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Growth performance of sixty tree species in smallholder reforestation trials on Leyte, Philippines

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Abstract Although many reforestation projects have attempted to mitigate deforestation in the Philippines, most have focused on planting introduced trees, often with low success rates. A smallholder-based project in the Visayas region planted native species instead. This study assessed the growth performance of forty-four native and sixteen introduced species in 25 sites established by this project between 1995 and 2000. Diameter at breast height and total height were measured for 2,789 trees. Mean annual increments for diameter (MAID) at breast height and height (MAIH) were significantly higher for trees planted on limestone-influenced soils (MAID = 1.19 cm/year; MAIH = 1.05 m/year) than on purely volcanic soils (MAID = 0.81 cm/year; MAIH = 0.78 m/year). Growth of two native species, *Melia dubia* and *Terminalia microcarpa,* was higher than that of the widely planted exotic *Swietenia macrophylla*. The height increment for the highest-performing dipterocarp species, *Shorea guiso*, *Shorea contorta*, and *Parashorea malaanonan*, was not statistically different from the MAIH of *S. macrophylla*. A range of soil characteristics predicted performance, with organic matter predicting growth for six species, and percent nitrogen and percent clay predicting performance of five species. These findings show that certain native species can perform better than some exotic species when planted in open areas. They also disprove the widely held belief in the Philippines that Dipterocarpaceae cannot be planted in grasslands, and suggest that dipterocarps can be used successfully in reforestation. Finally, the findings show that more research is needed on species-site matching and on silvicultural management of native species plantations.

Keywords Dipterocarpaceae · Growth rates · Restoration · *Shorea* spp. · *Swietenia macrophylla* · Visayas

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Introduction

Large-scale logging of primary dipterocarp forest and subsequent conversion of cut-over forests to agricultural lands has led to the reduction of forest cover in the Philippines from 70 % of the land area in the early 1900s to under 17 % by the end of the twentieth century (Lasco and Pulhin 2006; Suarez and Sajise 2010). Commercial logging in the Philippines began at the start of the twentieth century. Following the trajectory of commercial forest exploitation found in other Southeast Asian countries, many logged areas in the Philippines were converted to farms and, once soil productivity declined, were turned into pasture or coconut plantations (Garrity et al. 1997; Lawrence 1997; Chokkalingam et al. 2006; Sales-Come and Hölscher 2010). Escaped fires or abandonment in many cases have led to colonization by *Imperata cylindrica* (L.) Raeusch., a fire-tolerant grass which impedes natural regeneration to secondary forest (Garrity et al. 1997; Göltenboth and Hutter 2004; Suarez and Sajise 2010). Garrity et al. (1997) estimate that 17 % of the Philippines is covered by *Imperata*. While the government classifies all land with slopes of 18 % or more as "forest land", regardless of cover, only 41 % of these areas are actually under forest cover, leaving almost 60 % of designated forest land to be reforested (Chokkalingam et al. 2006).

Reforestation efforts in the Philippines have mostly focused on large-scale monoculture plantations of exotic species, such as *Acacia mangium* Willd., *Gmelina arborea* Roxb., and *Swietenia macrophylla* King (Freese 1983; Lasco and Pulhin 2006; Chokkalingam et al. 2006; Tolentino 2008). Between 1960 and 2002, about 1.7 million ha of land were planted, primarily with exotic tree species. Exotics were favored over natives because of their wide adaptability and tolerance to stress, because they were perceived to grow faster than native species, because germplasm was widely available, and because their silviculture was better understood (Tolentino 2008). However, the overall success of these reforestation efforts was low, with survival rates in some areas as low as 30 % (Margraf and Milan 1994; Lasco and Pulhin 2006).

In response to these large-scale efforts focused on exotic species, the Visayas State University (VSU) and the German bilateral aid organization GTZ (Gesellschaft für Technische Zusammenarbeit) developed the 'rainforestation' methodology in 1992, which promoted community-based reforestation primarily focused on native species (Margraf and Milan 1994; Milan and Göltenboth 2005). Since then, the rainforestation technique has been disseminated by VSU, and was declared one of the official reforestation methods of the Philippines Department of Environment and Natural Resources (DENR) in 2004 (Lasco and Pulhin 2006). The rainforestation methodology builds on the assumption that farming systems in the humid tropics are increasingly more sustainable as the system's structure and function become more similar to those of local rainforests. The methodology aims to provide a staggered income from high-value timber as well as from fruit, spices, and medicinals. The rainforestation methodology also aims to increase biodiversity by augmenting the area planted with native tree species, and to help restore soil productivity and protect watersheds on degraded sites.

The methodology proposes interplanting shade intolerant pioneer tree species at high stocking rates (2 m × 2 m) with shade tolerant canopy species (mainly Dipterocarpaceae) as well as fruit trees in open areas. Community-run nurseries produced seedlings of over sixty pioneer, dipterocarp, and fruit tree species by gathering seeds and wildlings from remaining forest fragments (Margraf and Milan 1994).

Between 1995 and 2000, VSU and GTZ worked with smallholders to implement the rainforestation method on 28 sites on the island of Leyte and developed a list of recommended species for planting on limestone and volcanic soil types. There are some recent studies on ecophysiological aspects (leaf morphology, sap flow and humus composition) on rainforestation sites that include measures of diameter and height for a subset of species on four sites (Dierick and Hölscher 2009; Navarrete et al. 2010; Sales-Come and Hölscher 2010). However, there is no study evaluating overall growth performance of different species across all of the sites.

