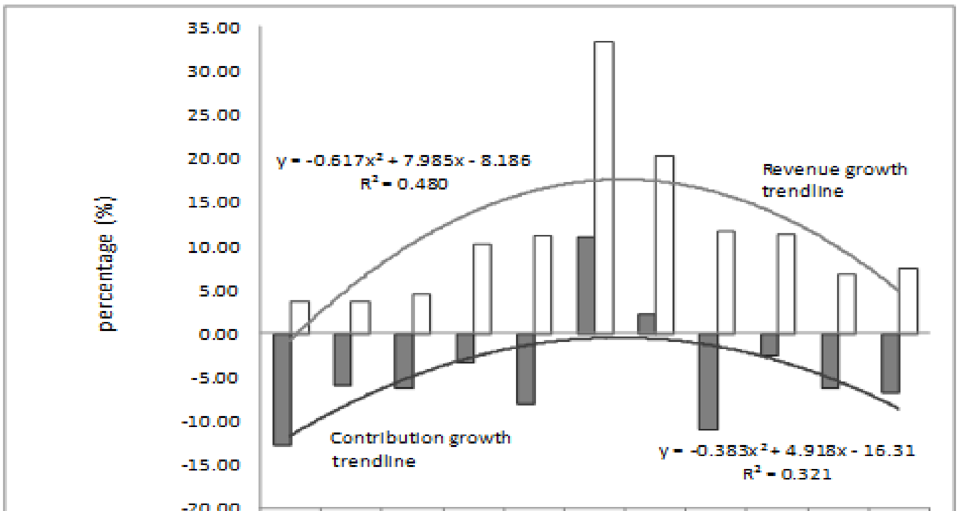
Law number 17 of 2007 on National Long Term Development Plan for 2005 to 2025 stated that the lack of sustainable management of natural resources is still a major obstacle for resolving national spatial planning. Incomplete spatial planning has led to the development of the sector, which does not take into account sustainability and environmental capacity, and does not pay attention to the vulnerability to natural disasters. It also has led to conflicts between land use sectors, where the most common example is the conflict between forestry and mining sectors. The completion of national spatial planning, one of the ways is through forest area demarcation, is necessary to accelerate the sustainable management of natural resources in Indonesia.

The fundamental of forest management is forest planning, by which permanent forests have been established. Permanent forest is characterized by the status and the boundaries that is clear, definite, legitimate and recognized by the public and stakeholders, and is accountable. Establishment of permanent forest prevents conflicts and increases security of existing forest, investment assets, biodiversity, and environment. Ministry of Forestry published the size of the terrestrial forest as 131 million hectares out of a total of 136 million hectares which include forests and waters as its forest territorial area. However, until 2011, only 15.22 million hectares or 11.6 percent of the forest area has been gazetted. Beside technical aspects of implementation, slow performance of forest boundary demarcation was influenced by conflicting interests of development of stakeholders, and lack of accommodation of community rights as well as access to forest during boundary demarcation (KPK, 2012).

On the other hand, Forestry Law number 41 of 1999 states that the adequacy of the forest area and forest cover for each watershed and/or island shall be at minimum 30 percent of the total area of the watershed and/or island which should be proportionally distributed. Although it is a progress from the previous forest policy (Law number 5 of 1967 on Basic Provisions of Forestry), there is no definite inventory to arrive at the absolute numbers of forest area adequacy according to watershed and/or island, besides the inherited history of the forest area of Indonesia from the Dutch administration.

Besides the calculation of the initial forest area, there is the calculation of the forest area which is allowed for conversion to the tune of 2% of the total national forest area (Joint decision by the Minister of Forestry, Minister of Agriculture, and the Head of the National Land Agency number: 364/Kpts-II/90; 519/Kpts/HK.050/90; and 23 - VIII - 1990), and the calculation of the proportional areas of the non-forest plantations with agricultural plantations by provincial areas (the Minister of Forestry regulation number: P. 33/Menhut-II/2010). However, harmonization of the three calculations of the forest areas during the implementation phase, as well as overcoming conflicts, was not done. This condition could lead to divergence forest area allocation for certain mainstreamed purpose of benefits. The accommodation to recent conditions, especially national social changes, could bring on policy changes. But, in fact, it should be worrying that large forest conversions, i.e. conversion to oil palm plantations and conversion for mining, have no definite arrangements, which will lead to natural forest destruction and biodiversity losses in the Indonesian rain forest ecosystems. These conditions were found during 1990-1999 (Manurung, 2001).

On the other hand, disputing the determination of forest area units together with unfinished implementation of forest boundary demarcation is also known. Along with the history of forest management, various concession management units between 1,000 to 400,000 hectares have been issued with licenses. The area of the unit depends on the existing forest area; the forest origin, forest status, and the capacity of management. During the historical period, there was a change in forest management from broad-scale natural forest management to plantation forest management. There was also the establishment of small forest management units of up to 100 hectares (Minister of Forestry Decree number: 05.1/Kpps/II/2000). Establishment of these small scale forest area units without assurances on management as well as forest boundaries could lead to wide occurrence of small, degraded, and fragmented forest areas.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Contribution growth (% per year)	-12.7	-5.83	-6.19	-3.30	-7.95	11.11	2.22	-10.8	-2.44	-6.25	-6.67
Revenue growth (% per year)	3.79	3.77	4.61	10.19	11.19	33.26	20.25	11.68	11.34	6.89	7.47

Source: MoF (2006), MoF (2008) and MoF (2012) (data processed)

Figure 3. Trend of Forestry Sector GDP and Contribution of the sector to national GDP

2. Problems in gaining forest revenues and high forest degradation

Since timber exploitation from natural production forests have resulted in excessive forest degradation, the log export ban was issued in 1985. During 1985-1997, the log export ban policy has led to the decline of timber product export revenues by 12 per cent, or a total decrease of USD 6 billion. In contrast, the resumption of log exports in 1998 has led to the widespread circulation of illegal timber and lack of timber raw material to the industries in the country compelling the Forestry Department (now the Ministry of Forestry) to withdraw the policy in 2001 (Manurung, 2008). Nevertheless, these policies encouraged the growth of domestic wood processing industries such as pulp and plywood industries. As it can be seen in Attachment - Figure 2, pulp exports showed an increasing trend during 2001 to 2011 with cumulative value of foreign exchange of USD 11 billion, while plywood exports also increased during 2006 to 2011.

Figure 2 shows the value of exports of processed timber during the period 2001-2011. Of the eight forest products, the exports value of pulp increased from USD 564 million in 2001 to USD 1,554 millon in 2011. It appears from the figure that the trend of increase in export value of pulp is confirmed signignificantly by the R2 value, 0.743, of the regression equation. Meanwhile, plywood exports also increased from 2001 to 2010. Compared to the trend of export values of pulp, trend of plywood export values seem to had its ups and downs characterized by a curved regression line. R2 0.629 of the regression indicates that the regression line is well fitted to the trend of the export value of plywood. On the other hand, it also can be seen that export values of some other products were very low compared to the value of the exports of pulp and plywood.

Figure 3 - in Attachment, shows the trend and the contribution of the forestry sector to the national GDP during 2001-2011. From the figure it can be seen that the R2 values of the two regressions are only 0.321 and 0.480, i.e. quite low, which is thought to occur because of the high fluctuation (standard deviation) of values of the independent variables for the contribution of the forestry sector and the national GDP, i.e. 6, 23 and 8.29, respectively. But, in general it can be seen that the growth curve of the national GDP is above zero, while that for the contribution of the forestry sector is below zero. Therefore, from the graph it can

be seen that the overall contribution of the forestry sector to the growth of the national GDP during the years 2001-2011 was negative. During the period 2001 to 2011, there was a positive growth in GDP of the forestry sector by an average of 11.31% per year. However, the increasing growth of GDP was not followed by positive growing trend of the sector to the national GDP that declined by an average of -4.44 % per year over the same period (Figure 3). Although using the GDP as the sole measure of the strength or weakness of the sector's role in the national development is debatable, since one is only calculating the tangible product value (Nurrochmat, 2008), but the declining contribution of the forestry sector triggered the need to increase as well as sustain the GDP of the sector.

Besides the low GDP contribution, forest economic development faced problems of massive forest losses and forest degradation. The World Bank (2006b) stated that a quarter of the "state forest area" lacks tree cover and up to 2 million hectares of forest was lost per year. In contrast, forest and land rehabilitation efforts faced obstacles from a low reforestation fund obtained from the economic utilization of the forest. By 2007, critical forest areas have reached 59.2 million hectares and the cost for forest and land rehabilitation (RHL) was estimated at IDR 296 trillion. With assuming a cost of IDR 5 million per hectare, RHL costs cannot be covered by the available amount of the reforestation fund, remaining is approximately IDR 10 trillion, with an addition of IDR 1-2 trillion (Subarudi and Dwiprabowo, 2007). In line with the lack of the reforestation fund, the results of the examination of the financial management of the forestry sector is showing the ineffectiveness of the management with potential irregularities which has caused total state losses of IDR 2.14 trillion (BPK, 2012), that increased the concern about the failure of the Ministry to eradicate nationwide the high rate of forest degradation.

On the other hand, many factors, including external and internal factors considered as the contributing causes to the large forest losses and degradation of Indonesian forests complicated and confused the efforts for overcoming such high forest degradation as well as destruction. Wardojo and Masripatin (2002) stated that large discrepancy between supply and demand of log production and consumption, which has brought about illegal logging and illegal trade, is the main factor causing large forest degradation. The World Bank (2006b) stated that forest degradation and forest loss in Indonesia was resulted mainly by illegal cutting and land conversion fuelled with excessive processing capacity of industries and lack of effective management and law enforcement. Kartodihardjo (2006a) stated that the forestry programs which were implemented by district/ province governments and central government with lack of institutional strengthening efforts has resulted in policy failures to reach its targets and led to enormous forest destruction. On the other hand, in more general term, Barr et al. (2011) stated that lack of efficiency and accountability has led to insecurity of management as well as forest sustainability.

3. Social conflicts

Nurjaya (2005) stated that social conflict in forestry happened due to the state-based government's policies, centralized pattern, which was solely oriented toward economic growth. In line with this, Sumardjani (2005) explained that the rise of the social conflicts in forestry implicitly lies in the history of the forest development during four important periods of time, as follows:

1. 1970-1980. This period has begun with the establishment of timber concessions and timber enterprises in and outside Java. Natural forest timber has been exploited massively, and Indonesia became the largest producer of tropical timber in the world. No social conflict was found during this period. People felt quite satisfied with their lives, even so their social lives can be said to have been simple.
2. Early to mid-1980s. In this period, rush for timber exploitation by concessionaires grown rapidly, up to 454 units of concessions were awarded. It has led to concern about promotion of forest conservation, as well as growth of wood processing industries

and log export ban was introduced. In 1985, the ban has led the international logging companies to leave Indonesia. Meanwhile, the management of the degraded forests as well as the unproductive wastelands was done by issuing industrial plantation forest management rights (HPHTI). In contrast, the change in forestry development to utilize degraded forest was followed by people's awareness of the gap between their lives compared with the "outside" communities, which were getting higher economic benefits from "their" forests.

3. 1990s. During this period, as the awareness of the communities of the gap increased, the government's concern about forest communities was increasing. The government issued licenses to the holder of forest management rights (HPH) as well as HPHTI to train people in and around the forests. The number of HPH licenses has grown to 564 units with a total area of 59.62 million hectares, while the forest was divided into three functions, namely protected areas, forestry cultivation region and non-forestry cultivation region. As forest development was continued, HTI-trans was created and forest conversion was started. On the other hand, people began to realize that the gap widened.
4. 1998s. This period was marked by Soeharto's resignation due to massive demonstrations of students and the communities and also because of the riots which were destroying public facilities. Economic condition was getting hard due to the economic crisis, and the gap between the realities of living with a reference group could no longer be bearable. In this period, forest dependent people started the massive forest encroachment to feed their families.

The history indicated that gap of economic as well as social welfare between local community and the forest concession management unit has slowly increased community's demand for better economic and social life. However, the increasing demand has been followed by a sense of injustice, the feeling of being neglected, and the disgust that timber concessionaires as well as management has destroyed "their" ancestors' inheritances. After the New Order collapsed in 1998, decentralized development as well as the introduction of autonomy has produced the competition of capital for development between central and district governments (Subarudi and Dwiprabowo, 2007). The social conflict has been raising with some district/ local governments to act as "leaders" to face the central government. On the other hand, social demand has developed from subsistence demand for forest-related social services into demand for forest economic benefits, and the latest demand was for forest land use and ownership. The latest demand resulted in high forest tenure conflicts in most parts of forest areas. The occurrence of forest tenure conflict was resulted from: (1) insufficient or unfair accommodation of forest tenure rights; (2) insufficient capacity of tenure holders to exercise their rights, manage forest sustainably, and develop livelihoods; and (3) inadequate ability of state institutions to support tenure holders and uphold regulations (Mayers *et al.,* 2013). Thus, the social conflicts have been the most hard and complicated problems in sustaining site-level forest management.

