Properties and Utilization of *Acacia mangium Willd.* Timber at Different Ages and Sites in Caraga Region, Philippines

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The mechanical properties (static bending, compression parallel, and perpendicular-to-grain, shear, hardness), lumber recovery, and grades of 4-, 6- and 8-year-old mangium trees collected from three sites in Caraga Region (Region XIII), Philippines, were tested to evaluate their suitability for lumber conversion at younger ages. The sites studied were Esperanza, Agusan del Sur, Nongnong, Butuan City, and Las Nieves, Agusan del Norte. Standard procedures for testing the above properties were followed. Lumber quality per log was evaluated based on the National Hardwood Lumber Association (NHLA) Standards. The data were analyzed using Three Factorial in Complete Randomized Design (CRD). Site (S) and age (A) significantly affected lumber recovery (LR), lumber recovery factor (LRF), and all mechanical properties except hardness (end). The effects of interactions among treatments were, however, not consistent, either significant or not significant. The mechanical properties at 4 years old fell under medium strength (C3) and medium to moderately high strength (C3-C2) at 6 and 8years old. The cost-benefit analysis of converting mangium to lumber at 4, 6, and 8 year old ages was computed and discussed.

Keywords: Mechanical properties; Lumber recovery; Lumber grades; Cost-benefit analysis; Acacia mangium Willd.

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INTRODUCTION

The Philippine government in 2011 imposed a moratorium on the harvesting of timber in natural and second-growth forests. Exempted from the log ban are industrial tree plantation species (ITPS), which are cheaper and faster-growing than the traditional tree species.

ITPS are gaining prominence as the main source of wood for the country's log processors. Their use, in fact, has become a major strategy for meeting the wood-based industries' demand for sustained raw materials supply. ITPS are grown, harvested, and processed by wood processing mills in Region XIII (Caraga) and nearby provinces such as Misamis Oriental and Bukidnon. At present, thousands of Filipinos are actively engaged in ITPS production (Personal Communication, for example, Villanueva, DENR Caraga).

Caraga is an administrative region of the Philippines, on the northeastern portion of the island of Mindanao designated as Region XIII. It is composed of five provinces and six cities. The total land area is 18,850 km^2, of which 71.2% is forestland and 28.8% is alienable and disposable land. The region is characterized by mountainous areas, flat, and rolling lands. It has Type II climate and rainfall distribution of 3,000 - 5,000 mm/year from July – December (www.mediawiki.org).

Mangium (*Acacia mangium* Willd.) belonging to the family Leguminosae is one of the recommended species for tree plantations in the Philippines. It is a fast-growing legume tree that was introduced to Sabah, Malaysia from its native habitat in the tropical rainforest of Queensland, Australia in 1922. Growing as fast or faster than *Gmelina arborea* (Verbenaceae) and *Eucalyptus deglupta* (Myrtaceae), mangium reaches a height of 30 m and diameter of 90 cm, with a straight bole that may be unbranched for more than half of its total height. On adverse sites, it may not reach 10 m tall (NRC 1983, Rojo 1999).

From the total ITPS log production of 111,600 m^3 from local plantations, 39% were from mangium in Region XIII (Caraga). Of the total mangium lumber production of 1,102,400 m^3, 69.4% likewise came from the region (DENR 2014).

Mangium wood is a dense, all-purpose hardwood with an attractive medium-brown color, harvested and utilized for various end-uses such as veneer, lumber, and for other construction purposes at 10 to 12 years old. It is commonly tapped as a substitute to the county's almost depleted traditionally used timber species. Thus, it has been serving as a necessary source of raw materials by the local wood- based industry.

While harvesting ITPS at 10 to 12 years old has been the common practice, it may be feasible to lower the harvesting age at say 6 to 8 or even at 4 years old. It may not be practical to prolong harvesting age if the wood properties of younger trees would not significantly vary from those of the older ones.

Evaluation of mangium's wood properties, lumber recovery, and grades at younger ages (4-, 6- and 8-year-old) would be necessary for the optimum utilization of the species, particularly for lumber conversion. Hence, this study was conducted to attain the following objectives: 1) test and evaluate the log and lumber recovery, and mechanical properties of 4-, 6- and 8 year-old mangium, and 2) compute and evaluate the cost-benefits of converting mangium logs into lumber at these ages.

