ISSN 2355-7079
E-ISSN 2406-8195
No. 754/AU3/P2MI-LIPI/08/2016

Indonesian Journal of Forestry Research

Vol. 3 No. 2, October 2016

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

Indonesian Journal of Forestry Research

Vol. 3 No. 2, October 2016

Annals of the Indonesian Journal of Forestry Research

Indonesian Journal of Forestry Research (IJFR) was first published as Journal of Forestry Research (JFR) on November 2004 (ISSN 0216-0919). The last issue of JFR was Volume 10 Number 2 published on December 2013. The Journal of Forestry Research has been accredited by the Indonesian Institute of Sciences since 2008. The last accreditation was on September 2016(accreditation number: 754/AU3/P2MI-LIPI/08/2016) which will be valid until June 2021. IJFR will be issued in one volume every year including two issues which will be delivered every April and October. This Journal is published by Research, Development and Innovation Agency (FORDA), Ministry of Environment and Forestry, formerly known as Forestry Research and Development Agency, the Ministry of Forestry Republic of Indonesia. The name of publisher has been changed due to the amalgamation of the Ministry of Forestry with the Ministry of Environment into the Ministry of Environment and Forestry, Republic of Indonesia (Perpres No. 16/2015). Consequently, the Forestry Research and Development Agency was transformed into Research Development and Innovation Agency for Forestry and Environment. The logo of the ministry was reformed, accordingly.

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Website : http://ejournal.forda-mof.org/ejournal-litbang/index.php/IJFR

Printed in Indonesia

Electronics edition is available at:
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Accredited by the Indonesian Institute of Science
No. 754/AU3/P2MI-LIPI/08/2016

Acknowledgement

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

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ABSTRACTS

ISSN 2355-7079 | Vol. 3 No. 2, October 2016

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UDC/ODC 630*907:73(594.53)

Ricky Avenzora, Tutut Sunarminto, Priyono E. Pratiekto and Ju-Hyoung Lee

PRICING STRATEGY FOR QUASI-PUBLIC FOREST TOURISM PARK: A CASE STUDY IN GUNUNG PANCAR FOREST TOURISM PARK, BOGOR INDONESIA

(STRATEGI PENETAPAN HARGA UNTUK TAMAN WISATA ALAM QUASI-PUBLIK: STUDI KASUS DI TAMAN WISATA ALAM GUNUNG PANCAR, BOGOR INDONESIA)

Dinamika konflik kepentingan tiga pihak (pemodal, masyarakat, lokal dan pemerintah) dalam meraih pemasukan aktual dari bisnis taman wisata alam di Indonesia semakin memburuk sejak diberlakukannya Peraturan Pemerintah Nomor 12 Tahun 2014 tentang Jenis dan Tarif Penerimaan Negara Bukan Pajak yang Berlaku pada Kementerian Kehutanan (PP 12 /14) yang bersifat "sangat progresif". Pada satu sisi, semua pihak sepakat untuk memperbaiki regulasi tarif dalam PP 59/1998 yang sudah berumur lebih dari 17 tahun, di sisi lain "ketidakjelasan" alasan penetapan tarif baru dalam PP 12/2014 meresahkan berbagai pihak serta menimbulkan kesulitan baru ketika diterapkan di lapangan. Tulisan ini mempelajari pola pengeluaran dan nilai kesediaan membayar (*willingness to pay*/WTP) pengunjung dalam setiap skenario pelayanan rekreasi menggunakan metode survey valuasi kontingen dengan instrumen kuesioner elisitasi berpola terbuka. Berdasarkan karakteristik Taman Wisata Alam Gunung Pancar (TWAGP), metode tersebut digunakan untuk menjustifikasi strategi penetapan harga tiket yang pantas di TWAGP sebagai taman wisata alam yang memiliki karakter quasi-publik. Survey WTP secara spesifik juga diarahkan untuk menemukan harga tiket yang sesuai dengan asumsi kelayakan finansial dari rencana usaha investor dan aktivitas ekonomi masyarakat lokal. Hasil survey menunjukkan nilai WTP pengunjung berada pada rentang 3,4 kali (sebagai respon terhadap skenario-1) hingga 12,7 kali (sebagai respon terhadap skenario-5) dari harga tiket yang berlaku saat studi dilakukan. Sementara peningkatan WTP yang diperoleh dari Skenario-2, 3, dan 4 masing-masing adalah sebesar 4,7 kali, 6,2 kali, dan 7,5 kali. Analisis lebih lanjut menggunakan Regresi Tobit menunjukkan terdapat 7 peubah penting yang berpengaruh positif terhadap nilai WTP dan 6 peubah penting yang berpengaruh negatif terhadap nilai WTP.

Kata kunci: Taman Wisata Alam, metode valuasi kontingen, kesediaan membayar, harga tiket

UDC/ODC 630*232.311.3

Noor K. Kartikawati

FERTILITY VARIATION OF *Melaleuca cajuputi* subsp. *cajuputi* AND ITS IMPLICATION IN SEED ORCHARD MANAGEMENT

(VARIASI FERTILITAS *Melaleuca cajuputi* subsp. *cajuputi DAN IMPLIKASINYA TERHADAP MANAJEMEN KEBUN BENIH*)

Informasi tentang variasi fertilitas pembungaan di kebun benih meliputi penentuan kualitas produksi benih dan perkiraan keanekaragaman keturunan genetik masih jarang tersedia. Tulisan ini mengevaluasi variasi fertilitas, ukuran populasi efektif dan keragaman genetik yang dihitung berdasarkan nilai koefisien sibling (Ψ) di kebun benih kayu putih di Paliyan, Gunungkidul untuk mengoptimalkan pengelolaan kebun benih ke depan. Sejumlah 160 pohon induk di kebun benih dievaluasi berdasarkan jumlah pohon berbunga dan jumlah bunga dan jumlah buah selama 3 periode pembungaan (2011-2013). Hasil penelitian menunjukkan bahwa variasi fertilitas (Ψ) berturut-turut adalah 1,39, 1,25 dan 1,43. Hal ini mengindikasikan terjadi penyimpangan dari perkawinan secara acak karena ada variasi fertilitas dari pohon-pohon di kebun benih. Pengamatan dalam 3 periode pembungaan menunjukkan pola yang cenderung sama, namun jumlah individu berbunga terbanyak terjadi pada tahun 2011. Ukuran populasi efektif (Np) diperoleh 15, menunjukan 15 famili yang didukung oleh 75% pohon-pohon di kebun benih berkontribusi terhadap pembungaan. Keragaman genetik yang dihitung berdasarkan variasi fertilitas menunjukkan angka yang cukup tinggi yaitu diatas 0,9 dalam 3 periode pengamatan. Sebagai konsekuensi akibat variasi fertilitas adalah dalam penyebaran benih perlu dilakukan pencampuran benih dari semua famili yang memproduksi benih dalam proporsi yang seimbang agar tidak terjadi dominasi famili-famili tertentu dan terjadinya damparan genetik (*genetic drift*). Tindakan manipulasi lingkungan perlu dilakukan untuk mendorong terjadinya keseragaman fertilitas dalam kebun benih sehingga seluruh potensi genetiknya dapat diwariskan.

Kata kunci: *Melaleuca cajuputi*, kebun benih, variasi fertilitas, ukuran populasi efektif, keragaman genetik.

UDC/ODC 630*232.315

Muhammad Zanzibar and Dede J. Sudrajat

EFFECT OF GAMMA IRRADIATION ON SEED GERMINATION, STORAGE, AND SEEDLING GROWTH OF *Magnolia champaca* L.

(PENGARUH IRADIASI SINAR GAMMA TERHADAP PERKECAMBAHAN, PENYIMPANAN BENIH, DAN PERTUMBUHAN BIBIT *Magnolia champaca* L.)

Iradiasi sinar gamma pada benih diketahui sebagai salah satu faktor yang dapat merangsang proses biokimia dan fisiologi. Tulisan ini menyelidiki pengaruh iradiasi terhadap perkecambahan, daya simpan benih dan karakter pertumbuhan bibit *Magnolia champaca*. Benih diiradiasi dengan dosis 0, 5, 10, 15, 20, 40, 60, 80, dan 100 Gy dengan Cobalt-60. Benih-benih yang diiradiasi dibagi ke dalam 3 kelompok perlakuan, yaitu untuk uji perkecambahan, uji penyimpanan, dan uji karakteristik pertumbuhan bibit. Pengamatan dilakukan untuk parameter daya berkecambah benih, indeks perkecambahan, waktu berkecambah rata-rata, nilai perkecambahan, dan karakter pertumbuhan bibit seperti tinggi, diameter pangkal akar, jumlah daun, panjang akar, dan berat kering total. Hasil penelitian ini menunjukkan bahwa iradiasi pada dosis 30 Gy diduga telah mencapai LD50, dan iradiasi pada dosis 80 Gy telah menyebabkan kematian sebagian besar benih. Peningkatan parameter perkecambahan benih tertinggi terjadi pada dosis 10 Gy, dan kemudian perkecambahan mengalami penurunan. Laju pertumbuhan dalam bentuk tinggi bibit, diameter pangkal akar, jumlah daun dan berat kering total juga meningkat pada dosis iradiasi sinar gamma hingga 80 Gy, namun dosis 10 Gy menghasilkan persen hidup dan pertumbuhan yang lebih stabil dalam menghasilkan nilai tertinggi untuk sebagian besar parameter. Dengan demikian, perlakuan iradiasi dosis rendah (10 Gy) dapat digunakan untuk meningkatkan perkecambahan, daya simpan, dan pertumbuhan bibit *M. champaca*.

Kata kunci: *Magnolia champaca*, iradiasi gamma, perkecambahan, pertumbuhan.

UDC/ODC 630*561

Sandhi I. Maulana, Yohannes Wibisono and Singgih Utomo

DEVELOPMENT OF LOCAL ALLOMETRIC EQUATION TO ESTIMATE TOTAL ABOVEGROUND BIOMASS IN PAPUA TROPICAL FOREST

(PENYUSUNAN PERSAMAAN ALOMETRIK LOKAL UNTUK MENDUGA BIOMASSA TOTAL DI ATAS PERMUKAAN TANAH DI KAWASAN HUTAN TROPIS PAPUA)

Saat ini, persamaan alometrik pantropis telah umum digunakan untuk mendapatkan nilai dugaan biomassa di atas permukaan tanah di kawasan hutan, termasuk di Indonesia. Akan tetapi, sehubungan dengan adanya perbedaan dalam karakteristik diameter, tinggi dan berat jenis pohon, kurangnya pengukuran data, khususnya di daerah timur Indonesia menyebabkan adanya keraguan terkait besarnya simpangan dan bias yang dihasilkan oleh penggunaan persamaan pantropis di daerah tersebut. Oleh karena itu, tulisan ini mempelajari perbandingan persamaan alometrik yang dibangun secara spesifik terhadap lokasi dan persamaaan alometrik pantropis yang telah dipublikasikan oleh Chave dkk. Pendugaan biomassa pada penelitian ini dilaksanakan berdasarkan pengukuran dan penimbangan secara langsung secara destruktif. Hasil dari penelitian ini menunjukkan bahwa persamaan lokal yang sesuai untuk pendugaan nilai biomassa di atas permukaan tanah di kawasan hutan tropis Papua adalah Log(TAGB) = -0.267 + 2,23 Log(DBH) +0,649 Log(WD) (CF=1,013; VIF=1,6; R2= 95%; R2-adj= 95,1%; RMSE= 0,149; P<0,001). Apabila dibandingkan dengan persamaan alometrik pantropis yang telah dipublikasikan sebelumnya, model lokal tersebut menghasilkan nilai dugaan yang lebih baik dengan nilai simpangan rata-rata hanya 6,47% dan nilai bias relatif sebesar 5,37. Hasil ini mengindikasikan bahwa persamaan alometrik yang dibangun secara lokal sebaiknya dijadikan pertimbangan utama untuk mendapatkan nilai dugaan total biomassa di atas permukaan tanah yang lebih akurat.

Kata kunci: Pantropis, lokal, alometrik, biomassa, Papua

UDC/ODC 630*232.318

Sumardi, Hery Kurniawan, and Prastyono

GENETIC PARAMETER ESTIMATES FOR GROWTH TRAITS IN AN *Eucalyptus urophylla* S.T. Blake PROGENY TEST IN TIMOR ISLAND

(PENDUGAAN PARAMETER GENETIK SIFAT PERTUMBUHAN PADA UJI KETURUNAN *Eucalyptus Urophylla* S.T. Blake DI PULAU TIMOR)

Pendugaan parameter genetik sifat pertumbuhan dilakukan terhadap uji keturunan Ampupu (*Eucalyptus urophylla* S.T. Blake) yang ditanam di Timor Tengah Selatan, Provinsi Nusa Tenggara Timur. Data berasal dari 45 *famili half-sib* pada usia satu tahun. Hasil evaluasi menunjukkan bahwa terdapat variasi genetik antara famili *E. urophylla* yang diuji untuk sifat tinggi dan diameter. Sifat pertumbuhan memiliki heritabilitas individu maupun heritabilitas famili yang tinggi, dimana untuk karakter tinggi adalah masing-masing 0,28 dan 0,55 sedangkan untuk karakter diameter adalah sebesar masing-masing 0,41 dan 0,66. Korelasi genetik antara sifat tinggi dan diameter tanaman sangat kuat (0,96). Namun demikian, hasil pendugaan parameter genetik ini harus ditafsirkan secara hati-hati mengingat umur tanaman yang masih sangat muda. Evaluasi parameter genetik terhadap uji keturunan ini perlu dilakukan secara berkala untuk mendapatkan pemahaman yang lebih baik mengenai dinamika interaksi antara genetik dengan lingkungan, umur yang efektif untuk melakukan seleksi dan prediksi perolehan genetik.

Kata kunci: Ampupu, *Eucalyptus urophylla*, uji keturunan, heritabilitas, korelasi genetik

UDC/ODC 630*181.8

Nurul L. Winarni, Dewi R. Kurniasari, Diny Hartiningtias, Meyner Nusalawo, and Niken Sakuntaladewi

PHENOLOGY, CLIMATE AND ADAPTATION: HOW DOES DIPTEROCARPS RESPOND TO CLIMATE?

(FENOLOGI, IKLIM, DAN ADAPTASI: BAGAIMANA DIPTEROCARPACEAE BEREAKSI TERHADAP IKLIM?)

Suhu, curah hujan dan cuaca ekstrim telah diindikasikan mempengaruhi pola fenologi dan produktivitas hutan dengan menggeser musim berbunga dan berbuah, menggeser pola, serta produksi buah. Dipterocarpaceae adalah pohon bernilai tinggi untuk hasil hutan kayu dan non-kayu nya. Tulisan ini mempelajari respon dari pola fenologi pembungaan dan pembuahan Dipterocarpaceae terhadap peubah iklim. Penelitian dilakukan di Stasiun Penelitian Way Canguk PHKA/WCSIP Taman Nasional Bukit Barisan Selatan (TNBBS), Lampung selama Mei-November 2012 dengan menganalisis 14 tahun (1998-2012) data fenologi Dipterocarpaceae. Survei fenologi dilakukan secara bulanan dengan melakukan estimasi persentase berbunga dan berbuah (dibagi menjadi skoring 0-4) serta estimasi produksi buah. Hasil penelitian menunjukkan bahwa pola fenologi Dipterocarpaceae di daerah ini digambarkan berupa pola mayor dan minor tanpa waktu berbunga massal, yang berbeda dari laporan sebelumnya untuk Kalimantan atau Sumatera Utara. Puncak musim berbunga minor menunjukkan pola berbunga teratur terutama selama Maret-Juli setiap tahunnya. Namun, terdapat musim berbunga mayor, yang terjadi pada bulan November 2002 (20,2%), September 2006 (21%), dan Oktober-November 2011 (20,3%). Rata-rata produksi buah bulanan menunjukkan puncak pada akhir musim kemarau. Musim berbunga mayor tampaknya bertepatan dengan periode El Nino utama pada bulan November 2002 dan September 2006, sementara yang lain terkait dengan La Nina. Hasil penelitian ini menunjukkan bahwa fenologi dan perubahan iklim mungkin memiliki implikasi dalam merancang strategi pengumpulan bahan benih untuk mendukung program konservasi dan perkebunan dari Dipterocarpaceae.

Kata kunci: Dipterocarpaceae, fenologi, perubahan iklim, Taman Nasional Bukit Barisan Selatan

Indonesian Journal of Forestry Research Vol. 3, No. 2, October 2016, 65-82 ISSN: 2355-7079/E-ISSN: 2406-8195

PRICING STRATEGY FOR QUASI-PUBLIC FOREST TOURISM PARK: A CASE STUDY IN GUNUNG PANCAR FOREST TOURISM PARK, BOGOR INDONESIA

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Received: 17 December 2015, Revised: 27 August 2016, Accepted: 20 September 2016

PRICING STRATEGY FOR QUASI-PUBLIC FOREST TOURISM PARK: A CASE STUDY IN GUNUNG PANCAR FOREST TOURISM PARK, BOGOR INDONESIA. The dynamic of 3-parties conflict of interests (investor, local people and government) in having actual income from the nature tourism park business in Indonesia became worse since a "very progressive" Government Regulation on Forestry Related Services Tariff (so called PP 12/2014) was issued. On one hand, everybody agrees to improve the 17 years old tariff regulation of PP 59/1998. On the other hand, the "unclear reason" of the new tariffs in PP 12/2014 has shocked many parties and created many difficulties while implemented. This paper studies visitors' expenditures and their willingness to pay (WTP) for every recreation services scenario by using contingent valuation method (CVM) survey with open-ended eliciting questionnaire instrument. Regarding the characteristic of Gunung Pancar Forest Tourism Park (GPFTP) the method was used to justify a reasonable and eligible ticket pricing strategy at the GPFTP as a quasi-public recreation park. The survey has also specifically addressed the reasonable ticket-price that aligns with the financial assumption of investor's business plan and local people's economic activities. Results of the survey show that the continuum of visitors' WTP is ranging from 3.4 times (as the response to scenario-1) up to 12.7 times (as the response to scenario-5) of the recent ticket price. The WTP of scenario-2, 3 and 4 are ranging from 4.7, 6.2 and 7.5 times, respectively. Furthermore, the results of Tobit Regression Analysis show that seven important variables are positively correlated, while six variables are negatively correlated with the WTP.

Keywords: Tourism Park, contingent valuation method, willingness to pay, ticket pricing

*STRATEGI PENETAPAN HARGA UNTUK TAMAN WISATA ALAM QUASI-PUBLIK: STUDI KASUS DI TAMAN WISATA ALAM GUNUNG PANCAR, BOGOR INDONESIA. Dinamika konflik kepentingan tiga pihak (pemodal, masyarakat lokal dan pemerintah) dalam meraih pemasukan aktual dari bisnis taman wisata alam di Indonesia semakin memburuk sejak diberlakukannya Peraturan Pemerintah Nomor 12 Tahun 2014 tentang Jenis dan Tarif Penerimaan Negara Bukan Pajak yang berlaku pada Kementerian Kehutanan (PP 12 /14) yang bersifat "sangat progresif". Pada satu sisi, semua pihak sepakat untuk memperbaiki regulasi tarif dalam PP 59/1998 yang sudah berumur lebih dari 17 tahun, di sisi lain "ketidakjelasan" alasan penetapan tarif baru dalam PP 12/2014 meresahkan berbagai pihak serta menimbulkan kesulitan baru ketika diterapkan di lapangan. Tulisan ini mempelajari pola pengeluaran dan nilai kesediaan membayar (*willingness to pay/*WTP) pengunjung dalam setiap skenario pelayanan rekreasi menggunakan metode survei valuasi kontingen dengan instrumen kuesioner elisitasi berpola terbuka. Berdasarkan karakteristik Taman Wisata Alam Gunung Pancar (TWAGP), metode tersebut digunakan untuk menjastifikasi strategi penetapan harga tiket yang pantas di TWAGP sebagai taman wisata alam yang memiliki karakter quasi-publik. Survey WTP secara spesifik juga diarahkan untuk menemukan harga tiket yang sesuai dengan asumsi kelayakan finansial dari rencana usaha investor dan aktivitas ekonomi masyarakat lokal. Hasil survei menunjukkan nilai WTP pengunjung berada pada rentang 3,4 kali (sebagai respon terhadap skenario-1) hingga 12,7 kali (sebagai respon terhadap skenario-5) dari harga*

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 doi: http://dx.doi.org/10.20886/ijfr.2016.3.2.65-82

tiket yang berlaku saat studi dilakukan. Sementara peningkatan WTP yang diperoleh dari Skenario-2, 3 dan 4 masing-masing adalah sebesar 4,7 kali, 6,2 kali, dan 7,5 kali. Analisis lebih lanjut menggunakan Regresi Tobit menunjukkan terdapat 7 peubah penting yang berpengaruh positif terhadap nilai WTP, dan 6 peubah penting yang berpengaruh negatif terhadap nilai WTP.

Kata kunci: Taman Wisata Alam, metode valuasi kontingen, kesediaan membayar, harga tiket

I. INTRODUCTION

Ticket pricing strategy on a quasi-public tourism forest area (QPTFA) in Indonesia has become an important issue for the investor in tourism facilities and services provider, and become a crucial problem between any parties which has interest to gain any benefit from a tourism forest area. The term "quasi-public forest tourism area" in this paper is defined as a tourism forest area that is owned by the government, but its management and utilization are done cooperatively with private parties as investors.

Historically, the cheap ticket price which was applied in QPTFA since the beginning of 1980s until 2014 can be inferred as a burden of government position on providing recreation services for the inhabitants. In fact, the government undeniably has public service obligation to provide recreation service for its citizen (Krauss, 1998)) but the inappropriate understanding and implementation of its obligations have caused losses and conflicts.

Before the 1998 economic crisis and political reform, the important dynamics of loss and conflicts on QPTFA in Indonesia included: (a) the damage of resources and tourism objects caused by government's low ability to provide maintenance and security funds; (b) the low economic benefits gained by local people since they were less-involved in any forest tourism activities; (c) ecological impacts; and (d) several social impacts like demonstration effect and inflation effect (Pizam, 1978; Mathieson & Wall, 1982).

After the political reform, the government issued Government Regulation No. 59 of 1998 (PP 59/1998), which has significantly increased local people's participation in utilizing and managing tourism forest areas. But, several losses and conflicts are still remained, such as: (a) degradation of tourism resources and ecology-fragmentation caused by local people's economic activities; (b) decrease of visitors' satisfaction caused by multi-ticketing dynamics that was applied by local people in their village area surrounding a QPTFA; and (c) the increase of exploitation in pristine area by the ownership of Nature Tourism Business Concession (locally so called *Izin Pengusahaan Pariwisata Alam* – IPPA). Previously, the concession duration of IPPA was maximum 20 years but it has been changed to maximum 55 years.

Indonesia has abundance resources for the potential supply of QPTFA. Up to now, Indonesia has around 51 National Parks, 221 Nature Reserves, 75 Wildlife Sanctuaries, 116 Quasi-Public Forest Tourism Parks (*Taman Wisata Alam*), 163 State-Owned Forestry Enterprise Tourism Parks (*Wana Wisata*) which is a kind of forest tourism park in Java Island managed by the state-owned forestry enterprise (*Perum Perhutani*), 24 Provincial Forest Parks (*Taman Hutan Raya*), 12 Game Hunting Forest Parks and more than 1,000 attraction points of nature tourism objects in the protected forest areas that are well distributed throughout the country (Supriyanto & Sari, 2013).

On one hand, all of those tourism resources on the public forest areas have good potentials to be brought to a supply position by granting thousands of IPPA to the credible investors. However, up to now the government still cannot find a proper strategy to create better benefit from these resources since there are still less than 50 IPPA granted to investors (Supriyanto

& Sari, 2013). On the other hand, investors are factually not willing to invest in tourism facilities and services in their IPPA area. After getting the IPPA, generally IPPA-holder tends to only build "low quality" recreation facilities and services; arguing that they are still waiting for the government to provide basic infrastructure as feasibility prerequisite for making bigger investment.

The "low" quality of recreation facilities and services makes the dynamics of the business trapped inside low budget tourism activities. Those dynamics do not only decrease the investors' income, but also damage the recreation area caused by visitors and 'street vendor' activities who keep 'invading' the business activities surrounding the attraction points. Another case can also be found in the study of Ekayani, Nuva, Yasmin, Shaffitri and Tampubolon (2014) which state that the dynamics of low budget tourism activities in Gunung Halimun-Salak National Park tend to be exploited through free rider patterns by the local people for the sake of, and benefits to the locals themselves; without giving significant contribution to the conservation of the resources.

The dynamics of "low-budget tourism activities" lead to low taxes and incomes gained by the government. Consequently, government's ability to fund basic infrastructure development cannot be improved; as well as the funding of the maintenance.

In order to alleviate the above serious "domino effect", Indonesian Government has issued Government Regulation about Items and Tariff of Non-Taxes Income on Forestry Sector (PP 12/2014). The basic goal of this policy is to encourage an ideal and rational condition in developing a QPTFA; however the startling increased price of the tariff components–which has significantly risen by 50-8,000% times from the previously regulated tariff in PP 59/1998 has concerned many parties. In many ways, the tariff should have been concluded objectively as "not reasonable"; especially in terms of the binding of a space on providing any recreation resources/attractions for the visitors.

The disputation in determining the new tariff has never been solved since many parties are egocentric. On one side, the entrepreneurs (investors, tour operators and tourism service providers) are generally disagreeing with the new tariff. On the other side, the government is still hesitant, and unsure, thus the government is unable to properly implement the policy.

Considering these foregoing dynamics, a study of ticket pricing strategy in a QPTFA is important to be conducted. At the national level, this study is very important for an objective evaluation of the tariff system organized by the government. From the international perspective, this study will be a fundamental support to facilitate high interests of foreign investors to invest in Indonesian forests; such as the investment projects arranged by South Koreans in West Java and Lombok.

The main objectives of this study are: (1) to investigate customers' motive for visiting the vocal point, and (2) to investigate customers' purchasing power in consuming nature tourism services. These two objectives will be described through the value of their Willingness To Pay (WTP) and any other underlying factors.

The WTP becomes a reference of expenditure (money) that is willingly spent by the consumers to get benefits, including different quantity and better environment quality (Stern, 2000; Baysan, 2001; Zenginobuz, 2002; Uyarra, 2005; Togridou, Hovardas, & Pantis 2006; Budeanu, 2007; Gosken, Adaman, Ku & Chen, 2013; Nowacki, 2013; Ekayani & Nuva, 2013). Moreover, it is convinced by Pagiola, Agostini, Gobbi, de Haan, and Ibrahim (2004) that the concept of Payment for Ecosystem Services (PES) endorses the right of stakeholders in managing the sustainability of recreational resources that have to be fulfilled. The value of WTP can then be used to improve the economic aspects of the tourism management of the tourism without abandoning the aspects of consumer's satisfaction. This becomes important due to the role of nature and environment resources as a non-market public commodity, yet the money spent by the customers to get tourism access will certainly become a burden to their satisfaction (utilities).

The Gunung Pancar Forest Tourism Park (GPFTP) was chosen as the research site since it has management complexities, i.e. between "private good" and "public good". Therefore, the tourism service in this site should be classified as a quasi-public resource. One important characteristic of quasi-public forest tourism services in GPFTP involves the facilities of tourism services provided by a private party (PT. Wana Wisata Indah/WWI) through the IPPA. Therefore, it has the characteristic of clear property authority which can be handed over as "private commodity". However, another characteristic entails the attributes of the natural resources and environment in GPFTP which should be categorized as "public commodity", which cannot be aggregately separated in providing supply of nature resources..

For that reason, as "private commodity", the investment products of PT. WWI have rivalry and excludability characteristics. While as "public commodity", the forest area of GPFTP is owned by the government having obligation to fulfill people's needs of recreation; so it also has non-excludability and non-rivalry characteristics.

II. MATERIAL AND METHOD

A. Study Design

Visitors' WTP was measured through stated preference survey using Contingent Valuation Method (CVM). The CVM method (Bowen, 1943) is carried out through three main stages as proposed by Pearce, Atkinson and Mourato (2006) including:

(1) Identifying commodities and services that will be evaluated. The valuation aspects were limited into the condition of facilitates and tourism service in the utilization zone of GPFTP, which has been developed by PT. WWI.
(2) Constructing a hypothetical scenario. Five hypothetical scenarios were arranged gradually based on the review of any documents of the GPFTPs' development plans. The five scenarios were shown to visitors, so each of them could be measured explicitly through the most appropriate ticket price (Table 1).
(3) Eliciting the monetary value. Open-ended questions were used to elicit information regarding visitor's WTP; with intention to let them being honest in answering, and avoiding so called warm glow phenomena. In the warm glow phenomena the respondents are assumed to give answers that just please the interviewer by giving/showing agreement as found in dichotomous choice elicitation method (Andreoni, 1990; Bennett & Blaney, 2005).

