

Forest Resource Inventory Assessment in Gunung Rara Forest Reserve, Sabah, Using Stratified Field Sampling

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Abstract.—The objective of this paper is to assess the current timber volume by stratified sampling on a proposed plantation area. The study area is located in Gunung Rara Forest Reserve in the district of Tawau, Sabah, Malaysia. The size of the study area is 106,310 ha and consists mostly of logged-over forest lying in low areas (<240 m above sea level) with a slope of less than 15 degrees. However, a third of the area lies between 240 and 600 m above sea level and consists of rolling hills with slopes of 15 to 25 degrees. The survey was conducted by a limited field sampling undertaken in June 1997. Trees within 25 m on either side of a line were measured, plotted, and established in each of the five main forest stand types to obtain data for estimating timber stocking by species group and size classes. The position, species group, diameter classes, and crown width of all trees with diameters greater than 20 cm were recorded. A total of 13.75 ha of sample plots was established, representing about 0.01 percent of total study area. Trees were enumerated according to three broad species groups—Dipterocarps, non-Dipterocarp, and pioneer species—on one-tenth ha subsample plots (20 m along sample line by 25 m each side of sample line). Cross-comparisons were undertaken of the forest stand type areas and timber volumes from previous assessment. Data were then compiled for each of the 10 annual plantation working blocks. For each stand density, an average timber volume yield was estimated. The timber yield by species and diameter class was estimated based on the Stock Table Data from Sabah Forest Department Inventory 1995/96. The area proposed for plantation in each of the 10 annual working blocks was identified on the Forest Plan Map. Tables illustrating tree stocking by timber stand density class, tree stocking by species group, and tree stocking by tree size class were presented. An estimate of timber volume was calculated for each five diameter classes based on net recoverable tree volumes per tree. Based on a preliminary analysis and compilation of field data, the volumes of timber and pulpwood were about 120 and 40 m³/ha, respectively, of standing volume of commercial timber trees (> 40 cm diameter at breast height) and small diameter pulpwood (<40 cm diameter at breast height). Future studies will correlate the present field sampling data with hyperspectral imaging and integrate them into geographical information system spectral signatures of the main five forest density classes.

Benta Wawasan Sdn.Bhd., a wholly owned subsidiary of Innoprise Corporation¹, plans to establish an industrial forest plantation on approximately 106,310 ha of Yayasan Sabah's Forest Concession area². This project is an integral part of the Sabah Softwoods Sdn. Bhd. (SSSB)³ industrial tree plantation development program, which consists of a 60,000-ha forest plantation area⁴ (about half of which has been planted) plus the planned Benta Wawasan forest plantation area. The addition of the

¹ The holding company that manages Yayasan Sabah's (Sabah Foundation) commercial operations, including: Pacific Hardwoods, Silam Forest Products, and Sabah Softwoods.

² Sabah Foundation, a statutory state corporation, was established in 1966 to use commercial forestry revenue for the social benefit of Sabah residents. It has a 100-year concession on approximately 1 million ha of forest. The Benta Wawasan plantation represents about 10 percent of the total Yayasan Sabah concession area.

³ Sabah Softwoods Sdn Bhd (SSSB) was established in 1974, as a joint venture between Yayasan Sabah (60 percent) and North Borneo Timbers Bhd.(NTB) (40 percent).

⁴ In two blocks adjacent to the southeast boundary of the Benta Wawasan Forest Plantation Area.

Benta Wawasan plantation brings SSSB's total area targeted for industrial forest plantation development to 166,000 ha, making it Malaysia's largest commercial forest plantation.

Before the plantation program is implemented, there is a need to assess the growing stock and timber volume resources of the Benta Wawasan Concession area. The task of extensive forest inventory assessment reporting on tropical forest lands is not easy. The tropical forest is ecologically diverse, certain data are lacking, data types often are not well integrated, and past forest inventories do not allow for trend analysis (Kamaruzaman 1998). Kohl (1996) reported that a multiphase sampling design for tropical forests inventory has some major disadvantages that limit its application in forest surveys. In a study by De Gier and Sakouhi (1995) using a stratified random sampling procedure, a woody biomass inventory was successfully carried out in a forest area of Tunisia.

To address the need for information, a stratified field sampling design technique is used for estimating results for large forest areas and as ground truth data in airborne hyperspectral image processing for future extensive forest survey analysis. The overall objective of this forest inventory assessment is to review and verify previous estimates of the timber volumes on the proposed plantation area and to prepare a quantitative assessment of timber resources. The specific objective is to assist Benta

Wawasan's management in forecasting annual timber yield from plantation forest harvesting.