EXPERIMENTAL

Materials

The materials consisted of three trees per age: 4, 6 and 8 years old from three different sites in Caraga: Esperanza, Agusan del Sur (Site 1), Nongnong, Butuan City (Site 2) and Las Nieves, Agusan del Norte (Site 3). Information about the study sites is shown in Table 1 while a photo of an 8-year-old mangium tree is displayed in Fig. 1.

Table 1. Information about the Study Sites

	SITE 1	SITE 2	SITE 3
Barangay /Town	Esperanza, Agusan del Sur	Nongnong, Butuan City	Las Nieves, Agusan del Norte
Elevation	136 masl	100 – 400 masl	200-700 masl
Soil Type	Clay loam; Soil pH 5.4– 6.0; texture: medium	Camansa Series; Soil pH 5.0 – 7.0; texture: medium (rocky)	Clay loam ; Soil pH 5.3 – 6.0; texture: medium and granulated
Spacing	3m x 3m	3m x 3m	4m x 4m
Silvicul-tural Treatmen t	Clearing/weeding for 3 years; Fertilizer application (complete) for 3 years, 50 kg/sack, 2 sacks/ha	Clearing/weeding for 3 years; Fertilizer application (complete) for 3 years, 50 kg/sack, 2 sacks/ha	Clearing/weeding for 3 years; Fertilizer application (complete) for 3 years, 50 kg/sack, 2 sacks/ha

DBH = Diameter at Breast Height

Fig. 1. An eight year-old *Acacia mangium*

Methods

Three logs (1.83 to 2.14 m long) were taken from each tree to represent the butt, middle and top portions. The FPRDI Wood-mizer Lt28 was used in processing logs into lumber. Individual boards were marked correspondingly with lumber crayon as to species, site, log number and sequence of cut.

From the lumber recovered, three 50 mm (width) x 50 mm (thickness) x actual length were taken for conversion into various mechanical properties samples namely; static bending, compression parallel-to-grain (C//) and perpendicular-to-grain (C/), shear (S), hardness (H), and toughness (To). The standard dimensions of samples for each property were cut from the lumber.

The sampling scheme is shown in **Fig. 2.**

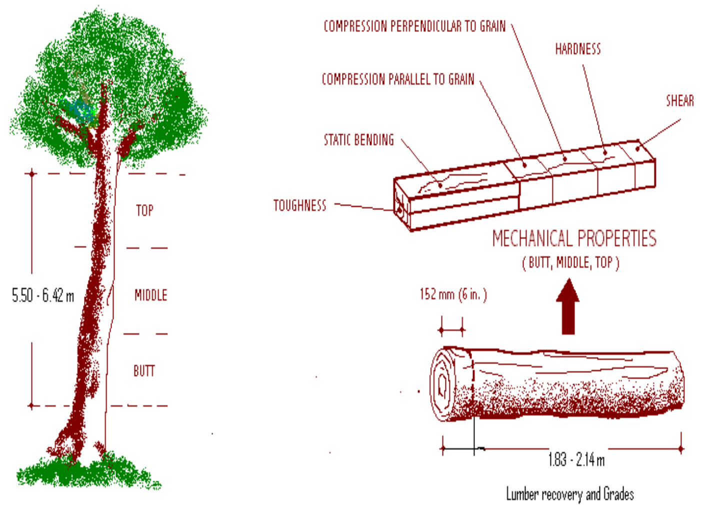

Fig. 2. Sampling scheme used in the study

Log and lumber recovery

The total lumber recovered from each log was tallied to determine the percent lumber yield based on the log gross volume. Each lumber piece was graded using the National Hardwoods Lumber Association (NHLA) grading rules.

The gross volume per log was determined based on the average of the big-end and small-end diameter inside bark (dib) using the Brereton formula,

$$V = 0.7854\, D^2 L \quad (1)$$

where V is the volume (m^3), D is the average diameter (cm, inside bark of the big and small-end diameters), and L is the length (m).

Each log was coded and volume recorded and tabulated to facilitate data analysis and evaluation. In the absence of grading rules for ITPS, the individual pieces of lumber were graded in green condition employing the US National Hardwood Lumber Association (NHLA) standards.

Mechanical properties

The mechanical properties were tested using the standard procedure of the American Society for Testing Materials Designation: D143-52 (ASTM 2005) for small clear specimens of timber.