4. Global community support related to climate change and global warming issues

Indonesia's consciousness of threatened geographical conditions due to climate change, the commitment of Indonesia to follow the agreement of the Bali Action Plan at the Conferences of Parties (COP 13) to the United Nations Framework Convention on Climate Change (UNFCCC) and the results of COP-15 in Copenhagen, and the COP-16 Cancun stressed the commitment of the Government of Indonesia to reduce greenhouse gas emissions by 26% if done alone and by 41% with international aid in 2020. The commitment will be integrated in the national development programs, such as stipulated in Presidential Regulation of the Republic of Indonesia Number 61 of 2011 on the National Action

Plan for Greenhouse Gas Emissions Reduction and Presidential Regulation of the Republic of Indonesia number 71 of 2011 on Greenhouse Gas Inventory Implementation.

Particularly with high greenhouse gas emissions from deforestation, forest fires and peatland degradation, forestry sector is expected to play an important role to reduce greenhouse gas emissions which are mainly located in the territory of forest management. Moediarta and Stalker, 2007, stated that Indonesia should also be able to rely on international assistance - not only for mitigation but also for actions that will be needed to help the poorest people to face the consequences of various weather conditions, which will be increasingly erratic and more extreme. And for that, the global concern for sustainability of forests in Indonesia was important, it needed to support Indonesia's forest development efforts in overcoming high forest degradation as well as the destructive conditions.

In line with the global concern for global warming, the World Bank policy supports Indonesia's forest management on three broad goals including promoting economic growth, providing widespread and equitable benefits to society (livelihoods and poverty reduction), and sustaining environmental services and benefits. Since Indonesia did not achieve all of these goals, the World Bank advised Indonesia's forestry management in engaging the support for:

1. Base level engagement, which calls for scaling up and mainstreaming successful initiatives and approaches, including: forest law enforcement and governance (FLEG), transparency, industrial restructuring and acceleration of plantations, community-driven development (CDD) of pilot projects, and conservation initiatives.
2. Medium level engagement, with deeper and more focused analytical work, including: forest monitoring and interagency collaboration on law enforcement, better balance between supply and demand for restructuring of industries, promote community-based timber growing efforts by improving the enabling conditions, transparency and revitalization of forest industries. Additionally, this stage would be pursued on land use, resource access and rights issues, proven scale up approaches in CDD and conservation resulting from existing activities.
3. High level engagement, which builds on prior efforts and potentially include lending operations that will help to resolve prior issues, including: forest monitoring, training and technology for law enforcement and information systems, plantation development or small- and medium enterprise promotion, rural livelihood development, and considerable progress on issues of tenure and interest in forest land use rationalization.

Since Indonesian forest development was hampered by hard and complicated problems of economic, environmental, and social conflicts, while increasing attention of global community responding to global warming as well as climate change issues has led to reinforcement of efforts of the Government of Indonesia to overcome high forest degradation as well as destruction, strengthen law enforcement and good governance, and improve community welfare as well as forest conservation, it was hoped that such conditions could lead to the accomplishment of the handling of the forest development problems in Indonesia. Although the hope has not yet being realized, but the efforts continue until today.

B. Discussion

Forest development in Indonesia will be achieved through five goals, namely ensuring that forests sufficient in area and evenly distributed; achieving a balance and sustainable benefit of forest; improving the carrying capacity of watershed; improving the capacity to develop ability of society; and ensuring equal and sustainable distribution of benefits (Law number 41 of 1999 on Forestry). Basically, the forest development goals are in line with the

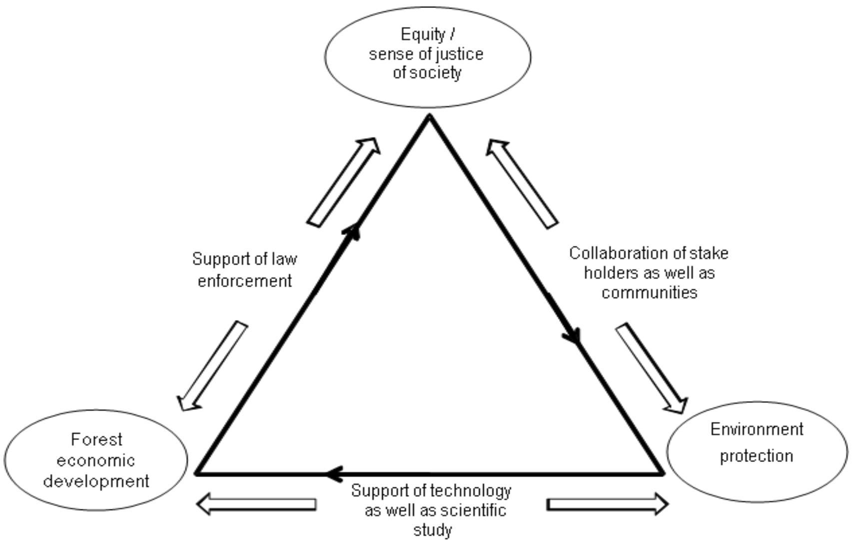


Figure 4. Sustainable forest development framework and supports

three goals of sustainable development, as it was assumed, including economic development, environmental protection, and equity/sense of justice of society (Campbell, 1996). However, the goals were accompanied by the occurrence of related conflicts, including: conflict of claim and use of forest properties, conflict of development, and conflict over forest resources.

Forest property conflict was resulted from collision of goals for economy and equity. Property conflict defines the boundary between private interests and public goods. Since private and customary forest was not included in this type of conflict, it was considered as a good of the state and ruled by the state, the conflict of property as it was stated in Campbell (1996) in this discussion was grounded in those activities that illegally claimed or used state-forest property. The activities included illegal logging, illegal hunting, illegal trading, and illegal occupancy of forest land for purposes of economic benefits. Since large forest destruction and high loss of capital for development of forests were caused by such illegal activities, law enforcement was importantly needed.

On the other hand, since illegal use and claim of forest property by community was mainly resulted from a sense of injustice during the implementation of the state-based forest management, the applicable law enforcement might not touched the root of the problems, but worsened the conflict conditions and led to violent as well as massive community resistance. Moreover, since credible penalties, effective law enforcement, and fair and just legal system in Indonesia were questionable (The World Bank, 2006a), efforts of better communication, extension, and community empowerment should be prioritized more than law enforcement. Meanwhile, building wide understanding, implementing extension, and facilitating implementation of community empowerment programs, the role of third parties as well as forestry extensions were needed. Since the understanding was achieved, the feeling of injustice was overcome, and a fair gain as well as sharing of the economic benefits of the forests was established, a balanced economic-equity relationship of sustainable development could be established.

As it was stated before, the discussion on conflict of forest property has neither included private forest nor customary forest. This was because the interest of the goverment was not fully known as regards to rule the private as well as the customary forest. Development conflict defines the need to increase social equity and protect the environment simultaneously, whether in a steady-state of economy or not. In the case that the rule of government on private and customary forest was based on their environmental functions, and ignored the economic value, and for that the increase of community income was not deemed neccesary, the development conflict was appearing. Meanwhile, in the case that the rule of the government was based on economic interest to obtain national revenue from private as well as customary forest, the conflict which was found in this condition was categorized as conflict of property.

It depended on the source of conflicts; sustainable development of both private and customary forest could be obtained by shifting to the center the balance of the economic-equity relationship, in case of poverty conflict, or shifting to the center the balance of equity-environmental relationship, in case of conflict of development. The same explanation was also valid for the conflict which was found during the forest boundary demarcation since the state objectives behind the boundary as well as in changes of forest area determination was known. The root of the conflict could be found since the demarcation included in the forest area non-forest areas i.e. agriculture, settlement, and plantation land. Many forest tenure conflicts were started by such collisioning conditions.

Included in the conflict of development was the rule of the government on forests that ignored the need of economic development of other sectors. This conflict of development could be identified from collision between the interests of the forestry sector on environmental protection with the interests of various non-forestry sectors, including agriculture, plantations, mining, etc. Lack of equity in forest land allocation, use, and access resulted in development of conflict. This conflict could be occurring between development sectors, central and local government, and central government with local communities or customary groups. This conflict was involving various parties as well as communities. For that, the various needs and interests of parties as well as communities complicated the efforts to overcome such conflict of development.

Since the criteria of sustainability of development is depended on, and determined by various parties point of views, solution to sustainable development is resulted from how far various parties have authorities and fair roles in the development (Ngakan *et al.,* 2008), and how fairly natural resources were allocated and distributed among parties as well as resource-user groups (Wondolleck, 1988). In these considerations, a way for obtaining conflict of development resolution could be achieved by involving various parties in the process of conflict resolution, while collaboration among parties could result in a broader vision of solution, by which conflict resolution could be achieved thoroughly.

On the other hand, contrary aims of obtaining high forest economic benefits that harm the existence of the forest resulted in forest resource conflict. Resource conflict did not define a fixed boundary as it was in property conflict. A boundary was a contradiction between mutually dependent forces, economic and environment, as well as present and future demand. Forest resources conflict in Indonesia was indicated by large loss of forest areas as well as biodiversity, forest degradation and forest fragmentation. Regrettably, such condition was followed by low economic revenue and loss of revenue due to irregularities. Hampered by such contradictive conditions, forestry development should consider to optimize economic benefits as well as to improve productivity of mostly small and fragmented forest areas, increase forest investment, improve management capacity, and overcome irregularities.

In such low economic revenue and high forest degradation of forest development, establishment of industrial plantation forest (HTI) could be another consideration in sustaining forest development. The plantation forest was established on degraded and unproductive forest land. The establishment of HTI could increase productivity and economic value of land and forests, increase employment, and enhance the incomes of forest community. Supporting the HTI establishment, a good financing system and good management (Hakim, 2009), an appropriate silvicultural technology and stable market (Cossalter and Pirard, 2006; Wahyudi, 2008), land conflict as well as handling of social conflict (Wahyudi, 2008), and cooperation between community and company in high conflict condition (Martin, 2008) were needed. Meanwhile, in terms of role of the policy in supporting HTI building, Kartodihardjo (2006b) emphasized the needs, including: subsidies/financing system, policy partnerships, and the land use conflict resolution policy.

Related to the need for overcoming problems of forest development in Indonesia, national efforts have been done. The effort was also involving the support from global community which was triggered by the high environmental risks of climate change as well as global warming. In line with this effort, some suggestions for maintaining the sustainability of Indonesia's forest were identified in this study, including: 1. support of law enforcement prioritizing communication, extension, and community empowerment for overcoming illegal access, use and claim to forest land and resources; 2. support of technology/scientific study mainly for improving forest economic revenue, forest productivity, and forest rehabilitation; 3. collaboration of stakeholders as well as communities in overcoming collision or interests of development. The three supports, as it was modified from Campbell (1996), is described in the Attachment - Figure 4.

In line with the supports which were achieved as described in Figure 4, it should be considered by management or society that, originally, natural resources are limited, while the population continues to increase faster than natural resources can recover from disturbances. Since it has happened, Hardin (1968) stated the necessity of restrictions, which are consciously done by society and management, and by applicable laws. On the other hand, since there is a lack of social justice as found in Indonesia and profound social change to overcome conflicts, which will come about putting pressure to vulnerable society, so that presenting ethical guidelines and promoting the importance of third parties are needed to build peace and overcome conflicts (Garcia, 2006). Meanwhile, since social conflict resulted in destruction of local culture and harmed social integrity, the important roles of third parties are to mitigate the hope of the community to accept the reality that is lower than their expectation (Sumardjani, 2005).

Related to statements above, aiming at overcoming social conflict resolution, Dharmawan (2007) stressed the important role of participatory processes and buttom-up development approaches. In line with this approach, Olsson et al. (2004) stated that a self-organized bottom-up process of adaptive collaborative management (ACM) can improve the success of conflict resolution during the implementation of natural resources management. This adaptive collaborative management includes the following: vision, leadership, and trust; sequence response to environmental events; institutional arrangements; funds; individual/management expands to others; social networks; obtaining and sharing ecological information and knowledge; community-based sense making; and arena of collaborative learning.

IV. CONCLUSION

1. Sustainable forest development in Indonesia is still faced with problems of uncertainty of management, insufficient management capacity, and lack of law enforcement. These conditions were indicated by high conflict of interests as well as lack of support from stakeholders, weak forest management actions at site-level, and high forest degradation.
2. National forest management needs to adopt more space for communication, openness, mutual learning, collaboration in addressing forest conflicts, and determining

the future direction of its sustainability goal of management.

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DEVELOPING SITE-SPECIFIC ALLOMETRIC EQUATIONS FOR ABOVE-GROUND BIOMASS ESTIMATION IN PEAT SWAMP FORESTS OF ROKAN HILIR DISTRICT, RIAU PROVINCE, INDONESIA

Nunung Puji Nugroho[1*]

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ABSTRACT

In forest biomass assessment studies, the selection or development of reliable allometric biomass equations is an essential step which determines largely the accuracy of the resulted biomass estimates. Unfortunately, only few studies on allometric biomass equations have been conducted for peat swamp forests and the results are usually not publicly accessible or well documented. Thus, the objective of this study was to develop site-specific allometric equations for above-ground biomass (AGB) estimations in tropical peat swamp forests in Indonesia. These equations were developed based on 51 destructively sampled trees. The results indicated that the developed site-specific allometric equations have coefficient of determination (R^2) greater than 95%. The R^2 values ranged from 97.0% to 98.7%, where the lowest R^2 value resulted from the simplest model which used only DBH as a predictor. Model 5, which used DBH, H and ϱ as predictive variables, provided best performance when estimating the AGB of the study area. Hence, as long as reliable data are available as input, Model 5 is recommended. The accuracy and applicability of the allometric equations for peat swamp forests could be improved further by adding more sampled trees from different tree species and/or with a wider DBH range. Considering the importance of wood density in the estimation of the AGB and the lack of this information for peat swamp forest tree species, research should be dedicated to analysing the wood density of the dominant tree species comprising the majority of the AGB density in the study area.

