Sitti Latifah

Inventory and Quality Assessment of Tropical Rainforests in the Lore Lindu National Park (Sulawesi, Indonesia)

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Inventory and Quality Assessment of Tropical Rainforests in the Lore Lindu National Park (Sulawesi, Indonesia)

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Sitti Latifah

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1. Introduction

1.1 Forests and timber production in Indonesia

In 2002, forests covered approximately 109.96 million hectare in Indonesia. This is about 57.22% of the total land area of 192.16 million ha. This forest area is classified according to its function as production, limited production, protection, conservation, and conversion forest. The area and the typical use of these various classes is given in Table 1.

Table 1.

Forest area in Indonesia

Forest classification	Area		Type of use
	Million Ha	%	
Production forest	27.82	25.3	Timber and non-timber production
Limited production forest	16.22	14.8	Low-intensity timber and non-timber production
Protection forest	29.04	26.4	To serve environmental functions
Conservation forest	23.21	21.1	Wildlife and habitat protection
Conversion forest	13.67	12.4	Clearance, permanent conversion to another form of land use
Total	109.96	100.0	-

Source : Ministry of Forestry (2003)

With the allocation of more than 50% of the area for production, Indonesia became a significant producer of tropical hardwood logs and lumber, plywood and other boards, and pulp. The forest is presently still one of the most valuable resources in Indonesia. Prior to the economic crisis, resource-related exports from the natural forests were an engine of economic growth. Forest-based exports (plywood, furniture, and pulp) rose from around 200 million US dollars in the early 1980s to more than 9 billion USD per annum in the mid-1990s. In 1997, just before to the economical crisis, the total output from forest-related activities was about 20 billion dollars or 10% of GDP (Gross Domestic Product). Royalties and other government revenues from forest operations exceeded 1.1 billion dollars per annum (WORLD BANK, 2001).

Timber is still the dominant forest product in Indonesia, and its utilization is the basis of many industries. Forest Watch Indonesia (FWI, 2002) stated that timber products are a major source of national revenue. In 1997, the forestry and wood processing sectors accounted for 3.9 % of the GDP, and exports of plywood, pulp and paper were valued at 5.5 billion USD.

This amount was nearly half the value of oil and gas exports, and represented nearly 10% of total export earnings.

The Ministry of Forestry (2002) stated that before 2000 annual timber production from natural and plantation forest was approximately 25.40 million m^3. By 1998, the government received 7.52 million USD in revenues from the primary forest commodity export alone.

These data illustrate the magnitude of the area and how valuable the forestry sector is for Indonesia. Conditions have changed rapidly since the economic crisis in 1998. Although the area, as well as the production of forest products sank during the past five years, forest products are still important for Indonesia. Production sank from about 25.317 million m^3 in 1995 to 17.2 million m^3 in 2000. Details of timber production from 1996 to 2000 are given in Table 2.

Table 2.

Timber supply from all legal sources

Source of production	**Production (1000 m^3)**				
	1996	**1997**	**1998**	**1999**	**2000**
Production forest	15,596	16,224	11,867	8,599	7,661
Conversion forest	7,232	9,525	7,249	6,239	4,644
Community forest	603	1,214	719	957	232
State-controlled timber plantation in Java	1,912	1,604	1.718	1,890	898
Industrial plantations	474	426	480	44,844	3,779
Total	25,817	28,992	22.035	22,531	17,214

Source: Ministry of Forestry, March 2001 quoted by FWI (2002)

Timber from the forest may be regarded as the final stage in the development of a living tree and it should be utilized wisely. There are several problems related to the planning of timber utilization in Indonesia. BUDIAMAN (2002) stated that timber utilization in Indonesia is, for the most part, poorly planned without consideration for the soil and the remaining stand, and also for economical and ecological sustainability. In addition, the use of the timber is usually limited to the best part of the trees. More than one third of the felled trees remain in the forest, although in Indonesia the raw material of the wood exists abundantly. Furthermore, due to the concession system implemented in Indonesia, an area of 11.7 million hectares has already been degraded.

This condition has been strengthened by the information from the Indonesian forestry ministry (2002) that there was a difference between legally wood supply and demand of around 32.84 million m^3. This number comes from the report that the annual legally felled wood supply is 25.25 million m^3, but the need of the industry sector is 58.24 million m^3. The WORLD BANK (2001) reported that in 1998 there was a shortfall of 57.7 million m^3 between the legally supply and demand of timber. The difference was fulfilled by the illegal cutting, not only from production forest but also from protected areas, national park area and other reserve conservation areas. This situation illustrates the poor planning of the utilization of forest products, especially the timber or wood.

Commitments have been made by the Indonesian government to correct the poor condition of the forests. Some of these are directly connected with forest inventory activities and the utilization planning of forest products, especially timber, namely:

- Promote forest resource valuation as the basis of national forest program formulation
- downsizing and restructuring the wood-based industry to reconcile demand with the supply of raw materials, and raise the competitive capacity
- recalculating the true value of timber (FWI, 2000; WORLD BANK, 2001 and Ministry of Forestry, 2002).

Forest inventory activities in Indonesia are basically aimed at exploring and collecting the complete data and information on the actual forest resource, the natural forest resource potential and the environment. This was done through survey methods related to the status and the forest physical condition, the flora and the fauna, human resources, and social conditions within the community inside and around the forest. The results of these forest inventory activities would then be used as the basis of forest reserve establishment, the arrangement of a forest resource balance, forest planning and a forest information system (Indonesian Forestry Act No. 41, 1999).

Based on the ‘Indonesian Selective Cutting and Replanting’ system, a forest is conducted inventory in production forests before and after cutting activities. The inventory before cutting is performed to collect information on the number, species, diameter and merchantable volume of the tree which will be cut, or protected and left as nucleus trees (diameter 20-49 cm with 25 trees per ha) and the condition of these nucleus tree (health stem and crown). The

objective for the inventory after cutting was different and recorded the dimensions and general condition (e.g. crown defect) of the remaining trees.

Unfortunately, the forest inventory activities that should be the key for successful forest management is becoming only a mere information provider. For example, the information gained from this inventory comprises only a number of trees, basal area and volume per hectare after diameter class and species groups. There is no further information related to the actual condition of the stand that would make it easier for the users to make decisions. Until now, the estimation of the stand value is based solely on volume and species groups. The stand potency information cannot be connected with the estimation of utilization planning, because there is no information pertaining to stand quality. This estimation can be misleading, because it cannot show the true condition of the stand value. It is not realized that information on the more or less valuable stand can be gained by such a quality assessment.

Some studies (see Table 3) have shown that there was only little difference between the utilized and the discarded portions. This result shows, that the standing trees have a potential value that is much higher than the value of the portion actually utilized.

Table 3.

Some research related with the utilization grade in some South East Asian countries

Source	Number of Sample felled trees	Utilized portion (%)	Discarded portion (%)
1. ATTC, Malaysia	-	54.0	46.0
2. Sarawak Hill Forest	-	56.8	43.2
3. Ullu Besut Forest, Malaysia	49	65.9	34.1
4. Pelagat Forest Reserve, Malaysia	73	56.4	43.6
5. ITTO	100	53.5	46.5
6. Nusa Tenggara Barat, Indonesia	50	51.9	48.1
7. Jambi, Indonesia	52	60.5	39.5
Average	-	57.0	43.0

Source: BUDIAMAN (2002)

LOETSCH (1973) stated, that particularly in tropical ‘virgin’ forests, there is a predominate proportion of trees affected either by external defects, internal decay or both. Such defects, according to degree of severity, diminish the merchantable volume, influence the utilization potential and accordingly also the value. The ratio between the gross volume (between stump and crown point) as assessed by an inventory and the net volume obtained after logging, may

vary between 10:8 and 10:3. It is evident that an inventory result consisting merely of the gross volume is nearly useless for the planning of logging operations in many forest areas. Hence, adequate assessment procedures for determining the timber quality in the widest sense are a necessity.

Even in intensively managed forest, it is seldom that any stand is exclusively stocked with sound, defect-free timber. In tropical 'virgin' forest in particular, the proportion of trees with defects is preponderant. The type of defect affects the merchantable volume and the value of the tree. In tropical forest, the relationship between the gross and the net volume can be as great as 10:8. Consequently, many inventories require a quantification of timber quality (KÖHL, 1993).

The information on tree quality is of great importance for calculating the value of a stand and giving assortment structure information. The results also have considerable meaning for forest resource management, especially for the optimal utilization of wood as a major utilisable forest and forests product, which are always influenced by market conditions.

1.2 Objectives of the study

This study was conducted within the German-Indonesian research project of "Stability Rain Forest Margin" (STORMA) under the Z-1 program (Theme: 'Monitoring von Zustand und Veränderung der Wald- und Landschaftsmonitoring').

The main objective of this study was to investigate the possibility of implementing the quality assessment concept in the forest inventory activity for standing trees in Indonesian natural forests. In addition, other objectives of this study are:

1. to provide alternative information, namely quality information of standing trees. This information is very useful for estimating the real tree value. The information gained by an inventory activity would thus be more detailed and could be used to estimate the stand value,
2. to implement and establish quality measurements methods for trees, which could be applicable for standing tree in the tropical natural forest,
3. to establish the quality key that could be used in the tropical natural forest.

2. State of the Art

Knowledge of forest stand quality and value development is very important for forest-structural and economic planning. The success or failure of the management depends on a regular collection of the data and an assessment of the value in a forest stand (AKÇA & KRAMER, 1985). Furthermore, WIEGARD (1998) states that the value of forest stand is not only the basis but also the prerequisite for making decisions in forest management. But the assessment of stand value is quite difficult and the results uncertain since the inner parts of the trees cannot be assessed directly.

2.1 Definition of tree quality assessment

Each tree or part of a tree has, in addition to its dimensions, other characteristics such as shape, aspect, defects and decay, which make its wood more or less useful and valuable for a given purpose. The classification, quotation or quantification of these characteristics, as well as recording and processing the corresponding data, which constitute quality assessment, are thus necessary to provide the users of the inventory results with more meaningful and detailed information (FAO, 1981).

2.2 Objectives of tree quality assessment

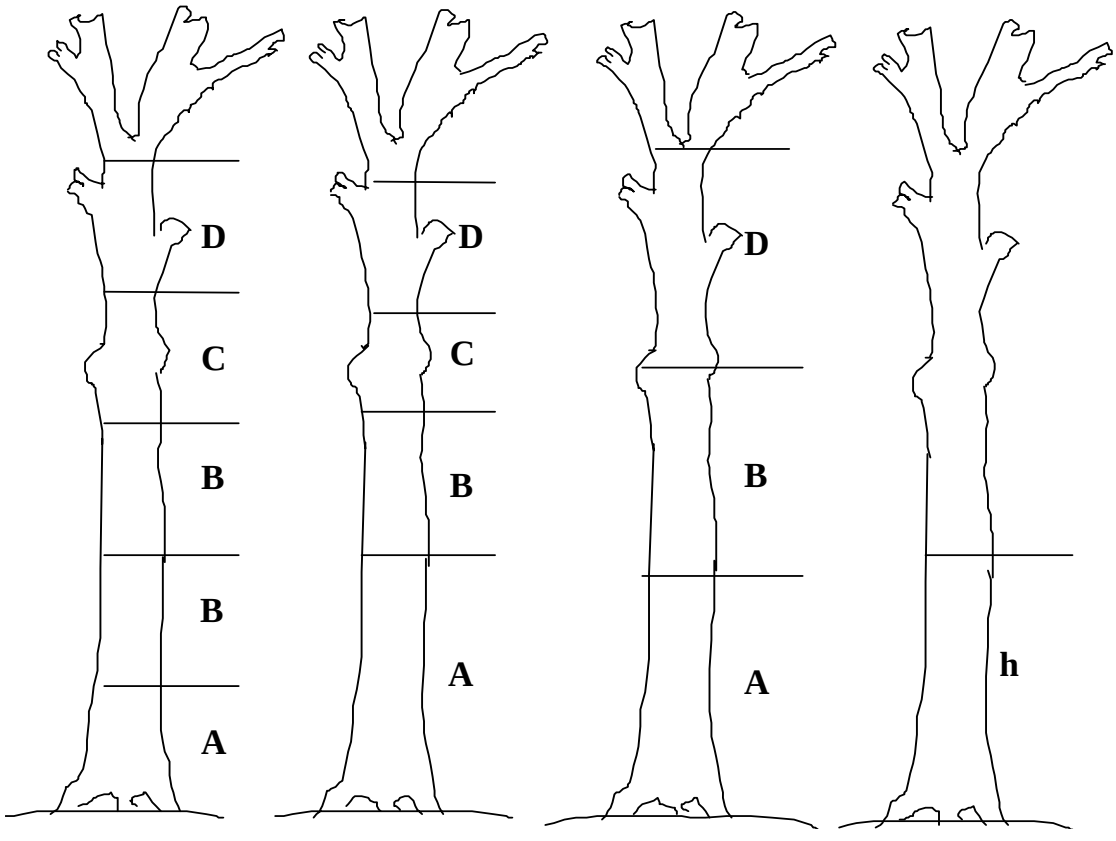
LOETSCH (1973) states that there are two main objectives of quality assessment of standing trees, namely:

a. Many concepts of intensive forest management have the goal of producing the highest possible volume of quality timber. Hence, the continuous control of success or failure of silvicultural measures through periodic inventories must include the qualitative structure of the growing stock in order to further this goal.
b. To collect reliable data on the utilization potential or the value. Particularly in forest areas designated for logging in the near future, it is important to obtain decision aids through information on the grade distribution, permitting an analysis of the profitability of intended investments. Where timber is sold on the stump, such data form the basis for the computation of the selling value.

2.3 Tree quality assessment methods

According to FAO (1981), there are two basic approaches that may be adopted for the assessment of external characteristics and defects on standing as well as felled trees, namely *the section concept* and *the tree concept*. *The section concept* means that the stem is divided into a number of sections, which can be of *absolute, relative* or *variable length* and each section are assessed. Another concept is *the tree concept*, which means the stem is classified according to a series of selected quality or defect classes.

According to WIEGARD (1998), the various methods of quality assessment can be divided into four groups, namely *the butt log method, the short-lengths method, the fixed-lengths method* and *the relative lengths method*. These methods are essentially the same as the section and tree concepts of FAO, and the terms will be used in this chapter.



Absolute section method (Fixed-lengths method) | Variable section method (Short-lengths method) | Relative section method (Relative-lengths method) | Tree concept method (Butt-log method)

Figure 1.

Schematic representation of quality assessment methods

2.31 The fixed-lengths method

The fixed-length method divides the standing tree into a remains constant stem length according to chosen specifications and depending on local requirements. A standard log section length of 5 m (± 16 feet) is often used. The gross volume of each section is assessed either by means of a taper function or on the basis of a percentage of the gross volume of the total derived from the sample trees used for the formulation of the volume equation, or possibly by measuring the diameter at the midpoint of the section.

2.32 The short-lengths method

This method divides a standing tree according to the location of significant defects, the purpose being to define logs deemed usable excluding the defective portions. The boundaries of each section are determined by visual experienced judgment. Volumes are calculated from the lengths of the sections using a taper function. If these functions are not available, one can measure end- or mid-diameters of the section. This method is accurate and practical for quality studies based on the measurements of felled trees. This short-length method could be found in BRABÄNDER value method (1957).

The value method of BRABÄNDER is based on collecting all assortments, quality and strength classes of a stand as exactly as possible by representative sampling. For this purpose, BRABÄNDER used the true stem form to create tables and graphs (structure-volume nomogram) representing the stem volume structure of all species as a function of their true stem factor ($\lambda_{0.9}$ after HOHENADL). This volume nomogram (greatly simplified for practical use) allows one to determine the volume percentage of each stem section in a simple manner at any stem height. Volume percentage computations can be also performed within a group of stems using the middle form. The deviations of the individual trunks even each other out. BRABÄNDER suggests determining the proportion of the individual assortments and grades in a representative trunk (mass central trunk). By using computer forecasting, one can obtain the sort- and grade allocation of the stand.

For value control the assortment of a tree and/or a stand is divided into a more valuable and a less valuable assortment group (e.g. log and laminated wood). The average price weighted by their individual portions is first determined for both groups. Dividing the solid cubic meter

price of the more valuable group by that of the less valuable assortment gives what is known as the "value proportionally factor". The higher the value proportionally factor, the larger is the percentage of the value of each part.

Subjective errors of the grades are possible here as well, and the procedure was not introduced into practice, since it is relatively complicated and complex.

2.33 The relative-lengths method

The relative-lengths method divides a standing tree from top to bottom into a pre-defined number of sections. The number of the sections remains constant for all trees, while the length of the section varies according to the length of the stem and is thus relative to the total length. By increasing the number of sections, quality assessment using this method becomes correspondingly more detailed and time consuming, and also less reliable as the allocation of defects to the appropriate sections become more difficult. The gross volume of each section is estimated by a taper function or from the data of sample trees used for the volume equation or by direct measurement of length and mid-diameter of each section. An example of this method is the quality method found in SPIEDEL (1955, 1957) and the method elaborated by the Centre Technique Forestier Tropical (C.T.F.T), Nogent-sur-Marne, France (LOETSCH, 1973).

The quality method of SPIEDEL is meant to record the largest possible portion of the stock according to mass and value when performing a quality assessment. For reasons of comparison, this portion should remain relatively constant. Quality classes serve as measures of tree quality.

The contribution of each quality class determines the value of a stand. The value class is estimated for young stands, with the expected future value being the decisive factor. For older stands the wood quality is determined at the time of measurement. Individual sample trunks are assessed with respect to their quality in a number of stands representatives for the type of stand in question. The size of the sample depends on the tree species and the stand quality.

Using a ranging pole (e.g. a walking stick or Kramer's dendrometer), the sample trees are optically divided into four approximately same length parts. The lower three sections are assigned to individual grades A, B, or C and/or to laminated wood (S). The proportional portions of the different grades (rounded to tenths) are multiplied by the value factors of the individual grades (A=1; B=3; C=4; S=5). This method is simple, and a large part of the volume (75%) can be assessed for quality.

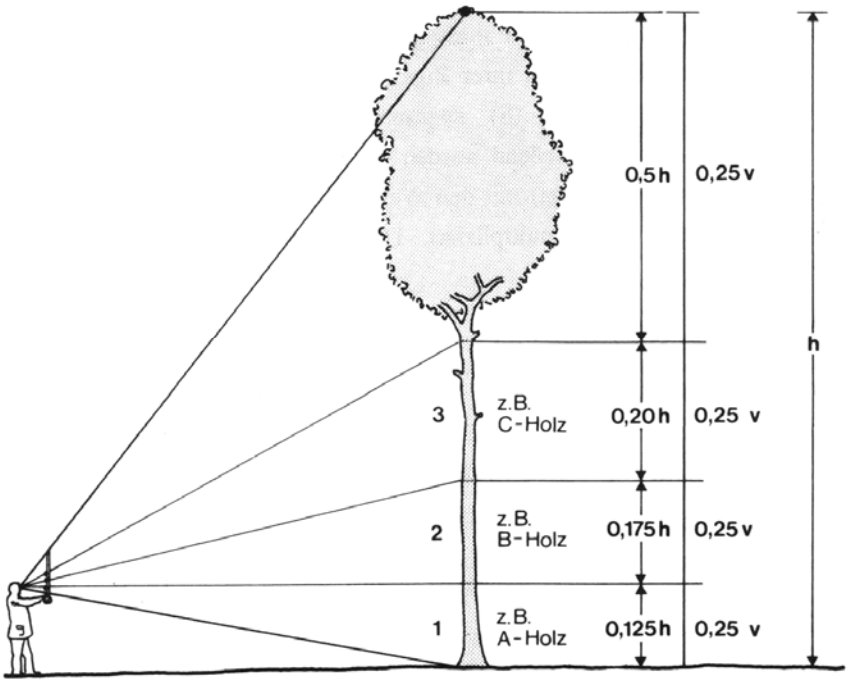


Figure 2.
Schematic diagram of quality assessment with the relative length method using walking stick

Some disadvantages of this method are that this mass division does not always correspond to the subordinated length division, and the accuracy of the quality assessment of the individual trunks remains unconsidered. Among the disadvantages of this method are the subjective character of the assessment, and the difficulty in making valid statements about the value supply of the stand from a few random samples (WIEGARD, 1998).

The method elaborated at C.T.F.T and published by LANLY (1969) and LANLY and LEPITRE (1970) in LOETSCH (1973) was developed for the tropical forests of West Africa. This method has two distinct phases. During a normal survey of species distribution, tree diameter and merchantable bole length, quality assessments are carried out on individual trees. The quality assessment of the first phase shows the following typical features: A tariff

with a single entry (d or $d^2\pi$) is used for volume determination. The merchantable bole is subdivided into three equal lengths which are assessed separately. For each third of the bole three quality categories are assessed, each with marks ranging from 1 to 5. These categories are shape, decay indication and aspect. To obtain the inventory grade for each third, the allowable combinations of the marks in the three categories is used. The second phase, referred to as "readjustment" by LANLY, is for converting inventory grades into commercial grades.

2.34 The butt-log method

This method uses the quality of only a specified lower portion of the tree to classify the whole tree. The specified length of this chosen portion does not usually exceed 6 to 8 m. Usually, only one specified length is used for each inventory, although, in some instances, it may be necessary to specify different lengths according to species. In buttressed trees the specified length is applied to the trunk above the buttress. The volume is presented as the total volume of the trees. In general, the lower portion of the trunk contains the greater part of the total volume and is that part of the trees with the greatest potential value. The advantages of this method compared with the section method are:

- the quality class specification can be determined more easily on the lower portion of the trees,
- the opportunities for subjective bias are reduced,
- the results of the quality assessment studies can also presented in the form of stand tables,
- the volume estimation is simpler.

The value method of Von Arnswaldt

VON ARSNWALDT (1950), cited in KRAMER and AKÇA (1985), used the lower six meters for beech stands (4 meters for oak stands) with three quality classes. The trees were marked, separated into A, B, C quality classes and diameter classes (d < 38 cm, 38 – 62 cm, > 62 cm), measured by calliper equipment and the basal area was estimated. WIEGARD (1998) states that this method is economically advantageous and this value assessment

method can be realised at relatively small cost. However, the information is limited, because only the butt-log data is used.

In SCHROEDER, et al (1968), cited by PRESTEMON, J.P and J BUGIONORNO (2000), southern pine tree grades were classified from A (best quality), over B to C (worst) or numerically recorded as 1, 2 or 3. Tree grades were based on the characteristics of the first 4.9 meters of the log. For these species, the higher the number of clear faces in the first 4.9 meters, the better the tree quality, with deductions for dead and overgrown knots, and other kind of biological or mechanical damage, sweep and crook.

WIEGARD (1998) developed five variations of the butt-log method. These are *the simple butt log method*, which is suitable for the inventory of young stands, in which the primary interest is focused on quality in general, *the differentiated butt log method,* which is appropriate for an inventory of more mature stands of lesser quality, *the simple, expanded butt log method,* which would be the proper choice if a cost-effective inventory of as many mass assortments as possible is to be conducted, for example, in a middle-aged pine stand, *the expanded*, *differentiated butt log method*, which provides an option to the second and third variation and *the expanded, differentiated butt log method with a subdivided upper butt-cut*, which is justified for valuable stands that have already attained or nearly attained harvesting age, and for target inventories of valuable tree species. Those various methods were implemented on mixed oak-beech stands, pure beech stands, mixed beech-ash stands and pure pine stands.

2.4 Tree quality assessment in Indonesian plantation forests

The quality assessment on teak plantations in Indonesia had been developed long before the natural rain forest in Indonesia started being exploited commercially. LOETSCH (1960), cited in LOETSCH (1973), instituted the quality assessment method for teak trees in Indonesia. A method was used that is similar to the fixed-length method. Trees were objectively subdivided into 4 metre long sections using a hypsometer and based on the "Christen" principle. Two quality classes - export timber and residuals - were used in this method. The specifications for export timber were taken from the Indonesian standard grading rules for teak round, with the only difference being that the minimum log length was

increased to 2 m. The admissible form defects (twist, flutes, shape and buttress) and surface defects (knots and branches, bee and bird holes) were compiled for the appraiser in concise instructions. The definition of this method is relatively simple and an allocation to classes directly in the forest is acceptable. This method of estimating the proportion of quality timber, based on the principle of the mean tree tariff is suited for even-aged stands and assumes that no correlation exists between diameter and tariff class. The result showed that this method was only 3.6% above the results of grading by a very experienced Indonesian grading officer.

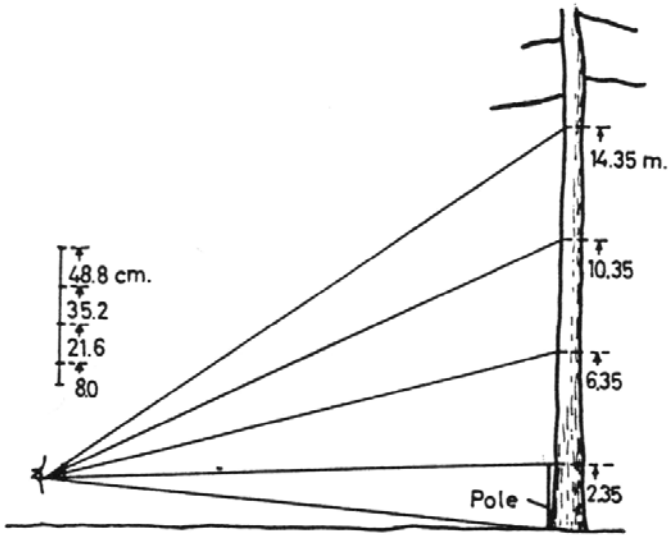


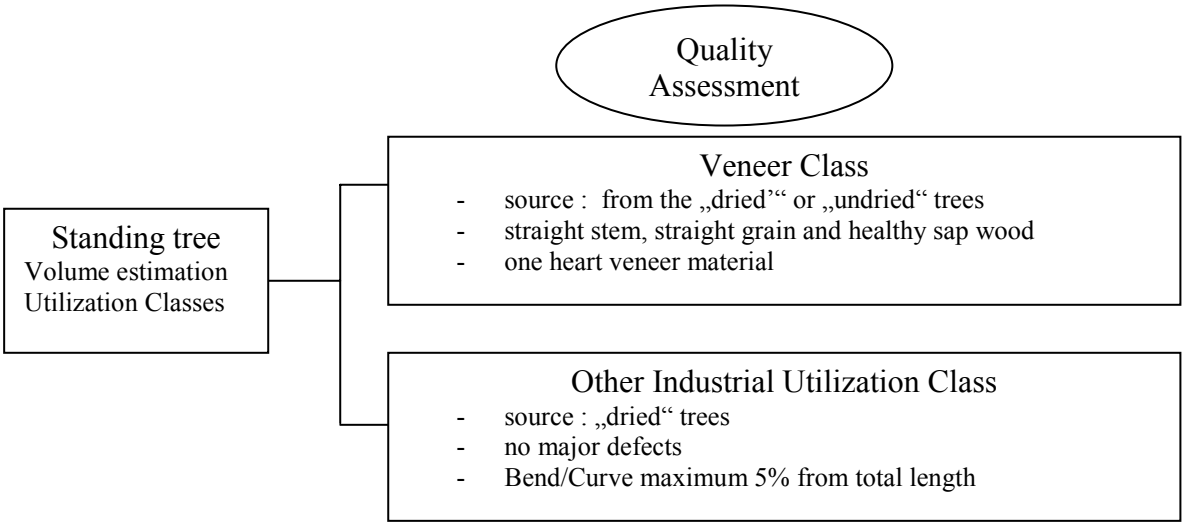
Figure 3.
Schematic the quality assessment on Indonesian teak plantation

The quality assessment method for teak standing trees has been used until the present. It seems that a combination of the tree and the section concept is used. The method, which has two phases, is made as simple as possible for standing trees in order to avoid measurement bias and the loss of time. The first phase is done for standing trees. The activity aims to estimate the potential usable tree, which includes the volume estimation and quality class assessment (veneer class and other industrial utilization class).

The second phase is well known as a stem management system performed on felled trees. With this system, a felled tree is assessed from the base to the top to arrive at a decision on utilization before beginning cutting activity. The stem is divided into a number of logs with different lengths and its utilization is determined. The system intends to get an additional

value from the teak wood, so that it has a higher value and is more valuable on the market. (PERHUTANI, 1993).

First Phase



Second Phase

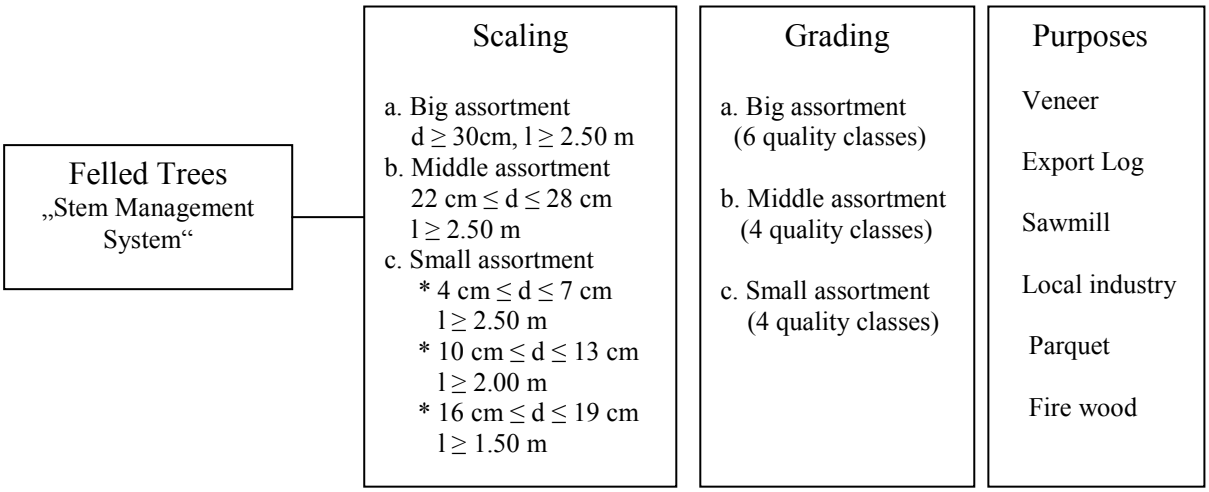


Figure 4.

Quality assessment activity on Indonesian teak plantation

The guidelines for quality assessment of standing trees remains unchanged for a number of years, but the regulations for felled trees changes almost every year depending on the market situation. Based on Indonesian National Standard (SNI 01-5007.1-2003) the big assortment

can be qualified as Prime, First, Second, Third, Fourth and Fifth grades. The first until fourth grades are used for middle and small assortments.

2.5 Tree quality assessment in Indonesian natural forests

Until the present, standing trees in Indonesian natural forests have not been usually subjected to quality assessment. The former usual method was to assess the trees after cutting and scaling activities; a method implemented for reasons of practicality. But the disadvantages of the system were the lack of information about the actual condition of standing trees. Therefore, the true value of the standing trees could not be estimated.

Some studies have tried to implement quality assessment as part of the inventory activity. The results show that the information gained was very valuable for estimating the true stand value.

VIRGIANTI (1993) and IRAWANSYAH (1993) tried to conduct tree quality assessments in South Sumatra-Indonesia by for Red Meranti (Shorea spec.) and Ramin (Gonystylus spec.), respectively, in order to estimate the standing tree value. The measurements were done on the standing trees. Quality assessment was performed using the variable-length method, which means that the standing trees were divided into section with variable length. The criteria for external defects were the defects which commonly occurred and were possible to estimate in the field, namely sound and unsound knots, branches, buttresses, hollowed, sweep, crook and decay. Three classes, A, B and C, were used. The results showed that increasing diameter at breast height DBH raises the value of the tree, but the value increase tends to be small and resembles to the optimal tree value at DBH $\geq$ 60 cm. The tree value of those species was influenced by the quality data and the best possible utilization.

HIDAYAT (1996) conducted research on quality assessment to estimate the value of Meranti Merah Lempung (Shorea parvifolia Dyer.) based on the volume distribution approach in East Kalimantan. The variable section method with lengths between 0.70 m and 4.0 m was employed in this research. External defects, such as sound and unsound knots (number, length and width), sweep (deviation) and branches (number); were determined on the felled trees. The trees were again divided into three classes (A, B, C). Assignment to a quality class was based on the quality data per section and the percentage of the dominant quality class per

section with reference to the raw material industry and the quality standard of Indonesian hardwood logs. The results showed that the value per stem and per volume unit for trees of class A was higher than that of class B or C trees. This is because class A trees have larger diameter trunks of good quality, and are thus more valuable.

Another study on using quality assessment to predict the value of Meranti trees (Shorea spec.) was also conducted by LATIFAH (1999) in Jambi. The fixed length method with 2 m section lengths was employed. Two hundred and twenty-five standing trees and 90 logs, which were derived from those standing trees, were measured. The external defect measurement for standing trees was simpler than for logs. Sweep and crook, sound and unsound knots, branches and buttress were measured on standing trees, whereas some internal defects (holes and decay), and the size of knots and distance between them were added for logs. The result showed that the standing tree value was higher than that for felled trees. The estimation of standing tree value was 27.4% higher than that for felled trees. This result is very important, because it can be shown that if value prediction is based on felled trees, the value only reaches 78.5% of the true standing tree value.

2.6 Logs grading system development

The development of log grading systems in Indonesia was preceded by the regulation from Indonesian Forestry Directorate No. 2443/A-2/DD/70 and changed into No. 97/Kpts/Dj/I/75 about the Indonesian grading rules for hardwood logs. These grading rules were based on the value of visible defects as related to the percentage of the sound volume of the logs, taking into account general as well as specific requirements of lumber or other products produced from them. The Indonesian hardwood logs were classified into five grades: Prime grade, which was graded on the extent visible defects only, Second, Third and Local grades, which were graded on the percentage of sound volume, and First quality, which was graded on the extent of visible defects as a percentage of sound volume. Only logs with a diameter over 60 cm were considered for the Prime and First grades, and a minimum diameter of 50 cm was required for the Second and Third grades used in this system. The system, which was intended for all logs produced in Indonesia, had the disadvantage that only large diameter logs had the opportunity of receiving a good grade. The consequence of this meant that only the best parts of the trees were for industry, and the smaller parts were left in the forest due to their lower grade and price. This system was used until the middle of the 1980s.

A significant change in the Indonesian grading system began in the mid 1980s, and a significant development has continued until now. Each rule is now legitimised as a National Indonesian Standard (SNI) by the national standardization agency. Among the first of these were SNI 01-0188-1987 and SNI 01-0189-1987 regulating the grading of softwood and hardwood logs produced in Indonesia. Since then many rules have been defined for various species, such as log grading rules for the Mahoni groups (*Swietenia machrophylla* King. and *Swietenia mahagoni* Jaqc. 2001), one hundred hardwood logs species produced in Java (2000), the Merbau and Perupuk groups (2000), Agathis (*Agathis* spec), Rasamala (*Altingia exelca*, Tusam (*Pinus merkusii* Jungh. et de Vr), Sonokeling (*Dalbergia latifolia* Roxb.) and Sonokembang (*Pterocarpus indicus* Wild), Sengon (*Paraserianthes falcataria* L. Nielsen) and Jabon (*Anthocephalus chinensis* Lamk A. Rich. Syn *Anthocephalus cadamba* Mig.) (2001) and Teak (2003).

Based on the latest general grading rules for hardwood logs (SNI 01-5007.3-2000) the log quality is divided into four grades: First, Second, Third and Fourth grades. Diameter limitations are not used in this system, but are used to differentiate the assortment class, which are "big" (log diameter 30 cm and over), "medium" (between 20 and 29 cm) and "small" (log diameter less than 20 cm). The grade classification is based on the assortment length, shape and surface defect, and also butt defect. The advantage of this system is that each log has the same opportunity to be assigned a high grade. This is very important because not only the large diameter part of the tree will be used by industry but also the smaller diameter parts also will have a good chance of being used. Therefore, the ratio between usable and non-usable parts can be reduced.

2.7 Tree quality assessment in some other countries

Most of the research in other countries, especially from temperate area in Europe and America, assessed the quality of standing trees and studied the relationship to timber grades, the products and their value. Some of the reasons why quality assessment is more highly developed in these countries than in tropical countries are:

- there is a long history of forest management and sustainable forestry began in European countries, especially in German, nearly 400 years ago,
- there are fewer species of commercial interest compared to tropical countries which have very high species diversity,

- timber comes mainly from management areas, so that complete historical information regarding age, site, dimension and specific characteristics are available,
- the measurement methods and grading rules are well developed,
- sophisticated equipment is provided,
- a good policy is followed, and accurate market information is provided to each stakeholder.

WIEGARD (1998) investigated the development of flexible quality assessment of forest stands of oak, beech, ash and pine. The variations of the butt-log method were developed, and faults in the round wood were recorded according to a tree-species criteria key. The quality class assignment is based on the respective, specific user requirements or on individual, customer-oriented requirements. SCHORETER (2000) improved this approach and conducted a study whose main aim was to develop a method of quality rating for standing oak trees, taking special customer preference into consideration. The butt log quality grading method was improved featuring quantitative and qualitative recording of properties in accordance with costumer preferences (taken from the survey). SCHUMANN (2001) conducted quality assessment with the butt-log method in beech stands.

PRESTEMON, J.P. and J. BUONGIORNO (2000) developed an ordered-probit model to predict tree grades from tree- and stand-level variables and applied it in natural uneven-aged southern pine stands. The model showed that the grade of pine trees was highly correlated with tree diameter, tree height, and stand basal area, in a non-linear fashion. In addition, a tree was more likely to be of high quality if it grew in industry or government forestlands, on poorer sites, or in stands that had been partially cut in the past. The effects of changes in the variables on the unit value of recovered lumber were small. The exceptions were tree diameter and height, which were the most important indicators of lumber value.

GOBAKKEN (2000) developed the models for assessing timber grades distribution and economic value of standing birch trees. It is stated, that Grade = f (DBH, H_t, H_{dry}, H_{living}, H_{crown}, Price relation), where DBH is diameter at the breast height (cm), H_t = tree height (m), H_{dry} = height to the first visible dry branch along the stem (m), H_{living} = height to the first visible living branch along the stem (m), H_{crown} = living crown height and Price relation = price relation between the different timber grades. The models showed that the grade

distribution of birch trees of mixed birch and spruce stands was highly correlated with tree height and height to first visible dry branch.

KEYS and TIM (2002) conducted a study on about tree grade versus product output from a mature sugar maple stand in Cape Breton, Nova Scotia. Final tree grades were based on the tree's face grade and scale grade, as well as on the top diameter of the grading system. Face grade is based on the clear-cutting yield found on the second worst face of the tree's grading system. Scale grade is based on allowable scale (volume) deductions associated with various rot and seam defects, as well as sweep and crook. The results showed that the occurrence and percent volume of high value products was strongly associated with increasing tree grade.

3 Study Area

3.1 Geographical conditions

The study was conducted in the province of Central Sulawesi around the area of the Lore Lindu National Park. It is situated geographically between 1°8' to 1°30' south latitude and 119°58' to 120°16' east longitude. This National Park is under the administration of Donggala and Poso counties (Ministry of Forestry and Corp Estate, 1999).

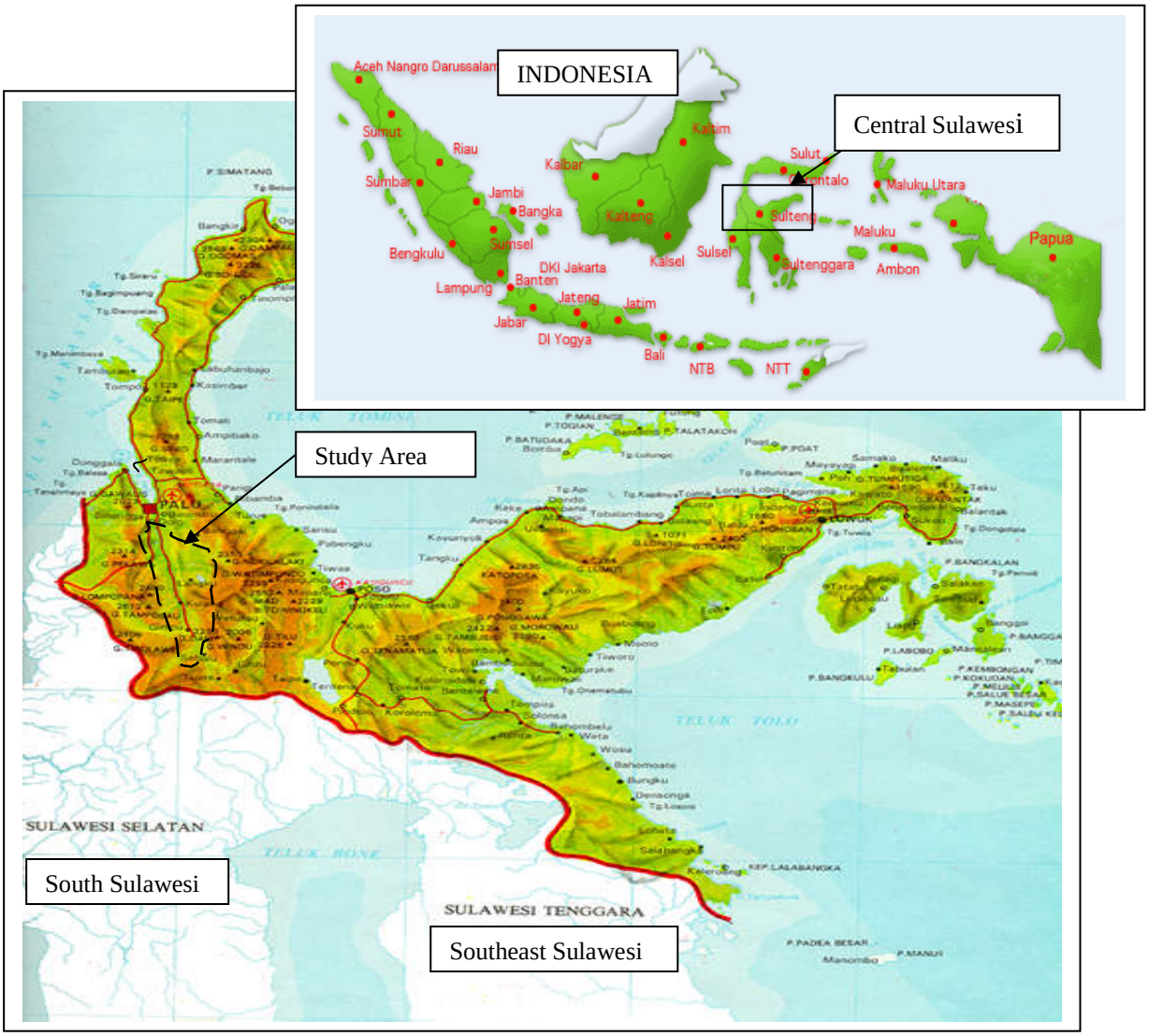


Figure 5.

Map showing the location of the research site

Five areas were chosen as research plot locations: Kamarora (Donggala county), Kalimpaa Lake, Bulu Sombua, Wuasa and Rompo (Poso county). Kamarora is located at the

northeastern part of the Lore Lindu National Park area and about 50 km from Palu, the capital city of Central Sulawesi province. Bulu Sombua and Kalimpaa are located about 80 km to the east. Wuasa and Rompo are located at about 100 km to the southeast and 125 km from Palu. Those areas are within the study area of the German-Indonesian research project of "Stability Rain Forest Margin" (STORMA, SFB 552).

According to the Ministry of Forestry Decree No. 757/Kpts-II/1999 of September 23, 1999, the forest area in Central Sulawesi is approximately 4.3 million ha or about 69.01% of the entire area of the Central Sulawesi province. These forests are divided into three functional categories: conservation area, protected forest area and production forest. The conservation area is about 0.7 million ha, the protected forest area encompasses about 1.5 million ha and the production forest is about 2.2 million ha. The Lore Lindu National Park itself covers about 217.991,18 ha according to the Forest Ministry Decree No. 464/Kpts-II/1999 of June 23, 1999. This is approximately 5% of the total forest area. This national park has become one of the most important areas in Central Sulawesi and even Indonesia, because it has been designated as a biosphere reserve by the UNESCO.

3.2 Climate conditions

According to the 1981 World Wide Fund (WWF) report based on the Agro-climatic map of OLDEMAN and DARMIYATI (1977), the area of Lore Lindu has a tropical climate with annual rainfall of 2000-3000 mm in the northern part (climatic type E-1) and 3000-4000 mm in the southern part (climatic type C-1). The rainy season is usually from November until April, the same time as the west monsoon.

According to the classification of agroclimatic zones of OLDEMAN and DARMIYATI (1977) as described in WHITTEN et al. (2002,) the area around the Lore Lindu National Park encompasses various agroclimatic zones, from B, C, and D zones in the south to an E zone in the north. Classification of an area as a B zone means that this area has 7 to 9 consecutive wet months and 3 or fewer consecutive dry months per year. C zones have 5 or 6 wet months and 3 or fewer dry months, while D zones have 3 or 4 consecutive wet months and 2 to 6 consecutive dry months. The northern part is dominated by an E zone with zero to two consecutive wet months and up to six consecutive dry months.

According to the SCHMIDT and FERGUSSON classification (1951), most of the area around the Lore Lindu National Park is permanently humid with a climatic type of A. Some areas are slightly seasonal and are thus type B, while the strongly seasonal areas are types E to H (WHITTEN, et. al., 2002).

There are three meteorological stations in the national park, one each at Palolo, Wuasa and Kulawi. Based on the SCHMIDT and FERGUSSON classification (1951), the climate around Palolo (northern area of national park) is seasonal climatic type C/D with an average annual rainfall of 855 to 1200 mm, that around Wuasa (eastern part) is type B with an average rainfall of 344 to 1400 mm per year, while Kulawi has a permanently humid climate with an average annual rainfall between 1200 and 2200 mm (Anonymous, 1995 quoted by HAMZARI, 2001).

Rainfall density inside the national park varies: in the northern part, the annual rainfall is between 2000 and 3000 mm and in the southern part between 3000 and 4000 mm. The wettest months are between November and April (Directorate General for Forest Protection and Nature Conservation, 1994).

The climate information collected in the study areas is very limited, and period observation data is no longer collected around the research area. According to the data collected during the Z2 – STORMA project between January and September 2002, temperature and humidity also vary between the research locations. The results are shown in the table below:

Table 4.

Temperature and humidity in each sample plot location

Sample plot location	Site station*)	Temperature (^{o}C)			Humidity (%)		
		min	max	mean	min	max	mean
Kamarora	Nopu	22.12	26.68	24.64	68.28	92.89	82.60
Kalimpaa & B.Sombua	Rore Katimbu	13.06	17.95	15.64	62.92	97.70	86.92
Wuasa	Watumaeta	18.48	23.56	21.00	69.35	95.63	82.33
Rompo	Talabosa	19.12	23.58	21.23	70.79	95.82	84.03

*) The nearest site station with the sample plots location

Source: STORMA (project program Z2, data collection between January-September 2002)

Precipitation was also recorded between January and September 2002. There was 1060.94 mm with 119 rainy days at Nopu, 1411.38 mm and 142 rainy days at Rore Katimbu, 1189.36 mm of rain and 119 rainy days at Watumaeta, and 1398.92 mm with 117 rainy days at the Talabosa site station.

3.3 Soil conditions and topography

The Lore Lindu National Park lies at an altitude of 500 to 2600 metres above sea level. The topography is flat and undulating, to hilly and mountainous in the north. About 70% of the area lies between 1000 and 1500 m, 20% is above 1500 m and only 10% below 1000 m. The highest peaks are Mt. Rorekatimbu (ca. 2610 m) and Mt. Nokilalaki (ca. 2335 m) (Directorate General for Forest Protection and Nature Conservation, 1994).

Table 5.

Topography around the research areas

Topography	Slope	Area	
		%	Location
Flat	0 – 8%	7%	Lindu Lake, Besoa valley, parts of Lamea, Rampo and Sopu River
fairly flat	8% - 15%	6%	Katu and Dodolo villages, around Torire and Rompo villages
fairly steep	15% - 25%	15%	Eastern part of this National Park, esp. top of Karakatu River, Lanea, Piri, Torire, Langka, Hinanou and eastern slope of Tumawu Mountain
steep	25% - 45%	4%	Eastern part of Lore Lindu, western slope of Mt. Nokilalaki, small part of Torro Village
very steep	> 45%	68%	Throughout most of mountain in Lore Lindu National Park such as Lampu and Mt. Tapolo

Source: Anonymous, 1995 quoted by HAMZARI, 2001

The area of the Lore Lindu National Park consists of 90% dry lands, 5% wet lands or swamp (around Lindu Lake) and 5% water (lake, Lindu and Kalimpaa/Tambing). The topography of the dry land areas varies from flat to steep or very steep (Anonymous, 1995 quoted by HAMZARI, 2001).

According to the soil map (scale 1:1,000,000) prepared by the AGROCLIMATE and SOIL RESEARCH CENTRE of the Agriculture research and development agency (1991) in Bogor-Indonesian, the northern part of the research area is dominated by red-yellow podsolic soil and litosol of the Tropepts, Udults and Orthents subordo. The area is undulating and

composed of material from metamorphic rocks. There are some areas with alluvial flats at the northeast composed of alluvial rocks and organic matter with alluvial, alluvial hydromorphic and organosol soils from the subordo of Aquepts, Aquenzs and Fluvents. All sample plots lay within the eastern and southern parts. These are mountainous areas composed of volcanic material with latosol soil from subordo of Tropepts, Udults and Udox. The areas around Lindu Lake and the Besoah Enclave are categorized as Alluvial flats from alluvial material. The soils in these areas are alluvial, alluvial hydromorph and brown forest soil from the subordo of Aquepts, Aquents dan Tropepts. In the south western mountainous area composed of metamorphic rocks and sediment, red-yellow podsolic and latosol soils from the subordo of Tropepts, Udults and Aquepts are dominant. Red-yellow podsolic soil of the subordo udults dan tropepts also occurred predominantly in the west to northwest area, which has precipitous physiography from material source of sedimentary rocks.

3.4 Vegetation

The natural vegetation on Sulawesi (WHITTEN et al., 2002), is typical of lowland forest at altitudes below 1000 m. Lower montane forest is found between 1000 and 2100 m, while upper montane forest is found between 2100 and 3250 m and sub-alpine forest between 3250 and 3450 m.

WHITTEN et al. (2002) mention that a useful classification for differentiating the forest types for Sulawesi would be lowland and hill forest (0 to 1500 m), lower montane forest (1500 to 2400 m), upper montane forest (2400 to 3000 m) and sub-alpine forest (above 3000 m).

The Lore Lindu area can be categorized into three forest types according to altitude. The forest below 1000 m belongs to lowland rain forest, with sub-montane forest from 1000 to 2000 m and montane forest above 2000 m (SUMEDI and RAHARDIAN, 1999).

According to the WWF (1981) and Department of Regional Forestry (1999) reports, the lowland rain forest covers less than 10% of the total Lore Lindu area. This is found mainly between the northern and western areas at an altitude of 200 to 1000 m. The floristic composition is quite heterogeneous with no particular dominant species. The area is characterized by the presence of ‘Pawa’ (Rubiaceae), ‘Ntorode’ (*Pterospermum celebicum*), ‘Ndolia (*Cananga odorata* Hook. F. & Thomson), ‘Ngkera’ (*Horsfieldia* spec.) and also Palm

'Saguer' (*Arenga pinnata*) and 'Take' (*Arenga* spec.). These species are usually not present at altitudes above 1000 m. Some important species, such as 'Tahiti' (*Dysoxylum* spec.), 'Tea Hera' (*Artocarpus elasticus*), 'Tea Uru' (*Artocarpus teijmannii*), 'Durian' (*Durion zibethinus*), 'Benua' (*Octomeles sumatrana*), 'Lekatu' (*Duabanga moluccana*) and 'Betau' (*Calophyllum soulattri*) are also present in this area.

Table 6.