Except in toughness, for which the US Forest Products Laboratory type testing machine was used, all strength properties were tested using the Shimadzu Universal Testing Machine (2 to 10 tons load capacity).

Static bending properties such as modulus of rupture (MOR), stress at proportional limit (SPL) and modulus of elasticity (MOE) were calculated using a simple flexure formula,

$$\text{MOR (MPa)} = 3P_{m}L/2bh^{2} \quad (2)$$

$$\text{SPL (MPa)} = 3P_{1}L/2bh^{2} \quad (3)$$

$$\text{MOE (GPa)} = P_{1}L^{3}/4bh^{3}Y \quad (4)$$

where P_m is the maximum load (N), P_1 is the load at the proportional limit (N), L is the length of span (mm), b is the width of specimen (mm), h is the height of specimen (mm), and y is the center deflection at the proportional limit (mm)

Maximum Crushing Strength (MCS) in Compression Parallel-to-Grain is given by,

$$\text{MCS (MPa)} = P_{max}/bh \quad (5)$$

where P_{max} is the maximum load (N), b is the width of specimen (mm), and h is the height of specimen (mm). The Compression Perpendicular-to-Grain is given by,

$$C\ \text{(MPa)} = P_{el}/W \text{ x } W_{w} \quad (6)$$

where P_{el} is the load at elastic limit (N), W is the width of plate (mm), and W_w is the width of wood (mm)

Maximum Shearing Strength (MPa) was recorded as the maximum load as registered in the testing machine. Hardness (kN) is defined as the load required to embed ½ of the steel ball diameter on the surfaces of the specimen is the measure of hardness. Toughness (Joule/specimen) is based on the initial and final angles on the scale of the machine; toughness values taken from the energy table prepared for the purpose.

Statistical analysis

Analysis of Variance (ANOVA) in Three-Factorial Complete Randomized Design (CRD) was used in the statistical evaluation of data while Duncan Multiple Range Test (DMRT) was used to determine significance of property means between and among sites and ages.

Cost analysis

The procedure of the United Nations Industrial Development Organization (UNIDO 1986) was followed using two scenarios of analysis: (1) a sawmill enterprise just starting in the business of processing logs into lumber, thus an amount of loan is assumed to be included in the investment, and (2) a sawmill enterprise which has already existed for more than five years and has already recouped the investment cost.

The costs of the following were gathered from sawmills in Butuan City: mangium logs, labor, utilities, other indirect expenses, equipment and machineries, land, and building. Production cost was calculated based on a set of assumptions for different age classes and log diameters.

Projected financial analyses through projected financial statements such as income statement and cash flow statement were done to determine the profitability of sawmilling logs from different diameter age classes. Discounted and undiscounted indicators were used with an interest rate of 10% in the discounted method, equivalent to the bank interest rate. For discounted method, the net present value (NPV), Benefit-cost ratio (BCR) and internal rate of return (IRR) were computed while the return of investment (ROI), and cash payback period for the undiscounted method.

RESULTS AND DISCUSSIONS

Lumber Recovery and Grade

The ANOVA and DMRT for log and lumber recovery (LR), processing rate (PR) and lumber recovery factor (LRF) of mangium are shown in Tables 2 and 3.

Variations in log and lumber features (log diameter and volume, lumber volume and recovery, PR and LRF) among sites (S), ages (A), interactions between S and A and height (H) were highly significant except for log diameter (S x H). The effect of log length was not significant except among sites, while interactions among S x A x H did not significantly vary.

Site 3 had significantly larger log diameter than Sites 1 and 2, while log length in Site 1 was significantly higher than in Sites 2 and 3. In terms of LR and LRF, Site 3 had significantly higher values with no significant difference between Sites 1 and 2.

The results confirmed that variation in LR and LRF is due to differences in log diameter and length. Similarly, log diameter significantly increased from 4- to 8-year-old resulting in highest LR and LRF in the 8-year-old. On the other hand, log diameter decreased from butt to top. Consequently, the LR and LRF also decreased.

The differences in lumber recovery along the height of the tree can be attributed to the decreasing diameter of the trunk with increasing tree height. With increasing tree height, the taper of the log became prominent, resulting in lower LR because more material was lost in removing the taper during the slabbing and edging process.

