Project Title :**Utilization of Small Diameter Logs from Sustainable Sources for Bio-Composite Products**

Ordinal Number : **PD 40/00 Rev. 4(1)**

Project Executing Agency : **Faculty of Forestry**
Bogor Agricultural University
Indonesia

Coordinating Institution : **Forest Products Research and Development Institute (FPRDI)**

Location of Project : **Philippines**

Development Objective

To contribute to the continuity of timber production, forest resource security, socio-benefit from sustainable sources, determination of SDL wood properties and technology transfer of utilization of SDL for value-added bio-composite products.

Specific Objective 1: To assess market needs of SDL from tropical rain forest.

Summary of Output:

Output 1.1: Current and future demand of bio- composite products identified.

Activities

1.1.1 Review market data and examine trends on bio-composite products that are sold today and where they are sold.

1.1.2 Determine where the potential for future market growth for bio-composite products exists.

Specific Objective 2: Determine the wood properties and utilization technology of SDL and transfer this technology for manufacturing of value-added bio-composite products.

Summary of Output:

Output 2.1 Properties and utilization technology of SDL determined.

Activities

2.1.1 Identify suitable wood species and evaluate physical and mechanical properties.

Four (4) wood species namely: *Eucalyptus citriodora*, *Eucalyptus urophylla*, *Alstonia macrophylla* and *Polyscias nodosa (*Blume*) Seemann* were used in the study. Three trees each of *Eucalyptus citriodora*, *Eucalyptus urophylla*, and two trees of *Alstonia macrophylla* were collected from the Integrated Forest Management Agreement (IFMA) of the Provident Tree

Farms, Inc. (PTFI) San Teodoro, Mindoro, Philippines. The other *Alstonia macrophylla* tree was purchased from the coconut farm in Sitio Bigaa, San Teodoro, Mindoro. On the other hand, *Polyscias nodosa (*Blume*) Seemann* was collected from Atimonan, Quezon, Philippines.

The *E. citriodora* trees were interplanted in 1985 with other eucalyptus in a 6.5 hectares area. *E. urophylla* was sourced from 0.60 hectare planted in 1982. The two *Alstonia macrophylla* trees were naturally growing with other dipterocarps in the IFMA. The other *Alstonia macrophylla* growing with other coconut trees purchased from Sitio Bigaa was estimated to be 20 years old.

Based on Table 2.1, *E. citriodora*, *E. urophylla*, *Alstonia macrophylla* and *Polyscias nodosa (*Blume*) Seemann* have not been commercially utilized. Among the plantation species, *P. falcataria* topped the list that was harvested in 2006 while *H. brasiliensis* has the lowest volume of harvest.

According to a report, the total production of logs from plantation forests accounted for 83.5% of the total log production in 2006.Sawlog/veneer log utilization from plantation species was 367,812 cu m (42%), pulpwood at 471,985 cu m (54%) and poles and piles was 25,097 cu m (4%).

Table 2.1 Log Production by species: 2006 (In cubic meters)
Source: Timber Licensee's Report, FMB, DENR, Philippines

Species	
Acacia (*Samanea saman*)*	18,923
Almon (*Shorea almon*)	5,911
Antipolo (*Artocarpus blanco*)	10,114
Apitong (*Dipterocarpus grandiforus*)	2,921
Bagras (*Eucalyptus deglupta*)*	34,018
Bagtikan (*Parashorea plicata*)	6,326
Binuang ((*Octomeles sumatrana*)	5,663
Falcata (*Paraserianthes falcataria*)*	319,904
Gubas (*Endospermun peltatum*)*	15,831
Ipil-ipil (*Leucaena leucocephala*)*	15,339
Loktob (*Duabana moluccana*)	2,361
Mahogany (*Swietenia mahogany*)*	78,081
Mangium (*Acacia mangium*)*	101,361
Mayapis (*Shorea squamata*)	15,267
Para rubber (*Hevea brasiliensis*)*	7,177
Red Lauan (*Shorea negrosensis*)	24,300
Tanguile (*Shorea polysperma*)	13,673
Toog (*Combretodendron quadrialatum*)	2,962
White Lauan (*Pentacme contorta*)	6,105
Yakal (*Shorea gisok*)	2,107
Yemane (*Gmelina arborea*)*	166,806