Native species reforestation is complicated because less silvicultural knowledge exists for native species than for established plantation species. Also, dipterocarp forests are notoriously difficult to restore. Many dipterocarp species are found only at low densities in natural forest, and have limited dispersal ranges through recalcitrant seeds in periodic mast fruiting events (Kettle 2010). Further, dipterocarp species in past studies have been found to have poor survival and grow more slowly than pioneers or exotic tree species in open grasslands (Otsamo et al. 1996; Otsamo et al. 1997; Tolentino 2008). In addition, the family used to be categorized as shade obligate. More recently, studies have shown significant variations in shade tolerance among the different genera in the Dipterocarpaceae (Suzuki and Jacalne 1986; Ashton and Berlyn 1992; Ashton 1995; Ashton et al. 1995; Weinland 1998). While more recent research in Singapore has shown that native species, including certain dipterocarps, can successfully be planted in open lands (Shono et al. 2007), other studies demonstrate the need for nurse trees (Ashton et al. 1997, 1998). Some research has also shown that dipterocarps performed well in enrichment plantings in semi-open selectively logged plantations (Millet et al. 2013). However, understanding of silvicultural requirements and growth rates of dipterocarps and other native tree species is still limited in the Philippines (Langenberger 2006; Tolentino 2008).

Further, knowledge about habitat ranges of many native species in the Philippines is lacking, and more work is needed to determine species-site interactions and site requirements for the long-term sustainability of reforestation efforts (Langenberger 2004, 2006; Santos Martín et al. 2010). Beyond soil type (volcanic or limestone), taking into account other individual site characteristics such as soil fertility parameters, soil texture, elevational range, position and aspect of slope, shade tolerance, and drainage class requirements could help improve survival and growth rates in reforestation projects (Ashton et al. 2001). Due to the conversion of nearly all of the lowland forest to agricultural uses in Leyte, current species distributions need to be combined with analyses of microhabitat and site conditions to predict the original ranges. Prolonged trials on species-site matching would be an important contribution to the success of reforestation projects (Wishnie et al. 2007; van Breugel et al. 2011), but in many cases this not feasible due to lack of funding. In most established reforestation sites, little information is available on survival rates and other indicators of success. Comparisons of species performance across a range of soil types in an active reforestation setting is therefore a feasible way to help fine-tune site preparation and species composition for future plantings (Langenberger 2006).

This study therefore aims to improve the silvicultural understanding of native species in the Visayas region by assessing growth and performance of the species planted in 25 smallholder rainforestation sites between 1995 and 2000. Species choice and site-species matching are key decisions in reforestation projects, and there is little published data available to compare performance in actual plantings. This is especially true for native species, for established trees, and for smallholder-managed sites. Since rainforestation is now promoted at the national level, and could inform restoration efforts in *Imperata* grasslands in other parts of Southeast Asia, data on performance of a wider range of native and exotic species are an important addition to the reforestation literature.

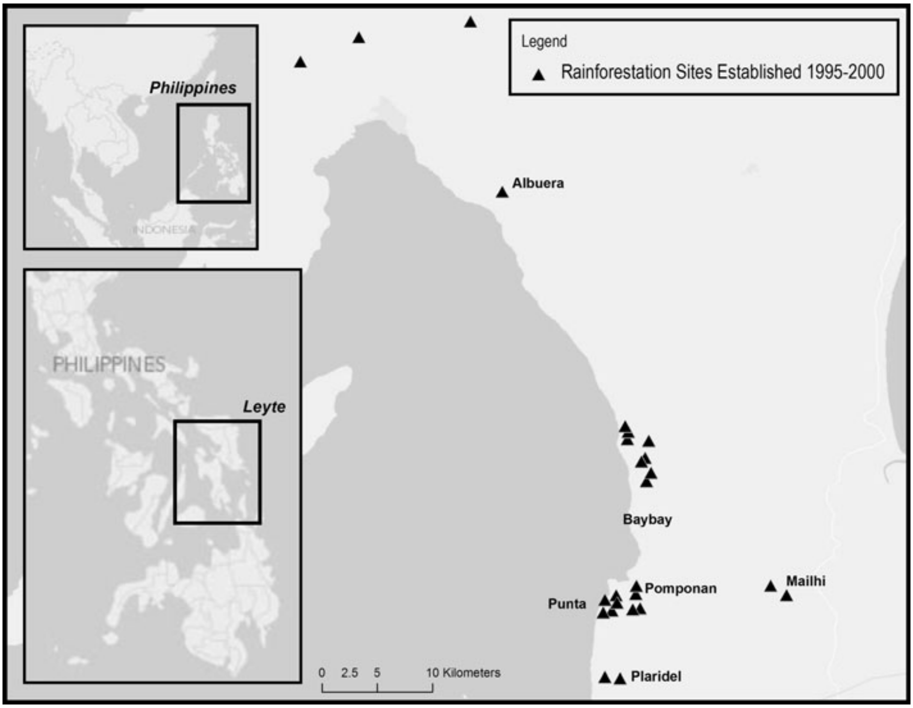

Fig. 1 Research sites in the province of Leyte, Visayas Region (Philippines)