Referring to the price theory of Kahneman, Knetsch and Thaler (1986), it can be justified that the price printed on the ticket has an important role as a strong internal reference price for visitors to give properly and rationally assessment toward "new ticket price". Therefore the "old ticket price" can be a proxy to avoid negative bottom limit of WTP values.

Considering those mentioned references,

Table 1. Hypothetic scenarios for GPFTP

Scenario	Benefits for visitors
1	Renovation and addition of only general facilities (including roads, clean water, toilet, praying room, bench and shelter)
2	Scenario 1 plus addition of board sign, information board, symbols, signs and labels of tourism attractiveness interpretation in the whole forest areas
3	Scenario 2 plus addition of extra food stall/cafeteria facilities in the areas of camping grounds
4	Scenario 3 plus addition of extra free playing ground for children in the family picnic areas
5	Scenario 4 plus addition of free access to outbound and flying fox areas

this study used open-ended questions through Tobit Censored Regression Analysis (Tobin, 1958) instead of common Ordinary Least Square (OLS) Regression. The proxy of printed price on the old ticket indicated that the limit values of WTP would be an estimation method that may cause an inconsistent and biased parameter presumption.

The regression model of Tobit utilizes the maximum technique to provide a consistent and not biased parameter presumption. An application of Tobit model in estimating dependent variable (y) in form of WTP values toward "new ticket price" of the GPFTP that is above IDR 2,000 can be specified in the following equations of the latent y^* variable:

$$\text{If } y^* = X\beta + e > 2000, \text{ then } y = XB + e \quad (1)$$

$$\text{If } y^* = X\beta + e \leq 2000, \text{ then } y = 0 \quad (2)$$

where $X\beta$ is scalar of independent variable X multiplied by the appropriate Tobit coefficient of β, and e is normally distributed error.

The Tobit Formula for expected value of independent variable for every case (Ey) is formulated in Equation 3:

$$Ey = [X\beta \times F(X\beta/\sigma)] + [\sigma \times f(X\beta/\sigma)] \quad (3)$$

where $X\beta$ is defined in Eq.1; $F(X\beta/\sigma)$ as cumulative normal distribution function; $f(X\beta/\sigma)$ as normal density function; and σ as standard deviation of the error (Wagner, Hu & Duenas, 2000). In other words, the regression coefficient of Tobit Equation Model is corrected, and the possible WTP values will be above IDR 2,000.

The influencing factors of WTP values used as variables for the Tobit regression analysis toward WTP values in each scenario are presented in Table 2. These variables are in line with the theoretical framework formulated by Ramdan and Mohamed (2014) and research into relationship between environment literacy and WTP (Togridou, 2006; Wang & Jia, 2012; Szell & Hallett, 2013), that demographic variables are corresponding with personal value aspects and individual environment literacy, like motivation, sensitivity and concern toward environment condition. These aspects provide significant influence toward WTP and individual tendency to act.

The values gained from the survey were then analyzed by using profit-loss and company cash-flow approaches to find out the financial implementation feasibility. The ticket price resulted from this study was developed based on WTP assessment that fulfill the assumption of financial feasibility.

Table 2. Regression variables

Variables	Explanation
DAY	Visiting days; 1= weekend (Saturday and Sunday), 0= weekdays (Monday-Friday)
SEX	Sex; 1= male, 0= female
MARITAL	Marital status; 1= married, 0= not married
AGE	Age, stated in years old
EDU	Educational background, stated in the years spent at formal education
HOUSEHN	Number of dependents, stated in number of person
INCOME	Monthly income, stated in Indonesian Rupiah (IDR)
KNOW	Owned information and promotion
TVISIT	Total number of visits made to the GPFRP
COSTS	Expenditure per one visit to the GPFRP, stated in IDR
TRIPL	Time needed to reach the GPFRP, stated in hours
MOTIV	Motivation to visit; stated in extended Likert Scale; 1= very low, 7= very high
CPERF	The assessment towards leisure activities performance in the GPFRP, in extended Likert Scale; 1= very disappointing to 7= very satisfying (Avenzora, 2008)

B. Sample and Data Collection

The WTP survey of entrance ticket to the GPFTP was conducted between May-August 2014 through direct survey of weekday and weekend visitors. Considering the research results conducted by Batubara (2013) and Kristinawanti (2014) in the GPFTP, the number of respondents was decided to be properly represented by 30 weekday visitors and 100 weekend visitors; as there were different significant numbers between weekdays and weekend visitors.

The questionnaire used in this survey consisted of four parts, namely A, B, C and D. In Part A, the questions were intended to get information of visitors' personal background. In Part B, the questions were used to grab visitors' motivation and their perception towards recreation activities and current environment condition in the GPFTP. Questions on motivation and perception were presented in close-ended pattern using Likert-scale, which was extended into 7 scales (Avenzora, 2008); since the Indonesian people always have a detailed terminology in expressing values therefore it was important to extend the Likert-scale from 1-5 to 1-7.

In Part C, the respondents were asked about their expenditure in every phase of tourism activities and also about their satisfaction after spending some money. More detailed information was asked in Part D, which were addressed to answer the main research question proposed in this study concerning the visitors' willingness to pay in terms of entrance ticket toward five hypothetical scenarios of the GPFTP development.

III. RESULT AND DISCUSSION

A. Characteristic of Study Area

The GPFTP is situated in the administrative area of Karang Tengah Village, Babakan Madang Sub District, Bogor Regency. This area is located in the working area of the *Balai Besar Konservasi Sumber Daya Alam* of West Java (BKSDA; a Primer Regional Office of Nature Conservation under the Ministry of Forestry). According to the Minister of Forestry Decree No. 156/Kpts-II/1988 of 21 March 1988, the total area of this tourism park is 447.50 Ha.

The forest coverage is dominated by *Pinus merkusii, Falcataria mollucana*, *Maesopsis eminii*, and *Shorea* spp., which were planted in 1982-1983. The vegetation of nature forest (± 15 hectare) can be found on the slopes of Pancar Mountain. It consists of *Altingia excelsa*, *Quercus* spp., *Schima walichii*, *Castanopsis argentea*, *Podocarpus imbricatus* and liana. Wild animals can also be found in this area, such as *Macaca fascicularis*, *Trachypithecus auratus* and *Sus scrofa*.

The area of GPFTP is located 300-800 meters above sea level (masl), with the height top of Pancar Mountain at 800 masl. The topography varies from slightly slope to very steep slope with 8-80% tilt. The slope in the south east area (Pancar Mountain) and east area (Pasir Astana Hill) is above 25%, while the slope in the north and west is about 8-25%.

The main attraction of the GPFTP includes some natural hot springs that have been developed for health tourism activities. It also provides a wide natural mountainous view of pine forest, which creates a freshening and comfortable ambience for the visitors.

The concession of nature tourism in GPFTP is held by PT. Wana Wisata Indah (WWI); the IPPA was granted through The Decree of Forestry Minister No. 54/Kpts-II/1993. Some of the major outdoor recreation activities provided by the PT. WWI are gathering, camping, biking, jogging, hiking, outbound and horse-riding. PT. WWI provides facilities such as a challenging international-standard track for downhill mountain bike, camping ground and a function-hall.

B. Visitor Profile and Visiting Pattern

Referring to the proportion of their employment, monthly income and age classes; the visitors of GPFTP can be classified as middle-class society in productive age (Table 3). This middle-class society is one of the largest market segments in Indonesia with a total

Table 3. Dominant characteristics of respondents

Characteristic	Weekday visitor (%)	Weekend visitor (%)
Sex		
Male	77	60
Female	23	40
Age (years)		
10-19	23	22
20-29	43	36
30-39	17	16
40-49	4	23
>50	13	3
Marital Status		
Single	63	52
Married	37	47
Widowed/divorced	0	1
Education		
Junior High School	-	6
Senior High School	70	47
Vocational Diploma	23	10
University Degree	7	35
Others	-	2
Occupation		
Student	23	24
Civil Public Servant	7	8
Private Employees	37	48
Self employed	30	13
Housewife	3	7
Monthly Income		
Not answered	-	1
< IDR 1 million	30	26
IDR 1-4 million	50	41
IDR 4,1-10 million	13	22
> IDR 10 million	7	10
Home Area		
Jakarta	33	22
City of Bogor	10	6
Municipality of Bogor	33	34
Bekasi Regency	20	21
Depok City	3	11
Others	1	6

number of about 99 million in 2009 and shared around 43% of the total national household consumption (Nizar, 2015). Furthermore, Nizar (2015) also stated that this middle class contributed positively to the economic development because it created demand for high quality consumption commodities with increasing returns to scale. Therefore, it is obvious that GPFTP has big market potential and able to provide continuity assurance demanded in the future.

Table 4 shows that individual visitors comprised the biggest portion from the total visits; and reached 57% during the weekdays and 40% during the weekend. Then, it was followed by family visitors, which reached 30% during

Table 4. The dominant visiting pattern of GPFTP

Characteristic of Visit	Weekday visitor (%)	Weekend visitor (%)
Category of visitors		
Teenagers individual	27	15
Adult individual	30	25
Family	30	36
Group/organization	13	24
Pattern of visit		
Independent tour	87	76
Guided tour	13	24
Staying overnight		
No	90	86
Yes	10	14
Time length of knowing the object		
< 1 year	27	35
1-3 year(s)	20	35
> 3 years	53	30
First-time visit		
Yes	27	47
No	73	53

the weekdays and 36% during the weekend.

Most visitors of GPFTP only took a short trip, approximately four hours per visit. The number of visitors who stayed overnight was less than 15% from the total number of visits, both during weekdays and weekend. The average duration of overnight stay was mostly two days and one night. This short duration of trips was also strongly predicted and was caused by limited lodging facilities provided by management in the camping ground areas.

The average total number of visits (since the beginning) was 5 times among weekday visitors and 4 times among weekend visitors. Moreover, the number of visits during the last past year were 3 times among weekday visitors and 2 times among weekend visitors. The finding shows that GPFTP visitors have a positive trend to repeatedly visit the object.

C. Motive and Perception of Visitor

The respondents' visit was triggered by their motives to escape from routines and to enjoy beautiful scenery for hunting photography (Figure 1). They stated that the area of GPFTP is beautiful and natural; it provides freshening ambience and panorama to indulge their physical and mind relaxation and refreshment.

The beauty of the area formed by pine stands, rocky mountains and mountainous landscape motivated the visitors to take photos and display them in various social media. The presence of esthetic pine stands also became the main attraction for the tourists. It was strongly related with the purpose of their visits to make movie, photos for memory album, pre-wedding photos; and even for individuals, education, research, and commercial interests or needs.

Other dominant motives were the encouragement to have family picnic and to attend community gathering; with specific intention to improve the quality of family bonds. The same reasons came from the community groups who wanted to maintain the quality of their relationship and cooperation between groups and/or organizations. The difference was created in the way they arranged the meeting; the community/groups usually created a varied and programmed educational tour and training, compared to family or acquaintance meetings.

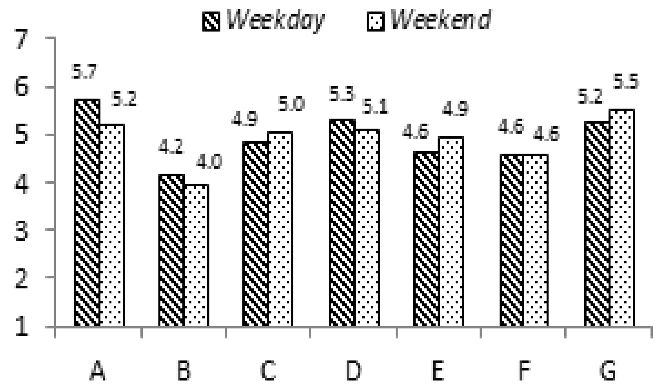

Figure 1. Number of visit according to their motives to visit GPFTP

Remarks:
A= Outdoor recreation; B= Sports and wellness; C= Family picnic; D= Group/community gathering; E= Education/knowledge; F= Special hobby/interest; G= Photo hunting; 1= Very Low; 2= Low; 3= Rather low; 4 = Moderate; 5= Rather high; 6= High; 7= Very high

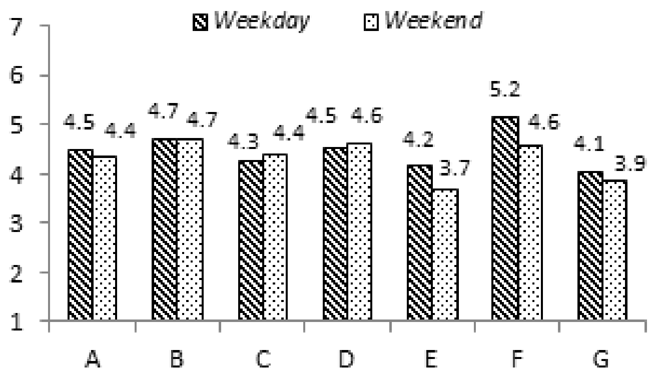

Figure 2. Number of visits according to factors that attracts visit to GPFTP

Remarks:
A= Diversity of tourism potentials; B= Costs and fare; C= Visitor crowdness; D= Accessibility; E= Facilities and services; F= Cleanliness and comfort; G= Information and promotion; 1= Very Low; 2= Low; 3= Rather low; 4= Moderate; 5= Rather high; 6= High; 7= Very high

Figure 2 shows the highest rated GPFTP attractions including cleanliness and comfort of the area, affordable cost and fare, and easy access to reach the forest park. However, the provision of varies tourism attractions did not become the main factor that attracted visitors. The other important factors, which are directly linked to the management performance such as facility, services and promotion, got the lowest scores in this survey.

Weekday visitors gave higher scores towards any kinds of recreation activities in GPFTP compared to weekend visitors (Figure 3). The activities that are directly linked to natural ambience, such as sightseeing, enjoying coolness and taking photographs, provide the highest satisfaction to the visitors. However, some visitors rated "somewhat disappointed" towards wildlife watching activities, since wild animals were difficult to encounter.

Improving environment condition and facilities becomes a challenge for PT. WWI. Figure 4 shows that generally visitors were not ‘satisfied’ with the environment conditions and facilities. Visitors were generally quite satisfied with the cleanliness and the beauty of the areas. However, there was still lack of basic cleanliness facilities, like trash bins which were mentioned by visitors as one area that need improvement. Furthermore, the bad road condition might

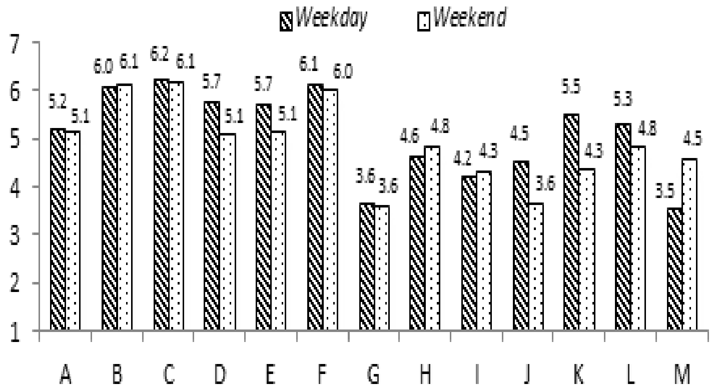

Figure 3. Rating of recreational activities

Remarks:
A= Picnic; B= Sightseeing; C= Enjoying coolness; D= Camping; E= Mountain biking; F= Photo taking; G= Wildlife watching; H= Flora observation; I= Hot-water bathing; J= Horse riding; K= Tracking& climbing; L= Gathering; M= Outbound; 1= Very Low; 2= Low; 3= Ratherlow; 4= Moderate; 5= Rather high; 6= High; 7= Very high

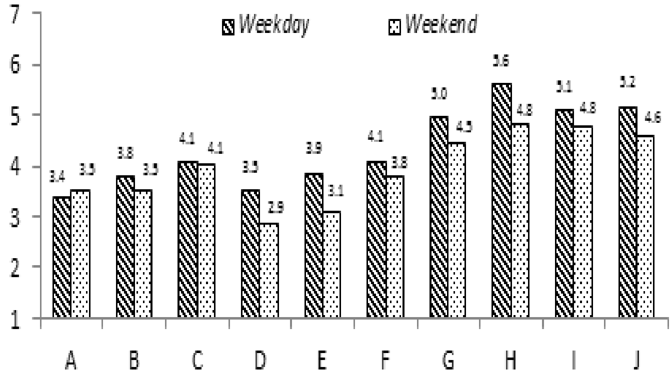

Figure 4. Perception towards environment condition and facilities

Remarks:
A= Road access; B= Parking area; C= Recreational facilities; D= Trash & sanitation facilities; E= Telecommunication network; F= Information & service center; G= Security; H= Green & cleanliness; I= Attitude of the local community; J= Staff's' performance; 1= Very Low; 2= Low; 3= Ratherlow; 4= Moderate; 5= Rather high; 6= High; 7= Very high

lead to lessening visitors' satisfaction "on travel phase"; while the visitors perceived that this tourism area is a strategic and accessible place.

D. Expenditure and Satisfaction

The average expenditure of a weekday visitor was IDR 100,142 and of a weekend visitor was IDR 103,624. Those expenditures were mostly spent for transportation and food; otherwise, the average expenditures on some specific items, like tourism facilities and services, accommodation, souvenir or hot spring services were aggregately low (Figure 5).

Furthermore, most of visitors' expenditure was spent during departing to the site and on returning home phases (Figure 6). The relatively low expenditure at "on site activities" is not just an important indicator of middle-low visitor's budget, but also as a result of uncreative supply of touristic goods and services; such as proper food, drink and even souvenirs.

The visitors' satisfaction towards trip expenditure in each phase is perceived "fair". It indicates that the visitors of GPFTP consider

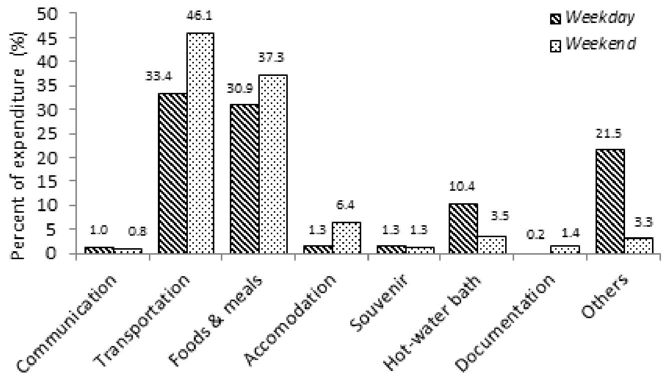

Figure 5. The expenditure proportion of GPFTP visitors based on expenditure items

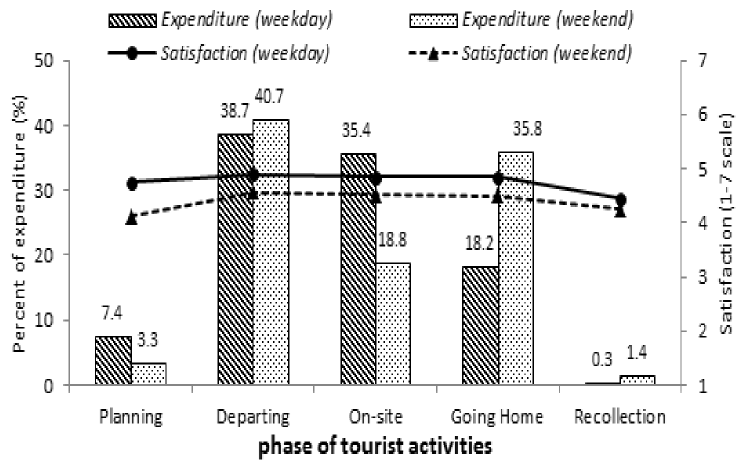

Figure 6. The proportion and satisfaction level of visitors' expenditure based on the phase of tourist activities

the expenditure amount is reasonable so that visitor satisfaction towards tourism expenditure does not give significant influence toward the satisfaction of the whole trip. Therefore it is still possible to increase the tariff of tourism services in optimizing the buying ability.

E. WTP Estimation

Table 5 presents the estimation values of WTP with five scenarios of facility and service development in the GPFTP. All respondents were willing to pay the same or higher than that of the entrance ticket, which is IDR 2,000 as regulated in the PP 59/1998; as the internal reference price that was still applied when the survey was conducted.

There is a quite significant difference between WTP values in each scenario. In other words, respondents are willing to pay more expensive ticket if they got better and more complete facilities and services. It indicates that the visitors show their utilitarian aspects by considering prices, benefits and other attributes in assessing tourism service.

This result of WTP that arises from utilitarian consideration is logically accepted, since tourism services in the GPFTP is a well-known quasi-public and can be compared with other nature tourism objects in the same markets. It is different with any case on public and non-market commodities, since the contingent, where the contingent assessment towards public commodities and services are made based on the consideration of moral satisfaction to contribute toward the preservation of commodities or public

Table 5. The WTP estimation on five scenarios of development on the GPFTP

WTP Est.	Mean[a]	LB Mean[b]	UB Mean[c]	Median	SD	Min.	Max.	$(Q_3\text{-}Q_1)^d$
Scenario 1[e]								
Weekday	8,266.7	7,065.9	9,467.4	10,000	3,215.6	5,000	20,000	5,000
Weekend	6,405.0	5,655.0	7,155.0	5,000	3,779.7	2,000	20,000	3,000
Overall	6,834.6	6,187.5	7,481.8	5,000	3,729.4	2,000	20,000	5,000
Scenario 2								
Weekday	11,716.7	9,964.8	13,468.6	10,000	4,691.7	5,000	25,000	7,000
Weekend	8,825.0	7,924.9	9,725.1	10,000	4,536.3	3,000	25,000	5,000
Overall	9,492.3	8,674.0	10,310.6	10,000	4,715.5	3,000	25,000	5,000
Scenario 3								
Weekday	13,733.3	11,984.2	15,482.5	12,250	4,684.4	7,500	25,000	5,500
Weekend	12,130.0	10,437.9	13,822.1	10,000	8,527.9	3,000	50,000	8,000
Overall	12,500.0	11,142.4	13,857.6	10,000	7,823.4	3,000	50,000	6,250
Scenario 4								
Weekday	15,666.7	13,310.0	18,023.4	15,000	6,311.4	7,500	35,000	10,000
Weekend	14,715.0	12,487.3	16,942.7	10,000	11,227.1	3,000	70,000	8,000
Overall	14,934.6	13,149.3	16,719.9	12,000	10,288.4	3,000	70,000	8,500
Scenario 5								
Weekday	30,833.3	21,312.3	40,354.4	25,000	25,497.9	10,000	150,000	10,000
Weekend	23,715.0	19,209.0	28,221.0	20,000	22,709.0	3,000	150,000	15,000
Overall	25,357.7	21,284.4	29,430.9	20,000	23,473.2	3,000	150,000	15,500

Remarks:
a= Mean of stated WTP in Indonesian Rupiah (IDR); b= Lower-bound mean at 95% confidence interval;
c= Upper-bound mean at 95% confidence interval; d= Interquartile range, 75th percentile minus 25th percentile;
e= See Table 1 for description of each scenario

resources (Kahneman & Knetsch, 1992; Ajzen & Driver, 1992).

The data in Table 5 shows that the average WTP gained from weekday visitors is significantly higher compared to the WTP of weekend visitors. The one-way Mann-Whitney test at 95% confidence interval resulted in each scenario to a conclusion that the weekdays visitors of the GPFTP stated higher WTP compared to weekend/holiday visitors (p-value $< \alpha=0.05$).

Above all, the respondents of GPFTP are willing to pay IDR 6,834.6 for entrance ticket for Scenario 1; IDR 9,492.3 for Scenario 2. These two WTP values of Scenario 1 and 2, when being compared with external reference prices (the price entrance ticket in other nature tourism objects), are more-or-less equivalent with the entrance ticket price of *Tirta Sanita* Hot Spring in Parung District and Ciparay Hot Spring in Tourism Areas of *Gunung Salak Endah*, Western Bogor; both are also in Bogor Regency.

In Scenario 3 and 4, the values of willingness to pay were increasing, IDR 12,500 and IDR 14,934.6 or quite equivalent with the entrance ticket to *Taman Wisata Matahari* (also in Bogor Regency) that is IDR 15,000. While in Scenario 5, the WTP has jumped to IDR 25,357.7. This value is higher than the entrance ticket of *Taman Buah Mekarsari* (IDR 25,000 in Cianjur Regency), but still lower than the entrance ticket price of the most popular hot spring *Sari Ater* in Subang Regency (West Java) that charges IDR 35,000.

F. The WTP Variables

There are 10 of 13 independent variables that have consistent (always same) regression coefficient in every presumption model of

Table 6. Analysis result of Tobit model (dependent variable= stated WTP)

Variables[a]	Scenario 1[b]		Scenario 2[c]		Scenario 3[d]		Scenario 4[e]		Scenario 5[f]	
	Beta	*t*-Stat.	Beta	*t*-Stat.	Beta	*t*-Stat.	Beta	*t*-Stat.	Beta	*t*-Stat.
Constant	1194.48	0.40	9008.81	3.27**	11097.23	2.91**	13860.43	2.85**	21801.57	2.28**
DAY	−1535.41	−1.96*	−2733.35	−3.56**	−3231.28	−3.17**	−3602.22	−2.78**	−6737.90	−2.63**
SEX	798.55	1.20	342.65	0.54	78.03	0.09	340.11	0.30	4405.47	2.02**
MARITAL	−2040.26	−1.49	−25.07	−0.02	−754.51	−0.41	−1756.25	−0.75	−8154.59	−1.78*
AGE	−32.78	−0.73	−3.78	−0.09	−88.20	−1.52	−158.16	−2.15**	−149.14	−1.04
EDU	81.13	0.57	30.10	0.22	53.24	0.30	215.86	0.95	159.64	0.36
HOUSEHN	222.06	0.63	−112.42	−0.32	129.12	0.27	318.30	0.52	710.01	0.59
INCOME	1.66E−04	0.75	3.05E−05	0.27	3.41E−04	1.69*	3.59E−04	2.23**	2.37E−04	2.67**
KNOW	896.33	2.72**	395.97	1.22	967.60	2.23**	952.72	1.71*	1089.38	1.02
TVISIT	−62.84	−1.68*	−45.66	−1.27	−67.74	−1.39	−89.61	−1.44	217.02	1.8*
COSTS	1.91E−03	1.57	2.24E−03	1.95**	9.53E−04	0.60	1.37E−03	0.68	4.16E−03	1.05
TRIPL	146.30	0.50	412.92	1.48	279.73	0.74	218.61	0.45	858.90	0.91
MOTIV	115.20	0.22	261.22	0.51	901.15	1.30	1293.48	1.47	1036.48	0.60
CPERF	649.22	1.16	−308.55	−0.58	−711.50	−0.98	−1301.02	−1.41	−1227.91	−0.68
Sigma	3399.68		3200.25		4407.68		5577.57		10920.54	

Remarks:
a= Please refer to Table 2 for definitions of variables
b= Tobit model 1; N = 122; 5 left-censored observations at WTP <= 2000; 117 uncensored observations; 0 right-censored observations; LR $\chi2(13)$ = 31.17; prob> $\chi2$=0.0032; Log-likelihood = −1199.1048; pseudo R2= 0.0128
c= Tobit model 2; N = 122; 0 left-censored observations at WTP <= 2000; 122 uncensored observations; 0 right-censored observations; LR $\chi2(13)$ = 23.47; prob> $\chi2$=0.0364; Log-likelihood = −1157.7707; pseudo R2= 0.0100
d= Tobit model 3; N = 126; 0 left-censored observations at WTP <= 2000; 126 uncensored observations; 0 right-censored observations; LR $\chi2(13)$ = 26.71; prob> $\chi2$=0.0136; Log-likelihood = −1236.0653; pseudo R2= 0.0107
e= Tobit model 4; N = 124; 0 left-censored observations at WTP <= 2000; 124 uncensored observations; 0 right-censored observations; LR $\chi2(13)$ = 24.08; prob> $\chi2$=0.0304; Log-likelihood = −1245.6354; pseudo R2= 0.0096
f= Tobit model 5; N = 124; 0 left-censored observations at WTP <= 2000; 124 uncensored observations; 0 right-censored observations; LR $\chi2(13)$ = 28.59; prob> $\chi2$=0.0075; Log-likelihood = −1328.9501; pseudo R2= 0.0106
[*] = significant at 90% confidence interval; ** = significant at 95% confidence interval; LR = likelihood ratio

WTP in the five hypothetical scenarios (Table 6). The remaining three variables, the number of dependents (HOUSEHN) has negative coefficient only in Scenario 2, while in the other scenarios this variable is positive. Next, the total numbers of visit to GPFRP (TVISIT) is negative in all scenario models, except in Scenario 5; while the satisfaction towards leisure activities performance in the GPFRP (CPERF) is always negative except in Scenario 1. The type of visiting days (DAY) is the only independent variable that always gives significant influence to all WTP scenario models; while the educational background (EDU), the number of dependents (HOUSEHN), the time needed to reach the GPFRP (TRIPL), the motivation to visit GPFRP (MOTIV) and the satisfaction towards leisure activities performance in the GPFRP (CPERF) variables do not give significant influences to the five presumption models of WTP.