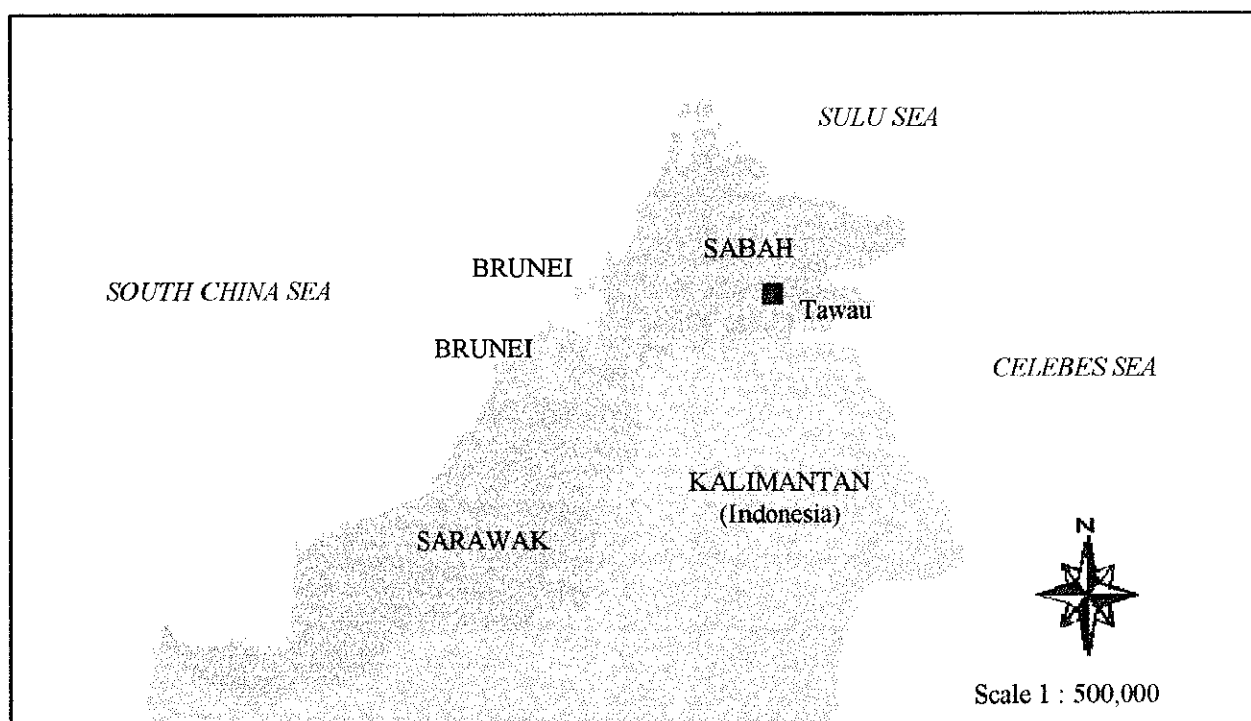
METHODS AND MATERIALS

Data from the previous forest resource assessment were reviewed and verified (or revised) using the following procedures :

- Limited field sampling was undertaken in June 1997. Linear sample plots were established in each of the five main forest stand types to collect tree data for use in developing estimates of timber stocking species groups and size classes.
- Cross-comparisons were undertaken of the forest stand type areas and timber volumes from previous forest resources assessments, with those of the current forest inventory assessment, to verify or revise timber stand area and volume estimates for the Benta Wawasan plantation area.
- Data from these confirmed or revised estimates were compiled for each of the 10 annual plantation working blocks.

Location and Description of Study Area

The project area, which consists of 106,310 ha of mostly logged-over forest is located about 40 km northwest of Tawau in the Kalabakan and Gunung Rara Forest Reserves in the district of Tawau, Sabah (fig. 1).



Study site (Kalabakan)

Figure 1.—A map of Malaysia showing the location of the study site.

Most of the project area (60 percent or 64,100 ha) consists of low elevation areas (<240 m above sea level) with relatively gentle topography (slope <15 degrees). A third of the project area (35,493 ha) lies between 240 m and 600 m above sea level and consists of rolling hills with slopes of 15 to 25 degrees. A relatively small portion of the project area (6 percent or 6,708 ha) lies at higher elevations, with generally hilly, broken topography and slope of >25 degrees.

