IWOKRAMA INTERNATIONAL CENTRE FOR RAINFOREST CONSERVATION AND DEVELOPMENT

PROCEDURES FOR A VOLUME AND DECAY STUDY IN THE SUSTAINABLE UTILIZATION AREA (SUA) OF THE IWOKRAMA FOREST

August 2007

International Tropical Timber Organization

Iwokrama International Centre for Rain Forest Conservation and Development

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1. Introduction

The capacity to estimate tree volumes is a requirement for the sustainable management of timber and forest resources. Any management plan will have to consider the volume and growth of the timber stands involved, and these are aggregations of trees.

An estimation of the merchantable volume of a tree takes into account the level of utilization, which is related to the final product, the estimated gross volume, and an estimation of decay and other losses. The practical use of these estimations, which provide reliable values of tree volumes by relating them to a few known attributes, like species and stem diameter, is related to their application to groups of trees in the forest. They are not used for attaining values of the volume of individual trees. The determination of volume and decay factors that make these estimations possible involves detailed stem analysis of sample trees and calculation of their net volume.

Sustainable timber management in the SUA of the Iwokrama Forest brings about the need to generate appropriate quantitative information on the timber resources of that area. Volume and decay information is a necessary support for the forest inventory work that is a part of the management operations on a permanent basis.

While it may not always be possible, it is important to utilize volume and decay data from the same area where these data are to be used. Local factors, including environmental factors as well as the management and utilization history of the area, have influence on volume and decay. In Guyana, a CIDA project in the early 1990's felled and measured a substantial sample of trees for volume and decay studies (Alder, 2000). This was done in other areas of the country, many of them with a history of logging interventions and other characteristics which make them different to the Iwokrama Forest.

Notwithstanding some differences among them, standard methods are regularly used for estimating volumes of trees. The estimation of decay losses, however, is based on rules developed for different local scenarios, taking into consideration several factors including local forest pathologies, environmental, economic and utilization factors, and the intensity of forest management.

In the elaboration of the procedures, the geographical information system originally developed for the 100% pre-harvest inventory, already extended to the complete Iwokrama Forest, was utilized. It provides the spatial framework for sampling. In turn, the 2003 management level inventory of the SUA, which allow for the possibility of assigning statistical weights to the sampled trees, had an influence on sampling procedures. Guidelines of the Guyana Forestry Commission were also taken into account. Finally, the recent document of the British Columbia (Canada) Ministry of Forests and Range, "Net Volume Adjustment Factor Sampling Standards and Procedures" was used extensively in those sections related to the determination of volumes (6.7, 6.9 and 6.10) but not to wood utilization and utilization factors.

2. Steps of the study

The results of the study will affect the way commercial timber volumes are estimated in the SUA. This requires ensuring an unbiased process. The definition of sample polygon (blocks) and the selection of sample trees should give all individuals of the target population a fair chance of being included in the sample.

Data collection for the study will take place in four steps. The first three steps lead to the selection of the sample trees. In a fourth and final step, data from these trees are collected through stem analysis and accurate measurement of their net volume. The process can be outlined as follows:

1. Selection of the sample blocks, utilizing the existing division of the SUA in 100 ha blocks for inventory and management purposes.
2. Selection of plots or sampling areas within the sample blocks.
3. Selection of the trees to be felled for the study.
4. The selected sample trees are felled and sectioned to measure actual net volume.

In a final stage data from all studied trees are analyzed and utilized to define factors affecting volume estimations of trees in the SUA and their utilization. The data analysis involves compiling the estimated net volumes and the actual net and merchantable volumes of the felled trees, as well as a calculation of the selection weights of each tree.

3. Selection of Blocks

3.1 The sampling frame

The SUA is divided into 100 ha blocks by a grid of N-S and E-W lines separated each other by a 1,000 m distance. This was originally done for implementing the 100% Operational Inventory required for carrying out reduced impact logging (RIL), in agreement with GFC regulations. This systematic grid can be used as a sampling design framework for a variety of inventorying, monitoring and study activities within the SUA. It provides the sampling frame for the volume and decay study.