Forest types in the Lore Lindu National Park

Forest Type	Layer	Characteristic (common species/families)
Low land rain forest (200-1000 m)	Upper canopy	*Messaendopsis becccariana, Dysoxylum* spec., *Ficus* spec., *Myristica* spec., *Elmerialia ovalis, Celtis* spec, *Pterospermum subpeltatum, Canangium odoratum, Artocarpus elasticus, Artocarpus Durio zibenthinus*, lower part: *Octomeles sumatrana* and *Duabanga mollucana.*
	sub-canopy	*Gnetum gnemon, Pangium edule, Ardisia* spec., *Symplocos* spec., *Calophyllum* spec., *Cyathocaly kingii, Artocarpus vriesiana* and *Chisocheton* spec.
	Scrub-bush/ small trees	*Pleomele angustifolia, Gardenia anisophylla, Eugenia* spec., *Carallia bracheata, Garcinia* spec., *Ficus* spec., *Antidesma neurocarpus, Antidesma tetandrum, Antidesma stipulare.*
Mountain rain forest (1000 - 2000 m)	Upper canopy	Fagaceae families *(Castanopsis argentea, Lithocarpus* spec.*)*, small part: *Agathis philippinensis, Podocarpus neriifolia, Taxus baccatus, Dacrydium falciforne, Phyllocladus hypophyllus, Tristania* spec.
	sub-canopy	Myrtaceae and Lauraceae families, *Calophyllum* spec., *Garciania* spec., *Tetractonia haltumi, Ceratostylis, Dichrostichum elongatum, Aeschynanthus horsfieldii, A. radicans* (Gerneriaceae), *Pathos* spec., *Rhapidodendron* (Araceae)
	Scrub-bush/ small trees	Seedlings of canopy trees, rattan, bryophytes, *Vaccinium* spec., *Rhododendron* spec., *Drymis piperita, Liveria montana, Lasianthus* spec.
Alpine forest (> 2000 m)		*Leptospermum, Rapanea, Myrsine, Phyllocladus, Hyphophyllus, Eugenia* spec.

Source: Anonymous, 1995 quoted by HAMZARI, 2001

More than 90% of the Lore Lindu area lies between 1000 and 2600 m and is classified as montane rain forest. This forest area is characterized by the dominance of the members of the oak family (Fagaceae), such as 'Kaha' (*Castanopsis argente*) and species of Lithocarpus (Palili) in the canopy layer, as well as members of the Myrtaceae and Lauraceae families in the sub-canopy layer.

In the region between 1000 and 1500 m, usually referred to as low montane rain forest or submontane forest, 'Uru' (Elmerillia or Manglietia) and species of Turpinia, Stercularia, Vernomia, Engelhardtia and Canarium are common.

The **Kamarora** forest area is lowland tropical forest with an altitude below 1000 m. Based on GPS measurements, the first sample plot is located at 1°12'15.96" south and 120°09'43.64" east at an elevation of 843 m. The area is flat with hills, with an inclination between 1^o and 28^o.

There were 52 tree species from 29 families in the ten established sample plots. Although the floristic composition of the area was rather heterogeneous, no particular dominant species were found. The area is characterised by the frequently present "Benua" (*Octomeles sumatrana* Miq., Datiscaceae), "Kereya" (*Horsfieldia glabra* Warb.; Myristcaceae), "Tahiti" (*Dysoxylum* spec.; Meliaceae), "Anantawine" (*Litsea albayana* Vidal.; Lauraceae) and "Torode" (*Pterospermum* spec.; Sterculiaceae). Rattan and Aren (*Arenga pinnata*.; Arecaceae) were frequent in the lower strata.

With an altitude between 1000 and 1500 m, the forest in **Rompo** and **Wuasa** area is a hill forest. The position of the first sample plot at Wuasa area is 199908 m east and 9842410 m north at an altitude of 1064 m. The sample plot at Rompo lies 1204 m above sea level at 198593.0 m east and 9820079.3 m north. Wuasa is quite flat to hilly, with an inclination varying between 8.5^o and 26^o. The Rompo area is also quite flat to undulating and hilly, with steep areas in some places. The inclination varies between 8.1^o and 43^o.

Although both areas belong to submontane forest, the floristic composition is not exactly the same. About 46 species from 25 families were found in six sample plot areas in **Wuasa**. This area is characterized by the frequently found species of "Bangkaraha" (*Prunus* spec. Rosaceae), Bangkakarak (*Cryptocarya* spec.; Lauraceae), "Tahiti" (*Dysoxylum* spec.; Meliaceae), "Warani" (*Semecarpus heterophylla* Blume.; Anacardiaceae), "Bolaa" (*Trema orientalis* L. Blume.; Ulmaceae) and "Andolia" (*Cananga odorata* Hook.f & Thomson.; Annonaceae).

In **Rompo**, 45 species from 28 families were found in 12 sample plots. The most commonly found species are "Kume" (*Palaquium obovatum* (Griff. I) Engler var. orientale H.J.Lam.; Sapotaceae), "Numpibowe" (*Canarium hirsutum* Wild.; Burseraceae), "Palili" (*Lithocarpus* spec.; Fagaceae), "Lalari" (*Vitex quinata* F.N.Williams.; Verbenaceae) and "Warani" (*Semecarpus heterophylla* Blume.; Anacardiaceae).

With an elevation above 1500 m, **Bulu Sombua** and **Kalimpaa Lake** are classified as lower montane forest. The position of the first sample plot in Kalimpaa Lake area is 200535.5 m east and 9853293.2 m north at 1714.5 m elevation. This area is flat but hilly in places. The position of the sample plot at Bulu Sombua is 199797 m east and 9854034 m north with an elevation of 1817.9 m above sea level.

The floristic composition of these areas is decreased because of the elevation. The commonly present species are quite similar. Eight species from five families were found in **Bulu Sombua** and 28 species from 22 families in **Kalimpaa Lake**. These were "Haleka" (*Castanopsis* spec.; Fagaceae), "Mangkapa" (*Ilex cymosa* Blume.; Aquifoliaceae), "Palili" (*Lithocarpus* spec.; Fagaceae), "Manitu" (*Eugenia clavimyrtus* K.et.V.; Myrtaceae), Anantawine (*Litsea albayana* Vidal.; Lauraceae). "Agathis" (*Agathis damara* L.C.Rich.; Araucariaceae) and "Betau" (*Calophyllum soulattri* Burm. f.; Guttiferae) were also found in some places.

3.5 General condition of the sample plot areas

In 2000, 15 sample plots were established at the Kamarora location, but five plots had already been completely lost by 2001. The area of Kamarora was severely disturbed or fully destroyed, mostly by illegal cutting, burning and planting activities. More than 90% of the sample plots were disturbed; about 30% was completely cleared and had been turned into maize farmland. Sixty percent were disturbed at the lower layer. The lower layer had been cleared and planted with cacao and coffee. Only less than 10% still remained undisturbed, probably because the location of the plot was far from the nearest road (ca. 2 km).

Table 7.

The condition of sample plot areas

Location	Altitude	Forest type	Classification
Kamarora	ca. 800 m	Lowland forest	severely disturbed
Wuasa	ca. 1000 m	Hill forest	severely disturbed
Rompo	ca. 1200 m	Hill forest	not disturbed
Kalimpaa	ca. 1700 m	Lower mountain forest	slightly disturbed
Bulu Sombua	ca. 1800 m	Lower mountain forest	not disturbed

A similar situation was also found at the Wuasa location. More than 50% of the sample plot area was disturbed, mainly by illegal cutting. The rest of the area was slightly disturbed by human passage. A different situation was found at the Rompo location. Although the forest is located around the village, the condition was very good. All the plots (100%) were in good condition and there were no external disturbance.

The sample plots at the Kalimpaa Lake location were disturbed mainly by rattan harvesting activities. Only less than 5% cutting activity was found around the plot areas. The disturbed areas were mainly in the lower layers, because of the many pathways made to remove the rattan. The Bulu Sombua location was undisturbed, although this area contains with many valuable trees. This might be because the location is at a high altitude and is difficult to access.

4 Material and Methods

4.1 Study material

All trees located inside the sample plots, which that had been established in the five areas described above were evaluated in this study. Forty sample plots were established and assessed. The total number of sample trees was 1004 live trees and 98 dead trees (see Table 8).

Table 8.

Number of sample trees

Research Area	Number of Species	Live trees			Dead trees	Total trees
		Class diameter (cm)				
		$10 \leq d < 20$	$20 \leq d < 100$	≥ 100		
Kamarora	50	11	136	6	25	178
Kalimpaa	28	24	268	8	24	324
Bulu Sombua	8	4	37	0	9	50
Wuasa	46	9	122	1	17	149
Rompo	45	26	348	4	23	401
T o t a l		74	911	19	98	1102

4.2 Sample plot establishment

Forty sample plots were systematically established over the study area, each is using square spacing in the Kalimpaa and Rompo areas, and line spacing in the Kamarora and Wuasa areas. The distance between the plots was 250 m. Only one plot was established in the Bulu Sombua area.

Some advantages of using this systematic pattern are that it is not necessary to develop a frame prior to sampling, it is less time consuming and more cost efficient than establishing randomly located plots, and that the sample plots cover the entire inventory area and are not clustered (AKÇA, 2000). ALDER and SYNNOTT (1992) also mentioned that the systematic sampling format has the advantage of being simple to design and implement in the field. The sampling is objective and the coverage is as uniform as possible.

Due to the long distance between the sample plots, the sample plots could be considered as independent each others.

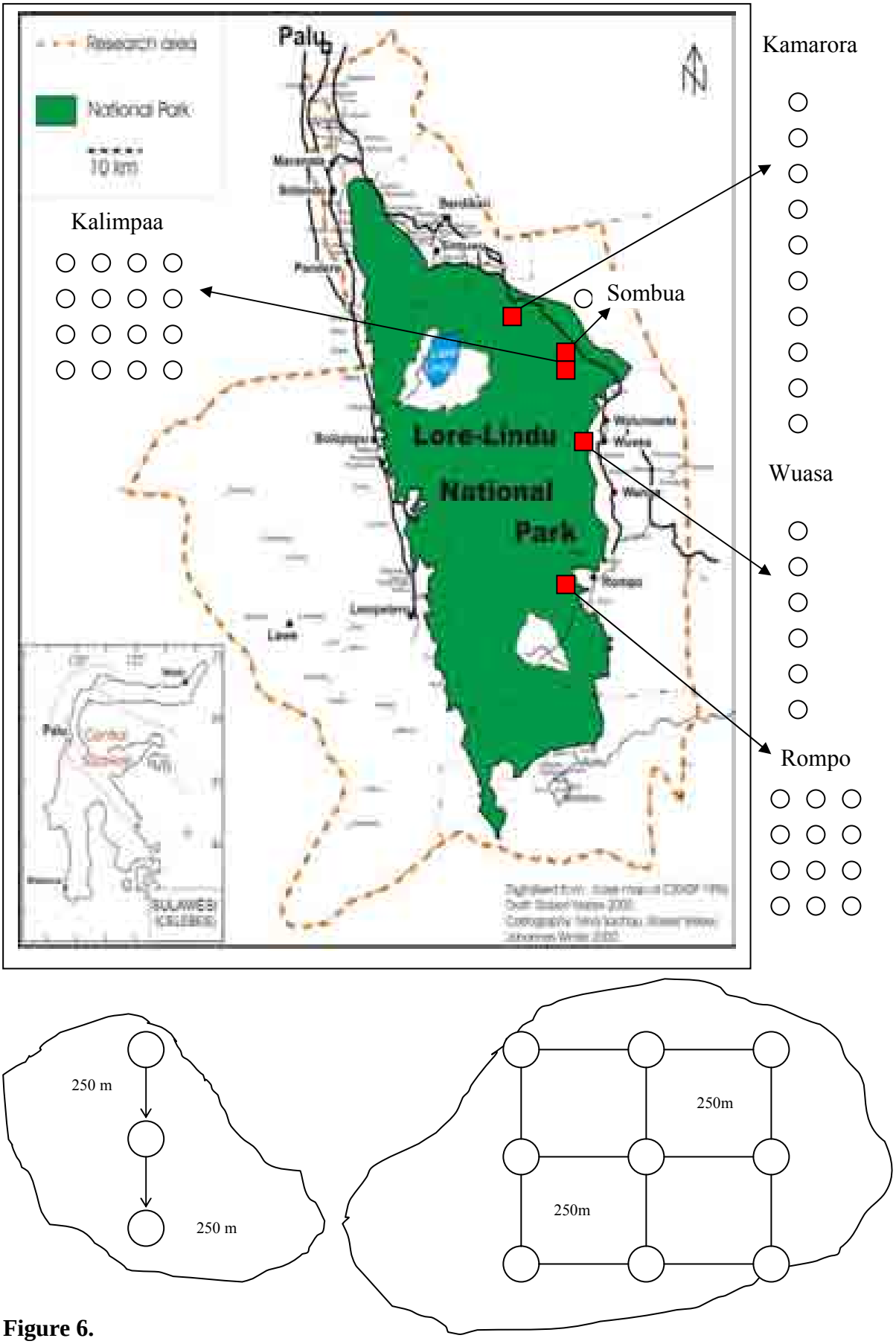
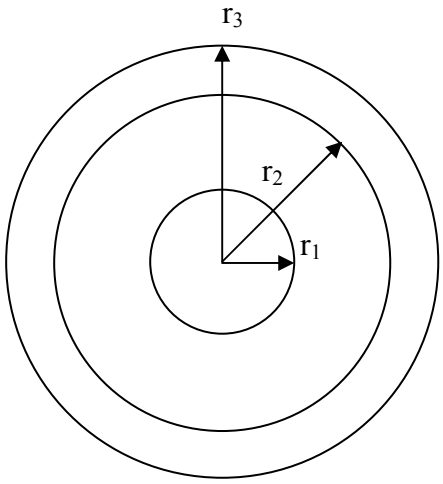


Figure 6.

Distribution of sample plots in study area

Concentric circular sample plots with three different radii from the same centre were used in this study. All trees with a Diameter at Breast Height (DBH) between 10 cm and 20 cm were measured in the inner circle, which had a radius of five metres. Those with a DBH between 20 cm and 100 cm were measured in the second circle with a radius of 20 metres, and trees with a DBH of 100 cm or more were measured in the outer circular plot with a 25 m radius.



r_1=5 m (78.6 m^2) for DBH-Class 10-20 cm
r_2=20 m (1257 m^2) for DBH-Class 20-100 cm
r_3=25 m (1964 m^2) for DBH-Class ≥ 100 cm

Figure 7.
Concentric circular sample plots

Circular plots have the smallest perimeter of any other geometric shape for a given surface area. They are therefore preferable to square or rectangular plots because one can correctly exclude or include trees near the plot boundaries, and they are also less time consuming to establish (AKÇA, 2000). HUSCH et. al. (2003) also stress the fact that the shorter perimeter for a given area necessitates fewer decisions on whether a tree is inside or outside the plot for trees near the plot boundaries. Decisions on such trees near boundaries can be a source of considerable bias; a situation frequently found on plantations.

Table 9.
Number and size of sample plots

Research Area	No. of Sample Plot	Sample plot size (m^2)			Sample plot size (m^2)
		r_1	r_2	r_3	
Kamarora	10	786.0	12570.0	19640.0	32996.0
Kalimpaa	11	864.6	13827.0	21604.0	36295.6
Bulu Sombua	1	78.6	1257.0	1964.0	3299.6
Wuasa	6	471.6	7542.0	11784.0	19797.6
Rompo	12	943.2	15084.0	23568.0	39595.2
T o t a l	40	3144.0	50280.0	78560.0	131984.0

The area of each sample plot used in this study was 0.4 ha. According to AKÇA (2000), a sampling unit between 0.2 and 0.5 hectare is considered to be a suitable compromise in tropical forest inventories.

4.3 Sample plot measurement

For all sample plots, the number of plots, plot radius, slope, exposition, strata and stand structure were used to describe the condition of the plots and the position of the sample trees. ARCVIEW GIS 3.2a (Environmental System Research Institute Inc., ESRI Geoinformatik GmbH, Germany) was used to draw the plots and for tree location mapping (See Appendix 1-5). Figure 8 shows an example the position of the trees inside a sample plot.

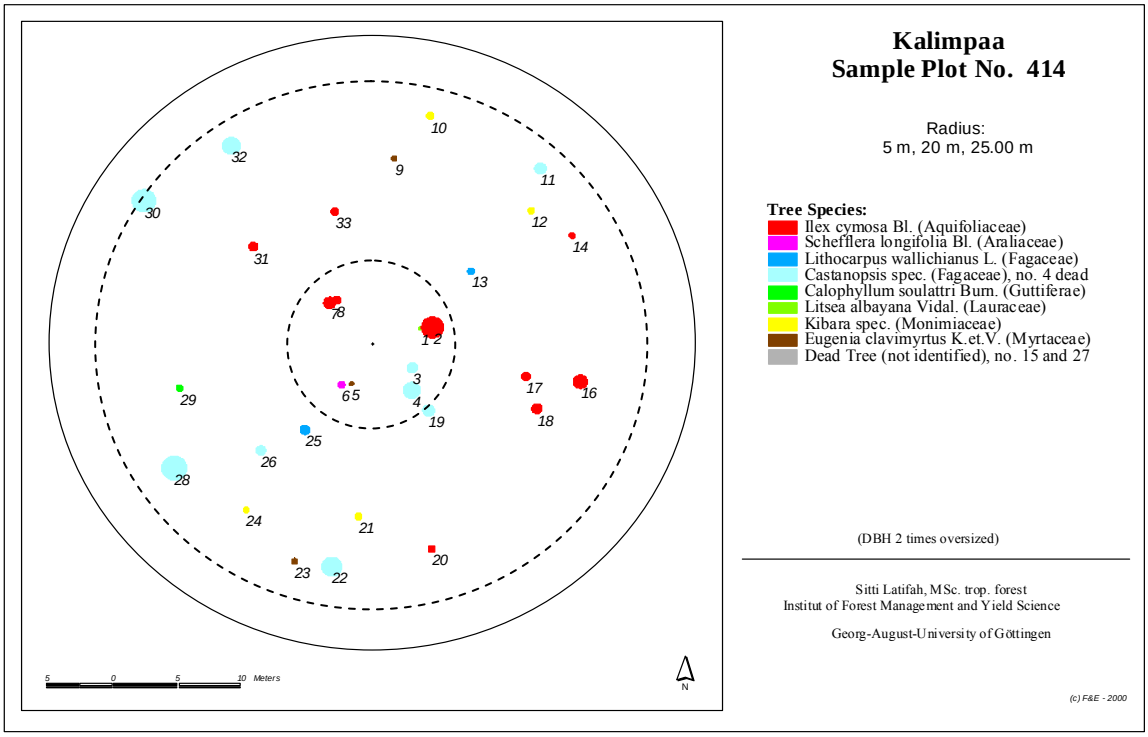


Figure 8.
Tree position inside a sample plot in the Kalimpaa area

Direct observations of disturbance characteristics were used to give a more detailed description of the condition of the sample plots. The types of disturbances were divided into disturbances caused by physical factors, such as wind, rainfall, lighting, sun brand and

disturbances caused by human activities, such as rattan harvesting, bark scratching, cutting, burning or planting activities.

Horizontal stand structure inside the plot was estimated from crown closeness classification, which is divided into six classes:

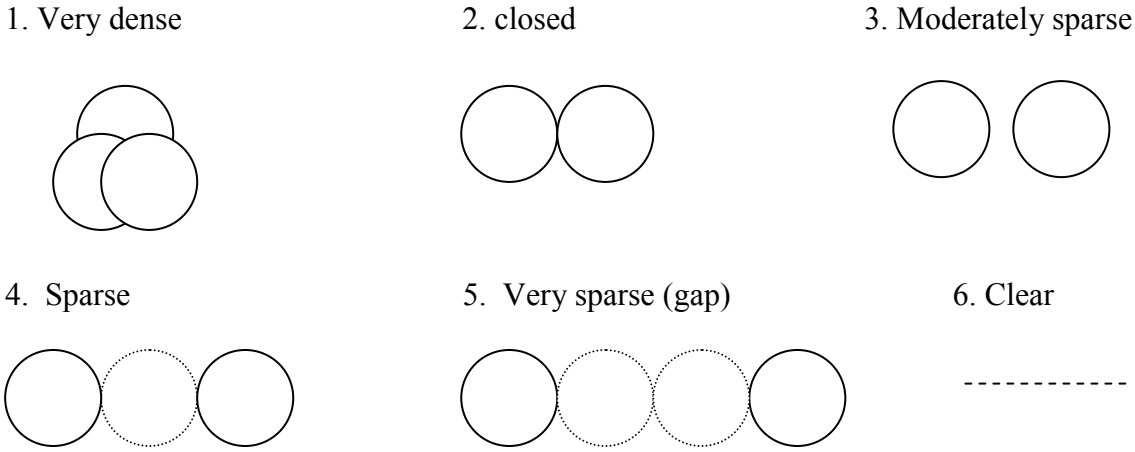


Figure 9.
Closeness classification (KRAMER and AKÇA, 1995)

4.4 Sample Tree Measurement

The parameters recorded in the respective plots are listed in Table 10 and are elucidated below:

Tree identification

Four local individuals with experience in tree identification and speaking three different local languages (Kulawi, Wuasa and Besoah) helped as identifiers in the field. Two expert species identifiers from the Forest Research Agency in Bogor and Herbarium Bogoriensis determined the botanical name of each tree species. A mini-herbarium consisting of specimens of leaves, as well as some flowers and fruits were taken along to facilitate the identification process. The list of identified trees is given in Appendix 6 until 10.

Table 10.

Tree parameters

Parameter	Measurement	Unit of measurement
Tree species	All trees	Local and botanical name
Tree position	All trees	
• azimuth		Gon
• distance		0.1 m and some 0.01 m
Tree dimension		
• d_B	Trees with no buttress	cm
• h_B	Trees with no buttress	0.1 m
• DBH	Regular trees	cm
• d_n	Irregular trees	cm
• h_n	Irregular trees	0.1 m
• Height (total)	All trees	0.1 m
• d_i and h_i	> 20 cm	0.1 cm and 0.1 m
Crown characteristic		
• Social class	All trees	KRAFT Classification
• Crown position	All trees	DAWKINS Classification
• Crown form	All trees	DAWKINS Classification

Tree diameter and height measurement

For all trees above 10 cm, the Diameter at Breast Height (DBH) and total height were measured. For all trees with no irregularities below 1.3 m, the diameter at the lowest part of the trees (d_B) and the height (h_B) were also measured. DBH was measured at a point 1.3 m above ground. For all irregular trees, for which it was not possible to measure the DBH at 1.3 m, normal diameter (d_n) and height (h_n) were obtained. Irregularities commonly occurring in tropical forests are high buttresses, burling, forking, branching, leaning, and flattened stem. For a subjectively chosen subset of trees above 20 cm, d_i and h_i as diameter at limited height (section diameter) and its height were measured. Diameter tape equipment was used to measure diameter. The following illustration shows the point used to measure diameter for some irregular trees:

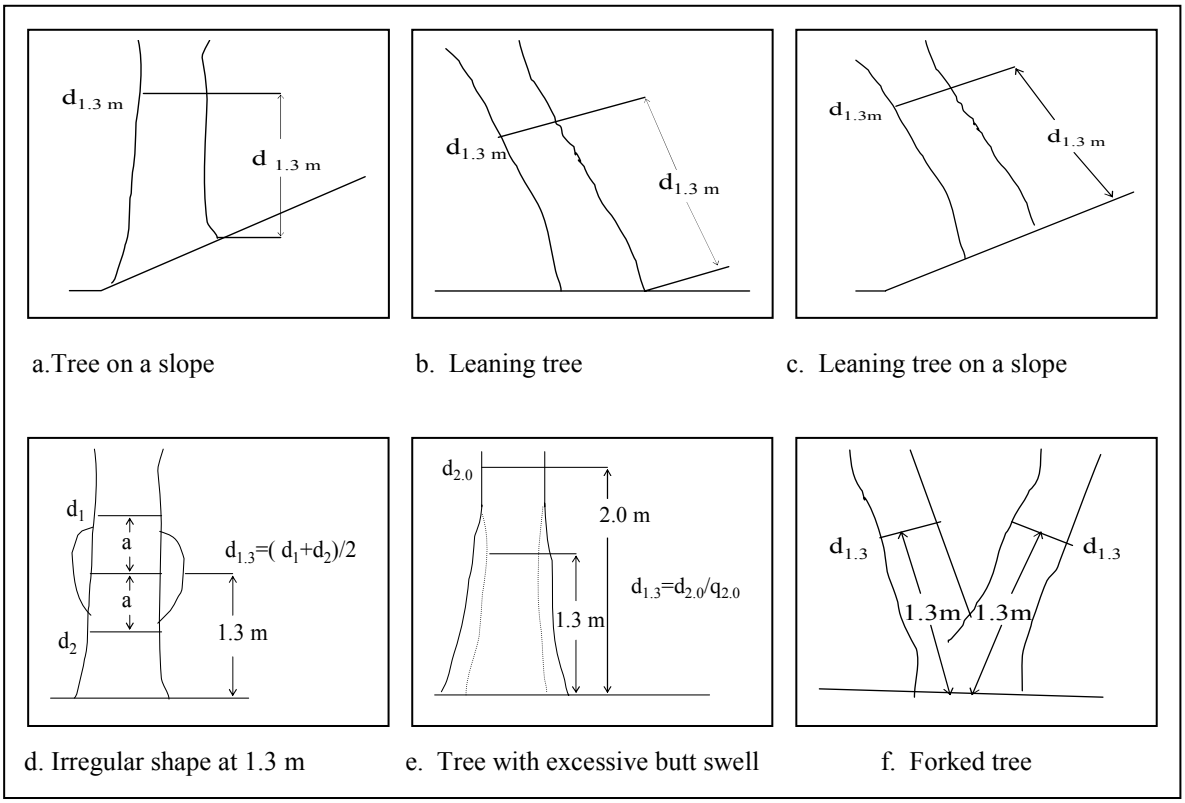


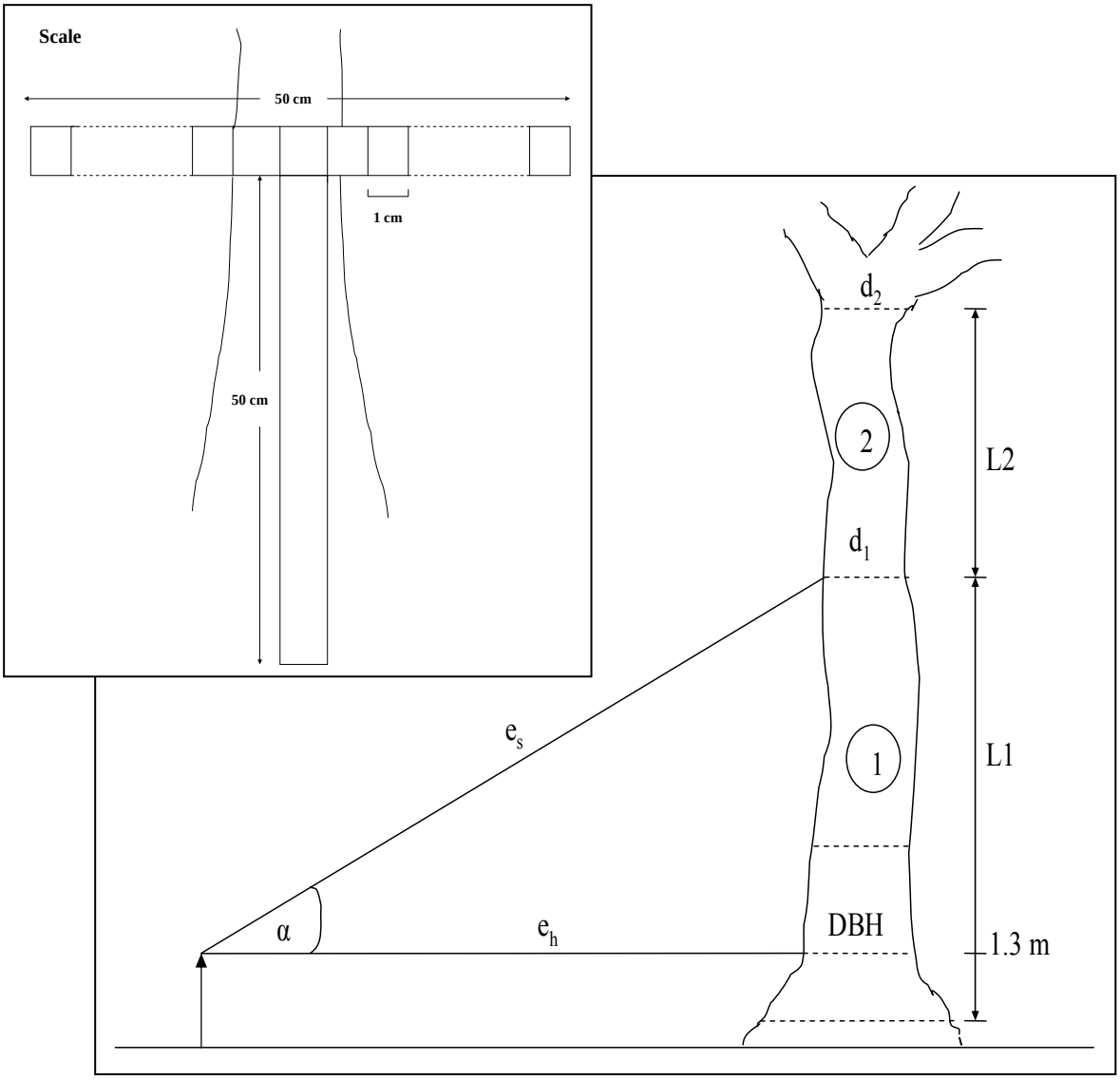
Figure 10.

Methods used to measure DBH (Source: v. LAAR and AKÇA, 1997)

Total and merchantable heights were measured using VERTEX equipment as well as distance and slope[1]. The merchantable height is defined as the distance along the axis of the tree stem between the ground and the terminal position of the last usable portion of the tree trunk. Determining the position of the upper terminal is somewhat subjective. It is set either at a minimum top diameter or at a point of branching, irregular form, or a defect limiting utilization. The minimum top diameter will vary with the intended use of timber and market condition; for example, it might be 10 cm for pulpwood and 20 cm for sawn timber (HUSCH et all, 2003).

The diameter at specified heights (section diameter) was estimated in order to achieve better performance of the tree form and volume estimations. Due to the density of the trees, it was difficult to estimate the diameter at the specified heights in the upper parts of the trees using optical equipment such as the Bitterlich Relascope. Therefore, the diameter was calculated from stem geometry using trigonometric functions.

[1] VERTEX was sometimes disturbed by kind of insects, which have the similar frequency of ultrasonic wave. Thus, suunto clinometer and haga hypsometer were used to measure slope and height.



Note: DBH = Diameter at Breast Height (cm), e_h = horizontal distance (m), e_s = diagonal distance (m)
α = degree (°), d_i (d_1 and d_2, etc) = diameter at specific height = e_s. (1/50). scale (cm)

Figure 11.

Methods for measuring height and diameter at the specified height[2]

An example of diameter calculation:

e_h = 10 m

α = 40.3°
scale = 2.3 cm

$$e_s = \frac{e_h}{\cos a} = \frac{1000\ cm}{40.3^o} = 1311 \text{ cm}$$

$$d = 1311 \text{ cm} \cdot \frac{1}{50} \cdot 2.3 = 60 \text{ cm}$$

[2] The scale equipment designed by Prof. Akça (2001)

Volume Estimation

Five regression models for all trees and six models for commercial trees were tested in order to determine the optimal model for estimating single tree volume (table 11). Models using diameter and height are preferable since:

- measurement of upper stem diameter is time consuming and expensive,
- variation in tree form has a much smaller impact on tree volume and weight than does height or dbh variation,
- with some species, the form is relatively constant regardless of tree size,
- with other species, tree form is often correlated with tree size, do that dbh and height variations often explain much of the volume (or weight) variation actually caused by form variations. (HUSCH et. al., 2003).

Table 11.

The regression model of single tree volume

Predictor Variable	Regression model	Author
V= f (d,h)	1. $V = b_0 + b_1 d^2 h$ 2. $V = b_0 + b_1 h + b_2 dh + b_3 d^2 h$ 3. $V = b_0 + b_1 dh + b_2 d^2 + b_3 d^2 h$ 4. $V = b_0 + b_1 d^2 + b_2 d^2 h + b_3 dh^2 + b_4 h^2$ 5. $V = b_0 + b_1 d + b_2 dh + b_3 d^2 h + b_4 d^2 h^2$	SPURR, 1952 SLOBODA, 1984 DWIGHT NASLUND, 1940 MYERS, 1972
V= f(d,h,di)	6. $V = b_0 + b_1 d_i dh$ 1)	SPURR, 1952
V= f(d,h,hi)	7. $V = b_0 + b_1 d^2 h_{0.67d}$ 2) 8. $V = b_0 + b_1 d^2 + b_2 d^2 h + b_3 dh^2 + b_4 h^2 + b_5 d^2 h_{merc}$	RUSTAGI, 1990 NASLUND

Source: v. LAAR and AKÇA, 1997; SOEDIRMAN, 1989; LOESTCH, 1973.

Note: 1) d_i is the diameter at specific heights. In this case 5 m, 7 m and 10 m height will be used.

2) Incorporates the height at which the diameter is two-thirds of the breast height diameter as an additional and useful predictor variable. (v. LAAR and AKÇA, 1997).

The first step in the selection process is to compare the coefficient of determination (R^2), which measures the proportion of the variation of one variable determined by the total variation. In other words, this coefficient expresses the proportion of the variation of Y (dependent variable) that is due to variation in X (independent variable) (SOKAL and ROHLF, 1997). This coefficient is also an indicator of how well the model fits the data. But

this coefficient does not give the correlation between independent variables. Models with fewer independent variables are usually preferred above others, since they compensate better for the negative effects of outliers (SOEDIRMAN, 1995). An additional advantage of a model with few predictor variables is the suppression of variation inflation (v. LAAR and AKCA, 1997).

The models were modified in the second step in order to find a compromise between the following demands and to optimise the performance of the model. The demands are:

- best possible minimization of the bias by altering the number of independent variables,
- cost minimization of the implemented model by using as few independent variables as possible (practicability) (JACKE, 1980 in SOEDIRMAN, 1989 and 1995).

To this end, an automatic selection procedure was used in this study. Using the stepwise variable selection implemented in STATISTICA (Version 6) partial correlations from the regression model were calculated automatically. The F-value was used in this analysis, as well.

The next step is residual analysis that can be displayed in a great variety of graphs. Residual analysis must take into consideration that:

- the residuals are distributed normally,
- the residual are uncorrelated,
- the variance of predicted variable is independent of independent variable.

The optimal model will be used to estimate the tree volume in each plot and after that to estimate the volume per hectare of the area.

Crown characteristics

KRAFT Classification was used to estimate visually the social class of trees.

KRAFT Classification: (KRAMER and AKÇA, 1995):

Social class 1 = Predominate
Social class 2 = Dominate
Social class 3 = Co-dominate, some overhead light
Social class 4 = Understorey
Social class 5 = Dead or nearly dead.

DAWKINS (1958, reproduced with illustrations in ALDER and SYNOTT, 1992), described a crown position and crown form classification with the following scoring system:

Score	Position	Form
5	Emergent	Perfect, complete circle
4	Canopy, full overhead light	Good, irregular circle
3	Lower canopy, some overhead light	Tolerable-distinctly asymmetrical or thin
2	Upper understorey, some side light only	Unsatisfactory with dieback and asymmetry
1	Lower understorey, no direct light	Very poor, degenerating, dead

4.5 Standing Tree Quality Assessment

4.51 The selection of sample trees

The sample trees were chosen from the commercial tree groups, especially from common families found in the study area. The following points were taken into consideration when the measurements were done in the field:

1. The sample trees must have a good position (e.g. avoid sample trees standing on very steep locations), so that the measurement can be done properly.
2. There were more than 100 species found in the study location, which were grouped together into their families.

In this study, 1102 sample trees were measured after prior species identification. These trees were divided into commercial (n = 727) and non-commercial trees (n = 275). The condition of all commercial trees with a diameter of more than 10 cm was noted. The relative items included living or dead condition, standing or fallen, and general defects, such as crown, bark or stems defects. The defects were measured to evaluate common defects found in the field. An additional diameter was determined at a height from the base of 20% of total height and 30% of merchantable height. More detailed characteristics were noted in selected commercial trees in the Rompo area. The objective was to quantify those standing trees using measurement methods described below (4.52).

4.52 Methods of measurement

The measurement method used in this research is based on methods developed by WIEGARD (1998) on the butt-log and the relative-length methods. As also mentioned by FAO (1981), the butt-log method is simpler than any other method.

The basic butt-log method is a quality measurement done only on a specific lower portion of the tree, the simple butt-log method (Figure 12). Due to the differing conditions between natural tropical forests and temperate forests, some adjustments were also made. For example, the combination of height measurement was done in order to adapt to field conditions.

VON ARNSWALDT (1950) used the first six metres in beech stands (4 metres for ash stands) to quantify tree quality. SCHROEDER et al. (1968) cited in PRESTEMON and BUGIONORNO (2000) used the clear faces in the first 4.9 metres of southern pine logs, whereas WIEGARD (1998) used the first six metres. Since species and height are variable in tropical forests, the relative height can also be used for the measurement. Therefore, the relative height of 20% of total height (equivalent to 30% of merchantable height) was defined as the butt log, in which the quality measurement was performed. The results show that the average height of the butt log defined in this way was five metres. Experience in the field showed that, in practice, this height was attainable for measurement. Using the relative height can also reduce the height variation between species. Experience showed that it was possible to employ this method for trees with no or very low buttress.

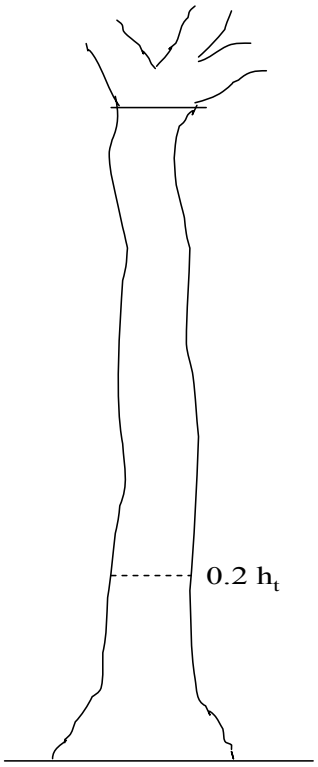


Figure 12.
The simple butt-log method

Since, in Indonesia, quality assessment is not performed on standing trees, no criteria for defect measurement are provided. Many quality classes have been developed in Indonesia, some based on species and some for industrial purposes, but these are for felled trees (logs). Four quality classes are generally used for grading Indonesian logs. In this study, an attempt was undertaken to combine the common defects found in the study area and the criteria from Indonesian logs grading rules for some species and purposes. Therefore, tree quality will be differentiated into four classes, A, B, C and D. The tree quality class represents a theoretical construct for each species, but it is very difficult to determine in practice and not feasible for standing trees. Therefore, the criteria were synthesized to be as simple as possible, taking time for measurement, cost and practicability into consideration.

The measurements and recordings at the lower part are performed with as much detail, objectivity and care as possible, because this will be used to determine the classification the tree as A, B, C or D quality classes. The recorded criteria are entered into a spreadsheet program, so that a stand analysis with individually definable quality grades (A, B, C, D classes) can be carried out for each single tree.

Tree quality is evaluated based on four column criteria, the type of visible defects, the size, number limit and value as defect code. The criteria are differentiated between trees with a class diameter below 20 cm or 20 cm and more. The decision algorithm used to determine tree quality is shown in Tables 12 and 13.

Table 12.

Defect criteria for the butt log method for the diameter class 20 cm and up

Visible defect	Standard size	Number	Value
Sound knot	No		10
	≤ 10 cm	≤ 2	111
		> 2	112
	≤ 15 cm	≤ 5	121
		> 5	122
	> 15 cm	≤ 5	131
		> 5	132
Dead/decay knot	No		20
	≤ 10 cm	≤ 5	211
		> 5	212
	> 10 cm	≤ 5	221
		> 5	222
Knob/limb	No		30
		≤ 3	311
		> 3	312
Holes	No		40
	≤ 5 mm	≤ 30	411
		> 30	412
	> 5 mm	≤ 30	421
		> 30	422
Sweep/crook	No		50
	≤ 5 cm	≤ 1	511
		> 1	512
	> 5 cm	≤ 1	521
		> 1	522
Groove	No		60
	≤ 1/5	≤ 1	611
		> 1	612
	> 1/5	≤ 1	621
		> 1	622
Grain	Straight		70
	≤ 1/10		711
	> 1/10		712
Wound/decay/cancer	No		80
	≤ 10 cm	≤ 1	811
		> 1	812
	> 10 cm	≤ 1	821
		> 1	822
	Hollowed		831

The visible defect column consists of external defects that can be recorded and measured as criteria keys in quality assessment. These defects consist of sound knots, decay/dead knots,

knobs/limbs, holes, sweep/crook, groove, grain and wound/decay/cancer. Other defects, such as abnormal or decayed heart, brittle heart, heart checks, discoloration and heart rot were not measured since these defects are not visible from the exterior.

The size of the external defects is differentiated in the standard size column. Each size in this column shows the average size defect allowed for each tree. After recording the type of external defects and their size, one can begin determining the quality classes. As shown in Table 12, the diameter of sound knots for trees in the diameter class of 20 cm and up is differentiated into groups with less than 10 cm, less than 15 cm and over 15 cm. Dead or decayed knots are differentiated into groups smaller than 10 cm and larger than 10 cm. Knobs or limbs are counted but their size is not measured. Holes, which normally occur in groups, are differentiated into groups with a diameter less than or more than 5 mm. With an average relative height of 5 metres, the permissible sweep/crook is 5 cm over a length of 5 m. Grooves are measured by dividing their depth with the tree diameter. One differentiates groups with a ratio of less than 1/5 or over 1/5. Grain is differentiated into groups with a deviation direction to the tree axis equal to or less than 1/10 or over 1/10. Wound, decay and cancer are also part of the criteria. One differentiates sizes below 10 cm, above 10 cm and hollowed (large hole over 50 cm with decay symptoms).

The number column determines the allowable number of defects for each relative tree height; in this study the average was 5 metres. This column also gives the acceptable combination for each quality class (A, B, C and D). The value column determines the connection between the allowable size and number of each defect. The quality class is determined by the combination of these columns. An example of the criteria for determining A quality for trees with a diameter up to 20 cm up is:

$$\{\text{VALUE: } (10 \vee 111) \wedge 20 \wedge (30 \vee 311) \wedge 40 \wedge (50 \vee 511) \wedge 60 \wedge (70 \vee 711) \wedge 80\} \rightarrow \{\text{A}\}$$

A tree classified as A-quality may contain one sound knot with a diameter less than 10 cm in each 2 m length (111), **and** no dead knot (20), **and/or** fewer than 3 knobs/limbs (311), **and** no holes (40), **and/or** 1 cm of sweep/crook per one meter (511), **and** no groove (60), and/or grain less than 1/10 (711). A tree would be downgraded to B-quality simply by the presence of dead knot, for example, the value can be 111, 211, 311, 511, 711. Defects must therefore be recorded carefully, since the tree might otherwise be misclassified.

Table 13.

Defect criteria for the butt log method for the diameter class below 20 cm

Visible defect	Standard size	Number	Value
Sound knot	No		10
	≤ 5 cm	≤ 3	111
		> 3	112
	> 5 cm	≤ 3	121
		> 3	122
Dead/decay knot	No		20
	≤ 5 cm	≤ 3	211
		> 3	212
	> 5 cm	≤ 3	221
		> 3	222
Knob/Limb	No		30
		≤ 3	311
		> 3	312
Holes	No		40
	≤ 5 mm	≤ 30	411
		> 30	412
	> 5 mm	≤ 30	421
		> 30	422
Sweep/crook	No		50
	≤ 5 cm	≤ 1	511
		> 1	512
	> 5 cm	≤ 1	521
		> 1	522
Grain	Straight		60
	≤ 1/9		611
	> 1/9		612
Wound/decay/cancer	No		70
	≤ 10 cm	≤ 1	711
		> 1	712
	> 10 cm	≤ 1	721
		> 1	722
	Hollowed		731

Buttresses and other abnormalities such as flattened, hollowed, etc. are the common characteristics found on the lower part of trees in tropical forests. These characteristics bring problems not only when determining quantity but also quality assessment, and are responsible for the shape of the trees not acceptable for high quality classes. These must be downgraded to a lower quality class because of the irregularities. For example, trees with high buttresses sometimes have a very good quality in their upper parts. Therefore, the classification problem will only occur when the simple butt-log method is used. One must combine methods in order to eliminate doubt when differentiating the quality classes. It is suggested that one differentiates Diameter at Breast Height (DBH) or at normal diameter for trees with irregular shape above DBH. Another variation of the simple butt log method which implements the differentiation the defect below the relative height (5 m) is the differentiated butt-log method

(Figure 13). The assessment using the simple butt log method was always decided by summing the defect from the base until the height of 5 m. This could be one source of the mistake when one tree has still a very good performance from the specific height below the relative height. As an example, one tree has a sound knot of ≥ 15 cm at the height of one meter. The quality assessment using the butt-log method would directly decide that this tree would be qualified at least as B- or C- quality. If this happened repeatedly, this would become a source of negative systematic error for A-quality and a positive systematic error for B- and C- quality. Therefore, this mistake can be corrected by differentiating the defect assessment below the height of 5 m into section.

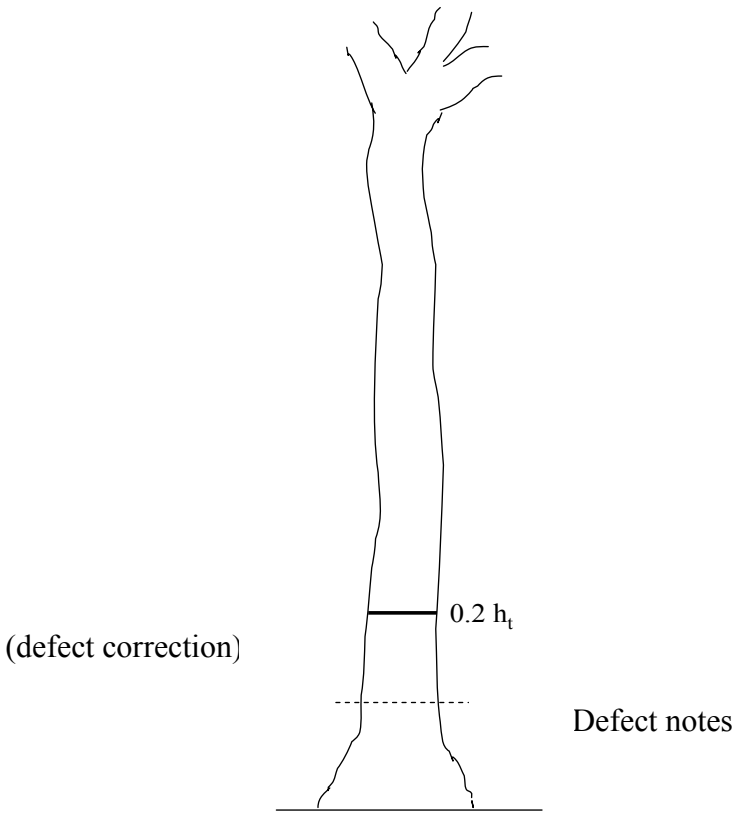


Figure 13.
The differentiated butt log method

Problems also arise when the irregularities continue higher than the relative height point. The condition of the upper part must also be taken into consideration. Experiments have shown that due to the conditions in tropical forests, trees with irregularities above the relative heights are frequently of A-quality in their upper parts. Therefore, one must also examine for defects in the upper parts to strengthen the decision of classifying a tree with higher quality. This method tried to combine between the objective assessment using defect criteria for the first

5 m and the ocular observation for the upper part in deciding the quality classes. Although the defect can only be estimated by sight, the result can at least reduce the error made by only using the above-mentioned methods (Figure 14).

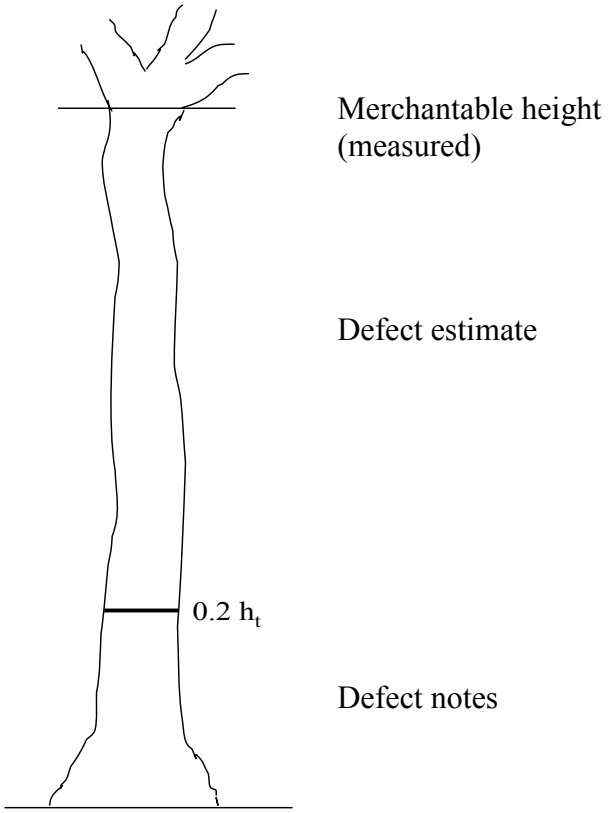


Figure 14.
The simple, expanded butt-log method

A combination of the methods described above was also developed by WIEGARD (1998). These methods are especially useful for highly valuable trees, or mature stands or for scientific investigations. The method that combines the differentiated and the simple, expanded butt log is known as the expanded-differentiated butt log method. In the tropical forest, this method is applicable for trees with continuous, abnormal shapes from the lower to the upper parts (Figure 15). Firstly, the defect was noted for the first 5 m and the quality assessed using the defect criteria, and it was found that the differentiate was needed, than the first 5 m could be divided into section. Together with the defect estimation of the upper part, the tree could be qualified as A-, B-, C- or D- quality classes.

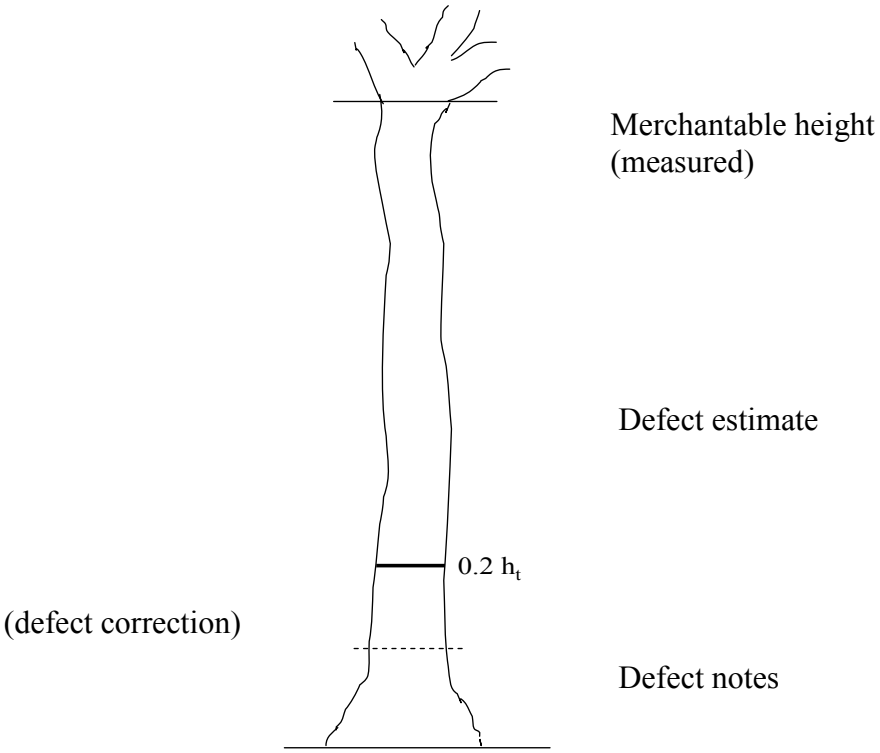


Figure 15.

The expanded, differentiated butt-log method

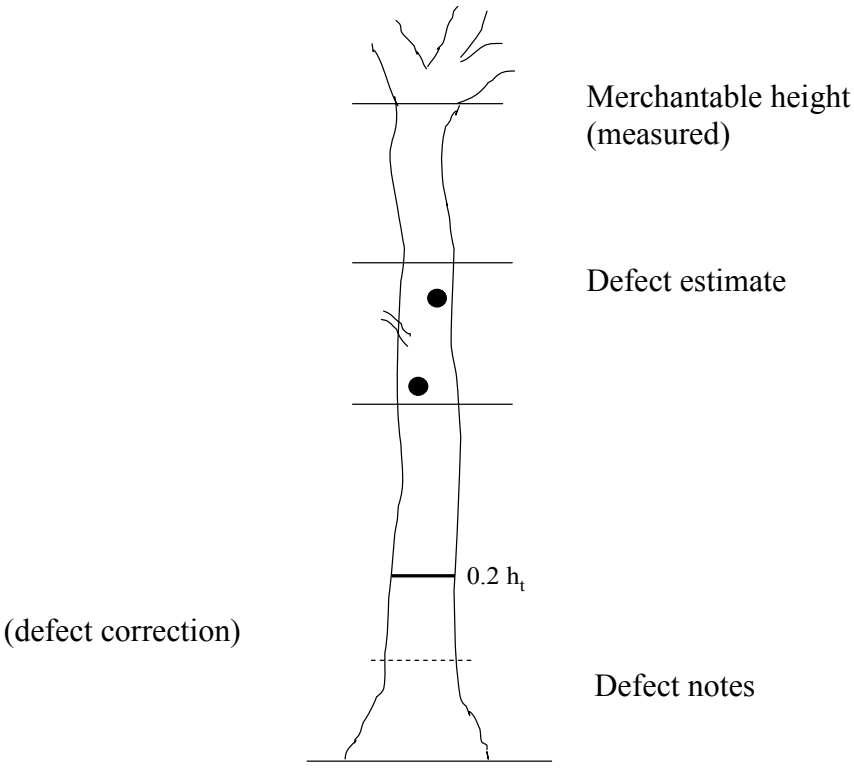


Figure 16.