Keywords: Site-specific, allometric equation, above-ground biomass, peat swamp forest, Riau

ABSTRAK

Dalam kajian-kajian penaksiran biomassa hutan, pemilihan atau pengembangan persamaan-persamaan alometrik biomassa yang dapat diandalkan merupakan langkah penting yang sangat menentukan ketepatan dari dugaan biomassa yang dihasilkan. Sayangnya, hanya sedikit kajian-kajian tentang persamaan alometrik biomassa yang dilakukan di hutan rawa gambut dan hasil-hasilnya biasanya tidak dapat diakses secara umum atau terdokumentasi dengan baik. Jadi, kajian ini bertujuan untuk mengembangkan persamaan-persamaan alometrik spesifik tapak untuk pendugaan biomassa atas permukaan di hutan rawa gambut di Indonesia. Persamaan-persamaan tersebut dikembangkan berdasarkan 51 pohon contoh yang ditebang. Hasil dari kajian ini menunjukkan bahwa persamaan-persamaan alometrik yang dikembangkan mempunyai koefisien determinasi lebih dari 95% dengan rentang nilai mulai dari 97,0% sampai dengan 98,7%. Dalam hal ini, koefisien determinasi yang paling rendah dihasilkan oleh persamaan alometrik yang paling sederhana dengan satu peubah, yaitu diameter setinggi dada (Model 1). Model 5 yang menggunakan tiga peubah (diameter setinggi dada, tinggi total dan kerapatan kayu) menghasilkan dugaan biomassa atas permukaan yang paling baik di wilayah kajian. Oleh karena itu, selama data peubah tersebut tersedia, maka Model 5 direkomendasikan dalam pendugaan biomassa atas permukaan di hutan rawa gambut. Ketepatan dan penerapan dari persamaan-persamaan alometrik ini dapat ditingkatkan dengan menambahkan pohon contoh dari jenis lain dan/atau dengan rentang diameter setinggi dada yang lebih besar. Mempertimbangkan pentingnya kerapatan kayu dalam pendugaan biomassa dan kurangnya informasi ini untuk jenis-jenis pohon di hutan rawa gambut, maka penelitian perlu dilakukan untuk menganalisis kerapatan kayu untuk jenis-jenis dominan yang menyumbang kerapatan biomassa terbesar pada wilayah kajian.

Kata Kunci: Spesifik tapak, persamaan alometrik, biomassa atas permukaan, hutan rawa gambut, Riau

[1]Research Institute for Forestry Technology on Watershed Management, Jl. Jend. A. Yani Pabelan Kotak Pos 295, Surakarta, Central Java 57012 - Indonesia

[*]Corresponding Author: np_nugroho04@yahoo.com

I. INTRODUCTION

Accurate estimation of above- and below-ground biomass (AGB and BGB) in tropical peat swamp forest ecosystems is important to understand their roles in the global carbon cycle, particularly in relation to climate change. Reliable information on the biomass ("organic material both above-ground and below-ground, and both living and dead"(FAO, 2006, p.172), expressed as oven-dry ton or Megagramme (Mg) per ha) of forest ecosystem is also crucial for assessing forest structure and condition (Chave *et al.,* 2003; Zianis, 2008; Návar, 2009), forest productivity (Clark *et al.,* 2001; Zianis, 2008) and nutrients cycle and energy fixation (Zianis *et al.,* 2005; Zianis, 2008). Biomass is also an indicator of site productivity (Návar, 2009), both in biological and economical terms (Cole and Ewel, 2006) and is important to support the implementation of sustainable forest management (Zianis *et al.,* 2005; Labrecque *et al.,* 2006; Lucas *et al.,* 2006) and the conservation of biodiversity (Lucas *et al.,* 2006).

Knowledge of the spatial distribution of and changes in the biomass has been required for some time but the need is becoming more urgent, particularly because of emerging mechanisms for mitigating greenhouse gases (GHGs), such as Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries (Gibbs *et al.,* 2007; Sierra *et al.,* 2007; Basuki *et al.,* 2009; Goetz *et al.,* 2010; Saatchi *et al.,* 2011). To best quantify carbon dynamics, consecutive measurements of forest biomass (Chambers *et al.,* 2001; Clark *et al.,* 2001) and accumulation rates (Sierra *et al.,* 2007; Návar, 2009; Wijaya *et al.,* 2010; Banskota *et al.,* 2011) are needed together with information on the extent and rate of forest disturbances associated with natural or anthropogenic land use changes and fire events (Brown *et al.,* 1995; Sierra *et al.,* 2007; Wijaya *et al.,* 2010).

Many studies on forest biomass assessment are focused on AGB (e.g. Brown, 1997; Foody *et al.,* 2001; Ketterings *et al.,* 2001; Losi *et al.,* 2003; Aboal *et al.,* 2005; Segura and Kanninen, 2005; Saatchi *et al.,* 2007; Basuki *et al.,* 2009; Kenzo *et al.,* 2009a) because it represents the largest carbon pool[2] of forest vegetation and is directly impacted by deforestation and degradation (Gibbs *et al.,* 2007). Field-based measurement is one of the methods for estimating the biomass of the forest ecosystems (Lu, 2006; Anaya *et al.,* 2009). This method is commonly conducted by applying allometric biomass regression equations or simply allometric equations (Brown, 2002; Verwer and Meer, 2010). These are mathematical equations that relate easily-measured variables (e.g. diameter at breast height, base diameter and tree height) to attributes that are more difficult to assess (e.g. standing volume and biomass or leaf area) (Ketterings *et al.,* 2001; Goetz *et al.* 2010).

Many allometric equations have been developed for tropical forests, with some being site-specific and developed from in situ harvesting of sampled trees of mixed-species (e.g. Yamakura *et al.,* 1986; Chambers *et al.,* 2001; Ketterings *et al.,* 2001; Segura and Kanninen, 2005; Jepsen, 2006; Basuki *et al.,* 2009; Kenzo *et al.,* 2009a; Kenzo *et al.,* 2009b). Others (e.g. Brown *et al.,* 1989; Brown, 1997; Zianis and Mencuccini, 2004; Chave *et al.,* 2005; Pilli *et al.,* 2006) are more generalized having been developed from trees sampled across a wider geographical range and as a function of forest type. Well-known and commonly used equations include that of Brown (1997), which was derived from sampled trees collected across the pan-tropical region, and Chave *et al*., (2005), which considered the differences between dry and wet forest types. These equations have used data from the Neotropics, Southeast Asia and Oceania, including Indonesia, but none of the sampled trees have been collected from peat swamp forests (Verwer and Meer, 2010). The use of allometric equations is advocated as direct field measurement, whilst it is more accurate (Lu, 2006), but it is also expensive, time consuming and labour intensive (Houghton,

[2] In peat swamp forests, the AGB represents the second largest carbon pool after peat soil.

2005).

Compared to other tropical forest ecosystems, peat swamp forest is considered a unique and fragile ecosystem (Page *et al.,* 1999; Rieley, 2007). It is characterized by its occurrence on peat soil with high-rainfall, high-temperature, waterlogged and acidified substrate conditions that lack oxygen (Wösten *et al.,* 2006; Hirano *et al.,* 2007; Jaenicke *et al.,* 2008; Posa *et al.,* 2011) where the decomposition rate of woody plant debris is slower than the accumulation rate of the materials (Maltby and Immirzi, 1993; Rieley and Page, 2005). This ecosystem is fragile because of the strong interdependency between hydrology, ecology and landscape morphology (Page *et al.,* 1999) where a change in any of these components will alter and affect the balance of the ecosystem (Hooijer *et al.,* 2009; Hooijer *et al.,* 2010). As a consequence of this characteristic, peat swamp forest ecosystem has the potential to store huge amounts of carbon (Sorensen, 1993; Tawaraya *et al.,* 2003; Jaenicke *et al.,* 2008), especially as Soil Organic Matter (SOM) (Hirano *et al.,* 2007).

Although peat swamp forest is a significant repository of carbon, disturbance can transform it to a large source of carbon emissions (Rieley and Page, 2005). However, there is a lack of information on the amount of the biomass stored within the peat swamp forest (Verwer and Meer, 2010). The majority of studies have focused mainly on the impacts of fire and subsequent recovery of the forest ecosystem, the amount of carbon in the peat soils, mycorrhizal activity, and biodiversity (Page *et al.,* 2002; Tawaraya *et al.,* 2003; Wahyunto *et al.,* 2003; Wahyunto *et al.,* 2004; Wahyunto *et al.,* 2005; Hooijer *et al.,* 2006; Wahyunto *et al.,* 2006; Wösten *et al.,* 2006; Jaenicke *et al.,* 2008; Uryu *et al.,* 2008; Wahyunto and Suryadiputra, 2008; Wösten *et al.,* 2008; Wahyunto *et al.,* 2010). Few studies have been conducted on the biomass of the peat swamp forests (e.g. Ludang and Jaya, 2007; Krisnawati and Imanuddin, 2011; Tan *et al.,* 2011) and most have used the available generalized or pan-tropical allometric equations (e.g. Brown *et al.,* 1989; Brown, 1997; Chave *et al.,* 2005) instead of allometric equations specific to peat swamp forests and from Indonesia. Currently, site-specific allometric equations for peat swamp forest that are publicly available are limited (see Solichin *et al.,* 2011; Krisnawati *et al.,* 2012). Thus, the objective of this study was to develop site-specific allometric equations for AGB estimations for tropical peat swamp forests, with special reference to peat swamp forests in Rokan Hilir District, Riau Province.

II. MATERIAL AND METHOD

A. Study site

This study was conducted at the selected logging blocks within the concession area managed by PT. Diamond Raya Timber (PT.

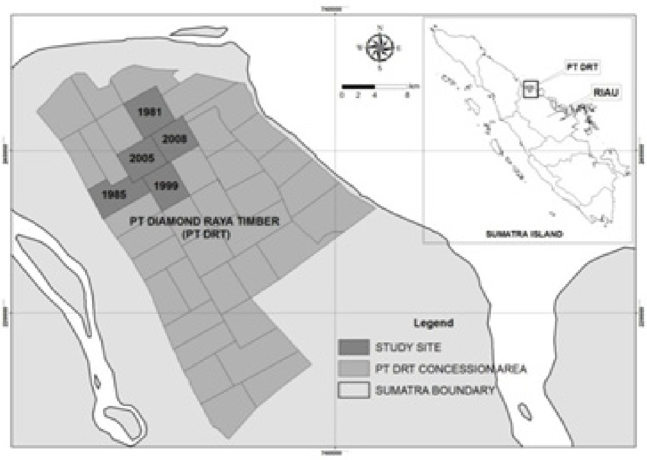

Figure 1. The selected study site within the forest concession area of PT. Diamond Raya Timber

DRT) (Figure 1) in Rokan Hilir District, Riau Province, Indonesia (100°48' – 101°13' E and 1°49' – 2°18' N (Istomo, 2002). It is mainly covered by the lowland peat swamp forest with the dominant commercial species of balam (*Palaquium obovatum* (Griffith) Enql.), meranti batu (*Shorea uliginosa* Foxw.), ramin (*Gonystylus bancanus* (Miq.) Kurz.), and terentang (*Camnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis). This forest is also the important habitat for the endangered species of the Sumatran tiger (*Panthera tigris sumatrae*).

The topography of the area is flat with the elevation ranges from 0-8 m a.s.l. (meter above sea level). In addition, the area is geologically dominated by peat dome along with alluvial and marine groups (Istomo, 2002). The dominant soil type is thick peat soil with a depth of more than 3 m, while the minor ones are gley, alluvial and podzolic. Based on the Schmidt and Ferguson climate classification, the area is classified as A type with Q value of 10.1% (Istomo, 2002). The average monthly rainfall ranges from 51.3 to 301.6 mm where the highest is in November (301.6 mm) and the lowest is in March (51.3 mm). Furthermore, the mean annual temperature ranges from 25 to 27 °C and the relative humidity ranges from 79% to 90%.

B. Data collection

The data collection through destructive sampling was carried out from August to September 2008. A total of fifty one healthy[3] trees comprising eleven species with the DBH ranging from 5.2 to 62.7 cm were felled (details are presented in Appendix 1). The sampled trees were mainly selected based on dominant tree species present in the study area according to the available data from the permanent sample plot (PSP). Out of the eleven tree species felled during the fieldwork, nine were associated with the dominant species. The DBH, which is the diameter at 1.3 m above the ground or 30 cm above the buttress (FAO, 2004), was measured using a diameter tape before the tree was felled. The scientific name of the sample trees were verified using the database of the World Agroforestry Centre (CGIAR, 2008) and a previous study (Istomo, 2002).

After the tree was felled, the total tree height (H) was measured using a 50-m measuring tape. Then, the sample tree was separated into four components: (1) leaves, (2) twigs (diameter < 3.2 cm), (3) small branches (diameter between 6.4 cm and 3.2 cm), and (4) large branches and stems (diameter > 6.4 cm) following the procedure used by Kettering *et al*., (2001). All of these components were weighed directly in the field to obtain their fresh weight using a portable hanging balance with 100-kg capacity.