3.2 Stratification of blocks

The SUA is stratified recognizing distinct forest types. There are four forest types within the Net Operable Area (NOA), this is, where harvesting will occur: Mixed Greenheart, Black Kakaralli, Wamara Forest (MGK); Mora, Manicole, Crabwood, Trysil Forest (MMC); Mixed Greenheart, Sand Baromalli, Soft Wallaba Forest (MGB) and Wallaba Forest (WF). The existing maps of these forest types provide the stratification to be used for the selection of blocks per stratum.

3.3 Selection of blocks

The number of blocks will be proportional to the area of the strata or forest types. This can be done by listing the blocks in a systematic order within each forest type and then doing a systematic selection with a random start. This procedure is normal in cases of small random samples; it prevents the lack of representation that could result if blocks are assigned on the forest types with *probability* proportional to area of the strata.

Ground data collection is a costly exercise. For this reason, it is more cost effective to have a few sample blocks where many trees are selected for felling, rather than having many blocks where only one or very few trees are felled.

The number of blocks is estimated on the basis of the target number of trees for the study and the number of sample trees per block. Assuming a target of 156 trees and 12 trees per block, the number of sample blocks will be 13, this is, 156/12. The option of determining sample size (number of trees) by targeting a pre-defined sampling error is not realistic at this stage. There are no similar studies in the area which could provide information on the variation within the population of the factors which are the subject of the study. At the same time, while the study will result in more credible estimations of standing commercial timber volumes, there is a "thirst" of data that will not be satisfied for a first study of this type. When dealing with the diversity of tropical rainforests, this is particularly true for sub-strata and sub-populations, like specific commercial species or certain tree size classes. Thus, there is no risk of overdoing, and a target set on the basis of timing and resources is appropriate at this time.

Assuming that the number of sample blocks will be 13 (156 trees, 12 trees per block), the number of blocks per forest type, on a proportional basis to the area of the forest type strata, is as follows:

Forest type	*Area in NOA (ha)*	*Sample blocks*
Mixed Greenheart, Black Kakaralli, Wamara Forest (MGK)	56,650.3	7
Mixed Greenheart, Sand Baromalli, Soft Wallaba Forest (MGB)	15,859.2	2
Mora, Manikole, Crabwood, Trysil F (MMC)	30,768.0	3
Wallaba Forest (WF)	5,714.3	1
Total	*108,991.8*	*13*

Note that there will be two sample selection scenarios in the SUA. On a part of the Essequibo Compartment the selection of blocks will take place with the 100% pre-harvest inventory already completed. This allows for a better selection of the sample, taking into account species and other attributes of significant interest. On the rest of the SUA, the vast majority of its area, including the other four compartments, the sample selection will occur prior to the pre-harvest inventory. While a management inventory was completed for the SUA in 2003 (IIC, 2003), it will be useful for other aspects of this study (e.g. tree selection weights), but will have a limited use for the selection of blocks. On the area where the pre-harvest inventory was not done yet, sample selection will require a selection of additional blocks. They will be used in case tree attributes of interest for the study are not found or are underrepresented within the initially selected blocks. The blocks are mapped but not marked on the ground in that large area, but this does not prevent their utilization for the study.

The alternative of utilizing a different sampling structure in the area where the pre-harvesting inventory is not completed, even making use of the 2003 inventory plots, is not recommended considering the convenience of the systematic grid as a frame for this and other activities as stated in 3.1.

4. Selection of Sample Plots within the Blocks

For pre-harvesting inventory purposes, the 100 ha blocks are divided into 50 m x 1000 m (5 ha) quadrats, with their length running from North to South. In a regular situation, the pre-harvesting inventory starts on the SW corner of the most western quadrat and continues advancing North within that quadrat.

For purposes of this study, within each sample block, and starting from the SW corner of the block, a sample plot from where tree selection will take place is delimited. This plot consists of the first 300 m of the first quadrat, this is, the most western quadrat, on a Northern course. This is a 50 m x 300 m rectangular plot of 1.5 ha, where 12 sample trees will be selected for felling.

5. Selection of the Trees to be Felled

In the pre-harvest inventoried area, the mapped trees and their records provide the sampling frame for the selection of trees to be felled for stem analysis.