The soils of the project area are predominantly mudstones, sandstones, and miscellaneous and igneous rocks of the Gumpal, Crocker, Malubok, Lokan., Kretam, and Bang Associations. These six soil types account for 88 percent of the soils in the project area. The geology of the eastern portion of the project area is dominated by chert-spilite-greywacke and limestone formation. In the west, the Tanjong Formation dominates with mudstone, siltstone, and sandstone materials.

The project area is divided into 10 annual working blocks that are further subdivided into 2,000- to 2,500-ha sub-blocks. This forest inventory assessment focuses on the quantification of forest resources on each of the 10 annual working blocks, as described in the following section.

Forest Inventory Data Sources

This forest inventory assessment is based on two previous forest resource assessments, supported by additional field sampling. The previous forest resource assessments include:

- Forest inventory of the Yayasan Sabah Concession conducted by Sabah Forest Department in 1995/96. This inventory included the Kalabakan, Gunung Rara Forest Reserve, which is part of the Benta Wawasan plantation area. This inventory involved extensive field sampling.
- Timber volume estimates from a detailed aerial survey of project area by C.H. Williams, Talhar, and Wong in 1996. No field samples were undertaken to confirm these estimates.

The 1995/96 Forest Inventory of the Yayasan Sabah Forest Concession included 430 "L" shaped inventory sample plots in the North Borneo Timbers (NBT) block, which is located within the Kalabakan/Gunung Rara Forest Reserve that encompasses the Benta Wawasan plantation area. A Stock Table for this block shows the timber volume per hectare by species group and tree size class. This Stock Table is used in estimating the species group and size classes of timber available from plantation land clearing on the Benta Wawasan plantation area.

Forest Area and Estimated Timber Yield

The project area was stratified into five timber stand (density) classes based on data from the previous forest resource assessments. For each stand density, an average timber volume yield was estimated as illustrated in table 1.

Table 1.—Area and Timber Volume by Forest Density Class

Stand density	Avg. timber yield <i>m³/ha</i>	Area <i>ha</i>	Approx. total timber yield <i>m³</i>
Very high	60	4,626	277,560
High	40	5,326	213,040
Medium	20	17,489	349,780
Low	10	23,763	237,630
Very low	5	55,106	275,530
Total area volume		106,310	1,353,540

Data source: 10-year working plan of Benta Wawasan plantation area.

Because most of the forest area has been logged, the average timber yield is relatively low (12.73 m³ per ha). According to these estimates, the commercial timber volume on each proposed plantation working block is 1.35 m³.

Species and Size Distribution of Timber Yield

The timber yield by species and diameter class was estimated based on the Stock Table data from the 1995/96 Sabah Forest Department Forest Inventory of the NBT block. The data are summarized in tables 2 and 3. The total volume of all trees greater than 20 cm diameter at breast height is 135 m³—66 percent in trees of commercial timber species and 50 percent in commercial trees with diameters greater than 40 m³.

Table 2.—Average timber volume (m^3/ha) by species group and diameter class.

Species	Percent of species group	Diameter(cm)>				Total
		20-39	40-49	50-59	60+	
<i>m³/ha</i>						
Red Seraya		9.4	3.1	3.5	10.8	26.8
White Seraya		3.5	1.1	1.6	6.9	13.1
Melapi		0.5	0.1	0.2	0.3	1.0
Yellow Seraya		0.6	0.1	0.2	0.8	1.7
Subtotal Light Hardwood	32	14.0	4.4	5.5	18.8	42.7
Kapur		2.1	0.6	0.9	2.8	6.4
Keruing		2.4	0.7	1.1	2.7	6.9
Subtotal Medium Hardwood	10	4.5	1.3	2.0	5.5	13.3
Selangan		1.0	0.3	0.4	0.5	2.2
Selangan Batu		0.8	0.2	0.5	2.0	3.5
Resak		0.6	0.1	0.1	0.3	1.1
Subtotal Heavy Hardwood	5	2.4	0.6	1.0	2.8	6.8
TOTAL DIPTEROCARP	47	20.9	6.3	8.5	27.1	62.8
Non-Dipterocarp Comm.	19	12.3	2.8	2.6	7.5	25.2
Other Species Non-Comm.	27	28.4	4.6	2.3	1.9	37.2
Pioneer Species	7	5.4	1.5	1.0	1.7	9.6
NON-DIPTEROCARPS	53	46.1	8.9	5.9	11.1	72.0
Subtotal Commercial	65	33.2	9.1	11.1	34.6	88.0
Subtotal Non-Commercial	35	33.8	6.1	3.3	3.6	46.8
Grand total	100	67.0	15.2	14.4	38.2	134.8
% Distribution by diameter class		50	11	11	28	100

Source: 1995/96 Sabah Forest Department Inventory-NBT Block Yayasan Sabah Concession (430 plots).
Sampling Error (95 percent) $\pm$ 12.74 m^3 .

