Growth and survival rates of tree seedlings in a rehabilitation area of Central Kalimantan, Indonesia

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Introduction

Agricultural development has been one of the corner stones in developing human societies (Elasha, 2010; Larsen, 1995; Lipton et al., 2002; Marlowe, 2005; Ranis, 2004). Indeed, as of 2011 more than 1.3 billion people were active in agricultural production on the Earth (FAO, 2012), and agriculture continue to play a major part of most countries' gross national product (FAO, 2012). In 2010 approximately 4.9 billion hectares of the Earth was allocated for some form of agriculture (FAO, 2012). Of this, palm oil plantations take up less than 0.5%, but due to the extraordinary high yields palm oil production is a key revenue earner for many countries, particularly, Malaysia and Indonesia, the World's two largest palm oil producers. At a Global scale, palm oil occupies a very small land area compared to other food crops (e.g. wheat, maize, rice and soy) that occupies 10-15 times more land area per crop (FAO, 2010). Despite the relatively small land area used for palm oil production and the importance in contributing to nations' economic development, the extensive landuse change has also come with significant environmental costs (Dermawan, 2001; Fuller et al., 2004; Greenpeace, 2008a, b, c; Greenpeace 2007; Koh, 2007; Malcolm et al., 2006; UNEP, 2007) with large tracts of intact tropical forested regions cleared for oil palm development (Koh et al., 2011; Carlson et al., 2013; Carlson et al., 2012).

With the formation of the Round Table of Sustainable Palm Oil (RSPO) in 2004, the sector has seen a progressive shift towards environmentally sound development practices that increasingly integrates environmental concerns into standard operational practices. In some cases RSPO-certified companies are required to rehabilitate degraded land and restore riparian zones to its original conditions. This also applies, when companies take over already degraded land or areas where previous owners were in violation of respective national environmental laws or the RSPO rules. The RSPO Principles and Criteria (RSPO, 2007) stipulate that member companies are responsible for rehabilitating land areas that were cleared in contravention of the RSPO P&C by its previous owner after 2000.

Tropical forest rehabilitation can be a complicated and tedious process (Kettle, 2010), because different species require different sprouting, growth and survival conditions that are usually determined by micro-habitat (Dalling and Hubbel, 2002; Herault et al., 2010; Kettle, 2010; Rey et al., 2004), seed size (Baraloto and Forget, 2007; Khan, 2004; Rees and Venable, 2007; Ruger et al., 2011; Turnbull et al., 2012), competition (Baraloto et al., 2005; Gonzalez et al., 2010; Muscarella et al., 2013; Paz et al., 2005), predator pressure (Eichorn et al., 2010; Eichorn et al., 2007; Koricheva, 2002; Lamarre et al., 2012; Shuldt et al., 2012) and local light conditions (Baraloto and Forget, 2007; Bloor and Grubb, 2003; Kettle, 2010; Ruger , 2011). In addition, the significant time required to restore clear felled areas to tropical rainforests habitat means that very little practical knowledge is available to support and guide an effective rehabilitation and restoration programme of tropical forests in Southeast Asia. In areas, where oil palms have already been planted, restoration often begins with clearing and uprooting existing vegetation with subsequent planting of tree seedlings.

Various tree species require different light and microhabitat conditions for optimal growth rate in the

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early and later growth stages (Baraloto et al., 2005; Bloor and Grubb, 2003; Kettle, 2010; Ruger et al., 2011). Some seedlings adapt well to elevated light exposure, though it may impair the growth rate, whereas overexposure to the sunlight inhibits growth rates for others (Krause et al., 2012; Krause et al., 2006). Many tropical rainforest tree species require shady conditions in the early stages of growth to reduce the negative effects of temperature and evaporation (Muscarella et al., 2013; Bloor and Grubb, 2003). Therefore, complete removal of existing palms may not necessarily provide suitable growth and survival conditions for some native tree seedlings and, consequently, clear felling of palms may not necessarily be advisable when restoring tropical forests habitat. This study aimed at testing the effect of three different rehabilitation approaches for the restoration of a tropical flooded forest in Central Kalimantan, Indonesia.