*Plantation species

Collection raw materials

Felling, carabao skidding, cutting and hauling from cutting area of the *E. citriodora*, *E. urophylla* and *Alstonia macrophylla and Polyscias nodosa (*Blume*) Seemann* are shown in the following photos.

E. citriodora plantation

Felled *E. citriodora*

Bucking *E. citriodora*

0.40m bolts of *E. citriodora*

E. urophylla plantation

Felling of *E. urophylla*

Rolling of *E. urophylla*

Disc cutting of *E. urophylla*

Alstonia macrophylla with coconut trees

Felling of *Alstonia macrophylla*

Preparation of *Alstonia macrophylla* for skidding

Carabao skidding *Alstonia macrophylla*

*P. nodosa (*Blume*)* with coconut trees

Felling of *P. nodosa (*Blume*)*

*P. nodosa (*Blume*)* logs

Checking/labeling of *P. nodosa (*Blume*)*

Evaluation of Physical and Mechanical Properties

Test specimens

Shrinkage test samples

Relative density & MC test samples

Compression test samples

Bending, shear and other test samples

The physical and mechanical properties of the Philippine-grown *E. citriodora*, *E. urophylla*, *Alstonia macrophylla* and *Polyscias nodosa (*Blume*) Seemann* were investigated and the results are presented in (Table 2.3 to 2.6). Considering the relative density of *Alstonia macrophylla* which is 0.55 and *Polyscias nodosa (*Blume*) Seemann* which is 0.36, they are found suitable for wood wool cement board (WWCB) manufacture. This is based on the previous studies on the manufacture of WWCB wherein the relative density of the wood species used are mostly low to medium as listed in Table 2.2. Processing of *E. citriodora* and *E. urophylla* through a shredding machine (a machine used for the preparation of wood wool) was also tried but they were too difficult to shred compared to *Alstonia macrophylla* and *Polyscias nodosa (*Blume*) Seemann.*

Table 2.2. Relative density of different wood species in the Philippines (Alipon et al 1987, Alipon & Floresca 1991) and their respective bending strength when manufactured into WWCBs (Mallari et al 1994, Cabangon 1997, Pablo & Cabangon 1997, Eusebio et al 2002a & 2002b, Eusebio et al 2001)

Common Name	Scientific Name	Relative Density (Green)	Bending Strength*, MPa
Antipolo	*Artocarpus blanco* (Elmer) *Merr.*	0.42	5.7
Auri/Earpod wattle	*Acacia Auriculiformis* A. Cunn. Ex Benth	0.5 – 0.6**	5.4
Banilad	*Stecula cosmosa* Wall.	0.32	4.5
Binuang	*Octomeles Sumatra* Miq.	0.27	6.0
Binunga	*Macaranga tanarius* (L.) Muell. Arg.	0.30	6.2
Gray gum	*Eucalyptus tereticornis* Sm.	0.6 – 0.80**	6.0
Gubas	*Endospermum peltatum* Merr.	0.30	6.4
Kaatoan Bangkal	*Anthocephalus chinensis* (Lamk.) A. Rich ex. Walp.	0.34	6.4
Loktob	*Duabanga moluccana* Blume.	0.37	5.5
Big-leaf mahogany	*Swietenia macrophylla* King	0.54	5.7
Mangium	*Acacia mangium* Willd.	0.46	6.5
Moluccan Sau	*Paraserianthes falcataria* (L.) Nielsen	0.25	8.2
Rarang	*Erythrina subumbrans* (Hassk.) Merr.	0.24	7.1
River red gum	*Eucalyptus camaldulensis* Dehnh.	0.68	5.9
Rose gum	*Eucalyptus grandis* W. Hill ex Maiden	0.42 - 0.50**	6.1
Tanguile	*Shorea polysperma* (Blanco) Merr.	0.47	3.0
Ulaian/Celebes Oak	*Lithocarpus celebicus* (Miq.) Rehd.	0.62	3.3
White lauan	*Shorea contora* Vidal	0.46	2.9
Yemane/Gmelina	*Gmelina arborea* Roxb.	0.41	7.3