The subsamples for each component were collected from each sampled tree for oven-dry weight analysis. Depending on the DBH, three subsamples (with a minimum weight of 100 g for each subsample) were collected for each component. For large branches and stems, small branches and twigs, the subsamples were collected from the lower, middle and upper part of the tree for each component pool, whereas for leaves, the subsamples were taken from the total amount of the leaves taken from the tree. These subsamples were weighed in the field to obtain their fresh weight using a small balance with 2-kg capacity and stored in sealed plastic bags such that moisture was retained before sending them to the laboratory. A total of 592 subsamples from 51 sampled trees were sent to the Soil Science Laboratory of the Faculty of Agriculture in Sebelas Maret University (UNS), located in Surakarta, Central Java of Indonesia, for oven dry weight analysis. The wood and leave subsamples were oven-dried at 105°C until a relatively constant weight was obtained (Nelson *et al.,* 1999; Ketterings *et al.,* 2001). The total dry weight or Dry Matter (DM) of the stems were calculated using equation (1) (Jayaraman, 1999).

$$TDW_{stem} = \frac{TDW_{samples}}{TFW_{samples}} \times TFW_{stem} \quad \text{.................................}(1)$$

[3] Healthy tree in this article is defined as a tree without broken top or infected by a disease.

where TDW_{stem} is the total dry weight of the stems, $TDW_{samples}$ is the total dry weight of the stems' subsamples, $TFW_{samples}$ is the total fresh weight of the stems' subsamples and TFW_{stem} is the total fresh weight of the stems. In addition, the stump height (l) and diameter (D_{stump}) were measured to estimate its volume using a cylinder volume formula as in equation (2), while its dry weight were estimated by multiplying its volume with the wood density of the stem (ρ) (Ketterings *et al.,* 2001).

$$V_{stump} = \frac{\pi (D_{stump})^2 l}{4} \quad \text{.......................................(2)}$$

where V_{stump} is the stump volume, π is a constant value (3.142), D_{stump} is the stump diameter and l is the stump height/length. Similarly, the total dry weight for all other components of the tree was calculated based on equation (1) by taking into account the total dry weight of the subsamples of the components, the total fresh weight of components' subsamples and the total fresh weight of the components. Moreover, the total dry weight of the sampled tree was calculated as the sum of the dry weight of its components and stump. This refers to the above-ground biomass of the tree (AGB_{tree}). Furthermore, data on DBH and H from destructive sampling and ρ data from the database of the World Agroforestry Centre (CGIAR, 2008), which are available online, were used to develop site-specific allometric equations.

C. Data analysis

1. Regression models

Three types of regression models were used to develop the biomass equations: (1) Type I was developed using DBH (AGB_{tree} – D model), (2) Type II was developed using DBH and H (AGB_{tree} – D – H model), and (3) Type III was developed using DBH, H and ρ (AGB_{tree} – D – H – ρ). Details of these models are presented in Table 1. The data analysis for constructing the models was carried out using the SPSS® 14.0 statistical package (SPSS Inc., 2005).

2. Model selection

The model selection was based on six statistical parameters, of which five are explained by Parresol (1999): (1) fit index (*FI*), (2) standard error of estimate in actual unit (Se), (3) coefficient of variation (*CV*) in percent, (4) Furnival's index (*I*), and (5) corrected mean percent standard error of prediction (($\overline{S}$ (%)) or average (unsigned) deviation (Nelson *et al.,* 1999; Basuki *et al.,* 2009). The sixth parameter is the Akaike's Information Criterion/*AIC* (Akaike, 1974) calculated using equation (3). The best model will have the lowest *AIC* value. where *AIC* is the Akaike's Information

Table 1. Type of allometric equation models for AGB estimation

Type	Allometric equation	Model
I.	$AGB_{tree} = exp\ (a + b \times In\ (D))$	1
II.	$AGB_{tree} = exp\ (a + b \times In\ (D^2H))$	2
	$AGB_{tree} = exp\ (a + b \times In\ (D) + C \times In\ (H))$	4
III.	$AGB_{tree} = exp\ (a + b \times In\ (D^2H\tilde{n})$	3
	$AGB_{tree} = exp\ (a + b \times In\ (D) + c \times In\ (H) + d \times In\ (\tilde{n}))$	5

Notes: AGB_{tree} is the above-ground biomass per tree (kg DM $tree^{-1}$), exp is *e* raise to the power of, ln is natural logarithm, *D* is the diameter at breast height (cm), *H* is the total tree height (m), ρ is the wood density or the wood specific gravity (g cm^{-3}), and *a, b, c,* and *d* are the regression coefficients

$$AIC = C \ln\left(\frac{S_e}{C}\right) + 2p^* \text{.....................................(3)}$$

Criterion, C is the number of observed data, ln is natural logarithm, SS_e is the residual sum of squares, and p^* is the number of parameters or coefficient in the models, including intercept.

3. Model prediction

During the analysis, the field data were transformed based on natural logarithm. This process introduced a systematic bias of the biomass estimates when they were back-transformed to the actual unit, whereby the biomass estimates were usually an underestimate of the actual biomass (Chave *et al.,* 2005). For this reason, biomass estimates should be multiplied by a correction factor (*CF*), which is a number close to 1. In this study, the biomass estimates were corrected using equation (4) from Snowdon (1991).

$$CF_{SD} = \left(\frac{\frac{\sum_{i=1}^{n} Y_i}{n}}{\frac{\sum_{i=1}^{n} \hat{Y}_i}{n}}\right) \text{.....................................(4)}$$

where CF_{SD} is the correction factor described by Snowdon (1991), Y_i is the observed data of the i^{th} sample, $\hat{Y}_i$ is the estimated data of the i^{th} sample, and n is the number of sample.

III. RESULT AND DISCUSSION

A. Results

All the regression models were statistically highly significant ($p < 0.0001$) and generally fitted the data well. The residuals for AGB models were relatively normally distributed and did not show any pattern (Appendix 2). The regression coefficient and the statistical summary for each model are presented in Table 2. Based on the model summary, Model 3 and 5, which used DBH, H and ϱ, performed better in estimating AGB. This was indicated by the higher R^2 and adjusted R^2 and the lower SEE and MSE. Between Model 3 and 5, Model 5 (which uses three single-variables), performed better than the combined variable of Model 3. There was no difference in statistical summaries between Model 2 and 4 in relation to the type of variable used. Model 1, which is the simplest model, gave the lowest performance. However, in general, all the models had acceptable goodness-of-fit to the data indicated by R^2 which was greater than 0.95.

When using only DBH as a predictive variable (Model 1), 97% of the variation of the AGB (Table 2) was explained. Adding *H* as a second predictor improved the performance of the model by increasing R^2 and adjusted R^2 and subsequently reducing *SEE* and *MSE*. Since the R^2 for Model 1 was already high, adding H has only slightly increased the R^2. For combined variable (Model 2), R^2 has increased relatively by 1.1%, while *SEE* was reduced relatively by 19.8%. Adding ϱ to the model as the third predictor has slightly improved the performance of the models. As a combined variable (Model 3 to Model 2), ϱ improved the R^2 by 0.4% and reduced the *SEE* by 11.2%. As an independent variable (Model 5 to Model 4), ϱ increased the R^2 by 0.6% and decreased the *SEE* by 15.0%.

The model selection was based on the comparison parameters explained by Parresol (1999) and is summarised in Table 3. Based on these parameters, Model 5, which used three independent variables, outperformed all other models, which is indicated by the highest *FI* value and the lowest S_e, CV, I, $\bar{S}$ *(%)*, and AIC values. Adding *H* to the DBH reduced the Se up to ~50 kg, the *CV* (as a measure of dispersion around the mean) up to ~6% and the $\bar{S}$ *(%)* (as a measure of precision) up to ~4% (non-corrected models). Based on the comparison parameters in Table 3, Model 2 performed slightly better in estimating AGB in the study area, which previously could not be observed from the statistical summary of the models in Table 2. Adding the H and ϱ together to the

Table 2. Regression coefficients and statistical summary for each AGB model

Model	Coefficient			Model Summary			
	Symbol	Value	*SE*	R^2	Adjusted R^2	*SEE*	*MSE*
1.	*a*	-2.551	0.208	0.970	0.969	0.333	0.111
	b	2.660	0.067				
2.	*a*	-3.398	0.182	0.981	0.980	0.267	0.071
	b	0.995	0.020				
3.	*a*	-2.965	0.154	0.985	0.984	0.237	0.056
	b	0.990	0.018				
4.	*a*	-3.580	0.256	0.981	0.980	0.267	0.071
	b	1.827	0.166				
	c	1.229	0.232				
5.	*a*	-3.126	0.240	0.987	0.986	0.227	0.051
	b	2.011	0.147				
	c	0.966	0.206				
	d	0.641	0.145				

Notes: SE = standard error of the coefficient, R^2 = coefficient of determination, *SEE* = standard error of the estimate and *MSE* = mean square error. All models and coefficients are statistically significant at $\alpha = 0.05$ (p <0.0001, except for coefficient *d* in Model 5: $p = 0.001$)

Table 3. A summary of comparison parameters of the developed models for AGB estimation

Model	Comparison parameters							*CF*
	FI	*Se*	*CV*	*I*	$\overline{S}$ (%)	*AIC*	Bias	
1	0.91	337.90	40.59	84.79	25.97	595.88	-19.74	NC
	0.91	339.84	40.82	84.79	26.63	596.47	0.00	1.024[a]
2	0.93	288.09	34.60	67.99	22.21	579.61	-22.32	NC
	0.93	287.41	34.52	67.99	22.51	579.37	0.00	1.028[a]
3	0.93	283.79	34.09	60.35	20.71	578.08	-15.47	NC
	0.93	285.99	34.35	60.35	21.07	578.87	0.00	1.019[a]
4	0.93	288.32	34.63	67.99	22.10	580.64	-23.68	NC
	0.93	286.92	34.46	67.99	22.41	580.15	0.00	1.029[a]
5	0.96	233.52	28.05	57.80	19.32	560.07	-17.42	NC
	0.96	232.94	27.98	57.80	19.52	559.82	0.00	1.021[a]

Notes: *FI* = Fit Index, S_e = Standard error in actual unit, *CV* = Coefficient of Variation, *I* = Furnival's index, $\overline{S}$ *(%)* = Average deviation, *AIC* = Akaike's Information Criterion, *NC* = Not Corrected, a = corrected using formula from Snowdon (1991)

DBH in the AGB models reduced the Se up to ~104 kg, the *CV* up to ~12% and the $\overline{S}$ (%) up to ~7% (non-corrected models). In this case, Model 5 (which uses three single predictors) performed better than Model 3 (which uses a compound of three variables). Adding extra variables into the models increased the *FI* values up to 5%.

Log-transformation of the datasets during the model construction resulted in the underestimation of the actual biomass as indicated by the negative values of the bias (Table 3). The underestimation of actual biomass was also observed using a scatter plot of predicted AGB against observed AGB as presented in Appendix 3. Multiplying the predicted biomass by a *CF* was intended to remove the systematic bias due to back-transformation. In this study,

Table 4. Mean average deviation ($\bar{S}$ *(%)*) per DBH class for each model

Model	Mean $\bar{S}$ *(%)*			
	DBH<= 10 cm	10 cm <DBH<= 30 cm	30 cm<DBH<= 50 cm	DBH> 50 cm
1	29.10	28.26	21.15	30.49
2	25.75	22.77	19.18	23.53
3	22.87	22.92	18.31	18.80
4	26.44	22.34	18.82	23.53
5	21.79	20.79	16.60	18.49

the formula of Snowdon (1991) was used. Furthermore, regardless of use, the CF did not necessarily improve the performance of the models in total (Table 3), as evaluated from the increased values of S_e, *CV*, $\bar{S}$ *(%)*, and *AIC*. However, the *CF* formula from Snowdon (1991) was useful in removing the bias of the models.

This study was conducted in peat swamp forests that have been actively logged by a commercial company. Following the current silvicultural system, the company is extracting the commercial tree species with a minimum DBH of 30 cm (Istomo *et al.*, 2010). Therefore, it is important to evaluate the $\bar{S}$ *(%)* based on the DBH classes. This information is useful in selecting the model for the biomass study in relation to the forest condition, especially the distribution of the diameters. The developed models have generally low $\bar{S}$ *(%)* of AGB (< 30%; Table 4). The exception was Model 1 with a DBH greater than 50 cm (30.5%). All of the equations tended to have a higher $\bar{S}$ *(%)* when the smaller DBH classes were considered. For DBH class less than 10 cm, the $\bar{S}$ (%) ranged from 21.8% to 29.1%, while for DBH class 10-30 cm, the $\bar{S}$ *(%)* ranged from 20.8% to 28.3%. This $\bar{S}$ *(%)* decreased with larger DBH classes giving common values of less than 20%, except for Model 1 (30.5% at DBH > 50 cm). In general, Model 5 provided the most precise estimate of AGB in the study area, as indicated by the smallest values of $\bar{S}$ *(%)* in all DBH classes. The visualization of the $\bar{S}$ *(%)* based on the DBH classes is presented in Figure 2.