Methods

Study area

The study area is located in Central Kalimantan, Indonesia (2°29'33.14"S; 111°47'32.86"E) and consists of 36ha of degraded freshwater swamp forest. The area was cleared and planted with oil palm in 2005, but because it contravened with the RSPO P&C, the new owner – an RSPO-member - set it aside for rehabilitation purposes. Since there had been no tree species inventory undertaken in the area prior to clear felling, the species composition was assumed to be similar to adjacent forests in Central Kalimantan. Acep Komara (2008) and Irwanto (2006) were used as additional guidance.

Preparation of seedlings

We collected and propagated seeds from 17 different tree species. In the rehabilitation process we focused on five species only, namely; Rengas (*Gluta renghas*), Ubar (*Calophyllum castaneum*), Idat (*Cratoxylum arborescens*), Belangiran (*Shorea balangeran*) and Penaga (*Mesua sp*). All five species were propagated in polybags and watered once per day for five months, before being out planted into the study area.

Site preparation

The study site was left without external treatment (weeding, fertilizer) for more than 12 months to prevent residual chemicals and/or fertilizer from influencing growth and survival rates of the tree seedlings. Harvesting of the remaining oil palms continued at regular intervals. The study site was divided into three different categories;

Category A: All planted oil palms remained and tree seedlings were planted between the palm rows in grids of 10m by 10m. Harvesting continued but no additional treatment (weeding, fertilizer) was carried out.

Category B: 50% of the oil palms were uprooted and removed. Tree seedlings were planted in the empty palm rows in grids of 20m by 10m. Harvesting continued but no additional treatment (weeding, fertilizer) was carried out.

Category C: All palms were uprooted and removed. Tree seedlings were planted in grids of 10m by 10m.

A total of 1358 seedlings from five different species were planted in Plots A, B and C in the period 12th of January to 22nd of February, 2011. The growth rate (height) was measured in centimetres (cm) from substrate to highest leaf point; the trunk growth rate was measured in millimetres as the diametre at 20cm above substrate.

Results

Growth rates (Fig. 1)

The growth rates measured in height (cm) and trunk diameter (mm) varied significantly between species and Pstudy lot. Compared across all three study plots, Rengas' vertical growth rate (height, cm) was reversely correlated with its trunk growth rate (diameter, mm) (Pearson, r = -0.83). The growth rate patterns of Idat showed no correlation between height and trunk growth rates (Pearson, r = 0.03) and for Penaga there was a positive correlation between height and trunk growth rates (Pearson, r = 0.90). There were also no correlation between height and trunk growth rate across study plots of Ubar and Belangiran (Pearson, r = 0.03 and 0.027, respectively).

Survival rates (Fig. 2)

There was no significant difference in survival rate between the study plots when all species were combined ($p>0.05$, t-test). In each individual category, Rengas sp survived significantly better than Idat in Plot A and C ($p<0.05$, t-test), whereas Idat and Belangiran survived significantly better than Ubar and Penaga in Plot B ($p<0.05$, t-test).