Materials and methods

Study site

Fieldwork was conducted in 2011 on the island of Leyte, in the Visayas region of the Philippines (Fig. 1). VSU established 28 rainforestation sites on Leyte between 1995 and 2000. The island has two main soil types: slightly acidic volcanic Andisols and Ultisols, and neutral to slightly basic Quarternary limestone Inceptisols influenced by volcanic deposition (Jahn and Asio 1998; Asio et al. 2006). The climate is classified as Af in the Koeppen climate classification system, and it is warm and humid, with an average annual temperature of 27.5 °C, and average annual precipitation of about 2,700 mm/year without a marked dry season (PAGASA 2010). The natural vegetation of the island is lowland dipterocarp forest, which today persists on only about 2 % of the area and is restricted to the steeper slopes of the Leyte Cordillera, stretching north to south from sea level up to the highest peak, Mt. Pangasugan, at 1,150 m.a.s.l. Degraded grassland covers 40 % of the island, and coconut plantations another 40 % (Langenberger 2006).

Of the 28 sites established by the project, 25 were sampled (Fig. 1). Three sites were not included in this study due to access restrictions. Size of the sites ranged from 0.25 to 5.4 ha on both volcanic and calcareous soils. Planting design, stocking rate, and species composition varied widely across sites according to landowner preference and seedling availability at the time of establishment. A total of 60 tree species were identified ("Appendix"). Since sites were planted according to availability of planting stock in the VSU nursery, there was little overlap in species composition across sites. Planting locations were chosen by landowners in collaboration with VSU staff, and site preparation, planting and weed management were conducted by project staff for 11 of the 25 sites. The landowners chose to implement the planting in 14 cases, with support from VSU for seedling procurement and weed management. In all cases, seedlings and technical assistance were provided free of charge by VSU-GTZ project staff.

Sampling design

At all sites, total tree height and diameter at breast height (DBH) (1.4 m) of planted individuals were measured with a SUUNTO clinometer and diameter tape and trees were identified to species. Site characteristics (elevation; slope; aspect; previous land use) were recorded, and data on plot establishment and management (year of establishment; evidence of disease, fire, flooding, livestock, or other disturbance; post-harvest treatments, trees harvested) were compiled from baseline information collected by VSU and from interviews with landowners and project staff, and validated during site assessment. A pooled composite soil sample was taken from each site with a 20 cm soil auger and soil samples were analyzed by the VSU Department of Agronomy and Soil Science and the Philippine Rootcrops Research and Training Center.

The sampling methodology was adapted to the three types of rainforestation sites encountered: sites planted in straight lines, sites with scattered arrangement, and sites with high mortality with few surviving trees. On sites planted in lines, 2 m × 30 m parallel line transects were established based on randomly chosen lines, and all trees in each transect measured for a total of at least 100 live trees per site (nine sites). On sites planted with scattered distribution, randomly chosen 6 m × 10 m fixed plots were established along a NSEW grid and all trees measured within each plot for a total of at least 100 live trees per site (four sites). In sites with high mortality, all surviving trees were measured in a site census (twelve sites).

Data analysis

Mean annual increment for diameter (MAID) and height (MAIH) measurements were calculated for all species and all sites by dividing height and diameter values in 2011 by plantation age. One-way analyses of variance (ANOVA) were performed on the MAI values of individual trees to test the significance of soil types across all species, as well as to test species effects on MAID and MAIH for the twenty most frequently sampled species across all sites. A Tukey test was run on the MAI values of these twenty species to determine which mean growth increments were statistically different from each other. No interaction effect was tested due to the highly unbalanced data with high variability in species composition between sites. Regression analysis was used on soil variables for the MAID values of individual trees of the nine species found in at least five sites with at least five individuals each to identify significant predictors of species growth performance. Regression analysis was also performed for MAIH values, but since fewer soil variables were found to be significant, and the coefficient values were smaller, these results are not included here.

Results

A total of 2,789 live individuals of 60 tree species were measured and MAID and MAIH calculated (“Appendix”). Mean growth performance of both diameter and height were statistically higher in limestone sites than in volcanic sites (Table 1; Fig. 2a, b).

Table 1 One-way ANOVA of mean annual increment for diameter and height across limestone and volcanic sites

Sites	N[1]	Mean MAI DBH	SD	F value[2]	R^2 (adj)
Limestone	1,001	1.19 a	0.71	199.7***[3]	8.01
Volcanic	1,281	0.81 b	0.58		
Sites	**N**	**Mean MAI height**	**SD**	**F value[2]**	**R^2 (adj)**
Limestone	1,001	1.05 a	0.48	218***	8.68
Volcanic	1,281	0.78 b	0.37		

Letters after values for MAID and MAIH denote difference among species (a > b > c) at $p = 0.05$