* Obtained from 12-mm thick boards manufactured at a density of 750 kg/m^3 (except for *E. camaldulensis* with a board density of 600 kg/m^3), wood/cement ratio of 40/60, 3% addition of CaCl and using wood wool soaked in tap water for 24 hours.

** Data obtained from species not grown in the Philippines (Shikaputo et al 1986, Anonymus, 1996)

Table 2.3. Strength properties of *E. citriodora*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (MPa)	MOE (GPa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (MPa)	Hardness (kN)	
										Side	End
1	Butt	62.16	0.748	74.91	32.46	13.25	39.38	9.28	10.39	8	8.46
	Mid	58.89	0.770	87.38	47.57	14.47	49.14	6.15	9.46	9.6	7.59
	Top	54.20	0.800	93.52	49.37	13.59	45.89	7.74	8.25	9.93	8.97
	Mean	**58.42**	**0.773**	**85.27**	**43.13**	**13.77**	**44.85**	**7.72**	**9.37**	**9.18**	**8.34**
2	Butt	72.71	0.715	93.34	51.62	13.39	36.16	4.70	10.36	8.38	7.77
	Mid	66.88	0.713	84.94	20.26	12.26	37.91	5.52	7.54	6.99	7.18
	Top	56.45	0.790	94.35	51.45	12.50	49.68	6.07	11.16	6.87	7.94
	Mean	**65.35**	**0.739**	**90.88**	**41.11**	**12.73**	**41.25**	**5.43**	**9.69**	**7.41**	**7.63**
3	Butt	63.55	0.74	88.13	18.74	12.96	39.39	4.99	10.62	7.85	6.30
	Mid	61.63	0.73	104.37	34.91	13.96	51.29	4.28	7.79	7.90	8.14
	Top	59.76	0.75	85.66	48.63	13.00	24.85	2.98	10.40	7.74	7.88
	Mean	**61.65**	**0.74**	**92.72**	**34.09**	**13.31**	**38.51**	**4.08**	**9.60**	**7.83**	**7.41**

Table 2.4. Strength properties of *E. urophylla*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (MPa)	MOE (GPa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (MPa)	Hardness (kN)	
										Side	End
1	Butt	87.52	0.64	70.78	28.19	12.95	27.03	6.63	7.01	4.91	5.09
	Mid	74.73	0.67	85.30	24.86	14.26	40.27	6.22	7.71	6.83	7.02
	Top	72.32	0.68	73.34	28.45	12.53	30.20	6.42	8.92	6.35	7.15
	Mean	**78.19**	**0.66**	**76.47**	**27.17**	**13.25**	**32.50**	**6.42**	**7.88**	**6.03**	**6.42**
2	Butt	82.00	0.67	66.34	27.12	11.00	34.53	6.78	8.97	6.28	6.23
	Mid	71.74	0.71	83.21	30.55	11.24	41.91	7.01	9.37	6.37	6.05
	Top	59.42	0.76	86.73	36.95	10.94	44.42	11.7	10.17	7.98	7.68
	Mean	**71.05**	**0.71**	**78.76**	**31.54**	**11.06**	**40.29**	**8.50**	**9.50**	**6.88**	**6.65**
3	Butt	84.41	0.65	80.01	40.08	10.02	34.52	9,66	9.79	6.69	7.01
	Mid	73.76	0.67	62.09	31.75	8.64	31.06	6.06	9.79	6.13	6.20
	Top	65.92	0.71	93.32	45.85	14.46	42.77	8.57	12.54	7	7.09
	Mean	**74.70**	**0.67**	**78.47**	**39.23**	**11.04**	**36.12**	**8.10**	**10.71**	**6.61**	**6.77**