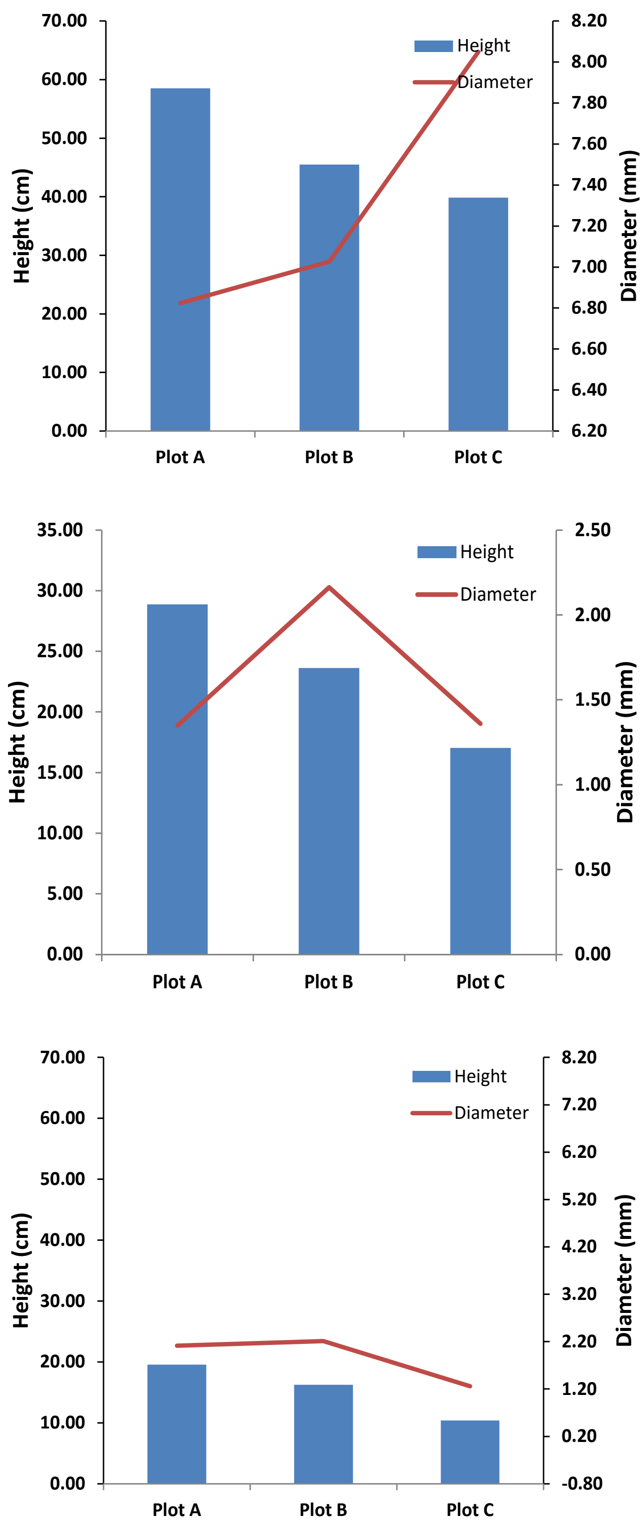

Figure 1. The growth rate measured in height and trunk diameter from February-July 2011 for *Gluta renghas* (top), *Cratoxylum arborescens* (middle) and *Mesua sp.* (bottom).

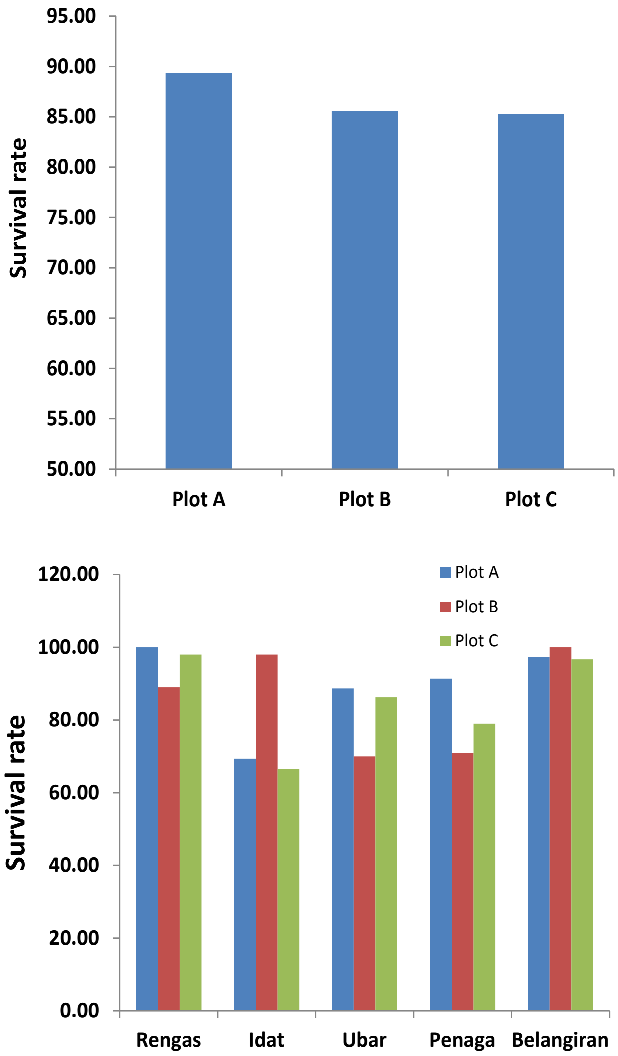

Figure 2. The average survival rate of all species in the three study plots (top) and the survival rate for each species in each study plot (bottom).