B. Discussion

1. Allometric equations

The selection or development of reliable allometric biomass equations is an essential

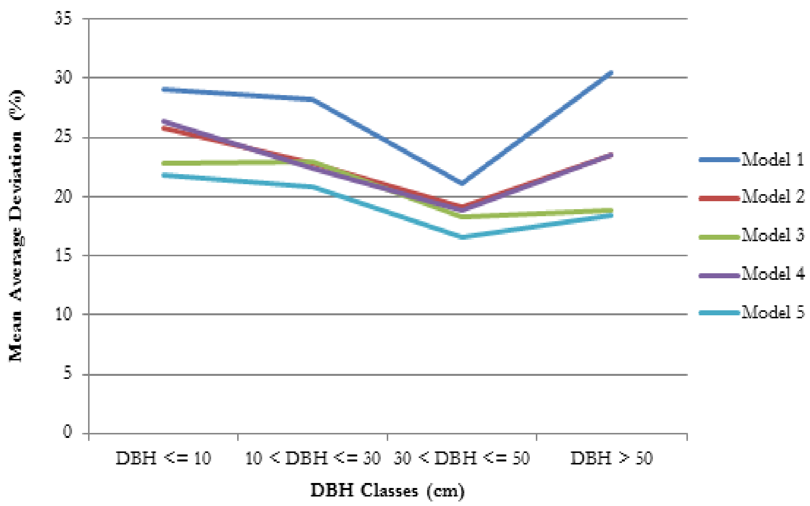

Figure 2. The mean average deviation ($\bar{S}$ *(%)*) based on DBH classes for each allometric model

step in estimating the AGB of the forest (Crow, 1978; Cunia, 1987; Brown *et al*., 1989; Chave *et al*., 2001; Houghton *et al*., 2001; Chave *et al*., 2004; Chave *et al*., 2005). The basic idea of developing allometric equation is to estimate the difficult-to-measure tree characteristics (e.g. biomass) from one that is relatively easy to measure such as DBH (Goetz *et al*., 2010). Chave *et al*. (2004) pointed out that the most important source of error in forest biomass studies is the incorrect or inappropriate choice of allometric equation. Species-specific allometric equations, which are commonly used in the biomass study of temperate forest (e.g. Ter-Mikaelian and Korzukhin, 1997; Jenkins *et al*., 2003; Zianis *et al*., 2005), are not applicable to tropical forest which has high number of species per ha. In this case, the mixed-species allometric equations are more suitable (Ketterings *et al*., 2001; Chave *et al*., 2005).

Many studies have been conducted to develop mixed-species allometric equation for biomass estimation in tropical forest (e.g. Brown *et al*., 1989; Brown *et al*., 1995; Brown, 1997; Araujo *et al*., 1999; Nelson *et al*., 1999; Chambers *et al*., 2001; Chave *et al*., 2001; Ketterings *et al*., 2001; Chave *et al*., 2005; Nogueira *et al*., 2008b; Basuki *et al*., 2009; Kenzo *et al*., 2009a; Kenzo *et al*., 2009b). However, few studies on allometric biomass equations have been conducted for peat swamp forests and the results are usually not publicly accessible (Verwer and Meer, 2010; Solichin *et al*., 2011). Therefore, it is expected that this study will contribute significantly to the improvement of biomass and carbon estimation accuracies in peat swamp forests.

DBH as a variable has been found to have a strong correlation with biomass (with R^2 typically more than 95%). Previous studies recommended the application of the allometric equation which uses only DBH, although largely for practical reason (e.g. Brown, 1997; Basuki *et al*., 2009; Návar, 2009). This is because the DBH is more easily measured in the forest and collected during the regular forest inventory (Segura and Kanninen, 2005). In this study, allometric equation with only DBH as a predictor (Model 1) had an R^2 of 97.0%. The $\overline{S}$ *(%)* value was 26.6% which is comparable with the $\overline{S}$ *(%)* of the DBH-only model in mixed-dipterocarp forest in East Kalimantan (Basuki *et al*., 2009). This statistic indicates the average size of error as a percent of the mean and can be used as a precision indicator (Parresol, 1999), where the lower the value the higher the precision. Although the DBH-only model is more practical, the model tends largely to underestimate or overestimate the actual biomass. For example, *Parastemon urophyllum* and *Palaquium obovatum* with the same DBH of 7.6 cm have weights of 35.15 kg and 8.94 kg, respectively. Using only DBH as a predictive variable, Model 1 estimated AGB for these two tree species to be 17.6 kg. As a result, the $\overline{S}$ (%) for *P. obovatum* was very large (96.8%), and almost twice than the $\overline{S}$ *(%)* for *P. urophyllum* (49.9%). This is because the architecture of the tree is not accounted in the model (i.e. the H differs being 11.52 m and 7.83 m, respectively). For trees with larger DBH, the $\overline{S}$ *(%)* is relatively lower but the actual residual is large. Therefore, adding H as a second predictor in the model is important.

Numerous other studies on forest biomass (e.g. Crow, 1978; Nelson *et al*., 1999; Ketterings *et al*., 2001; Chave *et al*., 2005; Cole and Ewel, 2006; Fehrmann and Kleinn, 2006; Wang, 2006) have previously noted that adding H can improve the model performance. Adding H to DBH in the AGB models increases the R^2 by up to 1.7% relative to Model 1. Although adding H can only marginally increase the R^2, the *SEE* was reduced significantly (up to 22%). In addition, the Se was reduced as well as the *CV* and the $\overline{S}$ *(%)*. Using Model 2, the estimated biomass values for *P. urophyllum* and *P. obovatum* were 22.13 kg and 15.07 kg, respectively. The $\overline{S}$ *(%)* was reduced to 68.5% (-28.3%) and 37.0% (-12.9%), respectively.

Model 4, which considers H as an independent variable, provided a better estimate. The estimated biomass values for *P. urophyllum* and *P. obovatum* were 14.64 kg and 23.52 kg, respectively and the $\overline{S}$ *(%)* values were

63.7% and 33.1%, respectively. The advantage of adding H was more evident for larger trees. For example, *Ilex macrophylla* and *Gonystylus bancanus* have the same DBH (40.0 cm) but their *H* and AGB_{tree} were different, with these being 24.14 m and 30.21 m, and 1186.95 kg and 1779.28 kg, respectively. The estimated AGB_{tree} using Model 1 gave 1458.87 kg for both tree species and the $\overline{S}$ (%) values were 22.9% and 18.0%, respectively. When Model 4 was used to estimate the biomass of these trees, the $\overline{S}$ *(%)* values for *I. macrophylla* and *G. bancanus* became 2.2% and 10.1%, respectively.

Further improvement can be achieved by adding ϱ to the model. The ϱ is an important tree parameter in estimating biomass, in particular for larger trees (Baker *et al*., 2004; Chave *et al*., 2005; Nogueira *et al*., 2008a). This study found that allometric equation which uses three independent variables (i.e. DBH, *H* and ϱ) gave the best performance (Model 5) and supports previous studies (e.g. Nelson *et al*., 1999; Chave *et al*., 2005). Incorporating ϱ into the DBH-*H* models increased the R^2 by less than 1% but reduced the relative *SEE* by up to ~15%. Adding H and ϱ together to DBH increased the performances of the model significantly based on the comparison parameters. However, for some tree species, the ϱ was not an important parameter. For example, *Shorea uliginosa* and *P. urophyllum* have the same DBH of 43.70 cm and relatively the same *H* (33.30 m and 33.46 m) and also dry weight biomass (2300.50 kg and 2392.44 kg), but their ϱ values were different (0.640 g cm^{-3} and 1.040 g cm^{-3}). In this case, the most important factor was the difference in canopy structure (branching system). *S. uliginosa* tends to have a heavier canopy with more branches and bigger leaves compared to *P. urophyllum*. Thus, although *P. urophyllum* has significantly higher ϱ, the dry weight biomass values were not largely different. For these species, Model 5, which uses three independent variables, resulted in lower precision than Model 4, which uses two independent variables (without ϱ). The $\overline{S}$ *(%)* values were 13.9% and 13.6% (Model 5) and 7.9% and 10.9% (Model 4). Basuki *et al.* (2009) found that ϱ is not statistically significant for *Dipterocarpus*, *Hopea* and *Shorea* in East Kalimantan. Nelson *et al.* (1999) also found that ϱ is not significant for *Bellucia* species in the central Amazon.

The results of the model comparison indicated that increasing number of parameters or independent variables increases the performance of the model. However, it is important to note that including more variables in the model increases the regression error or uncertainty of the biomass through error propagation (Chave *et al*., 2004; Chave *et al*., 2005). In addition, information on species-specific ϱ for peat swamp forest species is not always available in the database of the World Agroforestry Centre (CGIAR, 2008), although the average value of the wood density for the genus can be used instead (Krisnawati *et al*., 2012), and H is usually not collected during the forest inventory (Chave *et al*., 2005). An alternative way to acquire *H* information is by constructing a stand-specific allometric relationship between *H* with DBH from destructively sampled trees and then using the developed equation to predict the *H* for the rest of the trees being studied (Brown *et al*., 1989; Chave *et al*., 2005), although errors in this relationship need to be accounted for. Adding *H* can improve the model's performance, but *H* is rarely used in practice because of two reasons: (1) measuring *H* in a forest ecosystem, particularly in dense tropical forests is much more difficult and time consuming but less accurately estimated than DBH (Gower *et al*., 1999); and (2) adding *H* into the model increases the regression error in the biomass estimate (Chave *et al*., 2005).

2. The applicability of the developed site-specific allometric equations

The developed models are considered as the site-specific allometric equations for the study area as the sampled trees that were used to construct the model were harvested *in situ*. The models should be used in the biomass studies of peat swamp forests within their DBH range (5.2-62.7 cm). It is important to consider the DBH range in applying allometric equations as the error tends to increase with increases in DBH. Applying allometric equations outside the DBH range will result in bigger errors, especially for the larger trees.

3. The limitations of the developed site-specific allometric equations

There are several limitations in developing site-specific allometric models for AGB in this study. Firstly, during the oven-dry weight analysis, the sub-subsampled tree components were used instead of the subsampled ones. Pre-analysis was carried out to find the moisture differences between field fresh weight and laboratory fresh weight using 44 randomly selected subsampled tree components (stems, branches, twigs, and leaves). The average percent differences were 2.8%, 4.0%, 4.9%, and 5.9% for stems, branches, twigs and leaves, respectively. The correction for each component was conducted by adding the lower value of confidence interval in paired samples t-test as suggested by Statistical Consulting Unit at the Australian National University, with these being 7.60 g, 6.86 g, 7.02 g, and 6.58 g for stems, branches, twigs, and leaves, respectively. This correction may introduce a systematic bias in the predicted biomass.

Secondly, this study used a limited number of species for constructing the allometric models (11 species in total with nine dominant species) within a relatively narrow DBH range (i.e. 5.2-62.7 cm). Based on the plot measurement during the field campaign, approximately 53 tree species have been identified (mostly by their local name) and four species were unknown. Considering the number of sampled tree species across the DBH range, the models may not well represent the peat swamp forest at large (Chave *et al*., 2005). Third, the tree species were recorded by their local names and because there are different local names for the same species and different species with the same local name, identifying the correct scientific name in the literature or database can lead to misidentification. Furthermore, this can lead to an incorrect use of ϱ estimates from the database.

IV. CONCLUSION

In this study five site-specific allometric equations have been developed based on destructively sampled trees. Model 5, which used DBH, H and ϱ as predictive variables, has the best performance in estimating the AGB of the study area. As long as reliable data are available for those variables, the application of Model 5 is recommended in estimating the AGB of peat swamp forests. However, when reliable data on H and ϱ are unavailable, the simplest model that uses only DBH as a predictor (Model 1) can be applied. The accuracy and applicability of the site-specific allometric equations could be improved further by adding more sampled trees from different tree species and/or with a wider DBH range. Considering the importance of wood density in AGB estimation and the lack of this information for peat swamp forest tree species, research should be dedicated to analysing the wood density of the dominant tree species comprising the majority of the AGB density in the study area. In addition, it is important to test the models at other sites (peat swamp forest at different locations). Combining the dataset from a wide-range of geographical area may improve the generic applicability of the models.