The result of Tobit regression model (see Table 6) is in line with the result of previous similar researches in several countries (Romsa & Blenman, 1989; Davis & Tisdell, 1998; Villalobos-Céspedes, Galdeano-Gómez & Tolón-Becerra, 2002; Tisdell & Wilson, 2005; Pouta, Neuvonen & Sievänen, 2009; Curtin, 2010; Lee, Lee, Kim & Mjelde, 2010), in which WTP values of visitors toward nature tourism products/services are determined by many factors, i.e. age, sex, education level and income. The education variable that has positive coefficient in the scenario model is considered appropriate; since generally educated visitors have sufficient knowledge and high expectation toward the quality of tourism products/services.

Table 7. Ticket price recommendation

Scenario	Total Ticket Price (IDR)	Share for Company[a] (IDR)
1	8,000	3,000
2	10,000	5,000
3	12,000	7,000
4	15,000	10,000
5	25,000	20,000

Remarks:
[a] Company income after being subtracted with non-tax revenue paid to the government

Table 8. Investment analysis

Variable	Scenario 1	Scenario 2	Scenario 3
NPV	715,498,000	2,547,010,000	5,030,956,000
IRR	23.10%	38.11%	83.28%
BCR	2.17	4.00	6.48
BEP	Year-10	Year-5	Year-3

The insignificant influence of education level is strongly predicted related with the well-educated visitors of the GPFTP. Then, the positive coefficient in income variable is in line with other research results that visitors who have higher income are willing to pay more, while visitors who have lower income are sensitive to price changes, and even reluctant to make some purchases in a premium or high price tour (Eagles & Cascagnette, 1995; Jang, Morrison & O'Leary, 2002; Reynisdottir, Song & Agrusa, 2008). Further, in this study the phenomenon of income sensitivity towards premium price is well described in Scenario 3, 4, and 5, where the income level has significantly influenced the WTP. Therefore, the benefits of better service quality are valued higher than that of in Scenario 1 and 2.

The variables of visiting days that significantly influence all five models of WTP can be explained from the visitors' characteristics who visit that day. The "family/outdoor activities seekers" is still the biggest market segment of the GPFTP during weekends/holiday; while "escape/relaxation seekers" are typical visitors on weekdays. The second type of visitors, according to Jang, Morrison, and O'Leary (2002), has willingness to spend more money to fulfill the needs of environment, knowledge and entertainment; so that weekdays visitors have approximately higher WTP compared to weekend visitors. For that reason, the policy of premium price that are mostly based on "lack of access perspective" in peak visits during holidays, can be considered to be changed into a policy that is based on satisfaction level of service and high quality of amenity perspective during a weekday visit.

The result also indicates a insignificant positive correlation between visit motivation variable toward WTP. It also shows negative correlation between recreation activities performance and environment condition variables-which are similar to the research results conducted by Ajzen and Driver (1992) in Massachusetts, USA. In relation to these results, Ajzen and Driver (1992) stated that the cause is moral consideration toward ticket price and emotional experiences related to activities done in the areas.

Negative correlation between number of visits and performance assessment towards WTP values implies that returning visitors and satisfied visitors tend to be reluctant to pay

Table 9. The increase of government non-tax revenue tariff due to PP 12 Year 2014

Component	"Old" Tariff [a] (IDR)	"New" Tariff [b] (IDR)	Increase Rate
Foreign Tourist	15,000.00	100,000.00	567%
Domestic Tourist	2,000.00	5,000.00	150%
Motorbike	1,000.00	5,000.00	400%
Car	1,500.00	10,000.00	567%
Bus/truck	2,500.00	50,000.00	1,900%
Bicycle	1,000.00	2,000.00	100%
Horse	1,000.00	1,500.00	50%
Camping	5,000.00	5,000.00	0%
Jungle tracking	NA	2,500.00	NA
Wildlife-watching	NA	5,000.00	NA
Outbound	NA	75,000.00	NA
Commercial Video	1,000,000.00	10,000,000.00	900%
Handycam	12,500.00	1,000,000.00	7,900%
Photo[c]	3,000.00	250,000.00	8,233%

Remarks:
[a]Based on PP 59/1998
[b]Based on PP 12/2014

premium ticket price; this indicates a potential of the so called "free-rider" problems by Baumol (1952); which is often found in public commodities. This should be fully considered by the management, that even though the free-riders are willing to pay additional cost for better service, in fact they might choose other more affordable tourism objects, which might influence the number of visits to GPFTP. In other words, the increase of WTP among free-riders is vague, since it is merely a warm glow impact (Andreoni, 1990; Bennett & Blaney, 2005).

G. Optional Strategies on Ticket Pricing

Considering those aforementioned research results, the possible ticket price range is described in Table 7. The recommended price is not exactly the same with the WTP values gained from the study, but it is rounded up to ease the transaction of the nominal value that is included in the statistical confidence interval.

IV. CONCLUSION

Results that visitors responses toward ticket price changes in the area of a quasi-public forest tourism park tend to be influenced by the following aspects: (a) day of visit; (b) received information and promotion; (c) the income level of visitors; (d) the perception values toward the quality of recreation resources; and (e) the satisfaction level gained by visitors. The satisfaction level of visitors tends to be influenced by the number of visitors. Visitors have higher satisfaction level when there is lower number of visitors, which is expressed through higher WTP to pay entrance ticket.

In terms of objective assessment actually a multi stakeholder investment is reliable to be done which may lead to a communal benefit. However, it needs an integrity, and willingness to be transparent to each other. Therefore, the government regulation to improve the income through increasing the tariff of entrance ticket should not be refused by the entrepreneur of quasi-public tourism forest. The setting of tariff level should consider the principles of equality, appropriateness, sustainability, and multiple economic benefits on regional mindset instead of just focal point only. Concerning all of the above findings, there are several important chances to improve the Government Regulation on Forestry Related Services Tariff (so called PP 12/2014), i.e. the existing tariff for domestic individual visitor can be increased ranging from 1.4 times to 5 times higher than the tariff in PP 12/2014.

To gain a more comprehensive and objective description of quasi-public forest recreation services in Indonesia, it is suggested to conduct similar research in other forest tourism parks. Knowing that Indonesia has rich and varies tourism parks, similar research should be conducted in four different types of quasi-public tourism forest areas such as national park, wildlife sanctuary, provincial forest park and forest recreational park.

ACKNOWLEDGEMENT

A special appreciation is addressed to the Management of PT. Wana Wisata Indah who has openly provided access and supports to facilitate the study.

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Indonesian Journal of Forestry Research Vol. 3, No. 2, October 2016, 83-94 ISSN: 2355-7079/E-ISSN: 2406-8195

FERTILITY VARIATION OF *Melaleuca cajuputi* subsp. *cajuputi* AND ITS IMPLICATION IN SEED ORCHARD MANAGEMENT

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Received: 16 February 2015, Revised: 16 September 2016, Accepted: 19 September 2016

FERTILITY VARIATION OF *Melaleuca cajuputi* subsp. *cajuputi* AND ITS IMPLICATION IN SEED ORCHARD MANAGEMENT. Information about fertility variation of flowering trees in seed orchard including determining the quality of seed production and estimating the genetic diversity are still lacking. This paper evaluates fertility variation, effective population size and genetic diversity among cajuput trees in seedling seed orchard at Paliyan, Gunungkidul for optimizing seed orchard management. A total of 160 trees were observed in three flowering periods of 2011-2013. The fertility based on the number of flowers and fruits were registered for each tree at the age of 12, 13 and 14 years. Results show that there are similar patterns of fertility after three years observation. Sibling coefficients (Ψ) which show fertility variation during three flowering periods are 1.39, 1.25 and 1.43 respectively. They show deviation from random mating, because of individual imbalance for producing flowers and fruits. However, the number of fertile trees was comparatively higher at 2011. More than 15 families of effective population size were recorded each year and supported more than 75% individuals in seed orchard to contribute flowers and seeds. High value of genetic diversity was calculated based on fertility variation (0.965, 0.967 and 0.957, respectively). Fertility variation led to consequence on seed deployment, including seeds of fertile families which should be collected equally and mixed to compose equal proportion of seeds and to avoid domination of highly fertility families and genetic drift. Silvicultural treatments in seed orchard management were indispensable to promote fertility uniformity and to increase effective population size in seed orchard for obtaining maximal genetic gain.

Keywords: *Melaleuca cajuputi,* seed orchard, fertility variation, effective population size, genetic diversity

VARIASI FERTILITAS Melaleuca cajuputi subsp. cajuputi *DAN IMPLIKASINYA TERHADAP MANAJEMEN KEBUN BENIH. Informasi tentang variasi fertilitas pembungaan di kebun benih meliputi penentuan kualitas produksi benih dan perkiraan keanekaragaman keturunan genetik masih jarang tersedia. Penelitian ini bertujuan untuk mengevaluasi variasi fertilitas, ukuran populasi efektif dan keragaman genetik yang dihitung berdasarkan nilai koefisien sibling (Ψ) di kebun benih kayu putih di Paliyan, Gunungkidul untuk mengoptimalkan pengelolaan kebun benih ke depan. Sejumlah 160 pohon induk di kebun benih dievaluasi berdasarkan jumlah pohon berbunga, jumlah bunga, jumlah buah selama 3 periode pembungaan (2011-2013). Hasil penelitian menunjukkan bahwa variasi fertilitas (Ψ) berturut-turut adalah 1,39, 1,25 dan 1,43. Hal ini mengindikasikan terjadi penyimpangan dari perkawinan secara acak karena ada variasi fertilitas dari pohon-pohon di kebun benih. Pengamatan dalam 3 periode pembungaan menunjukkan pola yang cenderung sama, namun jumlah individu berbunga terbanyak terjadi pada tahun 2011. Ukuran populasi efektif (*Np*) diperoleh 15, menunjukan 15 famili yang didukung oleh 75% pohon-pohon di kebun benih berkontribusi terhadap pembungaan. Keragaman genetik yang dihitung berdasarkan variasi fertilitas menunjukkan angka yang cukup tinggi yaitu diatas 0,9 dalam 3 periode pengamatan. Sebagai konsekuensi akibat variasi fertilitas adalah dalam penyebaran benih perlu dilakukan pencampuran benih dari semua famili yang memproduksi benih dalam proporsi yang seimbang agar tidak terjadi dominasi famili-famili tertentu dan terjadinya damparan genetik (genetic drift). Tindakan manipulasi lingkungan perlu dilakukan untuk mendorong terjadinya keseragaman fertilitas dalam kebun benih sehingga seluruh potensi genetiknya dapat diwariskan.*

Kata kunci: Melaleuca cajuputi*, kebun benih, variasi fertilitas, ukuran populasi efektif, keragaman genetik*

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I. INTRODUCTION

Melaleuca cajuputi subsp. *cajuputi* or cajuput is one of Melaleuca species producing essential oil, mainly 1.8 cineole. It grows naturally in Northern Territory, Western Australia and East Timor (Brophy, Craven, & Doran, 2013). Cajuput plantation is the main source of cajuput oil industry in Indonesia. Breeding program of cajuput carried out by Biotechnology and Forest Tree Improvement Research and Development Institute, Yogyakarta, in collaboration with Commonwealth Scientific and Industrial Research Organization (CSIRO) Australia has established seed orchards in Paliyan, Ponorogo and Cepu. The seed orchards are expected to produce genetically improved seed in an adequate quantity to improve productivity of cajuput plantation. The expected genetic gain 10% of 1.8 cineole content and 21% of oil yield (Susanto, Doran, Arnold, & Rimbawanto, 2003) has been predicted, based on assumption of 100% effective population size. However, variation of fertility and mating system might reduce genetic gain, diversity and vigor of seed crop (Kamalakannan, Varghese, & Lindgren, 2007).

The genetic structure of seed orchard offspring is determined by several factors and processes, namely flowering synchrony, fertility variation, mating system components (inbreeding/outbreeding, pollen dispersal within the seed orchard, and pollen contamination from outside sources), composition and size of the maternal population and viability selection operating on zygotes. The reproduction dynamic in seed orchard (flowering time, fertility variation, pollen dispersal, and mating system) is an important consideration in management of seed orchard to deliver good quality of seed. In reality, asynchrony phenology, fertility variation and pollen contamination are very common in seed orchard, both in conifer and broad leaves species.

Knowledge about fertility variation is important for seed orchard managers, especially with respect to seed production output, and also for prediction of gene diversity (Bila, Lindgren & Mullin, 1999; Kang & Mullin, 2007). Most seed orchard's fertility variation studies have shown that there are fertility variation among trees in a seed orchard, ranged from 1.0 to 41.7 (Kang, Bila, Harju, & Lindgren, 2003). Variation of fertility can influence the genetic gain and genetic diversity of the offspring, hence not all genetic potential is heritable to the offspring.

However, information about fertility variation in seed orchard has not been always available including in cajuput as the species of interest in this study. Therefore, a research was carried out with the main objective to evaluate fertility variation, effective population size and genetic diversity among trees in the seedling seed orchard of cajuput at Paliyan, Gunungkidul.

II. MATERIAL AND METHOD

A. Seed Orchard

The research was carried out at the seedling seed orchard at Paliyan, Gunungkidul, Yogyakarta (at 7º 59'10.4"S latitude, 110º29'10.8

Figure 1. Location of Paliyan Seedling Seed Orchard

''E longitude and 150 m altitude, annual rainfall 2,000 mm) (Figure 1). It was established in 1998 using Randomized Complete Block Design with 19 families (hal-sib) consisting of 10 tree plots (line plots) per family and 10 blocks as replication (Table 1). The seed orchard covers an area of 0.5 ha with initial spacing of 3m x 1.5m. After final thinning, this seed orchard consisted of 160 individuals.

B. Assessment of Flowering

Flower and fruit production were recorded during three flowering periods (2011-2013). An assembled bamboo ladder was used to climb to the top of the tree for data collection (Figure 2). The number of primary, secondary and tertiary branches was counted in each sample tree. The number of flowers in one inflorescence was recorded based on 10 samples collected from inflorescences in each tree. The total numbers of flower and fruit of each tree were obtained by extrapolating the count made on fruits in top crown, middle and lower crown (Bila et al., 1999; Kang & Lindgren, 1999). Observation was conducted at peak flowering.

C. Variation in Fertility

Cajuputi flowers was categorized as hermaprodite. Male and female fertility of a tree is measured by the estimated number of flowers and fruits respectively produced by the tree. Gender fertilities were calculated as the number of reproductive structures (flowers and fruits) produced by a tree relative to the total structures produced by all trees. It was computed based on the estimated number of flowers (assumed to be equal to male fertility) and fruits (assumed to be equal to female fertility) for each tree. Total fertility of a tree (*pi*) was taken as the average of the male (*mi*) and female (*fi*) fertilities of each tree. Sibling coefficient (*Ψ*) is the probability that two genes randomly drawn from the gamete gene pool originates from the same parent compared to the probability if the parents have equal representation (Kang & Lindgren, 1999). Sibling coefficient is a measure used to describe fertility variation among the trees in a population. It is calculated from the number of families in the orchard (*N*) and individual fertility (*pi*) of each family as the following:

Figure 2. Picture of branches of *Melaleuca cajuputi* subsp. *cajuputi*

Table 1. Detail information of cajuputi families using as material in Paliyan SSO

No Family	Seedlot	Oil content (W/W % DW)	*Cineole* (%)	Provenance name	Latitude (°S ')	Longitude (°E ')	Altitude (m)
1	MM2033	3,88	47	Ratagelombeng, Buru	03º08'33"	126º54'36"	40
2	MM2054	2,53	62	Masarete, Buru	03º22'38"	12708'12"	20
3	MM2057	2,45	59	Masarete, Buru			
5	MM2060	2,84	59	Masarete, Buru			
25	MM2064	1.01	32	Masarete, Buru			
8	BVG2913	3,35	47	Waipirit, Seram	03º19'43"	128º20'20"	10
9	BVG2919	3,02	57	Pelita Jaya, Seram	03º03'00"	128º08'00"	100
10	BVG2920	2,79	52	Pelita Jaya, Seram			
11	BVG2923	1,82	67	Pelita Jaya, Seram			
12	BVG2936	2,82	64	Cotonea, Seram	03º37'02"	128º18'40"	60
13	BVG2937	1,82	54	Cotonea, Seram			
14	BVG2941	2,93	60	Cotonea, Seram			
18	BVG2973	2,32	59	Suli, Ambon			
19	DL786	2,78	59	Wangi, NT Australia	13º09'00"	130º35'00"	30
20	DL1705	2,96	55	Port Keats, NT Australia	14º14'02"	129º31'11"	5
21	DL1787	4,85	47	Beagle Bay, W Australia	16º58'33"	122º40'04"	10
22	DL1797	3,47	52	Beagle Bay, W Australia			
23	DL1803	3,59	58	N Broome, W Australia	17º46'00"	122º16'00"	10
24*	Gundih ptn			Gundih Cent. Java	07 11'07	110 54'19"	60

$$\psi = N\sum_{i=1}^{N} p_i^2 \tag{1}$$

A maternal sibling coefficient (*Ψf*) and a paternal sibling coefficient (*Ψm*) can be given as (Kang & El-Kassaby, 2002):

$$\psi_f = N\sum_{i=1}^{N} f_i^2 \tag{2}$$

$$\psi_m = N\sum_{i=1}^{N} m_i^2 \tag{3}$$

D. Co-ancestry and Effective Population Size

Group Co-ancestry (Θ) is the probability that two genes chosen at random from a gene pool are identical by descent. If the trees are non-related and non-inbred, all pair co-ancestries are equal to zero and all self co-ancestries are equal to 0.5. Group Co-ancestry is calculated using the methods from Lindgren and Mullin (1998) in Varghese, Nicodemus, Nagarajan, and Lindgren (2006):

$$\Theta = 0,5\sum_{i=1}^{N} p_i^2 \tag{4}$$

The effective population size (*Np*) is independent of how parents are related or inbreed, the status number depends on the relatedness of the parent. It is practical to have a unique term for effective number based on fertility variation among parents only. *Np* is equivalent to the status number (*Ns*) of a seed orchard where families are unrelated and non-inbred (Lindgren & Mullin, 1998). *Np* is calculated as follows (Kang & Lindgren, 1999):

$$N_p = \frac{N}{\psi} \tag{5}$$

E. Genetic Diversity

Genetic diversity is the function of the group co-ancestry and can be calculated in the orchard relative to a reference population. The reference population (natural forest) has zero group co-ancestry as it is considered to have an infinite number of unrelated individuals (Varghese et al., 2006). The genetic diversity (*GD*) is calculated as follows:

$GD = 1 - \Theta$ ....(6)

III. RESULT AND DISCUSSION

A. Variation of Fertility

Observation during three flowering periods in cajuput seedling seed orchard showed significant number of flower, fruit and fruit-set which contributed 143 (89%) individuals in 2011; 113 (70%) individuals in 2012 and 121 (76%) in 2013. Fertility variation, effective population size and genetic diversity in three flowering seasons are shown in Table 2.

If each individual in cajuput seed orchard had the same fertility value (Ψ), it would be equal to 0.00625. In fact, the fertility value of individuals ranged from 0 to 0.031. This indicates unequal contribution among individuals in seed production. The same trend was obtained in fertility observation in consecutive year. Dominant individuals in seed production impacted on genetic variation as a majority of seed produced from seed orchard. The observation in 3 successive years of flowering periods showed low variation of total fertility ((Ψ)=1.25 – 1.47) while female fertility variation (Ψf) varied between 1.59 – 1.71 Male fertility (Ψm) showed varied 1.40 to 1.75, almost similar to female fertility. These indicate balance in fertility between female and male, as available pollen was sufficient for fertilizing the ovule.

Although fertility variation and number of trees producing flower decreased between 2011 and 2012, the fruiting ability increased to 15%, which was possibly due to the climatic factors. The total precipitation and the rainy days in each year would have an impact on fertility of trees. Lower precipitation in 2012 (1,904 mm) compared to precipitation in 2011 (2,163mm) (Dinas Tanaman Pangan dan Perikanan, 2012, 2013) was received in location during the observation periods. Therefore, pollinator activity might be more intensive in 2012 and fertilization could be optimized. During the same periods, it showed low deviation of the

Table 2. Average of diameter, height, flower, fruitset, fertility variation, effective population size and genetic diversity of cajuput seedling seed orchard at Paliyan, Gunungkidul

Remarks	Observation in 2011	Observation in 2012	Observation in 2013
Age (yr)	12	13	14
Average diameter (cm)	14.3	14.9	15.4
Average height (cm)	7.80	8.01	8.75
Average flower per tree	2116	1622	1967
Average fruit per tree	1293	825	1063
Average fruitset	0.53	0.68	0.61
Number of trees	160	160	160
Fertile trees (%)	89	70	76
Male fertility variation (Ψ_m)	1.545	1.405	1.75
Female fertility variation (Ψ_f)	1.710	1.599	1.63
Total fertility variation (Ψ)	1.392	1.250	1.47
Coancestry (θ)	0.035	0.033	0.043
Ns (Status number)	15.1	14.9	15.4
Genetic diversity	0.965	0.967	0.957

daily average of air temperature (24ºC in the morning to 30ºC in the afternoon) and air humidity (70% in the morning and decreased to 56% in the afternoon) (Dinas Tanaman Pangan dan Perikanan, 2012, 2013). This low deviation did not influence pollinator activities.

Kang et al. (2003) reported that a sibling coefficient of 2 would be typical in good or moderate flowering years in mature seed orchard. Recent study on cajuput seed orchard in Paliyan, Gunungkidul revealed fertility variation of 1.39. This indicates that there was a deviation of 1.39 times from random mating to inbreeding. The deviation from random mating might be due to flowering asynchrony, family arrangement, and combining abilities or pollen contamination; so that it changed the allele frequency in a population (Kang & Mullin, 2007). The sibling coefficient (Ψ) expresses the increase in the probability that sibs or relatives occur in comparison to the ideal situation where families have equal fertility. Codesido and Fernandez-Lopez (2014) mentioned if there was a perfect positive correlation (r = 1) between gender fertilities, the sibling coefficients for maternal, paternal and total fertility were the same ($\Psi = \Psi f = \Psi m$). On the other hand, if there was a perfect negative correlation (r = -1), the sibling coefficient for total fertility equals one ($\Psi = 1$) and $\Psi f = \Psi$m. In dioecieus, species female fertility and male fertility are usually unbalanced. When the difference in fertility between genders is large, it may significantly affect the gene diversity of the offspring in seed orchard (Ertekin, 2010; Kang, & Kim, 2012). In this study, observations in three consecutive years showed low variation of fertility in cajuput seed orchard at Paliyan, Gunungkidul, and indicated similarity of fertility, included between female fertility and male fertility. In general, fertility variation tends to be small and effective large number of good seed production. Assessment in three successive years (2011- 2013) indicated high seed production and low fertility variation.

Fertility of trees may change from time to time. The previous research showed that fertility of trees is an interaction of 2 major factors. The first factor is genetics (Gömöry, Bruchanik, & Paule, 2000) and environment, which includes precipitation, temperature, and days length (Lesica & Kittelson, 2010; Giménez-Benavides, García-Camacho, Iriondo, & Escudero, 2010). The second factor is seed orchard management practices, including top prunning, fertilizer and hormone application for flower stimulation (Cherry, Anekonda, Albrecht, & Howe, 2007). Fertility variation also occurs in seed orchard of some species, such as *Eucalyptus camadulensis* and *E. tereticornis* (Kamalakannan et al., 2007), *Chamaecyparis*

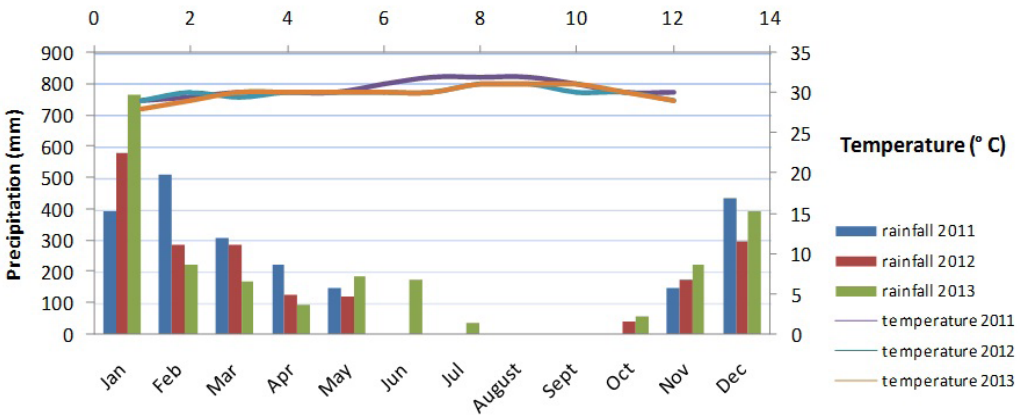

Figure 3. Profile of precipitation and temperature at Paliyan 2011-2013

obtusa in Korea (Kang & Mullin, 2007); *Tectona grandis* in India (Varghese, Kamalakannan, Nicodemus, & Lindgren, 2008); *Tectona grandis* in Cepu, Indonesia (Sumardi, 2011) and some pines (Bilir, Kang, & Ozturk, 2002; Bilir, & Temiraga, 2012).

The assessment of fertility variation in 3 successive years indicated that flowering time and duration may depend on a large extent of temperature increase, and mainly on water availability. In the first year of assessment (2011), the stand which received rainfall 2,163 mm/year (Dinas Tanaman Pangan dan Perikanan, 2012), showed longer duration and more abundant of flowering production compared to the second assessment (2012) which had rainfall of 1,904 mm/year (Dinas Tanaman Pangan dan Perikanan, 2013). While in 2013, the stand received rainfall 2,317 mm/year (Dinas Tanaman pangan dan Perikanan, 2013). Profile of precipitation and temperature at Paliyan is shown in Figure 3. The same phenomenon was also occurred in *E. camadulensis* at Panampally, India (Varghese, Kamalakannan, Harwood, Lindgren, & McDonald, 2009), which was flowering more abundantly in wet season. Young, Boshier, and Boyle (2000) mentioned that in some cases, flowering in environment with higher humidity appeared to be delayed. However, it was followed by prolonged flowering time and more abundant of flowers. In contrast, rainfall could hamper the pollination and fertilization success through decreasing pollinator activity and stabilizing fertilization process. Baskorowati, Moncur, Cunningham, Doran, and Kanowski (2010) reported that fertilization in *Melaleuca alternifolia* occurred 4 days after pollination. As *M. cajuputi* has close relationship with *M. alternifolia*, they are likely to have similar timing phenomenon of fertilization. This study revealed that peak flowering occur during very dense precipitation, with 24 days rainfall in a month.

The site condition is influenced by not only plant growth, but also fertility of individuals. Establishment of seed orchard is usually located in a similar site to plantation distribution of the species, such as establishment of cajuput seed orchard in Paliyan, Gunungkidu*l*. It has similar micro site to the extensive plantation of cajuput established by Forest District of Gunungkidul. The seed orchard is located 150 m above sea level at 7º59'10.4"S and 110º29'10.8"E. The local climate is categorized as Type C according to Schmidt and Fergusson, with the precipitation of 2,100 mm per year, and soil texture is categorized as clay loam. The genetic materials for establishing cajuput seed orchard are originated from Buru Island, Ambon Island, Seram Island, Western Australia, Northern Australia and Gundih. Similar soil texture and microclimate in Gundih (Central Java) and Paliyan (Gunungkidul) supported that seedlots from Gundih were more adaptive and produced more flowers and fruits abundantly in comparison to the others. On the contrary, seedlots from Western Australia and Northern Australia were difficult to adapt to different climate and geographical condition. Of the nineteen seedlots in seed orchard studied, seedlot no 24 (from Gundih) has the best fertility, while seedlot no 21 (from Australia) has the worst fertility.