Discussion

Rehabilitation of degraded tropical rainforest is still in its infancy. In Southeast Asia, some of the more prominent large scale forest restoration and rehabilitation project have taken place in Luason Forest Reserve, Sabah and Harapan, Sumatra (Harrison and Swinfield, 2015; YS Sabah, 2007). In these cases, however, sites consisted primarily of lowland dipterocarp forest that had been subjected to logging, but not clear-cut. Restoration of wetland, peat forest or a similar habitat that has been cleared and replaced with a single species, such as oil palms, offers a very different challenge (Abdul Razak, 2007).

The results reveals that different species exhibit significantly different growth strategies, with some species exhibiting a very rapid height growth rate, and others tend to grow a bigger trunk size (Fig. 1). Microclimate also appears to influence the growth statistics; Rengas' height and trunk growth is reversely correlated between the three study plots (Fig.1; Pearson, r = -0.83). This is likely due to the photosynthesis competition with taller palms in Plot A (planted between palm rows), whereas in Plot C there were no competition for sunlight. However, there were also no palms to shield against wind gusts either, and growing a stronger trunk to prevent possible wind damage could be a likely reason for the slower height growth and larger trunk growth. In contrast Penaga exhibited a positive correlation (Pearson, r = 0.90) between height and trunk growth across the three plots, whereas there were no correlation recorded for Ubar., Belangiran and Idat.

The survival rates for all five species were almost similar across all three study plots. Rengas, however, survived significantly better than Idat in Plot A, and this may be due to Idat's slower height growth rate (Rengas averages ~60cm; Idat averages ~30cm) that makes it less likely to capitalise on photosynthesis amongst taller palms.

The results from this study reveals that rehabilitation of an area previously planted with oil palms requires approaches that consider growth strategies of the specific tree species that is out planted. Our study suggests that following the "all palms must be cleared" approach is not an optimal practical solution, because it creates growth conditions that are unfavourable to many seedlings to either survive, or to maximise growth potential.

We recommend that rehabilitation practitioners should make use of the existing palms to "mimic" natural growth conditions in an undisturbed forest habitat, however, with active intervention to maximise photosynthesis opportunities for the seedlings and better rehabilitation success.

References

Abdul Razak (2007). Makalah Pengelolaan DAS "Peranan Lahan Basah (Wetland) dalam (DAS) pengelolaan Daerah Aliran Sungai". Universitas Gadjah Mada. Yogyakarta.

Acep Komara (2008). Komposisi Jenis dan Struktur Tegakan *Shorea Balangeran* (Korth) Burck, *Hopea bancana* (Boerl) Van Slooten dan *Caumarouna Odorata* Anbl. Di Hutan Penelitian Dramaga, Bogor Jawa Barat. Departemen Silvikultur Fakultas Kehutanan IPB. Bogor.

Baraloto, C. and P.M. Forget (2007). Seed size, seedling morphology, and response to deep shade and damage in neotropical rain forest trees. *American Journal of Botany* **94(6)**: 901–911.

Baraloto, C., Goldberg, D. and D. Bonal (2005). Performance trade-offs among tropical tree seedlings in contrasting microhabitats. *Ecology* **86(9)**: 2461–2472

Bloor, J.M.G and P.J. Grubb (2003). Growth and mortality in high and low light: trends among 15 shade-tolerant tropical rain forest tree species. *Journal of Ecology* **91**: 77–85.

Carlson, K. M, Curran, L.M., Ratnasari, D., Pittman, A.M., Soares-Filho, D.S. Asner, G.P., Trigg, S.N., Gaveau, D.A., Lawrence, D. and H.O. Rodrigues (2012). Committed carbon emissions, deforestation, and community land conversion from oil palm plantation expansion in West Kalimantan, Indonesia. *Proc. Natl Acad. Sci.* **109**: 7559-7564.