[1] *N* number of individuals sampled

[2] Degrees of freedom: 2,281

[3] Significance levels: *** <0.001

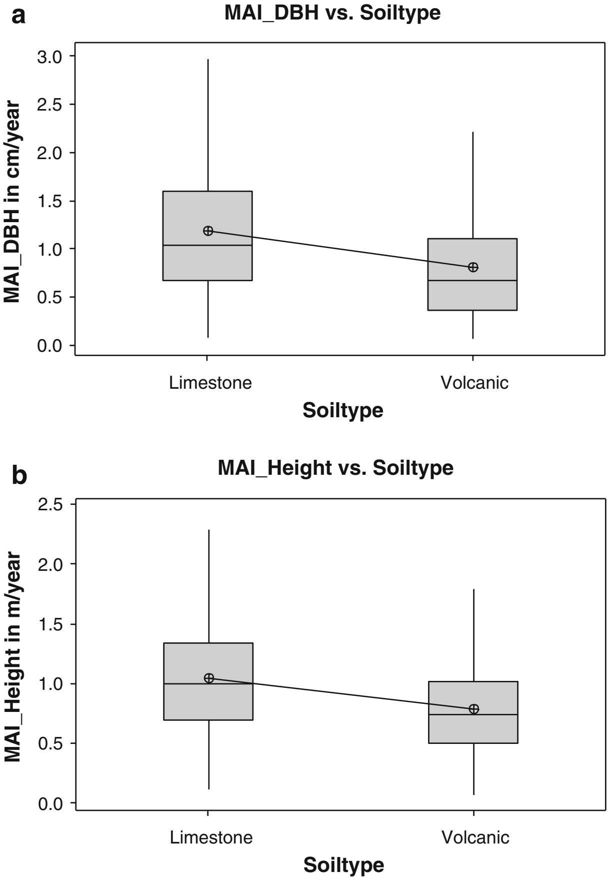

Fig. 2 **a** Mean annual increment of diameter (MAID) across limestone and volcanic sites. **b** Mean annual increment of height (MAIH) across limestone and volcanic sites

Analysis of the twenty most frequently measured species across all 25 sites assessed showed that there were significant differences between species performance, with the highest diameter growth rates found in *Melia dubia* and *Terminalia microcarpa* and the lowest growth rates found in *Podocarpus rumphii* and *Intsia bijuga* (Table 2).

In a Tukey comparison of means, the diameter growth rates of the two highest performing species (*M. dubia* and *T. microcarpa*) were found to be significantly different from those of the third-fastest growing species and most frequently found exotic tree, *S. macrophylla*. The diameter and height growth increments for the highest performing dipterocarp species, *Shorea guiso*, was found to be statistically similar to *S. macrophylla*. The height increment of two other dipterocarp species, *Shorea contorta* and *Parashorea malaanonan* was also found to be statistically similar to the MAIH of *S. macrophylla*.

Regression analysis of the nine species occurring with at least five individuals across at least five sites showed a range of significant predictors for diameter growth (Table 3). The factors most frequently found to be significant were percent organic matter (significant for six species), percent nitrogen and percent clay (significant for five species). The variation in growth rates explained by all the predictors tested ranged from a low of 17.5 % for *Vitex parviflora* to a high of 62.7 % for *Calophyllum blancoi*. Most of the nine species tested showed site preferences in some soil characteristic in fertility and structure.

Discussion

Contrary to the widely held belief that native species, and especially dipterocarp trees, perform poorly when planted in the open and on degraded lands invaded by *I. cylindrica* (Suzuki and Jacalne 1986; Otsamo et al. 1996; Otsamo et al. 1997; Tolentino 2008), our results demonstrate that these species can be used successfully in restoration of grasslands. Also, although exotics have in many cases been favored in reforestation projects due to the assumption that they grow faster than native species, the findings presented in our study show that two native species *M. dubia* and *T. microcarpa* had statistically higher mean annual height and diameter increments than *S. macrophylla* in the 25 rainforestation sites assessed on Leyte. In addition, the dipterocarps *S. guiso*, *S. contorta* and *P. malaanonan* were all found to have statistically similar height growth to *S. macrophylla* in the sites visited, and *S. guiso* also showed statistically similar diameter growth to *S. macrophylla*.

These results support the assessments by Shono et al. (2007) and Santos Martín et al. (2010) that native trees, including some Dipterocarpaceae, can survive and perform well in open degraded sites. Native tree species therefore merit further research into silvicultural management and site-species matching to improve survival and performance (Langenberger 2006; Wishnie et al. 2007; Millet et al. 2013). In fact, *M. dubia* and *Shorea* sp. were chosen as priority trees for smallholder-oriented domestication projects in the Philippines in 2000 (Gunasena and Roshetko 2000). However, domestication efforts remained limited, probably due to problems with germplasm multiplication, distribution, and availability. Information about germplasm and nursery management, and silviculture of native species is still much less developed than for commonly planted exotics (Tolentino 2008). The growth rates provided by this study for forty-four native and sixteen exotic tree species help improve understanding of native and exotic species for future reforestation projects. For most of these species, no published data on growth performance exist, and most of the studies focus on recently established plantings. There are very few data points for plantations of more than 10 years, or for smallholder-managed sites. Thus, this study helps

Table 2 Mean annual increment of diameter at breast height (MAID) and tree height (MAIH) of the 20 most frequently sampled species in twenty-five rainforestation sites in Leyte province, Visayas region (Philippines)