Alcachupas (2014) reported similar trends in log and LR of falcata [*Falcataria moluccana* (Miq.) Barneby & J. W. Grimes]. Likewise, Natividad et al. (1988) reported that large diameter logs yield more lumber per volume of input except in extremely large and over-mature logs which contain a high percentage of unsound materials, *i.e.* brash center, heart rot, *etc.*

Table 4 presents the yield data (lumber tally) and grade distribution (%) at different ages and sites. Lumber quality increased with percentage recovery of FAS (First and Seconds) and No.1C. The increase in the yield of FAS was evident in the 8-year-old log samples at 24-36 cm diameter range. Log samples in the 6- year-olds yielded mostly the No. 1C while No. 2C, No. 3C and below grade (BG) lumber were highest in the 4-year-old except in 8 years old of Site 1 (No.2C).

Table 2. ANOVA for Log and Lumber Recovery (LR), Processing rate (PR) and Lumber Recovery Factor (LRF) of Mangium

		Log			Lumber			
		Diameter	Length	Volume	Volume	Recovery	PR	LRF
	DF	F-VALUE						
Site (S)	2	316.3**	309.9**	221.9**	14.69**	12.56**	1.92ns	10.09**
Age (A)	2	155.2**	0.04ns	114.1**	10.60**	53.54**	16.07**	32.51**
Site*Age (S x A)	4	5.78**	1.81ns	4.66**	1.32ns	4.30**	2.75*	3.31*
Height (H)	2	55.2**	2.38ns	51.07**	4.24*	35.5**	19.82**	15.95**
Site*Height (S x H)	4	2.50ns	2.38ns	4.67**	1.09ns	2.66*	4.01**	2.57*
Age*Height (A x H)	4	3.92**	0.22ns	5.31**	1.58ns	1.49ns	0.37ns	0.57ns
Site*Age*Height	8	0.77ns	0.46ns	0.68ns	1.06ns	0.84ns	0.84ns	1.19ns
Error	63							
R^2 CV		94.6 7.52	91.1 2.63	92.9 16.4	57.1 73.0	81 4.32	64 27.9	73 5.45

**Highly significant at 99% probability level PR – Processing Rate
*Significant at 95% probability level LRF –Lumber Recovery Factor
ns not significant

Table 3. DMRT for Log and Lumber Recovery of Mangium

		Log			Lumber			
		Diameter	Length	Volume	Volume	Recovery	PR	LRF
Site	1	25.61b	2.14a	0.114a	0.067b	57.54b	0.418a	243.64b
	2	16.67c	1.83c	0.043b	0.034c	57.44b	0.405a	240.14b
	3	27.96a	1.87b	0.117a	0.106a	60.41a	0.364a	255.58a
Age	4	19.57c	1.94a	0.065c	0.054b	55.09c	0.338b	233.45c
	6	22.96b	1.95a	0.085b	0.050b	58.35b	0.359b	244.29b
	8	27.70a	1.95a	0.124a	0.104a	61.94a	0.489a	261.62a
Height	Butt	25.89a	1.95a	0.112a	0.080a	61.26a	0.495a	256.09a
	Mid	23.26b	1.95a	0.090b	0.079a	58.37b	0.371b	246.75b
	Top	21.09c	1.94a	0.073c	0.048b	55.76c	0.319c	236.53c

Means within the same row for each property followed by the same letter are not significantly different.
a, b, c = highest, next to the highest, lowest value, respectively. PR= Processing Rate
LRF = Lumber Recovery Factor

Table 4. Lumber Grade Yields of Mangium at Different Sites and Ages

Site	Age Class	Lumber Tally (m^3)	Lumber grade distribution (%)					Total (%)
			FAS	No.1C	No.2C	No.3C[1/]	BG	
1 (Pating-ay, Prosperidad, Agusan del Sur)	8-year-old	0.861	28	22	38	8	4	100
	6-year-old	0.4779	16	35	21	13	15	100
	4-year-old	0.3297	7	15	30	31	17	100
2 (Nong-nong, Butuan City)	8-year-old	0.3878	20	34	25	17	4	100
	6-year-old	0.2133	15	41	27	11	6	100
	4-year-old	0.0906	6	15	32	40	7	100
3 (Las Nieves, Agusan del Norte)	8-year-old	0.4349	22	37	23	15	3	100
	6-year-old	0.1507	12	43	26	10	9	100
	4-year- old	0.1093	5	12	34	37	12	100

* Up to No.3 Common-timber for furniture and construction.
1/No. 3C grade is a combination of No. 2A and No. 2B grades

The occurrence of natural growth-related defects and end-splits on the log samples influenced the resulting lumber quality. Sound and unsound knots were prevalent in lumber sawn from the center of the log, specifically in smaller diameter classes. Pith was also discernible on the surface of some samples and in some cases extended throughout the board's length with spike knots resulting from these growth-related defects. Some boards also split due to the presence of growth stresses. Lumber cut diametrically from the logs split through the pith with two halves curving outward from each other.