Domestication process of a species led to changes in physiology of plant, including the fertility. Individuals with high value of fertility tend to be selected for domestication, so that seed orchard or artificial plantation should have low variation of fertility. Varghese et al., (2009) reported that *Eucalyptus camaldulensis* in Panampally, India, increased fertility in the first generation of seed producing area after domestication process. Fertility variation among individuals influences the different contribution of gamets. Individuals with higher value of ertility contributed more gamets. Flowering as representation of fertility value of each individual leads to changes in pattern and level of genetic variation within population through fruit and seed production (Young et al., 2000).

B. Genetic Diversity and Effective Population Size

The observation during three flowering periods showed variation number of flowering individuals in peak flowering time. Examination conducted in 2011 showed that out of 160 trees in the seed orchard, 143 trees contributed to seeds production during peak flowering period. It indicated that 89% trees took part in seed production. On the contrary, examination conducted in 2012 resulted in slightly decreasing number to only 113 (70%) flowering individuals during peak flowering time. However, observation in 2013 resulted in increasing number of flowering trees.

Genetic diversity predicted based on the fertility on three observation periods is categorized to high value (*GD*=0.96). It is a valuable asset for development of the next generations of seed source. Genetic diversity of seeds produced by seed orchard is influenced by many factors, including fertility variation among individuals, flowering synchrony, mating system, compatibility among individuals, and pollen contamination from outside of seed orchard (Lai et al., 2010); (Machanská, Bajcar, Longauer, & Gömöry, 2013). The maximum genetic diversity within seed orchard (*GD*= 1) will be achieved if all individuals in seed orchard contributed to produce seed equally. This assumption is virtually never fulfilled and is commonly observed that seed orchard produced seeds disproportionately due to small portion of flowering trees.

Kartikawati, (2015) reported flowering synchrony at Paliyan seedling seed orchard in 2011-2012 tend to synchrone. About 70-80% mother trees in the seed orchard producing flower at the same time. Furthermore, Kartikawati, Naiem, Hardiyanto, and Rimbawanto (2013) observed mating system di Paliyan seedling seed orchard in 2011 mentioned that there is random mating in that seed orchard. However, this research indicates that fertility rate among individual trees is uneven due to domination of several families. Uneven contribution was possibly due to fertility variation and flowering asynchrony in seed orchard (Gates & Nason, 2012). Kang, Lindgren, and Mullin (2001) also confirmed that variation of fertility lead to increase inbreeding and reduce diversity in produced seeds. Therefore, genetic diversity of seed orchard is often not equal to produced seed at any time. The most important factors that determine the genetic diversity of seeds from seed orchards is the quality of flowering and flowering synchrony (Chen & Hsu, 2011). Early and late flowering individuals tend to be pollinated by related individuals or even individuals outside seed orchard with synchronous flowering phenology.

If all individuals had relatively the same fertility values, the genetic diversity of produced seed will be equal to one. The genetic diversity of produced in cajuput seed orchard at *Paliyan* was equal to 0.96. It indicated a reduction in the genetic diversity of 0.04. The uneven fertility in seed orchard of *E. tereticornis* leads to reduce 4.2% of genetic diversity in the second generation and 4.4% in the third generation (Varghese, Ravi, Gu Son, & Lindgren, 2003). Kang et al. (2005) also confirmed that decreasing genetic diversity in seed orchard from a generation to generation was due to fertility variation. However, the genetic diversity of cajuput seed orchard in Paliyan is categorized as high. The high genetic diversity will support future adaptability of the species.

Effective population size as a parameter which is closely correlating with the genetic and genotypic diversity of the seed orchard output is an important indicator of seed orchard function. Parent effective population size (Np) of cajuput seed orchard in Paliyan was calculated based on fertility variation data which showed high values of parent effective population size in both flowering seasons observation of 2011 (Np=15.1), 2012 (Np=14.9) and 2013 (Np=15.4). It indicated that there were 15 families in cajuput seed orchard that contributed relative evenly in gamet availability.

Effective population size influences generative reproduction of a certain species, which is closely related to flowering, pollination, and fertilization aspects. Kartikawati et al. (2013) reported that supported by a large number of effective population size, panmixia random mating occur in *M. cajuputi* seed orchard. These factors will significantly determine seed production success, in term of its quality and quantity. A large effective population size allows to maintain genetic diversity. On the contrary, small effective population size increases the chances of inbreeding or selfing, and causes inbreeding depression. If effective population size was less than ten, the decreasing of genetic diversity on the next generation will mainly be influenced by genetic drift and very small fertility variation (Kang et al., 2001). Consequently, the decrease in seed genetic diversity will have a direct effect on the planted forest genetic diversity.

C. Implications for Optimizing Seed Orchard Management

Evaluation results on fertility variation, effective population size, and genetic diversity are essential to scientifically support the management of cajuput seed orchard at Gunungkidul. In general, based on the performance of cajuput seed orchard, including a lot of fertile trees (more than 75%), low variation of fertility (1.25 – 1.47), high genetic diversity of offspring (0.96), and large effective population size (*Nep*=15.4), are highly recommended to harvest the seeds and deploy them in an operational scale of plantation. The observation on *Eucalyptus nitens* stand in South Africa with more than 40% of flowering trees resulted better growth performance of their offspring (Swain, Verryn, & Laing, 2013).

The fertility variation of cajuput seed orchard indicated deviation from random mating by 1.39 times (observation in 2011), 1.25 times (observation in 2012) and 1.47 times (observation in 2013). The deviation was influenced by individual imbalance of flowering and fruiting productivity. Although the deviation is categorized as low, improvement of seed orchard management is important in order to promote fertility balance of individuals in the cajuput seed orchard.

Branch and top pruning of cajuput is essential in order to shape wide and low tree canopy and to promote growth of lateral branch to increase flowering and fruiting, so that seed production could be developed. It has been applied in several plants (Lawande, Haldankar, Dalvi, & Parulekar, 2014). Fertilizing and hormone might be applied to stimulate and preserve flowering. Hormone application to stimulate flowering using paclobutrazole was proven to increase fertility and the number of capsules in some species of *Eucalyptus* (Varghese et al., 2009). This method could be applied to cajuput with adjusted-dose use.

The observation in three flowering periods resulted fertility variation and difference number of trees contributed to produce seeds. Management strategy should be adopted to anticipate fertility variation in difference flowering times. Seed harvesting should be maintained in the same volume for each tree to avoid the domination of certain families and to prevent genetic drift. The seeds domination of certain families stimulates the accumulation of genetically related seeds and the reduction of genetic diversity. Another strategy is to mix the seed crops of different harvesting times in order to maintain genetic diversity and effective population size in seed orchards.

IV. CONCLUSION

The observation on flowering and fruiting time during 2011, 2012, and 2013 showed that most individuals (80-89%) in seed orchards contributed to produce seeds with fertility variation of 1.39, 1.25 and 1.47 respectively. The genetic diversity remains high (0.96) for three observation periods, with relative stable effective population.

Silvicultural treatments such as fertilization, branch pruning, and hormone paclobutrazole may be applied subject to prior experimental results. They are essential to homogenize the fertility rate and to obtain genetic improvement as expected. Fertility dynamics should be observed in some flowering periods to detect certain families that either are dominant or do not contribute in producing seeds. Management strategy in the application of genetically improved seed should be adjusted in order to maintain (even to increase) the genetic diversity of the planted forest.

ACKNOWLEDGEMENT

The author is very grateful to Prof. Moh. Na'iem, Dr. Eko Bhakti Hardiyanto, and Dr. Anto Rimbawanto for their invaluable comments and supports. The author would also like to express gratitude to Sunaryanto and Sunar for their help and support on data collection.

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Indonesian Journal of Forestry Research Vol. 3, No. 2, October 2016, 95-106 ISSN: 2355-7079/E-ISSN: 2406-8195

EFFECT OF GAMMA IRRADIATION ON SEED GERMINATION, STORAGE, AND SEEDLING GROWTH OF *Magnolia champaca* L.

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Received: 2 September 2015, Revised: 18 October 2016, Accepted: 21 October 2016

EFFECT OF GAMMA IRRADIATION ON SEED GERMINATION, STORAGE AND SEEDLING GROWTH OF *Magnolia champaca* L. Gamma irradiation of seeds is known as an important factor in stimulating biochemical and physiological processes. This paper investigates the effect of seed irradiation on the seed germination, storability, and seedling growth traits of *Magnolia champaca*. Seeds were irradiated with 0, 5, 10, 15, 20, 40, 60, 80 and 100 Gy by Cobalt-60. The treated seeds were grouped into three lots, namely germination test, storage test and seedling growth characteristics. Observations were made for seed germination percentage, germination index, mean germination time, germination value and growth traits such as height, collar diameter, number of leaves, root length, and dry weight. Results showed that irradiation at a dose of 30 Gy was close to LD50, and irradiation at doses of 80 Gy and higher caused lethal effect. The maximum increase of germination parameters on irradiated seed was recorded at a dose of 10 Gy, and then it decreased. Growth rate in terms of seedling height, collar diameter, number of leaves, and dry weight have also increased in gamma irradiation doses up to 80 Gy, but the dose of 10 Gy resulted in survival and growth that was more stable and gave the highest values for most of the parameters. Hence, lower dose (10 Gy) of irradiation treatment can be used to increase seed germination, storability and seedling growth of *M. champaca*.

Keywords: *Magnolia champaca,* gamma irradiation, germination, growth

PENGARUH IRADIASI SINAR GAMMA TERHADAP PERKECAMBAHAN, PENYIMPANAN BENIH, DAN PERTUMBUHAN BIBIT Magnolia champaca L.. *Iradiasi sinar gamma pada benih diketahui sebagai salah satu faktor yang dapat merangsang proses biokimia dan fisiologi. Tulisan ini menyelidiki pengaruh iradiasi terhadap perkecambahan, daya simpan benih, dan karakter pertumbuhan bibit* Magnolia champaca. *Benih diiradiasi dengan dosis 0, 5, 10, 15, 20, 40, 60, 80, dan 100 Gy dengan Cobalt-60. Benih-benih yang diiradiasi dibagi kedalam 3 kelompok perlakuan, yaitu untuk uji perkecambahan, uji penyimpanan, dan uji karakteristik pertumbuhan bibit. Pengamatan dilakukan untuk parameter daya berkecambah benih, indeks perkecambahan, waktu berkecambah rata-rata, nilai perkecambahan, dan karakter pertumbuhan bibit seperti tinggi, diameter pangkal akar, jumlah daun, panjang akar, dan berat kering total. Hasil penelitian ini menunjukkan bahwa iradiasi pada dosis 30 Gy diduga telah mencapai LD50, dan iradiasi pada dosis 80 Gy telah menyebabkan kematian sebagian besar benih. Peningkatan parameter perkecambahan benih tertinggi terjadi pada dosis 10 Gy, dan kemudian perkecambahan mengalami penurunan. Laju pertumbuhan dalam bentuk tinggi bibit, diameter pangkal akar, jumlah daun, dan berat kering total juga meningkat pada dosis iradiasi sinar gamma hingga 80 Gy, namun dosis 10 Gy menghasilkan persen hidup dan pertumbuhan yang lebih stabil dalam menghasilkan nilai tertinggi untuk sebagian besar parameter. Dengan demikian, perlakuan iradiasi dosis rendah (10 Gy) dapat digunakan untuk meningkatkan perkecambahan, daya simpan, dan pertumbuhan bibit* M. champaca.

Kata kunci: Magnolia champaca*, iradiasi gamma, perkecambahan, pertumbuhan*

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 doi: https://doi.org/10.20886/ijfr.2016.3.2.95-106

I. INTRODUCTION

Magnolia champaca (synonym *Michelia champaca* L. family: Magnoliaceae), locally known as cempaka kuning and bambang lanang, is a tree with golden-yellow fragrant flowers and aggregate fruits. This species is native to Indonesia, globally distributed in the Indo-Malaya ecozone. Within Indonesia it is distributed in Sumatra, Kalimantan, Sulawesi and the Lesser Sunda Islands (Sosef, Hong, & Prawirohatmodjo, 1998). This species produces timber for construction, furniture and plywood (Lukman, 2011; Kimho & Irawan, 2011) and various parts of the plant possess anti-inflammatory, antimicrobial, antioxidant and antimicrobial activities (Kumar, Kumar, Shashidhara, Anitha, & Manjula, 2011). In several areas such as South Sumatra and North Sulawesi, *M. champaca* is an important tree for cultivation. Propagation of *M. champaca* still has some problems due to poor seed storage and seedling viability. The seed propagation is time consuming (slow germination: 5 weeks to 4 months to germinate) and generally low percentage of germination and quick loss of viability (Zabala, 1990; Hossain & Nizam, 2002; Candiani, Galetti, & Cardoso, 2004). The species has been reported to be recalcitrant or intermediate due to its relatively short life span (Bisht & Ahlawat, 1999; Fernando, Jayasuriya, Walck, & Wijetunga, 2013). Chemical or physical seed treatments will be needed for enhancing germination. Gamma irradiation, one of the physical treatments, can be useful for altering its physiological characters (Kiong, Lai, Hussein, & Harun, 2008) and improving germination and seedling growth.

Gamma irradiation is one of the common practices to induce genetic variation in many plant species (De Micco, Arena, Pignalosa, & Durante, 2011; Moussa, 2011) including tree species (Iglesias-Andreu, Octavio-Aguilar, & Bello-Bello, 2012). It has a profound influence on plant growth and development by inducing genetical, cytological, biochemical, physiological and morphogenetic changes in cells and tissues depending on the levels of irradiation (Ikram, Dawar, Abbas, & Javed, 2010). The material and energy necessary for initial growth is already available in the seed, but some stimulants are required to activate those substances already stored in the cotyledons. Low doses of irradiation may increase the enzymatic activation and awakening of the young embryo, which results in stimulating the rate of cell division and affects not only the germination, but also the vegetative growth (Sjodin, 1962; Piri, Babayan, Tavassoli, & Javaheri, 2011).

The biological effect of gamma radiation is mainly due to the formation of free radicals by the hydrolysis of water, which may result in the modulation of an anti-oxidation system, accumulation of phenolic compounds and chlorophyll pigments (Wi et al., 2007; Ashraf, 2009). Treatment of tree seed with low dose gamma irradiation has been found to improve seed germination and seedling growth (Iglesias-Andreu et al., 2012). Enhancement of germination and growth along with plant metabolites, using irradiation technology, could be employed for improving the quality of seed, including their seedling growth. Furthermore, gamma irradiation has been applied to achieve a delay in the ripening of some fruits (World Health Organization & Food and Agriculture Organization of the United Nations, 1988), to reduce bacterial populations, fungi, insects and other germination pathogens (Gruner, Horvatic, Kujundzic, & Magdalenic, 1992) so it can be applied to increase the seed storability.

Despite the usefulness of ionizing irradiation to increase the germination potential and generating useful mutations in agricultural crops, there are not many references in the literature on the use of nuclear techniques on forest tree species (Iglesias-Andreu et al., 2012) because most of the seed germination studies of forest tree species were carried out by physical and/or chemical pre-sowing treatments. The irradiation techniques focused more to generate the variation for mutation breeding purposes. It is well known that the sensitivity of plants to irradiation are dependent on many factors such as plant species or varieties, plant parts, and irradiation dose (Esnault, Legue, & Chenal, 2010; De Micco et al., 2011). Hence, this paper investigates the effects of gamma rays on the germination of seeds, growth, and biochemical attributes of *M. champaca* seedlings.

II. MATERIAL AND METHOD

A. Materials

Mature fruits of *M. champaca* were collected from the identified seed source of Talang Pelawi, Muara Payang Village, Sub-district *Jarai*, District Lahat, South Sumatra in February 2011. The application of Cobalt-60 gamma irradiation (Gamma Chamber 4000A-Irpasena, India) was conducted at the Center for the Application of Isotope and Radiation Technology, National Nuclear Energy Agency, Jakarta, Indonesia. The seed germination and seedling growth tests were conducted at the Laboratory of Forest Tree Seed, Forest Tree Technology Research Institute, Bogor between March to September 2011.

B. Gamma Irradiation

Seeds were extracted based on wet extraction method as stated by Bonner, Fozzo, Elam, & Land, (1994) and the seeds were dried in room temperature to reach 10-12% moisture content. Fresh, uniform and healthy seeds were irradiated with 0, 5, 10, 15, 20, 40, 60, 80 and 100 Gy of gamma irradiation from Cobalt-60 (1 Gy = 100 rad) (Piri et al., 2011). The treated seeds in each dose were divided into three groups, germination test, storage test and seedling growth characteristics assessment.

C. Effect of Gamma Irradiation on Seed Germination and Seed Storage

For germination test, all the treated seeds were sowed on top of the straw paper in the germination box (IPB 73/1, Bogor Agricultural University). Each treatment was replicated four times with 50 seeds in each replicate and arranged in a randomized complete design.

Other treated seeds were stored in the refrigerator (temperature 4°C, relative humidity 40-50%) for 3 months. Seeds were packed in porous cloth bag. Each treatment was replicated four times with 50 seeds in each replicate and arranged in a randomized complete design. Similar parameters with germination test were measured for assessment of seed germination after storage.

The number of germinated seeds was counted every day. Final germination time was defined as the day when no further germination occurred for four successive days (Xu et al., 2016). Germination index (*GI*) and mean germination time (*MGT*) were calculated using the method of Czabator (1962), Ruan, Xue, & Tylkowska (2002) and Akinci & Akinci (2010). The germination value (*GV*) is an index combining speed and completeness of germination where larger values indicate faster and more complete germination (Czabator, 1962; M. A. Hossain, Arefin, Khan, & Rahman, 2005). The traits were calculated as follows:

$$GP = G/T \times 100 \quad (1)$$

$$GI = \Sigma(Gt/Tt) \quad (2)$$

$$MGT = \Sigma TtGt/\Sigma Gt \quad (3)$$

$$GV = (\Sigma DGs/N) \times GP/10 \quad (4)$$

where *GP* is the germination percentage at the end of experiment, *G* is the total number of germinated seeds, *T* is the number of sowed seeds, *Gt* is the number of newly germinated seeds on day *t* and *Tt* is the number of days, *DG* is the daily germination speed obtained by dividing the cumulative germination percentage by number of days since sowing, Σ*DGs* is the total germination obtained by adding every *DG* value obtained from the daily counts, *N* is the total number of daily counts starting from the first germination, and 10 is constant. The lethal dose 50 (LD50) was calculated following regression of the germination data per cent lethality over control of gamma rays doses (Singh & Balyan, 2009).

D. Effect of Gamma Irradiation on Seedling Growth

Subsequently, the irradiated seeds (fresh/non storage seeds) of *M. champaca* and their corresponding controls were sowed separately under greenhouse conditions in germination boxes containing a mixture of forest soil and sand in a 1:1 volume/volume. After 40 days in the germination box, seedlings were transplanted into polythene bags (diameter 12 cm, height 15 cm) and arranged in a randomized block design with six replications. Twenty seedlings formed a square for each replication. When the seedlings were 6 months in the nursery, the seedlings were measured regarding height, root collar diameter, number of leaves, tap root length, above ground and belowground biomass, total biomass, and sturdiness quotient. For biomass measurements, all plants were harvested and divided into roots, stems and leaves. Roots, stems and leaves were dried separately in a drying oven at 70°C for 48 hours and weighed to ±0.0001 g. Leaves and stems were aggregated and are subsequently referred to as aboveground biomass and roots are referred to as belowground biomass. Total biomass is the sum of aboveground and belowground biomass. The sturdiness quotient is the height (*h*) in centimeters divided by the stem diameter (*d*) in millimeters (Thompson, 1985).

E. Data Analysis

The data were analyzed using IBM SPSS (v21) statistical software (SPSS Inc. Chicago, IL, USA) following a randomized, complete block design. The mean values were compared using Duncan's Multiple Range Test (DMRT) at 0.05% level of probability.

III. RESULT AND DISCUSSION

A. Effect of Gamma Irradiation on Seed Germination and Storability

The irradiated *M. champaca* seeds, both without and with storage in refrigerator for 3 months, have shown a significant increase in the germination percentage, germination index, mean germination time, and germination value compared to control, but then the parameters tended to decrease by increased irradiation doses (Table 1). Similar trend was reported by Iglesias-Andreu et al. (2012) in *Abies religiosa*, the percentage of germination increased with increased frequency of mutation up to 10 Gy and then decreased gradually with increased gamma ray dose. Habba (1992) in *Hyoscyamus muticus* seed reported that by increasing the dose of gamma rays it has gradually increased the germination percentage up to 100 Gy. Marcu, Cristea and Daraban (2013) and Bodele (2013) also reported increasing germination parameters in low doses of gamma ray irradiation as compared to untreated plants. Responses of increased doses of gamma rays on germination traits were different among species.

The maximum increase of germination percentage and germination index on irradiated fresh seeds of *M. champaca* was recorded at 10 Gy with an increment percentage of 9.4% from control for germination capacity and increment percentage of 30% from control for germination index. For storage of irradiated seeds, the maximum increase of germination capacity was also recorded at 10 Gy (increase 34.1% to control) and for mean germination time and germination value, an increase was observed up to 15 Gy, and then it decreased. For both irradiated fresh and stored seeds, the dose of 10 Gy showed the highest values for all germination parameters (Table 1 and 2). Aynehband and Afsharinafar (2012) reported a significant increase in the germination, which was the speed of emergence of seedlings, in three amaranth lines observed after pre-sowing irradiation treatment. However, the critical dose that increased seed germination varied among species and also ranged from genotype to genotype within species. In *Pterocarpus santalinus* a lower dose of 25 and 50 Gy significantly increased the germination index and vigor compared to the control (Akshatha & Chandrashekar, 2013).

Irradiation at dose higher than 30 Gy and below 40 Gy is considered being the lethal dosage (LD50) for *M. champaca* seeds (Table 1; Figure 1). Lethal dosage (LD50) is different for different species. Wegadara (2008) mentioned that LD50 of *Anthurium andreanum* seeds is lower than 40 Gy, while for *Amorphophallus*

Table 1. Effect of different doses of gamma irradiation on the germination of *Magnolia champaca* seeds

Doses (Gy)	Germination parameters			
	Germination percentage (%)	Germination index	Mean germination time	Germination value
0	53.67± 3.28 ab	1.67±0.08ab	12.69±3.74 a	0.078±0.021 a
5	49.33± 3.78 ab	1.81±0.14 ab	13.74±3.05 a	0.056±0.008ab
10	58.67± 2.66 a	2.17±0.11 a	16.17±2.83 a	0.078±0.007 a
15	46.00± 2.42 ab	1.70 ±0.11ab	11.36±3.19 a	0.048±0.005 b
20	35.00±10.12 b	1.26±0.38 b	8.37±4.91 a	0.038±0.015 b
40	13.00± 6.46 c	0.42±0.21 c	5.45±5.11 a	0.007±0.006 c
60	12.67± 5.64 c	0.42±0.19 c	6.49±5.33 a	0.006±0.004 c
80	9.33± 4.91 c	0.30±0.16 c	6.18±5.76 a	0.004±0.003 c
100	5.33± 1.83 c	0.16±0.05 c	6.46±5.91 a	0.001±0.001 c
F-test	14.045**	35.312**	0.659ns	11.377**

Remarks: The data shown are mean ± standard error of six replicates; Different letters a, b, c, d and ab denote significant difference ($P \leq 0.05$) between different treatments; ** = Significant at $P < 0.01$; ns = not significant.

muelleri, irradiation at a dose higher than 10 Gy and below 20 Gy is considered the lethal dosage (LD50) (Santosa, Pramono, Mine, & Sugiyama, 2014). According to Soeranto (2015), doses between LD20 (between 15-20 Gy in this study) and LD50 are considered as optimal doses for increasing the variation especially used for mutation breeding program, and in low doses, the irradiation has stimulatory effects. A radiostimulant low-dose is defined as any dose from environmental radiation level and the threshold that marks the boundary between positive and negative biological effect (Iglesias-Andreu et al., 2012).

Improvement in seed germination at lower doses of gamma radiation was also observed on *Tectona grandis* (Bhargava & Khalatkar, 1987), *Acacia leucophloea, Albizia lebbeck*, *Zizyphus mauritiana* (Selvaraju & Raja, 2001), *Pterocarpus santalinus* (Akshatha & Chandrashekar, 2013), and *Terminalia arjuna* (Akshatha, Chandrashekar, Somashekarappa, & Souframanien, 2013). The stimulating effect of low dose gamma ray on germination may be attributed to the activation of RNA synthesis, or protein synthesis (Kuzin, Vagabova, & Revin, 1976) which occurred during the early stage of germination. Gamma rays are ionizing radiation having low wavelength with high penetrable power, interact with atoms or molecules to produce free radicals in the cells. The free radicals can damage or modify components of plant cells. It has been reported to affect seed germination, morphology, anatomy, and physiochemical characteristics of plants, depending on irradiation level (Maamoun, El-Mahrouk, Dewir, & Omran, 2014). Whereas higher doses of gamma rays affected to inhibit the germination. Hell and Silveira (1974) stated that on *Phaseolus vulgaris*, treating seeds with high rates of gamma radiation reduced germination. Kumar and Mishra (2004)) reported that in okra (*Abelmoschus esculentus*) germination percentage generally decreased with increasing doses of gamma rays. Reduced germination percentage with increasing doses of gamma radiation has also been reported in *Pinus* (Thapa, 2004) and *Cicer arietinum* (Khan, Qureshi, Hussain, & Ibrahim, 2005). Yusuf and Nair (1974) inferred that gamma irradiation interfered with the synthesis of enzymes and at the same time accelerated the degradation existing enzymes involved in the formation of auxins and thus

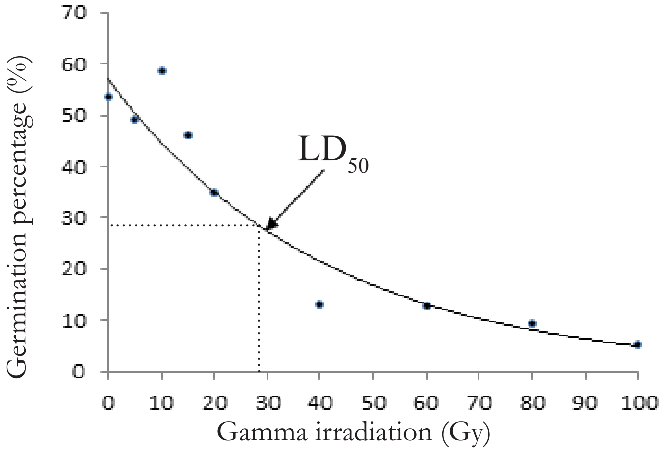

Figure 1. LD50, 50% seed germinated after gamma irradiation treatment

reduced the germination of seeds. Reduced seed germination due to mutagenic treatments may might be as a result of the damage of cell constituents at molecular level or altered enzyme activity (Khan & Goyal, 2009).

The irradiation of gamma rays also improved the storability of *M. champaca* seeds. The irradiated seeds that were stored for 3 months had better germination than control up to 20 Gy, and then tended to decrease thereafter (Table 2). Gamma irradiation has a long-term beneficial effect on the integrity and function of the plasma membrane of hypodermal mesocarp tissue. The long-term beneficial effects of irradiation included greater retention of total plasma membrane protein, a diminished decline in total plasma membrane phospholipids and in the phospholipid: protein ratio, and maintenance of a greater overall H+-ATPase activity (Lester & Whitaker, 1996). Irradiation was also effective to reduce the attack of a number of biological agents (microorganisms, rodents, and insects) causing the losses in the quality and quantity of the stored seeds (Darfour, Ocloo, & Wilson, 2012), so the low dose irradiation could improve seed storability.

There was no big difference in seed germination between *M. champaca* fresh (unstored) seeds and stored seeds. Based on the International Standard Testing Association tolerance value between two germination tests,the germination capacity of fresh and stored seeds, was within the tolerance level. The germination capacity between 42% and 59% has the tolerance value (differential value between two germination tests) of 11% (The International Seed Testing Association, 2011). In this testing, the germination capacities of the control fresh and stored seeds were 55% and 44%, respectively. On the other hand, the mean moisture content of fresh seeds was 12.2% (after drying in room temperature) and it was not significantly reduced during 3 months of storage in the refrigerator (moisture content 11.4%). In a graph of seed weight vs seed moisture content, *M. champaca* was plotted between the orthodox and recalcitrant species but closer to orthodox (Hong & Ellis, 1995). Result of this research indicates that *M. champaca* seeds storage behavior may be best classified as intermediate. Although some researcher (Bahuguna, Rawat, & Naithani, 1987) reported that the seeds of M. champaca are short-lived, but the loss of viability can be minimized by moist storage especially at low temperatures (4°C) for up to 9 months (Bisht & Ahlawat, 1999).