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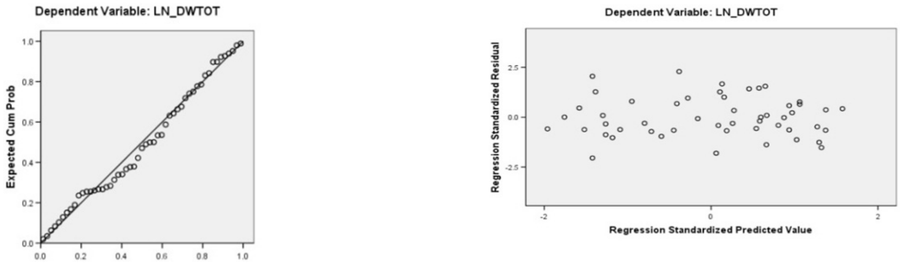
APPENDIX 1. Sampled trees destructively collected to develop site-specific allometric equations for AGB estimation in tropical peat swamp forests

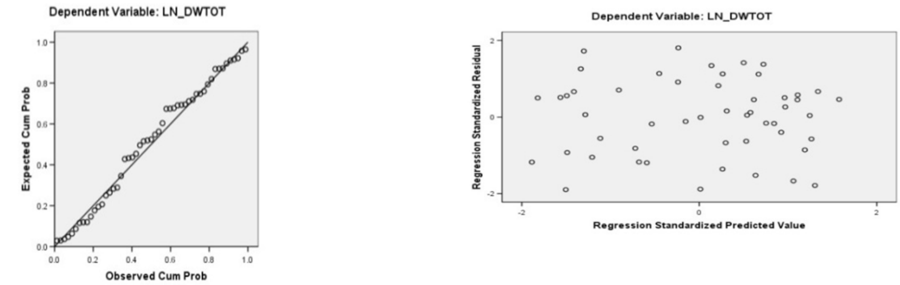
ID	Tree species		DBH	*H*
	Local name	**Scientific name**	**(cm)**	**(m)**
1	Terentang	*Campnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis	9.6	10.3
2	Terentang	*Campnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis	15.1	12.4
3	Terentang	*Campnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis	21.6	12.2
4	Terentang	*Campnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis	31.5	23.5
5	Terentang	*Campnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis	42.6	32.1
6	Terentang	*Campnosperma coriaceum* (Jack.) Hallier f. ex v. Steenis	52.5	34.3
7	Kelat	*Carallia brachiata* (Lour.) Merr.	8.3	10.0
8	Jambu-jambu	*Eugenia* sp.L.	7.8	10.3
9	Jambu-jambu	*Eugenia* sp.L.	15.5	13.8
10	Jambu-jambu	*Eugenia* sp.L.	22.3	19.8
11	Jambu-jambu	*Eugenia* sp.L.	33.1	17.9
12	Manggis-manggis	*Garcinia celebica* (Burm.) L.	6.0	6.9
13	Manggis-manggis	*Garcinia celebica* (Burm.) L.	18.5	17.1
14	Manggis-manggis	*Garcinia celebica* (Burm.) L.	25.1	18.7
15	Manggis-manggis	*Garcinia celebica* (Burm.) L.	31.2	21.5
16	Ramin	*Gonystylus bancanus* (Miq.) Kurz.	5.2	8.1
17	Ramin	*Gonystylus bancanus* (Miq.) Kurz.	11.8	15.5
18	Ramin	*Gonystylus bancanus* (Miq.) Kurz.	24.8	22.4
19	Ramin	*Gonystylus bancanus* (Miq.) Kurz.	38.3	30.7
20	Ramin	*Gonystylus bancanus* (Miq.) Kurz.	40.0	30.2
21	Ramin	*Gonystylus bancanus* (Miq.) Kurz.	62.7	39.4
22	Darah-darah	*Horsfieldia glabra* (Blume) Warb.	7.1	9.3
23	Darah-darah	*Horsfieldia glabra* (Blume) Warb.	8.5	7.5
24	Darah-darah	*Horsfieldia glabra* (Blume) Warb.	13.6	13.8
25	Darah-darah	*Horsfieldia glabra* (Blume) Warb.	23.6	22.5
26	Darah-darah	*Horsfieldia glabra* (Blume) Warb.	33.0	23.9
27	Pasir-pasir	*Ilex macrophylla* Hook. F.	6.8	8.7
28	Pasir-pasir	*Ilex macrophylla* Hook. F.	10.6	12.5
29	Pasir-pasir	*Ilex macrophylla* Hook. F.	22.0	16.6
30	Pasir-pasir	*Ilex macrophylla* Hook. F.	36.5	24.5
31	Pasir-pasir	*Ilex macrophylla* Hook. F.	40.0	24.1
32	Pasir-pasir	*Ilex macrophylla* Hook. F.	54.4	27.9
33	Balam	*Palaquium obovatum* (Griffith) Engl.	7.6	7.8
34	Balam	*Palaquium obovatum* (Griffith) Engl.	17.0	17.2
35	Balam	*Palaquium obovatum* (Griffith) Engl.	28.5	24.8
36	Balam	*Palaquium obovatum* (Griffith) Engl.	30.3	23.2
37	Balam	*Palaquium obovatum* (Griffith) Engl.	41.0	29.1
38	Balam	*Palaquium obovatum* (Griffith) Engl.	51.5	28.1
39	Milas	*Parastemon urophyllum* (Wallich. ex A. DC) A.DC	7.6	11.5
40	Milas	*Parastemon urophyllum* (Wallich. ex A. DC) A.DC	15.8	20.0
41	Milas	*Parastemon urophyllum* (Wallich. ex A. DC) A.DC	23.1	26.4
42	Milas	*Parastemon urophyllum* (Wallich. ex A. DC) A.DC	32.7	28.8
43	Milas	*Parastemon urophyllum* (Wallich. ex A. DC) A.DC	43.7	33.5
44	Milas	*Parastemon urophyllum* (Wallich. ex A. DC) A.DC	54.5	33.2
45	Meranti bunga	*Shorea teysmanniana* Dyer ex Brandis	9.0	9.8
46	Meranti batu	*Shorea uliginosa* Foxw.	8.5	6.4
47	Meranti batu	*Shorea uliginosa* Foxw.	12.5	12.8
48	Meranti batu	*Shorea uliginosa* Foxw.	22.7	25.0
49	Meranti batu	*Shorea uliginosa* Foxw.	31.0	28.8
50	Meranti batu	*Shorea uliginosa* Foxw.	43.7	33.3
51	Meranti batu	*Shorea uliginosa* Foxw.	50.7	33.3

APPENDIX 2. Normal P-P Plot of regression standardized residual and scatterplot of regression standardized predicted value against regression standardized residual for each model: (a) Model 1, (b) Model 2, (c) Model 3, (d) Model 4, and (e) Model 5

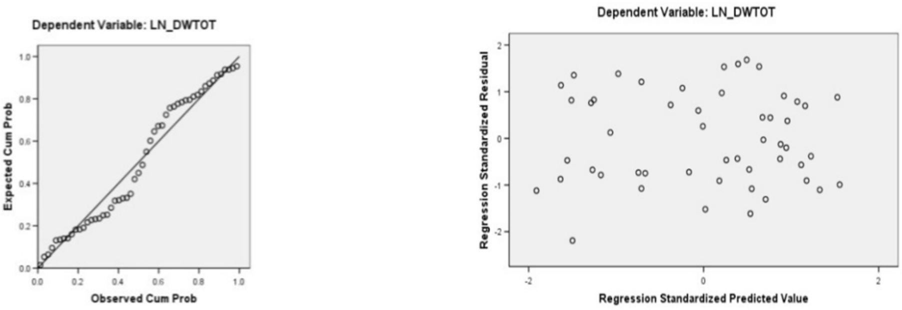
(a)



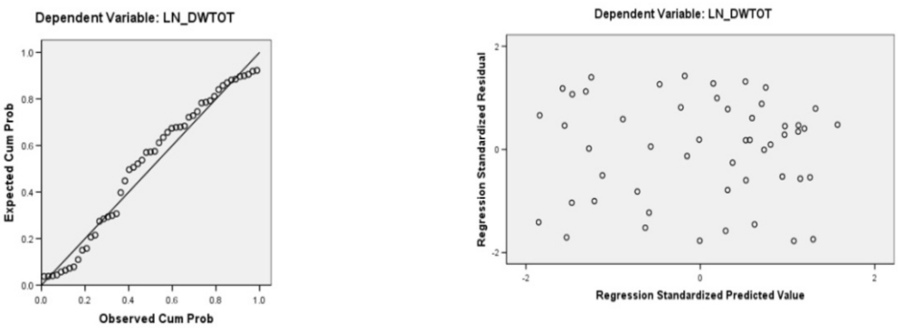
(b)



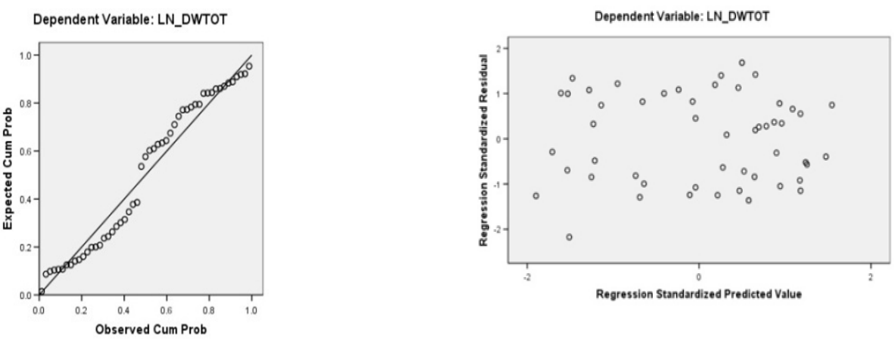
(c)



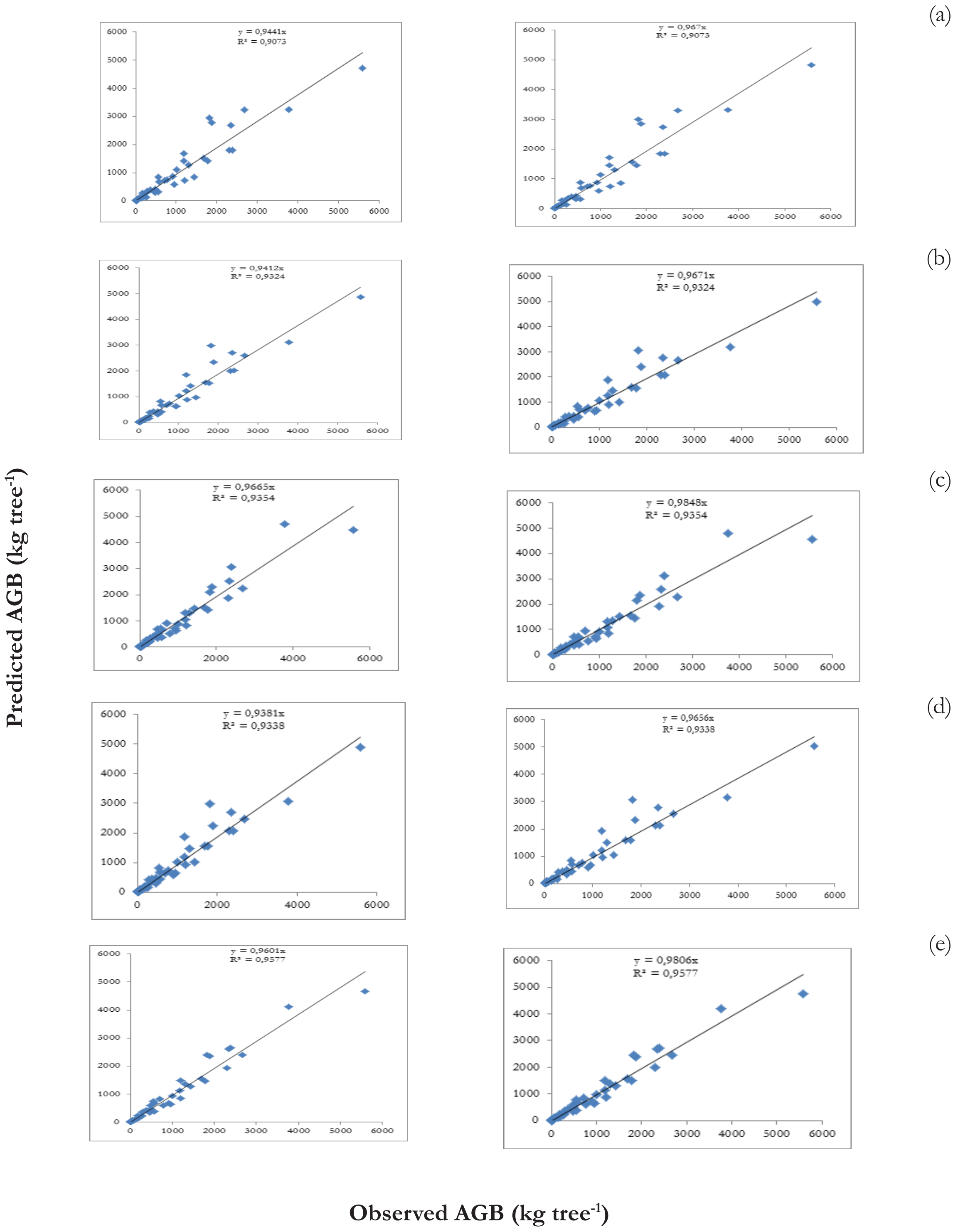
(d)



(e)



APPENDIX 3. Scatterplots of predicted AGB against observed AGB for each model without correction (left hand side) and with correction using Snowdon's formula (right hand side): (a) Model 1, (b) Model 2, (c) Model 3, (d) Model 4, and (e) Model 5.



DECOLORIZATION OF AZO DYES AND MINERALIZATION OF PHENANTHRENE BY *TRAMETES* SP. AS03 ISOLATED FROM INDONESIAN MANGROVE FOREST

Asep Hidayat[1*] and Sanro Tachibana[2]

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ABSTRACT

Textile industry contributes the most disposals of synthetic dyes, and about 40% of textile dyes has been generating high amount of colored wastewater. Polycyclic aromatic hydrocarbons (PAHs), such as phenanthrene, is a group of organic compounds, that structurally comprised of two or more benzene rings, which persist in air, water, and soil. The organic pollutants of dyes and PAHs have adversely effects the food chain and are potentially toxic, mutagenic, and carcinogenic to the environment. The objective of this research is to screen and investigate the potential fungus from mangrove forest to degrade azo dyes and phenanthrene. In this study, fungi were collected from mangrove forest in Riau Province – Sumatra – Indonesia. Previously, *Trametes* sp. AS03 is one of the fungi isolated from mangrove forest in Riau Province, that was able to decolorize Remazol Brilliant Blue R (RBBR). The capability of *Trametes* sp. AS03 to decolorize four azo dyes, Remazol B. Violet (V5), Levafix Orange E3GA (Or64), Levafix B. Red E-6BA (R159), and Sumifix S. Scarlet 2GF (R222), were further evaluated. The result shows that *Trametes* sp. AS03 decolorized 91, 60, 48, and 31 of V5, R222, R159, and Or64, respectively. By showing its capability to decolorize some of the dyes, *Trametes* sp. AS03 was used to break down phenanthrene. AS03 degraded more than 70% of phenanthrene in 15 days.