Table 3.—Estimated gross and net recoverable timber and pulpwood volumes from the 1995/96 Sabah Forest Department Forest Inventory of North Borneo Timber (NBT) block of the Yayasan Sabah Forest Concession

Timber/Pulp size classes	Gross volume	Net recovery volume
Commercial Species > 40 cm dbh ¹	54.8	43.8
Comm. & Non-Comm. < 40 cm dbh ²	67.0	40.2
TOTAL	121.89	84.0

¹Timber vol. reduced by 20 percent to account for waste, decay, breakage, etc.

²Pulpwood vol. reduced by 40 percent to account for non-pulpable species, breakage, waste, etc.

Annual Harvest Area and Volume by Species and Size Classes

The area to be cleared and planted in each of the 10 annual working blocks is identified on the project plan maps. The estimated yield volume from each of these annual working blocks is summarized by species and size classes in table 4. It should be noted that areas classified as Virgin Jungle Reserve (VJR) are not included in these estimates.

Field Sampling Design

Continuous Linear Sample Plots

A series of linear sample plots was established as "training sites" to correlate data from field sampling with future remote sensing data of the training sites. The sample plots consisted of surveyed lines, along which trees within 25 m on either side of the line were measured and plotted. The position, species group, diameter class, and crown width of all trees with diameters greater than 20 cm were recorded.

Allocation of Field Samples by Timber Stand Type

The sample plots were allocated within four of the five timber stand classes. No field samples were established in the very low stand density class because there is no commercial timber in these stands. A total of 13.75 ha of sample plots was established, representing about 0.01 percent of the Benta Wawasan plantation area.

Field samples were allocated across a range of slope and elevation classes encountered on the project area. The length (m) and (ha) of sample plot, and the total area and estimated volume of each stand type were estimated.

Field Sampling Team Organization

Field sampling teams consisted of 2 to 3 people: a forester/crew leader, dendrologist, and a surveyor/mapper.

Field Sampling Productivity and Intensity

The daily productivity of the field sampling team was 350 m of 50-m-wide survey line (1.75 ha per day). During a 1-week survey period, 2,750 m (13.75 ha) of linear sample plot was established, representing 0.01 percent of the 106,000-ha project area.

Location of Sampling Units

The starting points of the linear sample plots were located at points along roads to reduce non-productive travel time to the sample areas, and to mark the start of each sample line clearly on the road, so that it can be located and referenced to the remote sensing survey flight lines. Subsample plots (1 per 10 ha) were established at intervals of approximately 100 m along the main sample line to measure smaller diameter trees (20 to 30 cm dbh), suitable for pulpwood. A total of 30 subplots was established.

Establishment of Field Sample Plots

A forest crew established and marked the start of linear sample plot line at a visible point along a logging road. A criterion for the establishment of this point was that it must be visible from the air so that it can be located and used as a point of reference for the airborne remote sensing flight lines of the field plots. The survey team located the center line of the sample plot line. Plot boundaries were established 255 m each of the sample

Table 4.—Field sample allocation by timber stand classes

Timber stand class	Estimated yield	Area	Estimated volume	Total extent of sample plots	
	m ³ /ha	ha	m ³	Length m	Area ha
Very high	60	4,626	277,560	850.00	4.25
High	40	5,326	213,040	950.00	4.75
Medium	20	17,489	349,780	600.00	3.00
Low	10	23,763	237,630	350.00	1.75
Very low	5	55,106	275,530	NA ¹	NA
Total		106,310	1,353,540	2,750.00	13.75

¹NA = No plots available.

line. Within this linear sample plot, the location, diameter, stem height, crown width, and species of all trees >30 cm dbh were measured and recorded. One-tenth hectare subsample plots were established at intervals of 50 m along the sample line to enumerate trees suitable for pulpwood (20 to 30 cm dbh).

Field Sample Measurement

a. For larger trees, including:

- Dominant and co-dominant trees whose crowns occupy the forest canopy.
- Trees in 30 to 40 cm; 40 to 50 cm, and >60 cm dbh classes.