B. Effect of Gamma Irradiation on Seedling Growth

Table 3 presents the growth traits of *M. champaca* seedlings, both for the control and irradiated fresh (unstored) seed samples. The

Table 2. Effect of different doses of gamma irradiation on the germination of stored seed for 3 months

Doses (Gy	Germination parameters			
	Germination percentage (%)	Germination index	Mean germination time	Germination value
0	44.00±1.46 bcd	1.67±0.05 a	15.68±2.42 ab	0.89±0.16 c
5	49.00±4.97 abc	1.67±0.17 a	12.87±3.72 ab	1.00±0.23 bc
10	59.33±1.60 a	1.97±0.05 a	21.24±1.98 a	2.15±0.11 a
15	50.00±3.86 abc	1.66±0.13 a	18.92±2.26 a	1.56±0.23 ab
20	52.33±2.02 ab	1.72±0.07 a	17.98±2.89 a	1.68±0.12 a
40	45.00±5.92 bcd	1.68±0.23 a	8.19±4.39 a	0.44±0.01 b
60	37.67±8.08 d	1.12±0.25 b	11.75±4.91 ab	1.06±0.33 bc
80	0.33±0.33 e	0.01±0.01 c	5.50±5.50 bc	0.00±0.00 d
100	0.33±0.33 e	0.01±0.10 c	0.00±0.00 c	0.00±0.00 d
F-test	14.307**	37.359**	3.855*	16.070**

Remarks: The data shown are mean±standard error of six replicates; Different letters a, b, c, d and ab denote significant difference ($P \leq 0.05$) between different treatments; ** = Significant at $P < 0.01$; * = Significant at $P < 0.05$.

use of irradiated fresh seeds represented the assessment of the effect of all gamma irradiation treatments on seedling growth rather than irradiated stored seeds because on the irradiated stored seed, for some treatments (80 and 100 Gy), the germination percentage was near 0% (0,33%). There were not enough seedlings for growth analysis.

The statistical analysis showed that the growth traits were affected by the dose of gamma rays, except for root length. The seeds irradiated with 5, 10, and 15 Gy have shown significant increase in the seedling survival compared to the controls, with the highest being observed at 5 Gy (Table 3). The seedling survival continuously decreased after 20 Gy. According to Nazir, Mohamad, Affida, and Sakinah (1988), if the doses were too high, too many plants would be killed because mutagens could have direct negative effect on plant tissue and many mutations could be lethal. This was due to the fact that primary injuries are retardation or inhibition of cell division, cell death affected the growth habit and changes in plant morphology. Conversely, the high dose of gamma irradiation induced the mutation in plants (Piri et al., 2011) produced new gen combination caused increase in variation. In this research, it can be shown in plant growth that varied more in seedling height and root collar diameter.

Increase seedling height was clearly evident and the maximum increase to the control was 77% at 80 Gy and it was not significantly different with doses of 10, 60, and 5 Gy with maximum increase of 75%, 65%, and 61%, respectively (Table 3). Although the dose of 80 Gy revealed as the highest mean of seedling height, the dose just provided low seedling survival (18%) with high variation in seedling height (higher standard error). The higher doses of gamma irradiations (>60 Gy) were generated more genetic variations as shown by the relative higher standard error.

Performance of *M. champaca* seedlings at 6 months age grown from irradiated seed at doses 0, 5, and 10 Gy was more uniform in each treatment and the dose of 10 Gy showed the best performance (Figure 2). Sakin (2002) stated that gamma ray irradiation treatment increased the average plant height compared with controls. In fact, many researchers have reported the effect of ionizing radiation on growth and morphology in different plant species (De Micco et al., 2011; Piri et al., 2011; Iglesias-Andreu et al., 2012). For seedling collar

Table 3. Effect of gamma irradiation on seedling survival and growth traits (mean ± standard error) of *M. champaca* seedlings at 6 months

Doses (Gy)	Survival (%)	Height (m)	Root collar diameter (cm)	Root length (cm)	Leaf number	Aboveground biomass (g)	Belowground biomass (g)	Total biomass (g)
0	47.64±2.39 b	17.05±0.71 b	3.14±0.11 b	23.7±2.35 a	11.4±0.65 b	1.67±0.23 bc	0.58±0.07 ab	2.26±0.29 abc
5	55.54±2.39 a	28.14±0.76 a	3.97±0.11 a	19.1±2.97 a	13.0±0.42 b	2.19±0.40 abc	0.69±0.09 ab	2.89±0.29 abc
10	53.27±2.04 a	29.88±1.03 a	4.17±0.14 a	17.8±2.16 a	11.9±0.63 b	4.25±0.09 a	0.65±0.07 ab	4.91±0.19 a
15	54.54±2.39 a	27.48±1.23 ab	3.38±0.11 a	17.7±2.28 a	11.6±0.59 b	1.81±0.16 abc	1.02±0.07 a	2.84±0.42 abc
20	47.64±2.39 b	24.47±1.21ab	3.68±0.15 ab	25.5±3.92 a	12.8±0.78 b	2.11±0.20 abc	0.70±0.06 ab	2.16±0.25 bc
40	29.19±1.25 c	24.33±1.20 ab	3.76±0.23 ab	18.6±1.99 a	11.4±0.53 b	1.61±0.31 bc	0.55±0.09 ab	2.17±0.39 abc
60	23.60±2.04 d	28.22±2.35 a	3.95±0.29 a	20.9±2.89 a	14.3±1.11 a	3.65±0.64 ab	0.97±0.18 a	4.63±0.82 ab
80	18.22±1.44 e	30.32±2.11 a	4.11±0.25 a	23.5±3.27 a	12.8±1.14 b	2.21±0.24 abc	0.53±0.65 ab	2.75±0.30 abc
100	10.08±1.44 f	20.33±3.79 b	3.65±0.43 b	20.8±1.63 a	8.8±0.82 c	0.53±0.23 c	0.27±0.81 b	0.80±0.31 c
F-test	122.711**	21.383**	6.616**	1.083ns	3.672**	1.987*	1.491*	2.200*

Remarks: The data shown are mean ± standard error of six replicates; Different letters a, b, c, d and ab denote significant difference ($P \leq 0.05$) between different treatments; ** = Significant at $P < 0.01$; * = Significant at $P < 0.05$

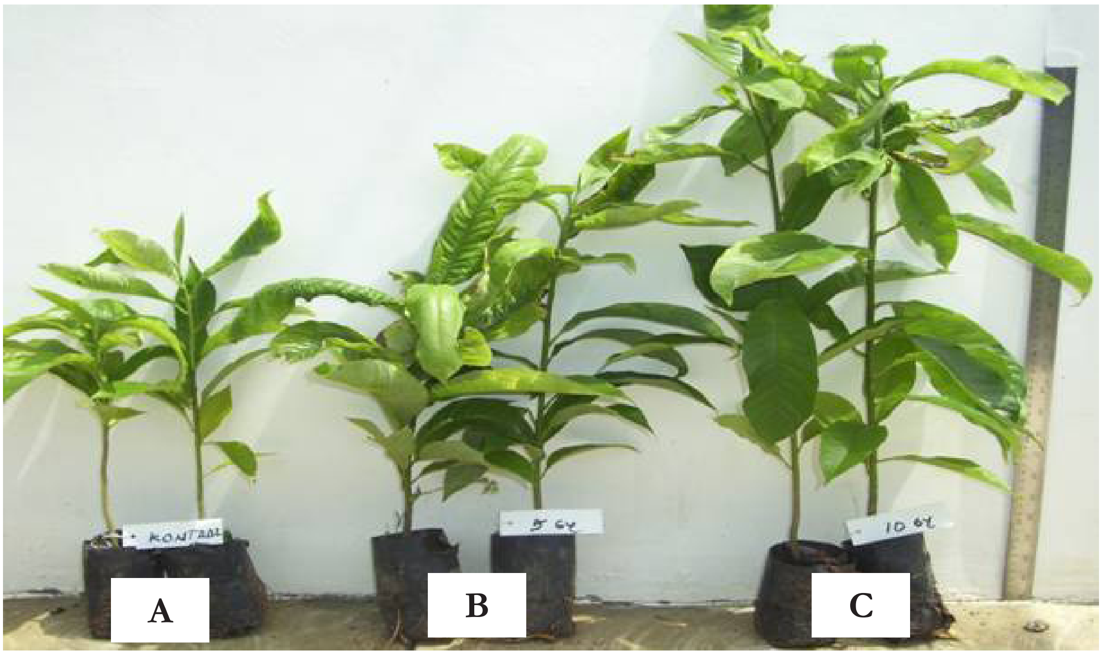

Figure 2. Performance of *Magnolia champaca* seedlings at 6 months age grown from irradiated seeds at doses 0 (A), 5 (B), and 10 Gy (C)

diameter, the maximum increase compared with control was 32% at 10 Gy and it was not significantly different with 5, 15, 60 and 80 Gy. The maximum increase of number of leaves was at 60 Gy. Dry weights of the seedlings were found to be significantly higher at 10 Gy (Table 3). This result was similar with Sherif, Khattab, Ghoname, Salem, and Radwan (2011) on *Hibiscus sabdariffa* that observed a significant increase in dry weight of the whole plant grown by irradiated seeds with low doses. Generally, the growth traits of *M. champaca* in this research decreased after 80 Gy. Villavicencio, Mancini-Filho, and Delinciee, (1998) stated that the critical dose that prevented growth varied among species and also ranged from genotype to genotype within species. In *Pinus kesiya* and *P. wallichiana*, an increased dose of radiation above 100 Gy reduced the shoot epicotyls and the root primordia, indicating its sensitivity toward the gamma rays (Thapa, 2004). However, *M. champaca* was found to be more sensitive to ionizing radiation. This result provided the expectation to solve the problem of seed germination, especially for improving the storability of *M. champaca* seeds that was categorized as intermediate seed with low storability.

IV. CONCLUSSION

Enhanced germination percentage, germination index, mean germination time, and germination value were observed in the low dose gamma irradiations of *M. champaca* seeds. The maximum increase of germination percentage on irradiated fresh seed of *M. champaca* was recorded at 10 Gy (increase 9.4% to control), while for storage of irradiated seed, the maximum increase was also recorded at 10 Gy (increase 34.1% to control). The seeds had LD50 close to 30 Gy, LD20 is about 15-20 Gy, and irradiation at doses of 80 Gy and higher caused lethal effect. Low dose gamma irradiation also improved the storability of the seeds. The optimum treatment for improving the seed germination and storability of *M. champaca* is 10 Gy. Growth rate in terms of seedling height, collar diameter, number of leaves, and dry weight have also increased in gamma irradiation doses up to 80 Gy. However, the growth traits were more stable and hadthe highest performances on seedling survival and growth at the dose of 10 Gy. Based on these results, it might be concluded that lower doses (10 Gy) of radiation might facilitate better seed germination, storability and seedling growth of *M. champaca*. This technique could be used for improving the seed and seedling quality to support the seedling procurement for establishing plantation forests.

ACKNOWLEDGEMENT

The authors thank to Center for the Application of Isotope and Radiation Technology, National Nuclear Energy Agency for providing the gamma cell facility required for the irradiation of the seeds.

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Indonesian Journal of Forestry Research Vol. 3, No. 2, October 2016, 107-118 ISSN: 2355-7079 / E-ISSN: 2406-8195

DEVELOPMENT OF LOCAL ALLOMETRIC EQUATION TO ESTIMATE TOTAL ABOVEGROUND BIOMASS IN PAPUA TROPICAL FOREST

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Received: 3 February 2015, Revised: 29 September 2016, Accepted: 21 October 2016

DEVELOPMENT OF LOCAL ALLOMETRIC EQUATION TO ESTIMATE TOTAL ABOVEGROUND BIOMASS IN PAPUA TROPICAL FOREST. Recently, pantropical allometric equations have been commonly used across the globe to estimate the aboveground biomass of the forests, including in Indonesia. However, in relation to regional differences in diameter, height and wood density, the lack of data measured, particularly from eastern part of Indonesia, may raise the question on accuracy of pantropical allometric in such area. Hence, this paper examines the differences of local allometric equations of Papua Island with equations developed by Chave and his research groups. Measurements of biomass in this study were conducted directly based on weighing and destructive samplings. Results show that the most appropriate local equation to estimate total aboveground biomass in Papua tropical forest is $Log(TAGB) = -0.267 + 2.23\ Log(DBH) + 0.649\ Log(WD)$ (CF=1.013; VIF=1.6; R^2= 95%; R^2-adj= 95.1%; $RMSE$= 0.149; $P<0.001$). This equation is also a better option in comparison to those of previously published pantropical equations with only 6.47% average deviation and 5.37 points of relative bias. This finding implies that the locally developed equation should be a better option to produce more accurate site specific total aboveground biomass estimation.

Keywords: Pantropical, local, allometric, biomass, Papua

PENYUSUNAN PERSAMAAN ALOMETRIK LOKAL UNTUK MENDUGA BIOMASSA TOTAL DI ATAS PERMUKAAN TANAH DI KAWASAN HUTAN TROPIS PAPUA. Saat ini, persamaan alometrik pantropis telah umum digunakan untuk mendapatkan nilai dugaan biomassa di atas permukaan tanah di kawasan hutan, termasuk di Indonesia. Namun sehubungan dengan adanya perbedaan dalam karakteristik diameter, tinggi, dan berat jenis pohon, kurangnya pengukuran data, khususnya di daerah timur Indonesia menyebabkan adanya keraguan terkait besarnya simpangan dan bias yang dihasilkan oleh penggunaan persamaan pantropis di daerah tersebut. Oleh karena itu, tulisan ini mempelajari perbandingan persamaan alometrik yang dibangun secara spesifik terhadap lokasi dan persamaaan alometrik pantropis yang telah dipublikasikan oleh Chave dan kelompok penelitinya. Pendugaan biomassa pada penelitian ini dilaksanakan berdasarkan pengukuran dan penimbangan secara langsung secara destruktif. Hasil penelitian menunjukkan bahwa persamaan lokal yang sesuai untuk pendugaan nilai biomassa di atas permukaan tanah di kawasan hutan tropis Papua adalah $Log(\mathrm{TAGB}) = -0,267 + 2,23\ Log(\mathrm{DBH}) + 0,649\ Log(\mathrm{WD})$ *(*CF*=1,013;* VIF*=1,6;* R^2*= 95%;* R^2*-adj= 95,1%;* RMSE*= 0,149;* $\mathrm{P}<0,001$*). Apabila dibandingkan dengan persamaan alometrik pantropis yang telah dipublikasikan sebelumnya, persamaan lokal tersebut menghasilkan nilai dugaan yang lebih baik dengan nilai simpangan rata-rata hanya 6,47% dan nilai bias relatif sebesar 5,37. Hasil ini mengindikasikan bahwa persamaan alometrik yang dibangun secara lokal sebaiknya dijadikan sebagai pertimbangan utama untuk mendapatkan nilai dugaan total biomassa di atas permukaan tanah yang lebih akurat.*

Kata kunci: Pantropis, lokal, alometrik, biomassa, Papua

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 doi: https://doi.org/10.20886/ijfr.2016.3.2.107-118

I. INTRODUCTION

Along with the progress of reducing emission from deforestation and forest degradation (REDD+) in Indonesia and the high possibility of benefits that might be achieved from conservation of forest carbon stocks, a verifiable and precise estimation of carbon stocks in the country's forestry sector is strongly needed. Estimating forest carbon stocks relies on certain approaches depending on the scales, starting from field weighing at local level to the application of geographical information system (GIS) at national level. However, all these approaches still rely on biomass measurement of the trees. (Clark & Kellner, 2012; Jaya et al., 2012; Achmad, Jaya, Saleh, & Kuncahyo, 2013). Nowadays, there is a risk of environmental deterioration as a result from direct biomass measurements, combined with the cost of such destructive approach that tends to be very high. The alternative that has been generally used is an allometric equation (Lewis et al., 2013; Ngomanda et al., 2014). In general, allometric equation is a statistical model to estimate the biomass of the trees using their biometrical characteristics, like height or diameter, which are non-destructive and simpler to measure (Eggleston et al., 2006; Maulana, 2014; Ngomanda et al., 2014). Up to now, Chave's pantropical allometric equations are the most commonly used across the globe, including in Indonesia (Lewis et al., 2009; Ngomanda et al., 2014). Nevertheless, in relation to regional differences in diameter, height and wood density, the lack of data measured from eastern part of Indonesia may question the degree of deviation and bias produced from the use of pantropical allometric which were developed by Chave, Andalo, Brown, Cairns, Chambers, Eamus, … Yamakura (2005) and Chave, Réjou-Méchain, Búrquez, Chidumayo, Colgan, Delitti, … Vieilledent (2014) in such area as evidenced by Maulana (2014).

Furthermore, debates over the application of Chave's pantropical allometric are continuing since several regional studies have came out with different results. A study by Fayolle et al. (2013) reported that pantropical equation is strongly justifiable to estimate the biomass of south-eastern Cameroon forests. Similar finding had also been contended by Vieilledent et al. (2012) for its validity over biomass estimation in Madagascar. In contrast, several studies also described that the use of Chave's pantropical equations might result in significant bias, as reported by Henry et al. (2010) in Ghana, Lima et al. (2012) in Amazonia, by Alvarez et al. (2012) in Columbia.

Hence, in order to answer the dilemma between the use of pantropical and locally developed equations, this paper studies the differences of local allometric equations for Papua Island with equations developed by Chave et al. (2005) and an improved pantropical allometric equation by Chave et al. (2014). Thus, the main objective of this study is to develop an improved allometric equation for mixed species in Papua Island. Considering this objective, this study produced local allometric equations for mixed species across Papua Island as an improvement to previously published equations by Maulana (2014) using new data that includes four additional genus, namely *Anthocephalus*, *Duabanga*, *Myristica* and *Syzygium*. Afterward, the study evaluated it against both Chave et al. (2005) and Chave et al. (2014) equations using actual (direct measurements) biomass data.

II. MATERIAL AND METHOD

A. Study Site

As depicted in Table 1 and Figure 1, this study was conducted at six regencies across Papua Island. Table 1 also contains the number of trees felled in this study, which were 83, with dbh (diameter at breast height/1.3 m) ranging from 5 to 48.5 cm, and consist of eight genera.

B. Biomass Measurement

Concisely illustrated in Figure 2, a set of proper and prudence procedure has been adopted to obtain reliable data and minimize any source of bias. To the extent of greater accuracy, as advised by Basuki et al. (2009), measurements of biomass in this study were

Table 1. Study area, coordinates and number of trees felled per genera

Site	Location	*Genera*	Coordinates	Number of trees felled
1	Sorong	*Anthocephalus*	0°33’ 42” – 1° 35’ 29” S 30°40’ 49” – 132°3’48” E	8
2	Mamberamo	*Duabanga*	01°28 - 3°50 S 137°46 - 140° 19 E	8
3	Fak-fak	*Intsia*	2°25'0"- 4°0'0" S 131°30'0" - 138°40'0" E	13
4	Bintuni	*Myristica*	1°57’50”-3°11’26” S 132°44’59”-134°14’49” E	9
		Palaquium		13
		Syzygium		9
5	Keerom	*Pometia*	140°15'0"-141°0'0" S 2°37'0" - 4°0'0" E	15
6	Raja Ampat	*Vatica*	0°10’ S - 0°20’ N 130°0’ W- 132°0’55” E	8
		Total number of trees felled		83

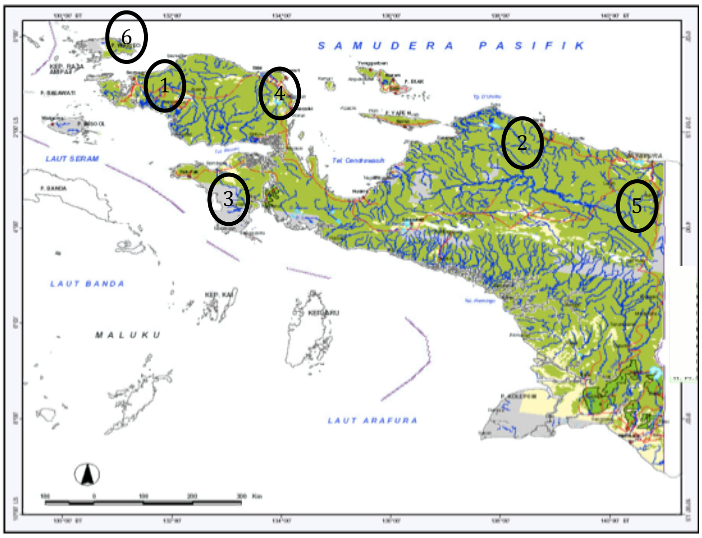

Figure 1. Study site map

Source: FWI (2004)

conducted directly based on weighing and destructive samplings. The dry biomass of the material of a pool of tree was measured using the aliquot approach, which is a piece of sample with a known mass as a fraction of the whole pool of the material. Based on this approach, dry biomass of a pool of material equals to the fresh biomass of the pool of the material divided by the fresh biomass of its aliquot times the dry biomass of the aliquot. This approach was logical if only the ratio of the dry over fresh biomass was homogeneous for the whole pool. Therefore, as suggested by Ketterings et al. (2001), each tree felled was divided into five pools, namely leaves, twigs (diameter <3.2 cm), small branches (diameter 3.2–6.4 cm), large branches (diameter >6.4 cm) and stems.

Each tree was felled so that its crown fell on the most open ground possible in its area, which limited the destruction of its foliage to the lowest possible loss. Once a tree was felled, the volume of each section was calculated using

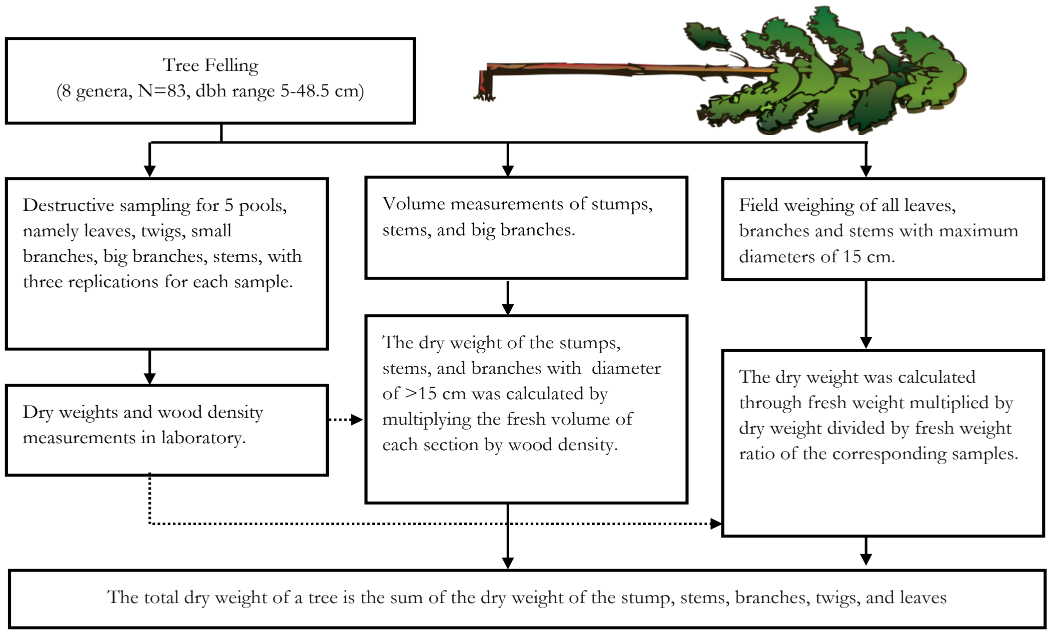

Figure 2. Flow chart of biomass measurement

Smalian's formula as cited by De Gier (2003), so that the total volume is the sum of the volumes of each section. Meanwhile, branches and stems with maximum diameters of 15 cm were measured directly in the field using hang-up balance of 50 kg capacity with an accuracy of 1%. Moreover, the smaller samples were weighed using a 1000 gr table scale with an accuracy of 0.5%. Three replications were taken for the samples from the partitioned trees and put into sealed plastic bags, and then brought to the laboratory to measure their moisture content. From that point, an analytical balance with maximum capacity of 500 gr and an accuracy of 0.001 gr was utilized to weigh those samples. Dry weights were obtained by drying the samples at 105^{o}C temperature until the constant value was obtained (Stewart et al., 1992; Ketterings et al., 2001).

In order to measure the wood density at the laboratory, samples were taken from the lower and upper parts of the main trunk sections with 2 meters interval. To include the inner and outer parts of the trunks with their bark, the samples were taken as a pie shape or cylinder (Nelson et al., 1999). Water replacement method was used in measuring the wood density. The samples were saturated at first to prevent size contraction during volume measurement. This was conducted through 48 hours rehydration. Each sample's volume was obtained from the displaced water volume when submerged. Finally, the wood density was equal to the oven dry weight divided by the saturated volume. The dry weight of the stumps, stems, and branches with diameter of >15 cm was calculated by multiplying the fresh volume of each section by wood density. For the other partitioned trees, the dry weight was calculated through fresh weight multiplied by dry weight divided by fresh weight ratio of the corresponding samples. The total dry weight of a tree is the sum of the dry weight of the stump, stem, branches, twigs, and leaves (Stewart et al., 1992).

C. Allometric Equations

1. Analysis of variance

Based on findings by Maulana (2014), in this study locally developed allometric for mixed species was established using two predictors, namely diameter at breast height (*DBH*) and wood density (*WD*). Hence, the equations to estimate total aboveground biomass (*TAGB*) were established according to the following basic models:

$Log(TAGB) = c + \alpha\, Log(DBH) + \beta\, Log(WD)$ (1)

$TAGB = c + \alpha\, DBH + \beta\, WD^2$ (2)

$TAGB = c + \alpha\, WD + \beta\, DBH^2$ (3)

Subsequently, in order to fulfill the assumptions in the regression establishment, four tests were conducted, namely Variance Influential Factors (*VIF*) for multicollinearity test, Pearson's correlation coefficient test, normal distribution of residuals test, and test for constant variance of residuals. Allometric model comparison and selection was analyzed using the values of standard error of the coefficient, R^2, R^2 (adj), and root mean square error (*RMSE*) based on Minitab 14.0 software. The chosen model would be the one with the highest values for R^2 and R^2 (adj), while having the lowest values of standard error of the coefficient and *RMSE*. Additionally, in order to enhance the reliability of the established log model (Equation 1), a correction factor (*CF*; Equation 4) for back transforming the model was calculated from the standard error of estimate (*SEE*; Equation 5) as defined in Sprugel (1983).

$CF = exp(SEE^2/2)$ (4)

$$SEE - \sqrt{\sum\left(\frac{LogY_i - Log\,\hat{Y}_i}{N - 2}\right)^2} \quad (5)$$

Where:

Log Y_i = values of dependent variable

Log $\hat{Y}_i$ = corresponding predicted values calculated from the equation

N = total number of observations

Afterwards, using data from actual biomass measurement in Papua Island, the chosen equation in this study was evaluated against Chave et al. (2005) equation, which were Equation 6 and Equation 7, as well as Chave et al. (2014)'s pantropical allometric as depicted in Equation 8. Meanwhile, as suggested by Basuki et al. (2009); Ngomanda et al. (2014) and Tedeschi (2006), criteria for this evaluation included average deviation (Eq. 9) and relative bias (Eq. 10).

