

Measuring the Short-term Success of Hill Dipterocarp Forest Restoration: The Use of Organic Materials

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Abstract

Restoring degraded logged-over forest which is indicated by low in soil fertility and organic matter due to imbalance nutrient cycle are of paramount importance as there has been increasing attention towards these forests as the sustainable use of these resources. Forest restoration through reintroduces tree species lost, especially fast growing dipterocarp is implemented to curtail degraded logged-over forest and improve the soil fertility through organic material application is important, but only few information is available on restoration of degraded forest. The objectives of this study were: (1) to evaluate the growth and biomass accumulation on different kind and application rate of organic materials; and (2) to determine suitable application for restoration of degraded forest in the humid tropics of Peninsular Malaysia. This study was conducted at *Shorea leprosula* stand in Tekai Forest Reserve, Pahang, Malaysia. To evaluate the effects of organic materials on survival, growth and biomass increment, mineral soils were amended with different application rates of organic materials, such as pulp mill sludge, compost, oil palm mesocarp and their combinations. Application rate of each organic materials were 0, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{3}{4}$ of v/v. Growth measurement was conducted in every month for early growth up to 3 months after application and continued for every three months, while biomass accumulation were measured on initial, 3-, 6- and 12-month after application by destructive sampling method. Plant growth and biomass accumulation was increased by all amendments, however their rates was decreased during early growth as a result of adaptation process. Up to 12 months analyses, the best diameter growth performance appeared by compost 66.67% (treatment 9) and combination 33.33% (treatment 17), followed by treatment 10 (compost 75%) and 18 (combination 50%), while the best height growth performance appeared by treatment 18 and 17 and followed by treatment 9. The biggest biomass increment was on treatment 9, followed by treatment 18 and 17. The treatment that should be avoided for restoration program were control (treatment 1; only mineral soil), all application rates of pulp mill sludge and mix organic materials which high rate of sludge. Root formations on sludge medium shown in broken-down condition since they absorb water and dissolved minerals from pulp mill sludge medium, moreover all leaves shown unhealthy and burned down. Restoration program in tropical degraded forest land without applied organic material indicated poor growth rate and biomass accumulation, then organic material application to be one of the requirement treatments needed for better results. Compost as well as the type of past forest structure were important factors which resulted the best growth performance with high survival rate and recommended for restoration technique in Tekai Forest Reserve, Pahang, Malaysia or other comparative areas.

Keywords: restoration, organic matter, *Shorea leprosula*, growth performance, biomass increment

1. Introduction

Ecosystem restoration is defined as the “process of assisting the recovery of an ecosystem that is damaged, degraded, or destroyed” (SER, 2004). Effective restoration projects and programs manage or manipulate biotic and abiotic variables in order to remove threats to an ecosystem, facilitate or accelerate its recovery, and reinstate connectivity within the larger landscape. The restoration of degraded forests often includes the reintroduction of

native species, removal of non-native invasive ones, reestablishment of appropriate fire regimes and soil and hydrologic conditions, and other activities that facilitate natural regeneration.

Soil and soil biota are recognized to be extremely important components of terrestrial ecosystems but have been neglected to a great extent in the practice of restoration ecology. Some of the most important processes that occur in soil are the processing of organic matter and recycling of nutrients, and these processes are often significantly altered in disturbed ecosystems. Soil organic matter, nutrients, and biological activity contribute to ecosystem-level process and are important for productivity, community structure, and fertility in terrestrial ecosystems (Stevenson, 1994). The application of organic wastes with a high organic matter content to infertile soils has become a common environmental practice for maintaining soil organic matter, reclaiming degraded soils, and supplying plant nutrients. Organic matter has been identified as a key attribute in numerous soil properties and processes, including bulk density, structure, temperature, water relations, nutrient availability and biological activity (Johnston, 1986; Heynes, 2005). However, the influence of organic matter on soil properties depends on amount, type, and size of added organic materials (Nelson & Oades, 1998; Barzegar et al., 2002).

In this study, we conducted experimental planting and evaluated tree mortality, growth performance and biomass increment of *Shorea leprosula* species in four types of organic materials: pulp mill sludge, compost, oil palm mesocarp and their combinations. *Shorea leprosula* is an indigenous species which make up most of the hill dipterocarp forests that have been commercially logged for many years and has suffered a massive population reduction mainly because of the rate of exploitation of its timber. *Shorea leprosula* is one of the most important species in the tropical Southeast Asia in terms of both ecological and economic aspects (Symington et al., 2004).

We attempted to answer the following two questions: (1) Which organic materials affect seedling mortality, growth and biomass increment during the initial 12 months (the most important period for the growth of planted *Shorea leprosula*) and (2) Do planted seedlings shows any inter-specific differences in their growth performance? Based on the results, we then discussed suitable organic materials application for restoration technique in Tekai Forest Reserve, Pahang, Peninsular Malaysia.

2. Method

2.1 Study Site and Experimental Design

The study site was located in the Tekai Forest Reserve, Pahang, Peninsular Malaysia, about 250 km Northeast of Kuala Lumpur. This is logged over hill dipterocarp forest and majority of the stocks are dipterocarp species. The first logging was done 30 years back that was in 1970's and the second logging in June 2006. The logging technique used crawler tractor whereby it created open and degraded sites. The climate is classified as the humid tropics.