Species[1]	Family	N[2]	Limestone sites	Volcanic sites	MAID (cm)	MAIH (m)	Wood Uses[3]
Melia dubia Cav.	Meliaceae	21	7	2	1.89 a[4]	1.31 a	Light construction
Terminalia microcarpa Decne.	Combretaceae	259	11	9	1.42 a,b	1.78 a	Light construction
Swietenia macrophylla King	Meliaceae	413	11	7	1.25 b,c	1.00 b	Furniture, woodwork, construction
Shorea guiso (Blanco) Blume	Dipterocarpaceae	52	0	4	1.19 b,c,d	1.07 b	Construction
Artocarpus odoratissimus Blanco	Moraceae	20	0	6	1.18 b,c,d,e	0.99 b,c	Fruit tree, light construction
Agathis philippinensis Warb.	Araucariaceae	77	0	5	1.05 c,d,e	0.79 c,d	Construction
Dracontomelon dao (Blanco) Merr.	Anacardiaceae	206	11	7	0.98 c, d,e	0.89 b,c	Furniture, construction
Toona philippinensis Elmer	Meliaceae	29	3	2	0.97 c,d,e,f	0.24 e	Light construction
Vitex parviflora A. Juss.	Lamiaceae	154	9	8	0.91 d,e,f	0.27 e	High quality furniture, posts and poles
Pterocarpus indicus Willd.	Fabaceae	192	12	9	0.89 d,e,f	0.80 c,d	High quality furniture
Shorea contorta S. Vidal	Dipterocarpaceae	286	5	11	0.87 d,e,f	0.97 b,c	Light construction
Casuarina equisetifolia L.	Casuarinaceae	50	0	2	0.86 d,e,f,g	0.75 c,d	Firewood
Artocarpus heterophyllus Lam.	Moraceae	46	4	8	0.84 d,e,f,g	0.71 c,d,e	Furniture, light construction, tool handles
Dipterocarpus grandiflorus Blanco	Dipterocarpaceae	21	1	4	0.69 d,e,f,g,h	0.71 c,d,e	Furniture, construction
Parashorea malaanonan (Blanco) Merr.	Dipterocarpaceae	145	4	8	0.62 f,g,h	0.89 b,c	Light construction
Hopea plagata (Blanco) S. Vidal	Dipterocarpaceae	156	3	9	0.57 f,g,h	0.75 c,d	Construction
Hopea malibato Foxw.	Dipterocarpaceae	60	1	6	0.53 f,g,h	0.72 c,d,e	Construction
Calophyllum blancoi Planch. & Triana	Calophyllaceae	49	2	6	0.52 f,g,h	0.64 c,d,e	Construction
Podocarpus rumphii Blume	Podocarpaceae	26	0	4	0.31 g,h	0.37 e	Light construction
Intsia bijuga (Colebr.) Kuntze	Fabaceae	20	0	2	0.31 g,h	0.45 d,e	Furniture

[1] Species are listed in declining order of MAID

[2] *N* number of individuals sampled

[3] Wood uses reported in Milan and Göltenboth (2005), Mangaoang and Pasa (2003), and in Wiemann (2010)

[4] Letters after values for MAID and MAIH denote difference among species (a > b > c) at $p = 0.05$

Table 3 Significant predictors[a] of mean annual increment of diameter (MAID) at breast height in nine species found with more than five individuals at more than five sites

Species[b]	df	Regression coefficient for independent variable											
		pH (1:1)	OM %	N %	P (mg/kg)	CEC mE/100 g	%clay	Exch K mg	Exch Na mg	Exch Ca mg	Exch Mg mg	Extrac Mn mg	Exch Al mE/100 g	R^2 (adj)
Calophyllum blancoi	43		0.73***	−13***										62.74
Dracontomelon dao	193						0.021***							18.8
Hopea plagata	143					−0.0073*								42.45
Parashorea malaanonan	135	0.31***	0.13***	−5.4***										45.48
Pterocarpus indicus	160	3.4**	20**	−22**	c = −0.018*	−0.39**	−0.20**	0.095**						35.98
Shorea contorta	279	−1.0***	−1.3***			−0.034***	−0.062***		0.073***	0.00040***	−0.0039***			37.69
Swietenia macrophylla	406	−1.7***	−0.61***	−12***	c = −0.020***	0.045***		0.0011***	0.047***	0.00040	−0.0058***	0.014***	−0.85***	34.36
Terminalia microcarpa	245		−0.41***	−18***	c = −0.020***		−0.046***					0.0089***		20.05
Vitex parviflora	146						c = 0.013***				c = 0.00022***			17.51

[a] Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

[b] Species are listed in alphabetical order

build knowledge about native species management, and provides a comparison point for relative species and site performance ("Appendix").

However, this study does not take into consideration several important factors that influence tree performance, including site management and frequency and intensity of weeding around planted trees. Future studies should also take into account smallholder-specific challenges in tree planting, such as capacity to access and manage tree germplasm, sufficient knowledge about plantation management, and information about and access to markets (Roshetko et al. 2008). Smallholders make decisions on whether or not to plant native trees for different reasons than researchers or large-scale reforestation projects. They are less likely to plant trees if they do not have secure tenure for their land, and if they still have access to remaining natural forest areas (Santos Martín et al. 2012). Accordingly, interest in site care and maintenance varied widely among the smallholders interviewed, and several had passed away, fallen ill, or emigrated. Since planting design across sites was highly variable, and because it was not possible to collect interview information from all landholders, this study could not quantify site management throughout all sites assessed.

Our study does indicate that many species do better in certain soil types and site conditions, suggesting better and more refined planting guidelines are needed. Species trials including different pure and mixed plots under varying levels of silvicultural management intensity (established on sites selected for a range of soil characteristics, slopes, elevation and aspect) might help advance site treatment recommendations for well-performing native species. Similar block experiments have led to important advances in silvicultural understanding of native species in Central America in different species combinations (Wishnie et al. 2007; Piotto et al. 2010; van Breugel et al. 2011).