Table 2.5 Strength properties of *Alstonia macrophylla*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (MPa)	MOE (GPa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (MPa)	Hardness (kN)	
										Side	End
1	Butt	104.04	0.56	78.1	27.83	10.16	26.29	5.56	8.56	4.23	5.03
	Mid	104.58	0.55	75.0	17.30	9.93	29.09	5.88	9.58	4.03	5.07
	Top	107.42	0.54	73.74	21.24	10.14	25.87	5.98	8.64	3.68	4.97
	Mean	**105.35**	**0.55**	**75.61**	**22.12**	**10.08**	**27.08**	**5.81**	**8.93**	**3.98**	**5.02**
2	Butt	103.44	0.55	73.26	30.92	8.52	31.55	6.32	8.41	4.57	5.73
	Mid	102.61	0.55	79.55	18.07	8.88	26.76	6.64	9.50	4.54	4.90
	Top	103.96	0.55	74.78	28.15	10.82	29.98	5.05	7.99	3.79	4.54
	Mean	**103.34**	**0.55**	**75.86**	**25.71**	**9.41**	**29.43**	**6.00**	**8.63**	**4.30**	**5.06**
3	Butt	95.77	0.58	73.29	32.41	9.67	27.82	4.54	8.20	4.35	4.89
	Mid	108.01	0.55	57.96	22.94	9.20	31.44	5.94	7.17	3.63	4.34
	Top	95.75	0.55	34.69	23.22	9.01	22.82	5.81	8.97	3.72	4.24
	Mean	**99.84**	**0.56**	**55.31**	**26.18**	**9.29**	**27.36**	**5.43**	**8.11**	**3.90**	**4.49**

Table 2.6 Strength properties of *Polyscias nodosa (*Blume*) Seemann*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (Mpa)	MOE (Gpa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (Mpa)	Hardness (kN)	
										Side	End
1-7	Mean of 7 trees	193.51	0.358	34.70	18.20	5.17	12.76	1.27	4.10	1.72	2.02

Table 2.3. Strength properties of *E. citriodora*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (MPa)	MOE (GPa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (MPa)	Hardness (kN)	
										Side	End
1	Butt	62.16	0.748	74.91	32.46	13.25	39.38	9.28	10.39	8	8.46
	Mid	58.89	0.770	87.38	47.57	14.47	49.14	6.15	9.46	9.6	7.59
	Top	54.20	0.800	93.52	49.37	13.59	45.89	7.74	8.25	9.93	8.97
	Mean	**58.42**	**0.773**	**85.27**	**43.13**	**13.77**	**44.85**	**7.72**	**9.37**	**9.18**	**8.34**
2	Butt	72.71	0.715	93.34	51.62	13.39	36.16	4.70	10.36	8.38	7.77
	Mid	66.88	0.713	84.94	20.26	12.26	37.91	5.52	7.54	6.99	7.18
	Top	56.45	0.790	94.35	51.45	12.50	49.68	6.07	11.16	6.87	7.94
	Mean	**65.35**	**0.739**	**90.88**	**41.11**	**12.73**	**41.25**	**5.43**	**9.69**	**7.41**	**7.63**
3	Butt	63.55	0.74	88.13	18.74	12.96	39.39	4.99	10.62	7.85	6.30
	Mid	61.63	0.73	104.37	34.91	13.96	51.29	4.28	7.79	7.90	8.14
	Top	59.76	0.75	85.66	48.63	13.00	24.85	2.98	10.40	7.74	7.88
	Mean	**61.65**	**0.74**	**92.72**	**34.09**	**13.31**	**38.51**	**4.08**	**9.60**	**7.83**	**7.41**