The study used a 4 x 5 factorial combination of organic materials and application rate in a randomized complete block design. This design was replicated with three blocks which consist of 10 individual seedlings for regular measurement and another 10 seedlings for destructive sampling.

The four levels of organic materials were: (1) Pulp mill sludge (S); (2) Compost (C); (3) Oil palm mesocarp/empty fruit bunch (Mesocarp); and (4) Combination (Mix). The application rates based on volume by volume ratio (soil: organic material) for easily application in the field were: (1) Control (0.00%); (2) 1:2 (33.33%); (3) 1:1 (50.00%); (4) 2:1 (66.67%) and (5) 3:1 (75.00%).

Soil was mixture with organic materials using medium capacity mixer. Trees were planted as seedling approximately 60 cm high. Growth parameters such as diameter at 10 cm above medium level (D), total height (H) and height of lowest branch (Hb) were collected in every month up to 3 months starting from initial growth of 2 week after planting, and continued in every three months, while destructive sampling for biomass estimation was conducted on 0-, 3-, 6- and 12-month-old. There was no other treatment except weed control to avoid intra-specific competition.

2.2 Biomass Measurement and Allometric Equations Development

Based on D and H data distribution, 10 representative seedlings were extracted at initial growth and 5 seedlings for each treatment were extracted at 3-, 6- and 12-month-old. Totally, 265 seedlings were extracted. After harvested, D, H, Hb and weight of tree components of the sample trees were measured in the field using digital caliper Mitutoyo, standard tape Richter, and analytic balance DIGI DS-425, respectively. All tree-components were brought to the laboratory to record the oven-dry weight. Fresh samples were dried at 85°C in a constant temperature oven for about 36 hours.

D and H were tested as independent variables. Preliminary analysis of alternative equations indicated that the best fitted was power equation $y = ax^b$ (where y is biomass (gr), x is D (mm) or D^2H (mm² cm), and a and b are

coefficients estimated by regression). The specific best fitted equation was used to estimate biomass accumulation of each seedling.

2.3 Statistical Analysis

The general linear model (GLM) was used to evaluate the seedling responses to treatments. The analyses were performed with a commercially available statistical package SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA).

3. Results and Discussion

3.1 Tree Mortality

In the sludge, mesocarp and combination applications, all applications were high survival rate ($\geq 90\%$) at the end of survey (12 months), except the 75% application rate of sludge that sharply decreased until 2 months with 87.67% of the average and the 66.67% application rate of combination that decreased between 6 to 9 months then remained rather constant over time (Figure 1). On the other hand, the compost and mesocarp showed similar mortality patterns with the highest mortality occurred in 33.33% application rate; the average mortality at 12 months was 30% and 10% in the compost and mesocarp, respectively.

In contrast, the mortality of *Shorea leprosula* in control, in application rate of 50% of sludge and combination, and in 75% application rate of mesocarp was the lowest value among the treatments at 12 months (0%). It means, *Shorea leprosula* seedlings could be planted in degraded lands without organic material applications.

3.2 Tree Growth

The diameter and height increment of the stand increased linearly in all treatments and almost higher values compared with control (Figure 1). The biggest diameter increment (≥ 9 mm) was in compost and combination treatments with application rate of 66.67 and 75.00% for compost and 33.33 and 50% for combination, respectively at 12 months. Whereas, the highest height increment (≥ 90 cm) was in compost of 66.67% application rate and in combination treatment of 33.33 and 50% application rate.