Further research is also needed on the availability of markets and economic competitiveness of native timber species in the Philippines. Financial analysis comparing the profitability of native and exotic plantation timber in Central America has shown that certain native species can compete economically with widely planted exotics, such as *Tectona grandis* (Griess and Knoke 2011). While such studies do not yet exist for the Philippines, it also needs to be pointed out that the logging ban declared in the Philippines by President Benigno Aquino in February 2011 complicates smallholders' ability to harvest native trees planted on their own land.

Smallholders therefore need to consider a variety of factors beyond growth rates when deciding which tree species to plant (Santos Martín et al. 2012). Depending on the landowner objective and desired end use for the trees planted (home construction, lumber sale, fruit production, soil restoration, watershed rehabilitation, erosion control, or biodiversity protection), other factors such as bole straightness, timber quality and density, fruit yield, and mast and habitat value for wildlife should also be considered when deciding on species composition of future sites. It should be noted that the wood density in the species planted might vary from density values on record, since density is affected by growth conditions and site characteristics (FAO 2006; Weber and Sotelo Montes 2008). Further research into the wood properties of planted native species could help facilitate their marketability and acceptance among landowners.

Finally, the high levels of tree species diversity encountered in the smallholder rainforestation sites also underscores the potential biodiversity benefits that native species reforestation efforts can provide. The study shows that both exotic and native species can perform well in forest restoration, and that continued research into species-specific nursery techniques, species-site matching, and silvicultural management of lesser-known native species is needed for successful forest restoration.

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Appendix

See Table 4.

Table 4 List of species identified on 25 rainforestation farms established on Leyte (1995–2000)

#	Species[a]	Common name	Family	N[b]	MAID (cm/year)[c]	MAIH (m/year)[d]
1	*Agathis philippinensis*	Almaciga	Araucariaceae	77	1.05	0.79
2	*Anisoptera thurifera*	Palosapis	Dipterocarpaceae	21	0.72	0.79
3	*Artocarpus blancoi*	Antipolo	Moraceae	20	0.72	0.68
4	*Artocarpus heterophylla*	Nangka	Moraceae	46	0.84	0.71
5	*Artocarpus odoratissimus*	Marang	Moraceae	20	1.18	0.99
6	*Azadirachta indica*	Neem Tree	Meliaceae	1	0.85	0.66
7	*Azfelia rhomboidea*	Tindalo	Fabaceae	4	0.55	0.75
8	*Bridelia minutiflora*	Sudyang	Phyllantaceae	1	0.95	0.94
9	*Calophyllum blancoi*	Bitanghol	Calophyllaceae	49	0.52	0.64
10	*Casuarina equisetifolia*	Agoho	Casuarinaceae	51	0.86	0.75
11	*Chrysophyllum cainito*	Caimito	Sapotaceae	2	0.42	0.61
12	*Citrus microcarpa*	Kalamansi	Rutaceae	2	0.57	0.70
13	*Dillenia philippinensis*	Catmon	Dilleniaceae	1	0.18	0.30
14	*Diospyros philippinensis*	Kamagong	Ebenaceae	15	0.25	0.31
15	*Diospyros pilosanthera*	Bolong-eta	Ebenaceae	6	0.46	0.64
16	*Diplodiscus paniculatus*	Balubo	Malvaceae (Tiliaceae)	15	0.46	0.55
17	*Dipterocarpus grandiflorus*	Apitong	Dipterocarpaceae	21	0.69	0.71
18	*Dracontomelon dao*	Dao	Anacardiaceae	206	0.98	0.89
19	*Dracontomelon edule*	Lamio	Anacardiaceae	4	0.68	0.87
20	*Durio zibethinus*	Durian	Bombacaceae	13	0.57	0.68
21	*Garcinia mangostana*	Mangosteen	Clusiaceae	21	0.27	0.33
22	*Garuga floribunda*	Bago	Burseraceae	2	0.26	0.41
23	*Gliricidia sepium*	Madrecacao	Fabaceae	2	0.90	1.06
24	*Gmelina arborea*	Gmelina	Lamiaceae	32	1.38	1.10
25	*Heritiera sylvatica*	Donggon	Malvaceae	1	0.15	0.43
26	*Hopea foxworthyi*	Dalingdingan	Dipterocarpaceae	5	0.97	1.05
27	*Hopea malibato*	Yakal Kaliot	Dipterocarpaceae	60	0.53	0.72
28	*Hopea plagata*	Yakal Saplungan	Dipterocarpaceae	156	0.57	0.75
29	*Intsia bijuga*	Ipil	Fabaceae	20	0.31	0.45
30	*Knema mindanensis*	Bonod	Myristicaceae	5	0.43	0.40
31	*Lansium domesticum*	Lanzones	Meliaceae	48	0.34	0.45
32	*Leucaena leucocephala*	Ipil–Ipil	Fabaceae	2	1.03	0.60
33	*Mangifera indica*	Mango	Anacardiaceae	16	0.95	0.67