Table 2.4. Strength properties of *E. urophylla*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (MPa)	MOE (GPa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (MPa)	Hardness (kN)	
										Side	End
1	Butt	87.52	0.64	70.78	28.19	12.95	27.03	6.63	7.01	4.91	5.09
	Mid	74.73	0.67	85.30	24.86	14.26	40.27	6.22	7.71	6.83	7.02
	Top	72.32	0.68	73.34	28.45	12.53	30.20	6.42	8.92	6.35	7.15
	Mean	**78.19**	**0.66**	**76.47**	**27.17**	**13.25**	**32.50**	**6.42**	**7.88**	**6.03**	**6.42**
2	Butt	82.00	0.67	66.34	27.12	11.00	34.53	6.78	8.97	6.28	6.23
	Mid	71.74	0.71	83.21	30.55	11.24	41.91	7.01	9.37	6.37	6.05
	Top	59.42	0.76	86.73	36.95	10.94	44.42	11.7	10.17	7.98	7.68
	Mean	**71.05**	**0.71**	**78.76**	**31.54**	**11.06**	**40.29**	**8.50**	**9.50**	**6.88**	**6.65**
3	Butt	84.41	0.65	80.01	40.08	10.02	34.52	9,66	9.79	6.69	7.01
	Mid	73.76	0.67	62.09	31.75	8.64	31.06	6.06	9.79	6.13	6.20
	Top	65.92	0.71	93.32	45.85	14.46	42.77	8.57	12.54	7	7.09
	Mean	**74.70**	**0.67**	**78.47**	**39.23**	**11.04**	**36.12**	**8.10**	**10.71**	**6.61**	**6.77**

Table 2.5 Strength properties of *Alstonia macrophylla*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (MPa)	MOE (GPa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (MPa)	Hardness (kN)	
										Side	End
1	Butt	104.04	0.56	78.1	27.83	10.16	26.29	5.56	8.56	4.23	5.03
	Mid	104.58	0.55	75.0	17.30	9.93	29.09	5.88	9.58	4.03	5.07
	Top	107.42	0.54	73.74	21.24	10.14	25.87	5.98	8.64	3.68	4.97
	Mean	**105.35**	**0.55**	**75.61**	**22.12**	**10.08**	**27.08**	**5.81**	**8.93**	**3.98**	**5.02**
2	Butt	103.44	0.55	73.26	30.92	8.52	31.55	6.32	8.41	4.57	5.73
	Mid	102.61	0.55	79.55	18.07	8.88	26.76	6.64	9.50	4.54	4.90
	Top	103.96	0.55	74.78	28.15	10.82	29.98	5.05	7.99	3.79	4.54
	Mean	**103.34**	**0.55**	**75.86**	**25.71**	**9.41**	**29.43**	**6.00**	**8.63**	**4.30**	**5.06**
3	Butt	95.77	0.58	73.29	32.41	9.67	27.82	4.54	8.20	4.35	4.89
	Mid	108.01	0.55	57.96	22.94	9.20	31.44	5.94	7.17	3.63	4.34
	Top	95.75	0.55	34.69	23.22	9.01	22.82	5.81	8.97	3.72	4.24
	Mean	**99.84**	**0.56**	**55.31**	**26.18**	**9.29**	**27.36**	**5.43**	**8.11**	**3.90**	**4.49**

Table 2.6 Strength properties of *Polyscias nodosa (*Blume*) Seemann*

Tree No.	Height	Moisture Content (%)	Relative Density	MOR (MPa)	SPL (Mpa)	MOE (Gpa)	Compression // (MPa)	Compression ⊥ (MPa)	Shear (Mpa)	Hardness (kN)	
										Side	End
1-7	Mean of 7 trees	193.51	0.358	34.70	18.20	5.17	12.76	1.27	4.10	1.72	2.02