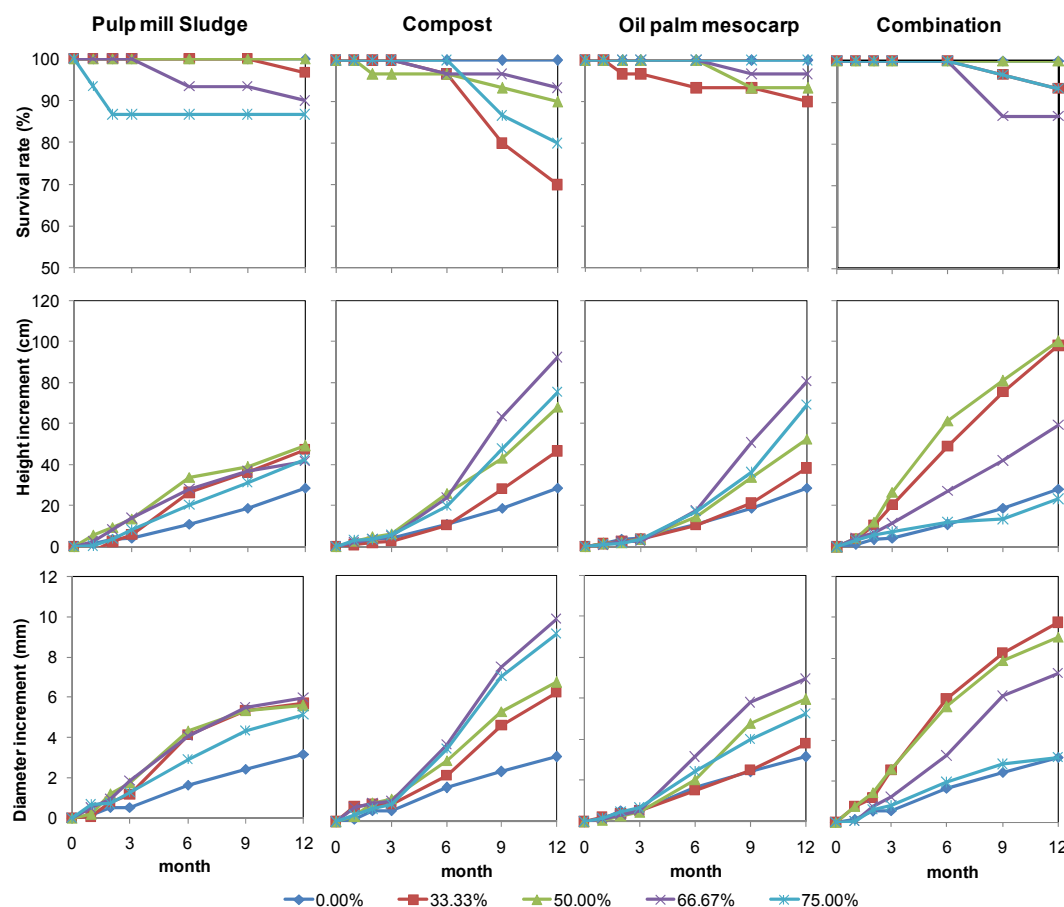


Figure 1. Mortality (%), diameter increment (mm) and height increment (cm) of planted *S. leprosula* under different application rates of organic materials

In the sludge treatments, the average growth of diameter and height increment was less than 5 mm and 6 cm, respectively and was the lowest growth performance compared with other treatments except control. Moreover, leaves shown unhealthy and burned down at all application rates starting from 6 months after application. In mesocarp treatments, the average growth increment rate was lower growth compared to compost and combination treatments but was higher than sludge treatments.

Applied organic materials are needed for stimulate growth rate of *Shorea leprosula* planted on restoration program in degraded lands. Compost is one of the best organic materials that have positive relationship to growth performance. The similar performance was also shown in mix treatment with application rate less than 50%.

Compost breaks down slowly in the soil and is very good at improving the physical condition of the soil (whereas manure and sludge may break down fairly quickly, releasing a flush of nutrients for plant growth). In many circumstances, it takes time to rejuvenate a poor soil using these practices because the amount of organic material being added is small relative to the mineral proportion of the soil.

Compost has also ameliorative effects on soil fertility and physical, chemical and biological soil properties. Well-made compost contains all the nutrients needed by plants. It can be used to maintain and improve soil fertility as well as to regenerate degraded soil.

3.3 Allometric Relationships and Biomass Increments

We developed two different kind of specific equations to estimate biomass accumulation, using single variable D and combination D and H. As shows in Table 1 and Figure 2-5, the model of spesific relationship indicated that using D alone as the predictor variable produced stable relationship, and the inclusion of H as a second predictor variable did not significant changed on the performance of the model.

Depending on allometric equations in each treatment, root-, aboveground- and total-biomass of every tree component could be calculated. These data could be used to calculate biomass increment of each treatment (Figure 6).

As indicated in Figure 6, the highest biomass increment was on treatment 9 and followed by treatment 18, 17 and 10, while the lowest biomass increment was on treatment 20 and followed by treatment 12, 1, 5 and 7.

Plant productivity is linked closely to organic matter (Bauer & Black, 1994). Organic matter also contributes to the stability of soil aggregates and pores through the bonding or adhesion properties of organic materials. Moreover, organic matter intimately mixed with mineral soil materials has a considerable influence in increasing moisture holding capacity. In soils with less compaction, plant roots can penetrate and flourish more readily. High organic matter increases productivity and, in turn, high productivity increases organic matter.

Table 1. Allometric equations used to estimate biomasses of *Shorea leprosula* in different tree components and treatments using D and combination of D and H