Mechanical Properties

Tables 5 and 6 show the ANOVA for mechanical properties of mangium in green condition and DMRT at different ages and sites, respectively.

Among Ages and Sites

The effect of age was significant except in shear (Table 5). Generally, the mechanical properties significantly increased from 4 to 8-year-old except in MOR and end hardness where the values significantly decreased from 6 to 8 years old (Table 6).

Table 5. ANOVA on Mechanical Properties of Mangium in Green Condition

Source of Variation	DF	MOR, SB	SPL, SB	MOE, SB	Hardness Side	Hardness End	Toughness, Radial (R)	Toughness Tangential (T)
		F- VALUE						
Site (S)	2	56.46**	66.5**	94.2**	2.58 ns	0.07 ns	5.69**	6.44**
Age (A)	2	7.88**	7.85**	6.93**	9.00**	5.77**	3.47*	6.05**
S X A	4	3.77**	2.30 ns	2.33 ns	7.04**	1.65 ns	5.01**	4.00**
Height (H)	2	5.68**	5.38**	3.47*	2.18 ns	0.70 ns	0.55 ns	3.63*
S X H	4	1.64 ns	2.29 ns	1.30 ns	3.25*	0.03 ns	0.77 ns	3.88**
A X H	4	1.06 ns	2.29 ns	0.11 ns	4.38**	0.67 ns	1.73 ns	2.35 ns
S x A x H	8	2.98**	1.80 ns	0.01*	2.59*	0.49 ns	2.01*	1.29 ns
Error	135							
R^2 (%) CV		58 14.2	60 16.8	65 14.9	44 13.8	16 24.1	32 39.8	38 44.2

Source of Variation	DF	Tough-ness (R+T)	Shear Radial (R)	Shear Tangential (T)	Shear (R+T)	Compression Parallel-to-Grain	Compression Perpendicular-to-Grain
		F - VALUE					
Site (S)	2	6.66**	34.5**	15.15**	9.35**	27.82**	16.5**
Age (A)	2	5.85**	8.85**	5.60**	2.89ns	10.84**	24.8**
S X A	4	5.61**	14.93**	11.06**	8.64**	5.26**	4.76**
Height(H)	2	1.26ns	0.20 ns	0.26 ns	1.57 ns	2.67 ns	4.43*
S X H	4	2.70*	0.18 ns	1.99 ns	0.22 ns	1.46 ns	2.03 ns
A X H	4	2.24 ns	8.26**	0.92 ns	0.017*	0.58 ns	0.40 ns
S x A x H	8	1.75 ns	2.56*	0.84 ns	0.655ns	1.85 ns	1.56 ns
Error	135						
R^2 (%) CV		38 36.1	60 12.4	44 15.8	39 16.7	48 14.9	49 23.5

**Highly significant at 99% probability level
*Significant at 95% probability level
n.s. means not significant

The significant increase in mechanical properties conforms to those reported by Makino *et al.* (2012). Their results showed that the mean stem diameter of 7-year-old (DBH = 21.9 cm) was higher than that of 5-year-old trees (DBH =13.1 cm), suggesting that a greater volume of stable wood in the stems of the 7-year-old than the 5-year-old trees. Consequently, the mechanical properties in the stems of the former were higher than the latter age.

The deviation from the above cited general trend may be due to inherent imperfect grain alignments on some samples in 8-year-olds which slightly affected the said properties. According to Kretschmann (2010), the resulting variations in wood grain (fiber) direction strongly affect the strength of the wood and even a small deviation in grain direction significantly weakens the lumber. He reported that a 15° deviation of the grain direction can almost halve the lumber strength, though, in the current study the decrease in MOR and hardness were 5.25% and 12.55% only from the age of 6-8, respectively.