$TAGB = WD exp\,[-1.499 + 2.148\, Ln(DBH) + 0.207\, (Ln(DBH))^2 - 0.0281\, (Ln(DBH))^3]$ (6)

$TAGB = WD exp\,[-1.239 + 1.98\, Ln(DBH) + 0.207\, (Ln(DBH))^2 - 0.0281\, (Ln(DBH))^3]$ (7)

$TAGB = 0.0673 \times (DBH^2 \times WD \times H)^{0.976}$ (8)

$$\bar{S} - \frac{100}{\eta}\sum_{i=1}^{\eta}\frac{|B_i - b_2|}{b_i} \quad (9)$$

$$RB - \frac{1}{\eta}\sum_{i=1}^{\eta}(B_1 - b_1) / b_i \quad (10)$$

Where:

$\bar{S}$ = average deviation

RB = relative bias

Bi = actual aboveground biomass for tree-i

bi = its estimation based on the model

η = number of observations

III. RESULT AND DISCUSSION

A. Local Equation

Compared to wood density values from published literature, as shown in Table 2, result of measurements in this study illustrate a highly rational wood density for each genera. However, it should be kept in mind that although samples for wood density measurements originated from both upper and lower parts (with 2m interval) of each main trunk, these data were also used to estimate the weight of the material of the trees that were difficult or even impossible to measure, such as big branches. As reported by Basuki et al. (2009), this approach might result in over-estimation in regard to total weight of the tree. Meanwhile, Nogueira et al. (2007) also noted that wood density of a tree tends to be higher at breast height than in the upper part of the bole, and also higher at the bottom of the trunk of the tree than at the living crown's base. Afterwards, following the previously determined model, three local equations were established as listed in Table 3. In this study, multicollinearity test was conducted by harnessing the value of Variance Influential

Table 2. Result of wood density measurements

Genus	Number of trees (N)	Number of wood density sample (n)	Wood density range (gr/cm^3)		Average (gr/cm^3)	Standard deviation	Coefficient of variation	PROSEA (2007)* (gr/cm^3)
			min	max				
Anthocephalus	8	36	0.30	0.56	0.43	0.09	0.21	0.29-0.56
Duabanga	8	42	0.28	0.48	0.38	0.07	0.18	0.27-0.51
Intsia	13	92	0.43	0.86	0.64	0.15	0.23	0.50-1.04
Myristica	9	87	0.41	0.63	0.52	0.08	0.15	0.40-0.65
Palaquium	13	86	0.33	0.56	0.44	0.07	0.16	0.45-0.51
Pometia	15	98	0.37	0.75	0.56	0.12	0.21	0.39-0.77
Syzygium	9	74	0.54	0.80	0.67	0.09	0.13	0.56-0.83
Vatica	8	44	0.54	0.67	0.60	0.05	0.08	0.60-0.76
Total	83	559	-	-	-	-	-	-

*published wood density

Factors (*VIF*). In short, according to Fahrmeir et al. (2013), the aim of such test is to investigate whether there is an indication of high correlation among predictors (input variables, x) or not. Evidently, none of the established models indicated the presence of significant multicollinearity among its predictors, since the *VIF* value only ranged from 1.4 to 1.6 point. As described by Fahrmeir et al. (2013), this means that there is only a very low degree of correlation among predictors used in the model, and that values of *VIF* were insufficient to be overly concerned.

Meanwhile, to strengthen the result of the multicollinearity test, analysis of correlation among variables was performed. The first step of this correlation test was to use a graphical approach or scatter plot to explore the appearance of correlation among involved variables (Chaturvedi & Raghubanshi, 2015). As shown in Figure 3, and in line with the result of multicollinearity test, apparently it is clear that there was no obvious relationship among predictors or input variables, *WD* and *DBH*. In contrast, both scatter plots for *TAGB* vs *WD* and *TAGB* vs *DBH*, which were basically output vs input variables, demonstrated a direct relationship. The strength of this correlation was further examined using Pearson's coefficient test and the results were depicted in Table 4. Considering the value of Pearson's correlation of coefficient (*r*) in the table, where $r>0.6$, it seems that *DBH* and *WD* were reliable input variables in predicting *TAGB*. This finding is

Table 3. Result of wood density measurements

Equations	Coefficient		Multicollinearity Test	
	Symbol	Value	Predictor	*VIF*
$\text{Log}(TAGB) = c + \alpha\ \text{Log}(DBH) + \beta\ \text{Log}(WD)$	c	-0.267	Log(*DBH*)	1.6
	α	2.23	Log(*WD*)	1.6
	β	0.649	-	-
$TAGB = c + \alpha\ DBH + \beta\ WD^2$	c	-557	*DBH*	1.4
	α	42.4	WD^2	1.4
	β	540	-	-
$TAGB = c + \alpha\ WD + \beta\ DBH^2$	c	-387	*WD*	1.4
	α	710	DBH^2	1.4
	β	0.891	-	-

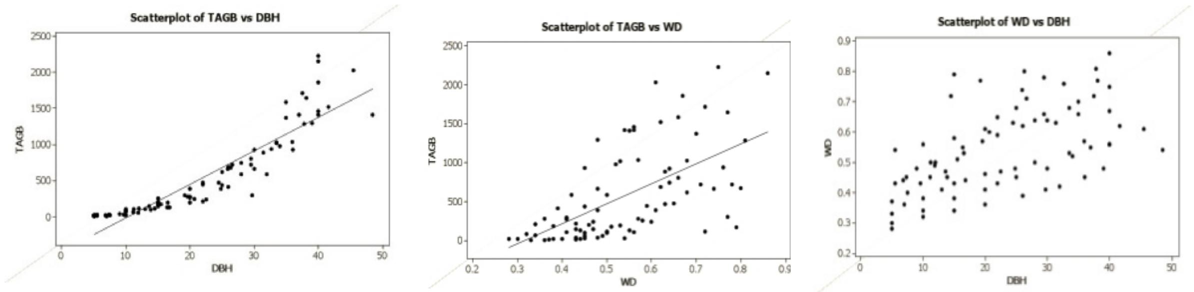

Figure 3. Scatter plots for output-input (*TAGB* vs *DBH*; *TAGB* vs *WD*) and input-input (*WD* vs *DBH*) correlations

Table 4. Pearson's correlation of coefficient for output-input variables

Equations	Output (y)	Input (x)	*r**	*P* value
Log(*TAGB*) = c + α Log(*DBH*)+ β Log(*WD*)	Log (*TAGB*)	Log (*DBH*)	0.97	<0.001
	Log (*TAGB*)	Log (*WD*)	0.68	<0.001
$TAGB = c + \alpha\, DBH + \beta\, WD^2$	*TAGB*	*DBH*	0.91	<0.001
	TAGB	WD^2	0.60	<0.001
$TAGB = c + \alpha\, WD + \beta\, DBH^2$	*TAGB*	*WD*	0.61	<0.001
	TAGB	DBH^2	0.94	<0.001

*Pearson's correlation of coefficient

in agreement with studies by Chaturvedi and Raghubanshi (2015) as well as Hunter (2015) that describe the important use of *DBH* and *WD* as input variables. Moreover, based on the value of r in the table, it appears that *TAGB* has more direct relationship with *DBH* (r>0.9) than *WD* ($0.6<r<0.7$).

Furthermore, in Table 3 normal distribution of residual test was conducted for each established local equation. The result of this test is shown in Figure 4. It illustrates that the residual points for each equation fall near to a straight line in the normal probability plot. As explained by Fahrmeir et al. (2013), this indicates that errors during observation have been normally distributed in every *x*-value and expresses the validity of the normality of the residual assumption.

The final phase of the evaluation for regression assumptions conducted in this study was testing the constant variance of residuals. This evaluation was crucial to make sure that error terms or 'residuals' were constant, and had a mean close to zero. In this study, this test was conducted based on residuals versus fitted values. The result of this test is depicted in Figure 5. Based on this graphical illustration, it can clearly be seen that only the log-based model (Log*TAGB* = -0.267 + 2.23 Log*DBH* + 0.649 Log*WD*) produces valid result to fulfill the assumption of constant variance of residuals. Points on the plot for this log-based model appear to be randomly scattered all over the zero line. Thus, it is highly reasonable to assume that the residuals may have a nearly zero mean and it is virtually constant (Gardner & Urban, 2003; Fahrmeir et al., 2013).

In contrast, there were noticeable U-shaped patterns for two other non log-based equations, namely $TAGB = -557+42.4DBH+540WD^2$, and $TAGB = -387+710WD+0.981DBH^2$. Points of residuals for these two equations were scattered on the positive sides with large

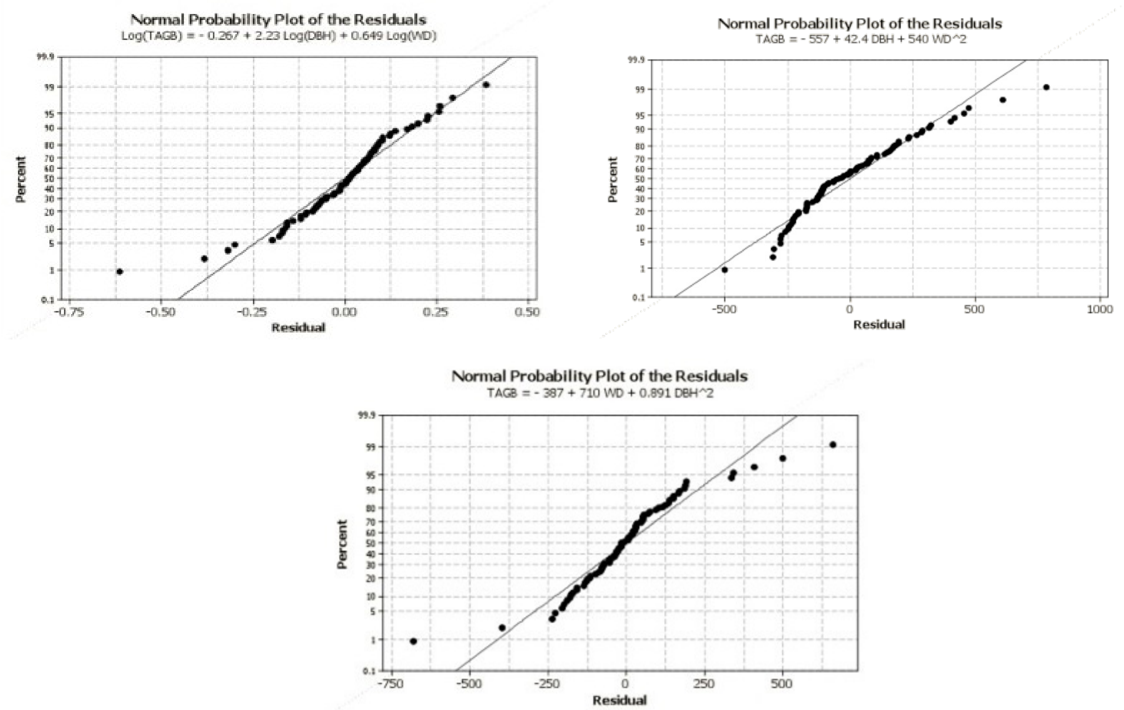

Figure 4. Normal probability plots of the residuals for each equation

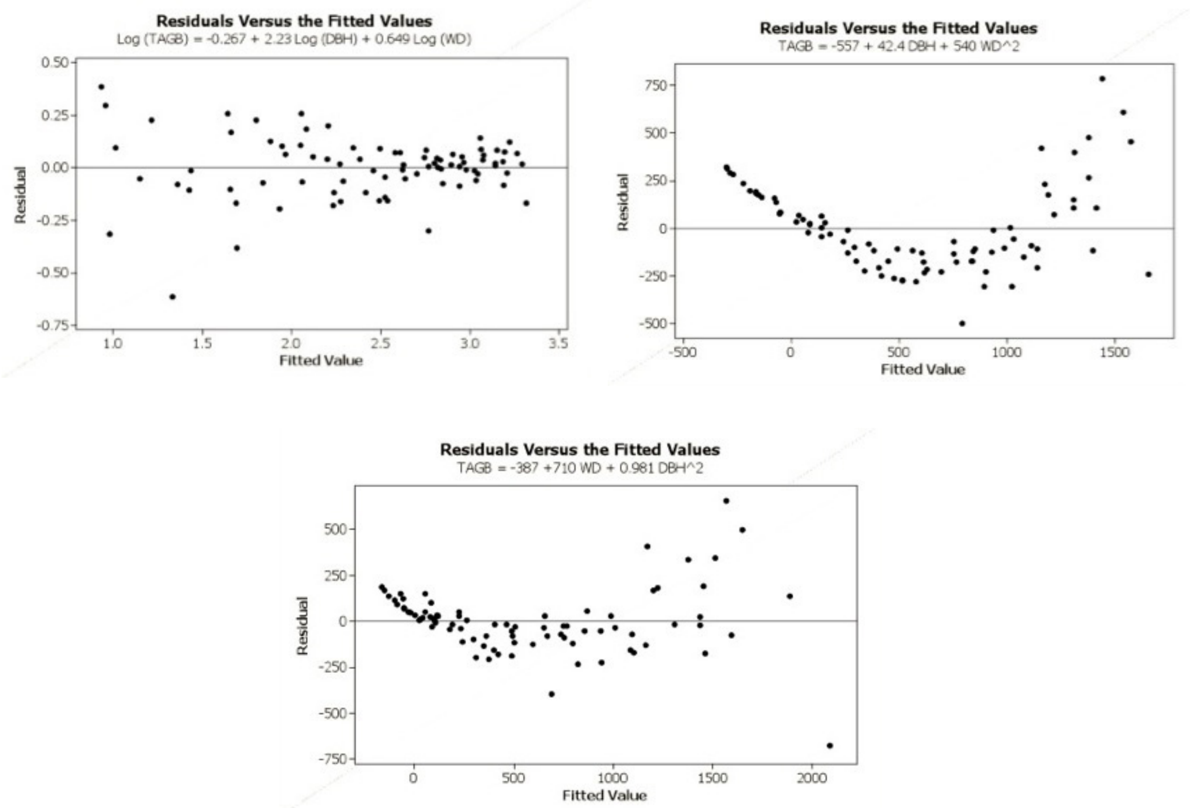

Figure 5. Results of constant variance of residuals test on three developed equations

Table 5. Evaluation of established local equation

Equations	Coefficient		Standard error of the coefficient	*T*-stat	R^2 (%)	R^2-adj (%)	*RMSE*	*P* value
	Symbol	Value						
Log(*TAGB*) = c + α Log(*DBH*) + β Log(*WD*)	c	-0.267	0.14	-1.89	95.1	95	0.149	<0.001
	α	2.23	0.078	28.35				
	β	0.649	0.186	3.49				
TAGB = c + α *WD* + β DBH^2	c	-387	81.53	-4.75	91	90.8	178.64	<0.001
	α	710	165.1	4.3				
	β	0.891	0.04	21.94				
TAGB = c + α *DBH* + β WD^2	c	-557	62.44	-8.91	85	84.6	230.31	<0.001
	α	42.4	2.609	16.25				
	β	540	191.8	2.82				

or small fitted values, while holding negative values in the middle. This pattern implies that residuals were less likely to be consistently scattered around the zero line from left to right. Hence, the consistency of the variance of the residuals for both of the non log-based models might become questionable.

Having evaluated the assumptions of regression for each established equation, it seems that the most appropriate model to estimate total aboveground biomass in Papua tropical forest is Log(*TAGB*) = -0.267 + 2.23 Log(*DBH*) +0.649 Log(*WD*) since it produces complete valid results for all given assumption tests. Besides, as shown in Table 5, this log-based equation has the highest coefficient of determination (*R-sq*) with about 95%, meaning that it enables to explain up to 95% of the variability of data response around its mean. This model also has the lowest value of standard error of the coefficient and *RMSE*. Additionally, this selected log-based model was also completed with its corresponding correction factor for back transforming the model. Correction factor (*CF*) for the selected log-based model in this study is 1.013. To the extent of greater accuracy, final estimation result obtained from this model should be multiplied with the correction factor.

B. Pantropical vs Local Equation

Following the selection of locally developed equation, the selected equation Log(*TAGB*) = -0.267 + 2.23 Log(*DBH*) +0.649 Log(*WD*) was then compared to two pantropical equations by Chave et al., (2005) namely $TAGB = WD \exp[c+\alpha \, Ln(DBH)+\beta(Ln(DBH))^2+d(Ln(DBH))^3]$ for moist type forest and $TAGB = WD \exp[c+\alpha \, Ln(DBH)+\beta(Ln(DBH))^2+d(Ln(DBH))^3]$ for wet type forest, and an improved model by Chave et al., (2014), which is $TAGB = 0.0673 \times DBH^2 \times WD \times H)^{0.976}$. Compared to the actual biomass data that was calculated directly at the research site based on destructive sampling and field weighing of mixed genus trees with the *DBH* range as covered in the model of this study, it seems that the local model has the lowest value of average deviation and relative bias, with only 6.47% and 5.37 points respectively. On the other hand, both Chave et al. (2005) and Chave et al. (2014) equations have more than 15% average deviation and 10 points of relative bias. Furthermore, in order to make it clear, Figure 6 shows a graphical illustration on the comparison of the results of the estimations from each equation with the actual biomass data.

Table 6. Evaluation against pantropical equations harnessing actual measurements data

Reference	Equations	Coefficient		Average deviation	Relative bias (+/-)
		Symbol	Value		
Chosen equation of this study	$\text{Log}(TAGB) = c + \alpha\ \text{Log}(DBH) + \beta\ \text{Log}(WD)$	c α β	-0.267 2.23 0.649	6.47%	5.37
Chave et al. (2005); pantropical allometric for moist type forest	$TAGB = WD\exp[c+\alpha\ \text{Ln}(DBH)+\beta(\text{Ln}(DBH))^2+d(\text{Ln}(DBH))^3]$	c α β d	-1.499 2.148 0.207 -0.0281	16.22%	-13.46
Chave et al. (2005); pantropical allometric for wet type forest	$TAGB = WD\exp[c+\alpha\ \text{Ln}(DBH)+\beta(\text{Ln}(DBH))^2+d(\text{Ln}(DBH))^3]$	c α β d	-1.239 1.98 0.207 -0.0281	34.63%	-28.74
Chave et al. (2014); improved pantropical allometric	$TAGB = c \times (DBH^2 \times WD \times H)^{\alpha}$	c α	0.0673 0.976	15.27%	-12.67

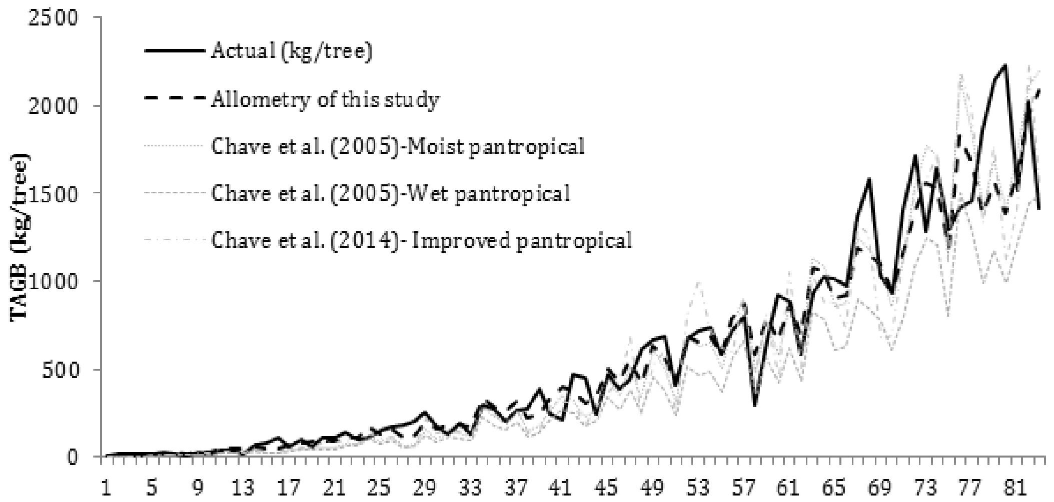

Figure 6. Comparison between actual biomass data and estimate values for each equation

IV. CONCLUSION

This study highlighted that the most appropriate local model to estimate total aboveground biomass in Papua tropical forest is $\text{Log}(TAGB) = -0.267 + 2.23\ \text{Log}(DBH) + 0.649\ \text{Log}(WD)$ (CF=1.013; VIF=1.6; R2=95%; R2-adj= 95.1%; $RMSE$=0.149; P<0.001). In addition, this model is also a better option compared to Chave et al. (2005) and Chave et al. (2014)'s improved pantropical equations with only 6.47% average deviation and 5.37 points of relative bias in estimating *TAGB* in Papua Island. This finding implies that the locally developed equation should be considered as a better option to produce more accurate site-specific total aboveground biomass estimation.

ACKNOWLEDGEMENT

We are grateful to the Forestry Research Institute of Manokwari for providing financial support to conduct this research. Thanks are also due to PT. Mamberamo Alas Mandiri in Mamberamo Regency, PT. Arfak Indra in Fak-fak Regency, PT. Batasa in Keerom Regency, PT. Manokwari Mandiri Lestari in Teluk Bintuni Regency and head of Waijan Village in Raja Ampat Regency for providing us with the necessary resources and support during the field work. We would like to also appreciate our researchers Mr. Jarot Pandu Panji Asmoro and Mr. Iga Nurapriyanto, as well as our technicians Mr. Frandon Itlay, Mr. Zeth Luther Rumawak, and Mr. Ette Panus for assisting us in the field and laboratory measurements.

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Indonesian Journal of Forestry Research Vol. 3, No. 2, October 2016, 119-127 ISSN: 2355-7079 / E-ISSN: 2406-8195

GENETIC PARAMETER ESTIMATES FOR GROWTH TRAITS IN AN *Eucalyptus Urophylla* S.T. Blake PROGENY TEST IN TIMOR ISLAND

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Received: 22 December 2014, Revised: 14 October 2016, Accepted: 14 October 2016

GENETIC PARAMETER ESTIMATES FOR GROWTH TRAITS IN AN *EUCALYPTUS UROPHYLLA* S.T. BLAKE PROGENY TEST IN TIMOR ISLAND. Genetic parameters were estimated for growth traits of Ampupu (*Eucalyptus urophylla* S.T. Blake) progeny test grown in Southern Central Timor - East Nusa Tenggara Province, Timor Island. When the trial was one year old data were collected from 45 half-sib open pollinated families and assessed. There were genetic variations in height and diameter among families of *E. urophylla*. Growth traits had moderate heritability, both individually and in family, i.e. 0.28 and 0.55 for height and 0.41 and 0.66 for diameter, respectively. Genetic correlation between height and diameter was strong (0.96). However, the estimation of genetic parameter should be interpreted carefully since the trial was very young. Re-assessment of the trial should be carried out periodically to provide better understanding of the species regarding the dynamic of the genetic interaction between the species and its environment, effective age of selection and prediction of genetic gain.

Keywords: Ampupu, *Eucalyptus urophylla*, progeny test, heritability, genetic correlation

PENDUGAAN PARAMETER GENETIK SIFAT PERTUMBUHAN PADA UJI KETURUNAN Eucalyptus urophylla S.T. Blake DI PULAU TIMOR. Estimasi parameter genetik sifat pertumbuhan dilakukan terhadap uji keturunan Ampupu yang ditanam di Timor Tengah Selatan, Provinsi Nusa Tenggara Timur. Data berasal dari 45 famili half-sib *pada usia satu tahun. Hasil evaluasi menunjukkan bahwa terdapat variasi genetik antara famili* E. urophylla *yang diuji untuk sifat tinggi dan diameter. Sifat pertumbuhan memiliki heritabilitas individu maupun heritabilitas famili yang tinggi, dimana untuk karakter tinggi masing-masing sebesar 0,28 dan 0,55, sedangkan untuk karakter diameter masing-masing 0,41 dan 0,66. Korelasi genetik antara sifat tinggi dan diameter tanaman sangat kuat (0,96). Namun demikian, hasil pendugaan parameter genetik ini harus ditafsirkan secara hati-hati mengingat umur tanaman yang masih sangat muda. Evaluasi parameter genetik terhadap uji keturunan ini perlu dilakukan secara berkala untuk mendapatkan pemahaman yang lebih baik mengenai dinamika interaksi antara genetik dengan lingkungan, umur yang efektif untuk melakukan seleksi dan prediksi perolehan genetik.*

Kata kunci: Ampupu, Eucalyptus urophylla*, uji keturunan, heritabilitas, korelasi genetik*

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 doi: https://doi.org/10.20886/ijfr.2016.3.2.119-127

I. INTRODUCTION

Ampupu (*Eucalyptus urophylla* S.T. Blake) is an endemic tree species in Indonesia with natural distribution in East Nusa Tenggara and Maluku, namely on the islands of Flores, Adonara, Alor, Lomblen, Pantar, Wetar and Timor at altitudes ranging from 70 m to 2,960 m above sea level and is spread across a distance of 500 km between longitudes 127°E and 122°E and between latitudes 7°30'S and 10°S (Eldridge, Davidson, Harwood, & Van Wyk, 1993). Since 1919 *E. urophylla* has been introduced to many countries and regions, including Australia, Papua New Guinea, China, Malaysia, Thailand, Vietnam, Argentina, Brazil and some African countries, which have humid and sub humid tropical climates with wet/dry seasons (Eldridge et al., 1993; Maid & Bhumibhamon, 2009). The popularity of planting this species either as a pure species or more commonly in hybrid with other eucalypt species, e.g. *E. grandis* and *E. camaldulensis* has increased significantly in Brazil, China, Vietnam and Thailand, particularly to provide raw material for pulp and paper production (Lan, 2011; Sein & Mitlohner, 2011; Manavakum, 2014; Kilulya, Msagati, Mamu, Ngila, & Bush, 2014; Ferraco et al., 2016). In these countries, this species has shown promising growth performance as reported by Maid and Bhumibhamon, (2009); and Sein and Mitlöhner, (2011).

E. urophylla is not widely planted in Indonesia because it requires a specific site and several regions in Indonesia are outside its natural range. Trials in Sumatra and Kalimantan showed very poor growth, *E. pellita* could only grow well in the trial sites and operational plantations (Hardiyanto & Tridasa, 2000). Commercial plantations of this species in Indonesia to some extent is limited in comparison with *E. pellita* and *Acacia mangium* and the genetic material that is currently being deployed into such plantations at an early stage of development.. Further genetic improvement is anticipated to lead to yield gains for growers. Production of high quality seed source for many tree species is time consuming, because genetic growth parameters need to be assessed in a progeny test that is well established and maintained. To initiate a genetic improvement programme, numerous provenance and progeny trials of the species had been established in small-scale experimental plantations at many locations in Indonesia. However, most of the tests failed due to various reasons such as livestock disturbances on the progeny test plots that had been developed in 1983 in West Nusa Tenggara. Since the earlier progeny trials were unsuccessful, the purposes of such trials of screening and re-selection for continued breeding and developing superior germplasma of *E. urophylla* had not been achieved. The dynamic of genetic interaction between a species and its environment based on genetic parameters therefore remains unknown. Established progeny test of *E. urophylla* is expected to be converted into a seedling seed orchard with individual and family tree selection. This will produce superior seeds that are expected to be adaptable to various plantation sites.

A progeny trial involving 45 families of *E. urophylla* had been established in Timor Island in October 2013. This paper evaluates the adaptability (survival) and genetic parameters for growth (height and diameter, heritability and genetic correlation) of families in the trial. The results will be used to form a basis for understanding the genotypic effects on growth of *E. urophylla* at an early age, and in the future it will be used to understand the relationships between early assessments of growth and survival and its impact at later ages. The data and information will then lead to a more effective targeting of the selection period to develop the best breeding strategies of *E. urophylla* in Indonesia.

II. MATERIAL AND METHOD

A. Material

The study was based on a progeny test, located at Bu'at (latitude 09°49'047" S, longitude 124°15'002" E, altitude 895 m a.s.l), South Mollo, Southern Central Timor District, East Nusa Tenggara Province, as shown in Figure 1

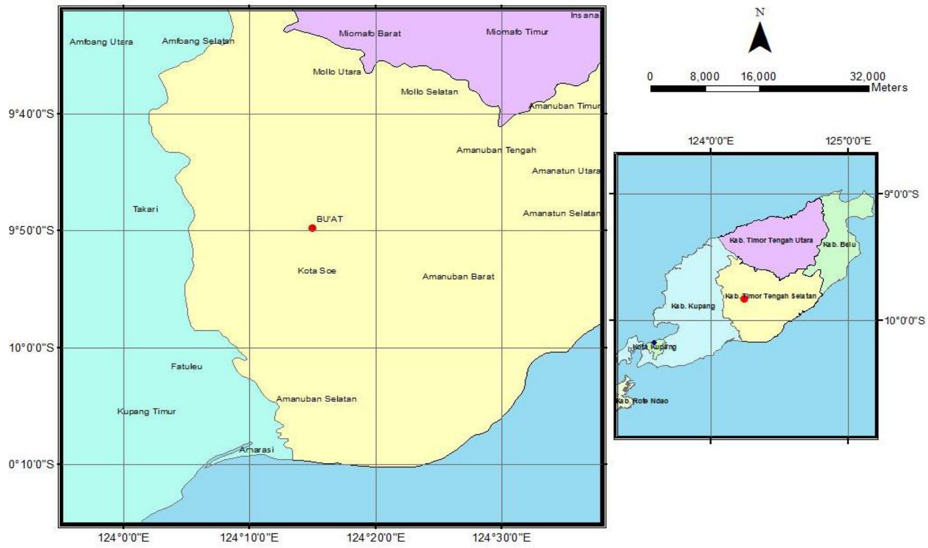

Figure 1. Map of the research site in Timor Island

and managed by the Forest Research Institute of Kupang. In 2014 the rainfall on the site was 1992.75 mm that occurred during 10 months with a total of 95 rainy days (BPS Kabupaten Timor Tengah Selatan, 2015). The progeny test was planted in November 2013, laid out as a randomised, resolvable Incomplete Block Design (IBD) that comprised of 45 families, 3 tree-plots and 5 complete block replications, at 4 × 4 m spacing. The row of each replication constitutes as incomplete blocks. The 45 families tested in the progeny trial were collected from the two largest population of *E. urophylla* in East Nusa Tenggara namely Fatumnasi (19 families) and Bu'at (26 families).