No	Treatment	Tree	D			D ² H		
		Component	a	b	r ²	a	b	r ²
1	Control	Total	16.52252	2.42926	0.93848	2.10925	0.81790	0.83118
		Aboveground	10.83913	2.51384	0.92755	1.11171	0.86358	0.85522
		Root	5.11946	2.23524	0.76338	1.58640	0.66820	0.53298
2	Sludge 33.33%	Total	15.70691	2.42322	0.96244	1.63857	0.84793	0.96102
		Aboveground	11.56755	2.45983	0.95837	1.16314	0.86106	0.95768
		Root	4.23034	2.28541	0.94280	0.50719	0.79841	0.93836
3	Sludge 50.00%	Total	15.85361	2.39066	0.95904	1.47397	0.85197	0.94914
		Aboveground	10.51217	2.46879	0.95837	0.92460	0.87715	0.94276
		Root	5.83553	2.13382	0.86245	0.65089	0.76920	0.87335
4	Sludge 66.67%	Total	18.94771	2.29850	0.96295	2.20157	0.81254	0.96302
		Aboveground	13.54358	2.35450	0.96907	1.47226	0.83416	0.97338
		Root	5.56162	2.09529	0.88337	0.82788	0.73333	0.86593
5	Sludge 75.00%	Total	16.48839	2.34310	0.98241	1.16644	0.87678	0.95285
		Aboveground	12.96256	2.35263	0.97934	0.89394	0.88218	0.95383
		Root	3.55031	2.28612	0.91538	0.28739	0.84668	0.86970
7	Compost 33.33%	Total	10.57301	2.63208	0.93271	0.55285	0.96521	0.95126
		Aboveground	7.76725	2.70020	0.92258	0.37173	0.99168	0.94377
		Root	2.95254	2.31992	0.87203	0.24322	0.83792	0.86277
8	Compost 50.00%	Total	12.67493	2.56945	0.97700	0.82027	0.93206	0.97392
		Aboveground	10.31682	2.57113	0.96998	0.66180	0.93349	0.97392
		Root	2.31720	2.54685	0.92520	0.15473	0.92301	0.92059
9	Compost 66.67%	Total	14.94078	2.45941	0.98176	0.93556	0.90782	0.98661
		Aboveground	12.28378	2.43348	0.96869	0.78331	0.89948	0.97616
		Root	2.56495	2.54745	0.94775	0.15367	0.93412	0.93992
10	Compost 75.00%	Total	16.42269	2.37285	0.95183	1.04219	0.88743	0.96576
		Aboveground	14.62694	2.32357	0.94760	0.98796	0.86843	0.96020
		Root	2.118172	2.54931	0.94758	0.11051	0.95571	0.96606
12	Mesocarp 33.33%	Total	18.97598	2.36316	0.97015	1.20769	0.87644	0.97106
		Aboveground	13.27184	2.43636	0.96552	0.75365	0.90718	0.97413
		Root	5.34163	2.13253	0.80901	0.50921	0.77397	0.77547
13	Mesocarp 50.00%	Total	17.89101	2.42184	0.96224	0.99795	0.91617	0.95123
		Aboveground	11.77491	2.50348	0.95956	0.58198	0.95000	0.95448
		Root	6.16376	2.19441	0.88150	0.49356	0.81888	0.84793
14	Mesocarp 66.67%	Total	15.45316	2.47341	0.96609	0.95594	0.90759	0.96631
		Aboveground	10.90998	2.54550	0.95752	0.62519	0.93349	0.95661
		Root	4.93074	2.18492	0.95067	0.41733	0.80306	0.95404
15	Mesocarp 75.00%	Total	19.85290	2.32607	0.93576	1.60188	0.85070	0.96115
		Aboveground	12.88790	2.41663	0.94257	0.96356	0.88124	0.96250
		Root	7.23485	2.05595	0.81306	0.73724	0.75889	0.85069
17	Combination 33.33%	Total	27.28794	2.15404	0.97425	2.03447	0.81544	0.97451
		Aboveground	22.98719	2.11219	0.96853	1.82415	0.79821	0.96545
		Root	4.86697	2.25628	0.93503	0.30617	0.85953	0.94713
18	Combination 50.00%	Total	26.48385	2.22983	0.99105	2.26492	0.80857	0.99097
		Aboveground	23.09892	2.19491	0.98581	2.02756	0.79724	0.98904
		Root	3.55075	2.38037	0.96023	0.27514	0.85595	0.94418
19	Combination 66.67%	Total	15.31347	2.42019	0.96552	1.09476	0.88778	0.96506
		Aboveground	13.10615	2.38950	0.96435	0.94732	0.87920	0.96980
		Root	2.27984	2.54389	0.92613	0.15574	0.92247	0.90461
20	Combination 75.00%	Total	19.98953	2.28656	0.93423	1.55839	0.85153	0.91052
		Aboveground	13.67893	2.35729	0.94134	0.94782	0.88271	0.92760
		Root	7.01666	2.02694	0.86686	0.82281	0.74012	0.81222