The expanded, differentiated butt log method with a subdivided upper butt cut

The final method, presented by WIEGARD (1998) is the expanded, differentiated butt log method with a subdivided upper butt cut. This method offers more detailed measurements and takes into account that a tree may consist of several quality classes. In this method, the upper part is divided into two relative lengths. However, experience in the field has shown that this relative length is difficult to use. It is suggested that it is better to use the short-length method for the upper part, which means that the differentiated length of the upper part is based on the defect locations (Figure 16).

4.53 Defect definition

Quality is determined on the basis not only of dimensions but also of defects. These are differentiated into technical and internal defects. Indicators of technical defect are forks, leans, sweep and crook, spiral grain limbs and knots, which indicate the presence of reaction wood or decay or may impair the technical usability of the timber. Internal defects may be indicated by the presence of conks, suspect scars, lightning scars, dead or broken tops, forks or pronounced crooks, and logging and other scars due to harvesting (KÖHL, 1993).

In developing a good quality key for the quality assessment, each defect criteria must be clearly defined. This is in order to avoid the doubtful in determining the defects. The important defects used in this study are explained below:

Knots

Knots are branch bases embedded into the trunk, and because all trees have branch bases included in the trunk, knots are the most commonly encountered defects. Knots can adversely influence mechanical properties because of heterogeneity they introduce, and create stress concentrations due to interruption of the continuous, parallel arrangement of the trunk cell. Degree of strength reduction varies from significant to minimal depending on the size and quantity of knots (BARNETT and JERONIMIDIS, 2003). From standpoint of sawlog and veneer log production, size and frequency of knots is perhaps the single most important aspect of quality. Knots greatly affect both appearance and strength, and because of this their occurrence is a primary factor in determination of log and lumber grades (BOWYER, SHMULSKY and HAYGREEN, 2003). According to Indonesian National Standard Agency (BSN, 2000), a knot is a portion of a branch or limb that has been surrounded by subsequent

growth of the wood of the trunk or other portions of the tree. Its shape can be round or elongated. There are two kinds of knots, sound knots and decayed or dead knots. A sound knot is a knot that is solid across its face, at least as hard as the surrounding wood and shows no indication of decay. A decayed or dead knot is a knot that is softer than the surrounding wood due to advanced decay. It is easily broken and can become a hole. Knob/limb is a protrusion or swelling at one side of or surrounding the body of the tree. A knob is classified as a defect when the size is more than 3 cm and free from knots or former branches (BSN, 2000).

Holes

A hole is an old defect visible on the tree surface and caused by insects, larvae or marine worms (such as torode) (BSN, 2000).

Sweep/crook

Sweep and crook are short and long curves or bends along the tree body (BSN, 2000).

Groove

A groove is a long dent along the body of the tree. The defect is described with regard to the number and the depth of the grooves. Sweep/crook and groove are classified as shape defects (BSN, 2000).

Grain

The straight-grained wood products are, of course, always desired, but in reality grain deviations usually occurred. Deviations in grain from parallel to the longitudinal axis occur naturally in the tree, usually from knots, spiral or interlocked grain. The sloping grain can drastically reduce the strength of wood (BARNETT and JERONIMIDIS, 2003; BOWYER, SHMULSKY and HAYGREEN, 2003). The grain defect is measured based on the deviation of grain direction relative to the tree axis (BSN, 2000).

Decay/Wound/Cancer

Wood decay is caused mainly by specialized fungi, and involves a number of phases, most of which continue over a number of years. Wood decay represents an economic loss while, for the general public, the resulting risk of structural failure can be a considerable hazard to life and property as well perhaps reducing the aesthetic value of trees. The first external

indication of the presence of decay is the appearance of fruit bodies of the causal fungus on whichever part of the tree is affected. Most wood decay fungi begin their attacks at wounds which may be on the main stem, in the crown, or on roots. Cancer or tumour can be defined as proliferating masses of tissue which are formed from cells that have undergone a particular transformation which causes their growth to become disorderly and unregulated by the plant (BARNETT and JERONIMIDIS, 2003). Decay development in living trees is a disease. Dead branches, wounds, and root tissue appears to be the principal infection courts for many stem-decay fungi (ZHANG, 1997).

5 Results

5.1 Characterisation of stands

The description of horizontal and vertical distribution of species and tree sizes within a forest stand, as well as the stand structure can be generally characterized by the distribution of tree composition, diameter and basal area, height and crown closure, density, volume, biomass and weight.

5.11 Mean diameter

Trunk diameter is the most widely used descriptor of stand structure. Diameter may be summarized into a single parameter, usually the average diameter of the stand, or used to compute cross-sectional area and summed to yield an estimate of basal area

One of the common methods for expressing diameter is to calculate the mean diameter. The average diameter (Diameter at Breast Height–DBH) of a stand is best suited for characterizing diameter distribution and may be expressed by the arithmetic or the quadratic mean. The arithmetic mean diameter of the stand is:

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$$

where

d_i = diameter of the individual trees

N = number of the trees in the stand

The quadratic mean diameter of the stand is calculated from:

$$d_q = \sqrt{\frac{\sum_{i=1}^{n} d_i^2}{n}}$$

This quadratic mean diameter corresponds to the diameter of the tree with the mean basal area (d_g) derived from the arithmetic mean of the basal area at the breast height ($\bar{g}$) of all trees of the stand.

$$\bar{g} = \frac{\sum_{i=1}^{N} g_i}{N} = \frac{\sum_{i=1}^{k} n_i . g_i}{N} \; ; \; \bar{g} = \frac{\pi}{4} d_g^2 \; ; \; d_g = 2.\sqrt{\frac{\bar{g}}{\pi}}$$

The diameter of basal area corresponds to the square average value of all diameters of the stand.

$$d_g = \sqrt{\frac{\sum n_i . d_i^2}{N}}$$

The relation between arithmetic mean and quadratic mean is:

$$d_g^2 = \bar{d}^2 + S_d^2$$

WEISE (1880) introduced a rule of thumb for estimating the quadratic diameter (d_w) and proposed the 60th percentile of the ranked set of diameters (v. LAAR and AKÇA, 1997; KRAMER and AKÇA, 1995).

Another way to express average diameter is the mean diameter method of HOHENADL (d_-, d_+), which is the span of the standard deviation (S_d) above and below the arithmetic mean diameter (KRAMER and AKÇA, 1995). In forest stands with normally distributed diameters, approximately 68% of all trees are likely to be within the HOHENADL diameter limits.

Values of the mean diameter for trees with a dbh equal to or larger than 10 cm in each study area are given in table 14.

Table 14.

Mean diameters of forest stand in each study area, trees with dbh ≥ 10 cm

Study area	$\bar{d} \pm S_d$ **(cm)**	S_d **(%)**	d_g **(cm)**	$d_g - \bar{d}$ **(cm)**	d_w **(cm)**	$d_g - d_w$ **(cm)**	**Number of trees (N)**
Kamarora	41.6 ± 28.4	68.3	50.5	8.9	35.5	15.0	150
Kalimpaa	39.2 ± 22.8	58.2	45.1	5.9	37.1	8.0	300
B. Sombua	35.7 ±14.3	40.0	38.4	2.7	35.7	2.7	41
Wuasa	36.3 ± 20.2	55.6	41.5	5.2	34.1	7.4	132
Rompo	34.6 ± 17.9	51.7	39.0	4.4	32.6	8.4	378

According to v. LAAR and AKÇA (1997), the difference between the arithmetic and quadratic mean increases with increasing variance and with increasing mean diameter. The differences found in the study areas varied. The difference between the arithmetic and

quadratic means was 8.9 cm in Kamarora, 5.9 cm in Kalimpaa, 2.9 cm in Bulu Sombua, 5.2 cm in Wuasa and 4.4 cm in Rompo. Using 100 by 100 m plots in a location near the area of this study, BRODBECK (2004) found $\overline{d}$ and d_g differences of 2.6 cm in the natural forests of Kulawi, 4.8 cm in Kamarora and 5.4 cm in Rompo.

Although the value of d_w reached the 60th percentile of the ordered set of diameters, the results showed that d_w was lower than d_g and $\overline{d}$ in the entire study area except in Bulu Sombua, where d_w was similar to $\overline{d}$. However, only one plot has been observed and surveyed there. This condition is not surprising, since the frequency of trees with smaller diameters in unevenly aged forests is much higher than that of trees with larger diameters. This is an indication of the range of diameter distribution. Therefore, d_w remains, for the most part, smaller than $\overline{d}$.

Kamarora had the largest range of diameters – from 12.0 cm to 172.9 cm – and the diameters thus, of course, had the largest variance and standard deviation. Variance is a measure of the dispersion of individual unit values with respect to the mean of the entire sample: a large variance indicates wide dispersion. Another common statistical term is the coefficient of variation. In the opinion of AKÇA (2000), the coefficient of variation simplifies estimating and comparing variations in different populations because it is independent of the mean value. With the smallest range of diameters – from 16.3 cm to 77.4 cm – Bulu Sombua had the lowest coefficient of variation (40.0%). BRODBECK (2004) found that the coefficient of variation in the natural forests near the area of this study area varied between 53% and 72%. The coefficient of variation observed in this study ranged between 40.0% and 68.3%.

5.12 Diameter distribution

According to v. LAAR and AKÇA (1997), the diameter distribution of a stand is required to draw up stand tables, to estimate the total and merchantable stand volume, and to estimate the volume of the wide range of products, which are recovered from a stand of a given mean diameter and mean height. Stand diameter distribution may be represented mathematically by a probability density function. A number of functions have been used, at least on a trial basis, including normal, exponential, binomial, normal logarithmic, gamma, beta and Weibull distributions (HUSCH, et. al., 2003; v. LAAR and AKÇA, 1997).

MALIK (2002), using 30 by 30 m plots, and BRODBECK (2004), using 100 by 100 m plots, found that the diameter distribution in Central Sulawesi natural forests was characterized by a large number of trees in the small diameter classes and gradually decreasing numbers in the higher diameter classes. This distribution is known as the inverse J-shape diameter distribution and can be expressed as a negative exponential function (see also CEDERGREN et al., 2002; SUNDARAPANDIAN and SWAMY, 2000). The diameter distribution in this study exhibited a slightly different form, since the number of small trees (diameters less than 10 cm) was not as large as that of the trees in the diameter class from 20 to 30 cm. One must therefore analyse the diameter distribution in each study area separately.

Table 15.

Chi-square and Kolmogorow-Smirnow-test to compare the observed diameter distribution with the Chi-square and Weibull distributions in each study area

Area[a]	N	Skewed	Chi-square Goodness of Fit Test		KS- Test				
					Chi-square distribution		Weibull distribution		
			χ^2	p	χ^2	p	d	P	Lilliefors-p
1	150	2.417	283.841	0.000	0.390	<0.01	0.316	<0.01	<ns+
2	300	2.359	345.160	0.000	0.285	<0.01	0.266	<0.01	<ns+
3	41	1.036	6.113	0.106	0.212	<0.01	0.290	<0.01	<ns+
4	132	2.508	94.993	0.000	0.300	<0.01	0.258	<0.01	<ns+
5	378	1.826	299.166	0.000	0.297	<0.01	0.260	<0.01	<ns+

Note:
χ^2 = Chi-square value
d = the Kolmogorov-Smirnov test value
p = level of significance; + not significant; * p < 5%, ** p < 1%, *** p < 0.1%
a = study area (1. Kamarora; 2. Kalimpaa; 3. B. Sombua; 4. Wuasa; 5. Rompo)

With the large number of the trees in the diameter class between 20 and 30 cm in all study areas, the diameter distribution seems to be asymmetrical (skewed to the right with a of value 1 to 2.5, see Table 15). An asymmetrical distribution function is required for the numerical description of the diameter distribution. The Chi-square test and the Kolmogorov-Smirnov test (KS-test) are used to test goodness-of-fit of the data to the chosen distribution function. The KS-test is a non-parametric method used to compare the actual distribution of the observation data with the theoretical distribution. It is based on the maximum difference between the cumulative distribution of the sample and the hypothetical cumulative distribution. In the KS-test, the Lilliefors probabilities should be used to determine whether the difference is statistically significant. If the KS-test shows the difference to be statistically significant, the hypothesis that the observed data follow the chosen distribution should be

rejected (STATISTICA programme). The lower value of χ^2 the better fit of the function. Table 15 shows the results of skewed values and fitting test to Chi-square and Weibull distributions. The values for skewedness that range between 1.036 and 2.508 indicate that the diameter distributions are skewed to the right.

Of the numerous functions used to describe diameter distributions, the Weibull function has received the greatest attention. The Weibull distribution has been widely applied in forest mensuration because of its flexibility (HUSCH, et. al., 2003; SHIFLEY and LENTZ, 1985; see also SUNDAWATI, L, 2001; YAHYA, et al, 2003). The function has been successfully used for modelling the diameter distribution in even-aged stands and for decreasing diameter distribution in all-age forests, although no systems under stress are necessary involved (v. LAAR and AKÇA, 1997). As described in v. GADOW and BREDENKAMP (1992), a skewed distribution can be modelled using the Weibull model. The Weibull distribution is characterized by the density function and the cumulative distribution function can be presented as three and two parameter distributions.

The density function:

$$f(x) = \frac{c}{b} \cdot \left[\frac{x-a}{b} \right]^{c-1} \cdot e^{-\left(\frac{x-a}{b}\right)^c}$$

The cumulative distribution function:

$$f(x) = 1 - e^{-\left(\frac{x-a}{b}\right)^c}$$

where a = location parameter, expressing the lower boundary

b = scale parameter (b > 0)

c = shape parameter (c > 0)

The shape parameter (c) affects the shape of the density function. The density function can take on a variety of forms based on the value of c. Different values of the shape parameter can have marked effects on the behaviour of the distribution. The Weibull distribution will be symmetrical and similar to normal distribution when the value of c is 3.6. For c < 1 the shape will be an inverse J-shape, for c = 1 there will be an exponential decrease, and for 1 < c < 3.6 it be positive asymmetrical and for c over 3.6 negative asymmetrical (HUSCH, et. al., 2003).

Changing the scale parameter (b) will have the same effect on the distribution as a change of the abscissa scale. For example, the increasing the value of b while holding c constant has the effect of stretching out the distribution function. Since the area under a density function curve has a constant value of one, the "peak" of the curve will decrease when b is increased. As the name implies, the location parameter (a) locates the distribution along the abscissa. Changing the value of a, has the effect of "sliding" the distribution and its associated function to the right (if a > 0).

The *two-parameter distribution* is developed by setting the location parameter to zero (a = 0) (KRAMER and AKÇA, 1995). The parameters a, b and c are estimated using *the method of moment* – an alternative to the maximum likelihood method. This method, which offers the advantages of speed and simplicity, was successfully applied by SHIFLEY and LENTZ (1985).

Table 16.

Weibull parameter using "Method of Moment" for diameter distribution

Area	Three-parameter function			Two-parameter function	
	a	b	c	b	C
Kamarora	11.96	30.11	1.056	46.04	1.410
Kalimpaa	10.10	31.43	1.214	44.05	1.723
B. Sombua	16.21	21.33	1.320	40.19	2.608
Wuasa	12.00	25.90	1.285	40.88	1.834
Rompo	10.50	26.32	1.336	39.05	2.066

Table 16 shows the values of the parameters a, b and c from the tree diameter distributions in the study areas. With a value of c between 1.056 and 1.834 for the three-parameter functions, or 1.410 and 2.608 for two-parameter functions, the diameter distribution is positively skewed. With 1.056, Kamarora has the lowest value for c. This makes the shape of the distribution more skewed than in other areas. The opposite condition was found in Bulu Sombua and Rompo. These areas assumed as to have no or very little human disturbance. These areas have higher values for c than the others. With the c value of 1.320 and 1.336 for three parameter and 2.608 and 2.066 for two parameter distributions (2.608), the diameter distribution shape for both areas approached a more symmetrical distribution shape (Figure 17).

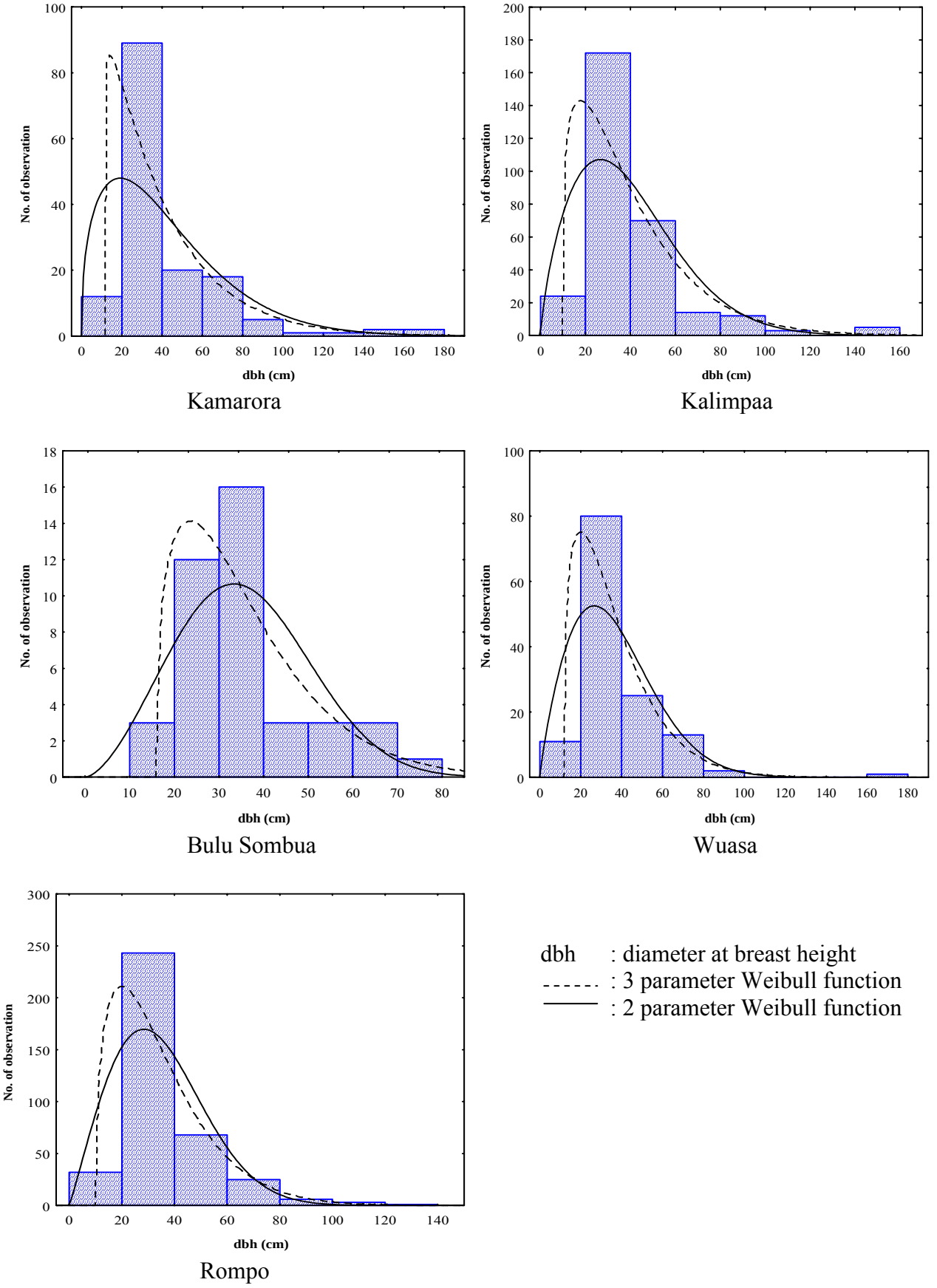


Figure 17.

Diameter distribution in each study area

It can be seen from the results that the values for a, b and c from each area are different because of the different stand structure. For areas categorized as disturbed areas, such as Kamarora, Kalimpaa and Wuasa, the distribution curves for the disturbed area (e.g. cutting, burning, rattan collecting, planting) deviate significantly from a symmetrical shape.

The values for a, b and c in one area can change over time, especially when the area is stressed by disturbances. These can be fire, drought, landslide, climatic variability, competition between trees and anthropogenic activities (e.g. illegal cutting, burning, planting). For example, based on measurements in the same plots in the Kamarora area at the end of the year 2000, the values of the parameters a, b and c were different from the values found in 2001.

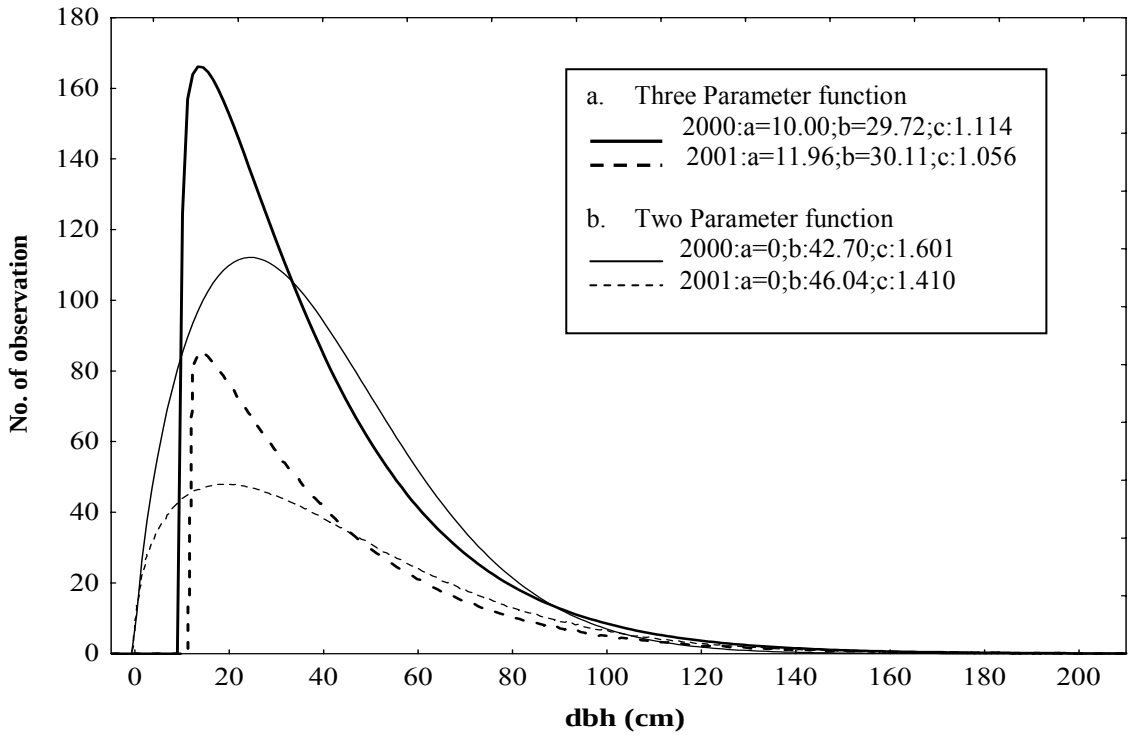


Figure 18.

Assessment of Weibull Parameters in Kamarora in 2000 and 2001

Figure 18 shows the different values of the parameters a, b and c in the years 2000 and 2001. One can see that in 2000, before forest destruction by human activities began in July 2001, the number of individual trees was much higher than after the destruction at the end of 2001. The value for c changed from 1.114 to 1.056 in the three-parameter model), and from 1.601 to 1.410 in the two-parameter model. In 2001, the shape of the diameter distribution was more

positively asymmetrical than in 2000. The change of value for c shows that the curve moves away from a symmetrical shape.

5.13 Stand height

Height is an important parameter in estimating individual trees and total stand volumes, increments and the site indexes of stands (HUSCH et al., 2003; VAN LAAR and AKCA, 1997).

5.131 Height distribution

Table 17 shows the skewedness, the goodness-of-fit test and test for fit to Chi-square and Weibull distributions. One can see that the height distribution is slightly asymmetrical and skewed to the right (skewedness between 0.312 and 0.980). The results of KS-test shows, the height distributions in Kamarora, Wuasa and Rompo deviate significantly from a symmetrical shape. The results for Kalimpaa and Bulu Sombua show that both areas deviate slightly and the distributions are close to symmetrical shape.

Table 17. Chi-square Goodness-of-Fit Test and KS-Test to adjust the observed height distribution with Chi-square and Weibull distribution in each study area

Area[a]	N	Skewed	Chi-square Goodness of Fit Test		KS- Test				
					Chi-square distribution		Weibull distribution		
			χ^2	P	χ^2	P	d	p	Lilliefors-p
1	150	0.980	76.255	0.000	0.193	< 0.01	0.232	< 0.01	<ns+
2	300	0.312	66.022	0.000	0.087	< 0.05	0.251	< 0.01	<ns+
3	41	0.467	2.121	0.346	0.128	< n.s	0.319	< 0.01	<ns+
4	132	0.821	54.683	0.000	0.124	< 0.05	0.288	< 0.01	<ns+
5	378	0.981	81.507	0.000	0.110	< 0.01	0.253	< 0.01	<ns+

Note:
χ^2 = chi-square value
d = the value of Kolmogorov-Smirnov Tests
p = level of significance; + not significant; * p < 5%, ** p < 1%, *** p < 0.1%
a = study area (1. Kamarora; 2. Kalimpaa; 3. B. Sombua; 4. Wuasa; 5. Rompo)

Table 18 shows the value of the parameters a, b and c for the height distribution in each study area. With values of c ranging between 1.601 and 2.494 (three-parameter model), and 2,410 and 3.135 (two-parameter model), the height distributions are positively skewed.

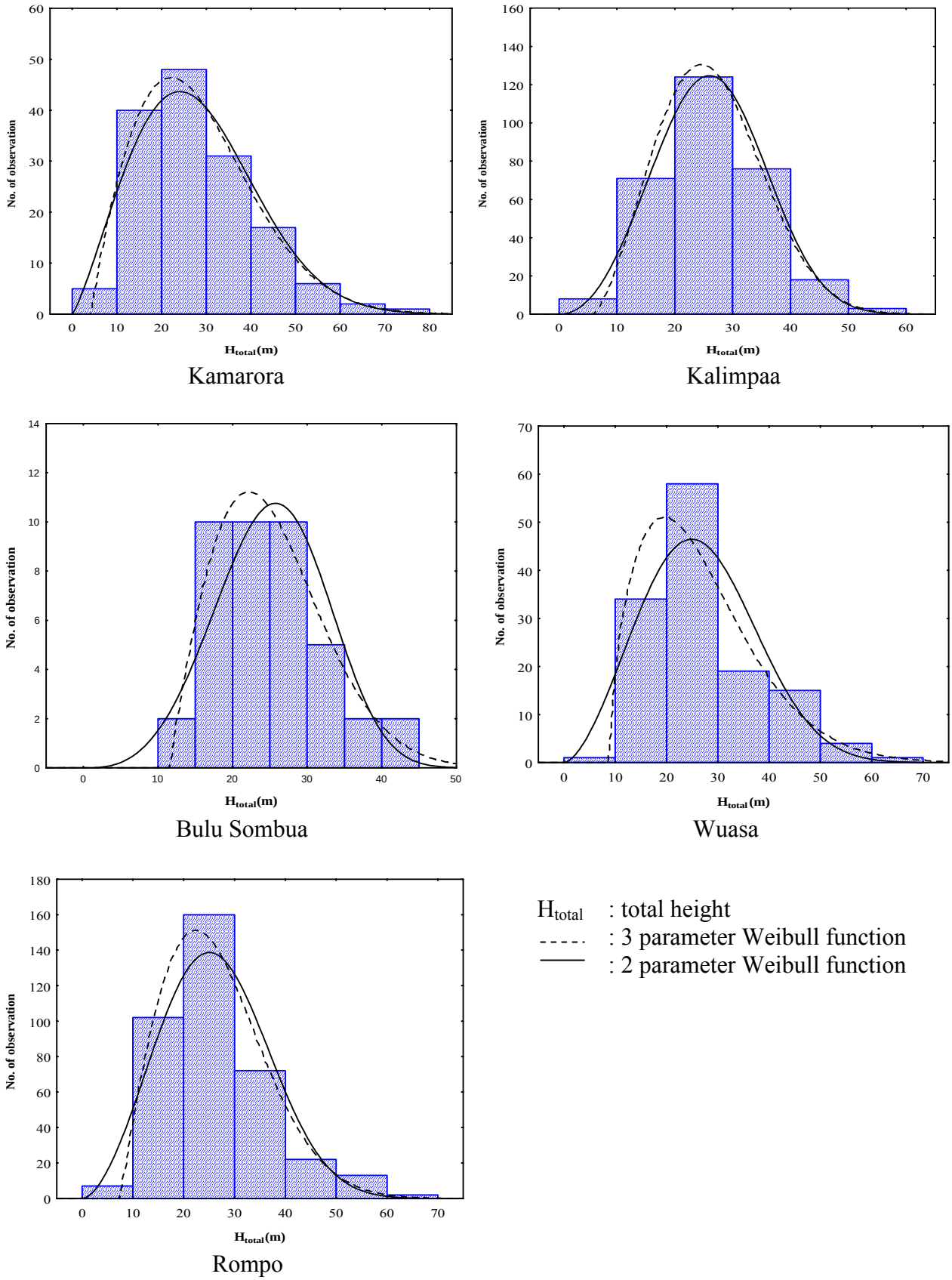


Figure 19.

Height distribution in each study area

Based on two parameter functions, a different result was found in Bulu Sombua. The value for c was 3.831 giving a negatively skewed height distribution. Overall, based on the value of the parameter c, the height distribution curves appeared to be more symmetrical than the diameter distribution curves (see also Figure 19).

Table 18.

Weibull-parameter using 'Method of Moment' for height distribution

Area	Three parameters			Two parameters	
	a	b	c	b	c
Kamarora	4.19	26.78	1.890	31.61	2.212
Kalimpaa	5.75	23.16	2.494	29.37	3.135
B. Sombua	11.56	15.40	1.945	27.88	3.831
Wuasa	8.88	19.72	1.601	29.88	2.629
Rompo	7.40	21.34	1.984	29.58	2.731

5.132 Fitting stand height curves

It is time consuming to measure the heights of all trees in a stand. Therefore, the tree height determination is based on representative measurements of a limited number of trees. The determination of tree height is facilitated by the relatively strong stochastic relationship between the diameter at breast height and tree height in a stand for each tree species. A stand height curve gives the relationship between tree diameter and height in a stand that can be employed as a graph, a table or a formula (KRAMER and AKÇA, 1995). A stand height curve represents the relationship between tree height and tree diameter can be presented as a plot of height against diameter or as an equation. This can be used to predict the height of a tree when only the diameter is known (BRACK, 1999).

A variety of equations have been proposed to fit height curves. A second-degree parable has been used very often as a stand height curve, as have logarithmic equations, which is the simplest stand height curve equation. But neither of them were suitable for stands with widely disperse diameters. KORSUN and FREESE functions are also often used for stand height curves but neither of them are asymptotic to the abscissa. PRODAN and PETTERSON functions fit to all aged and strongly structured stands. Those functions are characterized by an inflection point and have asymptotic properties. The PETTERSON function is especially well suitable for all-aged stand with a wide diameter class dispersion (KRAMER and AKÇA, 1995).

Table 19.

Six stand height equations

1. Second-degree parable	$h = A + B \cdot d + C \cdot d^2$
2. Prodan	$h = 1.3 + \frac{d^2}{A + B.d + C.d^2}$
3. Petterson	$h = 1.3 + \left(\frac{d}{A + B.d}\right)^2$
4. Korsun	$h = e^{(A+B.\ln d + C.(\ln d)^2)}$
5. Logarithmic equation	$h = A + B \cdot \ln d$
6. Freese	$h = e^{(A+B.\ln d + C.d)}$

in which:

h	= tree height	ln	= natural logarithm
d	= tree diameter	e	= 2.7182818 (base of nature logarithm)
A, B, C	= regression coefficients		

All living trees with a diameter class equal to or larger than 10 cm in the five study areas and six common stand height curve equations were used to predict the heights of the trees based on diameter measurements.

V. LAAR and AKÇA (1997) stated that the fitted curve should satisfy certain requirements. The equation should increase monotonously with increasing dbh, the standard deviation should be as low as possible and R^2 should be as high as possible.

All equations were fitted using the Gauss-Newton method of the STATISTICA non-linear least square procedure (nonlinear estimation and fixed non-linear regression; STATISTICA, release 6). Equations were compared using the R^2 value and root mean square error (RSME) calculated as:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(yi - \hat{y}i)^2}{\sum_{i=1}^{n}(yi - \bar{y})^2} \quad ; \quad RSME = \sqrt{\frac{\sum(yi - \hat{y}i)^2}{n}}$$

Where n is the number of observations, y is the measured height, $\hat{y}i$ is the estimated height, and $\bar{y}$ is the average of the measured height.

Table 20 gives the values of R^2 and RMSE from each height equation. One can see that the values resulting from each equation for the total and merchantable heights in each study area do not differ significantly. There was no indication that the R^2 values increased when more complex equations were used. The higher R^2 values and the lower RSME values can still not indicate that the observed data can be fitted to the function. Therefore, the correct function is also selected using a graph, which shows the observed diameters and heights as well as the function curve.

Table 20.

Comparison of stand height equations by study area

Equation		Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
h_{total}						
1	R^2	0.649	0.539	0.793	0.644	0.594
	RMSE (m)	7.7	6.2	3.3	6.4	6.5
2	R^2	0.650	0.547	0.795	0.636	0.574
	RMSE (m)	7.7	6.1	3.3	6.4	6.5
3	R^2	0.651	0.547	0.794	0.633	0.587
	RMSE (m)	7.6	6.1	3.3	6.5	6.6
4	R^2	0.651	0.548	0.795	0.636	0.598
	RMSE (m)	7.6	6.1	3.3	6.4	6.5
5	R^2	0.643	0.543	0.792	0.627	0.588
	RMSE (m)	7.7	6.1	3.3	6.5	6.6
6	R^2	0.652	0.547	0.795	0.640	0.597
	RMSE (m)	7.6	6.1	3.3	6.4	6.5
$h_{merchantable}$						
1	R^2	0.508	0.272	0.329	0.557	0.373
	RMSE (m)	5.3	6.4	4.1	4.5	5.4
2	R^2	0.522	0.337	0.333	0.557	0.369
	RMSE (m)	5.2	6.1	4.1	4.5	5.4
3	R^2	0.501	0.294	0.333	0.549	0.373
	RMSE (m)	5.3	6.3	4.1	4.6	5.4
4	R^2	0.522	0.320	0.333	0.557	0.374
	RMSE (m)	5.2	6.2	4.1	4.5	5.4
5	R^2	0.496	0.288	0.335	0.539	0.374
	RMSE (m)	5.4	6.3	4.1	4.6	5.4
6	R^2	0.518	0.299	0.331	0.557	0.374
	RMSE (m)	5.3	6.3	4.1	4.5	5.4

The value of R^2 for total height in Kamarora ranged from 0.643 to 0.652 with an RSME between 7.6 and 7.7, while, for merchantable height, R^2 ranged from 0.496 to 522 and RSME from 5.2 to 5.4. With the R^2 and RSME values of 0.651 of 7.6, respectively, for total height), 0.501 and 5.3, respectively, for merchantable height, the Petterson equation showed a better performance than the other equations. Therefore, this equation will be used as the stand height equation for trees in the Kamarora area.

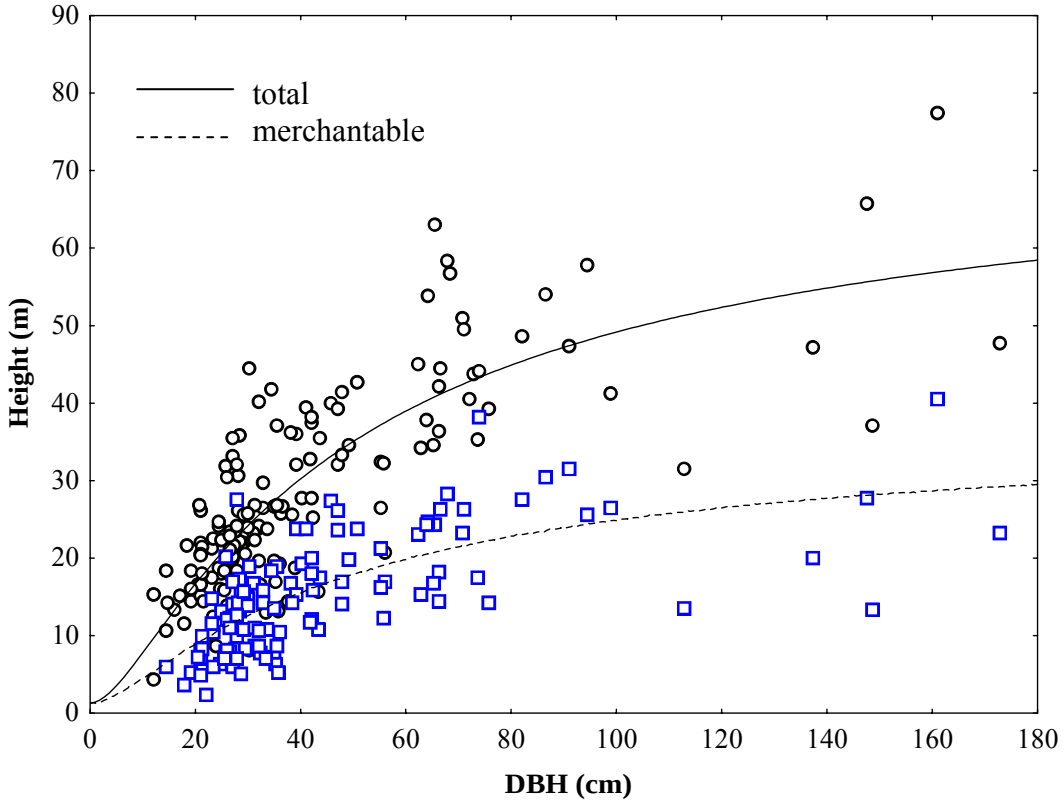


Figure 20.

Total and merchantable height curves in the Kamarora area using the Petterson equation

Similar results were also found in the Kalimpaa, Bulu Sombua and Wuasa areas. With relatively high values for R^2 and low values for RSME, the PETTERSON equation is also suitable for those areas. The RSMEs in the study areas are considerable high, because of the high number of tree species. The coefficients of the PETTERSON equation in Kamarora, Kalimpaa, Bulu Sombua and Wuasa are given in Table 21.

Table 21.

The coefficients of the PETTERSON equation

Area	Total Height		Merchantable Height	
	A	B	A	B
Kamarora	2.759	0.117	3.941	0.166
Kalimpaa	2.099	0.139	3.181	0.174
Bulu Sombua	2.529	0.129	3.077	0.190
Wuasa	2.593	0.120	4.164	0.146

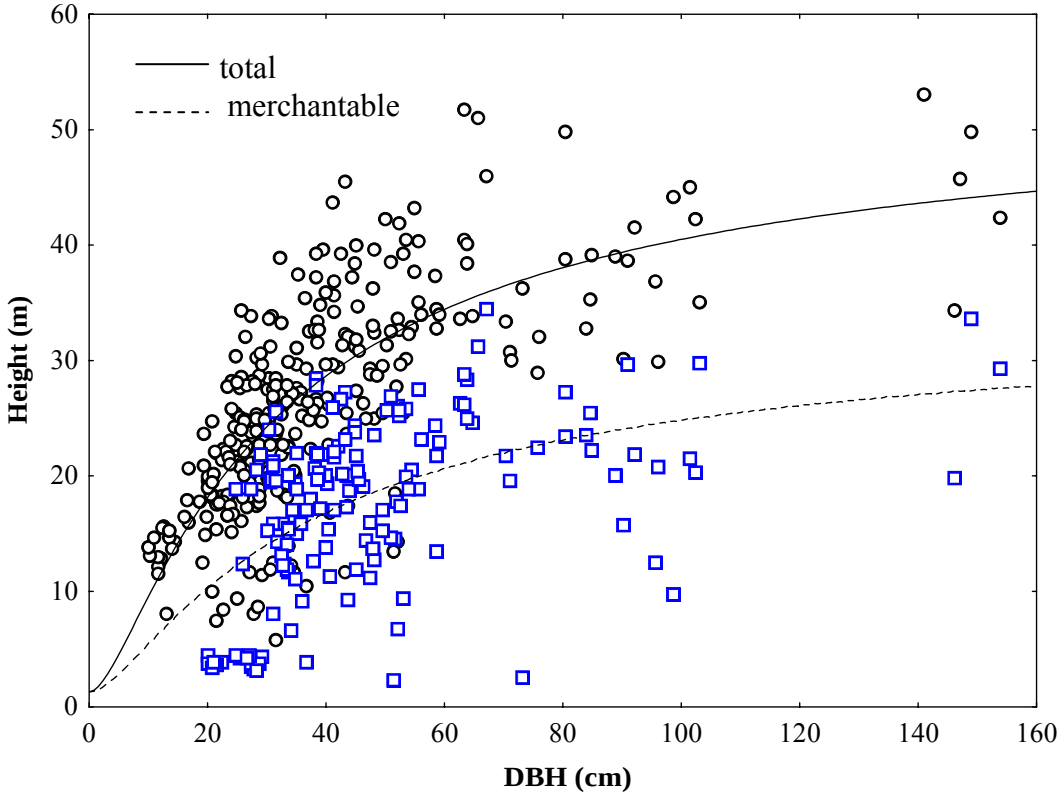


Figure 21.

Total and merchantable height curves in the Kalimpaa area using the Petterson equation

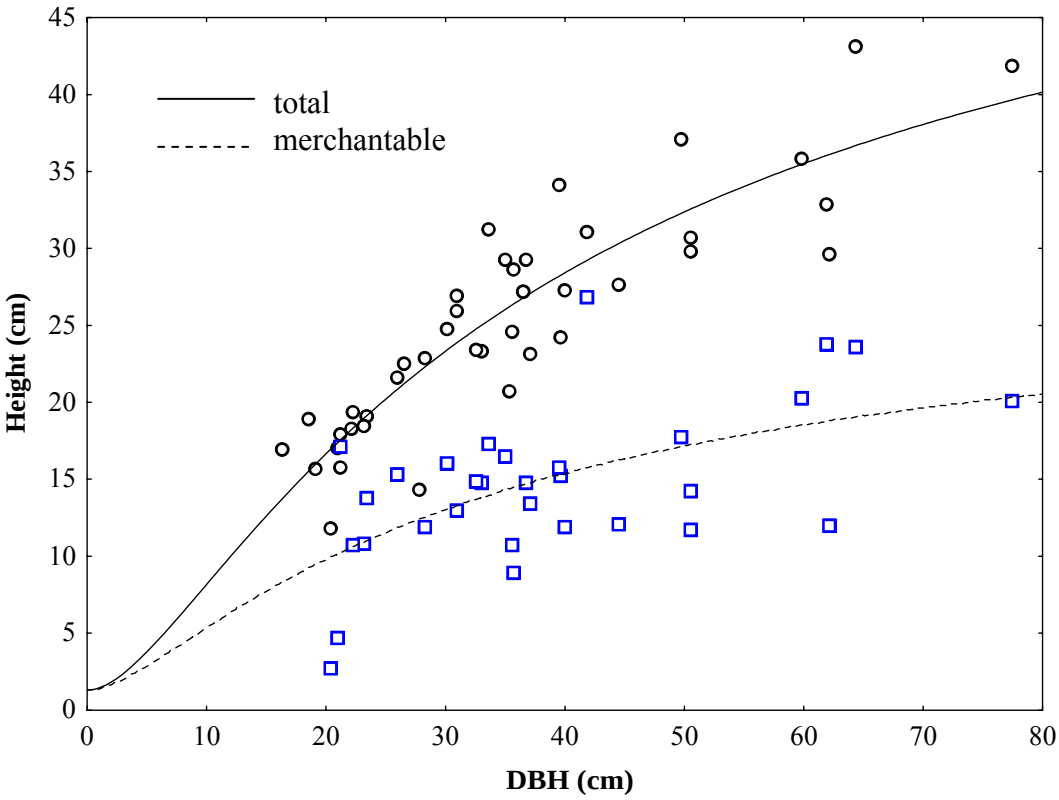


Figure 22.

Total and merchantable height curves in the Sombua area using the Petterson equation

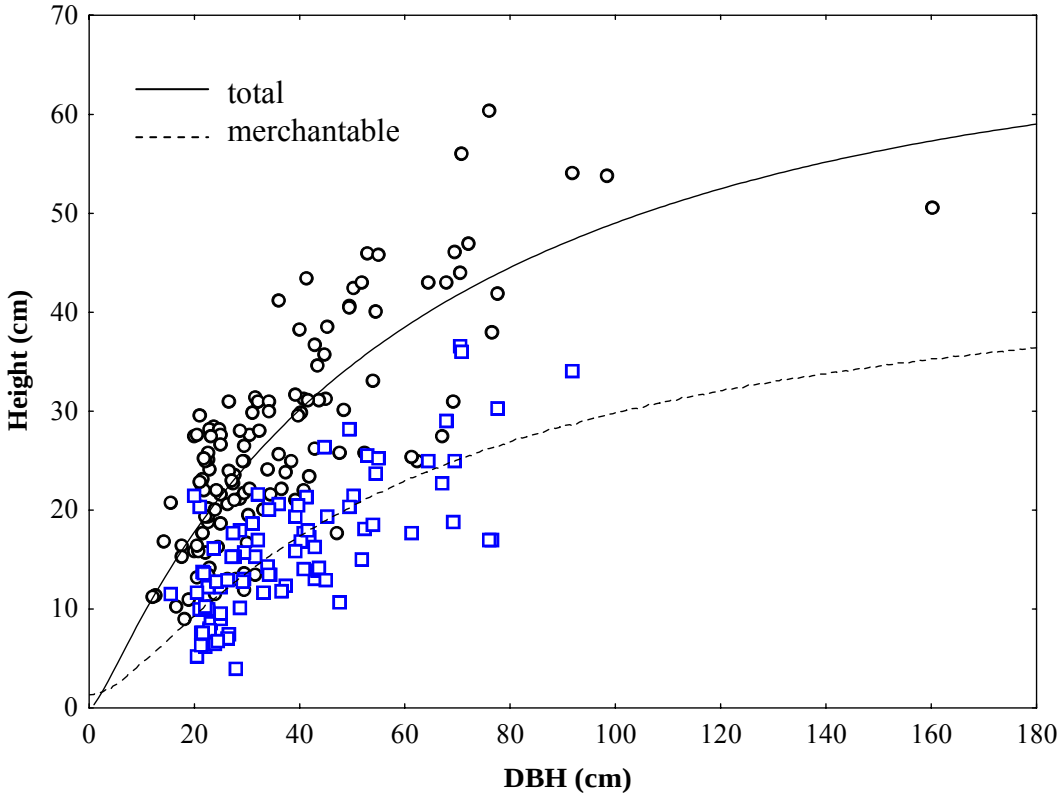


Figure 23.

Total and merchantable height curves in the Wuasa area using the Petterson equation

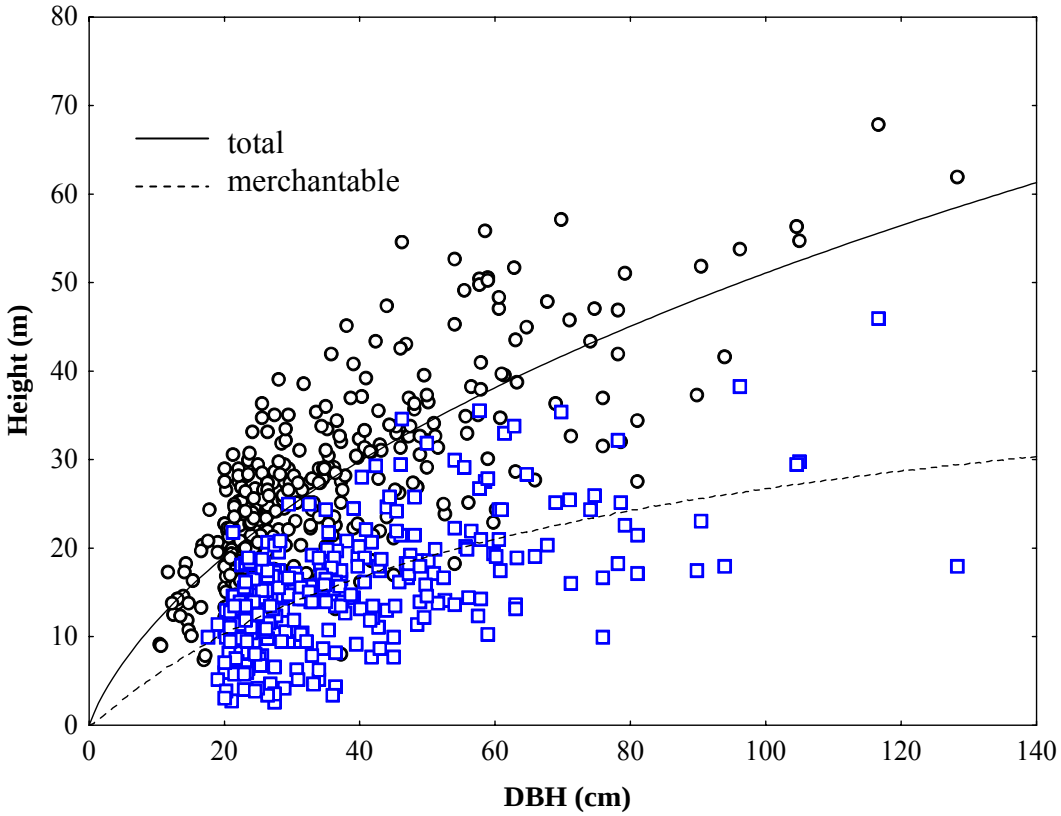


Figure 24.

Total and Merchantable height curves in the Rompo area using the Korsun equation

With R^2 and RSME values of 0.598 and 6.51, respectively for total height, and 0.374 and 5.4, respectively for merchantable height, the KORSUN equation gives slightly better values than the other function in the Rompo area. The graph also fits the observed data well, and gives better performance in this area than others. Therefore, the KORSUN function was chosen for Rompo. The function is given below:

Total height	$h = e^{(0.609135+0.889936*\ln(d)-0.036486*(\ln d)^2)}$
Merchantable Height	$h = e^{(-0.966228+1.432241*\ln(d)-0.110530*(\ln d)^2)}$

The stand height curve can also be used to compare the height of trees in different study areas. As shown in Figure 25, calculations using the PETTERSON function show that with the same diameter class, the trees in Kamarora are, as a whole, higher than those in the other areas, followed by the trees in Wuasa, Rompo, Bulu Sombua and Kalimpaa. Although it was only observation and not significantly tested, but the result is very interesting, since it shows that trees of similar diameter seems taller in lowland forests than those in hill and lower montane forests.