Carlson, K.M., Curran, L.M., Asner, G.P., Pittman, A.M., Trigg, S.N and J.M. Adeney (2013). Carbon emissions from forest conversion by Kalimantan oil palm plantations. *Nature Climate Change* **3**: 283–287.

Dalling, J.W. and S.P. Hubbell (2002). Seed size, growth rate and gap microsite conditions as determinants of recruitment success for pioneer species. *Journal of Ecology* **90**: 557-568.

de Kok, R.P.J., Briggs, M., Pirnanda, D. and D. Girmansyah (2015). Identifying targets for plant conservation in Harapan rainforest, Sumatra. *Tropical Conservation Science* **8(1)**: 28-32

Eichhorn, M.P., Nilus, R., Compton, S.G., Hartley, S.E. and D.F.R.P. Burslem (2010). Herbivory of tropical rain forest tree seedlings correlates with future mortality. *Ecology* **91(4)**: 1092–1101

Eichhorn, M.P., Fagan, K.C. and S.G. Compton (2007). Explaining leaf herbivory rates on tree seedlings in a Malaysian rain forest. *Biotropica* **39(3)**: 416–421.

Elasha, B.O. (2010). Mapping of climate change threats and human development impacts in the Arab region. Arab Human Development Report, Research Paper Series, UNDP, 51 pp.

Engel, D.H., and P. Suchart (2007). A Field Guide to Tropical Plants of Asia. Marshall Cavendish Editions.

Fakheran, S., Paul-Victor, C., Heichinger, C., Schmid, B., Grossniklauss, U., and L.A. Turnbull (2010). Adaptation and extinction in experimentally fragmented landscapes. *Proc. Natl. Acad. Sci.* **107**: 19120-19125.

Fowler, J., Cohen, L. and P. Jarvis (2009). Practical Statistics for Field Biology. John Wiley & Sons Ltd, The Atrium, Southerm Gate, Chichester, West Sussex PO19 8SQ, England.

Gonzalez, M.A., Roger, A., Courtois, E.A., Jabot, F., Norden, N., Chave, J., Paine, C. E. T., Baraloto, C. and C. Thebaud (2010). Shifts in species and phylogenetic diversity between sapling and tree communities indicate negative density dependence in a lowland rain forest. *Journal of Ecology* **98**: 137–146, doi: 10.1111/j.1365-2745.2009.01607.x

Harrison, R.D. and T. Swinfield (2015). Restoration of logged humid tropical forests: An experimental programme at Harapan Rainforest, Indonesia. *Tropical Conservation Science* **8(1)**: 4-16.

Herault, B., Ouallet, J., Blanc, L., Wagner, F. and C. Baraloto (2010). Growth responses of neotropical trees to logging Gaps. *Journal of Applied Ecology* **47**: 821–831 doi: 10.1111/j.1365-2664.2010.01826.x

Irwanto (2006). Pengaruh Perbedaan naungan terhadap pertumbuhan semai Shorea sp di persemaian. Pasca Sarjan jurusan Ilmu-ilmu Pertanian Program Study Ilmu Kehutanan UGM. Yogyakarta.

Kettle, C.J. (2010). Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. *Biodiversity Conservation* **19**: 1137–1151. DOI 10.1007/s10531-009-9772-6

Khan, M.L. (2004). Effects of seed mass on seedling success in *Artocarpus heterophyllus* L., a tropical tree species of north-east India. *Acta Oecologica* **25**: 103–110.

Koh, L.P., Miettinen, J., Liew, S.C. and J. Ghazoul (2011). Remotely sensed evidence of tropical peatland conversion to oil palm. *Proc Natl Acad Sci*. **108**: 5127–5132.

Koricheva, J. (2002). Meta-analysis of sources of variation in fitness costs of plant anti-herbivore defenses. *Ecology* **83**: 176-190.

Krause, G.H., Winter, K., Matsubara, S., Krause, B., Jahns, P., Virgo, A., Aranda, J. and M. García (2012). Photosynthesis, photoprotection, and growth of shade-tolerant tropical tree seedlings under full sunlight. *Photosynthesis Research* **113(1-3)**: 273-285.