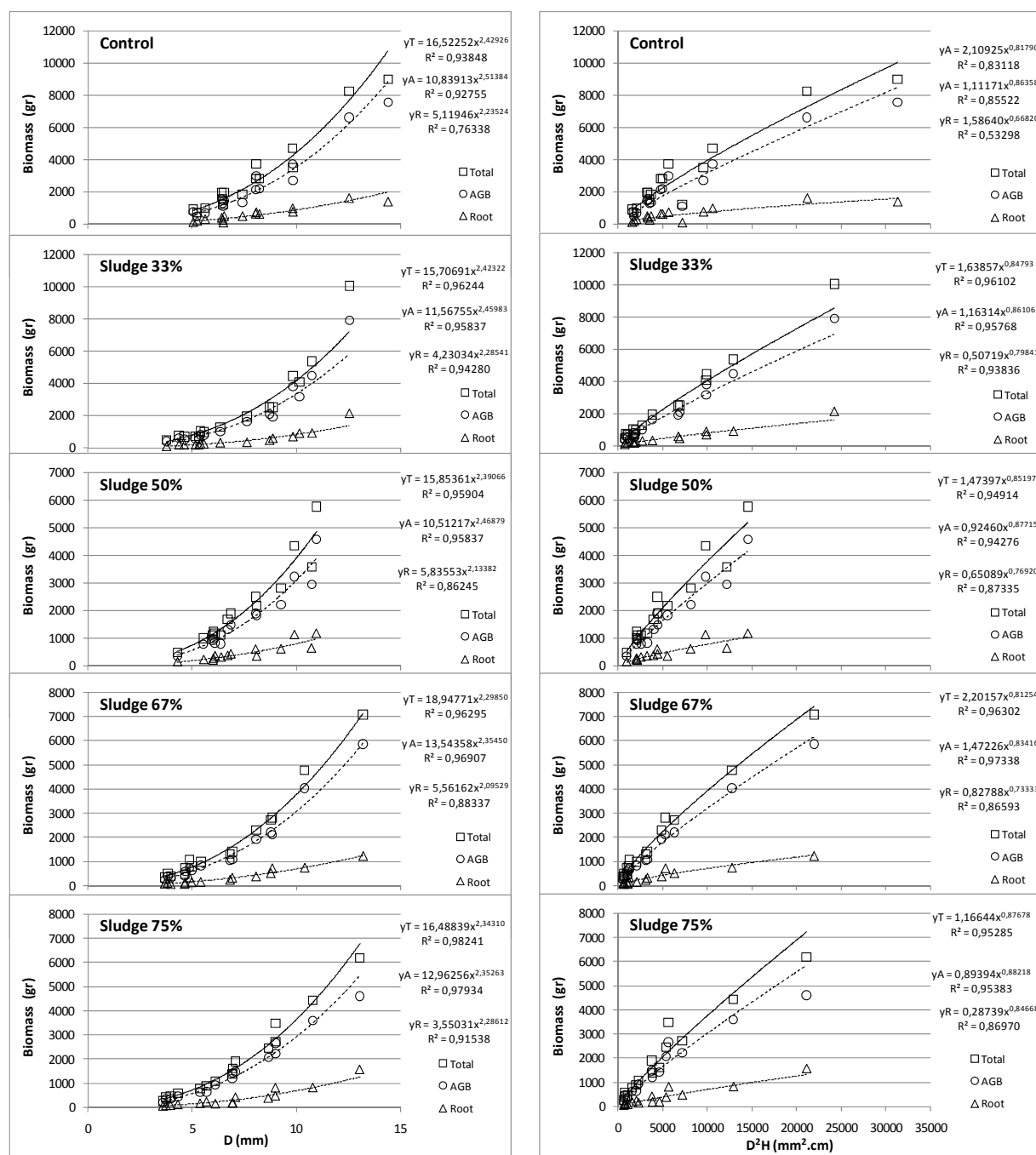


Figure 2. Biomass equations of control and sludge treatments in different application rate, using D (left) and D^2H (right)

yT=Total biomass, yA=Aboveground biomass and yR=Root biomass.