Keywords: *Trametes* sp. AS03, dyes, phenanthrene, biodegradation, decolorization

ABSTRAK

Sekitar 40% zat pewarna tekstil telah menyebabkan pencemaran pada air buangan. *Polycyclic aromatic hydrocarbons* (PAHs), seperti phenanthrene, adalah kelompok senyawa organik yang memiliki dua atau lebih cincin benzena dan keberadaanya sangat sulit terurai baik yang berada di udara, air dan tanah. Organik polutan seperti zat pewarna dan PAHs mempunyai efek negatif terhadap rantai makanan, dan berpotensi untuk menjadi toksik, mutagenik, karsinogenik di lingkungan. Penelitian ini bertujuan untuk melakukan skrening dan mengevaluasi potensi jamur yang berasal dari hutan mangrove sebagai agen pengurai zat pewarna dan phenanthrene. Dalam penelitian ini, tubuh buah jamur dikumpulkan dari Hutan Mangrove di Provinsi Riau-Indonesia. Jamur *Trametes* sp. AS03 berhasil diisolasi dan memiliki kemampuan untuk mengurai zat pewarna R*emazol Brilliant Blue R* (RBBR). Kemampuan *Trametes* sp. AS03 untuk mengurai empat (4) tipe zat pewarna, R*emazol B. Violet* (V5), *Levafix Orange E3GA* (Or64), *Levafix B. Red E-6BA* (R159), dan *Sumifix S. Scarlet 2GF* (R222), dievaluasi dalam penelitian ini. Hasilnya menunjukkan bahwa *Trametes* sp. AS03 mampu mendegradasi 91, 60, 48, dan 31% masing-masing untuk V5, R222, R159, and Or64 selama 3 hari masa inkubasi. Dari kemampuannya ini, *Trametes* sp. AS03 juga dicobakan untuk mengurai phenanthrene. Jamur AS03 mampu mendegradasi lebih dari 70% phenanthrene selama 15 hari masa inkubasi.

Kata kunci: *Trametes* sp. AS03, zat pewarna, phenanthrene, biodegradasi, pengurai warna

[1] Research Institute on Fiber Technology of Plantation Forest, Jl. Raya Bangkinang Kuok Km. 9, Bangkinang, Riau 28294 - Indonesia

[2] Department of Applied Bioscience, Faculty of Agriculture, Ehime University 3-5-7 Tarumi, Matsuyama, Ehime, 790-8566 -Japan

[*] Corresponding Author: ashephidayat@yahoo.com

I. INTRODUCTION

Colored substances are called a dye and widely used in many industries including paper printing, food, color photography, textile dyeing, pharmaceutical, paintings and other fields to support human daily-life. Among the different industries, the textile industry contributes the most disposal of synthetic dyes, from 10,000 different dyes for a production of about 700,000 tons/year (Zongllinger, 1991), and about 40% of textile dyes generated higher colored wastewater and it is a significant source of water pollution in the environment (Jin *et al.,* 2007). It could be understood because the discharge of a little amount of dyes (< 1 ppm) in water can absorb light penetration and may impedes the growth of microorganism, has adverse effect on food chain and to treatment processes (Ciullini *et al.,* 2008). Azo dyes have been widely used in textile processing and are dominating, contributing about 70% of dyestuffs on the worldwide market. Azo dyes and their substitutions are highly resistant to degradation (Enayatzamir *et al.,* 2009), toxic in their reductive metabolism product and potentially carcinogenic amine.

Phenanthrene is a polycyclic aromatic hydrocarbon (PAH) and structurally similar to azo dyes, it is composed of more than one benzene ring. Their major source is crude oil (Bamforth and Singleton, 2005; Passarini *et al.,* 2011), and they are categorized as the prime environmental pollutants (Bamforth and Singleton, 2005). These compounds are highly hydrophobic (Cerniglia, 1992), and persist in air, water, and soil (Bamforth and Singleton, 2005). Degradation by microbial agent has been claimed to be a viable, relatively low cost, low-technology technique and publicly acceptable to more traditional physical-chemical methods, which are expensive, create disposal problem and have limited applicability (Erdogan and Karaca, 2011). The use of lignin-degrading white-rot fungi have increased more than the bacteria because these organisms are able to degrade various recalcitrant organic pollutants (Verdin *et al.* 2004; Mastubara *et al.*, 2006). Their ligninolytic enzymes such as peroxidase and laccase-type enzymes are directly and indirectly involved in degradation processes (Cerniglia and Sutherland, 2001; Potin *et al.*, 2004; Singh, 2006). Although, white-rot fungi have been able to degrade organic pollutants but it remains a big challenge in finding the fungi from mangrove forests for their ability to degrade azo dyes and phenanthrene. The objective of this study was to investigate the capability of fungus screened from mangrove forest in Riau Province – Indonesia to degrade azo dyes and phenanthrene.

II. MATERIAL AND METHOD

A. Chemicals

Remazol B. Violet (V5), Levafix Orange E3GA (Or64), Levafix B. Red E-6BA (R159), Sumifix S. Scarlet 2GF (R222) were obtained from Textile Company-Japan. Remazol Brilliant Blue R (RBBR) was purchased from Sigma (St. Louis, USA). The structure of all dyes is displayed in Figure 1. Phenanthrene and other chemicals were purchased from Wako Pure Chemical Industry (Osaka, Japan) at the highest available purity.

B. Fungi and culture condition

Fungi used in this study was isolated from decay wood pieces and fungal body collected from mangrove swamps of Sungai Pakning and Tanjung Buton – Riau province, Indonesia (1 19'58" N 102 9'16" and 0 58'4" N 102 15'2" E). They were maintained on malt extract agar (MEA) medium containing malt extract (20 g L^{-1}), glucose (20 g L^{-1}), agar (20 g L^{-1}), and polypeptone (1 g L^{-1}) at 25^{o}C for several days and maintained at 4^{o}C.

C. Isolation and identification of fungi

The sample was firstly screened for the ability to decolorize RBBR (100 mg L-1) in the Czapek-Dox agar medium containing of glucose (10 g L^{-1}), saccharose (10 g L^{-1}), KH_2PO_4 (1 g L^{-1}), KCL (0.5 g L^{-1}), $MgSO_4$ $7H_2O$ (0.5 g L^{-1}), $FeSO_4$ $7H_2O$ (0.01 g L^{-1}), Yeast extract (2 g L^{-1}), polypeptone (2 g L^{-1}) and agar (15 g L^{-1}). The best fungus strain for each source was selected for further study.

DNA was extracted from cultured mycelia using a modified CTAB method (Murray and Thompson, 1980). The internal transcribed spacer ITS regions (Jellison and Jasalavich, 2000) was amplified by polymerase chain reaction (PCR) using the primers ITS1-F

(5'-CTTGGTCATTTAGAGGAAGTAA-3') and ITS4-B (5'-CAGGAGACTTGTACAGGTCCAG-3'). The PCR was performed in 20 µl of a solution containing 10 ng of genomic DNA, 5 pmol each of the forward and reverse primer, and 10 µl of Go Taq® Hot Start Colourless Master Mix (Promega, Wisconsin, USA) according to the manufacturer's instructions. Initial denaturation was performed at 95°C for 2 min, followed by 30-35 cycles of denaturation at 95°C for 0.5 min, annealing at 55-72°C, and polymerization at 72°C for 1 min, and final extension at 72°C for 10 min. Prior to sequencing, the PCR products were purified using rAPid Alkaline Phosphatase™ (Roche, Germany) and exonuclease I (New England Biolabs, Massachusetts, USA). The purified PCR products were sequenced and BLAST searched for ITS sequences in the GenBank database (http://www.ncbi.nlm.nih.gov/).

D. Decolorization of dyes by whole fungal culture

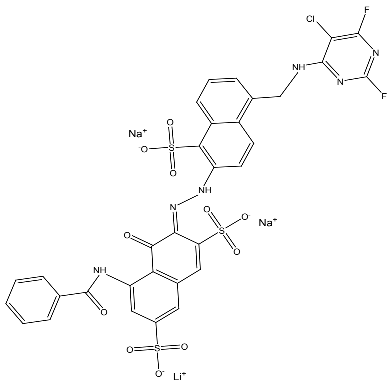
The decolorization of azo dyes was also evaluated in malt extract liquid medium (MEM) containing malt extract (20 g L^{-1}), glucose (20 g L^{-1}), and polypeptone (1 g L^{-1}). The medium was sterilized for 20 min at 121°C. Three disks (5mm diameter) of actively growing fungus on agar were added into each flask. Azo Dyes were contaminated after 7 days of fungi cultivation. 6 ml samples were withdrawn and filtered at regular intervals. Using the remaining 6 ml, the supernatants were analyzed at the wavelength of maximum absorbance (λ_{max}) of each azo dyes solution using a UV–visible spectrophotometer. Percentage decolorization was calculated as:

$$\% \text{ Decolorization} = ((Ao - At)/At) \times 100$$

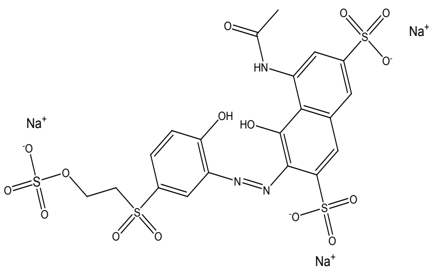
Where Ao and At are initial and final absorbance units, respectively (Couto, 2007).

E. Degradation of phenanthrene

Degradation of phenanthrene was performed in 100-mL Erlenmeyer flasks containing 20 mL of liquid medium. The medium was sterilized for 20 min at 121°C. Three disks (5mm diameter) of actively growing fungus on agar were added into each flask. The substrates, phenanthrene, dissolved in *N,N'* dimethylformamide (DMF), Tween80, and water) were added to each

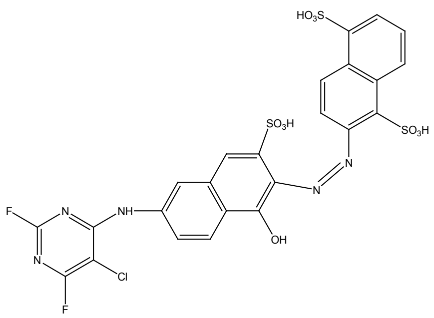


Levafix B. Red E-6BA
Reactive Red 159) – R159



Remazol B. Violet
(Reactive Violet 5) – V5

No identified chemical structure
Sumifix S. Scarlet 2GF – R222



Levafix Orange E2GA
(Reactive Or64) – Or64

Figure 1. Structure of azo dyes

culture and continuously incubated for 5, 10, and 15 days in the dark at 25°C. The effects of various liquid cultures were investigated: 1) ME medium, 2) modified Kirk's medium containing glucose (10 g L^{-1}), ammonium tartrate (0.2 g L^{-1}), KH_2PO_4 (0.2 g L^{-1}), $MgSO_4$ $7H_2O$ (50 mg L^{-1}), $CaCl_2$ $2H_2O$ (10 mg L^{-1}), thiamine (2 mg L^{-1}), and trace element (10 mL L^{-1}) with a trace mineral solution consisting of $MgSO_4$ $7H_2O$ (3 g L^{-1}), $MnSO_4$ 7H2O (0.5 g L^{-1}), NaCl (1 g L^{-1}), $FeSO_4$ $7H_2O$ (0.1 g L^{-1}), $CoCl_2$ (0.1 g L^{-1}), $ZnSO_4$ $7H_2O$ (0.1 g L^{-1}), $CuSO_4$ (0.1 g L^{-1}), H_3BO_3 (10 mg L^{-1}), and $(Na)_2$ MoO_4 H_2O (10 mg L^{-1}), and 3) mineral salt broth (MSB) medium containing glucose (10 g L^{-1}), ammonium tartrate (0.2 g L^{-1}), KH_2PO_4 (2 g L^{-1}), $MgSO_4$ $7H_2O$ (0.5 g L^{-1}), $CaCl_2$ $2H_2O$ (0.1 g L^{-1}), thiamine (1 mg L^{-1}), and trace element (10 mL L^{-1}) with the trace mineral solution consisting of $MnSO_4$ 7H2O (3 mg L^{-1}), $CoSO_4$ (1 mg L^{-1}), $FeSO_4$ $7H_2O$ (12 mg L^{-1}), $ZnSO_4$ $7H_2O$ (3 mg L^{-1}), and $(NH_4)_6$ Mo_7O_{24} $4H_2O$ (1 mg L^{-1}) (Tien and Krik, 1988; Arora and Gill, 2001; Hidayat *et al.,* 2012).