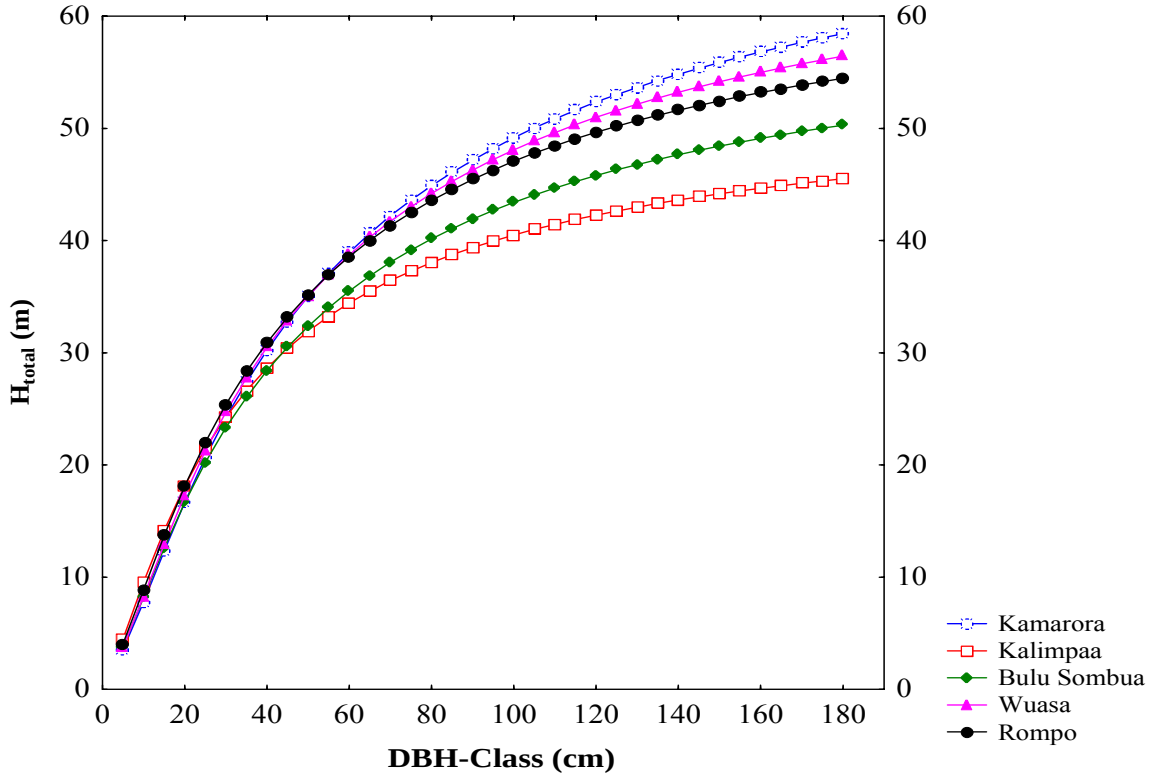


Figure 25.

Stand height curve using the Petterson equation for all trees in all study areas

The stand height curves are usually fitted on a species-wise basis. Since more than 40 species were found in each study area (except in Bulu Sombua with 7 and Kalimpaa with 28), the stand height curve on a species-by-species basis is difficult to fit. However, a better fit can be attained using the tree families. In this study, for example, the stand height curve was fitted for the Fagaceae family located in Kalimpaa. With 149 sample trees, the R^2 values of the Fagaceae family ranged between 0.469 and 0.505, and RSME between 5.7 and 5.9 for all functions. With an R^2 of 0.497, an RSME of 5.705, the PETTERSON function gave a better fit in this case, as well.

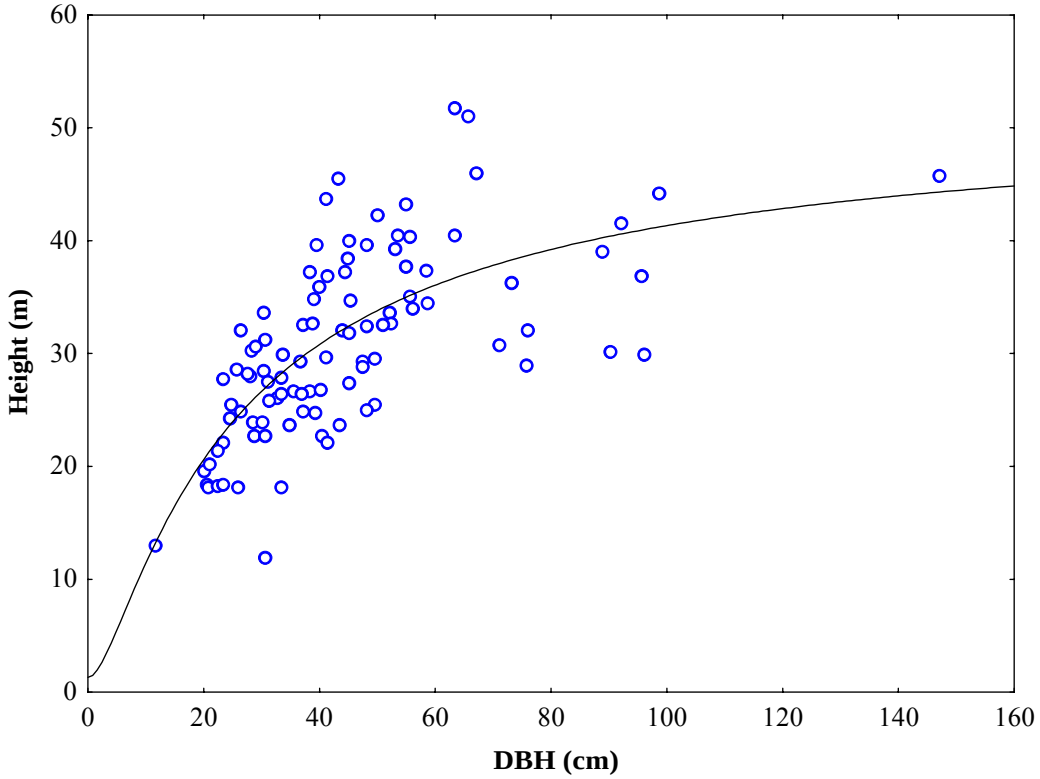


Figure 26.

Stand height curve using the PETTERSON equation for the Fagaceae family

5.133 Mean height

The mean height of the stand is required to estimate the volume of the trees and the volume per hectare using the square of the mean diameter (v. LAAR and AKÇA, 1997). According to KRAMER and AKÇA (1995), the mean height of a stand can be estimated using regression analysis of the observed heights and the corresponding diameters as discussed in chapter 5.11. Several common measures of mean height are:

$h_{\bar{d}}$ height corresponding to the arithmetic mean diameter $\bar{d}$

h_g height corresponding to the mean basal area or the quadratic mean diameter d_g or d_q

h_w height corresponding to the WEISE mean diameter d_w

Table 22.

Mean stand height in each study area, d ≥ 10 cm

Area	Total height			Merchantable height		
	h_w (m)	$h_{\bar{d}}$ (m)	h_g (cm)	h_w (m)	$h_{\bar{d}}$ (m)	h_g (cm)
Kamarora	27.8	31.2	35.6	14.5	16.6	19.2
Kalimpaa	26.7	29.1	32.0	15.5	17.7	20.0
B. Sombua	26.3	29.1	32.7	14.4	15.7	17.3
Wuasa	26.9	30.1	34.2	14.8	16.6	19.0
Rompo	30.4	30.8	34.7	15.4	16.9	19.0

Table 22 shows the mean stand height for each study area. The different measures of mean height follows the order of $h_w < h_{\bar{d}} < h_g$ for total height in all study areas. With 31.2 m for total height and 21.2 m for merchantable height, the Kamarora area had the highest stand mean height, followed by Rompo, Wuasa, Kalimpaa and B. Sombua. The results also indicate that the mean heights of trees in lowland forest areas are higher than those in uphill and lower montane forests. WHITTEN, et al. (2002) stated that the canopy height for lowland forests ranges between 25 and 45 m, while that in lower montane forests ranges between 15 and 33 m.

5.14 Volume equation

Until recently, single tree and stand volumes were estimated in Indonesia using the general equation:

$$V = f(d, h, f)$$

$$V = ¼\pi .d^2.h.f$$

in which : V = volume (m^3)

d = diameter at breast height (cm)

h = tree height (m)

f = form factor (0.7)

and this equation is used for all tree species in Indonesian tropical forests. The form factor of a tree or stem is defined as the tree or stem volume expressed as a fraction of the volume of a cylinder of the same height with a diameter equal to the stem diameter at the selected reference points:

$$f = \frac{\text{Tree or stem volume}}{\text{cylinder volume}}$$

The false, or breast height, form factor is conventionally used for computational purposes, for example, to estimate stem volume from tree basal area, tree height and stem form factor (v. LAAR and AKÇA, 1997). A form factor of 0.7 is still used in Indonesia for practical reasons, and it is known as an exploitation coefficient. The form factors of some species have been determined. For Shorea spec. in East Kalimantan it varies between 0.4 and 0.7 (MADRIN and JOHANSYAH, cited in SOEDIRMAN, 1989), and for ebony or Diospyros celebica Bakh. in Central Sulawesi it lies between 0.37 and 0.69 (MALIK, 2002). The average false form factors in the study areas were examined in order to get a realistic range of form factor values. The form factors of some important families are given in Table 23.

Table 23.

The form factors for total and merchantable volume of common sample trees by family bases in the study area

Family	**n**[1)]	**Form factor**		**Location**
		$f_{1.3}$ (h_{total})[2)]	$f_{1.3}$ ($h_{merch.}$)[3)]	
Fagaceae	149	0.49	0.68	Kalimpaa
Aquifoliaceae	49	0.49	0.65	Kalimpaa
Lauraceae	31	0.54	0.74	Rompo
Sapotaceae	35	0.47	0.64	Rompo
Verbenaceae	34	0.49	0.61	Rompo
Burseraceae	38	0.58	0.79	Rompo
Meliaceae	20	0.47	0.72	Rompo
Myrtaceae	26	0.53	0.79	Kalimpaa
Myristicaceae	20	0.48	0.67	Rompo
Anacardiaceae	23	0.45	0.65	Rompo
Others	vary between 0.48 and 0.70			

Note : 1) n = number of the sample trees
2) $f_{1.3}$ (h_{total}) = the false form factor using the total height measurement
3) $f_{1.3}$ ($h_{merch.}$) = the false form factor using the merchantable height measurement

The commonly used form factor of 0.7 for merchantable volume was not used in this study, but instead five regression models using the sample trees in the Kalimpaa and Rompo areas (see Chapter 4.4) were analysed.

The 'true' volume of each sample tree (V_j) was calculated from the sum of section volume:

$$V_j = \sum_{i=1}^{n} v_i$$

in which:

v_i = volume of the i^{th} section (in m^3);

where the volume of each section is calculated by the "SMALIAN'S" formulae :

$$v_i = \frac{(B_{li} + B_{si})}{2}.l_i$$

in which:

v_i = volume of the i^{th} section in m^3

B_{li} = cross-sectional area of large end of the i^{th} section in m^2

B_{si} = cross-sectional area of small end of the i^{th} section in m^2

l_i = length of the i^{th} section

Following commercial and non-commercial classifications, the sample trees from Rompo (n=378) representing the lowland and uphill forests, and Kalimpaa (n=300) for lower montane forests, will be used for the model. These areas were selected because of their species composition, which is quite representative, and because the forests were in good condition.

The selection of the volume equation is based on the correlation between tree volume and other measured parameters. Tables 24 to 27 show that there is a highly significant linear correlation between volume, diameter, and height. The form factor has a very weak linear correlation with volume, diameter and height.

Table 24.

The correlation matrix for volume, diameter, height and form factor in Rompo (n = 378)

Variable	V	d	h_t	f
V	1.000	0.765	0.874	-0.115
d	0.765	1.000	0.752	0.030
h	0.874	0.752	1.000	0.029
f	-0.115	0.030	0.029	1.000

Table 25.

The correlation matrix for volume, diameter, height and form factor in Kalimpaa (n = 300)

Variable	V	d	h_t	f
V	1.000	0.678	0.869	-0.094
d	0.678	1.000	0.578	-0.069
h	0.869	0.578	1.000	-0.042
F	-0.094	-0.069	-0.042	1.000

Table 26.

The correlation matrix for volume, diameter, height and form factor for commercial trees in Rompo (n = 212)

Variable	V	d	h_m	f
V	1.000	0.879	0.738	-0.008
d	0.879	1.000	0.594	-0.136
h	0.738	0.594	1.000	-0.001
F	-0.008	-0.136	0.001	1.000

Table 27.

The correlation matrix for volume, diameter, height and form factor for commercial trees in Kalimpaa (n = 127)

Variable	V	d	h_m	f
V	1.000	0.868	0.456	0.004
d	0.868	1.000	0.474	-0.149
h	0.456	0.474	1.000	-0.367
f	0.004	-0.149	-0.367	1.000

where: V = volume in m^3
d = diameter in cm at 1.3 m for regular trees and ± 20 cm above irregular part for irregular trees
h_t = total height in m
h_m = merchantable height in m
f = false form factor

Table 28 shows that the precision of the model does not increase significantly with the inclusion of additional independent variables in the Rompo area. However, for the Kalimpaa area one can see that including additional independent variables significantly affects the precision of the model.

The selection method was performed as described in chapter 4.43. The first step was to compare the value of R^2 (see also R^2 adjusted). If many independent variables are incorporated into a model, R^2 always increases. However, this also makes the model more instable. The adjusted R^2 takes account for the increasing number of variables.

Table 28.

The statistical values of the regression models for all sample trees in Rompo (n = 378) and Kalimpaa (n = 300)

Volume Model	R^2	R^2 adjusted	R	Sy.x (m^3)	F
ROMPO					
1. $V = b_0 + b_1 d^2 h$	0.903	0.903	0.950	1.02	3492.48
2. $V = b_0 + b_1 h + b_2 dh + b_3 d^2 h$	0.911	0.910	0.955	0.98	1277.51
3. $V = b_0 + b_1 dh + b_2 d^2 + b_3 d^2 h$	0.917	0.916	0.956	0.95	1373.80
4. $V = b_0 + b_1 d^2 + b_2 d^2 h + b_3 dh^2 + b_4 h^2$	0.916	0.916	0.957	0.95	1021.81
5. $V = b_0 + b_1 d + b_2 dh + b_3 d^2 h + b_4 d^2 h^2$	0.917	0.916	0.958	0.95	1029.08
KALIMPAA					
1. $V = b_0 + b_1 d^2 h$	0.855	0.855	0.925	2.01	1762.74
2. $V = b_0 + b_1 h + b_2 dh + b_3 d^2 h$	0.899	0.899	0.948	1.59	1320.53
3. $V = b_0 + b_1 dh + b_2 d^2 + b_3 d^2 h$	0.910	0.909	0.954	1.50	994.22
4. $V = b_0 + b_1 d^2 + b_2 d^2 h + b_3 dh^2 + b_4 h^2$	0.916	0.915	0.957	1.45	805.74
5. $V = b_0 + b_1 d + b_2 dh + b_3 d^2 h + b_4 d^2 h^2$	0.927	0.926	0.963	1.36	925.98

n = number of sample trees

At the next step, a stepwise variable selection method is used to obtain the optimal model. If a large number of independent variables are used in the model, the probability increases. But this coefficient does not give the correlation between independent variables. Models with fewer independent variables are usually preferred above others, since they compensate better for the negative effects of outliers (SOEDIRMAN, 1995) and an additional advantage of a model with few predictor variables is the suppression of variation inflation (v. LAAR and AKCA, 1997) (Chapter 4.4). Therefore, the simple model is better[1].

Table 29.

The results of stepwise variable selection (optimal model)

Volume Models	Variable in model	Variable not significant
ROMPO		
1. $V = b_0 + b_1 d^2 h$	d^2h	-
2. $V = b_0 + b_1 h + b_2 dh + b_3 d^2 h$	dh; d^2h	h
3. $V = b_0 + b_1 dh + b_2 d^2 + b_3 d^2 h$	dh; d^2h	d^2
4. $V = b_0 + b_1 d^2 + b_2 d^2 h + b_3 dh^2 + b_4 h^2$	d^2; d^2h; h^2	dh^2
5. $V = b_0 + b_1 d + b_2 dh + b_3 d^2 h + b_4 d^2 h^2$	dh; d^2h	d; d^2h^2
KALIMPAA		
1. $V = b_0 + b_1 d^2 h$	d^2h	-
2. $V = b_0 + b_1 h + b_2 dh + b_3 d^2 h$	dh; d^2h	h
3. $V = b_0 + b_1 dh + b_2 d^2 + b_3 d^2 h$	dh; d^2h; d^2	-
4. $V = b_0 + b_1 d^2 + b_2 d^2 h + b_3 dh^2 + b_4 h^2$	d^2; d^2h; dh^2; h^2	-
5. $V = b_0 + b_1 d + b_2 dh + b_3 d^2 h + b_4 d^2 h^2$	d; d^2h; d^2h^2	dh

[1] AKÇA (personal communication, July 2004)

As can be seen in Table 29, dh and d^2h are the correct variables to be used in regression models in the Rompo area, while d^2 and d^2h should be used in Kalimpaa. But, the simplicity of the model must also be considered during the selection phase. Therefore, the first model was selected for the Rompo area and the fourth model for Kalimpaa.

The volume function for all trees in both areas:

ROMPO :

$$Vol = 0.318221 + 0.000030\ DBH^2h_{total}$$

Table 30.

Analysis of variance of the related model.

Effect	Sums of squares	df	Mean squares	F
Regression	3666.894	1	3666.894	3492.484**)
Residuals	394..777	376	1.050	
Total	4061.671	377		

**) highly significant

KALIMPAA:

$$Vol = 1.024245 - 0.000644\ DBH^2 + 0.000031\ DBH^2h_{total} + 0.000079\ DBHh_{total}^2 - 0.002897\ h^2_{total}$$

Table 31.

Analysis of variance of the related model.

Effect	Sums of squares	df	Mean squares	F
Regression	6787.645	4	1696.911	805.7377**)
Residuals	619.174	294	2.106	
Total	7406.819	298		

**) highly significant

The same procedure was also performed for commercial trees using merchantable height as the height variable in the model. The results of the statistical analysis are shown in Table 30.

The results show that using an additional diameter measurement as an independent variable had a significant effect on the increase of R-square values in both areas. Based on these values, stepwise procedure and model simplicity, the model with the diameter at 10 m height together with diameter at breast height and merchantable height as independent variables gave better performance than the other models and is suitable for use in merchantable volume estimation.

Table 32.

Statistical analysis of the regression models for all commercial trees in Rompo (n = 212) and Kalimpaa (n = 127)

Volume Model	R^2	R^2 adjusted	R	Sy.x (m^3)	F
ROMPO					
1. $V = b_0 + b_1 d^2 h_{merch}$	0.922	0.922	0.960	0.85	2496.52
2. $V = b_0 + b_1 d_5 dh_{merch}$	0.926	0.926	0.962	0.83	2622.67
3. $V = b_0 + b_1 d_7 dh_{merch}$	0.930	0.930	0.964	0.80	2782.79
4. $V = b_0 + b_1 d_{10} dh_{merch}$	0.934	0.933	0.966	0.78	2959.96
5. $V = b_0 + b_1 d_{0.67hmerch} dh_{merch}$	0.803	0.802	0.896	1.35	857.14
6. $V = b_0 + b_1 d^2 + b_2 d^2 h_{total} + b_3 dh_{total}^2 + b_4 h_{total}^2 + b_5 d^2 h_{merch}$	0.951	0.949	0.975	0.68	793.22
KALIMPAA					
1. $V = b_0 + b_1 d^2 h_{merch}$	0.879	0.878	0.938	1.79	909.22
2. $V = b_0 + b_1 d_5 dh_{merch}$	0.877	0.876	0.936	1.81	887.13
3. $V = b_0 + b_1 d_7 dh_{merch}$	0.885	0.884	0.941	1.75	958.22
4. $V = b_0 + b_1 d_{10} dh_{merch}$	0.897	0.896	0.947	1.65	1088.76
5. $V = b_0 + b_1 d_{0.67hmerch} dh_{merch}$	0.807	0.805	0.898	2.27	522.51
6. $V = b_0 + b_1 d^2 + b_2 d^2 h_{total} + b_3 dh_{total}^2 + b_4 h_{total}^2 + b_5 d^2 h_{merch}$	0.913	0.910	0.956	1.54	254.41

Table 33.

The results of stepwise variable selection (optimal model)

Volume models	Variable in model	Variable not significant
ROMPO		
1. $V = b_0 + b_1 d^2 h_{merch}$	$d^2 h_{merch}$	-
2. $V = b_0 + b_1 d_5 dh_{merch}$	$d_5 dh_{merch}$	-
3. $V = b_0 + b_1 d_7 dh_{merch}$	$d_7 dh_{merch}$	-
4. $V = b_0 + b_1 d_{10} dh_{merch}$	$d_{10} dh_{merch}$	-
5. $V = b_0 + b_1 d_{0.67hmerch} dh_{merch}$	$d_{0.67hmerch} dh_{merch}$	-
6. $V = b_0 + b_1 d^2 + b_2 d^2 h_{total} + b_3 dh_{total}^2 + b_4 h_{total}^2 + b_5 d^2 h_{merch}$	$d^2 h_{total}$; $d^2 h_{merch}$	d^2; h_{total}^2 ; dh_{total}^2
KALIMPAA		
1. $V = b_0 + b_1 d^2 h_{merch}$	$d^2 h_{merch}$	-
2. $V = b_0 + b_1 d_5 dh_{merch}$	$d_5 dh_{merch}$	-
3. $V = b_0 + b_1 d_7 dh_{merch}$	$d_7 dh_{merch}$	-
4. $V = b_0 + b_1 d_{10} dh_{merch}$	$d_{10} dh_{merch}$	-
5. $V = b_0 + b_1 d_{0.67hmerch} dh_{merch}$	$d_{0.67hmerch} dh_{merch}$	-
6. $V = b_0 + b_1 d^2 + b_2 d^2 h_{total} + b_3 dh_{total}^2 + b_4 h_{total}^2 + b_5 d^2 h_{merch}$	d^2; $d^2 h_{total}$; $d^2 h_{merch}$	h_{total}^2 dh_{total}^2

The volume function for all trees in both areas:

ROMPO :

$$Vol = 0.404455 + 0.000048\ D_{10m} DBH h_{merchantable}$$

Table 34.

Analysis of variance of the related model.

Effect	Sums of squares	df	Mean squares	F
Regression	1804.553	1	1804.553	2959.962**)
Residuals	128.027	210	0.610	
Total	1932.581			

**) highly significant

KALIMPAA:

$$Vol = 0.304918 + 0.000052\ D_{10m}DBHh_{merchantable}$$

Table 35.

Analysis of variance of the related model.

Effect	Sums of squares	df	Mean squares	F
Regression	2979.681	1	2979.681	1088.759**)
Residuals	342.096	125	2.737	
Total	3321.77			

**) highly significant

5.15 Number of trees and stand basal area

After species identification, all living trees were classified into commercial and non-commercial trees. Table 36 shows the number of trees per hectare in each area after the classification.

Table 36.

Number of trees per ha with diameter ≥ 10 cm (N/Ha), Standard deviation (S_x), standard error ($S_{\bar{x}}$) and coefficient of variation (V%).

Location	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
All trees					
$\bar{x}$	125	225	336*	183	258
S_x	93.16	50.96		34.74	61.80
$S_{\bar{x}}$	29.9	15.4		15.3	17.8
V%	74	22.6		19	24
Commercial trees					
$\bar{x}$	88	172	336*	107	188
S_x	70	57.44		38.71	56.19
$S_{\bar{x}}$	23.6	17.3		15.8	16.2
V%	84.7	33		36	30
Non-commercial trees					
$\bar{x}$	37	53	0	73	73
S_x	28.14	34.31		18.26	28.82
$S_{\bar{x}}$	8.9	10.3		7.5	8.3
V%	80	65		25	39

* Only one plot

The entire sample plot area was approximately 13.2 ha (45 sample plots) and the total basal area occupied by the sample trees with more than 10 cm dbh was 146.4 m^2. The sample plot

areas at each location were Kamarora 3.3 ha, Kalimpaa 3.6 ha, Sombua 0.3 ha, Wuasa 2.0 ha and Rompo 4.0 ha. One hundred and fifty sample trees were measured in Kamarora with 30.1 m^2 basal area; 300 trees in Kalimpaa with a basal area of 48.6 m^2, 41 trees in Sombua with 4.7 m^2 basal area. There were 132 trees with a basal area of 17.9 m^2 in Wuasa, and 378 trees in Rompo with 45.1 m^2 basal area.

The average number of trees per hectare differed significantly between the locations. One can see that Kamarora, the area with the most severely disturbed conditions, had the lowest number of trees with the highest standard deviation, standard error and coefficient of variation. This is understandable when one considers that some plots in this area had been completely cleared while others contained many trees. The number of trees ranged between 8 and 309 per hectare. Whereas the number of trees per hectare in the Kalimpaa area ranged between 153 and 323 trees, the number in Wuasa was between 145 and 241 trees and in Rompo between 148 and 383 trees.

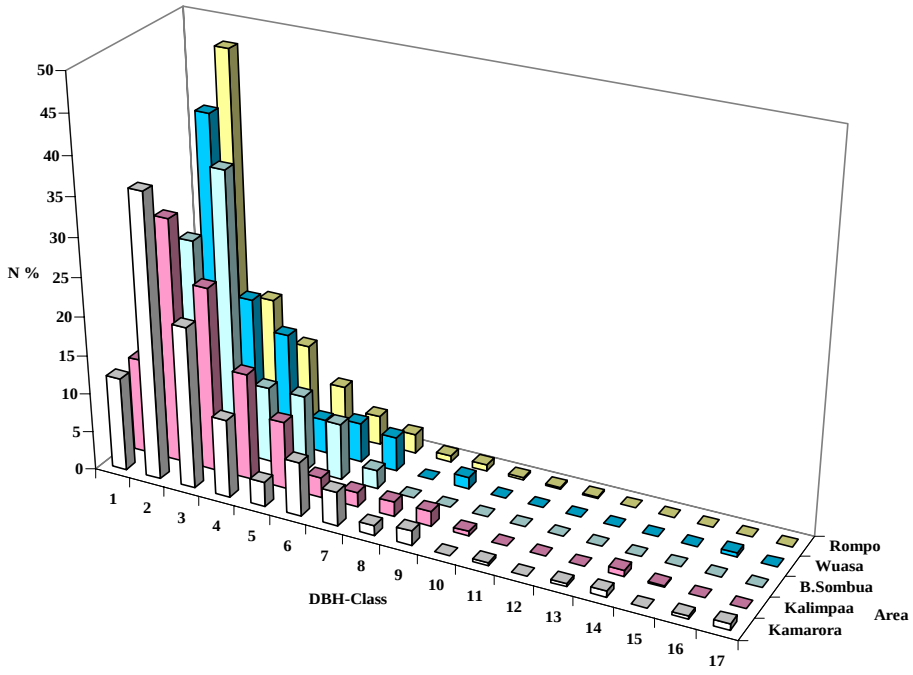


Figure 27 .
The relative number of trees in each DBH class in each sample area

DBH-Class	1	2	3	4	5	6	7	8	9
DBH (cm)	10-19.9	20-20.9	30-30.9	40-49.9	50-50.9	60-69.9	70-70.9	80-89.9	90-99.9

DBH-Class	10	11	12	13	14	15	16	17
DBH (cm)	100-109.9	110-119.9	120-129.9	130-139.9	140-149.9	150-159.9	160-169.9	170-179.9

Figure 27 give a summary of the diameter class distribution of all trees ≥ 10 cm diameter for all study areas. The largest number of trees per hectare for all species present was mainly in the DBH-class 20-29.9 cm. In Kamarora, 36.1 % of all trees fell within this class, while the numbers were 31.2% in Kalimpaa, 43.5% in Wuasa and 47% in Rompo. Only Bulu Sombua seems to differ slightly, since 36.6% of the trees were in the diameter class 30-39.9 cm and only 26.8% in the class 20-29.9 cm.

The total basal area of all trees, or of specified classes of trees, per unit area is a useful characteristic of forest stands. The basal area is directly related to stand volume and biomass, and is a good measure of stand density and competition. This parameter also incorporates the number of trees in a stand and their diameters (HUSCH, 2003). The stand basal area (*G*) can be computed by summing all cross-sectional areas of trees contained in a stand with the following equations:

$$G = \sum_{i=1}^{N} g_i \qquad \text{where} \qquad g_i = \frac{\pi}{4}.d_i^2$$

The stand basal area measured in this study varied between 20.81 and 38 m^2/ha. According to BRODBECK (2003) the stand basal area in some natural forests in Central Sulawesi varies between 31.6 and 33.1 m^2/ha (for trees ≥ 10 cm). MALIK (2002) reported that the stand basal area in the natural forests of Central Sulawesi with selective cutting system management varied between 21.5 and 25.29 m^2/ha.

Table 35 also shows that the coefficient of variation of the basal area for all commercial and non-commercial trees was higher in the Kamarora area than in the other study areas. The basal area per hectare for all trees in this area ranged between 2.5 and 65 m^2. This result was due to the presence of some trees with very large diameters, and the total absence of trees in parts of the plot (severely disturbed). Other areas only had a relatively low variation: Kalimpaa between 11 m^2 and 64 m^2, Wuasa 9.5 m^2 to 41.8 m^2 and Rompo 18.4 to 42.8 m^2.

The highest stand basal area (area of the cross section at breast height of all trees) in all sample areas was in the diameter classes between 20 and 70 cm. Sixty-two percent of the stand basal area in Kamarora was within these diameter classes. Meanwhile, it was 68% in

Kalimpaa, 97.2% in Bulu Sombua, 86.8% in Wuasa and 82.8% in Rompo. A detailed account of the relative number of the trees and stand basal area is given in Appendix 12-15.

Table 37.

Basal area per ha (m^2/ha), standard deviation (S_x), standard error ($S_{\bar{x}}$) and coefficient of variation (V%).

Location	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
All trees					
$\bar{x}$	20.81	32.46	38**	22.83	30.18
S_x	20.15	12.98		13.05	7.04
$S_{\bar{x}}$	6.4	3.9		5.3	2.0
V%	97	40		57	23
Commercial trees					
$\bar{x}$	17.81	28.82	38**	15.12	23.79
S_x	19.27	12.91		11.75	7.14
$S_{\bar{x}}$	6.1	3.9		4.8	2.1
V%	108	44.8		77.7	30
Non-commercial trees					
$\bar{x}$	2.69	3.55	0	7.68	6.01
S_x	2.29	2.59		3.72	2.19
$S_{\bar{x}}$	0.7	0.8		1.5	0.6
V%	85	73		48	36

** Only one plot

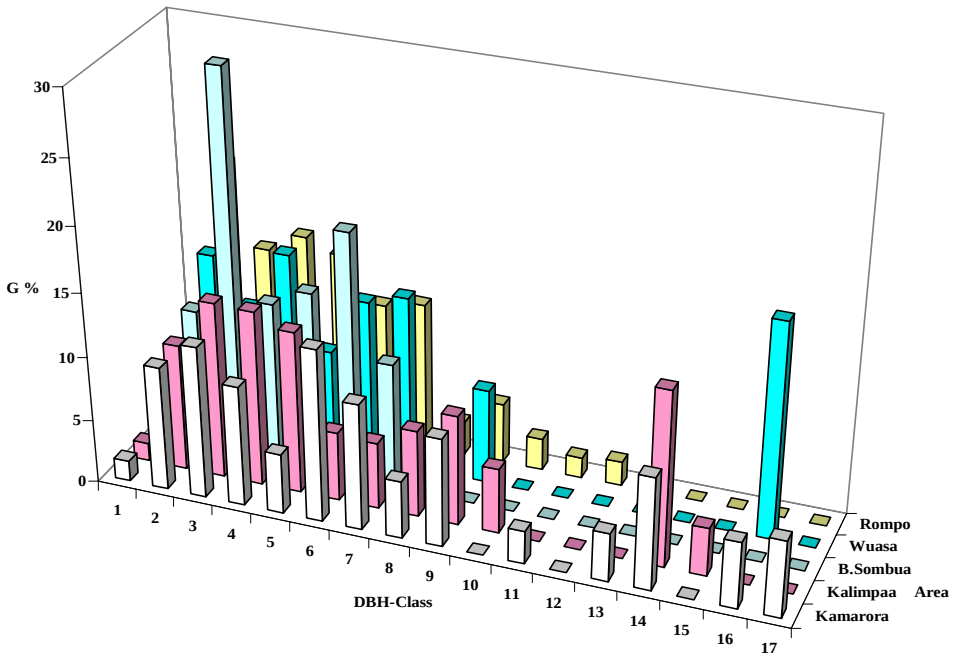


Figure 28.

The relative stand basal area in the DBH-classes in each sample area

5.16 Stand volume estimation

Stand volume is the most important parameter in stand inventories. It is a function of the number of trees, their individual or total basal area, individual or mean height and the individual or the average form of the trees (v. LAAR and AKÇA, 1997). Since the sample plots in this study consisted of three concentric rings each with a different radius but from the same plot centre (5 m, 20 m and 25 m), the volume per hectare for each diameter class can be calculated using the equations below:

$$\text{TVOL (10 - 20)} = \text{VOL (10-20)} \times 12.7 \ (m^3\text{; over bark})$$
$$\text{TVOL (20-100)} = \text{VOL (20-100)} \times 8.0 \ (m^3\text{; over bark})$$
$$\text{TVOL (> 100)} = \text{VOL (> 100)} \times 5.1 \ (m^3\text{; over bark})$$

where:

TVOL (10 – 20) ….etc. = Volume per hectare for diameter class (10-20cm)…. etc.

VOL (10 - 20) ….etc. = Sum of the standing trees in sample plot for diameter class (10-20 cm)…etc.

Table 38.

Volume per ha with diameter ≥ 10 cm (m^3/ha), standard deviation (S_x), standard error ($S_{\bar{x}}$) and coefficient of variation (V%).

Location	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
All trees					
$\bar{x}$	365	533	598	376	487
S_x	352.67	304.03		248.17	161.61
$S_{\bar{x}}$	111.52	91.67		101.31	46.65
V%	97	57		66	33
Commercial trees					
$\bar{x}$	313	483	585	255	388
S_x	343.15	306.37		212.36	135.19
$S_{\bar{x}}$	108.51	92.37		86.70	39.03
V%	110	63		83	35
Non-commercial trees					
$\bar{x}$	52	50	13	121	99
S_x	39.66	28.35		55.98	56.94
$S_{\bar{x}}$	12.54	8.55		22.85	16.44
V%	68	57		46	57

** only one plot

The mean stand volume in the study areas varied between 365 and 598 m^3/ha. These results are very similar to the values of 460 to 550 m^3/ha found by BRODBECK (2003) in natural forests of Central Sulawesi. However, MALIK (2002) found somewhat different conditions in production forests also located in Central Sulawesi, where the stand volumes were lower with values between 389.4 and 438.4 m^3/ha.

The results also show that the volume in commercial trees is concentrated in diameters between 20 and 100 cm. Large differences were found between the volumes of commercial and non-commercial trees in all study areas.

The volume distributions according to diameter classes in the Rompo and Kalimpaa areas are given in the Tables 40 and 41. One can see from these tables that the volume of commercial trees was distributed evenly over all diameter classes, between 1.7 and 16.1% in Rompo and 1.4 and 21.7% in Kalimpaa. Different conditions were found for non-commercial trees, for which the volume distribution was concentrated in the diameter classes below 60 cm (88.3% in Rompo and 99.8% in Kalimpaa).

Table 39.

Total volume (V_t) for commercial (V_c) and non-commercial (V_{nc}) trees (m^3/ha and %) in Kamarora, Kalimpaa, Bulu Sombua, Wuasa and Rompo

Location	TVOL (10-20) cm	TVOL (20-100) cm	TVOL (> 100) cm	TOTAL
Kamarora				
V_t	6.7(1.8%)	250.4(68.6%)	107.7(29.5%)	365(100.0%)
V_c	5.2(1.7%)	199.6(63.9%)	107.7(34.4%)	313(100.0%)
V_{nc}	1.5(2.9%)	50.8(97.1%)	0.0(0.0%)	52(100.0%)
Kalimpaa				
V_t	16.1(3.0%)	411.9(77.3%)	104.6(19.6%)	533(100.0%)
V_c	6.6(1.4%)	371.6(77.0%)	104.6(21.7%)	483(100.0%)
V_{nc}	9.5(19.1%)	40.4(80.9%)	0.0(0.0%)	50(100.0%)
B. Sombua				
V_t	13.0(2.2%)	585.2(97.8%)	0.0(0.0%)	598(100.0%)
V_c	13.0(2.2%)	585.2(97.8%)	0.0(0.0%)	598(100.0%)
V_{nc}	0.0(0.0%)	0.0(0.0%)	0.0(0.0%)	0.0(0.0%)
Wuasa				
V_t	8.9(2.4%)	333.5(88.7%)	33.4(8.9%)	376(100.0%)
V_c	3.8(1.5%)	217.6(85.4%)	33.4(13.1%)	255(100.0%)
V_{nc}	5.1(4.2%)	115.9(95.7%)	0.0(0.0%)	121(100.0%)
Rompo				
V_t	11.6(2.4%)	434.7(89.2%)	40.8(8.4%)	487(100.0%)
V_c	6.5(1.7%)	340.6(87.8%)	40.8(10.5%)	388(100.0%)
V_{nc}	5.1(5.1%)	94.1(94.8%)	0.0(0.0%)	99(100.0%)

Table 40.

Total volume (V_{tot}) and potentially usable volume ($V_{merch.}$) for commercial and non-commercial trees in the Rompo area (m^3/ha and %)

	DBH-Class										
V_{tot}	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**	**≥100**	**Total**
Comm											
m^3/ha	6.5	62.5	35.6	52.7	50.0	49.4	49.2	14.8	26.4	40.8	388
%	1.7	16.1	9.2	13.6	12.9	12.7	12.7	3.8	6.8	10.5	100
Non-Comm											
m^3/ha	5.1	25.1	18.9	11.8	20.0	6.8	0.0	1.5	10.1	0.0	99
%	5.2	25.2	19.0	11.9	20.1	6.9	0.0	1.5	10.2	0.0	100
Total											
m^3/ha	11.6	87.6	54.5	64.5	70.0	56.2	49.2	16.3	36.5	40.0	487
%	2.4	18.0	11.2	13.2	14.4	11.5	10.1	3.3	7.5	8.4	100
$V_{merch.}$											
Comm											
m^3/ha	6.3	56.9	29.9	44.0	42.3	41.8	35.6	11.2	19.8	28.0	316
%	2.0	18.0	9.5	13.9	13.4	13.2	11.3	3.5	6.3	8.9	100

Table 41.

Total volume (V_{tot}) and potentially usable volume ($V_{merch.}$) for commercial and non-commercial trees in the Kalimpaa area (m^3/ha and %)

	DBH-Class										
V_{tot}	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**	**≥100**	**Total**
Comm											
m^3/ha	6.6	30.3	51.9	60.5	65.5	39.8	25.2	47.0	51.4	104.6	482
%	1.4	6.3	10.8	12.5	13.6	8.2	5.2	9.7	10.6	21.7	100
Non-Comm											
m^3/ha	9.5	12.6	7.4	8.4	6.8	5.0	0.0	0.0	0.0	0.0	50
%	19.1	25.2	14.9	16.9	13.7	10.1	0.0	0.0	0.0	0.0	100
Total											
m^3/ha	16.1	42.9	59.4	68.9	72.3	44.8	25.2	47.0	51.4	104.6	533
%	3.0	8.1	11.1	12.9	13.6	8.4	4.7	8.8	9.6	19.6	100
$V_{merch.}$											
Comm											
m^3/ha	4.5	26.7	48.2	47.6	47.9	27.4	21.5	34.6	41.2	70.5	370
%	1.2	7.2	13.0	12.9	13.0	7.4	5.8	9.3	11.1	19.0	100

5.16 Species composition

HUSCH et al. (2003) stated that the species present in a stand have always been an important parameter in describing forest stands. Different species represent not only different forest products and values, but are also important indicators of wildlife habitat, site quality, and disturbance history. Typically, foresters express species composition as the distribution of individuals among the different species present in a stand. Species composition may be expressed using number of individuals, basal area, or volume and can be either the sum of

these parameters or a percentage of the total. From an ecological perspective, species composition can be viewed as having three components: frequency, abundance and dominance. Frequency is the number of units in the sample area in which a species is found. Abundance is the number of individuals in a population, and dominance is an expression of the size of individuals in a population. The "important value" is a parameter that has been widely used as a measure of species composition that combines frequency, abundance and dominance (GREIG-SCHMIDT, 1957):

$$Ij = 100\left(\frac{nj}{N} + \frac{dj}{D} + \frac{xj}{X}\right)$$

where Ij = important value of jth species

nj = number of trees in the sample where jth species is present

N = total number in the sample

dj = number of individuals of jth species present in sample population

D = total number of individuals in sample population ($D = \sum dj$)

xj = sum of size parameter (generally basal area or volume) for jth species

X = total of size parameter across all species ($X = \sum xj$)

nj/N = relative frequency

dj/D = relative density

xj/X = relative dominance

A total of 50 species from 29 tree families was found inside the sample plot in Kamarora. As shown in Table 42, the important values for *Ficus* spec. and *Octomeles sumatrana* Miq are higher than for other trees. But, in this case, this does not mean that these species are dominant species in this area. Kamarora is a lowland forest, and according to WHITTEN (2002), the lowland forests in Sulawesi are not dominated by one single family or tree. The presence of *Ficus* spec. and *Octomeles sumatrana* Miq within the observed plots is more closely related to the size of the trees. The trees from these families were left standing and were not being cut by humans, because the trees are mostly very large (large diameter and great height) and difficult to cut. Therefore, these trees were left standing and were usually used as shelter trees for coffee and cacao plantations, which are mostly planted on the forest floor in the Kamarora area.

Table 42.

The species found in Kamarora listed by their Important Value, d ≥ 10 cm (3.3 ha)

No.	Scientific Name	*Nj*	*nj/Nj*	*dj*	*dj/D*	*xj*	*xj/X*	*Ij*
1	*Ficus* spec.	5	3.3	4	4.0	6.38	21.2	28.5
2	*Octomeles sumatrana* Miq.	10	6.5	2	2.0	4.99	16.5	25.0
3	*Palaquium obovatum* (Griff.) Engler	7	4.6	5	5.1	1.95	6.5	16.2
4	*Dysoxylum* spec.	8	5.2	4	4.0	1.52	5.0	14.2
5	*Alstonia spectabilis* R. Br.	4	2.6	2	2.0	2.46	8.2	12.8
6	*Horsfieldia glabra* Warb.	10	6.5	4	4.0	0.62	2.1	12.6
7	*Pterospermum* spec.	6	3.9	3	3.0	1.53	5.1	12.0
8	*Litsea albyana* Vidal.	8	5.3	4	4.0	0.56	1.8	11.1
9	*Neonauclea* spec.	6	3.9	4	4.0	0.69	2.3	10.2
10	*Cryptocarya* spec.	7	4.6	3	3.0	0.42	1.4	9.0
11	*Alophyllus cobbe*	5	3.3	3	3.0	0.65	2.2	8.5
12	*Phoebe cuneata* Bl.	4	2.6	4	4.0	0.44	1.4	8.0
13	*Canarium hirsutum* Wild.	4	2.6	2	2.0	0.84	2.8	7.4
14	*Erythrina variegata* L.	3	2.0	3	3.0	0.67	2.2	7.2
15	*Cananga odorata* Hook. f.	5	3.3	1	1.0	0.75	2.5	6.8
16	*Macadamia hidelbrandii* Steen.	4	2.6	3	3.0	0.31	1.0	6.6
17	*Pleomele angustifolia* N.E.Br.	4	2.6	2	2.0	0.32	1.1	5.7
18	*Cyathocalyx* spec.	3	2.0	3	3.0	0.20	0.7	5.7
19	*Euphoria malaiensis* Radlk.	3	2.0	3	3.0	0.11	0.4	5.4
	Species : 19	106	69	59	59	25.00	84	213
	Total Species : 50	153	100	99	100	30.12	100	300

Table 43.

The species found in Kalimpaa listed by their Important Value, d ≥ 10 cm (3.6 ha)

No.	Scientific Name	*nj*	*nj/Nj*	*dj*	*dj/D*	*xj*	*xj/X*	*Ij*
1	*Castanopsis* spec.	72	24.0	11	11.7	13.73	28.3	64.0
2	*Ilex cymosa* Bl.	49	16.3	10	10.6	10.21	21.0	48.0
3	*Lithocarphus celebicus* (Miq) Rehd.	25	8.3	7	7.4	5.19	10.7	26.5
4	*Litsea albayana* Vidal	22	7.3	10	10.6	1.27	2.6	20.6
5	*Eugenia clavimyrtus* K. et. V	24	8.0	8	8.5	1.84	3.8	20.3
6	*Calophyllum soulattri* Burm.f	12	4.0	7	7.4	1.24	2.6	14.0
7	*Kibara* spec.	16	5.3	6	6.4	0.85	1.8	13.5
8	*Eucalyptus deglupta* Bl.	2	0.7	2	2.1	3.61	7.4	10.2
9	Palaka (local name)	9	3.0	4	4.3	1.31	2.7	10.0
10	*Erythrina variegata*.L.	3	1.0	1	1.1	2.58	5.8	7.9
11	*Ixora* spec.	7	2.3	4	4.3	0.53	1.1	7.7
12	*Cyathocalyx* spec.	11	3.7	3	3.2	0.35	0.7	7.6
13	*Alstonoia spectabilis* R.Br.	10	3.3	2	2.1	0.91	1.9	7.4
14	*Ficus* spec.	11	3.7	1	1.1	1.10	2.3	7.0
	Species : 14	273	91.0	76	80.9	44.72	92.7	264.6
	Total Species : 28	300	100	94	100	48,3	100	300

Different condition were found in the Kalimpaa area, which is a lower montane forest. Based on the important value, it is clear that the species of *Castanopsis* spec. and *Lithocarphus celebicus* (Miq) Rehd. from the Fagaceae family dominated the Kalimpaa area. WHITTEN (2002) reports that the lower montane forests are characterized by the large numbers of oak *Lithocarpus* and chestnut *Castanopsis* (Fagaceae).

Table 44.

The species found in Wuasa listed by their Important Value, d ≥ 10 cm (2.0 ha)

No.	Scientific Name	*nj*	*nj/Nj*	*dj*	*dj/D*	*xj*	*xj/X*	*Ij*
1	*Cananga odorata* Hook. f.	7	5.2	4	4.4	2.17	12.1	21.7
2	*Prunus* spec.	10	7.5	4	4.4	1.57	8.8	20.7
3	*Semecarpus heterophylla* Bl.	8	6.0	5	5.5	1.22	6.8	18.3
4	*Ficus* spec.	2	1.5	1	1.1	2.78	15.5	18.1
5	*Bischofia javanica* Blume.	6	4.5	4	4.4	1.41	7.9	16.8
6	*Cryptocarya* spec.	9	6.7	6	6.6	0.41	2.3	15.6
7	*Dysoxylum* spec.	8	6.0	5	5.5	0.46	2.6	14.1
8	*Lithocarpus wallichianus* L.	4	3.0	4	4.4	0.80	4.5	11.9
9	*Trema orientalis* L.	7	5.2	2	2.2	0.75	4.2	11.6
10	*Phoebe cuneata* Bl.	5	3.7	3	3.3	0.72	4.1	11.1
11	*Ilex* spec.	4	3.0	3	3.3	0.70	3.9	10.2
12	*Aglaia eximia*	6	4.5	3	3.3	0.25	1.4	9.2
13	*Meliosma* spec.	4	3.0	3	3.3	0.24	1.3	7.6
14	*Eugenia* spec.	4	3.0	3	3.3	0.17	0.9	7.2
15	*Antidesma* spec.	4	3.0	3	3.3	0.17	0.9	7.2
16	*Mallotus ricinoides* Muell.Arg	3	2.2	3	3.3	0.18	1.0	6.5
17	*Elaeocarpus petiolatus* Wall.	3	2.2	1	1.1	0.44	2.5	5.8
18	*Casearia* spec.	2	1.5	1	1.1	0.54	3.0	5.6
19	*Cratavea nurvala* Ham.	2	1.5	2	2.2	0.28	1.6	5.3
20	*Meliosma nitida* Bl.	2	1.5	2	2.2	0.25	1.4	5.1
	Species : 20	100	74.6	62	68.1	15.51	86.7	229.5
	Total Species : 46	134	100	91	100	17.9	100	300

Table 45.

The species found in Rompo listed by their Important Value, d ≥ 10 cm (4.0 ha)

No.	Scientific Name	*nj*	*nj/Nj*	*dj*	*dj/D*	*xj*	*xj/X*	*Ij*
1	*Lithocarpus wallichianus* L.	29	7.9	10	5.6	6.84	15.2	28.7
2	*Palaquium obovatum* (Griff.) Engler	35	9.6	11	6.1	5.24	11.6	27.3
3	*Canarium hirsutum* Wild.	35	9.6	12	6.7	2.20	4.9	21.2
4	*Vitex quinata* F. N. Will	29	7.9	9	5.0	2.67	5.9	18.9
5	*Semecarpus heterophylla* Bl.	22	6.0	10	5.6	2.45	5.4	17.0
6	*Cananga odorata* Hook. f.	11	3.0	8	4.5	3.91	8.7	16.2
7	*Ficus* spec.	9	2.5	5	2.8	4.39	9.7	15.0
8	*Horsfieldia glabra* Warb.	20	5.5	9	5.0	1.48	3.3	13.8
9	*Euphoria malaiensis* Radlk.	19	5.2	9	5.0	1.60	3.5	13.7
10	*Dysoxylum* spec.	19	5.2	5	2.8	1.50	3.3	11.3
11	*Cryptocarya* spec.	18	4.9	7	3.9	1.01	2.2	11.0
12	*Diospyros minahasae* Bakh.	12	3.3	7	3.9	0.83	1.8	9.0
13	*Ficus cycomoroides* Miq.	9	2.5	5	2.8	1.25	2.8	8.1
14	*Phoebe cuneata* Bl.	8	2.2	7	3.9	0.50	1.1	7.2
15	*Meliosma* spec.	10	2.7	5	2.8	0.41	0.9	6.4
16	*Elmerrillia ovalis* (Miq) Dandy	3	0.8	2	1.1	2.02	4.5	6.4
17	*Trema orientalis* L.	6	1.6	2	1.1	1.52	3.4	6.2
18	*Pleomele angustifolia* N.E.Br.	9	2.5	5	2.8	0.37	0.8	6.1
19	*Litsea albyana* Vidal.	5	1.4	5	2.8	0.45	1.0	5.2
20	*Drypetes longifolia* Fax et Hoffm.	6	1.6	4	2.2	0.54	1.2	5.1
	Species : 20	314	86.0	137	76.5	41.18	91.2	253.8
	Total Species : 45	365	100	179	100	45.14	100	300

With the large number of species and with no dominant trees present, Wuasa and Rompo appear to be areas shifted from lowland forest to lower montane forest: many species found in

these areas are also found in lowland and lower montane forests. With an altitude of about 1200 m, Wuasa and Rompo can be categorized as hill forests. As shown in Table 45, the species *Lithocarpus* spec. (Fagaceae) dominated in the lower montane forest, and *Palaquium obovatum* (Griff.) Engler (Sapotaceae), commonly found in lowland forests, was also found in Rompo with an important value higher than for other species.

It is expected that the tree species will increase with the increasing of sample plot area. The different result shows in this study. The area of sample plots seems not having the relationship with the number of the species. The sample plots laid in four different altitude and vegetation type. The number of species found in each study area seems to have more relationship with these factors. Based on the observation, it is found that the number of species decreased with the increasing of the altitude, although the sample plots used were bigger. The character of the forest can be also well described using the most dominant tree families found in the study area as shown in Table 46 below:

Table 46.