The following parameters were measured and recorded for all trees within 25 m of the sample line:

- Tree species
- Tree position (in relation to the surveyed line)
- Diameter at breast height (cm)
- Commercial stem length (m)
- Crown width (m)

b. For smaller trees, including:

- Understory trees
- Sapling and pole sized trees suitable for pulpwood
- Trees in the 20-30 centimeter diameter at breast height class

The trees were enumerated according to three broad species groups—dipterocarps, non-dipterocarps, and pioneer species—on one-tenth hectare subsample plots (20 m along sample line by 25 m each side of sample line).

RESULTS AND DISCUSSION

Field Sampling (Ground Truthing)

Results of the field samples are summarized in the following paragraphs. Table 5 contains summary description of the field sample plots, trees per ha by species group and tree size classes, as well as preliminary estimates of timber and pulpwood volumes per ha.

Tree Stocking by Timber Stand Density Class

The number of trees per ha (>20 m dbh) ranges from 58.5 trees per ha in areas of low stand density to 92.6 trees per ha in areas of high stand density. No field samples were undertaken in areas of very low and very high stand density.

Tree Stocking by Species Group

The percentage of trees of commercial species differed considerably between stand density classes, ranging from 46 percent of the trees enumerated on Transect 2 (low stand density class) to 81 percent of the trees enumerated on Transect 4 (high stand density class).

On average, 81 trees (>20 cm dbh) of commercial trees species were enumerated per hectare, representing 65 percent of trees sampled, with 35 percent being trees of pioneer species.

In the commercial species group, trees of the botanical family Dipterocarpus predominated, representing 56 percent of the trees of commercial species. Tree of other, non-Dipterocarp species made up the remaining 44 percent of commercial tree species.

Tree Stocking by Tree Size Class

Trees of commercial timber size (> 40 cm dbh), represented 43 percent of the trees enumerated, while smaller trees (<40 cm dbh), suitable for pulpwood, accounted for 57 percent of the growing stock.

The field sample indicated a higher concentration of large trees in areas classified as having high and medium stand density. For example, Transect 4 (high stand density) has the highest concentration of large trees, with 30 trees >50 cm dbh per ha, compared to 20 large diameter trees per hectare in the medium density class (Transect 3) and 12 to 14 trees per ha in the low density class (Transect 1 and 2).

Estimates of the timber and pulpwood volume per hectare were compiled from the tree species and size information discussed above. It was assumed that only trees of commercial species and size (>40 cm dbh) trees could be included in the commercial tree volumes. Small diameter (<40 cm) trees of all species would be available for pulpwood. In the absence of tree volume data at the time this paper was prepared, a rough calculation of volume was made, based on the following assumed net recoverable tree volumes per tree for each of the five diameter classes :

- 20-30 cm dbh class - 1 m³ per tree
- 30-40 cm dbh class - 2 m³ per tree
- 40-50 cm dbh class - 3 m³ per tree
- 50-60 cm dbh class - 4 m³ per tree
- 60 cm + dbh class - 5 m³ per tree

Table 5.—Summary of results of 1997 field sampling Benta Wawasan forest plantation

Parameter measurement	Transect Number 1	Transect Number 2	Transect Number 3	Transect Number 4	Total or Average
DESCRIPTION OF FIELD SAMPLE PLOTS (TRANSECTS)					
Timber stand class (as per 10-year working plan)	Low (5 m ³ /ha)	Low (10 m ³ /ha)	Med (20 m ³ /ha)	High (40 m ³ /ha)	
<i>Note: Transect in low, med., and high stand density classes-not in very low and very high density classes</i>					
Length (m)	950.00	850.00	600.00	350.00	2,750.00
Area (ha)	4.75	4.25	3.00	1.75	13.75
Time required (days)	3	3	1	1	8
TREES PER HECTARE BY SPECIES GROUP					
Dipterocarps	22.7	17.9	34.3	42.3	29.3
Non Dipterocarp	10.1	20.5	29.7	32.6	23.2
Subtotal Commercial	32.8	38.4	64.0	74.9	52.5
Percent Commercial	56%	46%	74%	81%	65%
Pioneers(pulp spp.)	25.7	45.2	23.0	17.7	27.9
	44%	54%	26%	19%	35%
Total all species group	58.5	83.6	87.0	92.6	81.1
	100%	100%	100%	100%	100%
TREES PER TRANSECT BY TREE SIZE (dbh)CLASSES					
20-29 cm	43	72	32	29	176
30-39 cm	124	156	109	52	441
40-49 cm	44	77	58	29	208
50-59 cm	26	20	23	20	89
60+ cm	41	30	39	32	142
Total all sizes classes	278	355	261	162	1,056
TREES PER HECTARE BY TREE SIZE (dbh)CLASSES (trees/ha)					
20-29 cm	9.05	16.94	10.67	16.57	13.3
30-39 cm	26.11	36.71	36.33	29.71	32.2
40-49 cm	9.26	18.12	19.33	16.57	15.8
50-59 cm	5.47	4.71	7.67	11.43	7.3
60+ cm	8.63	7.06	13.00	18.29	11.7
Total all sizes classes	58.53	83.53	87.00	92.57	80.4
ESTIMATED NET RECOVERABLE COMMERCIAL VOLUME PER HA BY SIZE CLASSES (m ³ /ha)					
20-29 cm	5	10	6	10	8.0
30-39 cm	31	44	44	36	38.7
40-49 cm	12	20	34	32	24.7
50-59 cm	10	7	18	30	16.1
60+ cm	19	13	38	59	32.4
Total all species, all sizes	78	94	140	167	120
SUMMARY OF ESTIMATED YIELDS (m ³ /ha) (based on field sample results)					
Comm.Sp.and sizes >40 cm dbh	42	40	90	121	68
Pulpwood sizes <40 cm dbh	37	54	50	46	39