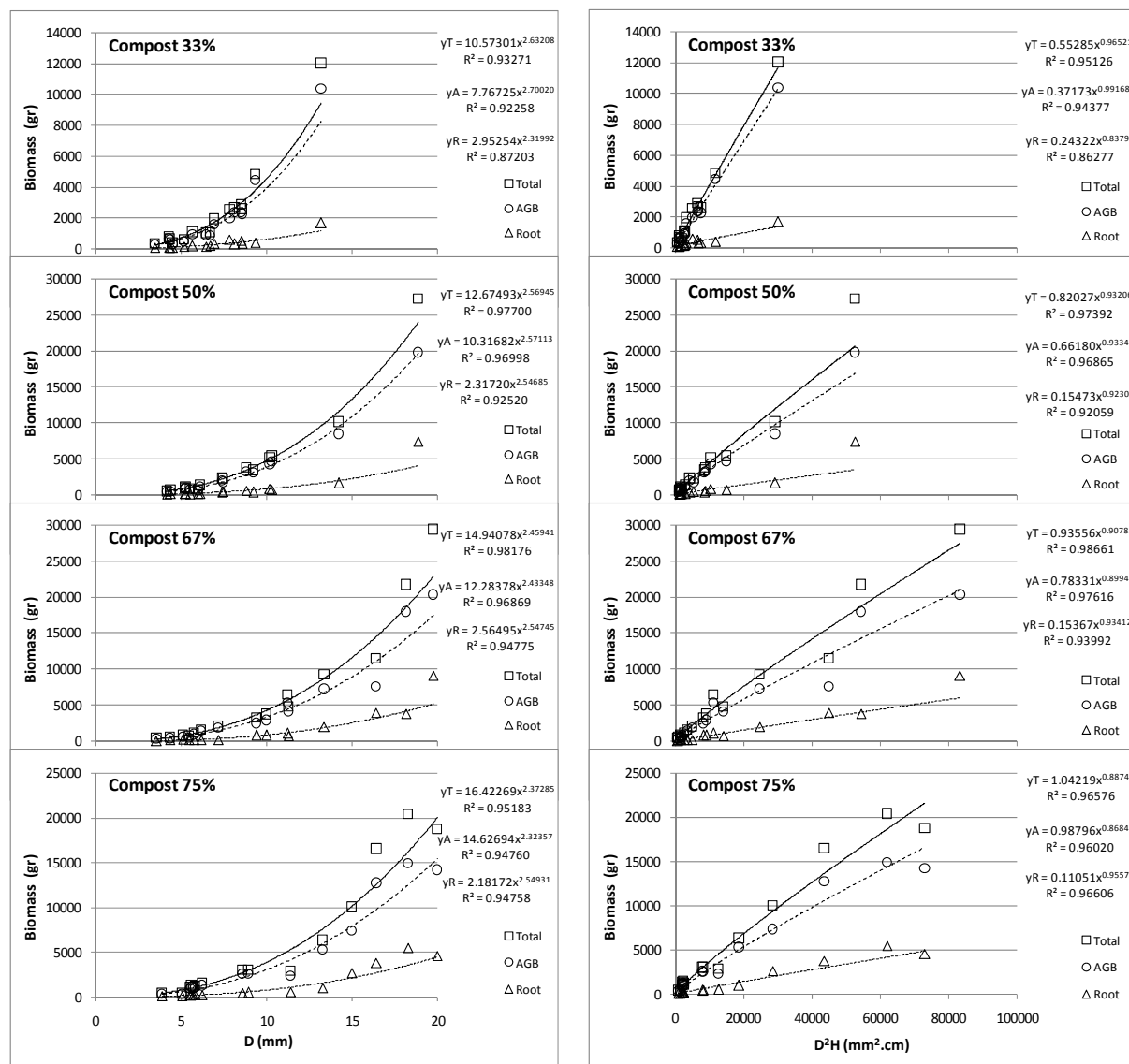


Figure 3. Biomass equations of compost treatments in different application rate, using D (left) and D^2H (right) yT = Total biomass, yA = Aboveground biomass and yR = Root biomass.

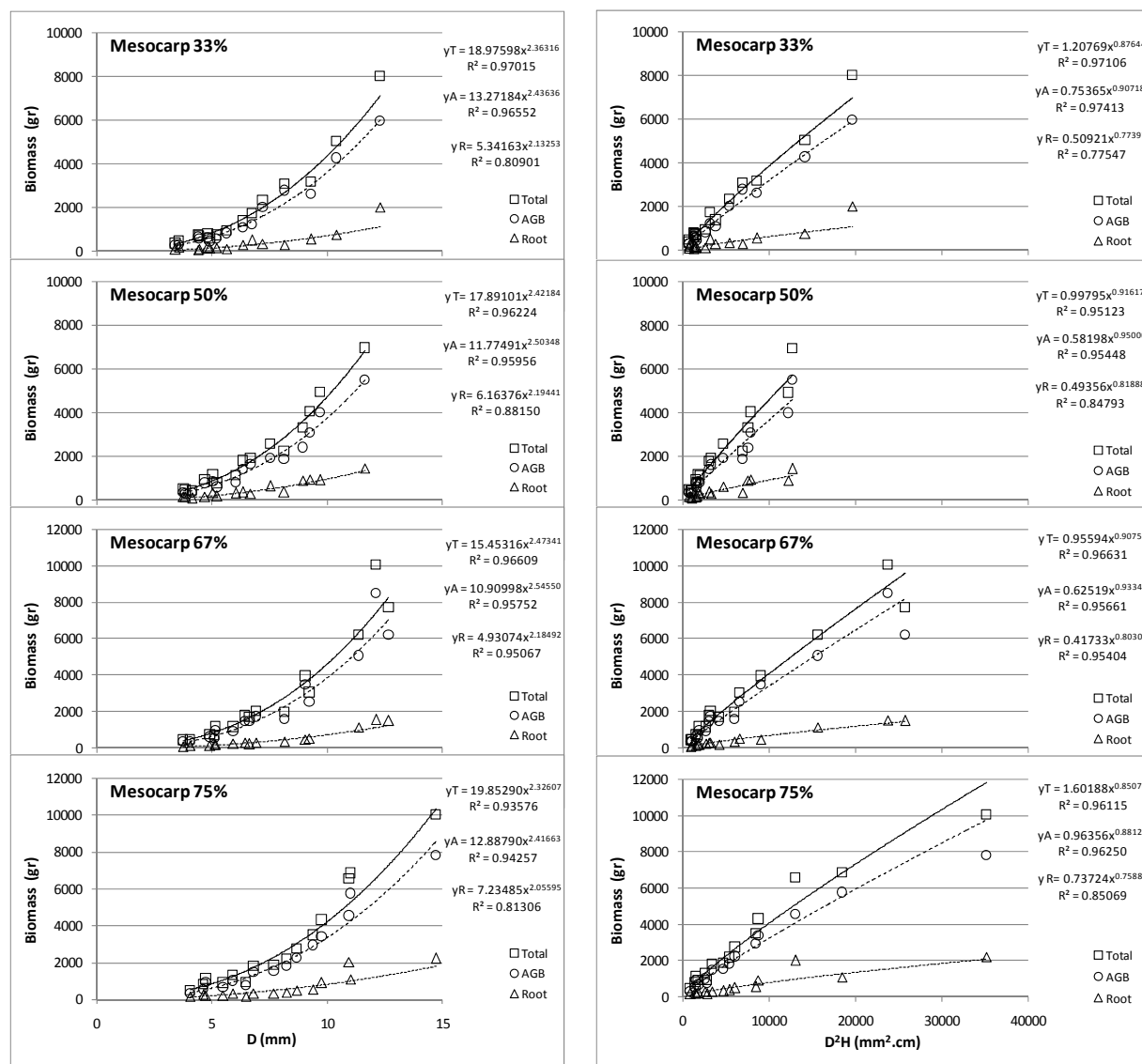


Figure 4. Biomass equations of mesocarp treatments in different application rate, using D (left) and D^2H (right) yT = Total biomass, yA = Aboveground biomass and yR = Root biomass.