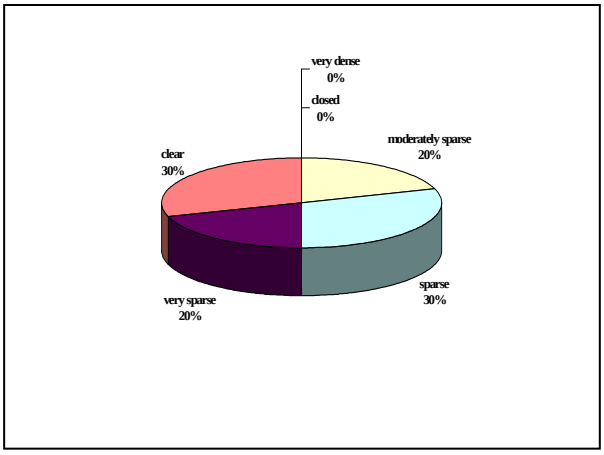
Most common tree families in study area according to the number of species, DBH ≥ 10 cm

	Kamarora	**Wuasa**	**Rompo**	**Kalimpaa**
Family (N species)	Lauraceae(5) Moraceae(4) Euphorbiaceae(4) Meliaceae (3) Rubiaceae(3) Annonaceae (2) Sapindaceae(2) Apocynaceae(2) Sabiaceae(2) Others (23)	Lauraceae(4) Moraceae(4) Euphorbiaceae(4) Meliaceae (4) Myrtaceae (2) Guttiferae (2) Others(26)	Euphorbiaceae(5) Rubiaceae(4) Moraceae(3) Lauraceae(3) Meliaceae(2) Annonaceae(2) Burseraceae(2) Aquifoliaceae(2) Others(22)	Fagaceae(2) Lauraceae(2) Meliaceae(2) Rubiaceae(2) Myrtaceae(2) Others(12)
Total species (N)	50	46	45	28
Total families(N)	29	25	28	22

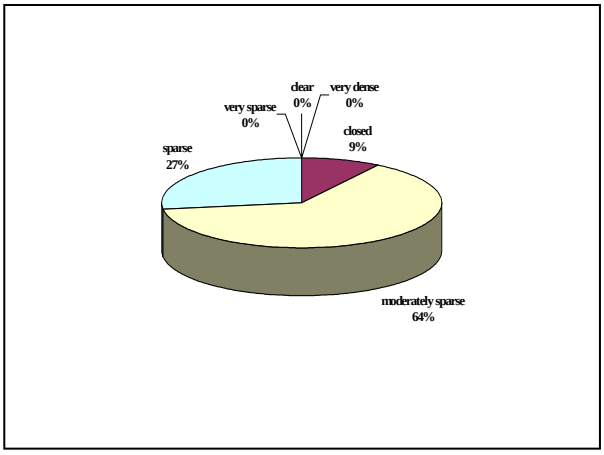
5.18 Horizontal stand structure (crown closure degree)

Crown closure describes the degree of area covered by tree crowns. Crown overlapping is not taken into consideration. Therefore, the degree of crown closure is rather more a measurement of surface occupation by the trees, than a parameter for inventory density. However, the crown closure degree is an important parameter for forest structural measurement and ecological condition. The degrees (see Figure 9) are defined as:

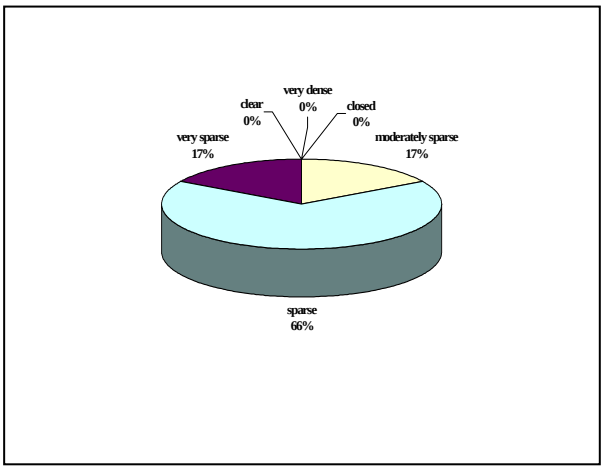
- very dense: crowns overlap or penetrate each other
- closed: the crowns touch with branch tips
- moderately sparse: crowns separated by a distance smaller than crown width
- sparse: crowns separated by the width of the crown
- very sparse (gap): crowns separated by a distance of several crowns width



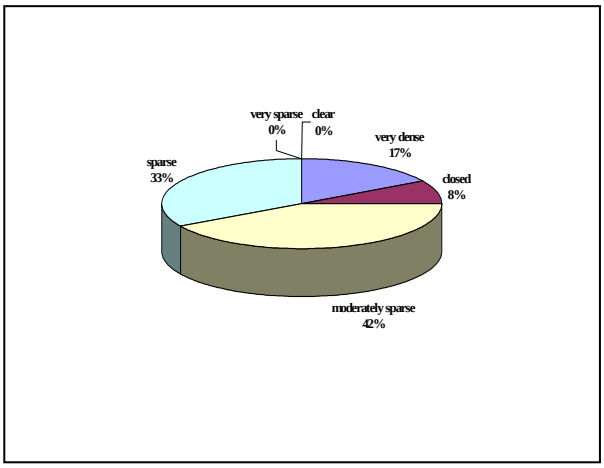
a. Kamarora



b. Kalimpaa



c. Wuasa



d. Rompo

Figure 29.

Crown closure degree in four study areas

In this study, the degree "clear" was added to the crown closure classification given above, since some plots were found to be without trees ("clear"). The results of the crown closure measurements show that clear areas were only found in Kamarora where they made up 30%. This is due to the severe disturbances, such as illegal cutting, burning and planting activities

in the area. The results also show that crown closure is mostly moderately sparse (17-64%) to sparse (17-66%). Very dense crown closure was found only in Rompo (17%), while close conditions were found in Kalimpaa (9%) and Rompo (8%).

5.19 Crown measurement

The most important aspect in tree growth is crown development. The tree crown is directly linked to transpiration, because the end process of CO_2 assimilation takes place here. The crown is not a static entity and it can be used as an indicator of the competition between trees within the stand (v. GADOW, 2003).

Crowns actually always have a precise construction, determined by the interaction of three main factors: apical versus lateral growth; radially symmetrical versus bilaterally symmetrical lateral meristem; and intermittent versus continuous growth (WHITTMORE, 1990).

5.191 Crown form

DAWKINS (1958) developed a classification for the shape of the crown that is an indication both of its photosynthetic capacity as well as the general vigour of the tree, and may be correlated both with increment and subsequent mortality (ALDER and SYNNOTT, 1992). Form scores are inevitably more subjective than those of position. Even so, they have proved of even greater value in interpreting growth rates (DAWKINS, 1958).

As can be seen in Figure 30, the tolerable form dominated crown form in the study area ranging from 29.2% to 47.9%. The percentage of perfect and good forms (14.6%) in Kamarora is much lower than that of poor and very poor forms (37.5%). This is the result of the area having been heavily disturbed by human activities, such as illegal cutting and burning. Also, due to the felling of other trees, many tree crowns are broken and die. Although the percentage of poor and very poor forms was also high in other areas with a range between 30% and 39%, better conditions were found in these areas, since perfect and good forms were abundant, ranging between 26% and 36%.

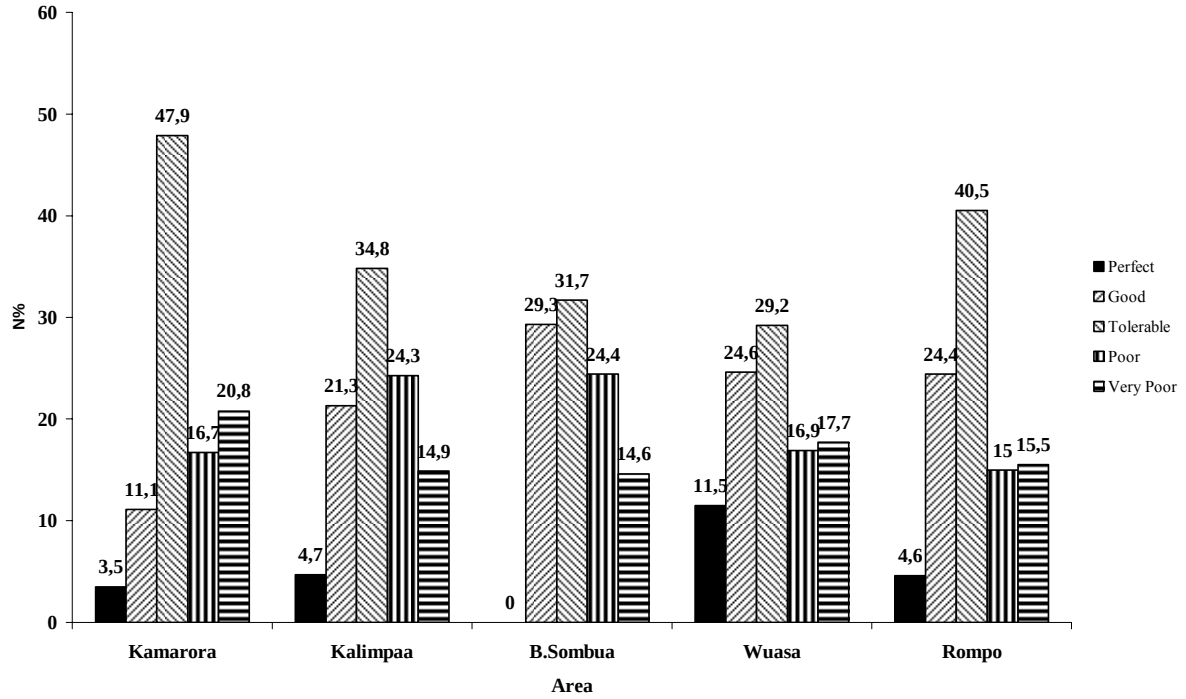


Figure 30.

Crown form classification in each study area

5.192 Crown position

Beside actual tree height, the vertical structure can be described using a system based on crown classification (HUSCH, et. al., 2003). A simple subjective system for crown classification was developed by DAWKINS (1958) and adopted for permanent sample plots in some tropical forests. The results appear to be reliable and consistent, and consistently better related to increment than tree diameter (ALDER and SYNNOTT, 1992).

One can see from Figure 31 that the lower canopy (crown plan partly exposed vertically and partly shaded vertically by other crowns) has the highest percentage in all areas, except for Kalimpaa, where the upper understorey position had the highest relative value (30%). The relative value of lower canopy position was 28% in Kamarora, 41% in Sombua, 31% in Wuasa and 27% in Rompo.

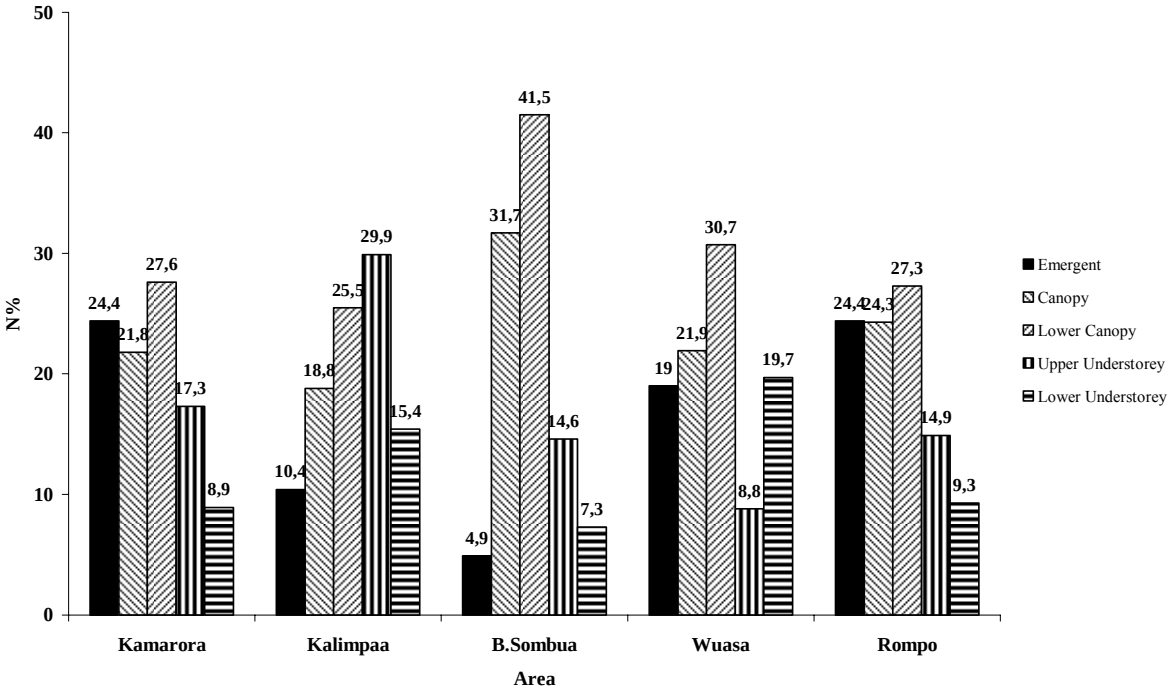


Figure 31.

Crown position classification in each study area

5.20 Tree social class

Tree social class is determined for the individual trees and is assigned according to their social position and their stature dynamics compared with their neighbours. This is very important, because it can indicate that only vital and strong trees will have well-developed crowns. Due to simplicity and practicability, KRAFT's classification system (1884) is suitable to fulfil this goal. KRAFT's classification is still predominantly used because it can clearly differentiate the demarcation of the social position of the trees within the stand.

Figure 32 shows the percentage of each tree social class using KRAFT's classification for each study area. A similar trend is seen in the Kamarora, Kalimpaa and Rompo areas. The percentage of the understrorey class is the highest, followed by less dominant, dominant, prevailing and dead/nearly dead classes. Different conditions are found in Bulu Sombua, since the less dominant class has the highest percentage. In Wuasa, the area with severe human disturbance, the dominant value is lower than prevailing. This is because the dominant trees, which have relative smaller diameters and shorter heights, were more easily cut than trees in the prevailing class.

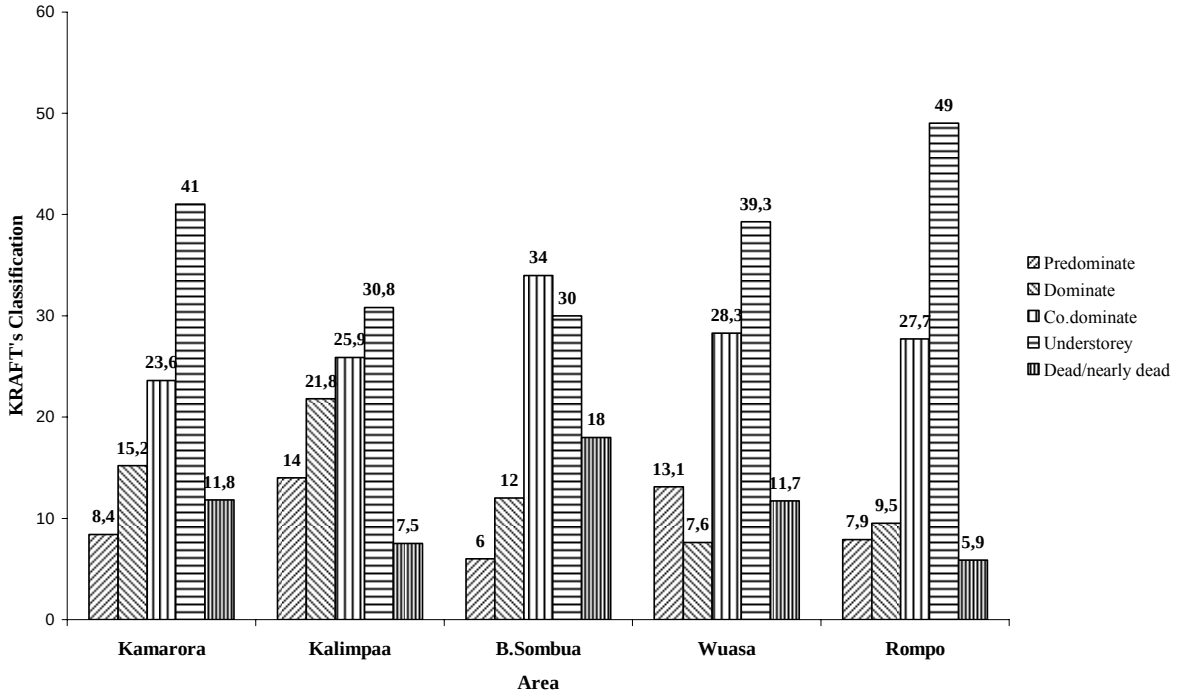


Figure 32.
Tree social class based on KRAFT'S classification

The highest dead/nearly dead value was found in Bulu Sombua (18%). But, unlike in Kamarora (11.8%) and Wuasa (11.7%), where the trees were mainly dead because of human disturbance, most trees in Bulu Sombua died of natural causes. The lowest value in this class was seen in Rompo (5.9%), since this area remains undisturbed.

5.2 Measurement of stand quality

5.21 Common defects in standing trees

Defects commonly found in sample trees in each study area are described in this section. The aim of this survey was to determine the general condition of defects of the sample trees before classifying the trees according to quality, therefore all sample living trees both commercial and non-commercial were assessed.

The quality class of each tree is assessed on the presence of visible defects on the surface of the tree (ocularly observed) and/or the measurement of those defects. The characteristic measurement was divided into three main categories: shape, knottiness and other defects.

Shape is the most important criterion in Indonesian quality assessment practice. The presence of buttresses, sweep/crook, humps, forks, grooves, flattened and screwing in the trees directly affects the shape condition (straightness and taper) as well as the tree quality. Log length and lumber yield generally increase with increasing stem straightness. The presence of sweep and crook should be considered serious because of their pronounced effect on both lumber yield and quality. It is reported that log recovery decreased to about 75% when sweep increased to 8 cm, and it also reported that sweep and crook had a statistically significant effect on tree value. In general, butt logs contain the greatest amount of sweep (KELLISON and PEARSON 1985; PARK et. al., 1989; PETRO and CALVERT 1976; OBERG 1989; BROWN and MILLER 1975; KELLOG and WARREN 1984; cited in ZHANG 1997). The presence and level of shape defects varied vary the study areas.

Table 47.

The percentage of the shape condition of sample trees in study areas

Shape condition	Frequency (%)				
	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
Cylindrical	11.0	22.5	35.1	26.7	21.4
Almost cylindrical	33.8	39.0	27.0	51.1	35.0
Not cylindrical	55.2	38.5	37.9	22.1	43.6

The shape condition of the trees is divided into cylindrical, almost cylindrical and not cylindrical. The tree is assumed to be cylindrical when its smallest diameter is no less than 90% of its greatest diameter. A tree with a ratio between its smallest and largest diameter of not less than 80% is considered almost or nearly cylindrical. A tree with a ratio lower than 80% is graded as not cylindrical. Table 47 presents the percentage of the shape conditions of the sample trees in each study area. It shows that for all sample trees in each area, there were fewer cylindrical trees than those with other shapes: almost/nearly cylindrical and not cylindrical trees were more frequent.

Table 48.

The frequency of various shape defects in sample trees in the study areas

Shape defect	Frequency (%)				
	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
Buttress	14.0	15.7	18.8	22.7	24.0
Sweep/crook	70.6	19.0	20.8	22.7	40.5
Humps	8.4	5.8	6.3	0.0	9.5
Flattened, Burl	24.5	8.3	6.0	12.9	27.8
Grain, Groove	11.9	6.3	0.0	0.8	20.6

a. High buttress and cave trees b. Trees with deep grain and groove

Figure 33.

Some shape defects of sample trees

Buttresses are lateral extensions of the lower part of a tree trunk and are both common and varied in tall tropical forests. Different species are relatively constant in the presence; shape and surface characteristics of buttresses and these characteristics can be useful in the identification of trees (WHITTEN, et. al., 2002). WHITTMORE (1998) stated that buttresses are prominent in some forest formations. Buttresses are tension structures, resonating when struck with an axe, and are mainly found on the uphill sides of trees or counterbalancing asymmetric or epiphyte-laden crowns. They are of structural importance in helping to support the tree. As seen in Table 48, the presence of buttresses and other shape defects is more frequent in lowland and uphill forests (Kamarora, Wuasa and Rompo) than in lower montane forests (Kalimpaa and B. Sombua). The average buttress height in Kamarora, Wuasa and Rompo was 2.1 m, while it was 2.7 m in Kalimpaa and 2.9 m in Bulu Sombua.

Knottiness is a commonly present defect and has become one of the most important criterion of the log grading rules for tropical trees. The prevalence of knottiness amongst the sample trees in the study area varied between 20% and 40% (Kamarora 20%; Kalimpaa 19.7%; B. Sombua 27%; Wuasa 28.9%; Rompo 39.7%). Knottiness has a detrimental effect on the mechanical properties of lumber. Knots affect mechanical properties mainly due to the grain deviation around the knots. A number of studies reported that knots were the most common reason for visual lumber downgrading. 29.1% of Douglas fir lumber is downgraded because of knots, and 47.7% of heavily thinned balsam fir stands would be downgraded if the lumber

were graded based on knots alone (TUSTIN and WILCOX 1987; BARRETTE and KELLOG 1986, 1991; PELLICANE et al. 1997; MIDDLETON and MUNRO 1989; ZHANG et al. 1997; cited in ZHANG 1997). The type of knot also has an important effect on strength. Dead or unsound knots have a more serious effect than living knots (ZHANG, 1997).

Figure 34.
Sound knot

The presence of sound knots in the Kamarora (61.3%), Wuasa (54.0%) and Rompo (54.7%) areas, the areas defined as lowland and uphill forests, are much higher than in Kalimpaa (23.7%) and B. Sombua (20.0%), which are lower montane areas.

Table 49.
The percentage of sound knots, unsound knots and knobs in each study area

Shape defect	Frequency (%)				
	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
Sound Knots	61.3	23.7	20.0	54.0	54.7
Unsound Knots	29.0	11.9	20.0	22.0	26.7
Knobs	9.7	59.0	60.0	24.0	18.6

It is important to include common defects found in the study area, such as crown, stem and bark defects, branchiness, decay, hole and hollowed into tree quality assessment. These defects could be a cause leading to the downgrading of tree quality. The results are shown in Table 50.

Crown defects are divided into crown broken, crown dry and crown dead, while stem defects are differentiated into stem and branch broken. Bark defects were divided into three levels:

scratch, broken and wriggle. Based on size, hole defects are divided into small hole and hollowed. Wound and decay was also commonly found in the field.

Table 50.

The percentage of some common defects in each study area

Shape defect	Frequency (%)				
	Kamarora	Kalimpaa	B. Sombua	Wuasa	Rompo
Crown defect	0.7	10.7	28.0	16.7	0.8
Stem defect	2.8	3.7	10.0	10.6	5.0
Bark defect	2.8	3.3	4.0	12.9	6.6
Hole	11.9	0.3	0.0	6.1	11.1
Wound/decay	9.1	1.0	4.9	7.6	2.9

a. Bark scratch b. Burl, insect disease attack

Figure 35.

Some common defects found in study area

With a percentage of 28%, Bulu Sombua had the highest amount of crown defects of the study areas. The opposite situation was found in Kamarora, which had the lowest prevalence of crown defects (0.7%). This might be because the area of Bulu Sombua lay at the highest altitude, and was therefore subjected to a greater amount of natural disturbances such as lightning, which is the main cause of crown defects.

An almost identical situation was found regarding stem defects. Although the presence of stem and bark defects was higher in Wuasa than in the other areas, these were also frequent in Bulu Sombua, as well. However, the reasons for this similarity are likely to be very different. The high percentage of stem defects in Wuasa is caused by human disturbance, such as illegal

cutting activity. But in Bulu Sombua, the stems are mostly disturbed by natural causes, since the area is very wet.

The presence of hole defects and hollowed trees in Kamarora (11.9%), Wuasa (6.1%) and Rompo (11.1%) was much higher than in Kalimpaa (0.3%) or Bulu Sombua (0.0%). This is because these lower lying areas were subjected to more intense disturbance, both natural and human, that can promote the entrance of destructive agents, such as insects and worms, which create holes in trees.

The temperature inside the forest also differs between the areas. The areas with higher temperatures (Kamarora, Wuasa, Rompo) have better conditions for many deterioration agents than the areas at higher altitudes and with lower temperatures (Kalimpaa and Bulu Sombua).

The presence of climbers was also common in tropical trees. It can be counted as a defect of the trees, but also a specific condition of trees. The presence of climbers was 1.4% in Kamarora, 7.3% in Kalimpaa, 2.0% in Bulu Sombua, 30.3% in Wuasa and 14.6% in Rompo.

Figure 36.
Climbers

5.22 Standing tree quality assessment

The result of the standing tree quality assessment using different measurement methods will be described in this part.

5.221 Tree quality assessment in Rompo area

Based on general condition of the forest area and the trees themselves, the stand in Rompo was is better general condition than the others. The number of the trees suitable for use as sample trees was also larger than in the other areas and they also had a wider range of diameters. Therefore, the commercial trees in the Rompo area were used as sample trees for the estimating standing tree quality. Seventy-six trees from 13 family groups were chosen as sample trees for assessment. To increase the precision of the volume estimation, trees were selected that had the lowest possible buttresses. With this condition, it was found that trees with a diameter under 60 cm were suitable for measurement.

The results will be presented under two aspects; quality criteria and volume estimation. The quality criteria were determined by the method described in chapter 4.52, while the volume was estimated with the equation developed in chapter 5.14.

Following the standard quality assessment rules for Indonesian hardwood logs, quality is divided into 4 overall classes; A, B, C and D. The diameter is differentiated into 3 classes; class diameter between 10 and 19 cm (small assortment), 20-29 cm (middle assortment) and over 30 cm (large assortment). These classifications will be employed in this study. It is assumed that each tree has the same probability of qualifying as good quality even if it is of small diameter. Therefore, each tree inventoried in this study has an equal opportunity to be defined as a tree of certain quality.

Following the conditions of log production in Indonesia which has been steadily declining recently, the diameter limit for allowable cuts has also decreased. Therefore, trees with a diameter below 20 cm might be eligible for utilization sometime in the future. It is very important to remember that not only the large diameter parts of the tree will be used by the industry, but also the parts with small diameter have a good opportunity of being used.

The simple butt-log method

The basis of the simple butt-log method is that quality measurement is done only at a specific lower portion of the tree. In this study, an average height of 5 metres (approximately equal to 0.2 of average total height) was used as the basis for the simple butt-log measurement. The

defect criteria used in the measurement were described in Chapter 4.2. An example of a tree that can be classified as an A-quality tree using this method is given in Table 51. For a tree with a diameter of a least 20 cm, the butt-log could have a maximum of one sound knot per 2 metres with diameter of 10 cm or less, no dead knots, a maximum of 3 knobs, no holes, no more than one sweep/crook, no grooves, a grain of maximally 1 cm per metre and no decay/wound or hollowed.

Table 51.

Example of quality criteria for a tree with A-quality

No. trees	BDH Cm	Sound knot ≤ 10 cm	Dead knot < 10 cm	Knob	Hole ≤ 5 mm	Sweep/ Crook	Groove ≤ 1/5	Grain ≤ 1/10	Decay ≤ 10 cm
--	≥ 20	< 3	< 1	< 4	< 1	< 2	< 1	< 2	< 1

The combination of the number and size of defects was made to define the B- and C-quality classes. The decision was easier for D-quality trees, since most of the down-grading was due to the presence of hollowed or large-sized decay defects. None of these defects were allowed in the other qualities (Table 52).

Table 52.

Example of quality criteria for a tree with B or C quality

No. trees	BDH Cm	Sound knot ≤ 10 cm	Dead knot < 10 cm	Knob	Hole ≤ 5 mm	Sweep/ Crook	Groove ≤ 1/5	Grain ≤ 1/10	Decay ≤ 10 cm
--	≥ 20	< 5	< 5	< 8	< 30	< 2	< 2	< 2	< 2

The results show that the sample trees were distributed almost evenly in the diameter classes between 20 cm and 44 cm. Tables 53 and 54 show that A-quality trees were distributed mostly in the diameter classes between 20 cm and 40 cm. The reason is because buttresses are frequent on the lower parts of the trees and defects very often present in these diameter classes. There were 27 A-quality trees (35.5 % of all sample trees) and 22 B-quality trees (28.9%). The result shows that more than 35% of the sample trees were classified into C (13 trees, 17.1%) and D-qualities (14 trees, 18.4%). The opposite situation was found in the diameter classes of 36 cm and above, in which trees of lower quality (B, C and D) were more frequent than high quality trees (A-quality). This situation occurs in tropical forests, since the non-cylindrical shape due to the presence of buttresses, grooves and defects such as hollowed and decay were more frequently present in the lower part of the trees in the larger diameter

class. One can conclude, that this method gave trees of larger diameter a smaller chance of qualifying for the higher quality class.

Table 53.

Number of sample trees using the simple butt-log method (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	5	10	6	2	3	1	-	-	-	-	-	-	27	35.5
B	5	9	4	-	1	2	1	-	-	-	-	-	22	28.9
C	2	4	4	-	1	1	-	-	-	-	-	1	13	17.1
D	1	5	3	2	1	1	1	-	-	-	-	-	14	18.4
∑	13	28	17	4	6	5	2	0	0	0	0	1	76	100.0

The 'SMALLIAN' volume equation was used to estimate the volume of each tree (Chapter 4.15).

Table 54.

Volume (m3, o.b.) of sample trees based on quality class and class diameter using the simple butt-log method (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	1.9	4.7	4.2	1.4	4.6	1.4	-	-	-	-	-	-	18.1	29.9
B	1.4	4.1	2.0	-	2.0	4.2	2.3	-	-	-	-	-	16.0	26.5
C	0.7	1.5	1.7	-	1.6	1.1	-	-	-	-	-	6.9	13.5	22.3
D	0.2	2.6	2.5	2.4	1.0	2.1	1.9	-	-	-	-	-	12.8	21.2
∑	4.2	12.9	10.4	3.8	9.2	8.8	4.3	-	-	-	-	6.9	60.4	100.0

Compared to the number of sample trees distribution, the volume distribution was more even in each diameter-class. Based on the volume estimation, the percentage of A- and B-quality classes decreased, relative to the percentage of the number of sample trees. The total volume estimation over bark of all quality classes was 60.4 m^3. This consists of 18.1 m^3, or about 29.9% for A-quality trees. B-quality is also lower with 16.0 m^3 or 26.5%. The percentages increased for C- and D-qualities. The percentages of the number of sample trees in these classes were only 17.1% and 18.4%, respectively, but using the volume estimation the percentages increased to 13.5 m^3 (22.3%) for C-quality and 12.8 m^3 (21.1%) for D-quality trees. This shift occurred, since trees in the larger diameter classes and with a greater merchantable height usually also have higher buttresses and a higher frequency of defects. This makes the trees unacceptable for the higher quality class.

By assessing volume distribution according to quality class, one can obtain further information to make an appropriate planning. From this information, one can get a quick overview of the potential distribution of tree quality in a stand.

The differentiated butt-log method

The variation of the simple butt-log method, namely the differentiated butt-log method, was also performed in order to reduce the problems arising from abnormalities of the lower parts of the tree (Chapter 4.52).

Table 55 shows that the differentiated butt-log method assigned more sample trees to the A-quality class. The number of A- and C-quality trees increased by 7.9% each compared to the number of trees assessed by the simple butt-log method. The opposite situation was seen in B- and D-quality trees, whose numbers decreased by 3.9% and 8.8%, respectively.

Table 55.

Number of sample trees using the differentiated butt-log method (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	7	12	6	2	4	2	-	-	-	-	-	-	33	43.4
B	4	7	6	-	-	1	1	-	-	-	-	-	19	25.0
C	2	8	4	2	2	1	-	-	-	-	-	1	19	25.0
D	-	1	1	-	1	1	1	-	-	-	-	-	5	6.6
∑	13	28	16	4	7	5	2	-	-	-	-	1	76	100.0

Table 56.

Volume (m^3, o.b.) of sample trees based on quality class and class diameter using the differentiated butt-log method (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	2.6	5.5	4.0	1.4	6.6	3.3	-	-	-	-	-	-	23.3	38.6
B	1.1	3.3	3.1	-	-	2.3	2.3	-	-	-	-	-	12.2	20.1
C	0.5	3.7	2.6	2.4	1.6	1.1	-	-	-	-	-	6.9	18.8	31.1
D	-	0.5	0.6	-	1.0	2.1	1.9	-	-	-	-	-	6.2	10.2
∑	4.2	12.9	10.4	3.8	9.2	8.8	4.3	-	-	-	-	6.9	60.4	100.0

The volume distribution shows a similar pattern (Table 56). With an increase of 5.2 m^3 (8.7%), the volume of A-quality trees improved significantly. The same was observed for C-quality trees, the volume of which increased by 5.3 m^3 (8.8%). Decreasing percentages were

found for B- and D-quality trees with a slight negative change for B-quality trees of 3.8 m^3 (6.4%) and a reduction of D-quality trees of 6.6 m^3 or approximately 11.0 %.

The simple, expanded butt-log method

Although the simple and differentiated butt-log methods have already provided information on the quality distribution, those methods do not give any information on the quality of the upper parts of the trees.

Using the simple, expanded butt-log method, the volume of the lower part of the sample trees is distributed more evenly in each diameter class (Table 57). With a volume of 7.8 m^3 (32.2%), the volume of the lower part of A-quality trees is only slightly larger than that of the other qualities. The lower part volume of B-quality trees was 6.5 m^3 (26.6%), while C-quality trees was 4.9 m^3 (20.4%) and D-quality was 5.1 m^3 (20.8%).

Table 57.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter classes of the first 5m (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	0.9	2.2	1.8	0.8	1.6	0.6	-	-	-	-	-	-	7.8	32.2
B	0.9	2.0	1.1	-	0.5	1.3	0.8	-	-	-	-	-	6.5	26.6
C	0.4	0.8	1.0	-	0.5	0.7	-	-	-	-	-	1.6	4.9	20.4
D	0.1	1.2	1.0	0.8	0.4	0.6	0.8	-	-	-	-	-	5.1	20.8
∑	2.2	6.1	4.9	1.6	3.0	3.2	1.6	-	-	-	-	1.6	24.3	100.0

Table 58.

Volume (m^3, o.b.) of the upper part of sample trees between 5 m height and merchantable height (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	0.8	1.8	1.6	-	1.8	0.8	-	-	-	-	-	-	6.8	18.8
B	0.8	1.3	2.1	0.6	1.8	2.7	-	-	-	-	-	-	9.2	25.4
C	0.2	2.7	1.3	0.5	-	2.1	-	-	-	-	-	5.3	12.1	33.6
D	0.1	1.0	0.6	1.0	2.6	-	2.7	-	-	-	-	-	8.1	22.3
∑	1.9	6.8	5.5	2.1	6.2	5.6	2.7	-	-	-	-	5.3	36.2	100.0

The opposite situation is observed in the upper parts of the trees, between 5 metres and the merchantable height. Table 54 shows that the upper parts of trees tend to be of lower quality, since more than 50% of them are distributed to the C- and D-qualities (C-quality with 12.1 m^3

or 33.6% and D-quality with 8.1 m^3 or 22.3%). An appreciable volume of the upper parts was also of B-quality (9.2 m^3 or 25.4%), while A-quality comprised only 6.8 m^3 or 18.8% of the total volume of the upper parts of the trees.

The results of the quality assessment using this simple, expanded method, as presented in Table 59, shows a huge improvement over the simple butt-log method. The method illustrates that trees with good quality in their lower parts did not necessarily having the same quality in the upper parts. Compared to the simple butt-log method, the volume of A-quality class trees decreased by 3.5 m^3 (5.8%), and B-quality decreased slightly by 0.4 m^3 (0.6%). Increases were observed in the C- and D-quality classes; the C group rising by 3.6 m^3 (6.0%) and the D group by 0.3 m^3 (0.5%).

One can conclude from this improvement that by using this method, the quality distribution in the lower and upper parts can be described. It shows that the upper parts can qualify for either a higher or a lower quality class.

Table 59.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter class using the simple, expanded butt-log method (3.96 ha)

Quality Class	DBH – Mid Class (cm)													
	20	**24**	**28**	**32**	**36**	**40**	**44**	**48**	**52**	**56**	**60**	**64**	**∑**	**%**
A	1.7	4.0	3.4	0.8	3.4	1.4	-	-	-	-	-	-	14.6	24.1
B	1.7	3.2	3.2	0.6	2.2	4.0	0.8	-	-	-	-	-	15.6	25.9
C	0.6	3.5	2.3	0.5	0.5	2.8	0.0	-	-	-	-	6.9	17.1	28.3
D	0.2	2.2	1.6	1.9	3.1	0.6	3.5	-	-	-	-	-	13.1	21.7
∑	4.2	12.9	10.4	3.8	9.2	8.8	4.3	-	-	-	-	6.9	60.4	100.0

The expanded, differentiated butt-log method

The expanded, differentiated butt-log method is a method that combines the differentiated butt-log method and the simple, expanded butt-log method (see Chapter 4.52). The quality distribution of the lower parts shows a huge improvement, with a more even distribution in the higher classes. Compared to the simple, expanded butt-log method, the A- and C-qualities of the lower parts of the trees show an rise in volume, with an increase of 1.9 m^3 (7.9%) for the A-quality and 2.0 m^3 (8.0%) for the C-quality. The increase in those qualities happened in most of the quality-classes (Table 60). The opposite condition seen for the B- and D qualities, since the volume in both classes dropped. B quality fell by 1.2 m^3 (4.9%) and D decreased by about 2.7 m^3 (11%).

Table 60.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter classes of the first 5m height using the differentiated butt-log method (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	**24**	**28**	**32**	**36**	**40**	**44**	**48**	**52**	**56**	**60**	**64**	**∑**	**%**
A	1.3	2.6	1.8	0.8	2.0	1.3	-	-	-	-	-	-	9.7	40.1
B	0.7	1.5	1.6	0.0	0.0	0.6	0.8	-	-	-	-	-	5.3	21.7
C	0.3	1.8	1.2	0.4	1.0	0.7	-	-	-	-	-	1.6	6.9	28.4
D	-	0.2	0.3	-	0.4	0.6	0.8	-	-	-	-	-	2.4	9.8
∑	2.2	6.1	4.9	1.1	3.5	3.2	1.6	-	-	-	-	1.6	24.3	100.0

This method also gives better results than using only the differentiated butt-log method, since the quality of each class was distributed more evenly. The percentage of each class was distributed between 18.0% and 31.3%. The results also show, that the upper part strongly influences quality distribution. Although the higher quality groups (A and B) already showed a good performance in the lower parts, after the addition of the upper parts, the volume distribution in each quality class was more even.

Table 61.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter class using the expanded differentiated butt-log method (3.96 ha)

Quality Class	DBH - Mid Class (cm)													
	20	**24**	**28**	**32**	**36**	**40**	**44**	**48**	**52**	**56**	**60**	**64**	**∑**	**%**
A	2.1	4.4	3.4	0.8	3.9	2.1	-	-	-	-	-	-	16.5	27.3
B	1.2	2.8	3.7	0.6	1.8	3.3	0.8	-	-	-	-	-	14.2	23.4
C	0.8	4.5	2.4	0.9	1.0	2.4	-	-	-	-	-	6.9	18.9	31.3
D	0.1	1.2	0.9	1.0	3.1	1.1	3.5	-	-	-	-	-	10.8	18.0
∑	4.2	12.9	10.4	3.3	9.7	8.8	4.3	-	-	-	-	6.9	60.4	100.0

Comparing to the differentiated butt-log method, it seems that this method did not give better performance in the higher quality group (A-quality), since there was a reduction in this class with A-quality trees decreasing from 23.3 m^3 (38.6%) to 16.5 m^3 (27.3%). The opposite was observed for B-, C- and D- qualities. The volume of B-quality increased slightly by 2 m^3 (3.3%), while C increased by 0.1 m^3 (0.2%) and D by 4.6 m^3 (6.8%).

Comparing to the simple, expanded butt-log method, the distribution of A-quality trees is better using this method. The A-quality class increased from 14.6 m^3 (24.1%) to 16.5 m^3 (27.3%) and C-quality increased from 17.1 m^3 (28.3%) to 18.9 m^3 (31.3%). The opposite was seen for the B- and D-qualities. The volume of B-quality trees decreased slightly by 1.4 m^3

(2.5%), while D dropped by 2.3 m^3 (3.7%). The primary conclusion to be drawn from this is that although the lower part of sample trees contains mostly A-quality wood, it does not necessarily follow that upper part if of the similar quality, as well. This method actually shows that the upper part of the trees tends to be of lower quality (C- and D-quality) than the lower parts.

The expanded, differentiated butt log method with a subdivided upper butt-cut

This method is a combination of the expanded, differentiated butt log method. The difference lies in the measurement at the upper part of the tree. The upper part of the tree was divided into several sections (parts) (see Chapter 4.52).

Table 62.

Volume (m^3, o.b.) of the upper parts of sample trees between 5 metres and merchantable height with subdivision in upper part (3.96 ha)

Quality	**DBH - Mid Class (cm)**													
Class	**20**	**24**	**28**	**32**	**36**	**40**	**44**	**48**	**52**	**56**	**60**	**64**	∑	**%**
A	0.5	1.2	1.4	-	1.8	0.8	-	-	-	-	-	-	5.7	15.7
B	1.0	1.7	2.3	0.6	1.8	2,6	0.5	-	-	-	-	-	10.5	28.9
C	0.4	2.5	0.9	0.5	0.7	1.7	-	-	-	-	-	5.3	12.2	33.8
D	0.2	1.2	0.9	1.0	1.9	0.4	2.2	-	-	-	-	-	7.8	21.6
∑	2.1	6.6	5.5	2.1	6.2	5.6	2.7	-	-	-	-	5.3	36.2	100.0

Table 63.

Volume (m^3, o.b) distribution of sample trees based on quality and diameter class using the expanded differentiated butt-log method with a subdivided upper butt-cut (3.96 ha)

Quality	DBH - Mid Class (cm)													
Class	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	1.8	3.7	3.2	0.8	3.9	2.1	-	-	-	-	-	-	15.4	25.5
B	1.7	3.2	3.9	0.6	1.8	3.3	1.3	-	-	-	-	-	15.7	26.0
C	0.7	4.3	2.1	0.9	1.7	2.4	-	-	-	-	-	6.9	19.1	31.6
D	0.2	1.4	0.9	1.3	2.4	1.1	3.0	-	-	-	-	-	10.2	16.8
∑	4.4	12.7	10.1	3.6	9.7	8.8	4.3	-	-	-	-	6.9	60.4	100.0

The results show that the upper part was more evenly distributed in the B-, C and D- quality classes. Compared to the results of the volume distribution of the upper part without division (Table 58) these results show only a slight improvement. The amount of upper parts with A-quality decreased slightly by about 1.1 m^3 (3.1%). A similar situation was also seen in the D-quality class, which decreased by 0.3 m^3 (0.7%). This was associated with an increase in the

B- and C-quality groups. B-quality increased by approximately 1.3 m^3 (3.5%) and C-quality increased very slightly by about 0.1 m^3 (0.2%) (Table 62).

The results show that the volume of A-quality trees decreased by about 1.1 m^3 (1.8%) and that of D-quality trees by about 0.6 m^3 (1.2%). An concomitant increase occurred in the B- and C-quality classes. The volume of trees with B-quality increased by 1.5 m^3 (2.6%) and that of C-quality trees by around 0.2 m^3 (0.3%).

After evaluating those five methods, it seems that the simple expanded butt log method provides sufficient information of the quality trees, and according to WIEGARD (1998) this method is the proper choice if a cost-effective inventory of as many mass assortments as possible is to be executed. Based on field experience for tropical forest conditions, the implementation of this method was also quite simple and not so time consuming. Thus, this method will also be used in the Kamarora and Kalimpaa areas.

5.222 Tree quality assessment in Kamarora area

A procedure similar to that used in the Rompo area for selecting the sample trees was also employed in the Kamarora area. Forty-one trees from 19 species and 15 families were chosen as sample trees for quality assessment.

Table 64.

Number of sample trees in each quality class using the simple butt-log method (1.98 ha)

Quality Class	DBH - Mid Class (cm)														
	20	24	28	32	36	40	44	48	52	56	60	64	72	∑	%
A	1	1	4	2	1	1	-	-	-	-	-	-	-	10	24.4
B	1	1	3	-	1	-	-	-	-	1	-	-	1	8	19.5
C	2	1	4	4	-	-	1	-	-	-	-	-	-	12	29.3
D	4	-	4	1	-	1	1	-	-	-	-	-	-	11	26.8
∑	8	3	15	7	2	2	2	-	-	1	-	-	1	41	100.0

The results show that the sample trees were almost evenly distributed in each quality class. There were 10 A-quality trees (24.4% of all sample trees) and 8 B-quality trees (19.5%). The results show that in Kamarora, the percentage of C-quality trees was the highest; more that 50% of the sample trees were classified into C (12 trees, 29.3%) and D-qualities (11 trees, 26.8%).

Compared to the Rompo area, the sample trees in Kamarora was more evenly distributed in C and D-qualities, while in Rompo, the trees were distributed more in A and B qualities. According to these results, the expectation that the tree quality in Kamarora, classified as a severely disturbed area, would be distributed more in the lower quality classes than in Rompo, an undisturbed area, has been confirmed.

Table 65.

Volume (m^3, o.b.) of sample trees based on quality class and class diameter using the simple butt-log method (1.98 ha)

Quality Class	DBH - Mid Class (cm)														
	20	24	28	32	36	40	44	48	52	56	60	64	72	∑	%
A	0.2	0.3	2.0	2.1	0.7	2.0	-	-	-	-	-	-	-	7.4	19.1
B	0.3	0.7	2.1	-	1.2	-	-	-	-	3.8	-	-	6.9	15.0	38.8
C	0.4	0.5	2.5	4.1	-	-	1.2	-	-	-	-	-	-	8.5	22.1
D	0.8	-	1.9	0.6	-	1.8	2.6	-	-	-	-	-	-	7.8	20.0
∑	1.8	1.6	8.3	6.9	1.9	3.8	3.8	-	-	3.8	-	-	6.9	38.7	100.0

Compared to the quality distribution, the volume was distributed more evenly in B and C-qualities. This was expected, since the B-quality trees were distributed more in higher diameter class classes. The estimated total volume over bark of all quality classes was 38.7 m^3. This was divided into 7.4 m^3, or about 19.1% for A-quality trees; 15.0 m^3 (38.8%) for B-quality trees; 8.5 m^3, or about 22.1% for C-quality trees and 7.8 m^3 (20.0%) for D-quality trees.

Compared to the volume distribution for each quality in Rompo area, the volume of sample trees in Kamarora was distributed more in B- and C- qualities (38.8% and 22.1%). In Rompo the sample trees were more evenly distributed in A- and B qualities (29.9% and 26.5%).

Table 66.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter classes of the first 5m (1.98 ha)

Quality Class	DBH - Mid Class (cm)														
	20	24	28	32	36	40	44	48	52	56	60	64	72	∑	%
A	0.2	0.2	1.2	0.9	0.5	0.5	-	-	-	-	-	-	-	3.3	20.4
B	0.2	0.2	1.0	-	0.5	-	-	-	-	1.3	-	-	2.3	5.5	33.2
C	0.3	0.3	1.2	1.6	-	-	0.7	-	-	-	-	-	-	4.0	24.5
D	0.6	-	1.2	0.4	-	0.6	0.8	-	-	-	-	-	-	3.6	21.9
∑	1.2	0.7	4.5	2.8	1.0	1.1	1.5	-	-	1.3	-	-	2.3	16.4	100.0

Using the simple, expanded butt-log method, one finds a more even distribution of the sample tree volumes in B- and C- qualities (Table 66). With a volume of 5.5 m^3 (33.2%), the volume of the lower part of B-quality trees is much higher than that of the other qualities. The lower part volume of A-quality trees was 3.3 m^3 (20.4%), while that of C-quality trees was 4.0 m^3 (24.5%) and D-quality was 3.6 m^3 (21.9%).

Table 67.

Volume (m^3, o.b.) of the upper part of sample trees between 5 m height and merchantable height (1.98 ha)

Quality Class	DBH - Mid Class (cm)														
	20	24	28	32	36	40	44	48	52	56	60	64	72	∑	%
A	-	-	-	0.5	-	1.6	-	-	-	-	-	-	-	2.2	9.7
B	-	0.5	1.9	0.5	0.2	-	-	-	-	2.5	-	-	4.6	10.1	45.4
C	0.4	0.4	1.2	3.1	0.7	1.1	0.5	-	-	-	-	-	-	7.3	32.8
D	0.2	-	0.7	-	-	-	1.8	-	-	-	-	-	-	2.7	12.1
∑	0.6	0.8	3.8	4.1	0.9	2.7	2.3	-	-	2.5	-	-	-	22.3	100.0

Similar conditions were also found in the upper part of the trees, between 5 meters and the merchantable height. Table 67 shows that the upper parts of trees tended to be of medium quality, since more than 17 m^3, or about 78.2% of them area were in the B- and C- quality classes (B-quality with 12.1 m^3 or 45.4% and C-quality with 7.3 m^3 or 32.8%) . With only 2.2 m^3, or about 9.7% of the volume, the volume of A-quality of the upper part had the lowest value.

Table 68.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter class using the simple, expanded butt-log method (1.98 ha)

Quality Class	DBH - Mid Class (cm)														
	20	24	28	32	36	40	44	48	52	56	60	64	72	∑	%
A	0.2	0.2	1.2	1.4	0.5	2.0	-	-	-	-	-	-	-	5.5	14.2
B	0.2	0.7	2.8	0.5	0.7	-	-	-	-	3.8	-	-	6.9	15.6	40.2
C	0.7	0.7	2.4	4.6	0.7	1.1	1.2	-	-	-	-	-	-	11.3	29.3
D	0.8	-	1.9	0.4	-	0.6	2.6	-	-	-	-	-	-	6.3	16.2
∑	1.8	1.6	8.3	6.9	1.8	3.8	3.8	-	-	3.8	-	-	-	38.7	100.0

The results of the quality assessment using this simple, expanded butt-log method, as presented in Table 68, show a trend similar to the simple butt-log method, in which the volume of sample trees was distributed more in B- and C- qualities. The advantage of this method is that it explains the distribution of lower and upper part of the trees. This method illustrates also that the trees with good quality in their lower part did not necessarily having

the same quality in the upper part. Trees with poor quality in their lower part did not always have poor quality in the upper part, as well. This can be seen from the changes of volume in each quality class. The volume of A-quality trees decreased from 7.4 m^3 (19.1%) to 5.5 m^3 (14.2%); B-quality increased from 15.0 m^3 (38.8) to 15.6 m^3 (40.2%); C-quality increased from 8.5 m^3 (22.1) to 11.3 m^3 (29.3%) and D-quality decreased from 7.8 m^3 (20.0%) to 6.3 m^3 (16.2%).

Compared with the result in Rompo, the volume of sample trees in Kamarora was distributed evenly among B-, C and D- qualities, while in Rompo, the volume was distributed more in A-, B- and C- qualities.

5.223 Tree quality assessment in the Kalimpaa area

Eighty trees from 11 species and 9 families were sampled in the Kalimpaa area, which is classified as a slightly disturbed area. Based on the number of sample trees, the results show that the trees were distributed in the medium quality class (B- and C-qualities). More than 60% of the sample trees were classified as B- and C-quality. There were 25 B-quality trees (31.3%) and 23 C-quality trees (28.8%). The number of A-quality trees was slightly lower, with 19 trees or about 23.8% and 13 trees of D-quality (16.3%).

Table 69.

Number of sample trees in each quality class using the simple butt-log method (3.63 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	-	6	4	1	-	3	2	-	3	-	-	-	19	23.8
B	1	3	3	11	1	4	1	-	1	-	-	-	25	31.3
C	6	8	1	3	3	2	-	-	-	-	-	-	23	28.8
D	1	3	4	1	2	1	-	1	-	-	-	-	13	16.3
∑	8	20	13	16	6	10	3	1	4	-	-	-	80	100.0

Compared to the results of the Rompo and Kamarora areas, the number of sample trees in Kalimpaa was distributed more evenly in the medium qualities, B and C. While, in Rompo, more sample trees were of higher quality (A and B), the poorer qualities (C and D) predominated in Kamarora.

The results of the volume distribution differ as shown in Table 70. The volume of the sample trees was distributed mostly in the A and B-classes. This is understandable, since the trees in the A and B classes usually had a higher diameter than C and D-quality trees.

Almost 80% of the sample tree volume was of A and B-quality. The total estimated volume over bark of all quality classes was 77.2 m^3. This consists of 26.9 m^3, or about 34.9% for A-quality trees; 26.3 m^3 (34.1%) for B-quality trees; 15.1 m^3, or about 19.5% for C-quality trees and 8.9 m^3 (11.5%) for D-quality tress.

Table 70.

Volume (m^3, o.b.) distribution of sample trees based on quality class and class diameter using the simple butt-log method (3.63 ha)

Quality Class	**DBH - Mid Class (cm)**													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	-	2.5	2.0	0.8	-	8.3	6.8	-	9.0	-	-	-	26.9	34.9
B	0.3	1.0	1.4	11.1	1.3	5.7	2.8	-	2.7	-	-	-	26.3	34.1
C	1.4	2.6	0.7	2.6	3.5	1.9	-	-	-	-	-	-	15.1	19.5
D	0.3	1.0	1.5	0.7	2.1	1.5	-	1.8	-	-	-	-	8.9	11.5
∑	1.9	7.1	5.5	15.1	7.0	17.5	9.6	1.8	11.7	-	-	-	77.2	100.0

Table 71 shows the volume distribution in the lower part of the trees for each quality. The volume was distributed mostly in A- and B-qualities.

Table 71.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter classes of the first 5m (3.63 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	-	1.4	1.1	0.5	-	2.0	1.7	-	3.1	-	-	-	9.8	32.2
B	0.2	0.6	0.8	4.6	0.6	2.5	0.8	-	1.1	-	-	-	11.1	34.3
C	0.9	1.7	0.3	1.2	1.6	1.3	-	-	-	-	-	-	7.1	19.7
D	0.1	0.6	1.0	0.4	1.0	0.6	-	0.8	-	-	-	-	4.5	13.9
∑	1.2	4.3	3.3	6.6	3.1	6.4	2.5	0.8	4.2	-	-	-	32.5	100.0

The results were different for the upper part between 5 meters and the merchantable height of the trees (Table 72). More that 80% of the sample tree volume was in the B, C and D classes. The upper part of the trees in this area tended to be of lower quality than the lower part. The total estimated volume over bark was 44.6 m^3, and consisting of 18.1 m^3 (40.7%) for B-quality trees, 9.1 m^3 (20.4 %) for C-quality trees, 9.0 m^3 (20.2%) for D-quality trees. Only 8.4 m^3 (18.8%) was of A-quality.