B. Data Collection

Assessments of growth parameters were undertaken in October 2014. The variables measured were survival rate to assess field adaptation, total height and diameter to assess growth performance. Plot survival rate (%) was the ratio of the number of surviving trees with those planted. All surviving trees in the trial were assessed for tree height and diameter. Survival data were summarised as percent plot-mean survival (i.e. the number of surviving trees in each plot divided by three). Total height (m) was measured from the ground to the top of the tree, and stem diameter at 5 cm above the ground. The measurement of diameter at a height of 5 cm above the ground was done because the height of the plant had not yet reached a diameter at breast height (dbh).

C. Data Analyses

1. Adaptability

Analyses of variance were performed to determine statistical significance of survival rate among families. The analyses of variance are based on the following linear model (Williams, Matheson, & Harwood, 2002):

$$Y_{ijkl} = +B_i + P_j + F_{k(j)} + E_{ijkl} \quad (1)$$

where :

Y_{ijkl} : observation of tree in the l^{th} plot, the i^{th} replication, j^{th} provenance and the j^{th} family;

μ : overall mean;

B_i : effect of the i^{th} replication;

P_j : the effect of the j^{th} provenance

$Fk_{(j)}$: effect of the k^{th} family nested within the j^{th} provenance

E_{ijkl} : residual

2. Variation in Height and Diameter

Breeders want to select trees for higher production, better quality and higher survival ability. Growth performances (height and stem diameter) of tree species are important variables to be assessed in an improvement programme especially for pulp wood as they indicate the productivity of the species. Variations in individual data of tree growth performances were analysed using the restricted maximum likelihood (REML) procedure. The following linear model was used (Williams et al., 2002):

$$Y_{ijklmn} = +B_i + P_j + R_k + CB_{li} + F_{m(j)} + FB_{mi} \quad (2)$$

where :

Y_{ijklmn} : individual observation of tree in n^{th} plot, the i^{th} replication, the j^{th} provenance, the k^{th} row, the l^{th} column, and the m^{th} family;

μ : overall mean;

B_i : fixed effect of the i^{th} replication;

P_j : fixed effect of the j^{th} provenance

R_j : random effect of the k^{th} row;

$CB_{k(i)}$: random interaction effect of the i^{th} column and the i^{th} replication;

$F_{m(j)}$: random effect of the m^{th} family nested within the j^{th} provenance

FB_{mi} : random interaction effect of the m^{th} family and the i^{th} replication (the plot effect)

E_{ijklmn} : random residual

3. Heritability

Genetic parameters including the narrow-sense heritability, "family heritability" and genetic correlation between traits were calculated using the REML variance component estimates. Heritability is the proportion of the genetic factors of interest that is inherited from parent to offspring (Zobel & Talbert, 1984). In other words, heritability is the statistical expression for the relative contribution of genotype and environment to the phenotype performance, and is useful in predicting gain from selection. The commonly applied coefficient of relationship for the first generation eucalypt progeny of 1/2.5 appears to be quite suitable for correcting variance component and heritability estimates (Bush, Kain, Matheson, & Kanowski, 2011). Individuals (h^2i) and a family (h^2f) heritabilities were calculated from the following equations (Zobel & Talbert, 1984):

$$h^2 i = \frac{2.5\,\sigma^2 f}{\sigma^2 f + \sigma^2 fb + \sigma^2 e} \quad (3)$$

$$h^2 f = \frac{\sigma^2 f}{\sigma^2 f + \sigma^2_{fb} / b + \sigma^2_e / nb} \quad (4)$$

where :

$\sigma^2 f$: variance component of family

$\sigma^2 fb$: variance component of family and block interaction

$\sigma^2 e$: variance component of error

n : harmonic mean of trees per plot sum

b : harmonic mean of blocks sum

4. Genetic Correlation

Estimating genetic correlations between traits of interest and genotype by environment interaction ($G \times E$) is also necessary in proposing the basis for setting up breeding populations and selecting environmentally stable genotypes. Genetic correlation can be used, for example, to determine the genetic relationships between the height and diameter traits of trees in a progeny test, and is a very important predictor of the effectiveness of the variable in the selection process (Gaspar, Louzada, Aguiar, & Almeida, 2008). Genetic correlations between growth traits (height and diameter) were calculated based on the following equation (Zobel & Talbert, 1984):

$$^rG = \frac{^{\sigma}f(xy)}{\sqrt{\sigma^2 f(x)^* \sigma^2 f(y)}} \quad (5)$$

where :

^rG : genetic correlation

$\sigma_{(xy)}$: covariance component between variable (x) and variable (y) interaction

$^2(x)$: variance component of variable (x)

$^2(y)$: variance component of variable (y)

III. RESULT AND DISCUSSION

A. Adaptability

At the end of the first year of growth, the survival rate across this progeny trial of *E. urophylla* was 83%. This was high and it might decrease with age. For example, in Chachoengsao Thailand, where *E. urophylla* was an introduced species that had to adapt to the new environment, the survival rate was 85%, 79%, 75% and 54% at the ages of 6, 8, 10 and 16 years, respectively (Maid & Bhumibhamon, 2009). The current progeny trial is within its natural distribution and natural altitudinal range. However survival rate also depends on adaptation to biotic and abiotic stress factors, and soil type and conditions (Maid & Bhumibhamon, 2009). The variable of survival rate could be used to select the best family, cause of this variable showed the adaptation of the family toward the extrame condition in their early establishment (Widiyatno, Naiem, Purnomo, & Jatmiko, 2014).

There were no significant differences in survival between the 2 provenances and the 45 families, although rates ranged between 33.33% and 100% per plot (families per replication) (Table 1). However, there were significant differences between replications, although silvicultural treatment and site preparation were similar. This might have been due to changes in soil properties and environmental gradients across the trial, but these were not measured. The progeny trial was located on a sloping area where there was a difference in the depth of the soil. Blocking was made across the slope so that replication at the lowest position has the deepest soil depth (more than 60 cm), while replication at the top of the slope had a shallower soil depth (less than 30 cm). Thus all families of *E. urophylla* were considered well-adapted to this site. It has happened because the species was planted in a location that has climate characteristics similar to its natural distribution. *Eucalyptus urophylla* has the largest altitudinal range of any *Eucalyptus* species covering 70 m to 2,960 m above sea level. Annual rainfall for this species in Timor Island is 1300–2000 mm and the dry season lasts for 3-4 months (Sein & Mitlöhner, 2011).

B. Variations in Height and Diameter

Across the 45 families, mean total height was 53.3 cm, ranged between 17.0 cm and 145.0 cm, and mean diameter was 0.38 cm, ranged between 0.11 cm to 1.13 cm. These values were lower than that of in an *E. urophylla* plantation after the first year of growth in Vietnam (200 to 209 cm height and 1.9 to 2.3 cm diameter) (Kien, Jansson, Harwood, & Thinh, 2009; Sein & Mitlöhner, 2011) and in Brazil, where the mean annual height and diameter growth was 100.6 cm and 1.5 cm, respectively (Whitesell, DeBell, Schubert, Strand, & Crabb, 1992).

There were significant effect of the provenances and families on plant height and diameter as shown in the Table 2. Trees of the Fatumasi provenance show their superiority over Bu'at provenance as indicated by the mean of height and diameter of the trees. Mean of height and diameter of the trees of Fatumnasi provenance was 56.07 cm and 0.40 mm respectively, while it was only 49.43 cm and 0.35 mm of the trees of Bu'at provenance. It is likely

Table 1. Analysis of variance of the survival rates of *E. urophylla* at the first year of growth

Source of variation	*d.f*	*s.s*	*m.s*	*F* pr.
Replication	4	10144	2535.877**	0.0002
Provenance	1	46.250	46.250^{ns}	0.7462
Family(Provenance)	43	18219	423.707^{ns}	0.5427
Residual	169	74362	440.011	

Note : *d.f* : degrees of freedom, *s.s* : sum of square, *m.s* : mean square, *F* pr. : *F* probability; ** : significantly different at $p<0.01$, ns : not significantly different at $p<0.05$

Table 2. Analysis of variance of the height and diameter

Source of variation	*d.f*	*s.s*	*m.s*	*F* pr.
Height				
Replication	4	54861	13715**	<.0001
Provenance	1	5892	5891.623**	<.0001
Row	40	21438	535.950^{ns}	<.0056
Replication*Column	20	31035	1551.774**	<.0001
Family(P)	43	34093	792.862**	<.0001
Replication*family(P)	109	41291	378.815 ^{ns}	0.0929
Residual	323	100154	310.074	
Diameter				
Replication	4	1.112153	0.278**	<.0001
Provenance	1	0.353244	0.353**	<.0001
Row	40	0.706117	0.018*	0.0102
Replication*Column	20	0.955678	0.048**	<.0001
Family(P)	43	1.644769	0.038**	<.0001
Replication*family(P)	109	1.294985	0.012 ^{ns}	0.2391
Residual	323	3.450651	0.011	

Note : *d.f* : degrees of freedom, *s.s* : sum of square, *m.s* : mean square, *F* pr. : *F* probability; **: significantly different at $p<0.01$, ns : not significantly different at $p<0.05$.

due to the fact that parent trees of Fatumnasi provenance which their progenies were included in this trial have a better performance in term of stem diameter to compare with those of Bu'at provenance. Significant differences among families within provenance tested on height and diameter traits indicated that there is high genetic variations families included in the trial. In other *Eucalyptus*, that among provenances and among families-within-provenances for both traits in *E. camaldulensis* were also shown a significant differences (Bush, Marcar, Arnold, & Crawford, 2013). As for survival, there were significant differences between replications, possibly for similar reasons to those stated above. This result reiterates the findings made by Maid and Bhumibhamon (2009) based on trial of up to six years old trees in Chachoengsao, Thailand. The differences among families of *E. urophylla* found in the present as well as other trials could be exploited to improve productivity of the plantations. Gains in genetic improvement programs could be achieved through family selection. The seed sources from the best performing families are the most appropriate choices for immediate future plantations in areas having conditions similar to the trial site when genetically improved seed orchards have not yet been established.

C. Heritability

The estimation of heritability and genetic correlations between traits shown in the Tabel 3 were based on the estimation of variance and covariance components (Bush et al., 2011).

Individual (h^2i) and family (h^2f) heritabilities for height and diameter were 0.28 and 0.41, and 0.55 and 0.66 respectively. These heritabilities can be considered moderate based on the Cotterill and Dean (1990) classification, that anticipates values of 0.1-0.3 and 0.4-0.6, respectively, for both variables. These heritabilities were quite high for these growth traits. It is most likely due to the seed were collected from closely together parent trees or there are more than usual inbred individuals or variability in inbreeding among families. Previous study by Borralho (1994) indicated that inbreeding depression and selfing among families could result overestimation of heritability calculation. Heritability for diameter in this study was found to be greater than heretability for height. This result is similar

Table 3. Estimated heritabilities and variance components of the height and diameter

Parameters	h^2_i	h^2_f	$\sigma^2 f$	$\sigma^2 fb$	$\sigma^2 e$
Height	0.28	0.55	0.0022	0.0007	0.0108
Diameter	0.41	0.66	42.32	26.12	310.53

Notes : *h2i* : individual heritability, h^2f : family heritabilitiy, σ^2f : variance component of family; $\sigma^2 fb$: variance component of family and block interaction, $\sigma^2 e$: variance component of error

with other studies of progeny trials of *E. urophylla* in Vietnam by Kien et al. (2009) and in China by Lan (2011) where heritabilities of both traits were relatively identical. It should be noted however that heritability is also expected to change with plant age. In general, heritability estimated for height and diameter had a tendency to increase with age. The trend of increasing heritability with age was also reported in the previous study of *E. urophylla* in China (Wei & Borralho, 1998) and in Vietnam (Kien et al., 2009). The later authors reported that heritabilities estimated for diameter and height increased about two fold in two progeny trials. Other eucalypt species (Gapare, Gwaze, & Musokonyi, 2003) and other tropical species such as *Araucaria cunninghamii* (Setiadi, 2010; Setiadi & Susanto, 2012) have also given similar trends. The change in heritability in long rotation crops such as forest trees is expected since genes involved in growth may change with age and these changes may be related to different growth phases (Missanjo, Kamanga-Thole, & Manda, 2013). Kien et al. (2009) stated that the increased heritability with age for growth traits could also result from competitive effects occurred at later ages in the stand, which may cause over estimation of heritability.

D. Genetic Correlation

The genetic correlation between height and diameter was 0.96. Thus the correlation was high and positive, which means that selecting for increase in diameter will be associated with an increase in height and vice versa. As for heritability, genetic correlation between tree height and diameter could be changed as trees get older. Genetic correlations estimated for diameter and height traits of two progeny trials of *E. urophylla* from year 1 to year 8 and year 9 at two different sites in Vietnam showed that the genetic correlation changed without specific trends. Genetic correlations at similar ages between diameter and height were strong at all ages at both sites (rg = 0.75 to 0.98) (Kien et al., 2009).

If a genetic correlation in this trial remains relatively constant with tree age as reported in the previous study by Kien et al. (2009), selection was likely to be more efficient if using one variable only. In practice, selection within *E. urophylla* would be more easily conducted by selection based on diameter traits rather than height as it would greatly reduce the cost of measurement especially in later ages when trees were relatively tall. However, as diameter was measured at 5 cm height, it would first be necessary to assess this correlation at breast height.

IV. CONCLUSION

Evaluation of a one year old *E. urophylla* progeny test showed that the survival rate was relatively high (83%). There were also significant differences between families in both height and diameter. Individual and family heritabilities were 0.1-0.3 and 0.4-0.6 respectively, for both variables, and the diameter was greater than the height. The genetic correlation between height and diameter was strong and positive (0.96). However, these estimated genetic parameters should be interpreted carefully as the trial was very young. Assessment of the trial at later ages should be done periodically to provide better understanding of the species regarding the dynamic of genetic interaction between the species and its environment, effective age of selection and predicted genetic gain. The progeny trial may be converted into seedling seed orchard through selection of superior individuals and families. This seedling seed orchard is expected to provide superior seeds for future plantation.

ACKNOWLEDGEMENT

The authors are very grateful to the organizers and instructors of ACIAR Paper-writing Workshop (Chris Beadle, Murni Greenhill, Daniel Mendham, Eko Bhakti Hardiyanto, Vivi Yuskianti, Anto Rimbawanto and Yayan Hadiyan (Center for Forest Biotechnology and Tree Improvement) for their invaluable comments on this paper. David Bush for his assistance in data analysis and his invaluable comments on this paper. Thanks also to Martinus Lalus, Johanis Naklui, Yunus Betty and Oktovianus Tanopo (Kupang Forestry Research Institute) for their help and support in the field.

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PHENOLOGY, CLIMATE, AND ADAPTATION: HOW DOES DIPTEROCARPS RESPOND TO CLIMATE?

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Received: 23 October 2013, Revised: 04 October 2016, Accepted: 17 October 2016

PHENOLOGY, CLIMATE AND ADAPTATION: HOW DOES DIPTEROCARPS RESPOND TO CLIMATE?. Temperature, rainfall and extreme weather have been indicated to affect the phenological patterns and forest productivity by shifting flowering and fruiting seasons and patterns, as well as crop production. Dipterocarpaceae are high value trees for both timber and non-timber forest products. This study aims to determine the response of phenological patterns of flowering and fruiting of Dipterocarps to climate variables. The study was conducted at Way Canguk Research Station of the Bukit Barisan Selatan National Park (BBSNP), Lampung during May-November 2012 by analyzing 14 years (1998-2012) of phenological data of Dipterocarps. The phenology surveys were carried out on monthly basis by estimating the percentage of flowering, fruiting (divided into 0-4 scoring) and the crop production. The results indicated that the phenological patterns of Dipterocarps in the area depicted major and minor patterns without mass-flowering time, different from what have been reported for Kalimantan or North Sumatra. Minor peak flowering season showed regular flowering, particularly during March to July every year. However, there were major flowering seasons in November 2002 (20.2%), September 2006 (21%), and October-November 2011 (20.3%). Average monthly fruit production showed a peak at the end of the dry season. Major flowering season seemed to coincide with the period of major El Nino events in November 2002 and September 2006, while others associated with La Nina. This study suggest that phenology and climate change may have implications in designing strategies for collection of seed materials to support the conservation and plantation programs of the Dipterocarps.

Keywords: Dipterocarpaceae, phenology, climate, Bukit Barisan Selatan National Park

FENOLOGI, IKLIM DAN ADAPTASI: BAGAIMANA DIPTEROCARPACEAE BEREAKSI TERHADAP IKLIM?. Suhu, curah hujan, dan cuaca ekstrim telah diindikasikan mempengaruhi pola fenologi dan produktivitas hutan dengan menggeser musim berbunga dan berbuah, menggeser pola, serta produksi buah. Dipterocarpaceae adalah pohon bernilai tinggi untuk hasil hutan kayu dan non-kayu nya. Tulisan ini mempelajari respon dari pola fenologi pembungaan dan pembuahan Dipterocarpaceae terhadap peubah iklim. Penelitian dilakukan di Stasiun Penelitian Way Canguk Taman Nasional Bukit Barisan Selatan (TNBBS), Lampung selama Mei-November 2012 dengan menganalisis 14 tahun (1998-2012) data fenologi Dipterocarpaceae. Survei fenologi dilakukan secara bulanan dengan melakukan estimasi persentase berbunga dan berbuah (dibagi menjadi skoring 0-4) serta estimasi produksi buah. Hasil penelitian menunjukkan bahwa pola fenologi Dipterocarpaceae di daerah ini digambarkan berupa pola mayor dan minor tanpa waktu berbunga massal, yang berbeda dari laporan sebelumnya untuk Kalimantan atau Sumatera Utara. Puncak musim berbunga minor menunjukkan pola berbunga teratur terutama selama Maret-Juli setiap tahunnya. Namun, terdapat musim berbunga mayor, yang terjadi pada bulan November 2002 (20,2%), September 2006 (21%), dan Oktober-November 2011 (20,3%). Rata-rata produksi buah bulanan menunjukkan puncak pada akhir musim kemarau. Musim berbunga mayor tampaknya bertepatan dengan periode El Nino utama pada bulan November 2002 dan September 2006, sementara yang lain terkait dengan La Nina. Hasil penelitian ini menunjukkan bahwa fenologi dan perubahan iklim mungkin memiliki implikasi dalam merancang strategi pengumpulan bahan benih untuk mendukung program konservasi dan hutan tanaman Dipterocarpaceae.

Kata kunci: Dipterocarpaceae, fenologi, iklim, Taman Nasional Bukit Barisan

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 doi: https://doi.org/10.20886/ijfr.2016.3.2.129-141

I. INTRODUCTION

The change of climate can have an impact on the ecosystems and biodiversity from land to sea (McCarty, 2001; Parmesan, 2006). In plants, climate change will affect photosynthesis, plant respiration, decomposition of organic matters and micro-biochemical processes. At the community and ecosystem levels, the combination of temperature and precipitation could shift the composition of vegetation resulting changes in habitat types (McCarty, 2001). Additional variabilities may also increase the effects of climate change such as forest fires and other human interferences. Changes in precipitation and temperature can cause changes in the pattern of plant phenology (Cleland, Chuine, Menzel, Mooney, & Schwartz, 2007). Several studies depicted changes in phenological response to climate change. Climate change may occur if there are changes in pattern of wet and dry months. In fact, changes in phenological pattern are considered as the first responses of plants to climate change and can cause adverse effects on wildlife that depend on seasonal food resources (Corlett & LaFrankie, 1998).

Phenology is the study of recurrent phases in an organism either animal or plant affected by climatic factors (Sakai, 2001; Cleland et al., 2007) The emerging and falling of leaves, flowering, and fruiting in terms of duration, frequency and quantity of production will describe the patterns of plant phenology (Newstrom, Frankie, & Baker, 1994). An understanding of these patterns is important to know how a plant can grow and reproduce, as well as providing a source of food for the animals at a time in a region (Van Schaik, Terborgh, & Wright, 1993). Phenology is also useful for understanding the process of restoration in the selection of tree species and seed harvesting time for a seed bank (Ehrenfeld & Toth, 1997). Plant phenological patterns are influenced by environmental factors, such as temperature and precipitation (Cleland et al., 2007). Phenological patterns of tropical regions are very diverse with very little information due to lack of available long-term data (Corlett & LaFrankie, 1998). Several research have been conducted on phenological patterns of Dipterocarpaceae in Asia such as in Kalimantan (Brearley et al., 2007), northern Sumatra (Van Schaik, 1986), and the Malay Peninsula (Ashton, Givnish, & Appanah, 1988; Yasuda et al., 1999; Numata, Yasuda, Okuda, Kachi, & Noor, 2003). However, the patterns of mass-flowering may vary (Corlett & LaFrankie, 1998).

Dipterocarpaceae are trees of the Asian tropical regions occupying a variety of habitats (Ashton, 1988; Appanah & Turnbull, 1998). This family is known as the main trees composing the tropical forests of Southeast Asia (Kettle, 2010) and therefore popular as timber trees. In fact, Indonesia is one of the major timber producers of Dipterocarps from tropical countries (Blaser, Sarre, Poore, & Johnson, 2011). In addition to timber, the Non-Timber Forest Products (NTFP) have also been used, i.e. fruit, bark, resin, leaves and sap (Rahayu, Susiarti, & Purwanto, 2007). Dipterocarps has become the target TPTII (SILIN/Intensive Silviculture) of the Ministry of Forestry. The trees are also important for the biodiversity. The large trees of Dipterocarps provide nesting cavity for hornbills (Kinnaird, & O'Brien, 2007) and the seeds are food for terrestrial mammals such as wild pigs and squirrels. In addition, many dipterocarp species are fast-growing species used in the restoration program of degraded land such as *Shorea acuminate* and *S. leprosula* (Shono, Davies, & Kheng, 2006; Shono, Davies, & Chua, 2007; Kettle, 2010). Several dipterocarp species are protected species with Endangered (EN) to critically endangered (CR) one according to IUCN (2015) such as *Anisoptera costata* (EN), *Dipterocarpus hasseltii* (CR), *Hopea sangal* (CR) and *Vatica obovata* (CR). The growth and regeneration of dipterocarp in logged forest is low (Pamoengkas, 2010). In general, flowering and fruiting of Dipterocarpaceae are not occurring annually. The seeds are recalcitrant in which the viability decreased after storing and treatment (Farnsworth, 2000). The regeneration of Dipterocarps as the main component of the dipterocarp lowland tropical forests in Southeast Asia is important.

Bukit Barisan Selatan National Park (BBSNP) in southern Sumatra contains significant populations of globally important wildlife, including Sumatran rhinoceros, tiger, elephant, and over 300 bird species. BBSNP, similar to other protected areas in Indonesia, is suffering from on-going pressure of deforestation (Suyadi & Gaveau, 2007) where lowland forest is the most critical habitat of many animals and species but is exposed to a high pressure of encroachment (Kinnaird, Sanderson, O'Brien, Wibisono, & Woolmer, 2003; Gaveau, Wandono, & Setiabudi, 2007). Surrounded by human settlements, BBSNP is an important economic source for the surrounding communities while also suffering from continuous deforestation at a rate of 1.69% per year between 1972-2002 (Gaveau, Wandono, & Setiabudi, 2007). In the last three decades, forest cover has been reduced by 50% (3,470 km^2) in West Lampung and South Bengkulu, the districts in which the park lies, and by 17% (520 km^2) in the park (Gaveau et al., 2007). Progressing threats due to deforestation increase the pressure on the lowland dipterocarp forests of the Bukit Barisan Selatan National Park.

Climatic factors such as temperature, rainfall and extreme weather events could affect the pattern of phenology and forest productivity through the shifting of flowering and fruiting seasons, as well as flower and fruit productions. This is clearly affecting the harvesting time of timber and non-timber products. Dipterocarps are known as emergent trees and the main component of lowland tropical forests (Ashton et al., 1988; Whitmore, 1998). Although the phenological patterns of Dipterocarpaceae is not widely known, but mass-flowering or fruiting were noted in Kalimantan and Sarawak and can occur within a few years associated with ENSO/El-Nino (Yasuda et al., 1999; Sakai, 2001). In Leuser, the flowering of dipterocarp was affected by the increase in temperature (Wich & Van Schaik, 2000). It is suggested that there is variability in phenological patterns that may be related to climatic conditions and the local environment. Thus, understanding the phenology is important as an adaptation to climate change. This study aims to determine the response of phenological patterns of flowering and fruiting of Dipterocarps to climate variables in Bukit Barisan Selatan National Park, Lampung.

II. MATERIAL AND METHOD

2.1. Study Area

This research was conducted in Bukit Barisan Selatan National Park (BBSNP), Sumatra in Way Canguk area (5°39' S; 104°24' E), which is located in the south western part of the park (Figure 1). This park is the third largest protected area (3,568 km^2) in Sumatra and lies in the extreme southwest of Sumatra spanning two provinces, Lampung and Bengkulu (O'Brien & Kinnaird, 1996). BBSNP contains some of the largest remaining tracts of lowland rain forest in Sumatra and functions as the primary watershed for southwest Sumatra (O'Brien & Kinnaird, 1996). This research station is located in the lowland forest and has a high diversity of wildlife including some endangered mammals, such as Sumatran Tiger (*Panthera tigris*), Sumatran rhino (*Dicerorhinus sumatrensis*), primates, and more than 200 species of birds. A human trail crossed the study area to Way Haru enclave which is approximately 7 km from the research station. The human trail has opened access to human presence in the park.

The study area encompasses an 800 ha forest with a grid of trails at 200 m intervals. The study area is bisected by the Canguk River and the two sections are referred to as North and South study sites. All transects are permanently marked at 50-m intervals. During the 1997 forest fire, approximately 165 ha was burned, some of the southern part of the study area (O'Brien et al., 1998; Kinnaird & O'Brien, 1998). This forest fire has changed the vegetation structure with higher tree as well as seedling and sapling mortality in the post-burned area (O'Brien et al., 1998; Sunarto, 2000).

2.2. Methods

The study was conducted at Way Canguk Research Station of the Bukit Barisan Selatan National Park (BBSNP), Lampung during May-November 2012 by analyzing 14 years (1998-2012) of phenological data of Dipterocarps. Phenology monitoring was conducted at 100 plots (10 x 50 m); 75 plots in the south and 25 plots in the north of the study site on trees with DBH ≥ 10 cm (Figure 2). Phenology observations were conducted using binoculars. The phenology monitoring were carried out on a monthly basis during the first week of the month by estimating the percentage of flowering and fruiting which was divided into 0-4 scoring (1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%) and estimated the crop production following Kinnaird, O'Brien, and Suryadi (1999).

Estimation of fruit production was based on the exponential scale, where the abundance estimates were divided into class intervals, namely 1-3, 4-6, 7-9, 10-30, 40-60, 70-90 and so on. Only the median values were then taken for further analysis (Leighton, 1982).

Rainfall and temperatures (maximum and minimum) were recorded daily at Way Canguk Research Station, BBSNP. Two types of temperature data were collected, within canopy and canopy free temperature. In this analysis, within and canopy free temperatures were averaged so that there was only one maximum and one minimum temperature.

Phenology and climate data were then synthesized to see if there was any particular pattern during the past 15 years. TLinear regression was carried out between particular climate variables of a particular month and particular phenological patterns in order to explore any relationship between climate variables of a particular month. Correlation of phenology and climate variables was carried out using Spearman Rank Correlation. All analysis was carried out using SPSS 16.