Table 4 continued

#	Species[a]	Common name	Family	N[b]	MAID (cm/year)[c]	MAIH (m/year)[d]
34	*Melia dubia*	Bagalunga	Meliaceae	21	1.89	1.31
35	*Myrica javanica*	Hindang	Myricaceae	9	0.90	0.75
36	*Nephelium lappaceum*	Rambutan	Sapindaceae	27	0.69	0.56
37	*Parashorea malaanonan*	Bagtikan	Dipterocarpaceae	145	0.62	0.89
38	*Persea americana*	Avocado	Lauraceae	4	0.68	0.63
39	*Petersianthus quadrialatus*	Toog	Lecythidaceae	12	0.43	0.45
40	*Podocarpus rhumbii*	Malakawayan	Podocarpaceae	26	0.32	0.37
41	*Polyscias nodosa*	Malapapaya	Araliaceae	3	0.86	0.68
42	*Pterocarpus indicus*	Narra	Fabaceae	192	0.89	0.80
43	*Samanea saman*	Thai Acacia	Fabaceae	41	1.19	0.80
44	*Sandoricum koetjape*	Santol	Meliaceae	12	1.33	0.85
45	*Securinega flexuosa*	Anislag	Phyllantaceae	17	1.08	0.67
46	*Shorea almon*	Almon	Dipterocarpaceae	3	0.74	0.86
47	*Shorea contorta*	White Lauan	Dipterocarpaceae	286	0.87	0.97
48	*Shorea guiso*	Guijo	Dipterocarpaceae	52	1.19	1.07
49	*Shorea polysperma*	Tanguile	Dipterocarpaceae	18	0.79	0.94
50	*Shorea squamata*	Mayapis	Dipterocarpaceae	19	1.71	1.53
51	*Strombosia philippinensis*	Tamayuan	Olacaceae	8	0.21	0.30
52	*Swietenia macrophylla*	Mahogany	Meliaceae	413	1.25	1.00
53	*Cleistocalyx operculatus*	Malaruhat	Myrtaceae	1	1.25	1.14
54	*Tectona grandis*	Teak	Lamiaceae	73	1.51	1.22
55	*Terminalia microcarpa*	Kalumpit	Combretaceae	259	1.42	1.18
56	*Theobroma cacao*	Cacao	Sterculiaceae	11	0.44	0.49
57	*Toona philippinensis*	Lanipga	Meliaceae	29	0.97	0.74
58	*Tristania decorticata*	Malabayabas	Myrtaceae	3	0.62	0.78
59	*Vitex parviflora*	Molave	Lamiaceae	154	0.91	0.72
60	*Viticipremna philippinensis*	Lingolingo	Lamiaceae	5	0.91	0.61

[a] Species are listed in alphabetical order

[b] *N* number of individuals sampled

[c], [d]MAID and MAIH calculated from all individuals measured across all sites by dividing 2011 values by plantation age

References

Ashton PMS (1995) Seedling growth of co-occurring *Shorea* species in the simulated light environments of a rain forest. For Ecol Manag 72:1–12

Ashton PMS, Berlyn GP (1992) Leaf adaptations of some *Shorea* species to sun and shade. New Phytol 121:587–596

Ashton PMS, Gunatilleke CVS, Gunatilleke IAUN (1995) Seedling survival and growth of four *Shorea* species in a Sri Lankan rainforest. J Trop Ecol 11:263–279

Ashton PMS, Gamage S, Gunatilleke IAUN, Gunatilleke CVS (1997) Restoration of a Sri Lankan rain forest: using Caribbean pine *Pinus caribaea* as a nurse for establishing late successional tree species. J App Ecol 34:915–925

Ashton PMS, Gamage S, Gunatlleke IAUN, Gunatilleke CVS (1998) Using Caribbean pine to establish mixed plantations: testing effects of pine canopy removal on plantings of rain forest tree species. For Ecol Manag 106:211–222

Ashton PMS, Gunatilleke CVS, Singhakumara BMP, Gunatilleke IAUN (2001) Restoration pathways for rain forest in southwest Sri Lanka: a review of concepts and models. For Ecol Manag 154:409–430

Asio VB, Cabunos CC Jr, Chen Z (2006) Morphology, physiochemical characteristics, and fertility of soils from quaternary limestone in Leyte. Philippines Soil Sci 17(8):648–661

Chokkalingam U, Carandang AP, Pulhin JM, Lasco RD, Peras RJJ, Toma T (eds) (2006) One century of forest rehabilitation in the Philippines: approaches, outcomes and lessons. Center for International Forestry Research (CIFOR), Bogor

Dierick D, Hölscher D (2009) Species-specific tree water use characteristics in reforestation stands in the Philippines. Agric For Meteorol 149:1317–1326

FAO (2006) Management of wood properties in planted forests. In: Jagels R (ed) A paradigm for global forest production. Planted forests and trees working papers, working paper 36E. Forest Resource Development Service, Forest Resources Division. FAO, Rome

Freese P (1983) Forests, trees, and people: a preliminary report on the impact of industrial tree plantations and tree-farming projects on small Filipino farmers. Alternate Resource Center, Davao City

Garrity DP, Soekardi M, van Noordwijk M, De La Cruz R, Pathak PS, Gunasena HPM, Van So N, Huijun G, Majid NM (1997) The Imperata grasslands of tropical Asia: area, distribution, and typology. Agrofor Sys 36:3–29

Göltenboth F, Hutter CP (2004) New options for rehabilitation and landscape ecology in Southeast Asia by "rainforestation farming". J Nat Conserv 12:181–189

Griess VC, Knoke T (2011) Can native tree species plantations in Panama compete with Teak plantations? An economic estimation. New For 41:13–39

Gunasena HPM, Roshetko JM (2000) Tree domestication in Southeast Asia: results of a regional study on institutional capacity for tree domestication in national programs. International Center for Research in Agroforestry (ICRAF), Bogor