Table 72.
Volume distribution (m^3, o.b.) of the upper part of the sample trees between 5 m height and merchantable height (3.63 ha)

Quality Class	DBH - Mid Class (cm)													
	20	24	28	32	36	40	44	48	52	56	60	64	∑	%
A	-	0.9	0.7	0.6	-	2.0	2.5	-	1.7	-	-	-	8.4	18.8
B	0.1	0.5	0.7	5.1	-	2.7	4.5	-	4.4	-	-	-	18.1	40.7
C	0.3	0.6	0.3	2.5	1.2	4.1	-	-	-	-	-	-	9.1	20.4
D	0.3	0.7	0.5	0.3	2.6	2.2	-	1.0	1.4	-	-	-	9.0	20.2
∑	0.7	2.8	2.2	8.4	3.9	11.1	7.1	1.0	7.5	-	-	-	44.6	100.0

Table 73.

Volume (m^3, o.b.) distribution of sample trees based on quality and diameter class using the simple, expanded butt-log method (3.63 ha)

Quality Class	**DBH – Mid Class (cm)**													
	20	**24**	**28**	**32**	**36**	**40**	**44**	**48**	**52**	**56**	**60**	**64**	∑	**%**
A	-	2.3	1.9	1.0	-	4.0	4.3	-	4.8	-	-	-	18.2	23.6
B	0.3	1.2	1.5	9.7	0.6	5.3	5.3	-	5.5	-	-	-	29.3	38.0
C	1.2	2.3	0.7	3.7	2.9	5.4	-	-	-	-	-	-	16.2	20.9
D	0.4	1.3	1.5	0.7	3.6	2.8	-	1.8	1.4	-	-	-	13.5	17.5
∑	1.9	7.1	5.5	15.1	7.0	17.5	9.6	1.8	11.7	-	-	-	77.2	100.0

Compared with the simple butt log method, the simple, expanded butt-log method showed a similar trend for the volume distribution. The sample tree volume was distributed more evenly in the A and B classes. But there was a significant change in the volume distribution for each quality. The volume of A-quality decreased from 26.9 m^3 (34.9%) to 18.2 m^3 (23.6%); B-quality increased from 26.3 m^3 (34.1%) to 29.3 m^3 (38.0%); C-quality increased from15.1 m^3 (19.5%) to 16.2 m^3 (20.9%) and D-quality increased from 8.9 m^3 (11.5%) to 13.5 m^3 (17.5%).

6. Discussion

6.1 Characterisation of stands

This study that employed concentric circular plots arranged in a systematic pattern in the research areas yielded very good results. The stand structures in the individual research areas could be clearly differentiated by the number of the trees, the basal area and the stand volume per hectare as well as the average tree height and number of species.

The number of trees and the basal area per hectare for all tree species with a diameter at breast height over 10 cm were 125 and 20.81 m^2, respectively, in Kamarora, 183 and 22.83 m^2 in Wuasa, 258 and 30.18 m^2 in Rompo, 225 and 32.46 m^2 in Kalimpaa, and 336 and 38.0 m^2 m in Bulu Sombua. The total volume per hectare of all tree species in each research area was 364.81 m^3 in Kamarora, 375.82 m^3 in Wuasa, 487.18 m^3 in Rompo, 532.69 m^3 in Kalimpaa and 598.20 m^3 in Bulu Sombua (Tables 34, 35 and 26). There were 50 tree species from 29 families in the sample plots in Kamarora, 46 species from 25 tree families were found in Wuasa, 45 species from 28 families in Rompo, 28 species (22 families) in Kalimpaa and 8 species from 7 families in Bulu Sombua. The number of tree species was lowest in Bulu Sombua, not only because Bulu Sombua is situated at the highest altitude, but also because only one plot was established in this area. The average tree height in Kalimpaa and Bulu Sombua was less than that in Kamarora, Wuasa and Rompo (Table 20). A similar trend was observed both for commercial as well as for non-commercial trees. Overall, the number of trees, the basal area and the stand volume per hectare are much higher for commercial trees than for non-commercial trees.

The results also show that the areas at different altitudes and of different forest type have a different stand structure (Table 7). Kamarora, a lowland forest at 800 m above sea level, has a lower number of trees per hectare, which are less dense and have a greater average height than in higher lying plots with different forest types, but it is richer with regard to species, and has a more heterogeneous floral composition. In contrast, Bulu Sombua, a submontane forest type at 1800 m above sea level, has a greater number of trees per hectare but fewer species, and a more homogenous floral composition. The trees stand more densely and have a smaller mean tree height. These results are in accordance with the characteristics of moist evergreen forests described by LAMPRECHT (1989) who states that montane forests have a higher

number of trees per hectare, are less rich in species, are more homogenous in their floral composition, denser and with a smaller average tree height compared to lowland forests.

Compared to the results of the study of BRODBECK (2003), it was found a large difference in the number of trees and the volume per hectare for all trees species with a DBH over 10 cm in the areas Kamarora and Rompo. There were 535 trees per hectare in Kamarora with a volume of 484 m^3, whereas there were 471 trees with 550 m^3 stand volume in Rompo. The differences are probably due to the different methods of measurement that were employed. BRODBECK had only one 100 m by 100 m observation plot in each area, while this study used many sample plots arranged in a systematic pattern through out the research area, with the primary aim of obtaining more representative data. The forest was of varying density throughout the study area which meant that some plots lay in areas with a high density of trees while some were located on very low density areas. One advantage of the systematic arrangement is that the sample plots cover the entire inventory data and do not clump (AKÇA, 2000). Particularly for quality assessment based only on a sub-sample of trees from the entire inventory sample, the selection of the sample must be made on a purely objective basis. Thus, the systematic procedure is recommended, insofar as it does not entail any other bias (FAO, 1981).

6.2 The quality measurement method

Timber production as the major forest product is still the primary objective of forest management in Indonesia. One economic assumption in forest management in Indonesia has never been fully realized in that the trees in the forest have never been calculated as fixed assets. Thus, there is no risk or responsibility for the entrepreneur for the loss or the degradation of forests that had been managed (KARTODIHARDJO, 1999). This means that the standing trees have never been properly valued and tend to be arbitrarily used without consideration to the surrounding environment. The trend that only the best parts of the tree are utilized means that the other parts, which are still utilizable by industry to be left in the field as waste. Some studies showed that the utilized portion of the tree was only about 51.9% to 60.5%. This means that between 39.5% and 48.1% are discarded (BUDIAMAN, 2002).

Since the beginning of forest utilization in Indonesia in 1970s, the estimation of standing tree value has been based only on the volume estimation according to the price of each species group. This has never been changed. Quality estimation has never been included when valuing the standing trees. Thus, the estimate was sometimes much lower or higher than the real value, which is a disadvantage to all who are taking part in this activity. This can also have a large disadvantage for the remaining trees, and is grounds for the concern that tree quality will continue to decrease in the future. The high diversity of tree species is one of the difficulties in implementing quality estimation of standing trees in tropical forests. There are many measurement techniques that can be used for quality estimation, but which have never been attempted to be implemented by the people involved in forest management in Indonesia.

Before determining the quality of the standing tree, the most common defects found in the field were identified. The results of this assessment were very important in order to obtain a general idea of common defects, which can be incorporated into a key to aid the estimation of standing tree quality. It was found that defects such as buttresses, sweep/crook, humps, forks, grooves, grain orientation, flattened, screwing, knottiness, defects on the crown, bark and stem, hole, wound/decay in the trees were common. LAMPRECHT (1989) stated that the buttresses are more common in lowland rain forests than in montane forests. The results in the study areas confirmed LAMPRECHT's statement. It was found that buttresses and other shape defects were more frequent in lowland and uphill forests (Kamarora, Wuasa and Rompo) than in lower montane forests (Kalimpaa and B. Sombua) (Table 48).

Buttresses, humps, forks, flattened, and screwing were unavoidable for some species, but the relevance of these characteristics could be manipulated by the measurement methods. However, knottiness, sweep/crook, grooves, grain orientation, hole, and wound/decay were too important to be manipulated by measurement methods. These defects can directly affect the appearance and strength of the wood products. These defects should therefore be used as defect criteria in establishing the quality key for standing trees in natural tropical forests. The number and type of knots, as well as other defects, should be considered because of their negative impact on quality (Chapter 5.21). MEGRAW (1986) cited in BARBOUR, MARSHALL and LOWELL (2003) stated that wood properties could be divided into two groups: microscopic and macroscopic. Some examples of microscopic properties are cell type, cell wall structure, permeability to treating chemicals, and dimensional stability. Some examples of macroscopic properties are size, frequency and distribution of knots; grain

orientation; grain pattern; stem form; stem straightness; reaction wood; colour and texture. In practice, macroscopic properties are more easily demonstrated than microscopic in standing trees.

Some methods have been in use for a long time, one of which was described by FAO (1981). FAO published the manual of forestry inventory with a special reference to mixed tropical forests. There are two basic approaches that can be adopted for quality assessment*:* the *section concept* and the *tree concept* (Chapter 2). The section concept appears to be more difficult than the tree concept. The disadvantages of this method are that much care is required to allocate defects to appropriate sections, and that it is time consuming, which directly influences the cost of making the inventory. The time and cost of the inventory activity using the tree concept are lower than with the former method. It is suggested that it may be necessary to specify lengths according to species. Based on the experience in the field, showed that it was very difficult to use different heights for each species. Since more than 40 commercial species were found in some areas, it was suggested that the average of relative height from some species be used. The average height of five meters, or 20% of total height (equal to 30% of merchantable height) was used in this study. Five variations of the tree concept or 'the butt-log method' were developed by WIEGARD (1998). The methods offer a low-cost means to measure the quality of standing tree, adaptable to given regional and site factors for oak, beech, ash and pine stands. The five variations are the *simple butt-log method,* the *differentiate butt-log method,* the *simple, expanded butt log method*, the *expanded, differentiated butt-log method* and the *expanded*, *differentiated butt log method with a subdivided upper butt-cut.*

The advantages of the *simple butt-log method* are that it is easy, simple and rapidly performed. This method is suitable for trees with low buttresses or for inventories intended to assess the general tree quality. The presence of buttresses is common in tropical trees, but there are reasons why some trees have no or only low buttress, such as genetic factors (some species are found without or with only low buttresses), low diameter-class trees, in which the buttress is also usually low, or location factors (no or only low buttress present more frequently in montane than lowland forests). Referring to the results of this method (Section 5.221) one sees that the proportion of high quality class trees (A- and B-quality) is higher with a mid-diameter under 40 cm (DBH-mid class $\leq$ 40 cm), with the opposite result being found for trees with a mid diameter class of more than 40 cm. There was because buttresses are less

frequent on trees with a mid-diameter below 40 cm. The disadvantage of this method is that the presence of buttress or other abnormality in the lower part of the tree caused it to be downgraded in quality, even though the upper part contains a good quality class.

The *differentiate butt-log method* tried to avoid the disadvantages of the simple butt-log method. The advantage of this method is that the lower part can be differentiated into parts and it can eliminate the lower part, which usually causes the reduction of the whole tree quality. In other word, the presence of defects of the lower part of the tree can be manipulated using this measurement method. The results show (Section 5.222) that the proportion in the high quality class increased, which is an indication of the advantage of this method. But, although the proportion of trees in higher quality classes increased, this method, as well as the butt-log method, can only give general quality of the trees based on their lower but not their upper parts. This condition was in accordance with FAO (1981), which suggested that in buttressed trees the length is to be applied to the trunk above the buttress.

The huge improvement was achieved by applying the *simple, expanded butt log method* and the *expanded, differentiated butt-log method.* WIEGARD (1998) stated that the simple, expanded butt-log method is the correct choice if a cost-effective inventory of as many mass assortments as possible is to be performed. Based on experience in the field, the implementation of these methods was quite simple and not time-consuming. In addition, the information gained with those methods was very important and valuable. Beside volume and quality information, the potential of assortment distribution in a stand can be properly viewed. Assuming that trees with good quality in their lower parts did not necessarily have the same quality in the upper parts could be described by both methods. The quality differentiation from the base to 5 m height and from 5 m to the merchantable height is a good way to reduce the errors of the further methods.

The *expanded, differentiated butt log method with a subdivided upper butt-cut* is the most complicated variation among the variations presented above. The disadvantage of this method is that it is time consuming, which can influence the cost of inventory activity. This method required more detailed measurements, both in tree dimension and quality. But, a huge advantage can be gained from this method, especially for the mature stands that are ready to harvest or for very valuable tree species. This method can give detailed information

on assortment volume and quality distribution, which is useful for planning the estimation of the assortment utilization.

As mentioned above, the simple, expanded butt log method has many advantages with regard to measurement technique, time, cost and experience in the field. This method was chosen for implementation in the other study areas Kamarora (severely disturbed, located in lowland forest) and Kalimpaa (slightly disturbed, located in submontane forest). The results of the quality assessment in these areas will be used to compare the quality of standing trees in these three different study areas with Rompo classified as a non-disturbed area. According to the results described in Chapter 5.22, the differing quality distribution in these areas can be generally detected using the simple butt-log method and the simple, expanded butt-log method. The evidence shows that there were gradual changes between the areas, from Rompo as a non-disturbed area to Kamarora, which was severely disturbed.

Based on the number of sample trees in each quality class it was clearly demonstrated that the trees in the Rompo area were distributed more in the high quality classes (A and B quality), the trees in the Kalimpaa area tended to be distributed in the medium quality classes (B and C quality), while the trees in Kamarora were mostly of poor quality (C and D quality). Since volume correlates strongly with diameter, the same differing results were found in the volume distribution in each quality class. The sample trees in Rompo and Kalimpaa, which were classified as A and B quality, mostly had larger diameters than the trees with C and D quality. The estimated volumes for these classes were also high. Based on the volume of the sample trees, the trees in Rompo and Kalimpaa were distributed evenly in high quality classes (A and B). The opposite condition was found in Kamarora, where the volume was evenly distributed in B and C quality classes.

In summary, compared to the inventory results obtained prior to including quality assessment, the additional information gained from including quality assessment is very valuable. Initially, the information gave only a general perspective of stand structure, such as the number of trees, their distribution with respect to diameter-class, as well as the volume distribution. After quality assessment, we have a very good overview of the real stand condition, not only the stand structure but also the assortment structure. This information can be used to conduct better tree value estimating and planning for forest management, especially for timber utilization.

7. Summary

With Indonesia's approximately 109 million hectares of forested land, the forestry and the forest industry play an important role in the country's economy. Timber is still the dominant forest product in Indonesia, and its utilization is the basis of many industries. In 1997, the forestry and wood processing sectors accounted for 3.9 % of the GDP, and exports of plywood, pulp and paper were valued at 5.5 billion US$. This amount was nearly half the value of oil and gas exports, and represented nearly 10% of total export earnings. Despite the importance of the forestry sector to the country's economy, timber utilization in natural tropical forests is for the most part, poorly planned, without consideration for the soil and the remaining stand, and also for economical and ecological sustainability. In addition, the use of the timber is usually limited to the best part of the trees. More than one third of the felled trees remain in the forest, although in Indonesia the raw material of wood exists abundantly. Furthermore, due to the concession system implemented in Indonesia, an area of 11.7 million hectares has already been degraded.

The standing trees have usually a potential value that is much higher than the value of the portion actually utilized. In tropical natural forests, in particular, trees with defects are common, and the type of defect affects the merchantable volume and the value of the tree. In tropical forests, the relationship between the gross and the net volume can be as large as 10:8. Consequently, many inventories require a quantification of timber quality. No attempt has been made to implement quality assessment of standing trees in practice because of the technical difficulties associated with the measurement. This study was aimed at determining ways to overcome this problem, and investigated the possibility of implementing this quality assessment concept in the forest inventory activity for standing trees in Indonesian natural forests.

The investigation was conducted in the province of Central Sulawesi around the area of the Lore Lindu National Park (1°S, 120°E). The climate in the research area can be characterized as permanently humid. The forests in the Lore Lindu National Park are predominately montane moist evergreen forests. Five areas were chosen as research locations: Kamarora, east of Lore Lindu National Park, at an altitude of 800 m above sea level, Kalimpaa Lake (1700 m asl), Bulu Sombua (1800 m asl), Wuasa (1000 m asl) are also in the east and Rompo in the remote of south-east at an altitude of 1200 m asl.

The sample plots were systematically established over the study area 250 meters apart using square spacing in the Kalimpaa (3.6 ha) and Rompo (4.0 ha), and line spacing in the Kamarora (3.3 ha) and Wuasa (2.0 ha). One plot was established in Bulu Sombua (0.3 ha). Concentric circular sample plots with three different radii from the same centre were used in this investigation (r_1=5 m (78.6 m^2) for DBH-Class 10-20 cm; r_2=20 m (1257 m^2) for DBH-Class 20-100 cm; r_3=25 m (1964 m^2) for DBH-Class ≥ 100 cm). In these recording units, a complete inventory of the tree vegetation (DBH ≥ 10 cm) was carried out and the following parameters were assessed: tree species, tree position, diameter and height at tree base (d_B and h_B), DBH (Diameter at Breast Height, 1.3 m above ground), diameter at merchantable height, diameter at specific height (d_i), tree height (total and merchantable), tree social class, crown position and form.

The scientific approach to quality assessment was to analyse the known methods. According to the FAO (1981), there are two basic approaches that may be adopted for assessing the external characteristics and defects of standing as well as felled trees, namely the *section concept* and the *tree concept*. The various other methods were developed from these two basic methods, namely: the *fixed-lengths method,* the *short-lengths method,* the *relative-lengths method* and the *butt-log method*. Each method was analysed in order to elucidate its strengths and its weaknesses, and to determine which method was most likely to be implemented in tropical natural forests.

Based on the measurement technique, time, cost and flexibility, it was found that the *butt-log method* had more advantages than the others and it was thus used in this study. The basic butt-log method is a quality measurement is done only on specific lower portion of the trees. The average height of five meters (30% of the average merchantable height) was defined as the butt log in this study, in which the quality measurement was performed. This measurement was taken only for commercial trees.

Five variations (WIEGARD, 1998) were implemented in this study. They are the *simple butt-log method*, which is suitable for trees with no or very low buttress; the *differentiated butt-log method*, which is appropriate for trees with shape abnormalities commonly found on tropical trees between the base of the tree to 5 meters; the *simple, expanded butt-log method,* which would be the proper choice when the quality assessment is primarily to conduct as much mass assortment as possible. Combinations of the second and the third methods are the *expanded*

differentiated butt-log method; and the *expanded*, *differentiated butt-log method with a subdivided upper butt-cut*, which gives more detailed measurements and takes into account that a tree may consist of several quality classes. These are appropriate for very valuable species.

The following major results were obtained:

1. Each study area has a different forest structure. Kamarora and Wuasa, which are categorized as severely disturbed forests, had the lowest number of trees per ha for all tree species with a DBH ≥ 10 cm (125 trees/ha for Kamarora; 183 trees/ha for Wuasa), the lowest basal area per ha (20.81 m^2/ha and 22.83 m^2/ha) and the lowest volume per ha (365 m^3/ha and 376 m^3/ha). Different conditions were found in the Kalimpaa, Bulu Sombua and Rompo areas, whose forest condition are categorized as undisturbed to slightly disturbed. These areas had a higher number of trees per ha, higher basal area per ha and higher volume per ha than the first two areas mentioned above. The number of trees per ha for Kalimpaa, B. Sombua and Rompo were 225, 336 and 258, respectively. The values of basal area per ha in these areas were 32.46 m^2/ha; 38.0 m^2/ha; 30.18 m^2/ha, resp., and the stand volume values for those areas were 533 m^3/ha, 598 m^3/ha and 487 m^3/ha, resp.

2. Due to the large number of the trees in the diameter class between 20 and 30 cm in all study areas, the diameter distribution was asymmetrical (skewed to the right with a of value 1 to 2.5), as was to be expected in the natural tropical all-aged forest. The diameter distribution curves in those five study areas can be approximated by the Weibull function. A similar function was also used to approximate the height distribution, but the shape of height distributions tend to be more symmetrical than diameter distribution.

3. Six stand height equations (second degree parable, Prodan, Petterson, Korsun, Logarithmic and Freese) were used in analysing the stand height curve of each location. The Petterson equation gave a better fit than the other equations for the Kamarora, Kalimpaa, Bulu Sombua and Wuasa areas, while the Korsun equation gave a good fit for stand height in the Rompo area. The stand height curves showed that the average stand height varied between the individual study areas. The average stand height in Kamarora (lowland forest) was higher than in Wuasa and Rompo (hill forest), Kalimpaa and Bulu Sombua (submontane forest).

4. The floristic assessment revealed a trend that fewer tree species were found the higher the location of the study area. Fifty species from 29 tree families were found in the sample plots in Kamarora, while there were 28 species (22 families) in Kalimpaa, 46 species (25 families) in Wuasa, and 45 species (28 families) in Rompo. In all of the sample plots, Lauraceae, Moraceae, Meliaceae, Myrtaceae, Euprobiaceae, Rubiaceae were among the ten most species-rich families.

5. The defect assessment of trees in all study areas showed that buttresses, sweep/crook, humps, forks, grooves, flattened and screwing in the trees, were commonly present as a direct influence on the shape quality (straightness and taper). The results showed that these defects were more common in the lower altitude areas (Kamarora, Wuasa and Rompo) compared to higher areas (Kalimpaa and Sombua). The presence of sound and unsound knots, knobs, wounds, or decay along the tree surface were common defects that directly influence the quality assessment for tropical standing trees. A similar trend of the effect of altitude on the occurrence of these defects was seen. The presence of sound and unsound knots was much higher in the lower altitude stands (Kamarora, Wuasa and Rompo) than in Kalimpaa and Sombua.

6. The analysis of five quality assessment variations are presented in a case study. One can conclude that the *simple butt-log method* gave trees of larger diameter a smaller chance of qualifying for the higher quality class, because shape and surface defects occurred mostly on the lower part of the trees. The *differentiated butt-log method* can reduce the problems arising from abnormalities of the lower parts of the tree and can enhance the chances for large diameter trees of qualifying for a higher quality class. The improvement of using the *simple, expanded butt-log method* was that the individual quality distribution of the lower and upper parts can be clearly described, and the upper parts can thus also qualify for either a higher or a lower quality class. The *expanded differentiated butt-log method* also gave a good chance for standing trees to be qualified properly. Although the *expanded*, *differentiated butt log method with a subdivided upper butt-cut* is quite complicated, the results show that each part of the tree has a similar chance to be qualified, and it shows that a single standing tree may consist of several quality classes. The results are presented under two aspects - quality and volume distribution.

7. *The simple, expanded butt-log* method was implemented in two other areas, which had stand conditions different than the Rompo area. This was aimed at determining if a differing degree of disturbance within an area would also give a different quality distribution of the standing trees. According to the number of sample trees, the trees in the Rompo area (classified as a non-disturbed area located in hill forest) were distributed more in high quality classes (A and B), the trees in Kalimpaa area (classified as a slightly disturbed area located in sub-montane forest) tended to be of medium quality (B and C), while the trees in Kamarora (classified as a severely disturbed area locatef in lowland forest) were distributed mostly in poor quality classes (C and D). Based on the volume of the sample trees, the trees in Rompo and Kalimpaa were distributed evenly in high quality classes (A and B), while they were mostly in the B and C quality classes in the Kamarora area.

In summary, compared with the results of the inventory alone without quality assessment, the additional information gained from quality assessment is very valuable. Inventory alone only gives general information on stand structure, such as the number of trees and their distribution with respect to diameter-class, as well as the volume distribution. After quality assessment, a very good picture of the real stand condition can be presented- not only the stand structure but also quality and assortment distribution. This information can be used to conduct better tree value estimation and planning for forest management, especially timber utilization.

8. Zusammenfassung

Mit etwa 109 Millionen Hektar Waldfläche spielt die Forstwirtschaft und Holzindustrie in Indonesien in der Ökonomie des Landes eine sehr wichtige Rolle. Holz ist nach wie vor das Hauptforsterzeugnis in Indonesien und bildet die Grundlage zahlreicher Industriezweige. Im Jahre 1997, stellten Forstwirtschaft und Holzverarbeitung 3,9% des Bruttoinlandproduktes dar, und die Exporte von Sperrholz, Pulp und Papier hatten einen Wert von 5,5 Milliarden US-$. Dieses entsprach ungefähr die Hälfte der Erdöl- und Erdgasexporte und repräsentierte fast 10% des gesamten Exporteinkommens. Trotz dieser Bedeutung der Forstwirtschaft für die Ökonomie des Landes erfolgt die Holznutzung in den tropischen Naturwäldern zum größten Teil planlos und ohne Berücksichtigung des Bodens, des verbleibenden Baumbestandes oder der ökonomischen und ökologischen Nachhaltigkeit. In der Regel werden nur die besten Anteil des Baumes verwendet. Der Rohstoff "Holz" ist in Indonesien überreichlich vorhanden, und mehr als ein Drittel der gefällten Bäume verbleiben im Forst. Darüber hinaus ist aufgrund des in Indonesien implementierten Konzessionssystems eine Fläche von mehr als 11,7 Millionen Hektar bereits geschädigt worden.

Die stehenden Bäume haben einen potentiellen Wert, der viel höher liegt als der des verwendeten Anteils. Besonders in Naturwäldern sind Bäume häufig defekt, und die Art des Defekts beeinflusst den verkäufbaren Volumen und den Wert des Baumes. In tropischen Wäldern kann das Verhältnis zwischen Brutto- und Nettovolumen einen Wert bis 10:8 erreichen. Infolgedessen erfordern viele Bestandsaufnahmen Inventuren eine Quantifizierung der Holzqualität. Aufgrund der mit der Durchführung verbundenen technischen Schwierigkeiten wurden bislang keine Versuche unternommen, eine Qualitätsansprache stehender Bäume in der Praxis einzuführen. Die vorliegende Studie hatte zum Ziel, Wege zu finden, um dieses Problem zu überwinden, und die Möglichkeit zu untersuchen, das Konzept der Qualitätsansprache in die forstinventuren für stehende Bäume zu implementieren.

Die Studie wurde in der Provinz “Central Sulawesi“ im Nationalpark “Lore Lindu“ (1°S, 120°E) durchgeführt. Das Klima im Untersuchungsgebiet kann als dauerfeucht charakterisiert werden. Die Wälder im Lore Lindu Nationalpark sind vorwiegend montan, feucht und immergrün. Es wurden fünf Gebiete als Untersuchungsareale ausgewählt: Kamarora, auf einer Höhe von 800 m über dem Meereshöhe, Kalimpaa Lake (1700 m üMH),

Bulu Sombua (1800 m üMH) und Wuasa (1000 m üMH), alle im Osten des Nationalparks und Rompo im abgelegenen Südosten auf einer Höhe von 1200 m üMH.

Die Probekreise wurden in den einzelnen Untersuchungsflächen systematisch angeordnet mit einem Abstand von 250 m. Die Anordnung war quadratisch in den Gebieten Kalimpaa (Flächensumme von Probeflächen: 3,6 ha) und Rompo (4,0 ha) und linear in den Flächen Kamarora (3,3 ha) und Wuasa (2,0 ha). Nur ein Probekreis wurde in Bulu Sombua (0,3 ha) etabliert. Konzentrische Probekreise mit drei unterschiedlichen Radien wurden für die Untersuchung verwendet ((r_1=5 m (78,6 m^2) für die DBH-Klasse von 10-20 cm; r_2=20 m (1257 m^2) für die DBH-Klasse von 20-100 cm; r_3=25 m (1964 m^2) für die DBH-Klasse über 100 cm). Auf diesen Flächen wurde eine komplette Bestandsaufnahme des Baumbestandes (DBH ≥ 10 cm) mit folgenden Parametern durchgeführt: Baumart, Standort des Baumes, Durchmesser und Höhe an der Basis, DBH (Durchmesser in Brusthöhe = 1,3 m über Grund), Durchmesser in der kommerziellen Höhe, Durchmesser bei einer vorgegebenen Höhe (d_i), Höhe des Baumes (gesamt und kommerziell), Baumklassen nach KRAFT, Position und Form der Krone.

Der wissenschaftliche Ansatz zur Untersuchung der Qualitätsbeurteilung war eine Analyse der bekannten Methoden. Nach der FAO (1981) gibt es zwei grundlegende Ansätze zur Beurteilung die äußeren Merkmale und Defekte stehender und auch gefällter Bäume. Diese sind das *Sektionkonzept* und das *Baumkonzept*. Die in der Praxis üblichen, wie z.B. *die Fixlängenmethode, die Unterlängenmethode, die Relativelängenmethode* und *die Erdstückmethode* sind Weiterentwicklungen dieser beiden Grundmethoden. Jede Methode wurde auf seine Vor- und Nachteile untersucht, um festzustellen, welche am ehesten in tropischen Regenwäldern implementiert werden könnte. Auf der Basis der Messmethoden, der benötigten Zeit, der Kosten und Flexibilität wurde festgestellt, dass die Erdstückmethode gegenüber den anderen Methoden mehr Vorteile aufwies und deshalb in dieser Studie verwendet wurde. Bei der Erdstückmethode wird nur auf einem spezifischen unteren Teil der Bäume Qualität angesprochen. Auf einer Sektion von durchschnittlich 5m Höhe (30% der durchschnittlichen kommerziellen Länge) wurde in dieser Studie Qualitätansprache nur bei kommerziell verwertbaren Bäumen durchgeführt.

Fünf Variationen dieser Methode (WIEGARD, 1998) wurden in die Studie herangezogen. Diese waren *die einfache Erdstückmethode*, die für Bäume ohne oder mit nur geringem

Brettwurzler geeignet ist; *die differenzierte Erdstückmethode*, die für Bäume mit den bei tropischen Bäumen typischen Formabweichungen bis zu einer Höhe von 5 Metern angemessen ist; *die einfache erweiterte Erdstückmethode*, wenn die Qualitätsbeurteilung in erster Linie der Durchführung einer größtmöglichen Massensortierung dienen soll. Kombinationen der zweiten und dritten Methode sind *die erweiterte differenzierte Erdstückmethode* und *die erweiterte differezierte Erdstückmethode mit dem unterteilten oberen Stammstück.* Beide ergeben detailliertere Messungen und berücksichtigen die Tatsache, dass ein Baum Anteile aus unterschiedlichen Qualitätsklassen enthalten kann, und sind für sehr wertvolle Baumarten angemessen.

Die Untersuchungen ergaben folgende Hauptergebnisse:

1. Jedes Untersuchungsgebiet hatte eine unterschiedliche Bestandesstruktur. Kamarora und Wuasa, als stark gestört klassifiziert, hatten die geringste Anzahl von Bäumen pro Hektar für alle Baumarten mit einem DBH von mehr als 10 cm (125 Bäume/ha für Kamarora, 183 Bäume/ha für Wuasa), die geringste Grundfläche (20,81 m^2/ha bzw. 22,83 m^2/ha) und das geringste Volumen pro Hektar (365 m^3/ha bzw. 376 m^3/ha). Abweichende Ergebnisse wurden in den Gebieten Kalimpaa, Bulu Sombua und Rompo gefunden. Diese Flächen werden als ungestört bis mäßig gestört eingestuft. Sie hatten eine höhere Anzahl von Bäumen, eine höhere Grundfläche sowie ein höheres Volumen pro Hektar als die erstgenannten Gebiete. Die Anzahl Bäume pro Hektar für Kalimpaa, B. Sombua und Rompo waren 225, 336 bzw. 258. Die Grundflächen in diesen Gebieten waren 32,46 m^2/ha, 38,0 m^2/ha bzw. 30,18 m^2/ha, und das Volumen betrug 533 m^3/ha, 598 m^3/ha bzw. 487 m^3/ha.

2. Aufgrund der hohen Anzahl von Bäumen in der Durchmesserklasse zwischen 20 und 30 cm auf allen Untersuchungsflächen war die Durchmesserverteilung asymmetrisch (rechts-schief mit einem f-Wert von 1 bis 2,5) wie in tropischen Naturwäldern mit allen Altersstufen zu erwarten ist. Die Verteilungskurve der Durchmesser in diesen fünf Untersuchungsgebieten kann mit der Weibull-Funktion angenähert werden. Eine ähnliche Näherungsfunktion wurde ebenfalls für die Höhenverteilungen verwendet. Diese neigten allerdings eher zu einer mehr symmetrischen Form als die Durchmesserverteilungen.

3. Sechs verschiedene Gleichungen (Parabel zweiten Grades, Prodan, Petterson, Korsun, logarithmisch und Freese) wurden zur Analyse der Bestandshöhenkurven der einzelnen

Gebiete verwendet. Für die Gebiete Kamarora, Kalimpaa und Bulu Sombua ergab die Petterson-Gleichung eine bessere Anpassung als die anderen Gleichungen, während die Korsun-Gleichung eine gute Anpassung für die Bestandshöhen in Rompo gab. Die Bestandshöhenkurven zeigten, dass die mittleren Bestandshöhen in den einzelnen Untersuchungsgebieten unterschiedlich waren. Die mittlere Bestandshöhe war in Kamarora (Tiefland Feuchtwälder) größer als in Wuasa und Rompo (Berg Feuchtwälder), Kalimpaa und Bulu Sombua (submontane Feuchtwälder).

4. Die floristische Auswertung zeigte eine Tendenz, dass weniger Baumarten gefunden werden je höher das Studiengebiet liegt. Fünfzig Arten aus 29 Familien wurden auf den Untersuchungsflächen in Kamarora gefunden, während 28 Arten (22 Familien) in Kalimpaa, 46 Arten (25 Familien) in Wuasa und 45 Arten (28 Familien) in Rompo gefunden wurden. Auf allen Untersuchungsflächen waren Lauraceae, Moraceae, Meliaceae, Myrtaceae, Euprobiaceae und Rubiaceae unter den zehn artenreichsten Familien.

5. Die Defektansprache der Bäume in allen Studiengebieten zeigte, dass Brettwurzler, Krummwüchsigkeit, Wimmerwuchs, Zwieselwuchs, Spannrückigkeit, Ovalität und Drehwuchs als häufiger Einfluss auf die Formqualität (Gradlinigkeit und form) vorhanden waren. Unsere Ergebnisse zeigten, dass diese Defekte in den tiefer liegenden Gebieten (Kamarora, Wuasa und Rompo) häufiger vorkamen als in den höher gelegenen Gebieten (Kalimpaa und Sombua). Das Vorhandensein von gesunden oder toten Astlöchern, Beulen, Wunden, oder Faulstellen auf der Baumoberfläche waren häufige Defekte, die die Qualitätseinteilung stehender tropischer Bäume direkt beeinflussten. Es wurde ein ähnlicher Einfluss der Höhe über Meereshöhe (üMH) auf das Auftreten dieser Defekte beobachtet. Gesunde und tote Astlöcher waren in den tieferliegenden Beständen (Kamarora, Wuasa und Rompo) häufiger als in Kalimpaa oder Sombua.

6. Die Auswertung von fünf unterschiedlichen Variationen der Qualitätsbeurteilung werden in einem Fallbeispiel vorgestellt. Es kann der Schluss gezogen werden, dass *die einfache Erdstückmethode* Bäumen mit einem größeren Durchmesser eine geringere Chance einräumte, in höhere Qualitätsklassen eingestuft zu werden, da Form- und Oberflächendefekte meistens auf den unteren Abschnitten des Baumes auftraten. *Die differenzierte Erdstückmethode* kann die Probleme, die von den Formabweichungen der unteren Baumabschnitte herrühren, vermindern und die Chancen für Bäume größeren

Durchmessers verbessern, in eine höhere Qualitätsklasse eingestuft zu werden. Die Verbesserung, die durch die Anwendung *der einfachen erweiterten Erdstückmethode* erzielt wurde, war, dass die Qualitätsverteilung zwischen unterem und oberem Anteil genau beschrieben werden konnte, und dass der obere Anteil für sich in eine höhere oder niedrigere Qualitätsklasse eingestuft werden konnte. *Die erweiterte differenzierte Erdstückmethode* ergab ebenfalls eine gute Chance für stehende Bäume korrekt eingestuft zu werden. Obwohl *die erweiterte differezierte Erdstückmethode mit dem unterteilen oberen Stammstück* verhältnismäßig kompliziert ist, zeigen die Ergebnisse, dass die einzelnen Abschnitte eines Baumes gleiche Chancen hatten, für eine höhere Qualitätsstufe in Frage zu kommen. Sie zeigen auch, dass ein einzelner stehender Baum aus Abschnitten unterschiedlichster Qualitätsklassen bestehen kann. Die Ergebnisse werden unter zwei Aspekten -Qualitäts- und Volumenverteilung – dargestellt.

7. *Die einfache erweiterte Erdstückmethode* wurde in zwei weiteren Gebieten angewandt, die unterschiedliche Standortbedingungen als Rompo aufwiesen. Hierdurch sollte festgestellt werden, ob das Ausmaß der Störung innerhalb des Standortes unterschiedlich war, und ob dieses eine veränderte Qualitätsverteilung der stehenden Bäumen verursachte. Der Anzahl nach waren die Bäume im Rompo-Gebiet (als nicht-gestörtes Gebiet klassifiziert, im Berg Feuchtwälder gelegen) eher in Klassen höherer Qualität (A und B) eingestuft. Die Bäume im Kalimpaa-Gebiet (mäßig gestört, Submontane Feuchtwälder) waren eher in Klassen mittlerer Qualität (B und C) eingestuft, während die Bäume in Kamarora (schwer gestört, Tiefland Feuchtwälder) zum größten Teil schlechterer Qualität (C und D) waren. Dem Volumen nach waren die Bäume in Rompo und Kalimpaa gleichmäßig in Klassen hoher Qualität (A und B) und die in Kamarora in die Qualitätsklassen B und C verteilt.

Zusammenfassend kann festgestellt werden, dass der Informationsgewinn durch die Anwendung einer Qualitätsbeurteilung im Vergleich zur Bestandsaufnahme ohne Qualitätsansprache sehr wertvoll ist. Die Bestandsaufnahme allein ergibt nur allgemeine Informationen über die Bestandsstruktur, wie z.B. Anzahl Bäume und ihre Verteilung hinsichtlich Durchmesserklassen und Volumen. Nach der Qualitätsbeurteilung erhält man einen sehr guten Überblick über den tatsächlichen Zustand des Bestandes – nicht nur die Bestandsstruktur, sondern auch noch Qualitäts- und Sortiments. Diese Informationen können zur besseren Wertermittlung und Planung in der Forstwirtschaft (insbesondere Holznutzung) verwendet werden.

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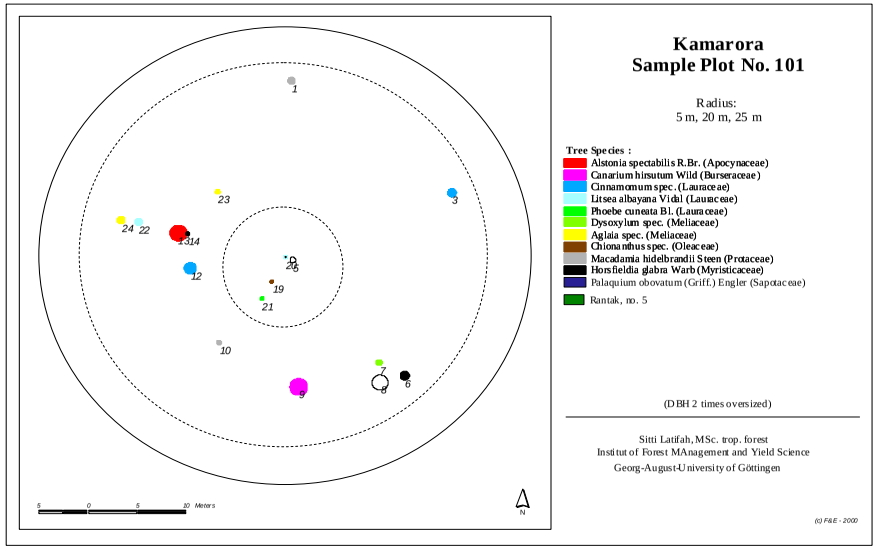
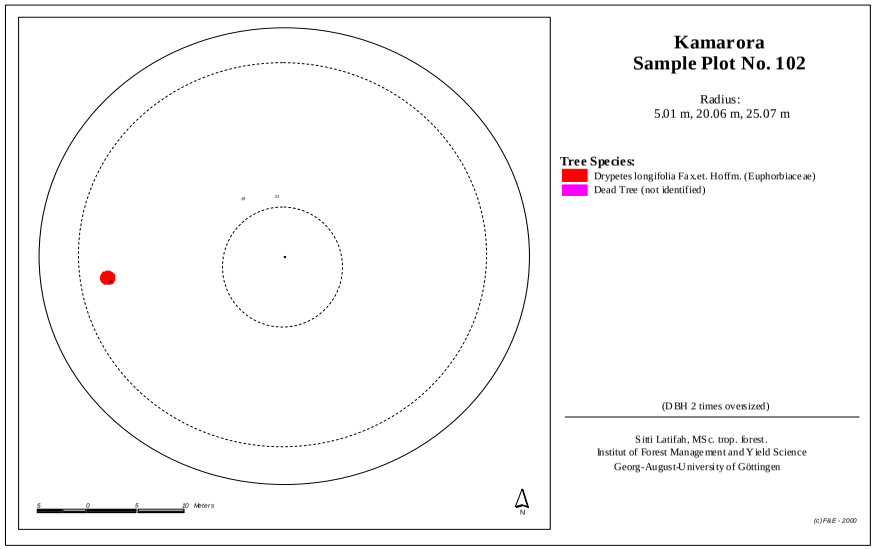
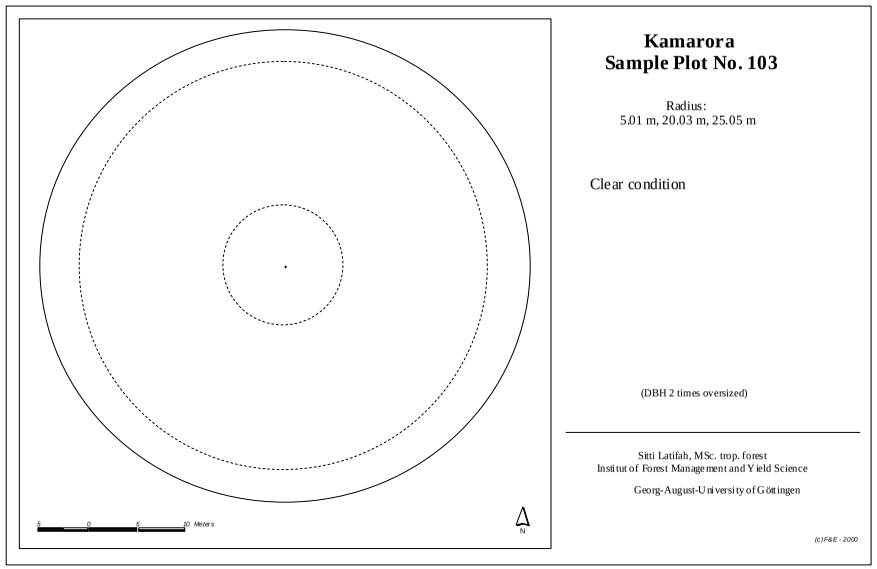
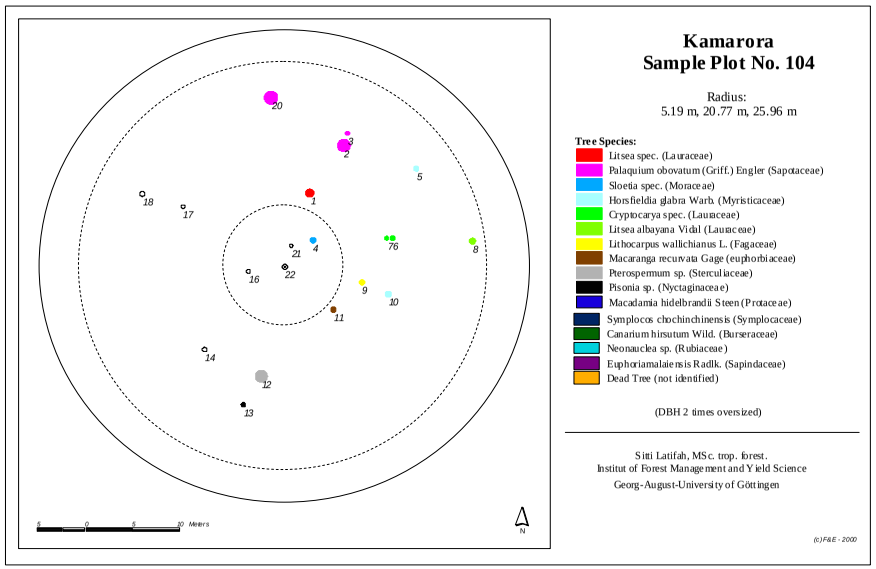
10. Appendices

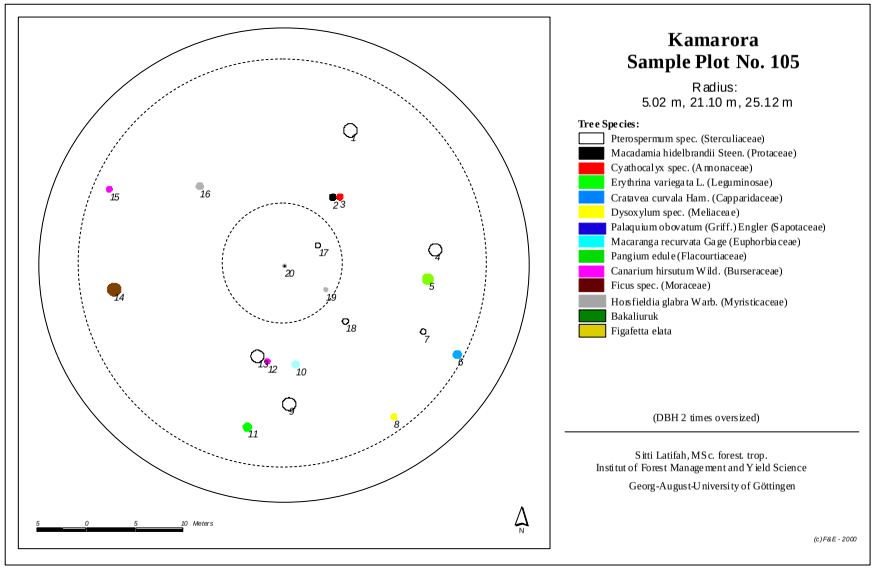
Appendix 1. The Position of Sample Trees inside Sample Plot in Kamarora Area

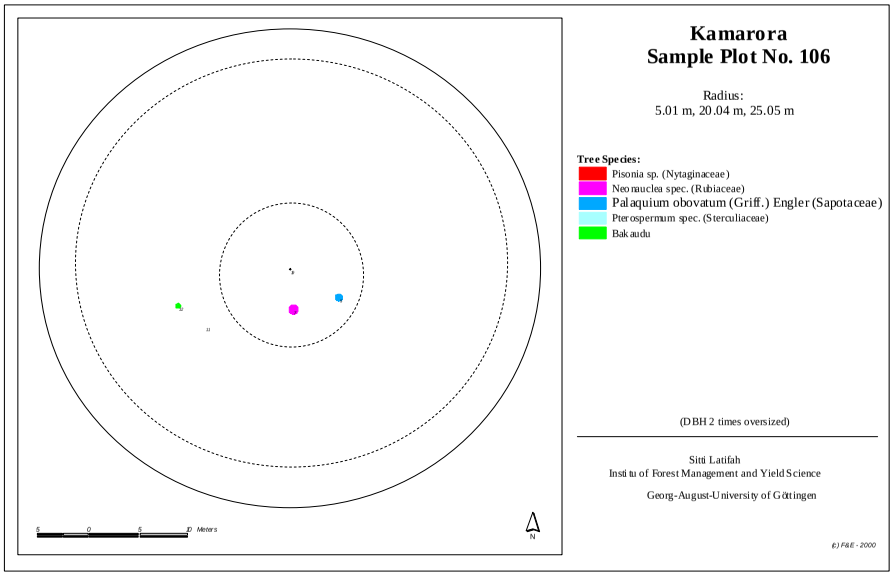


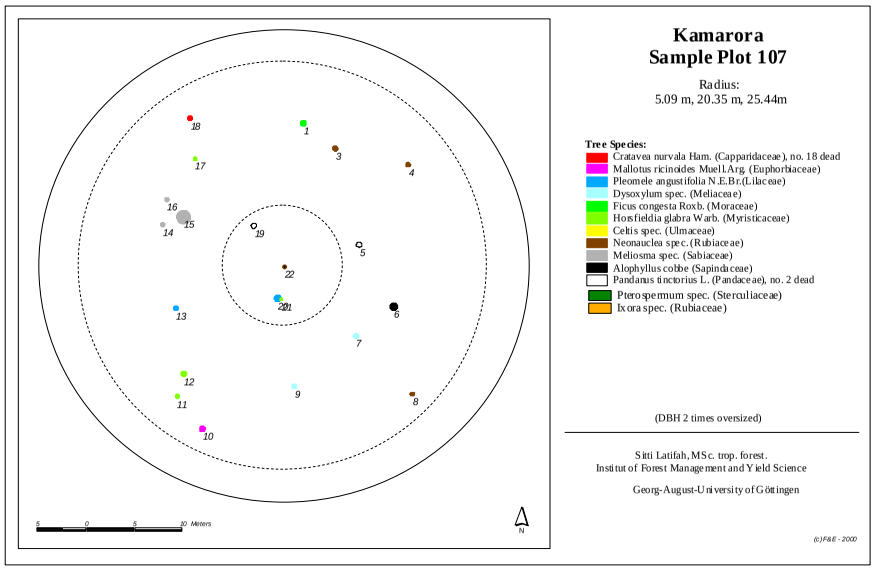


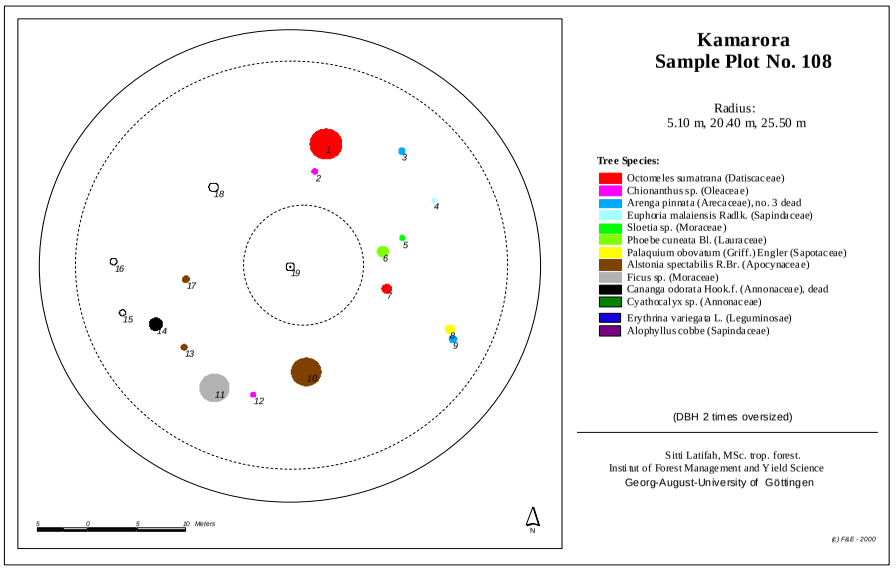





Kamarora
Sample Plot No. 105
Radius:
5.02 m, 21.10 m, 25.12 m
Tree Species:
Pterospermum spec. (Sterculiaceae)
Macadamia hidelbrandii Steen. (Protaceae)
Cyathocalyx spec. (Annonaceae)
Erythrina variegata L. (Leguminosae)
Crataveva curvala Ham. (Capparidaceae)
Dysoxylum spec. (Meliaceae)
Palaquium obovatum (Griff.) Engler (Sapotaceae)
Macaranga recurvata Gage (Euphorbiaceae)
Pangium edule (Flacourtiaceae)
Canarium hirsutum Wild. (Burseraceae)
Ficus spec. (Moraceae)
Horsfieldia glabra Warb. (Myristicaceae)
Bakaliuruk
Figafetta elata
(DBH 2 times oversized)
Sitti Latifah, MSc. forest. trop.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000
Meters
N


Kamarora
Sample Plot No. 106
Radius:
5.01 m, 20.04 m, 25.05 m
Tree Species:
Pisonia sp. (Nyctaginaceae)
Neonauclea spec. (Rubiaceae)
Palaquium obovatum (Griff.) Engler (Sapotaceae)
Pterospermum spec. (Sterculiaceae)
Bakaudu
(DBH 2 times oversized)
Sitti Latifah
Institu of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000
Meters
N