Table 6. DMRT of Mechanical Properties of Mangium at Different Sites and Ages in Caraga

Property	Age (years)			Site		
	4	6	8	1	2	3
Static bending						
Modulus of rupture (MPa)	60.2b	67.2a	63.6b	74.4a	58.62b	58.13b
Stress at proportional limit (MPa)	34.9b	38.6a	39.3a	45.2a	36.0b	31.4c
Modulus of elasticity (GPa)	7.7b	8.4a	8.5a	10.0a	7.2b	7.2 b
Compression parallel to grain						
Maximum crushing strength (MPa)	24.3b	27.2a	27.4	28.9a	26.7b	23.3c
Compression perpendicular to grain						
Stress at proportional limit (MPa)	4.8b	4.9b	6.4a	6.1a	4.84b	5.2b
Shear parallel to grain						
Average of Radial and						
Tangential (MPa)	6.7a	7.3a	6.9a	7.5a	6.8b	6.6b
Hardness						
Side grain (kN)	4.3b	4.4b	4.8a	4.7a	4.5a	4.4a
End grain (kN)	5.5a	5.5a	4.8b	5.2a	5.2a	5.3a
Toughness						
Average of Radial and						
Tangential (Joule/specimen)	28.9a	33.0ab	36.7a	32.8ab	28.8b	37.1a
Strength Classification	C3	C3-C2	C3-C2	C3-C2	C3	C3

Means within the same row for each property followed by the same letter are not significantly different.
C3 = medium strength C2 = moderately high strength
a, b, c = highest value , next to the highest, lowest value, respectively.

Alipon (2003) reported that the mechanical properties of 6- to 8-year-old mangium trees from one plantation site in PICOP, Surigao del Sur (also part of Caraga Region) fell under C5 and C4 strength classes, respectively. These properties were remarkably lower than results obtained from the 6- to 8-year-olds (C3-C2) and even the 4-year-olds (C3) in this current study. Likewise, the strength of 4-year-old mangium trees in this current study was at par with that of 12-year-old trees from Mindoro (Region IV).

The effect of site on the mechanical properties was highly significant except in hardness. The mechanical properties among sites were significantly highest in Site 1 (Table 5). There were no significant differences between Sites 2 and 3 except in SPL (SB), MCS, and toughness (Table 6).

Trees in Site 1 and 3 had bigger diameter than in Site 2, indicating better tree growth. Generally, Site 1 had significantly the highest mechanical properties, and there were no significant difference between Sites 2 and 3 except in SPL (SB) and MCS. Based on the mechanical properties classification devised at FPRDI (FORPRIDECOM 1980), trees in Site 1 fell under C3-C2 (medium to moderately high) while C3 (medium) in Sites 2 and 3. Information about the study sites were almost similar except in Site 1, where the soil type is not granulated unlike in Site 3 and Camansa Series (rocky) in Site 2. Similarly, the spacing in Site 3 (4 x 4 m) is wider than in Site 1 (3 x 3 m) (Table 1). These probably may have contributed to significant differences in some mechanical properties between sites.

The effects of interactions among Site x Age, Height, Site x Age, Age x Height and Site x Age x Height were not consistent, either significant or not significant (Table 5).

In contrast to the current findings, Mohd *et al.* (1998) reported that the mean values of MOE and MOR were not affected by the site. The properties of *Acacia mangium* were the same regardless of where they are planted.

According to Panshin and de Zeeuw (1980), Lantican (1975), and Wilkins (1989), the variability in wood arises from the physiological activities of the cambium. These activities are affected by several factors such as soil, elevation, silvicultural treatment, stand density and structure, and seed origin which in turn affect tree growth and consequently, wood properties.

Cost-Benefit Analysis

The cost of processing mangium logs into lumber depends on the average processing rate and lumber recovery for each diameter class and age group. Production cost for each diameter class was calculated from the cost of raw materials, labor, fuel and lubricants, repair and maintenance, and utilities.

Other expenses included items for depreciation calculated at PhP197,200.00 per year or PhP16,433.33 per month. Marketing cost, on the other hand, was calculated at a minimum of PhP1.00 per bd.ft. to cover expenses for marketing documents and delivery of lumber. Annual cost is reached at PhP691,200.00.