Krause, G.H., Gallé, A., Virgo, A., García, M., Bucic, P., Jahns, P. and K. Winter (2006). High-light stress does not impair biomass accumulation of sun-acclimated tropical tree seedlings (*Calophyllum longifolium* and *Tectona grandis*). *Plant Biology* **8(1)**: 31-41.

Lafrankie, J.V.Jr. (2010). Trees Of Tropical Asia. Black Tree Publications, Inc. Philippines.

Lamarre, G.P.A., ., Baraloto, C., Fortunel, C., Davila, N., Mesones, I., Rios, J.R., Rios, M., Valderrama, E., Pilco, M.V. and P.V.A. Fine (2012). Herbivory, growth rates, and habitat specialization in tropical tree lineages: implications for Amazonian beta-diversity. *Ecology* **93(8)**: S195–S210.

Larsen, C.S. (1995). Biological Changes in Human Populations with Agriculture. *Annual Review of Anthropology* **24**: 185-213.

Lipton, M., Saurabh Sinha and R. Blackman (2002). Reconnecting agricultural technology to human development. *Journal of Human Development* **3(1)**: 123-152

Marlowe, F.W. (2005). Hunter-Gatherers and human evolution. *Evolutionary Anthropology* **14**:54–67

Muscarella, R., Uriarte, M., Forero-Montana, J., Comita, L.S., Swenson, N.G., Zimmerman, J.K., Thompson, J., Nytch, C.J. and I. Jonckheere (2013). Life-history trade-offs during the seed-to-seedling transition in a subtropical wet forest community. *Journal of Ecology* **101(1)**: 171-182, doi: 10.1111/1365-2745.12027 Blackwell Science, Ltd

Paz, H., Mazer, S.J. and M. Martinez-Ramos (2005). Comparative ecology of seed mass in Psychotria (Rubiaceae): within- and between-species effects of seed mass on early performance. *Functional Ecology* **19**: 707-718.

Ranis, G. (2004). Human development and economic growth. Center Discussion Paper no. 887, Economic Growth Center, Yale University. 15 pp.

Rees, M. and D.L. Venable (2007). Why do big plants make big seeds? *Journal of Ecology* **95**: 926-936.

Rey, P.J., Alcantara, J.M., Valera, F., Sanchez-Lafuente, A.M., Garrido, J.L., Ramirez, J.M. and A.J. Manzaneda (2004). Seedling establishment in *Olea europaea*: seed size and microhabitat affect growth and survival. *Ecoscience* **11**: 310-320.

Ruger, N., Berger, U., Hubbell, S.P., Vieilledent, G. And R. Condit (2011). Growth strategies of tropical tree species: Disentangling light and size effects. *PLoS ONE* **6(9)**: e25330. doi:10.1371/journal.pone.0025330

Schuldt, A. Bruelheide, H., Durka, W., Eichenberg, D., Fischer, M., Krober, W., Hardtle, W., Ma, K., Michalski, S.G., Palm, W-U., Schmid, B., Zhou, H., Welk, E. and T. Assmann (2012). Plant traits affecting herbivory on tree recruits in highly diverse subtropical forests. *Ecology Letters* **15**: 732–739. doi: 10.1111/j.1461-0248.2012.01792.x

Surya Sawit Sejati Company (2008). Identification Variety of Flora, Fauna and High Conservation Value Area in the Plantation Area of Surya Sawit Sejati Company. Edutama Environment Institution. Pangkalan Bun.

Turnbull, L.A., Philipson, C.D., Purves, D.W., Atkinson, R.L., Cunniff, J., Goodenough, A., Hautier, Y., Houghton, J., Mathews, T.B., Osborne, C.P., Paul-Victor, C., Rose, K.E., Saner, P., Tayler, S.H., Woodward, F.I., Hector, A. and M. Rees (2012). Plant growth rates and seed size: a re-evaluation. *Ecology* **93(6)**: 1283-1289.

Yayasan Sabah (2007). Annual Report. Kota Kinabalu, Sabah, Malaysia.