Kamarora
Sample Plot 107
Radius:
5.09 m, 20.35 m, 25.44m
Tree Species:
Crataveva nurvala Ham. (Capparidaceae), no. 18 dead
Mallotus ricinoides Muell.Arg. (Euphorbiaceae)
Pleomele angustifolia N.E.Br.(Liliaceae)
Dysoxylum spec. (Meliaceae)
Ficus congesta Roxb. (Moraceae)
Horsfieldia glabra Warb. (Myristicaceae)
Celtis spec. (Ulmaceae)
Neonauclea spec. (Rubiaceae)
Meliosma spec. (Sabiaceae)
Alophyllus cobbe (Sapindaceae)
Pandanus tinctorius L. (Pandaceae), no. 2 dead
Pterospermum spec. (Sterculiaceae)
Ixora spec. (Rubiaceae)
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000
Meters
N


Kamarora
Sample Plot No. 108
Radius:
5.10 m, 20.40 m, 25.50 m
Tree Species:
Octomeles sumatrana (Datiscaceae)
Chionanthus sp. (Oleaceae)
Arenga pinnata (Arecaceae), no. 3 dead
Euphoria malaiensis Radlk. (Sapindaceae)
Sloetia sp. (Moraceae)
Phoebe cuneata Bl. (Lauraceae)
Palaquium obovatum (Griff.) Engler (Sapotaceae)
Alstonia spectabilis R.Br. (Apocynaceae)
Ficus sp. (Moraceae)
Cananga odorata Hook.f. (Annonaceae), dead
Cyathocalyx sp. (Annonaceae)
Erythrina variegata L. (Leguminosae)
Alophyllus cobbe (Sapindaceae)
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
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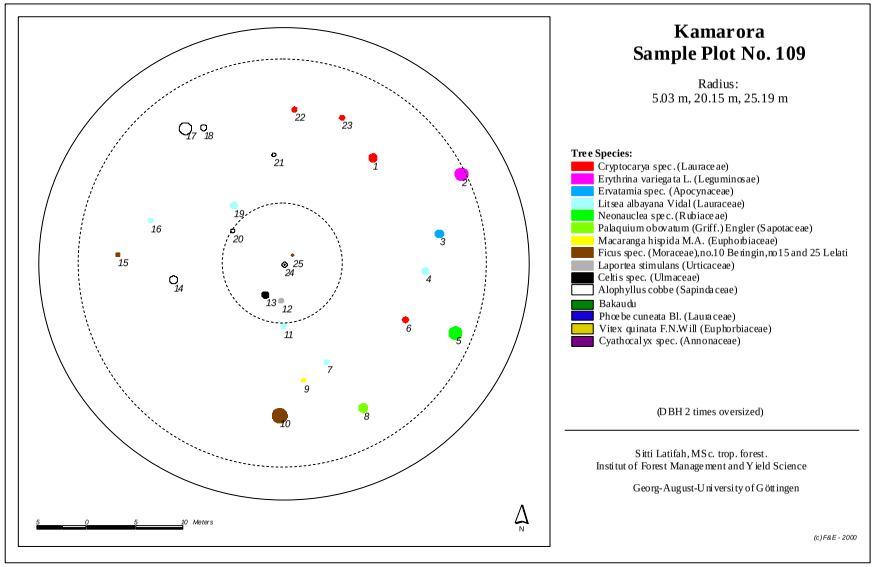
(c) F&E - 2000
Meters
N


Kamarora
Sample Plot No. 109
Radius:
5.03 m, 20.15 m, 25.19 m
Tree Species:
Cryptocarya spec. (Lauraceae)
Erythrina variegata L. (Leguminosae)
Evatamia spec. (Apocynaceae)
Litsea albayana Vidal (Lauraceae)
Neonauclea spec. (Rubiaceae)
Palaquium obovatum (Griff.) Engler (Sapotaceae)
Macaranga hispida M.A. (Euphorbiaceae)
Ficus spec. (Moraceae),no.10 Beringin,no15 and 25 Lelati
Laportea stimulans (Urticaceae)
Celtis spec. (Ulmaceae)
Alophyllus cobbe (Sapindaceae)
Bakaudu
Phoebe cuneata Bl. (Lauraceae)
Vitex quinata F.N.Will (Euphorbiaceae)
Cyathocalyx spec. (Annonaceae)
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
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Georg-August-University of Göttingen
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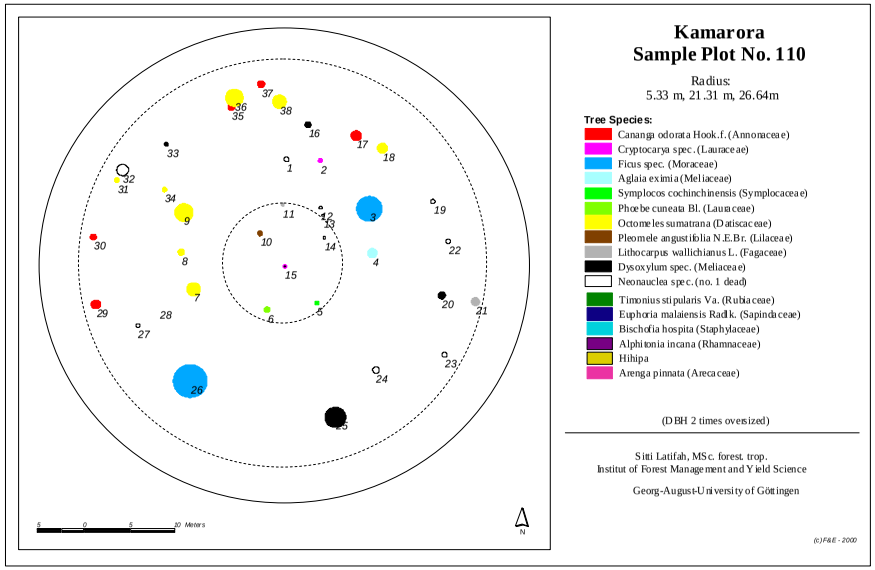
Meters
N


Kamarora
Sample Plot No. 110
Radius:
5.33 m, 21.31 m, 26.64m
Tree Species:
Cananga odorata Hook.f. (Annonaceae)
Cryptocarya spec. (Lauraceae)
Ficus spec. (Moraceae)
Aglaia eximia (Meliaceae)
Symplocos cochinchinensis (Symplocaceae)
Phoebe cuneata Bl. (Lauraceae)
Octomeles sumatrana (Datiscaceae)
Pleomele angustifolia N.E.Br. (Liliaceae)
Lithocarpus wallichianus L. (Fagaceae)
Dysoxylum spec. (Meliaceae)
Neonauclea spec. (no. 1 dead)
Timonius stipularis Va. (Rubiaceae)
Euphoria malaiensis Radlk. (Sapindaceae)
Bischofia hospita (Staphylaceae)
Alphitonia incana (Rhamnaceae)
Hihipa
Arenga pinnata (Arecaceae)
(DBH 2 times oversized)
Sitti Latifah, MSc. forest. trop.
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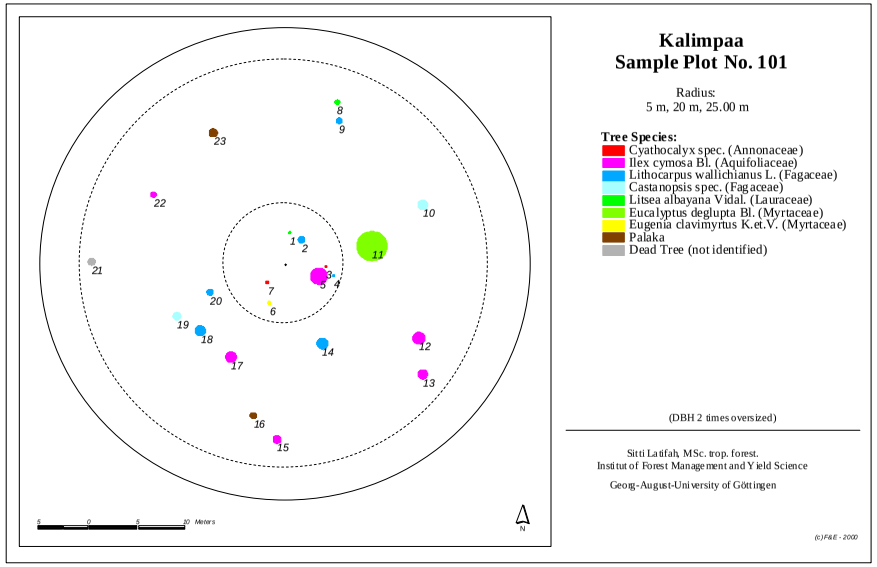
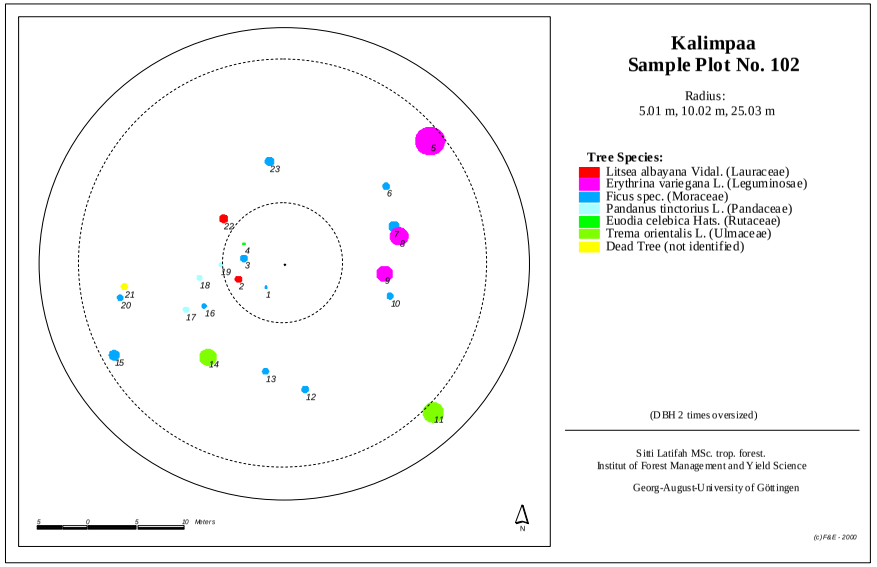
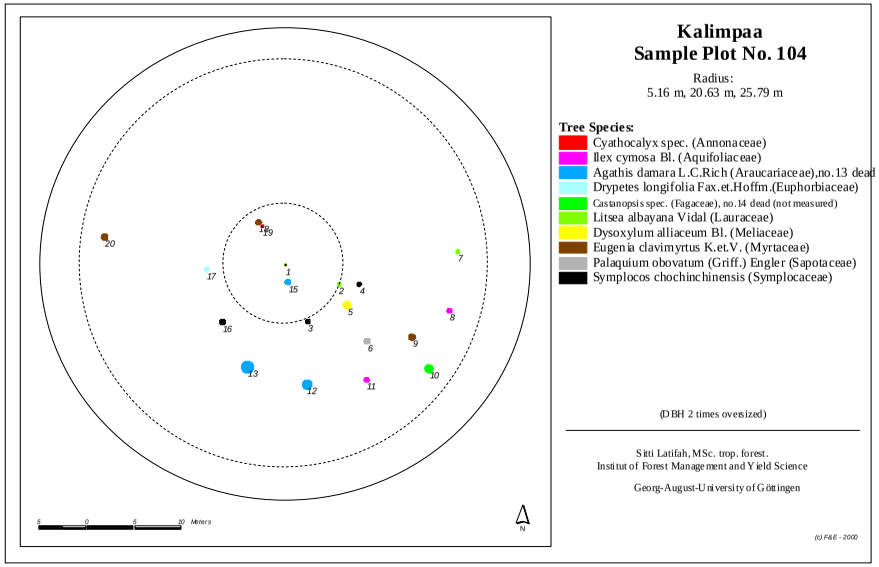
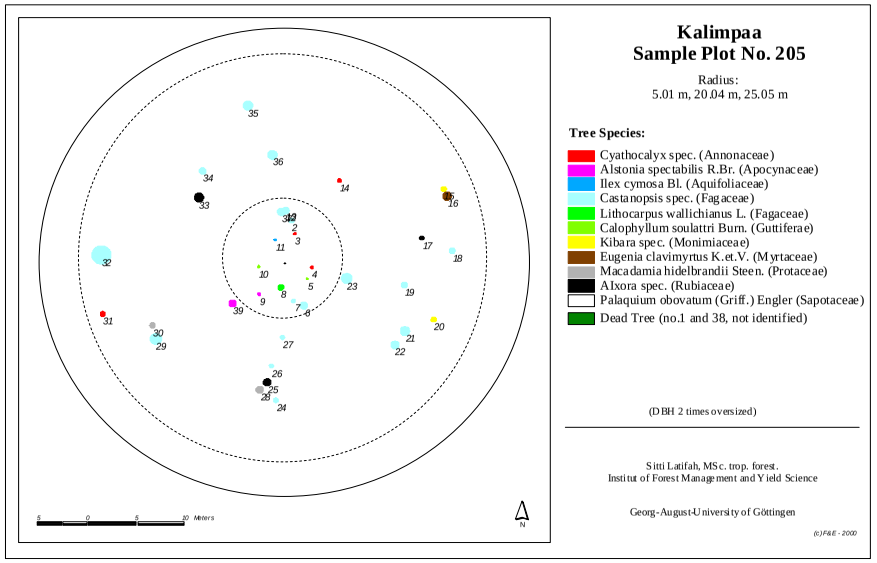
Meters
N

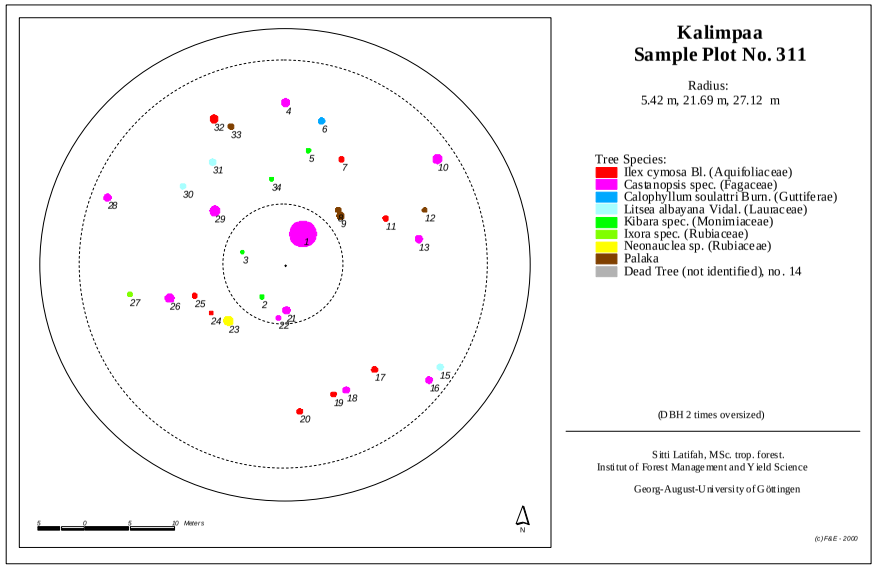
Appendix 2. The Position of Sample Trees inside Sample Plot in Kalimpaa Area










Kalimpaa
Sample Plot No. 311
Radius:
5.42 m, 21.69 m, 27.12 m
Tree Species:
Ilex cymosa Bl. (Aquifoliaceae)
Castanopsis spec. (Fagaceae)
Calophyllum soulattri Burm. (Guttiferae)
Litsea albayana Vidal. (Lauraceae)
Kibara spec. (Monimiaceae)
Ixora spec. (Rubiaceae)
Neonauclea sp. (Rubiaceae)
Palaka
Dead Tree (not identified), no. 14
(DBH 2 times oversized)
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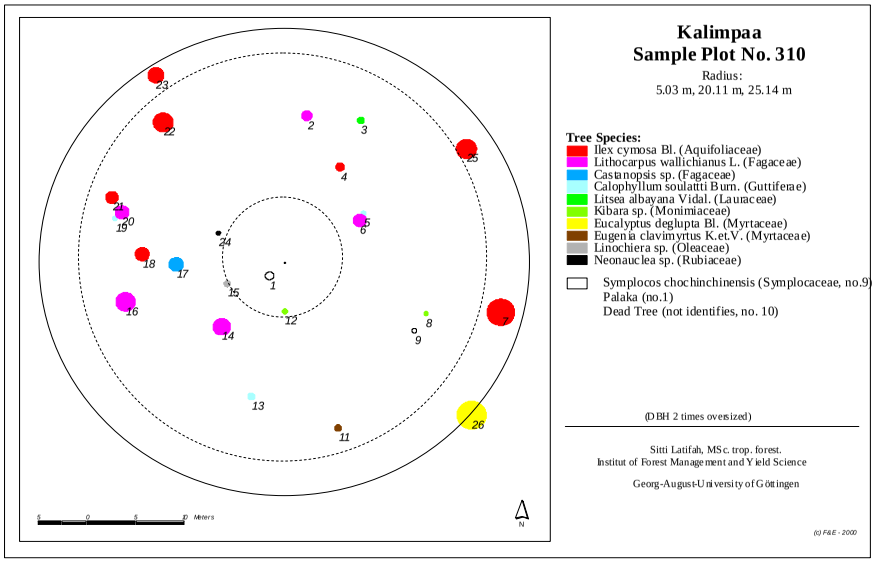
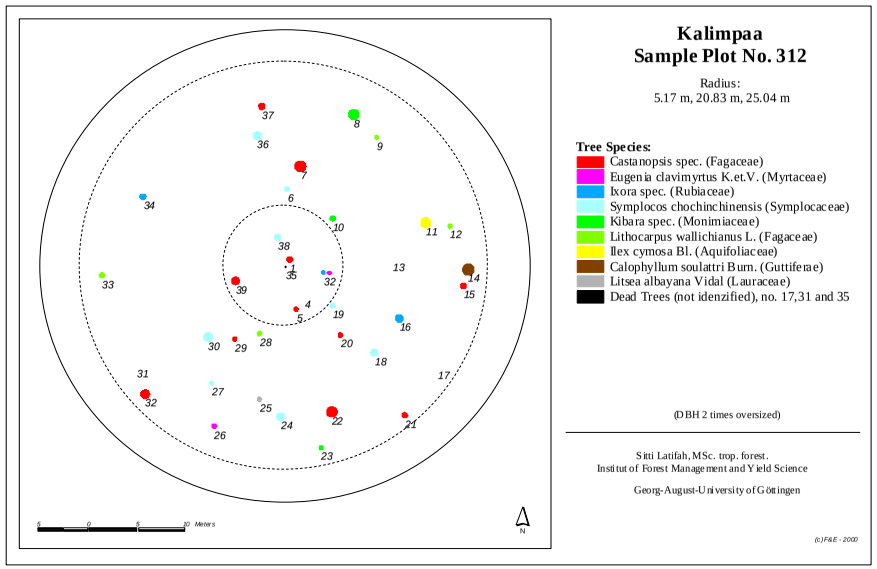
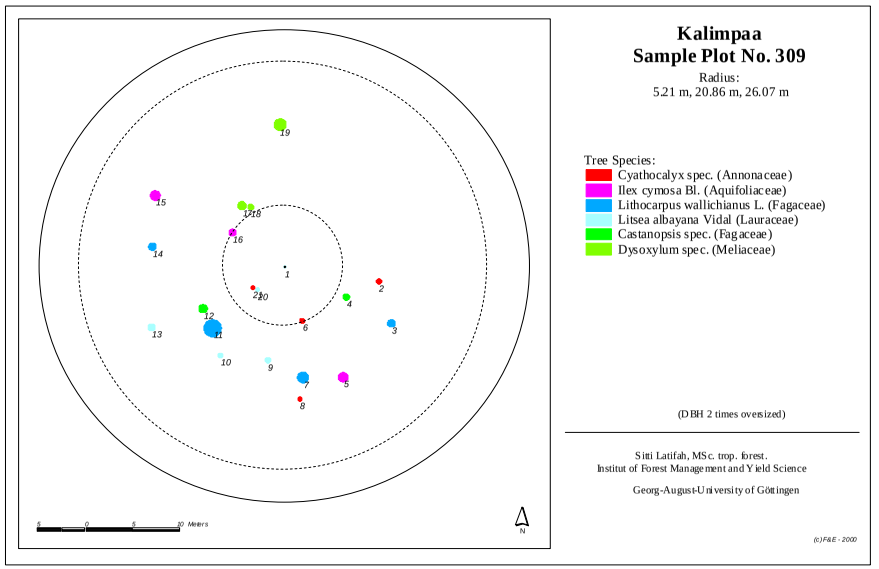
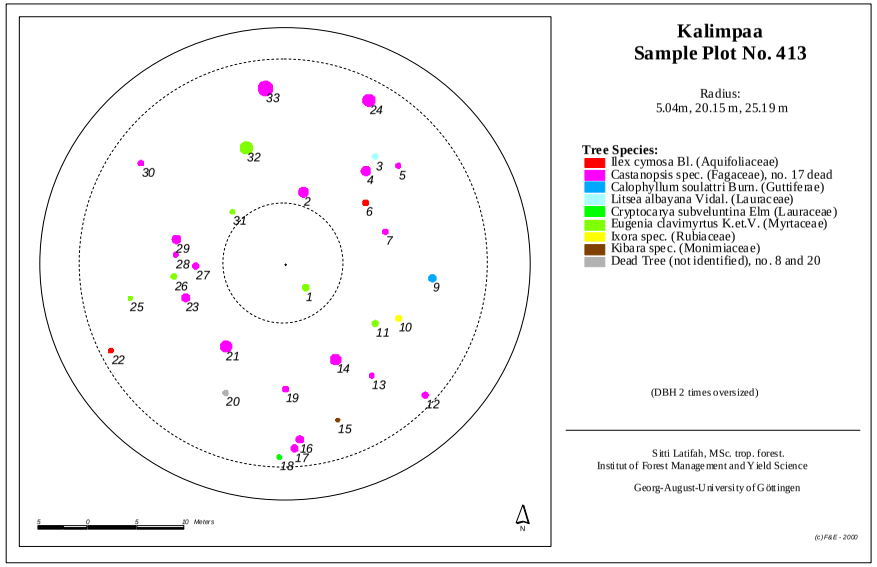
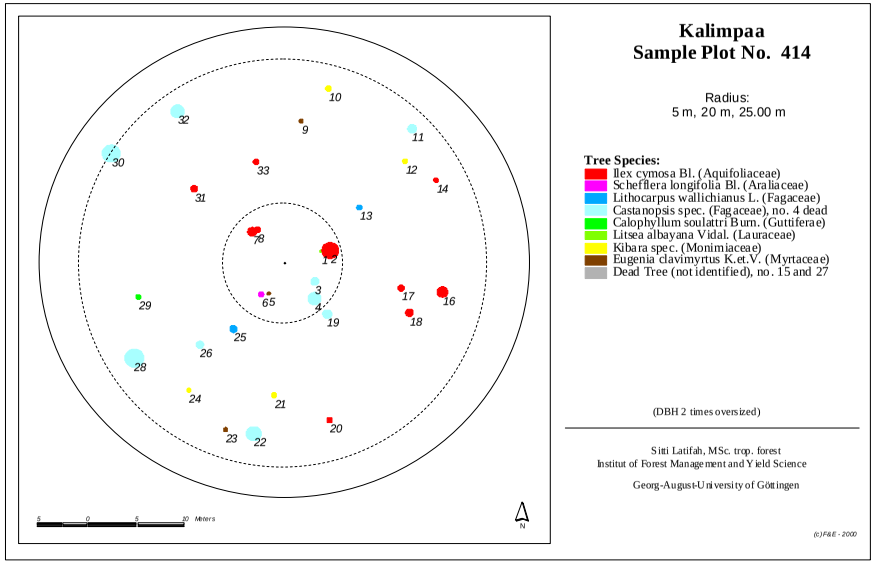
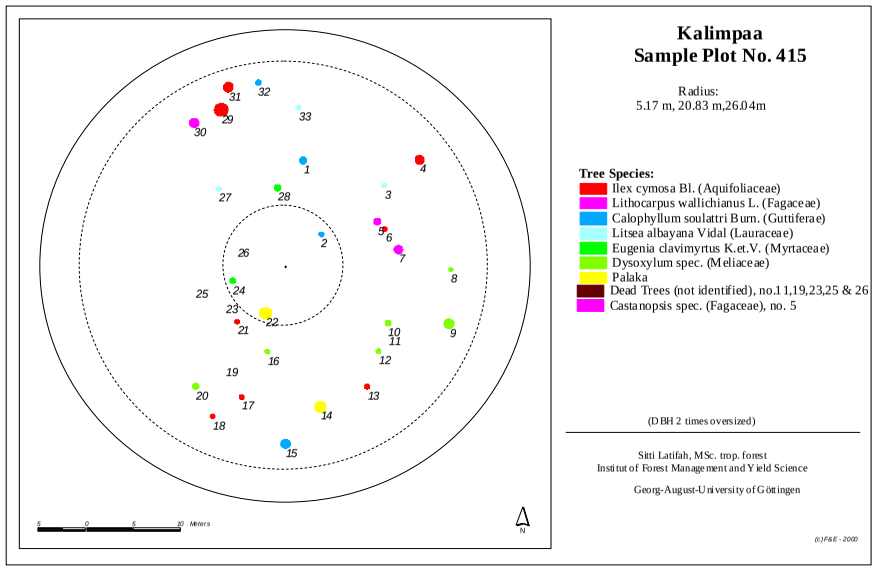

Kalimpaa
Sample Plot No. 310
Radius:
5.03 m, 20.11 m, 25.14 m
Tree Species:
Ilex cymosa Bl. (Aquifoliaceae)
Lithocarpus wallichianus L. (Fagaceae)
Castanopsis sp. (Fagaceae)
Calophyllum soulattri Burm. (Guttiferae)
Litsea albayana Vidal. (Lauraceae)
Kibara sp. (Monimiaceae)
Eucalyptus deglupta Bl. (Myrtaceae)
Eugenia clavimyrtus K.et.V. (Myrtaceae)
Linochiera sp. (Oleaceae)
Neonauclea sp. (Rubiaceae)
Symplocos chochinchinensis (Symplocaceae, no.9)
Palaka (no.1)
Dead Tree (not identifies, no. 10)
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000


Kalimpaa
Sample Plot No. 312
Radius:
5.17 m, 20.83 m, 25.04 m
Tree Species:
Castanopsis spec. (Fagaceae)
Eugenia clavimyrtus K.et.V. (Myrtaceae)
Ixora spec. (Rubiaceae)
Symplocos chochinchinensis (Symplocaceae)
Kibara spec. (Monimiaceae)
Lithocarpus wallichianus L. (Fagaceae)
Ilex cymosa Bl. (Aquifoliaceae)
Calophyllum soulattri Burm. (Guttiferae)
Litsea albayana Vidal (Lauraceae)
Dead Trees (not idenzified), no. 17,31 and 35
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000


Kalimpaa
Sample Plot No. 309
Radius:
5.21 m, 20.86 m, 26.07 m
Tree Species:
Cyathocalyx spec. (Annonaceae)
Ilex cymosa Bl. (Aquifoliaceae)
Lithocarpus wallichianus L. (Fagaceae)
Litsea albayana Vidal (Lauraceae)
Castanopsis spec. (Fagaceae)
Dysoxylum spec. (Meliaceae)
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000


Kalimpaa
Sample Plot No. 413
Radius:
5.04m, 20.15 m, 25.19 m
Tree Species:
Ilex cymosa Bl. (Aquifoliaceae)
Castanopsis spec. (Fagaceae), no. 17 dead
Calophyllum soulattri Burn. (Guttiferae)
Litsea albayana Vidal. (Lauraceae)
Cryptocarya subveluntina Elm (Lauraceae)
Eugenia clavimyrtus K.et.V. (Myrtaceae)
Ixora spec. (Rubiaceae)
Kibara spec. (Monimiaceae)
Dead Tree (not identified), no. 8 and 20
(DBH 2 times oversized)
Siti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000
Meters
N


Kalimpaa
Sample Plot No. 414
Radius:
5 m, 20 m, 25.00 m
Tree Species:
Ilex cymosa Bl. (Aquifoliaceae)
Schefflera longifolia Bl. (Araliaceae)
Lithocarpus wallichianus L. (Fagaceae)
Castanopsis spec. (Fagaceae), no. 4 dead
Calophyllum soulattri Burn. (Guttiferae)
Litsea albayana Vidal. (Lauraceae)
Kibara spec. (Monimiaceae)
Eugenia clavimyrtus K.et.V. (Myrtaceae)
Dead Tree (not identified), no. 15 and 27
(DBH 2 times oversized)
Siti Latifah, MSc. trop. forest
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000
Meters
N


Kalimpaa
Sample Plot No. 415
Radius:
5.17 m, 20.83 m,26.04m
Tree Species:
Ilex cymosa Bl. (Aquifoliaceae)
Lithocarpus wallichianus L. (Fagaceae)
Calophyllum soulattri Burn. (Guttiferae)
Litsea albayana Vidal (Lauraceae)
Eugenia clavimyrtus K.et.V. (Myrtaceae)
Dysoxylum spec. (Meliaceae)
Palaka
Dead Trees (not identified), no.1 1,19,23,25 & 26
Castanopsis spec. (Fagaceae), no. 5
(DBH 2 times oversized)
Siti Latifah, MSc. trop. forest
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
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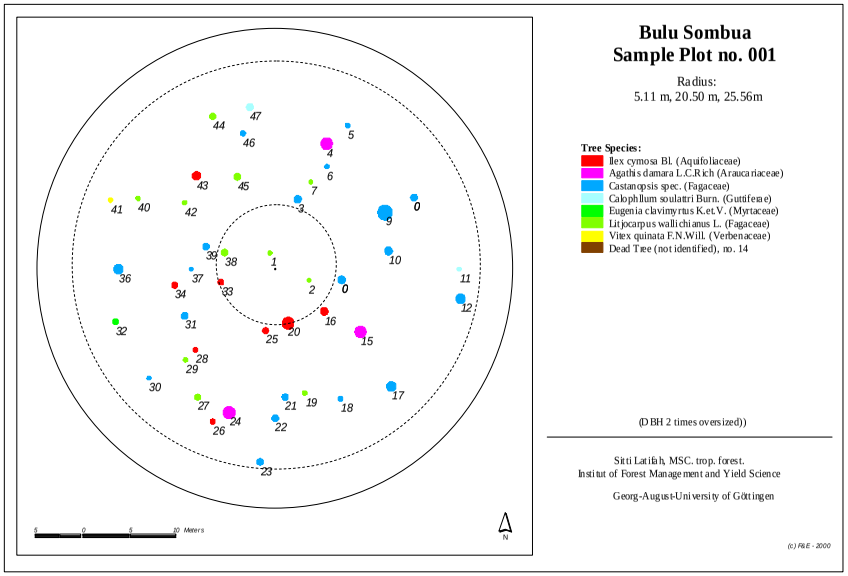
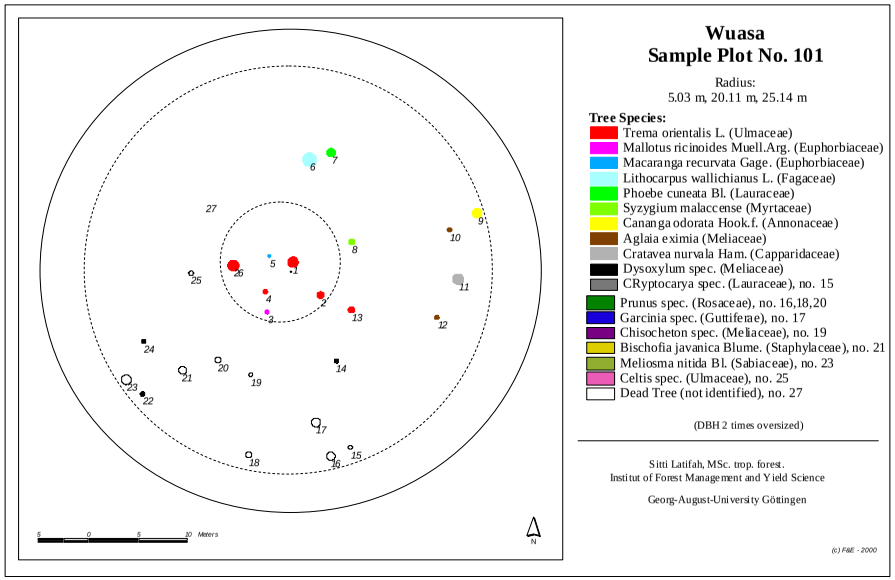
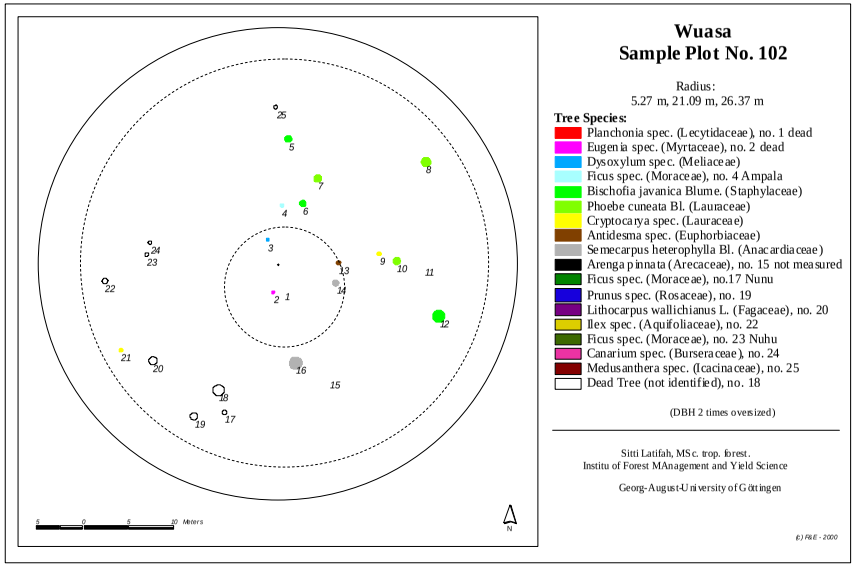
Meters
N

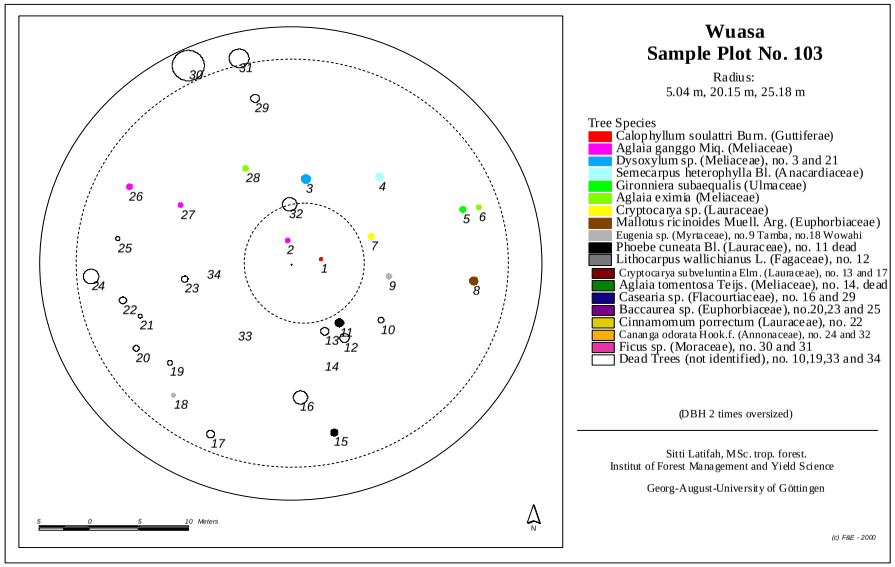
Appendix 3. The Position of Sample Trees inside Sample Plot in Bulu Sombua Area

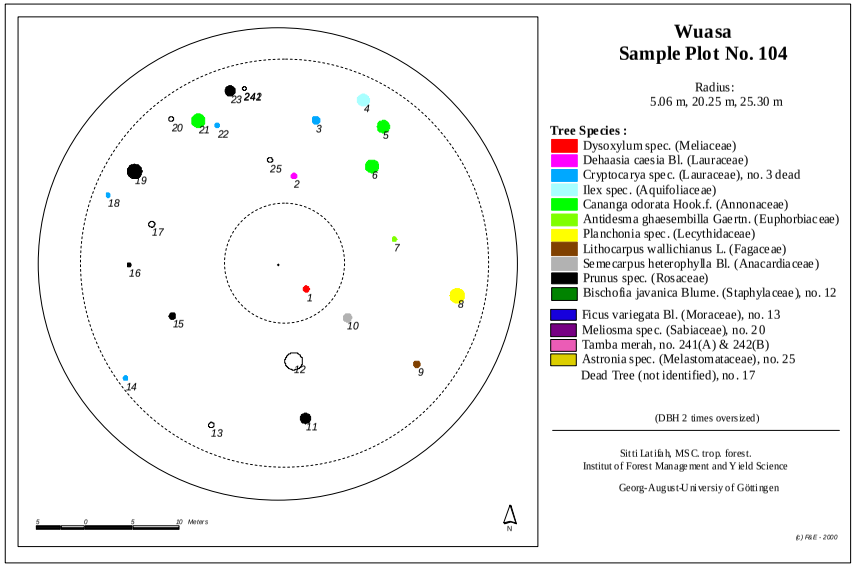


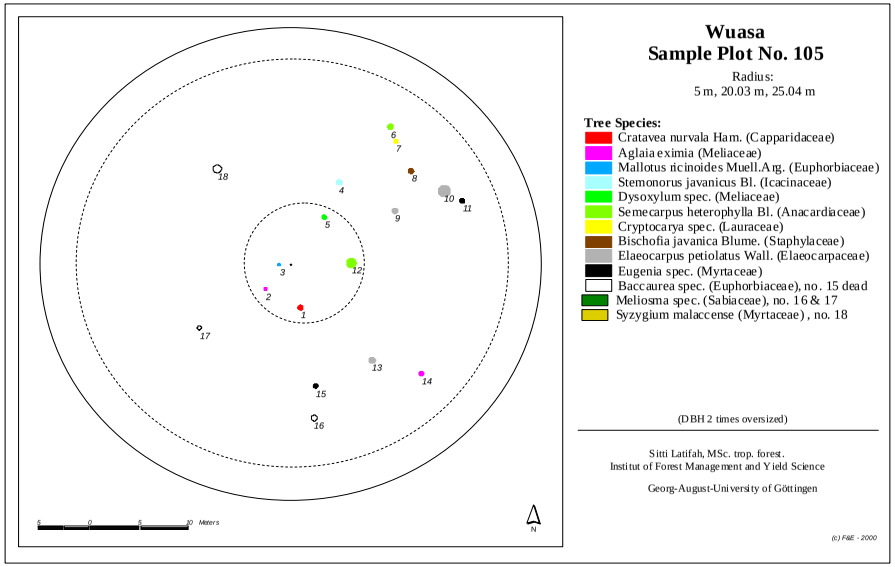
Appendix 4. The Position of Sample Trees inside Sample Plot at Wuasa Area

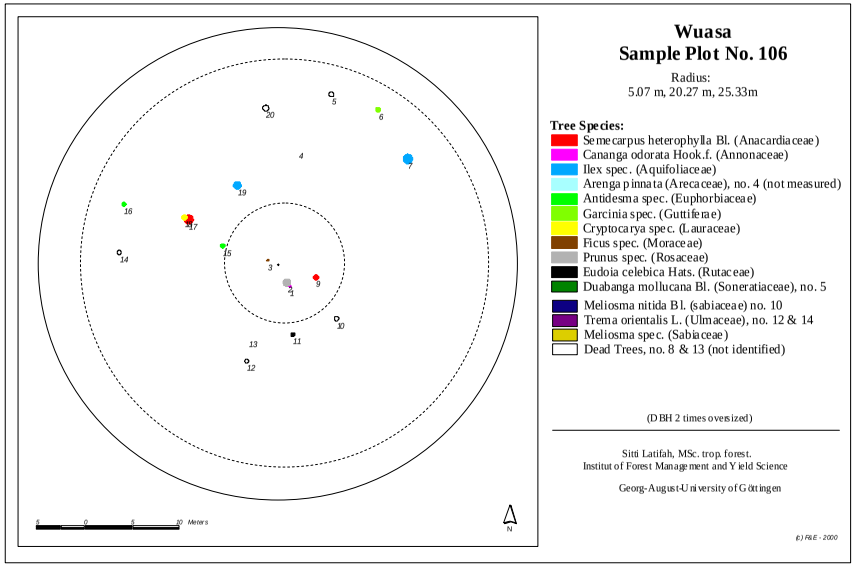









Wuasa
Sample Plot No. 105
Radius:
5 m, 20.03 m, 25.04 m
Tree Species:
Cratavea nurvala Ham. (Capparidaceae)
Aglaia eximia (Meliaceae)
Mallotus ricinoides Muell.Arg. (Euphorbiaceae)
Stemonorus javanicus Bl. (Icacinaceae)
Dysoxylum spec. (Meliaceae)
Semecarpus heterophylla Bl. (Anacardiaceae)
Cryptocarya spec. (Lauraceae)
Bischofia javanica Blume. (Staphylaceae)
Elaeocarpus petiolatus Wall. (Elaeocarpaceae)
Eugenia spec. (Myrtaceae)
Baccaurea spec. (Euphorbiaceae), no. 15 dead
Meliosma spec. (Sabiaceae), no. 16 & 17
Syzygium malaccense (Myrtaceae) , no. 18
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
(c) F&E - 2000
Meters
N


Wuasa
Sample Plot No. 106
Radius:
5.07 m, 20.27 m, 25.33m
Tree Species:
Semecarpus heterophylla Bl. (Anacardiaceae)
Cananga odorata Hook.f. (Annonaceae)
Ilex spec. (Aquifoliaceae)
Arenga pinnata (Arecaceae), no. 4 (not measured)
Antidesma spec. (Euphorbiaceae)
Garcinia spec. (Guttiferae)
Cryptocarya spec. (Lauraceae)
Ficus spec. (Moraceae)
Prunus spec. (Rosaceae)
Eudoia celebica Hats. (Rutaceae)
Duabanga mollucana Bl. (Soneratiaceae), no. 5
Meliosma nitida Bl. (sabiaceae) no. 10
Trema orientalis L. (Ulmaceae), no. 12 & 14
Meliosma spec. (Sabiaceae)
Dead Trees, no. 8 & 13 (not identified)
(DBH 2 times oversized)
Sitti Latifah, MSc. trop. forest.
Institut of Forest Management and Yield Science
Georg-August-University of Göttingen
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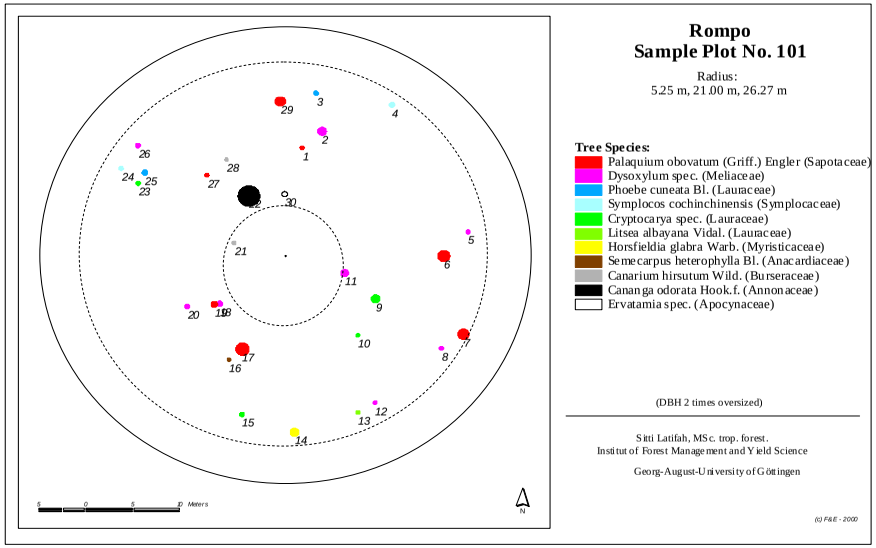
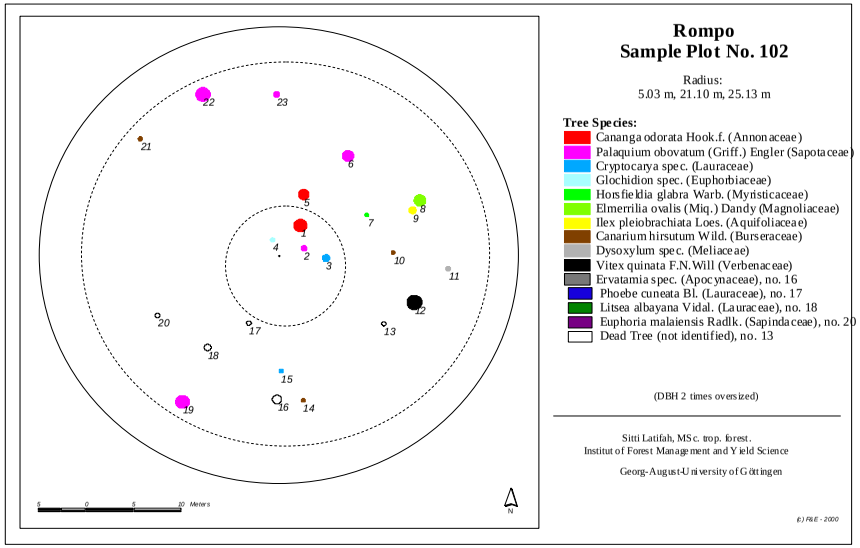
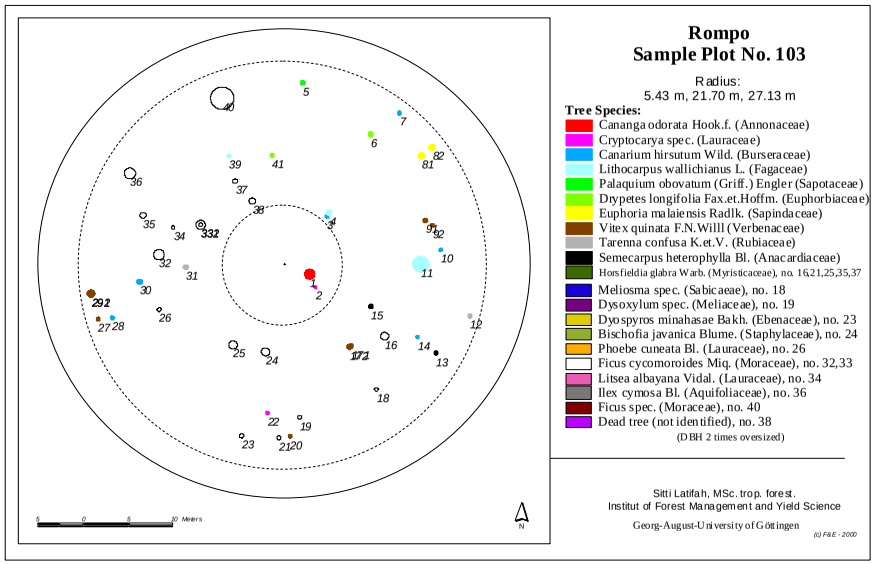
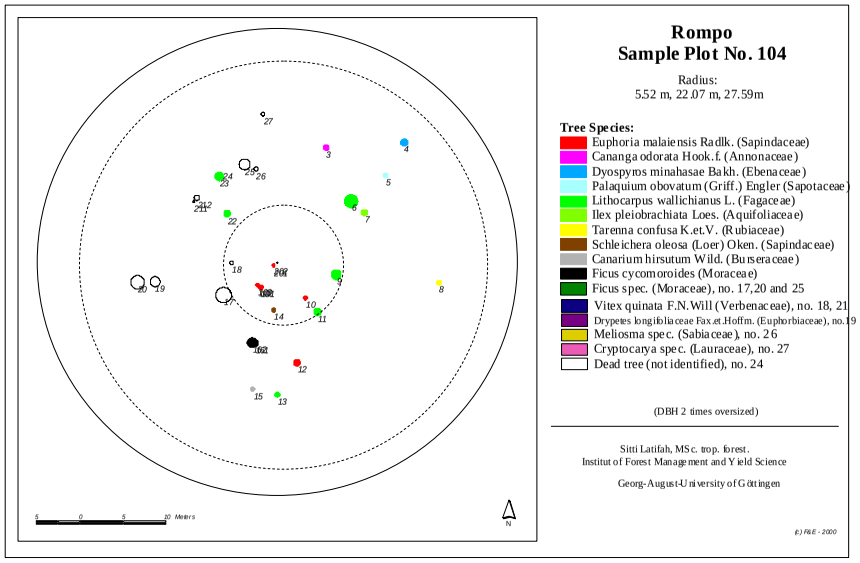
Meters
N

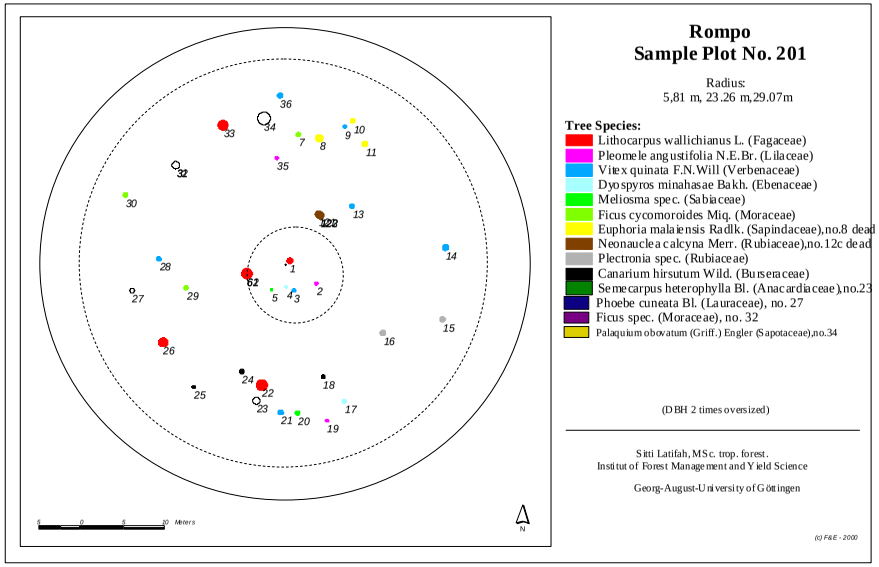
Appendix 5. The Position of Sample Trees inside Sample Plot in Rompo Area











Rompo
Sample Plot No. 201

Radius:
5,81 m, 23.26 m,29.07m

Tree Species:
- Lithocarpus wallichianus L. (Fagaceae)
- Pleomele angustifolia N.E.Br. (Lilaceae)
- Vitex quinata F.N.Will (Verbenaceae)
- Dyospyros minahasae Bakh. (Ebenaceae)
- Meliosma spec. (Sabiaceae)
- Ficus cycomoroides Miq. (Moraceae)
- Euphoria malaiensis Radlk. (Sapindaceae),no.8 dead
- Neonauclea calcyna Merr. (Rubiaceae),no.12c dead
- Plectronia spec. (Rubiaceae)
- Canarium hirsutum Wild. (Burseraceae)
- Semecarpus heterophylla Bl. (Anacardiaceae),no.23
- Phoebe cuneata Bl. (Lauraceae), no. 27
- Ficus spec. (Moraceae), no. 32
- Palaquium obovatum (Griff.) Engler (Sapotaceae),no.34

(DBH 2 times oversized)

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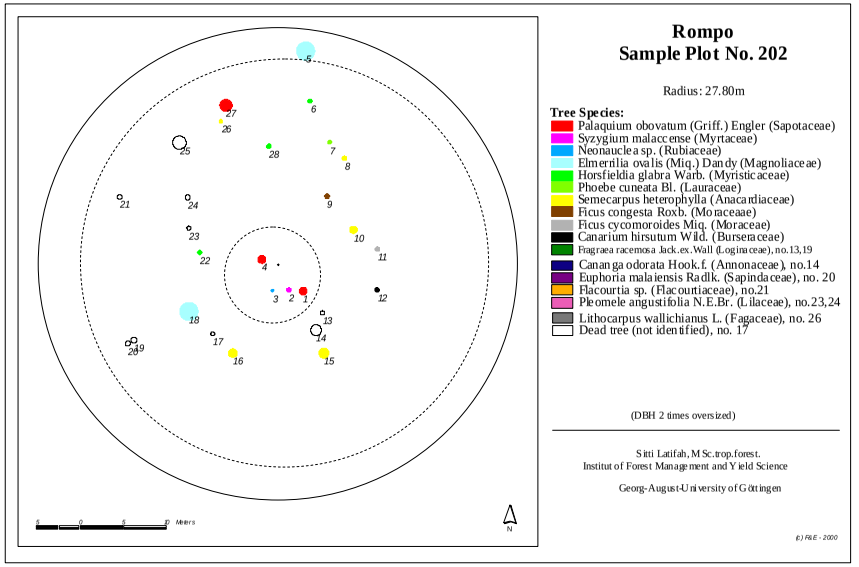