The cost of raw materials was the only variable item in the sawmilling operation, while other items were held constant. Cost of logs contributed 86% to the production cost while repair and maintenance contributed 4.3% because saw blades were often sharpened. Other items were at a minimum cost. Production cost was computed for each diameter size of mangium logs as shown below, where the exchange rate 1USD = Php50, was applied.

With a price of PhP 3,800.00 per cu m of mangium logs, cost of production was higher in the 4-year- old plantation with the lowest diameter size. The bigger the logs' diameter, the lower was the volume required to meet the 2,400 bd ft plant capacity. If diameter was smaller, more logs were needed to meet the capacity, thus the higher cost of producing lumber from 19.52 cm diameter logs.

The average production cost (Php) of processing mangium logs into lumber at different diameter is shown in Table 7. Based on the calculated cost per unit of mangium lumber produced from 19.52 cm, 22.67 cm, and 27.67 cm diameter logs, the production cost per bd ft was PhP18.83, PhP18.02, PhP17.00, respectively.

The selling price of mangium lumber ranged from PhP17.00 to PhP25.00 per bd ft. Mangium lumber belonging to the above diameter sizes should be carefully priced, since the production cost was already PhP18.83, PhP18.02, PhP17.00 at 4, 6, and 8 years old, respectively. The price of lumber should not be higher than PhP25.00 to be competitive.

Table 7. Average Production Cost (PhP) of Processing Mangium Logs into Lumber at Different Diameters

Average Diameter Size (cm)	Average Production Cost (PhP)			
	Per bd.ft	Daily	Monthly	Annual
19.52	18.83	45,192.00	1,084,608.00	13,015,296.00
22.67	18.02	43,248.00	1,037,952.00	12,455,424.00
27.67	17.00	40,800.00	979,200.00	11,750,400.00

1USD = Php50

Profitability Analysis

The common pricing method is derived by adding a certain profit margin to the production cost per unit. Since production cost is high, a 20 to 30% mark-up would not be appropriate, as the price will no longer be competitive. Thus, a selling price of PhP21 is recommended to realize better returns from processing the logs into lumber. Lower than this price, producing mangium logs will not be profitable especially for the 4-year-old logs (19.52 cm dbh) (Table 8).

At a selling price of PhP 21.00 per bd ft, profitability indicators generated positive results. The return on investment (ROI) was 21% to 47%. Payback period may take less than two to three years to be able to recover the investments of PhP 4,919,200.00.

With regard to the discounted method of profitability analysis, the net present value (NPV) generated for all sizes were positive figures. The internal rate of return (IRR) also had positive values higher than the opportunity cost of capital (OCC) which was set at 10%.

Table 8. Profitability Analysis for Processing Mangium Logs into Lumber

Average Diameter Size (cm)/Age	Profitability Indicators			
	ROI	Payback Period	NPV (PhP)	IRR
19.52 (4 yr. old)	37%	2.7years	2,744,352.61	21%
22.67 (6 yr. old)	48%	2.1 years	2,348,129.09	32%
27.67 (8 yr. old)	64%	1.6 years	9,956,589.55	47%

CONCLUSIONS

Although the mechanical properties of 4-year-old mangium lumber may be considered acceptable for medium construction, it is appropriate to prolong the harvesting age of the species from 4 to 6 or 8 years old due to the remarkable improvement in lumber recovery, grades, and properties. The wood of 6- to 8-year-olds from the three sites may be used for medium to high grade furniture and cabinets, millworks, picture frames paneling, sidings and window sash, and for other medium to moderately heavy construction purposes.

Sites 1 and 3 had larger tree diameters and generally better mechanical properties, lumber recovery, and grades than those in Site 2, although Site 1 had significantly higher mechanical properties (medium to moderately high strength) than trees in Sites 2 and 3 (medium strength)

The internal rate of return from 8-year-old trees is higher than from the 6- and 4-year-olds. Thus, it would be more advantageous for the farmers to wait for the trees to age from 4 to 8 years old.

On the other hand, in periods where there is a high demand for lumber and wood supply is scarce, the wood processors may opt to buy 6-year-old logs because their quality is comparable to 8-year-old logs. It is the option of the farmers to take advantage of the opportunity to recoup their investment at a shorter time by selling their logs at an earlier age.

Test results could be a useful guide in evaluating plantation management practices in relation to tree growth and quality and subsequently in establishing a pricing strategy for the logs as far as tree age and plantation sites are concerned.

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