All the experiments were conducted in triplicate. For the 5, 10, and 15 days cultures, the residual substrates were quantified by extracting three times with ethyl acetate in acidic conditions (5 mL of 1 N HCl per-flask culture). The ethyl acetate extract was dried over anhydrous Na_2SO_4 and dry evaporated in a vacuum at 40°C. The concentrate of extracts were quantified by gas chromatography (GC-FID Shimadzu 2014) with a TC-5 capillary column (length: 30 m, inner diameter: 0.24 mm). The carrier gas was helium delivered at a constant rate of 1.5 mL min^{-1} with a column pressure of 100 Kpa and interface temperature of 280°C. The temperature was started at 60°C, and increased by 10°C min^{-1} to 280°C where it was maintained for 10-20 min to allow late eluting compounds to exit the column (Hidayat and Tachibana, 2013).

F. MnP and laccases assay

The enzymatic activities were quantified directly after decolorization analysis (as mentioned in the section above). Activities of Manganese peroxidase (MnP) and laccases were assayed spectrophotometrically. Manganese peroxidase (MnP) activity was assayed using 50 mM malonate buffer and dimethoxyphenol in 20mM of manganese sulfate ($MnSO_4$) at 470 nm (Wariishi *et al.*, 1992). Laccase activity was assayed by measuring the increase in absorbance at 525 nm using syringaldazine as a substrate in sodium acetate buffer (Leonowicz and Grzywnowics, 1981). All experiments were carried out at 25°C. Activities were expressed as international units per liter of enzyme, where one unit of activity is defined as the amount of enzyme necessary to convert 1 μmol of substrate in 1 min.

G. Data analysis

All results were presented as means ± the standard deviation and analyzed using SPSS version 15 for windows. When necessary, results were also analyzed with Pearson correlation coefficients (*r*), a two-tailed test of significance ($P<0.05$). The azo dyes decolorization data collected from pH 8.2 with saline condition was expressed with first-order kinetics (Ting *et al.,* 2011) : $S = S_0 \exp(-k_1 t)$, $t_{1/2} = \ln 2/k_1$, where S_0 is the initial concentration, S is the substrate concentration at time t, t is the time period, and k_1 is the decolorization rate constant.

III. RESULTS AND DISCUSSION

A. Isolation and identification of fungi

A preliminary screening was performed using RBBR in agar medium, which has been used to identify fungi with the ability to break down various recalcitrant organic pollutants (Sato *et al.,* 2003; Passarini *et al.,* 2011). Among a total of 16 fruiting bodies of fungi collected, only 6 grew well, covering more than 70% of the Petri dish, and 1 isolate, named AS03 caused a change in the color of RRBR (Figure. 2).

These isolates were selected for further study, because they showed higher decolorization of RBBR compared with other isolates. The 560-bp ITS sequence (ITS1/5.8S) was compared with similar sequences in the GenBank database using the BLAST online search program. Alignments of the strains, both manually and using cluster W, were conducted. Alignment of the strains showed that a partial sequence of AS03 had a maximum similarity index of 99% relative to *Trametes hirsuta* (Accession No. JN048768, JX861099, and FJ891292) and so it was named as *Trametes* sp. AS03.

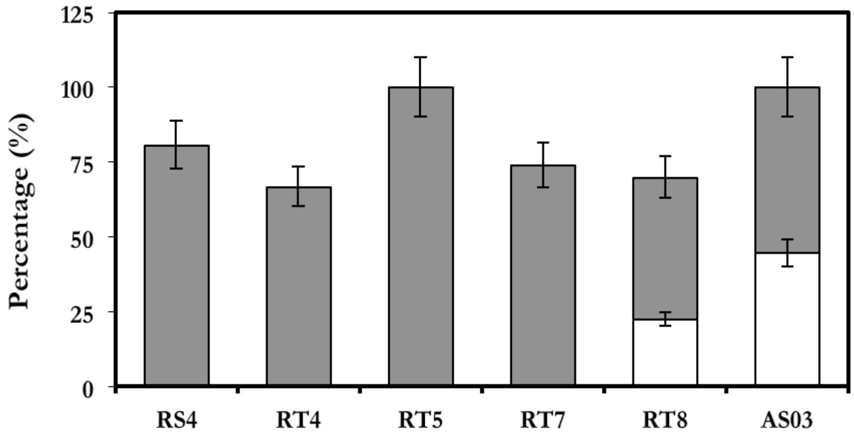


Figure 2. Growth of several isolated fungi in agar medium containing 100 mg L^{-1} of RBBR.

Remarks :
Observations were conducted on both the growth of fungi (grey bars) and the decolorization of RBBR (white bars) after 7 days incubation

B. Decolorization of some azo dyes

Decolorization of some of the azo dyes was further evaluated in liquid medium. Figure 3 shows the decolorization of four types of azo dyes by AS03. The ability of AS03 to decolorize dyes was 91, 48, 31 and 60% for V5, R159, Or64 and R222, respectively. The decolorization rate of four type of azo dyes was in the order of V5 > R222 > R159 > Or64 indicating that V5 is the most degradable azo dyes.

In alkaline condition, culture was adjusted to salinity ($35^{o}/_{oo}$) by addition of artificial sea water and pH 8.2. pH is an important key in the azo dyes decolorization. Over 83, 42, 31 and 58% of V5, R159, Or64 and R222 were decolorized by AS03 after 3 days incubation. Generally, the decolorization ability dropped less than 10% but this research result is an important finding because azo dyes decolorization by microorganisms in alkaline condition have been less studied, especially by fungi. The decolorization of dyes was greatly influenced by ligninolytic enzymes produced by fungi. In other hand, also pH was closely related to production of enzymes such as laccases and MnP. The contribution of the ligninolytic enzyme, laccase and MnP, to decolorization of azo dyes is crucial

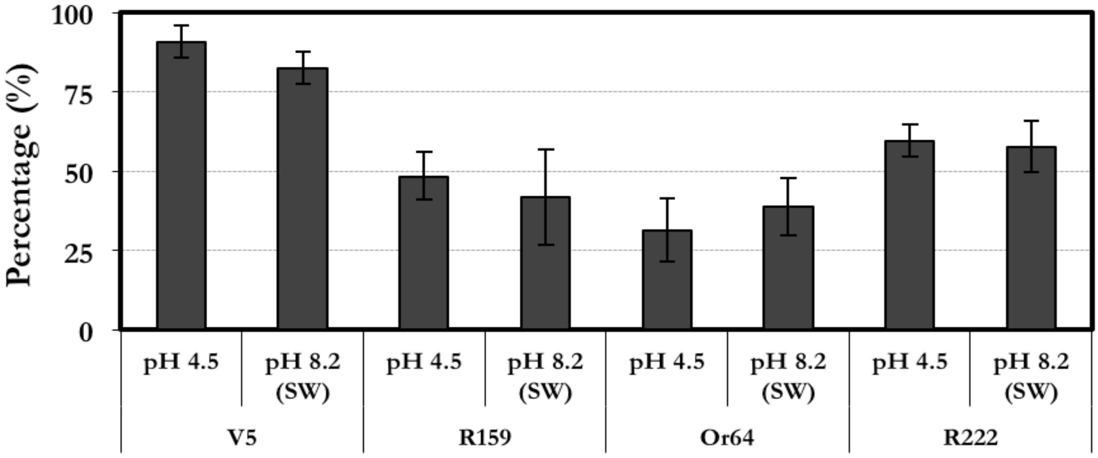


Figure 3. Decolorization of some of the azo dyes, Remazol B. Violet (V5), Levafix Orange E3GA (Or64), Levafix B. Red E-6BA (R159), Sumifix S. Scarlet 2GF (R222), by *Trametes sp.* AS03 in different pH and salinity (SW) after 3 days incubation

Table 1. Effect of some azo dyes on decolorization rate constants, MnP and Lac activities in malt the extract liquid cultured under saline condition (35 o/oo).

Fungi	Pigments[a]	K_1[b]	R[c]	Enzyme activities (U L^{-1})							
				MnP				Lac			
				Incubation period			r[d]	Incubation period			r[d]
				1	2	3		1	2	3	
Trametes sp. (AS03)	V5	0.62	0.93	**3.86**	**5.32**	**7.19**	**0.83***	**13.76**	**11.37**	**26.92**	0.66tn
	R159	0.15	0.64	0.93	1.73	2.66	0.84*	0.00	0.00	2.99	0.93**
	Or64	0.17	0.82	0.67	1.20	2.66	0.90*	2.99	4.79	5.38	0.38tn
	R222	0.30	0.94	1.06	2.00	2.66	1.00**	0.00	2.99	3.59	1.00**

Remarks :
Degradation rate constants were calculated as described by Ting *et al.*(2011).
Correlation coefficients were determined between pigments and enzymes activities (MnP or Lac)
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
tn Correlation is not significant
a Initial pigment concentration is 100 mg L^{-1}

to evaluate, especially in saline condition.

The MnP and laccase enzymes activities were detected in liquid culture at saline condition (pH 8.2), but varied greatly form one enzyme to another, type of azo dyes and time of incubation (Table 1). The azo dyes decolorization increased from 1 to 3 days incubation followed by increasing enzymes activities, both MnP and Laccase, in our experiments. The highest degradation was observed in the V5 azo dyes with decolorization rate constants (k_1) more than 0.62 per-days. The azo dyes decolorization correlated significantly with MnP. The Laccase enzymes activities also correlated significantly for R159 and R222. The role of laccase and peroxidases secreted by fungi is controversial, which can be seen in this experiment. MnP is a major enzyme involved in this process, but laccases and MnP collaborated in these processes, although the laccases had the highest activities compared to MnP. Kalme *et al.,* (2007) reported that degradation of azo dyes occurred if cleaved symmetrically and asymmetrically depending on the availability of enzymes. Although laccase and MnP are able to catalyst azo dyes, - breakdown azo bond and or cleavage between carbon of aromatic ring and nitrogen (Jadhav *et al.,* 2011) -, but to make sure the degradation mechanism of each azo dyes used in this research is correct, some investigations need to be repeated in the future.

C. Degradation of phenanthrene

Phenanthrene is considered to be a significant environmental pollutant due to their toxicity and mutagenicity (Bispo *et al.,* 1999). The degradation of phenanthrene by *Trametes* sp. AS03 was investigated in three liquid mediums: ME, Kirk's and MSB. The time periods of degradation of AS03 are displayed in Table 2. The degradation of phenanthrene over 15 days in Kirk's medium was much higher (72%) than that in ME (54%) and MSB (50%). Subsequently, metabolic studies were performed in Kirk's medium with phenanthrene as a substrate.

The mycelium biomass tends to increase with the incubation period for all mediums used (Table 2), but a high degradation rate was not associated with a high mycelium biomass. This indicates that the degradation of phenanthrene did not yield energy or carbon for fungal growth and the degradation occurred via intracellular detoxification (e.g. oxidation and hydroxylation), ring fission, and carbon assimilation (Cerniglia, 1984; Johnsen *et al.,* 2005). Furthermore, the level of laccase activity was 273 U L^{-1} in modified Kirk's medium with phenanthrene, while the level of MnP activity was 53 U L^{-1}. The enzymes activity levels were higher than in other types of medium, explaining why the degradation of phenanthrene was greater in modified Kirk's medium. The results also indicate that degradation of phenanthrene were truly associated with production of ligninolytic

Table 2. The effect of various liquid cultures on degradation of phenanthrene, mycelium biomass and enzymatic activities of AS03

Medium	Degradation (%) and weight mycelium biomass (mg)*						Enzymes activities (U L^{-1})		
	5 days		10 days		15 days		Lac	MnP	Lip
ME	29.5	(98)	35.4	(110)	53.7	(133)	235.8	44.8	11.5
Modified Kirks	14.6	(58)	34.7	(83)	71.7	(90)	272.5	53.5	nd
MSB	17.5	(35)	28.8	(49)	50.4	(66)	nd	0.8	2.8

Remarks :
* Values in parentheses are mycelium biomass of fungus (mg)
ME = Malt extract liquid medium, pH 4.5
Kirk's = Kirk's liquid medium, pH 4.5
MSB = Mineral salt medium, pH 4.5
n.d = not detected

enzymes, laccase and MnP (Ting *et al.*, 2011). Modified Kirk's medium is a suitable medium for fungi to enhance production of enzymes as well as the highest degradation was obtained with this medium. The production of enzymes by white-rot fungi is affected by the limitation of nitrogen concentration in medium and is not altered by the presence of phenanthrene (Kaushik and Malik, 2009). The initial step degradation of phenanthrene by ligninolytic fungi is often catalyzed by intracellular P-450 monooxygenase to produce dihydrodiol and extracellular peroxidase and laccase to produce quinone (Bamforth and Singleton, 2005).

IV. CONCLUSION

In this study, we demonstrated the ability of *Trametes* sp. AS03, a white-rot fungus collected from an Indonesian mangrove forest, to decolorize azo dyes and degraded phenanthrene. *Trametes* sp. AS03 decolorized 91, 60, 48, and 31 of V5, R222, R159, and Or64, respectively. The role of enzymes laccase and peroxidases secreted by AS03 in decolorization are still controversial, because MnP is a major enzyme in decolorization but laccases had the highest activities in comparison with MnP. Phenanthrene was degraded about 72% after 15 days incubation, and degradation processes was associated with a combination of non-ligninolytic and ligninolytic enzymes. Some investigations need to be repeated in the future regarding degradation mechanism of azo dyes and phenanthrene by AS03.

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