Rompo
Sample Plot No. 202

Radius: 27.80m

Tree Species:
- Palaquium obovatum (Griff.) Engler (Sapotaceae)
- Syzygium malaccense (Myrtaceae)
- Neonauclea sp. (Rubiaceae)
- Elmerrilia ovalis (Miq.) Dandy (Magnoliaceae)
- Horsfieldia glabra Warb. (Myristicaceae)
- Phoebe cuneata Bl. (Lauraceae)
- Semecarpus heterophylla (Anacardiaceae)
- Ficus congesta Roxb. (Moraceae)
- Ficus cycomoroides Miq. (Moraceae)
- Canarium hirsutum Wild. (Burseraceae)
- Fragraea racemosa Jack.ex.Wall (Loginaceae), no.13,19
- Cananga odorata Hook.f. (Annonaceae), no.14
- Euphoria malaiensis Radlk. (Sapindaceae), no. 20
- Flacourtia sp. (Flacourtiaceae), no.21
- Pleomele angustifolia N.E.Br. (Lilaceae), no.23,24
- Lithocarpus wallichianus L. (Fagaceae), no. 26
- Dead tree (not identified), no. 17

(DBH 2 times oversized)

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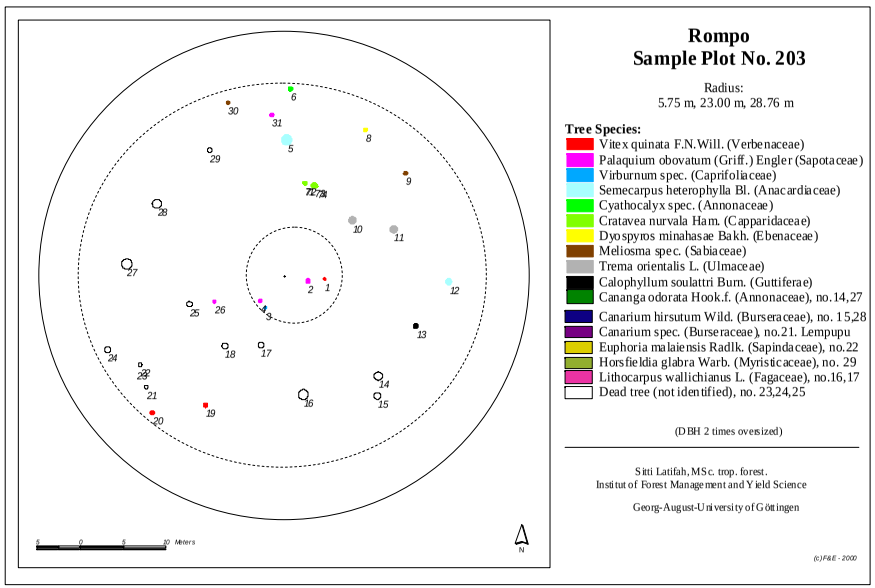

Rompo
Sample Plot No. 203

Radius:
5.75 m, 23.00 m, 28.76 m

Tree Species:
- Vitex quinata F.N.Will. (Verbenaceae)
- Palaquium obovatum (Griff.) Engler (Sapotaceae)
- Virburnum spec. (Caprifoliaceae)
- Semecarpus heterophylla Bl. (Anacardiaceae)
- Cyathocalyx spec. (Annonaceae)
- Cratavea nurvala Ham. (Capparidaceae)
- Dyospyros minahasae Bakh. (Ebenaceae)
- Meliosma spec. (Sabiaceae)
- Trema orientalis L. (Ulmaceae)
- Calophyllum soulattri Burm. (Guttiferae)
- Cananga odorata Hook.f. (Annonaceae), no.14,27
- Canarium hirsutum Wild. (Burseraceae), no. 15,28
- Canarium spec. (Burseraceae), no.21. Lempupu
- Euphoria malaiensis Radlk. (Sapindaceae), no.22
- Horsfieldia glabra Warb. (Myristicaceae), no. 29
- Lithocarpus wallichianus L. (Fagaceae), no.16,17
- Dead tree (not identified), no. 23,24,25

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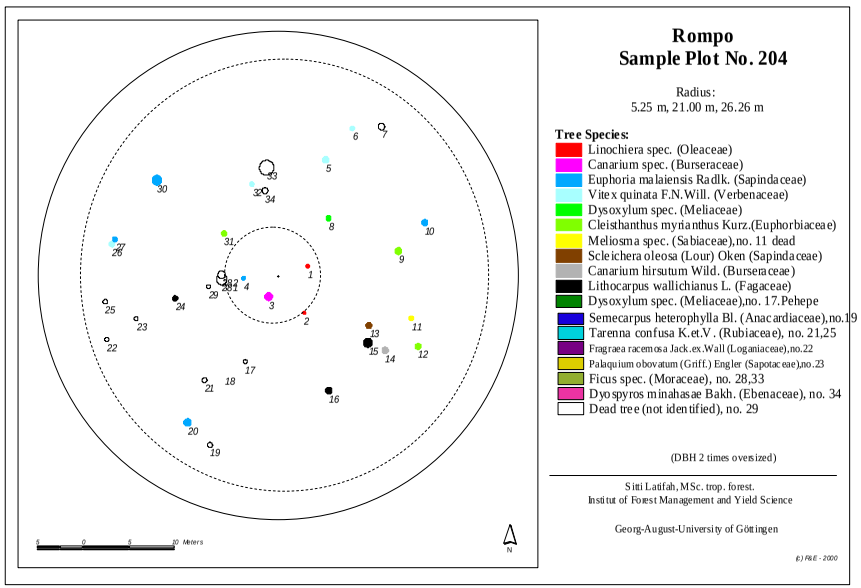

Rompo
Sample Plot No. 204

Radius:
5.25 m, 21.00 m, 26.26 m

Tree Species:
- Linochiera spec. (Oleaceae)
- Canarium spec. (Burseraceae)
- Euphoria malaiensis Radlk. (Sapindaceae)
- Vitex quinata F.N.Will. (Verbenaceae)
- Dysoxylum spec. (Meliaceae)
- Cleisthanthus myrianthus Kurz.(Euphorbiaceae)
- Meliosma spec. (Sabiaceae),no. 11 dead
- Scleichera oleosa (Lour) Oken (Sapindaceae)
- Canarium hirsutum Wild. (Burseraceae)
- Lithocarpus wallichianus L. (Fagaceae)
- Dysoxylum spec. (Meliaceae),no. 17.Pehepe
- Semecarpus heterophylla Bl. (Anacardiaceae),no.19
- Tarenna confusa K.et.V. (Rubiaceae), no. 21,25
- Fragraea racemosa Jack.ex.Wall (Loganiaceae),no.22
- Palaquium obovatum (Griff.) Engler (Sapotaceae),no.23
- Ficus spec. (Moraceae), no. 28,33
- Dyospyros minahasae Bakh. (Ebenaceae), no. 34
- Dead tree (not identified), no. 29

(DBH 2 times oversized)

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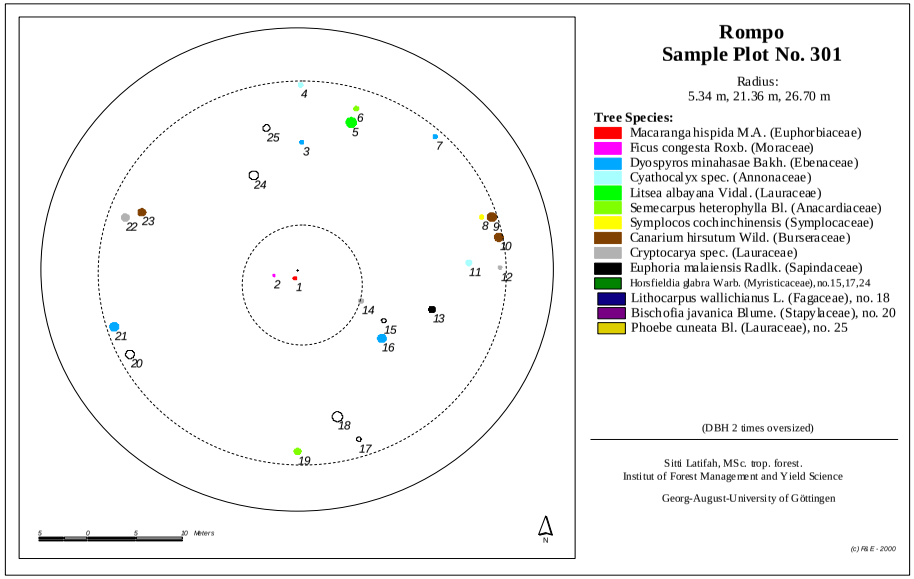

Rompo
Sample Plot No. 301

Radius:
5.34 m, 21.36 m, 26.70 m

Tree Species:
- Macaranga hispida M.A. (Euphorbiaceae)
- Ficus congesta Roxb. (Moraceae)
- Dyospyros minahasae Bakh. (Ebenaceae)
- Cyathocalyx spec. (Annonaceae)
- Litsea albayana Vidal. (Lauraceae)
- Semecarpus heterophylla Bl. (Anacardiaceae)
- Symplocos cochinchinensis (Symplocaceae)
- Canarium hirsutum Wild. (Burseraceae)
- Cryptocarya spec. (Lauraceae)
- Euphoria malaiensis Radlk. (Sapindaceae)
- Horsfieldia glabra Warb. (Myristicaceae), no.15,17,24
- Lithocarpus wallichianus L. (Fagaceae), no. 18
- Bischofia javanica Blume. (Stapylaceae), no. 20
- Phoebe cuneata Bl. (Lauraceae), no. 25

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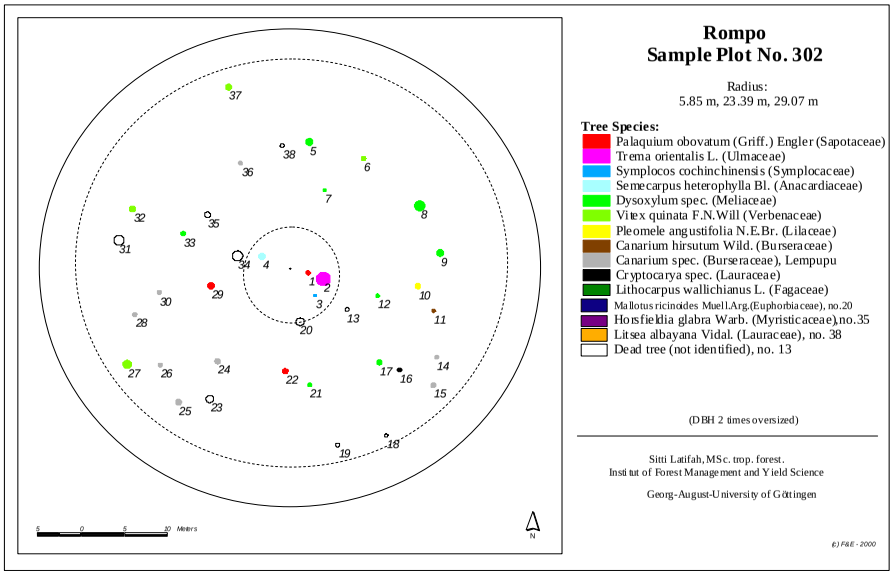

Rompo
Sample Plot No. 302

Radius:
5.85 m, 23.39 m, 29.07 m

Tree Species:
- Palaquium obovatum (Griff.) Engler (Sapotaceae)
- Trema orientalis L. (Ulmaceae)
- Symplocos cochinchinensis (Symplocaceae)
- Semecarpus heterophylla Bl. (Anacardiaceae)
- Dysoxylum spec. (Meliaceae)
- Vitex quinata F.N.Will (Verbenaceae)
- Pleomele angustifolia N.E.Br. (Lilaceae)
- Canarium hirsutum Wild. (Burseraceae)
- Canarium spec. (Burseraceae), Lempupu
- Cryptocarya spec. (Lauraceae)
- Lithocarpus wallichianus L. (Fagaceae)
- Mallotus ricinoides Muell.Arg.(Euphorbiaceae), no.20
- Horsfieldia glabra Warb. (Myristicaceae),no.35
- Litsea albayana Vidal. (Lauraceae), no. 38
- Dead tree (not identified), no. 13

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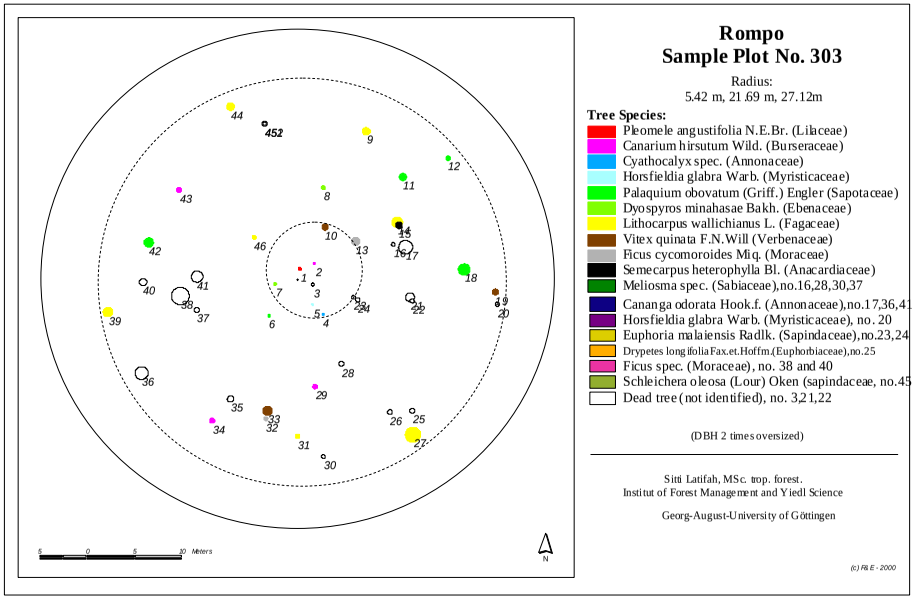

Rompo
Sample Plot No. 303

Radius:
5.42 m, 21.69 m, 27.12m

Tree Species:
- Pleomele angustifolia N.E.Br. (Lilaceae)
- Canarium hirsutum Wild. (Burseraceae)
- Cyathocalyx spec. (Annonaceae)
- Horsfieldia glabra Warb. (Myristicaceae)
- Palaquium obovatum (Griff.) Engler (Sapotaceae)
- Dyospyros minahasae Bakh. (Ebenaceae)
- Lithocarpus wallichianus L. (Fagaceae)
- Vitex quinata F.N.Will (Verbenaceae)
- Ficus cycomoroides Miq. (Moraceae)
- Semecarpus heterophylla Bl. (Anacardiaceae)
- Meliosma spec. (Sabiaceae),no.16,28,30,37
- Cananga odorata Hook.f. (Annonaceae),no.17,36,41
- Horsfieldia glabra Warb. (Myristicaceae), no. 20
- Euphoria malaiensis Radlk. (Sapindaceae),no.23,24
- Drypetes longifolia Fax.et.Hoffm.(Euphorbiaceae),no.25
- Ficus spec. (Moraceae), no. 38 and 40
- Schleichera oleosa (Lour) Oken (sapindaceae, no.45
- Dead tree (not identified), no. 3,21,22

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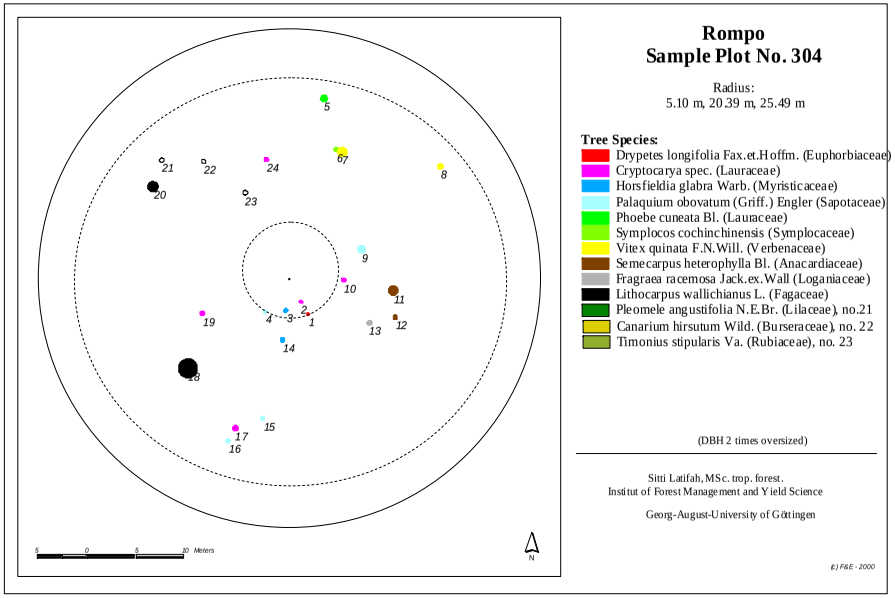

Rompo
Sample Plot No. 304

Radius:
5.10 m, 20.39 m, 25.49 m

Tree Species:
- Drypetes longifolia Fax.et.Hoffm. (Euphorbiaceae)
- Cryptocarya spec. (Lauraceae)
- Horsfieldia glabra Warb. (Myristicaceae)
- Palaquium obovatum (Griff.) Engler (Sapotaceae)
- Phoebe cuneata Bl. (Lauraceae)
- Symplocos cochinchinensis (Symplocaceae)
- Vitex quinata F.N.Will. (Verbenaceae)
- Semecarpus heterophylla Bl. (Anacardiaceae)
- Fragraea racemosa Jack.ex.Wall (Loganiaceae)
- Lithocarpus wallichianus L. (Fagaceae)
- Pleomele angustifolia N.E.Br. (Lilaceae), no.21
- Canarium hirsutum Wild. (Burseraceae), no. 22
- Timonius stipularis Va. (Rubiaceae), no. 23

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Appendix 6.

List of tree species in Kamarora area

Nr.	Local Name	Botanical Name	Familie
1	Anantawine	*Litsea albyana* Vidal.	Lauraceae
2	Andolia/ako	*Cananga odorata* Hook.f.	Annonaceae
3	Anga	*Cratavea nurvala* Ham.	Capparidaceae
4	Balo	*Chionanthus* spec.	Oleaceae
5	Bangkakarak	*Cryptocarya* spec.	Lauraceae
6	Bangkakuni	*Sloetia* spec.	Moraceae
7	Baru/enau/Arenga	*Arenga pinnata*	Arecaceae
8	Belantekuhe	*Mallotus ricinoides* Muell.Arg.	Euphorbiaceae
9	Benua	*Octomeles sumatrana*	Datiscaceae
10	Beringin	*Ficus* spec.	Moraceae
11	Bilitunga	*Bischofia hospita*	Staphyleaceae
12	Bitiahu	*Drypetes longifolia* Fax et Hoffm.	Euphorbiaceae
13	Bono	*Celtis* spec.	Ulmaceae
14	Bora	*Timonius stipularis* Va.	Rubiaceae
15	Bunga-bunga	*Alophyllus cobbe*	Sapindaceae
16	Butohulako	*Aglaia eximia*	Meliaceae
17	Empopi	*Ixora* spec.	Rubiaceae
18	Gampaya	*Pisonia* spec.	Nyctaginaceae
19	Hiha	*Ervatamia* spec.	Apocynaceae
20	Holai	*Ficus congesta* Roxb.	Moraceae
21	Kereya	*Horsfieldia glabra* Warb.	Myristicaceae
22	Koli	*Alphitonia incana*	Rhamnaceae
23	Kume	*Palaquium obovatum* (Griff.) Engler	Sapotaceae
24	Lalari	*Vitex quinata* F.N.Will	Verbenaceae
25	Lelati	*Ficus* spec.	Moraceae
26	Lelupa	*Litsea* spec.	Lauraceae
27	Lembanu	*Neonauclea* spec.	Rubiaceae
28	Malabono	*Cyathocalyx* spec.	Annonaceae
29	Marammawuluh	*Cinnamomum* spec.	Lauraceae
30	Marampule	*Euphoria malaiensis* Radlk.	Sapindaceae
31	Nantu	*Aglaia* spec.	Meliaceae
32	Numpibowe	*Canarium hirsutum* Wild.	Burseraceae
33	Palili	*Lithocarpus wallichianus* L.	Fagaceae
34	Pangi	*Pangium edule*	Flacourtiaceae
35	Potengkeah	*Phoebe cuneata* Bl.	Lauraceae
36	Putimata	*Macaranga recurvata* Gage.	Euphorbiaceae
37	Randa	*Erythrina variegata* L.	Leguminosae
38	Rano/Rauh	*Meliosma* spec.	Sabiaceae
39	Silana	*Macadamia hidelbrandii* Steen.	Protacea

Appendix 6. (continued)

Nr.	Local Name	Botanical Name	Familie
40	Taba	*Pleomele angustifolia* N.E.Br.	Lilaceae
41	Taiti	*Dysoxylum* spec.	Meliaceae
42	Tiroh	*Alstonia spectabilis* R.Br.	Apocynaceae
43	Torode	*Pterospermum* spec.	Sterculiaceae
44	Totuah	*Symplocos cochinchinensis*	Symplocaceae
45	Tumpulero	*Laportea stimulans*	Urticaceae
46	Banga	*Figafetta elata*	
47	Bakaliuruk	*not identified*	
48	Bakaudu	*not identified*	
49	Hihipa	*not identified*	
50	Rantak	*not identified*	

Appendix 7
List of tree species in Kalimpaa area

Nr.	Local Name	Botanical Name	Familie
1	Agathis	*Agathis damara* L.C.Rich	Araucariaceae
2	Anantawine	*Litsea albayana* Vidal	Lauraceae
3	Balo	*Kibara* spec.	Monimiaceae
4	Betau	*Calaphyllum soulattri* Burm.f	Guttiferae
5	Bitiahu	*Drypetes longifolia* Fax et Hoffm	Euphorbiaceae
6	Bolaa	*Trema orientalis.*L	Ulmaceae
7	Empopi	*Ixora* spec.	Rubiaceae
8	Haleka	*Castanopsis* spec.	Fagaceae
9	Hitanggah	*Schefflera longifolia* ***Bl***	Araliaceae
10	Kume	*Palaquium obovatum* (Griff.) Engler	Sapotaceae
11	Leda	*Eucalyptus deglupta* Bl.	Myrtaceae
12	Lelati	*Ficus* spec.	Moraceae
13	Lembanu	*Neonauclea* spec.	Rubiaceae
14	Malabono	*Cyathocalyx* spec.	Annonaceae
15	Mangkapa	*Ilex cymosa* Bl.	Aquifoliaceae
16	Manitu	*Eugenia clavimyrtus* K.et.V	Myrtaceae
17	Osi	*Euodia celebica* Hats	Rutaceae
18	Palaka	*not identified*	
19	Palem/Pola	*Pandanus tinctorius.*L.	Pandaceae
20	Palili	*Lithocarphus celebicus*(Miq)Rehd.	Fagaceae
21	Pana	*Linochiera* spec.	Oleaceae
22	Pogegeah	*Dysoxylum alliaceum* Bl.	Meliaceae
23	Randa	*Erythrina variegata*.L.	Leg.
24	Silana	*Macadamia hidebrandii* Steen.	Protaceae
25	Sipu	*Cryptocarya subveluntina* Elm.	Laur.
26	Taiti	*Dysoxylum* spec.	Meliaceae
27	Tiro(h)	*Alstonoia spectabilis* R.Br.	Apocynaceae
28	Totuah	*Symplocos cochinchinensis*	Symplocaceae

Appendix 8
List of tree species in Bulu Sombua area

Nr.	Local Name	Botanical Name	Familie
1	Agathis	*Agathis damara* L.C.Rich	Araucariaceae
2	Anantawine	*Litsea albayana* Vidal.	Lauraceae
3	Betau	*Calophyllum soulattri* Burn.	Guttiferae
4	Haleka	*Castanopsis* spec.	Fagaceae
5	Lalari	*Vitex quinata* F.N.Will.	Verbenaceae
6	Manitu	*Syzygium* spec.	Myrtaceae
7	Mangkapa	*Ilex cymoca* Bl.	Aquifoliaceae
8	Palili	*Lithocarpus wallichianus* L.	Fagaceae

Appendix 9
List of tree species in Wuasa area

Nr.	Local Name	Botanical Name	Familie
1	Ampala	*Ficus* spec.	Moraceae
2	Andolia	*Cananga odorata* Hook.f.	Annonaceae
3	Anga	*Cratavea nurvala* Ham.	Capparidaceae
4	Arenga/Enau	*Arenga pinnata*	Arecaceae
5	Aropi	*Baccaurea* spec.	Euphorbiaceae
6	Bangkakarak	*Cryptocarya* spec.	Lauraceae
7	Bangkaraha	*Prunus* spec.	Rosaceae
8	Bagantomumbu	*Meliosma nitida* Bl.	Sabiaceae
9	Belantekuhe	*Mallotus ricinoides* Muell.Arg	Euphorbiaceae
10	Betau	*Calophyllum soulattri* Burn.	Guttiferae
11	Beringin	*Ficus* spec.	Moraceae
12	Bolaa	*Trema orientalis* L.	Ulmaceae
13	Bono	*Celtis* spec.	Ulmaceae
14	Butohulako	*Aglaia eximia*	Meliaceae
15	Dilameo	*Astronia* spec.	Melastomataceae
16	Kahoni	*Medusanthera* spec.	Icacinaceae
17	Ketai	*Garcinia* spec.	Guttiferae
18	Lehune	*Chisocheton* spec.	Meliaceae
19	Lekatu	*Duabanga moluccana* Bl.	Sonneratiaceae
20	Lempupu	*Canarium* spec.	Burseraceae
21	Lohe	*Aglaia ganggo* Miq.	Meliaceae
22	Lowa	*Stemonurus javanicus* Bl.	Icacinaceae
23	Maralemo	*Ilex* spec.	Aquifoliaceae
24	Mbalahap	*Ficus variegata* Bl.	Moraceae
25	Mbangawai	*Planchonia* spec.	Lecythidaceae
26	Nuhu	*Ficus* spec.	Moraceae
27	Nunu	*Ficus* spec.	Moraceae
28	Osi	*Euodia celebica* Hats.	Rutaceae
29	Pakanangi	*Cinnamomum porrectum*	Lauraceae
30	Palili	*Lithocarpus wallichianus* L.	Fagaceae
31	Potimata	*Macaranga recurvata* Gage.	Euphorbiaceae
32	Potengkeah	*Phoebe cuneata* Bl.	Lauraceae
33	Pepolo	*Bischofia javanica* Blume.	Staphyleaceae
34	Rano	*Meliosma* spec.	Sabiaceae
35	Sala	*Girronniera subaequalis*	Ulmaceae
36	Siolangi	*Elaeocarpus petiolatus* Wall.	Elaeocarpaceae
37	Sipu	*Cryptocarya subveluntina* Elm.	Lauraceae
38	Taiti	*Dysoxylum* spec.	Meliaceae
39	Tamba	*Eugenia* spec.	Myrtaceae

Appendix 9. (continued)

Nr.	Local Name	Botanical Name	Familie
40	Tambe Kakao	*Syzygium malaccense*	Myrtaceae
41	Tambone	*Antidesma* spec.	Euphorbiaceae
42	Tanguluh	*Flacourtia* spec.	Flacourtiaceae
43	Tintimere	*Aglaia tomentosa* Teijs.	Meliaceae
44	Tuwa	*Casearia* spec.	Flacourtiaceae
45	Warani	*Semecarpus heterophylla* Bl.	Anacardiaceae
46	Wowahi	*Eugenia* spec.	Myrtaceae

Appendix 10
List of tree species in Rompo area

Nr.	Local Name	Botanical Name	Familie
1	Anantawine	*Litsea albyana* Vidal.	Lauraceae
2	Andolia	*Cananga odorata* Hook.f.	Annonaceae
3	Anga	*Cratavea nurvala* Ham.	Capparidaceae
4	Bangkakarak	*Cryptocarya* spec.	Lauraceae
5	Belantekuhe	*Mallotus ricinoides* Muell.Arg	Euphorbiaceae
6	Betau	*Calophyllum soulattri* Burn.	Guttiferae
7	Bitiahu	*Drypetes longifolia* Fax et Hoffm.	Euphorbiaceae
8	Bolaa	*Trema orientalis* L.	Ulmaceae
9	Bora	*Timonius stipularis* Va.	Rubiaceae
10	Hiha	*Ervatamia* spec.	Apocynaceae
11	Holai	*Ficus congesta* Roxb.	Moraceae
12	Kereya	*Horsfieldia glabra* Warb.	Myristicaceae
13	Kume	*Palaquium obovatum* (Griff.) Engler	Sapotaceae
14	Lalari	*Vitex quinata* F.N.Will	Verbenaceae
15	Lembanu	*Neonauclea* spec.	Rubiaceae
16	Lempupu	*Canarium* spec.	Burseraceae
17	Lulueh	*Neonauclea calcyna* Merr.	Rubiaceae
18	Malabono	*Cyathocalyx* spec.	Annonaceae
19	Mampa	*Dyospyros minahasae* Bakh.	Sonneratiaceae
20	Mangkapa	*Ilex cymosa* Bl.	Aquifoliaceae
21	Marampule	*Euphoria malaiensis* Radlk.	Sapindaceae
22	Maro	*Fragraea racemosa* Jack ex Wall.	Loganiaceae
23	Meapoh	*Macaranga hispida* M.A.	Euphorbiaceae
24	Numpibowe	*Canarium hirsutum* Wild.	Burseraceae
25	Nunu	*Ficus* spec.	Moraceae
26	Pahobo	*Ficus cycomoroides* Miq.	Moraceae
27	Palili	*Lithocarpus wallichianus* L.	Fagaceae
28	Pana	*Linochiera* spec.	Oleaceae
29	Patingkah	*Plectronia* spec.	Rubiaceae
30	Pehepe	*Dysoxylum* spec.	Meliaceae
31	Pepolo	*Bischofia javanica* Blume.	Staphyleaceae
32	Poharoa	*Tarenna confusa* K.et.V	Rubiaceae
33	Potengkeah	*Phoebe cuneata* Bl.	Lauraceae
34	Rano	*Meliosma* spec.	Sabiaceae
35	Taba	*Pleomele angustifolia* N.E.Br.	Lilaceae
36	Tambeanitu	*Ilex pleiobrachiata* Loes.	Aquifoliaceae
37	Tanguluh	*Flacourtia* spec.	Flacourtiaceae
38	Taiti	*Dysoxylum* spec.	Meliaceae
39	Timbu	*Glochidion* spec.	Euphorbiaceae

Appendix 10. (continued)

Nr.	Local Name	Botanical Name	Familie
40	Totuah	*Symplocos cochinchinensis*	Symplocaceae
41	Tumpudolo	*Virburnum* spec.	Caprifoliaceae
42	Uru	*Elmerrillia ovalis* (Miq) Dandy	Magnoliaceae
43	Wana	*Cleistanthus myrianthus* Kurz.	Euphorbiaceae
44	Warani	*Semecarpus heterophylla* Bl.	Anacardiaceae
45	Watu	*Schleichera oleosa* (Lour) Oken	Sapindaceae

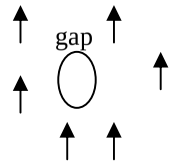
Appendix 11.
The Sample Plot Condition

Location	No. plot	Plot radius	Slope	Plot radius (correction)	Exposition (Gon)	Crown closeness	Plot condition	No. of Trees		No. of species	Note
								Life	Dead		
1	2	3	4	5	6	7	8	9	10	11	12
KAMARORA	101	5 m 20 m 25 m	1°	5 m 20 m 25 m	346	4 – 5	• 40% disturbed by human cutting activities • Plantation activities inside the plot (banana, coffee, chocolate).	16	8	15*	* 3 Spec. found dead
	102	5 m 20 m 25 m	6°	5.01 m 20.06 m 25.07 m	365	6	• Clear, only one life tree and 2 dead left. • Become a maize garden.	1	2	1	50 m radius clear.
	103	5 m 20 m 25 m	4.9°	5.01 m 20.03 m 25.05 m	20	6	• Plot clear, no tree • Maize garden	0	0	0	
	104	5 m 20 m 25 m	22°	5.19 m 20.77 m 25.96 m	360	4-5	• More than 40% of the plot disturbed • Coffee plantation inside the plot • Lower part clear, ready for planting	19	3	15	
	105	5 m 20 m 25 m	8.1°	5.02 m 20.10 m 25.12 m	140	4-5	• Lower part covers by coffee plantation • Plot disturbed 10-40% • Some trees were cut	19	1	14	
	106	5 m 20 m 25 m	5°	5.01 m 20.04 m 25.05 m	200	6	Clear, only 3 life/dead tree in burn condition	3	2	3	• Other trees have been cut. • Plantation preparation
	107	5 m 20 m 25 m	15°	5.09 m 20.35 m 25.44 m	80	4	No disturbance inside the plot	20	2	14	Around the plot, 50 m has been disturbed (Clear)
	108	5 m 20 m 25 m	16°	5.10 m 20.40 m 25.50 m	35	4-5	Lower part clean, ready for planting	17	2	13	Preparation of coffee plantation

Appendix 11 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
	109	5 m 20 m 25 m	10°	5.03 m 20.15 m 25.19 m	35	3-4	Lower part clean, ready for planting	22	3	16	Preparation of coffee plantation
	110	5 m 20 m 25 m	-28.3°	5.33 m 21.31 m 26.64 m	35	3	• Less 10% north part of plot disturbed. • General condition good.	36	2	17	
KALIMPAA	101	5 m 20 m 25 m	2°	5 m 20 m 25 m	240	3 - 4	Disturbed caused by human activities on rattan harvesting	22	1	8	
	102	5 m 20 m 25 m	3.7°	5.01 m 20.02 m 25.03 m	218	3 - 4	• on the plot (no disturbance) • around the plot cutting activities	22	1	6	
	104	5 m 20 m 25 m	20°	5.16 m 20.63 m 25.79 m	305	4	• No disturbance • Lay between 3 hill (deep slope)	18	2	10	Slope : 398 gon=69.3° 90 gon =43.8° 160 gon=77.3°
	205	5 m 20 m 25 m	5°	5.01 m 20.04 m 25.05 m	37	3	Disturbance cause by nature (wind)	37	2	11	In 3 weeks: disturbed by human activities on rattan (low)
	309	5 m 20 m 25 m	23.2°	5.21 m 20.86 m 26.07 m	172	3 - 4	No disturbance	21	-	6	
	310	5 m 20 m 25 m	8.4°	5.03 m 20.11 m 25.14 m	295	3-4	• human disturbance on rattan activities • rattan pathway	25	1	12	Clear/open area near the centre of the plot
	311	5 m 20 m 25 m	31.8°	5.42 m 21.69 m 27.12 m	250	3 - 4	• no disturbance • plot lay in difficult condition to measure dimension and characteristic	33	1	8	In 3 weeks: Low activities on rattan harvesting, rattan pathway
	312	5 m 20 m 25 m	4.7°	5.01 m 20.03 m 25.04 m	20	3	No disturbance	34	5	9	In 3 weeks : Heavy disturbance caused by human activities on rattan

Appendix 11 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
	413	5 m 20 m 25 m	9.9°	5.04 m 20.15 m 25.19 m	299	3 -4	No disturbance	30	3	8	
	414	5 m 20 m 25 m	2°	5 m 20 m 25 m	258	Lower: 2 Upper:3-4	No disturbance	30	3	8	
	415	5 m 20 m 25 m	-22.8°	5.17 m 20.83 m 26.04 m	322	3-4	Rattan pathway	28	5	8	
BULU SOMBUA	001	5 m 20 m 25 m	-17°	5.11 m 20.50 m 25.56 m	282	2	No disturbance	39	9	8	
WUASA	101	5 m 20 m 25 m	-8.5°	5.03 m 20.11 m 25.14 m	75	3 - 4	• Pathway inside the plot	25	1	17	
	102	5 m 20 m 25 m	-26°	5.27 m 21.09 m 26.37 m	50	4	• On the plot (no disturbance) • around the plot cutting activities	21	4	17	• 30m,170 dir cutting tree • many trees died naturally
	103	5 m 20 m 25 m	-9.8°	5.04 m 20.15 m 25.15 m	80	5 (only at he centre of plot, gap) 3-4 around the plot	• many trees lay on and around the plot because the illegal cutting activities • disturbed forest	28	6	19	
	104	5 m 20 m 25 m	-12.6°	5.06 m 20.25 m 25.30 m	170	4	• old pathway inside the plot • west dir. Deep slope and only bamboos • South dir. Opened	23	2	15	*maybe old illegal cutting activities
	105	5 m 20 m 25 m	-4.8°	5 m 20.03 m 25.04 m	65	4	• Disturbed forest • Shrub very close • North-East : River	17	1	13	• 310 dir cutting tree • 330 and 360 Bamboos

Appendix 11 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
	106	5 m 20 m 25 m	-13.1°	5.07 m 20.27 m 25.33 m	89	4	• Disturbed forest by illegal cutting • Shrub very close	18	2	15	• East-South West:gap • 186 dir lay big tree (illegal cutting)
ROMPO	101	5 m 20 m 25 m	-25.1°	5.25 m 21.00 m 26.27 m	200	3 - 4	No artificially disturbance	30	0	11	Plot cover hilly area (2 deep slope), diff. To measure dimension and quality
	102	5 m 20 m 25 m	-8.1°	5.03 m 20.10 m 25.13 m	183	4	No artificially disturbance	22	1	14	Plot lay surrounding by deep slope
	103	5 m 20 m 25 m	-31.9°	5.43 m 21.70 m 27.13 m	197	2-3	No artificially disturbance	40	1	20	Plot near watter line
	104	5 m 20 m 25 m	-34.8°	5.52 m 22.07 m 27.59 m	91	3-4	No artificially disturbance	25	2	15	North direction : little gap (20%) only little number of trees
	201	5 m 20 m 25 m	-42.3°	5.81 m 23.26 m 29.07 m	190	3 - 4	No artificially disturbance	35	1	14	Diff to measure distance and height, because slope to deep & centre plot stand between many slope, diff to see right position of the trees
	202	5 m 20 m 25 m	36.1°	5.56 m 22.20 m 27.80 m	312	3 - 4	No artificially disturbance	27	1	15	Centre of other group plot
	203	5 m 20 m 25 m	-40.9°	5.75 m 23.00 m 28.76 m	0	4	No artificially disturbance	27	4	16	

Appendix 11 (continued)

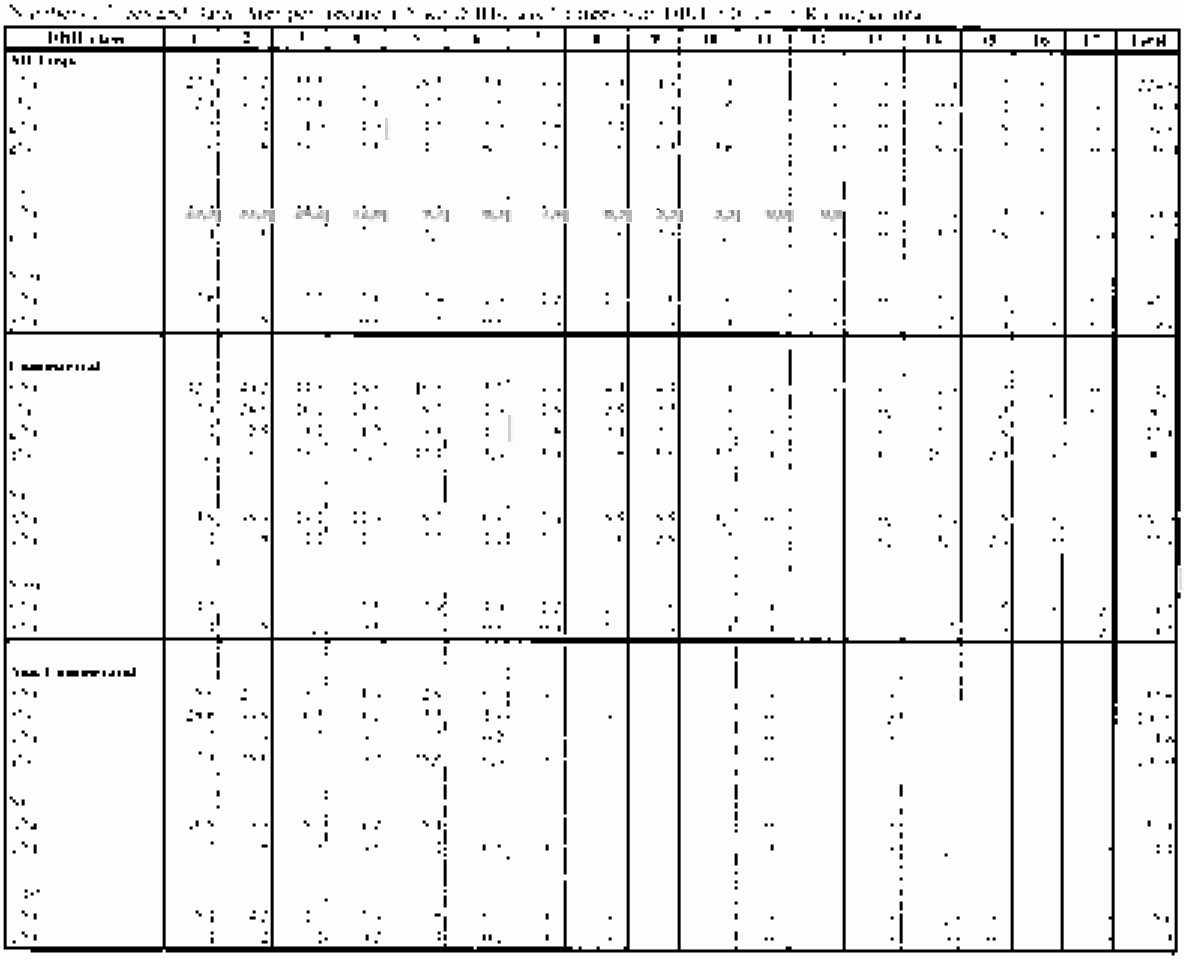
1	2	3	4	5	6	7	8	9	10	11	12
	204	5 m 20 m 25 m	-25.0^{o}	5.25 m 21.00 m 26.26 m	115	3-4	No artificially disturbance	30	4	18	
	301	5 m 20 m 25 m	-28.8^{o}	5.34 m 21.36 m 26.70 m	247	4	No artificially disturbance	25	0	15	N-E:Rattan shrub, only plenty of trees; plot covers by lower plant (shrub)
	302	5 m 20 m 25 m	-43.0^{o}	5.85 m 23.39 m 29.23 m	35	3	No artificially disturbance	37	1	14	
	303	5 m 20 m 25 m	-31.8^{o}	5.42 m 21.69 m 27.12 m	200	2	No artificially disturbance	43	3	17	Centre of the plot moves 14 m (east direction) due to the difficulty of the location)
	304	5 m 20 m 25 m	-15.9^{o}	5.10 m 20.39 m 25.49 m	250	4-5:upper 3-4:lower	No artificially disturbance	24	0	12	Centre plot move 50 dir, 20 m. High shrub and many small trees.

Appendix 12.

Natural [illegible] Mixed Hardwood - Pine : BH-class for tree [illegible] Number of trees

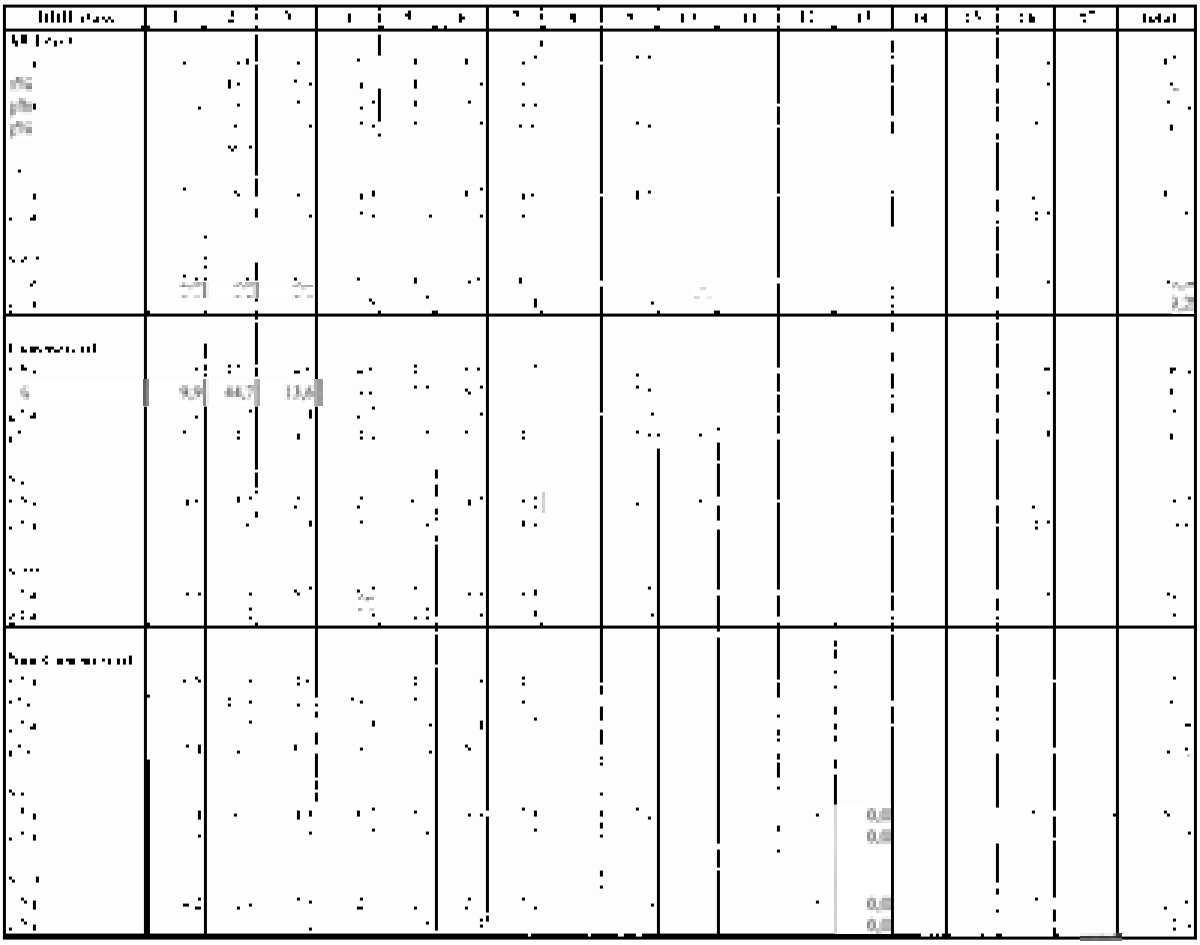
DBH class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
10 Trees																		
[illegible]			27,0	12,[illegible]														
[illegible]																		
[illegible]																		
[illegible]	1,5	12,2																
[illegible]																		
[illegible]	19,5	39,2																
[illegible]																		
[illegible]																		
[illegible]	

Appendix 11



Notes:

Appendix 12.



Notes:

Appendix 15.

Number of Trees and Basal Area per Hectare in Each DBH-class for trees with DBH≥ 10 cm in Rompo area

DBH-class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
All Trees																		
n/ha	28,6	122,0	41,8	28,5	17,2	9,3	6,6	2,0	2,0	0,4	0,4	0,4	0,0	0,0	0,0	0,0	0,0	259,3
n%	11,0	47,0	16,1	11,0	6,6	3,6	2,6	0,8	0,8	0,2	0,2	0,2	0,0	0,0	0,0	0,0	0,0	100,0
g/ha	0,5	5,7	3,8	4,4	4,2	3,2	2,5	1,1	1,4	0,7	0,5	0,9	0,0	0,0	0,0	0,0	0,0	28,7
g%	1,6	19,9	13,4	15,4	14,6	11,0	8,6	3,8	4,8	2,5	1,6	3,0	0,0	0,0	0,0	0,0	0,0	100,0
		82,8																
Sx																		
n/ha	26,6	39,9	20,1	14,6	4,6	7,5	7,5	3,6	3,6	1,5	1,5	1,5	0,0	0,0	0,0	0,0	0,0	132,3
g/ha	0,4	1,8	1,5	2,6	1,3	2,5	2,5	2,0	2,5	2,5	1,6	3,0	0,0	0,0	0,0	0,0	0,0	24,0
S err																		
n/ha	7,7	11,5	5,8	4,2	1,3	2,2	2,2	1,0	1,0	0,4	0,4	0,4	0,0	0,0	0,0	0,0	0,0	38,2
g/ha	0,1	0,5	0,4	0,7	0,4	0,7	0,7	0,6	0,7	0,7	0,5	0,9	0,0	0,0	0,0	0,0	0,0	6,9
Commercial																		
n/ha	14,8	88,2	27,2	23,2	12,6	8,6	6,6	2,0	2,0	0,4	0,4	0,4	0,0	0,0	0,0	0,0	0,0	186,5
n%	8,0	47,3	14,6	12,4	6,8	4,6	3,6	1,1	1,1	0,2	0,2	0,2	0,0	0,0	0,0	0,0	0,0	100,0
g/ha	0,3	4,0	2,5	3,7	3,1	3,0	2,5	1,1	1,4	0,7	0,5	0,9	0,0	0,0	0,0	0,0	0,0	23,6
g%	1,1	17,2	10,7	15,7	13,0	12,6	10,4	4,7	5,8	3,1	1,9	3,6	0,0	0,0	0,0	0,0	0,0	100,0
Sx																		
n/ha	17,9	36,8	14,2	15,7	6,3	7,2	7,5	3,6	3,6	1,5	1,5	1,5	0,0	0,0	0,0	0,0	0,0	117,0
g/ha	0,3	1,6	1,3	2,6	1,6	2,5	2,5	2,0	2,5	2,5	1,6	3,0	0,0	0,0	0,0	0,0	0,0	23,7
S err																		
n/ha	5,2	10,6	4,1	4,5	1,8	2,1	2,2	1,0	1,0	0,4	0,4	0,4	0,0	0,0	0,0	0,0	0,0	33,8
g/ha	0,1	0,4	0,4	0,7	0,5	0,7	0,7	0,6	0,7	0,7	0,5	0,9	0,0	0,0	0,0	0,0	0,0	6,8
Non Commercial																		
n/ha	14,8	33,8	14,6	5,3	4,6	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	73,8
n%	20,1	45,8	19,8	7,2	6,3	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	100,0
g/ha	0,2	1,7	1,3	0,7	1,1	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,2
g%	3,8	31,8	25,3	14,0	21,3	3,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	66,5
Sx																		
n/ha	13,1	14,8	10,1	5,2	7,2	2,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	52,7
g/ha	0,2	0,9	0,9	0,9	1,7	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,2
S err																		
n/ha	3,8	4,3	2,9	1,5	2,1	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,2
g/ha	0,1	0,2	0,3	0,3	0,5	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,5

Notes:

DBH-Class 1 10-19.9 cm
DBH-Class 2 20-29.9 cm
DBH-Class 3 30-39.9 cm
DBH-Class 4 40-49.9 cm
DBH-Class 5 50-59.9 cm
DBH-Class 6 60-69.9 cm
DBH-Class 7 70-79.9 cm
DBH-Class 8 80-89.9 cm
DBH-Class 9 90-99.9 cm
DBH-Class 10 100-109.9 cm
DBH-Class 11 110-119.9 cm
DBH-Class 12 120-129.9 cm
DBH-Class 13 130-139.9 cm
DBH-Class 14 140-149.9 cm
DBH-Class 15 150-159.9 cm
DBH-Class 16 160-169.9 cm
DBH-Class 17 170-179.9 cm

Curriculum Vitae

Personal data:

Name:	Sitti Latifah
Nationality:	Indonesian
Date of birth:	September 23rd, 1972
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Family status:	Married to Dr. Mansur Afifi, two sons (Fachry Abdul Razak Afifi and Fuad Abdurrahman Afifi)

Education:

1977 – 1983	Elementary School (SDN 09 Pagi) Jakarta, Indonesia
1984 – 1987	Junior High School (SMPN 68) Jakarta, Indonesia
1987 – 1990	Senior High School (SMAN 6) Jakarta, Indonesia
1990 – 1994	Faculty of Forestry, Bogor Agricultural Institute, Indonesia Degree: Diplom in Forestry (Sarjana Kehutanan/S.Hut)
1997 – 1999	Master course "Forestry in the Tropics and Subtropics", University of Göttingen, Germany Degree: Master of Science in Tropical Forestry
1999 – 2004	PhD studies, Institute of Forest Inventory and Management, University of Göttingen, Germany
04/2001-07/2001	German language course at Goethe Institute, Göttingen, Germany

Work experience:

01/1995-12/1995	Planning officer at the Indonesian State Forestry Enterprise (PT. INHUTANI III) Jakarta, Indonesia
Since 1996	Lecturer at the Forest Management Department, Faculty of Forestry, Bogor Agricultural Institute, Indonesia