Commercial timber volume included only commercial (Dipterocarp and non-Dipterocarp) timber species. To reduce the gross volumes from the sample estimates to net recoverable timber volume, the volume estimates from the field sample were reduced by 20 percent to account for waste, decay, and breakage during logging and transport.

Pulpwood volumes included all species in the 20- to 40-cm dbh classes. The estimated gross volume from the field sample estimates were reduced by 40 percent to account for non-usable species, breakage, waste, decay, and other losses during harvesting.

Using these assumptions and the improvised, preliminary per tree volume estimates, the average volume of all species and all sizes of trees is estimated to be 120 m³ per ha, ranging from 78 m³ per ha in low stand density areas to 167 m³ per ha in high stand density areas (table 5).

This volume conforms to the gross volume of commercial timber trees (>40 cm dbh) and pulpwood (<40 cm dbh) indicated in the Sabah Forest Department's 1996/97 Forest Inventory of the NBT Block which indicated a gross volume of commercial timber and pulpwood of 121.8 m³ per ha (table 3).

The commercial timber volume (tree >40 cm dbh) is estimated to be 40 m³ per ha in the low stand density class (Transect 1 and 2), which accounts for most of the plantation area. Timber volume per hectare for the medium stand density area (Transect 3) is estimated to be 90 m³ per ha, and for the high stand density class (Transect 4), 10 m³ per ha. It should be noted that the area of high density stands is relatively small (table 5).

It is estimated that an average of 39 m³ of pulpwood can be recovered from trees of all species in the 20- to 40-cm dbh classes. The highest pulpwood volume occurs on Transect 2 (low stand density) where a large number of small diameter trees contribute to a pulpwood volume of 54 m³ per ha. On Transects 1, 2, and 4, pulpwood volume averages 40 m³ per ha.

CONCLUSIONS

- The stratified field sampling technique of inventory assessment confirmed that the timber volume on the Benta Wawasan plantation area is similar to that indicated by the 1995/96 Sabah Forest Department Forest Inventory of the North Borneo Timber (NBT) Block.
- Based on this preliminary analysis and compilation of data from the stratified field sampling, the volumes of timber and pulpwood on the Benta Wawasan plantation area appear to conform to the Stock Table from the 1995/96 Sabah Forest Department Inventory. Both

sources indicated about 120 m³ per ha of standing volume of commercial timber trees (>40 cm dbh) and small diameter pulpwood (< 40 cm dbh).

- The standing volume indicated by these sources is much higher than the volumes indicated in the 10-year working plan for the Benta Wawasan Forest Plantation Project, which range from 5 m³ per ha to 60 m³ per ha.
- On most of the areas (areas of low to medium timber stand density), the estimated net recoverable volume in large trees (>40 cm dbh) of commercial timber species is expected to average 40 m³ per ha. On limited areas, where timber stand densities are high, the volume could be as high as 100 m³ per ha. This confirms estimates based on the Sabah Forest Department Inventory, which indicated a net recoverable timber volume of 43.8 m³ per ha (tables 3 and 5). The estimated average net recoverable pulpwood volume is 39 m³ per ha. This confirms estimates based on the Sabah Forest Department Inventory data, which indicate a net recoverable pulpwood volume of 40.2 m³ per ha.

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