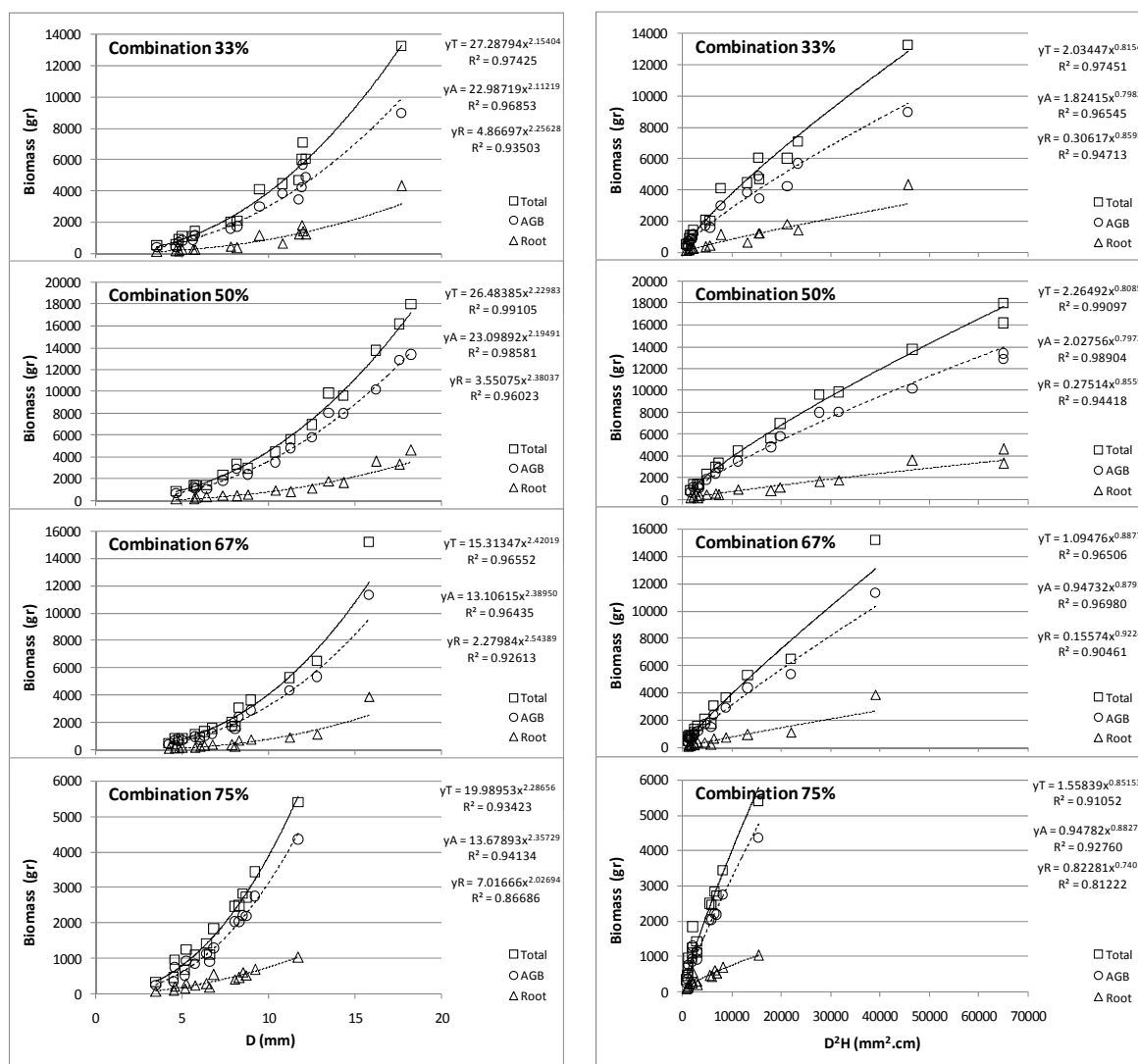


Figure 5. Biomass equations of combination treatments in different application rate, using D (left) and D^2H (right)

yT = Total biomass, yA = Aboveground biomass and yR = Root biomass.