III. RESULTS AND DISCUSSION

A. Climate Variables

Minimum temperature in *Way* Canguk, BBSNP ranged between 19 and 25^{o}C, while maximum temperature was between 24 and

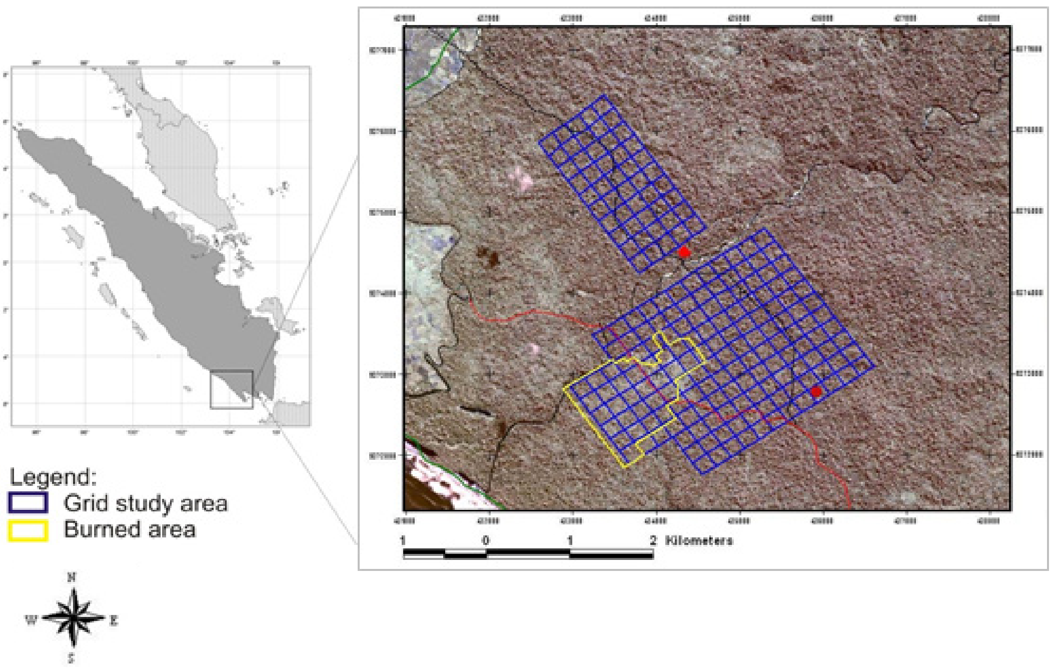


Figure 1. Location of Way Canguk Research Station and study area relative to Bukit Barisan Selatan National Park (BBSNP)

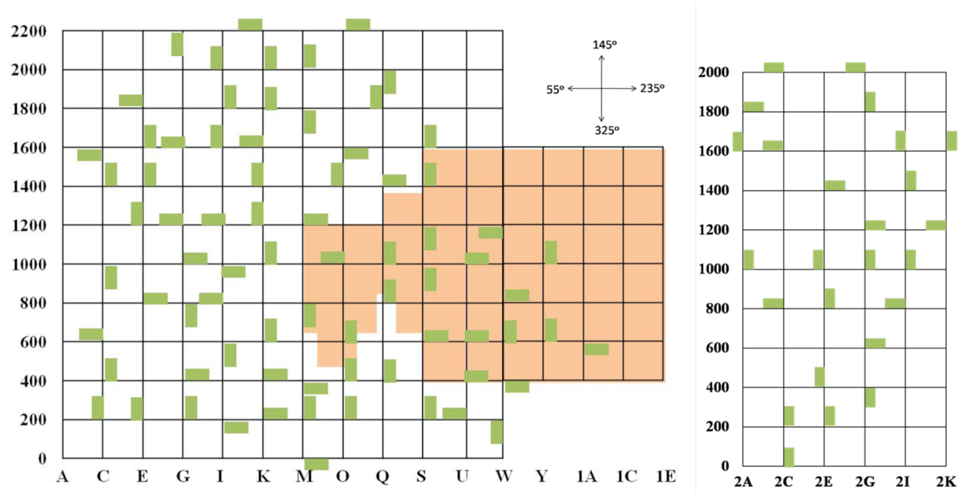


Figure 2. Phenology plots in Way Canguk Research Station, BBSNP

40°C. Average minimum temperature was 22.3°C while average maximum temperature was 37.8°C. The maximum temperature was increasing by 0.15°C per year while the minimum temperature outside canopy was decreasing by 0.19°C per year. In some years (2005, 2006, 2010, 2011, and 2012), average minimum temperature could drop below 21°C. Pattern of rainfall was unimodal with annual rainfall between 2000 and 4000 mm. The wettest year was 1999 (4005 mm) and the driest year was 2005 (2585 mm). The unimodal pattern is different from Leuser, North Sumatra which has bimodal pattern with two peaks of rainy seasons (Van Schaik, 1986) since Leuser is closer to the equator (Van Schaik, & Pfannes, 2005). In some months, rainfall could drop below 100 mm and sometimes there was no rainfall at all (Figure 3 and 4). Average daily rainfall was 13.17 mm. The wet season occurred during September – May while the dry season occurred during June – September.

B. Flowering

The phenological observations recorded 116 individuals from 11 Dipterocarpaceae species (*Anisoptera costata*, *Dipterocarpus gracilis*, *D. hasselti*, *D. humeratus*, *D. palembanicus*, *D. retusus*, *Hopea sangal*, *Shorea javanica*, *S. ovalis*, *S. ovata*, and *Vatica obovata*). The results indicated that the phenological patterns of Dipterocarps during 14 years (1998-2012) in the area depicted no mass-flowering time, different from what has been reported for Kalimantan or North Sumatra. The period of mass-flowering is usually marked with 80% flowering of all Dipterocarpaceae species (Ashton, et al., 1988). In BBSNP, the phenological pattern showed regular minor peak flowering during March to July every year. However, it is noted that there were major flowering seasons, in November 2002 (20.2%), September 2006 (21%), September-October 2008 (16.67%) and October-November 2011 (20.3%) (Figure 5). Within those years, minor peak flowering has also occurred. However, in 1999 the peak flowering season shifted in October. Shifting in the peak of flowering is thought to be correlated with the forest fires in 1997-1998. This percentage of flowering is much lower when compared to the peak flowering season in Barito Ulu, Central Kalimantan or Pasoh, Peninsular Malaysia where it reached more than 50% (Numata et al., 2003); (Brearley et al., 2007). The lower percentage of flowering could be due to the number of Dipterocarp species was fewer than that of in Borneo and Peninsular Malaysia. In Central Kalimantan, the composition of Dipterocarp species reached 39 species while there were only 11 species in BBSNP (Brearley et al., 2007).

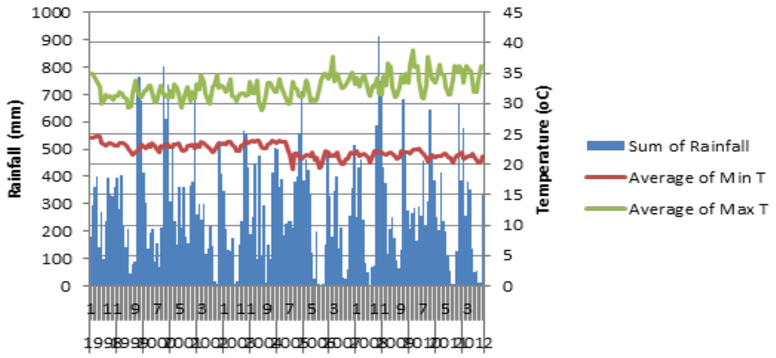


Figure 3. Pattern of rainfall as well as maximum and minimum temperatures during 1998-2012 in Way Canguk

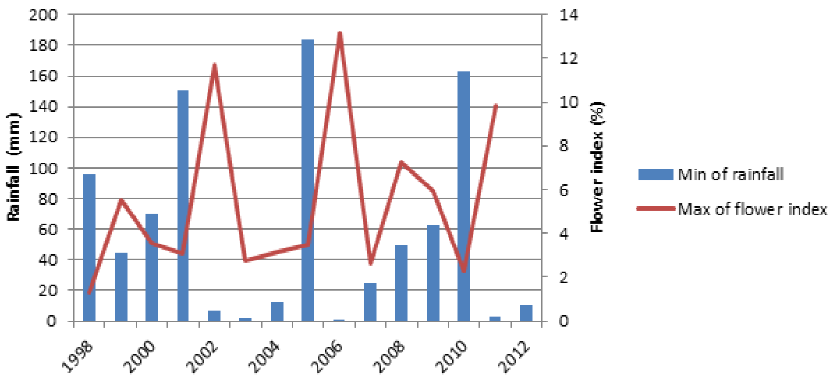


Figure 4. Minimum rainfall at particular month of each year and maximum flower index

Rainfall seemed to be an important factor in period of minor and major flowering. Mass-flowering in Central Kalimantan occurred approximately every three years as documented during 1991, 1994 and 1997 preceded by major drought periods in the previous month with more than 10 days of rainfall less than 100 mm (Brearley et al., 2007). In BBSNP, except in September 2008 where rainfall in the previous month was 74.20 mm, the period of major flowering in November 2002, September 2006, and October-November 2011 was preceded with one month with rainfall less than 10 mm. This was supported when regression was carried out between the highest percentages of flowering of each year over the rainfall of the previous month which suggested that rainfall of the previous month correlated to the peak of flowering. Comparing between linear and exponential regression, the relationship was more likely to be exponential (Linear: $R^2 = 0.42$, $P = 0.009$, Exponential: $R^2 = 0.82$, $P < 0.001$) showing that rainfall pattern in exponential function was more likely to exceed linear function in affecting flowering (Figure 6).

This pattern was made up by 5 species of Dipterocarpaceae which has supra-annual patterns such as *Anisoptera costata*, *Dipterocarpus humeratus*, *Shorea ovalis*, *Hopea sangal*, and *Dipterocarpus palembanicus* which have similar period of major flowering to the general pattern of the major flowering of Dipterocarpaceae.

C. Fruiting

In BBSNP, the period of fruiting was following the flowering period when there was a major or minor fruiting period. The major fruiting period was one-two months following the major flowering period (Figure 4). Percentage of fruiting trees during the major peak fruiting season happened in February 2003 (23%), February 2007 (21.7%), and February 2012 (23.5%). The average monthly fruit production showed a peak at the end of the dry season (Figure 6) showing a positive correlation with rainfall (*R2* = 0.401; *P* = 0.027).

D. Dipterocarps and Climate Sonsequences

In general, the pattern of the phenology of Dipterocarpaceae in BBSNP, southern Sumatra did not experience mass flowering season as happened in Kalimantan (Brearley et al., 2007) and Sarawak (Sakai et al., 1999). Patterns of mass flowering season is usually characterized by flowering up to 80% of the entire canopy Dipterocarp species (Ashton et al., 1988). Pattern of peak flowering and fruiting season in BBSNP showed that major flowering period occurred only 4 times in 15 years. Minor flowering season can be considered as the usual peak of annual flowering. Major flowering period occurred in the months of September, October, and November while in Kalimantan it could occur at any time of the year (Appanah, 1993).

Van Schaik and Supriatna (1996) suggested that phenology in the tropical rain forest community is more influenced by the sun rather than rainfall. Although, major flowering period occurred preceded by one driest month, general patterns of flowering trees (percentage of flowering trees) was more correlated to maximum temperature (Spearman Rank Correlation = 0.18, *P* = 0.02). Rainfall was more correlated to percentage of trees in fruiting (Spearman Rank Correlation = -0.25, *P* = 0.01) and crop production (Spearman rank correlation -0.17, *P* = 0.03) showed negative correlations.

Environmental cues such as temperature, rainfall, and drought sometimes have induced flowering (Reich, & Borchert, 1984). In several areas it was reported that mass-flowering was induced by the low night-time temperature (Yasuda, et al., 1999) while in Borneo, mass flowering was triggered by drought periods associated with ENSO (Sakai, et al., 2006). Sakai et al. (2006) suggesting that droughts occurred during the transition period between La Nina and El Nino, and at the beginning of El Nino. Ashton et al. (1988) also showed that strong flowering events in eastern Peninsular Malaysia coincided with El Nino events. Avoiding predators is also suggested to be one of the reasons of mass-fruiting (Van Schaik, 1986; Corlett & Primack, 2005). In BBSNP, the major period of flowering was proceeded by a dry month similar to Borneo. This flowering at BBSNP can be explained by two patterns: (1) Severe water stress during drought may induced major flowering period, but maximum temperature influenced the number of flowering trees in general and (2) Community composition of Dipterocarpaceae with less diversity in southern Sumatra than in Borneo obscured the mass-flowering period resulting in major and minor flowering periods. In the first pattern, there are two correlated climate variables responsible for flowering, period of the lowest rainfall and maximum temperature. Van Schaik, Terborgh, and Wright (1993) suggested several factors were enhancing photosynthetic and reproductive productivity such as dry years and high exposure to the sun (see also Appanah, 1993). In Costa Rica, anthesis was triggered by drought-induced leaf fall (Reich & Borchert, 1984). However, further data and analysis are still needed to ensure the response. In the second pattern, southern Sumatra has less diverse Dipterocarpaceae than Borneo and therefore gives less influence on the flowering pattern. *Shorea* spp. (six species) in Peninsular Malaysia are known to have staggered flowering which flowered sequentially to avoid competition for pollination (Ashton, et al., 1988). At least there are 14 species in Borneo (Brearley et al., 2007) while there are only three *Shorea* spp. in BBSNP. The less diversity may also obscure the effect of El Nino although geographical position may have an influence on the flowering pattern. Major flowering period in November 2002 and September 2006 seemed to coincide with a period of major El Nino in 2002 and 2006. However, other periods seemed to correlate

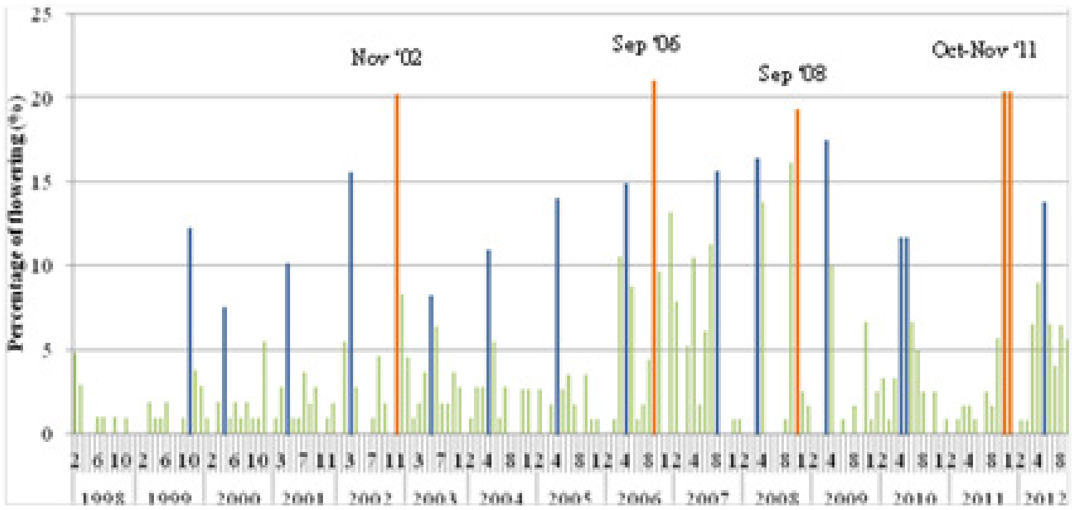
Table 1. Years with normal, La Nina, and El Nino months (National Weather Service 2014)*

Years	Normal	La Nina	El Nino	Reported mass or major flowering
1998	0	7	5	Sakai et al. 2006
1999	0	12	0	
2000	0	12	0	
2001	8	3	0	Numata et al. 2003
2002	3	0	9	This study
2003	8	0	3	
2004	5	0	7	
2005	7	3	2	
2006	3	4	5	This study
2007	4	6	2	
2008	5	7	0	This study
2009	5	0	7	
2010	0	7	5	
2011	2	10	0	This study
2012	5	4	0	

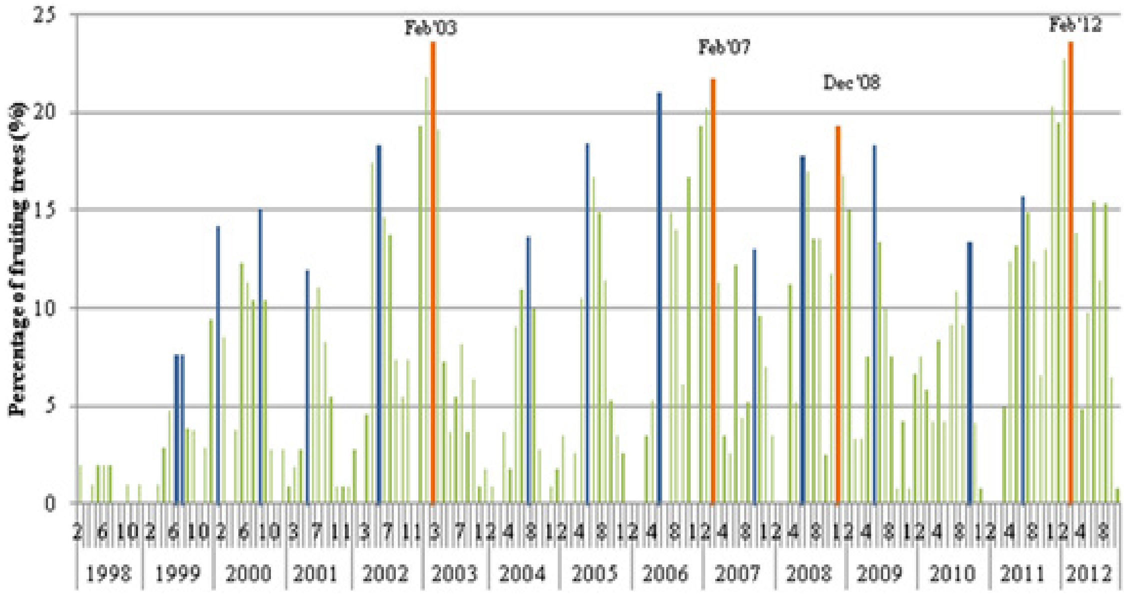
Note : * (Climate Prediction Center Internet Team, 2012)

with La Nina rather than El Nino period (Table 1, Figure 7). However, only Numata et al. (2003) and Sakai et al. (2006) reported similar event associated with El Nino, other reports was based on previous El Nino-La Nina events prior to 1998. Our results confirmed that ENSO event has little impact on areas west of Malaysia as also depicted in Leuser as suggested by Wich & Van Schaik (2000). All phenological data in Borneo recorded more than 20 species in their area (Curran et al., 1999; Sakai et al., 1999; Brearley et al., 2007).

In this study, fruit production of the Dipterocarpaceae did not seem to follow the major flowering period. In effect, this will produce low fruit production and thus low fallen seeds. In Borneo, altered climatic pattern is suspected to influence fruit production which resulted in low seed production (Curran et al., 1999). Response of fruiting phenology of plants to climate change is complex and may vary among species (Chapman et al., 2005) and therefore needs a thorough analysis of different potential variables. Habitat fragmentation may also have an impact on the reduction of effective population size (Kettle, 2010). In addition, Dipterocarps are usually shade-tolerant species showing an I-shape distribution where there are large number of young and lower number of mature individuals (Sist, Picard, & Gourlet-Fleury, 2003 see also Hartiningtias, 2013). According to strategy for collection of seed materials for supporting conservation and plantation programs, the information is important because major flowering period is correlated with preceding month of drought, water supply during droughts is also important to anticipate so that production of fruits for seed source can be available at all time. ENSO and climate prediction is important as many were associated with the major flowering period (and mass-flowering in other areas such as in Kalimantan) which can be the major source of seed bank. However, knowledge on seed collection and handling is important due to the recalcitrant character of the seeds (Kettle, 2010).



A. Flowering patterns of Dipterocarps during 1998-2012



B. Fruiting patterns of Dipterocarps during 1998-2012

Figure 5. Patterns of flowering and fruiting period of Dipterocarps during 1998-2012 (Kurniasari, Winarni, & Hartiningtias 2012)

IV. CONCLUSIONS

The study suggested that the general phenological pattern of flowering of Dipterocarpaceae in BBSNP was more correlated to maximum temperature which tended to increase during 15 years. There were no mass-flowering periods, but major flowering occurred during 2002, 2006, 2008 and 2011 preceded with one month of rainfall less than 100 mm. During major flowering, minor flowering still occurred at regular time. Rainfall in the previous month has negatively correlated with the number of trees in fruiting and crop production. Phenology and climate change may have implications in designing strategies for collection of seed materials of Dipterocarps in the natural forest.

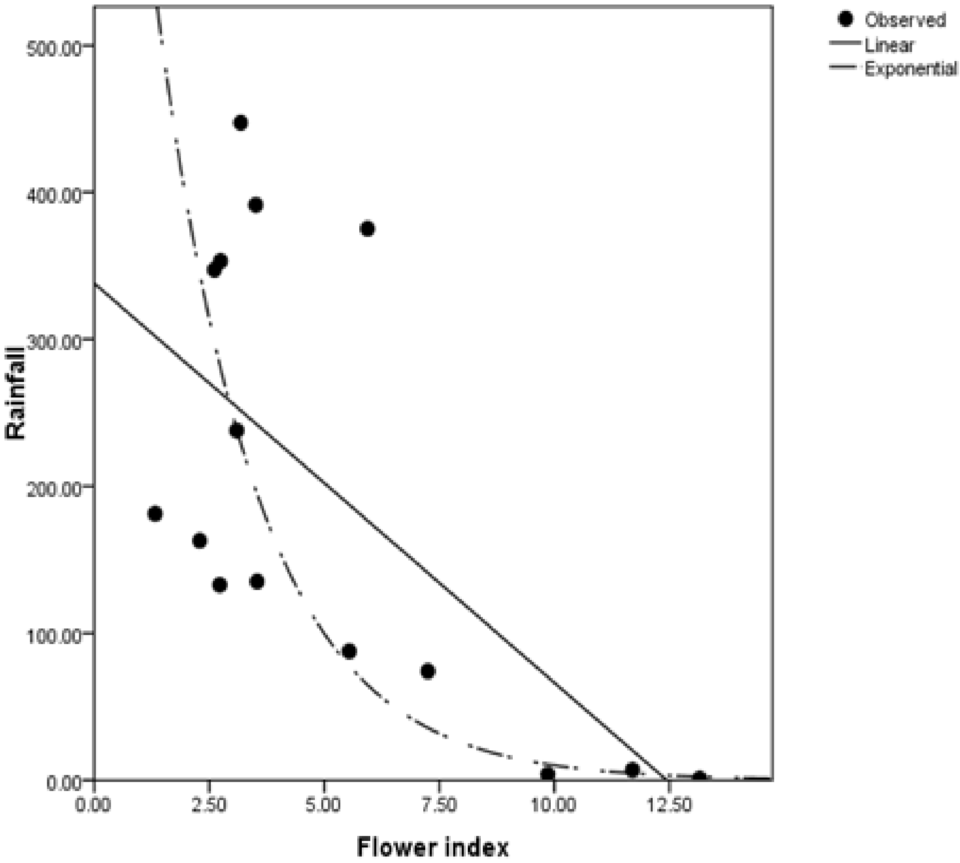


Figure 6. Correlation between rainfall in the previous month with maximum percentage of trees in flowering for each year. The figure compares linear and exponential regressions

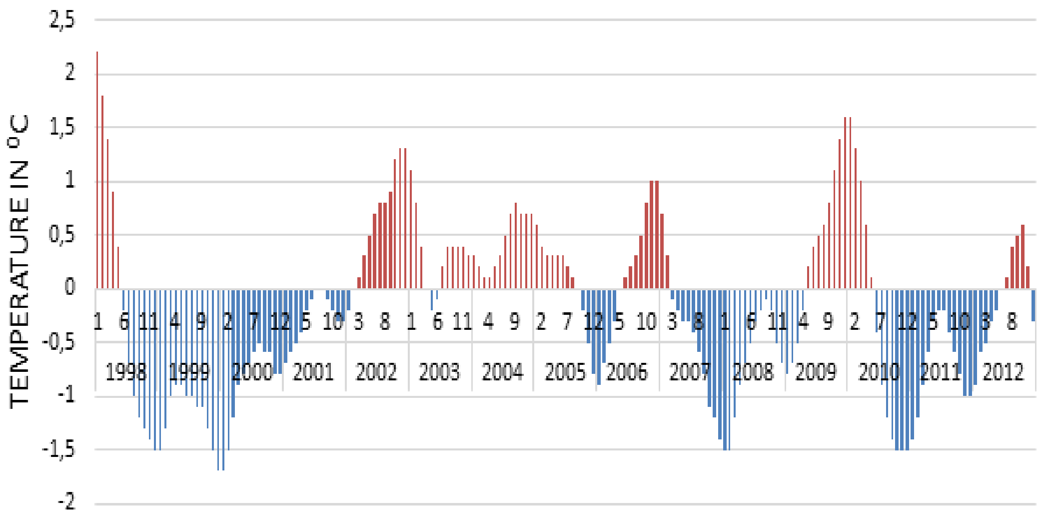


Figure 7. Years with El Nino and La Nina based on Oceanic Nino Index (ONI). The red bars indicating El Nino and blue bars indicating La Nino events Source: (Climate Prediction Center Internet Team, 2014)

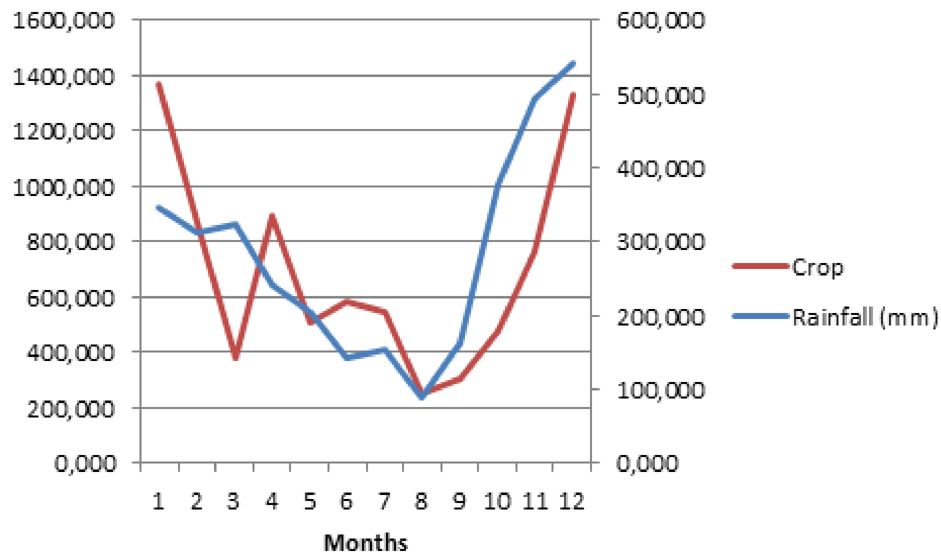


Figure 8. Monthly fruit production of Dipterocarpaceae (Kurniasari, Winarni, & Hartiningtias 2012)

ACKNOWLEDGEMENT

The authors would like to thank the Bukit Barisan Selatan National Park (BBSNP) for the permission and assistance during the study. This research was funded by Research and Development Center for Socio Economic, Policy and Climate Change - Ministry of Environment and Forestry (previously known as Puspijak). We are also grateful to the Wildlife Conservation Society Indonesia Program (WCS-IP) for data and field assistance during the study and we also thank Trinah Wati, Center for Climate Change and Air Quality of the BMKG.

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AUTHOR INDEX

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

Or

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

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JUDUL HARUS RINGKAS, INFORMATIF DAN SECARA JELAS MEREFLEKSIKAN ISI MANUSKRIP. Tuliskan terjemahan abstrak dalam bahasa Indonesia. Abstrak tidak lebih dari 300 kata. Abstrak menjelaskan keseluruhan isi artikel. Abstrak meliputi maksud, tujuan penelitian, metodologi yang digunakan, hasil dan kesimpulan. Maksud penelitian harus menjelaskan secara ringkas permasalahan yang diteliti menggunakan bahasa ilmiah umum yang mudah dimengerti oleh pembaca. Teknologi atau metodologi yang digunakan untuk pemecahan permasalahan penelitian harus dicantumkan secara lengkap dan ringkas dalam abstrak. Ringkasan hasil penelitian dan temuannya ditampilkan dalam ringkasan singkat. Kesimpulan harus menyatakan outcome yang dicapai dalam kegiatan penelitian.

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