Jahn R, Asio VB (1998) Soils of the tropical forests of Leyte, Philippines: 1. Weathering, soil characteristics, classification and site qualities. 2. Impact of different land uses on status of organic matter and nutrient availability. In: Schulte A, Ruhiyat D (eds) Soils of tropical forest ecosystems: characteristics, ecology and management. Springer, Berlin, pp 29–44

Kettle CJ (2010) Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodivers Conserv 19:1137–1151

Langenberger G (2004) A review of research on Philippine forest vegetation, particularly work since 1990. Agham Mindanaw 2:11–24

Langenberger G (2006) Habitat distribution of dipterocarp species in the Leyte Cordillera: an indicator for species-site suitability in local reforestation programs. Ann For Sci 63:149–156

Lasco RD, Pulhin JM (2006) Environmental impacts of community-based forest management in the Philippines. Int J Environ Sustain Dev 5:46–56

Lawrence A (1997) *Kaingin* in the Philippines: is it the end of the forest? Rural Dev For Netw Paper 21f:1–8

Mangaoang EO, Pasa AE (2003) Preferred native tree species for smallholder forestry in Leyte. Ann Trop Res 25(1):25–30

Margraf J, Milan P (1994) Rainforestation farming: an alternative to conventional concepts. Ann Trop Res 16:17–27

Milan P, Göltenboth F (2005) Abaca and rainforestation farming. A guide to sustainable farm management. Visayas State University, Baybay

Millet J, Tran N, Vien Ngoc N, Tran Thi T, Prat D (2013) Enrichment planting of native species for biodiversity conservation in a logged tree plantation in Vietnam. New For 44:369–383

Navarrete IA, Tsutsuki K, Navarrete RA (2010) Humus composition and the structural characteristics of humic substances in soils under different land uses in Leyte, Philippines. Soil Sci Plant Nutr 56:289–296

Otsamo R, Otsamo A, Adjers G (1996) Reforestation experiences with dipterocarp species on grasslands. In: Schulte A, Schöne D (eds) Dipterocarp forest ecosystems: towards sustainable management. World Scientific Publishing, Singapore, pp 464–476

Otsamo A, Adjers G, Hadi TS, Kuusipalo J, Vuokko R (1997) Evaluation of reforestation potential of 83 tree species planted on *Imperata cylindrica* dominated grassland. New For 14:127–143

PAGASA (2010) Philippine Atmospheric, Geophysical and Astronomical Services Administration, Philippines. URL http://www.pagasa.dost.gov.ph

Piotto D, Craven D, Montagnini F, Alice F (2010) Silvicultural and economic aspects of pure and mixed native tree species plantations on degraded pasturelands in humid Costa Rica. New For 39:369–385

Roshetko JM, Snelder DJ, Lasco RD, van Nordwijk M (2008) Future challenge: a paradigm shift in the forestry sector. In: Snelder DJ, Lasco RD (eds) Smallholder tree growing for rural development and environmental services. Springer, Netherlands, pp 453–485

Sales-Come R, Hölscher D (2010) Variability and grouping of leaf traits in multi-species reforestation (Leyte, Philippines). For Ecol Manag 260:846–855

Santos Martín F, Lusiana B, van Noordwijk M (2010) Tree growth prediction in relation to simple set of site quality indicators for six native tree species in the Philippines. Int J For Res 2010: 507392, 10 pages

Santos Martín F, Bertomeu M, van Noordwijk M, Navarro R (2012) Understanding forest transition in the Philippines: main farm-level factors influencing smallholder's capacity and intention to plant native timber trees. Small-Scale For 11:47–60

Shono K, Davies SJ, Chua YK (2007) Performance of 45 native tree species on degraded lands in Singapore. J Trop For Sci 19(1):25–34

Suarez RK, Sajise PE (2010) Deforestation, swidden agriculture and Philippine biodiversity. Philipp Sci Lett 3(1):91–99

Suzuki T, Jacalne DV (1986) Response of dipterocarp seedling to various light conditions under forest canopies. Bull For For Prod Res Inst 336:19–34

Tolentino EL (2008) Restoration of Philippine native forest by smallholder tree farmers. In: Snelder DJ, Lasco RD (eds) Smallholder tree growing for rural development and environmental services. Springer, Netherlands, pp 319–346

van Breugel M, Hall JS, Craven DJ, Dent DH, Wishnie MH, Deago J, Mariscal E, Ibarra D, Cedeño N, Park A, Ashton MS (2011) Early growth and survival of 49 tropical tree species across sites differing in soil fertility and rainfall in Panama. For Ecol Manag 261:1580–1589

Weber JC, Sotelo Montes C (2008) Geographic variation in tree growth and wood density of *Guazuma crinita* Mart. in the Peruvian Amazon. New For 36:29–52

Weinland G (1998) Plantations. In: Appanah S, Turnbull JM (eds) A review of dipterocarps. Taxonomy, ecology and silviculture. CIFOR, Bogor

Wiemann MC (2010) Characteristics and availability of commercially important woods. In: Forest Products Laboratory (ed) Wood handbook—wood as an engineering material. General Technical Report FPL-GTR-190. FPL, Madison, WI

Wishnie MH, Dent DH, Mariscal E, Deago J, Cedeño N, Ibarra D, Condit R, Ashton PMS (2007) Initial performance and reforestation potential of 24 tropical tree species planted across a precipitation gradient in the Republic of Panama. For Ecol Manag 243:39–49