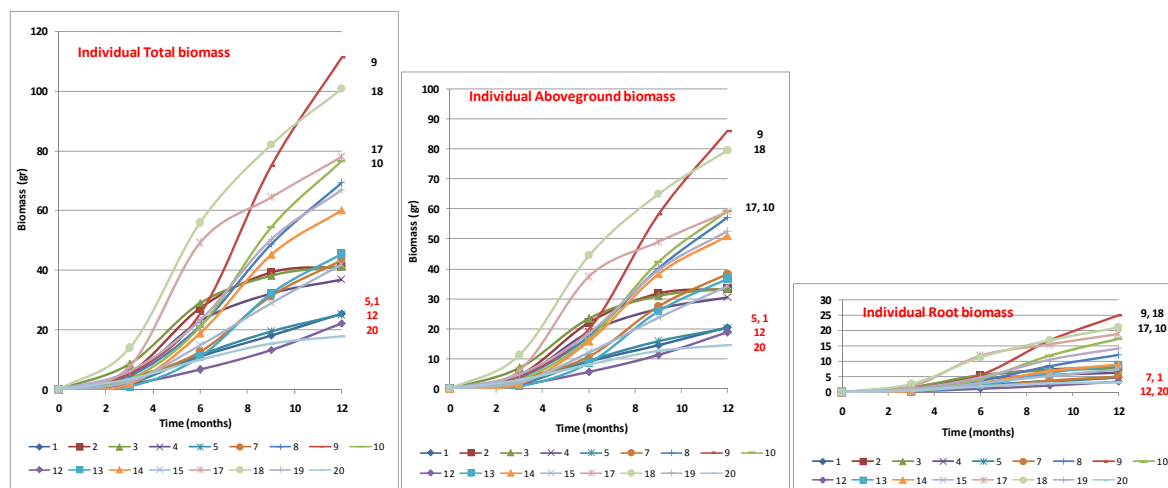


Figure 6. Biomass increment of tree component in different application rate

4. Conclusion

A consequence of forest use and management practices for timber production is the disappearance of the litter layer, with a consequent reduction in the numbers and variety of soil organisms. Studies have shown that as soil biodiversity declines, adapted species may take over from the indigenous species and the composition may change drastically (Curry & Good, 1992).

Soil resilience depends on a balance between restorative and degrading processes (Elliot & Lynch, 1994) and can be grouped in two categories: endogenous and exogenous. Endogenous factors are related to inherent soil properties (rooting depth, texture, structure, topography and drainage) and microclimate and mesoclimate. Exogenous factors include land use and management practice, technological innovations and input management (Lal, 1994). Hence, appropriate silvicultural practices can influence these factors in order to enhance soil resilience.

The establishment of a forest cover under good management is an effective means of increasing organic matter production. However, the land must have the productive capacity to support an appropriate forest type, which differs according to climate, soil, slope and the specific purpose of the forest. Therefore, the choice of species and the selection of an appropriate site are of particular importance for successful restoration of degraded forest.

Restoration program in tropical degraded forest land using *Shorea leprosula* without applied organic material indicated poor growth rate and biomass accumulation, then organic material application to be one of the requirement treatments needed for better results.

Initially, applied sludge and mesocarp on reforestation can be stimulate growth rate, however applied sludge with application rate 67% and more will be raising mortality rate. Growth rate of *Shorea leprosula* increased with decreasing application rate of mix organic materials, consequently. The best performance of mix organic materials was on application rate less than 50%, and in contrast, 75% application rate of it can be obstructed growth rate.

Based on this study, applied compost with application rate of 67% and 75% and mix organic materials with application rate less than 50% were the best four performance on growth and biomass accumulation, then recommended to be used for restoration program of degraded lands in Tekai Forest Reserve and other comparative areas.

The maintenance of soil organic matter levels and the optimization of nutrient cycling are essential to the sustained productivity of silvicultural systems. Maintaining soil organic matter content requires a balance between addition and decomposition rates. As changes in forest management practices can engender marked changes in both the pool size and turnover rate of soil organic matter, it is important to analyze their nature and impacts.

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References

- Barzegar, A. R., Yousefi, A., & Daryashenas, A. (2002). The Effect of Addition of Different Amounts and Types of Organic Materials on Soil Physical Properties and Yield of Wheat. *Plant Soil*, 247, 295-301. <http://dx.doi.org/10.1023/A:1021561628045>
- Bauer, A., & Black, A. L. (1994). Quantification of the effect of soil organic matter content on soil productivity. *Am. J. Soil Sci. Soc.*, 5, 185-193. <http://dx.doi.org/10.2136/sssaj1994.03615995005800010027x>
- Curry, J. P., & Good, J. A. (1992). Soil faunal degradation and restoration. *Adv. Soil Sci.*, 17, 171-215. http://dx.doi.org/10.1007/978-1-4612-2820-2_7
- Elliot, L. F., & Lynch, J. M. (1994). Biodiversity and soil resilience. In J. Greenland, & I. Szabolcs (Eds.), *Soil resilience and sustainable land use* (pp. 353-364). Wallingford, UK: CAB International.
- Haynes, R. J. (2005). Labile organic matter fractions as central components of the quality of agricultural soils: an overview. *Advance in Agronomy*, 8, 221-268. [http://dx.doi.org/10.1016/S0065-2113\(04\)85005-3](http://dx.doi.org/10.1016/S0065-2113(04)85005-3)
- Johnston, A. E. (1986). Soil organic matter, effects on soils and crops. *Soil Use and Management*, 2, 97-105. <http://dx.doi.org/10.1111/j.1475-2743.1986.tb00690.x>
- Lal, R. (1994). Sustainable land use systems and soil resilience. In J. Greenland, & I. Szabolcs, (Eds.), *Soil resilience and sustainable land use* (pp. 41-67). Wallingford, UK: CAB International.

- Nelson, P. N., & Oades, J. M. (1998). Organic matter, sodicity and soil structure. In M. E. Sumner, & R. Naidu (Eds.), *Sodic Soils: Distribution, Processes, Management and Environmental Consequences* (pp. 51-75). New York: Oxford Uni. Press.
- SER (Society for Ecological Restoration, Science and Policy Working Group). (2004). The SER International Primer on Ecological Restoration (available from <http://www.ser.org>) accessed in September 2011. Society for Ecological Restoration International, Tucson, Arizona.
- Stevenson, F. J. (1994). *Humus Chemistry: genesis, composition, reactions* (2nd ed.) (p. 496). New York: Wiley.
- Symington, C. F., Ashton, P. S., & Appanah, S. (2004). Forester's Manual of Dipterocarps. *Malaysian Nature Society*, 519.