With this information available, trees in the plot are grouped (stratified) into those categories (sub-populations) of interest to the study. In principle, species will be the attribute that will determine the sub-populations. Once the field work is initiated, it may be decided that a minimum number of trees with other specific attributes such as diameter size be included in the study. This would be taken into account for work in subsequent blocks.

The process of determining the number of trees to select for a sub-population (e.g. Greenheart trees) is subjective. It is based on several factors, including the relative importance of the sub-population, experience and knowledge of variation within the sup-population, and differential costs of sampling.

In the first plots, it may be decided not to target specific sub-populations, correcting any deficiencies in number of individuals sampled in categories of interest later, as field work proceeds.

The procedure to be used for selecting trees within a sub-population should ensure an unbiased selection. The procedures on the area where pre-harvest inventory results are available will be different to those on the rest of the SUA, for making use of that information, and for taking more informed sampling decisions before arriving to the ground.

On the 100%-inventoried area, the number of trees to be felled should be defined for each sub-population, taking into account all the blocks in an aggregate way. This may involve, for example, defining the number of Greenheart trees to be felled, number of trees of other species, etc. Then the trees to fell are located on the map at the office. As trees cannot be actually "seen" on the map, the process ensures an appropriate degree of randomness, without the need of utilizing lists, random numbers, nor sorting of any kind. This method requires an adjustment, however, for including pre-excluded trees.

Trees identified and numbered in the pre-harvest inventory do not include trees that were excluded in advance, mainly for been judged totally non-merchantable for decay reasons. There is a need to ensure that those trees have a fair chance of being sampled. The following procedure will be followed: Before locating the 12 pre-selected trees in the field, the number of "excluded" commercial-size trees for each sub-population to be sampled should be counted in the field. The result will be used for replacing a number of pre-selected trees with previously excluded trees. For each sub-population, the number of "good", pre-inventoried trees, and the number of "bad", not pre-inventoried trees, should have in the final list the same or a most similar proportion to their presence in the plot. Any random mechanism should be valid for the replacement process. All "new" trees should be mapped.

In deciding the trees to be felled, the GFC recommendation of limiting the number of felled trees to 10 trees/ha, as well as the 10 m proximity rule (GFC, 2002), should be followed. All sample trees shall be within the minimum diameter limit approved for harvesting for the species.

On the non-pre-harvest-inventoried area, the study will still utilize the products and results of the 2003 management inventory (IIC, 2003) for gaining some knowledge of what could be expected on the ground at the plot site. The study crew may approach the site with an ideal list of the number of trees to be selected per sub-population. On the site, the block SW corner should be marked with a stake and colour tape on the ground. From that corner, a 300 m transect with a North bearing shall be cut and flagged with colour tape. This will be the western side of the 50 m x 300 m 1.5 ha plot. Distances should be marked every 20 m along the long sides of the plot, for facilitating mapping of the trees. While walking the established plot from South to North, trees potentially useful for study purposes should be tallied and identified. When a list of 5 or 6 trees of a target sub-population is finished, one or two trees can be randomly selected from that list by any random mechanism. A 3/1 relationship of tallied trees to felled trees would be acceptable. If required, like in case a sub-population is under-represented in a plot, or in case the plot does not contain an abundance of commercial trees, this ratio may be lowered. All sampled trees, as well as those included in the lists for the random selection, shall be mapped in the plot. Sampled trees are indicated on the map by their number (see 6.4 below); all other trees in the lists are indicated on the map with no number, and only by their species two-letter code as recently defined for the pre-harvest inventory.

There are situations in which a selected tree needs to be replaced. Reasons may include safety reasons, special characteristics, the application of the 10 m proximity rule for reducing opening sizes (GFC, 2002), or a very high wildlife or NTFP value on that particular tree, among others. The GFC has standards for protecting host trees supporting Kufa and

Nibi of certain sizes (GFC, 2003). Some flexibility may be applied to the replacement process, as long as every care is taken for carrying out the replacement without bias.

In all cases, a fairly regular distribution of the felled trees within the 1.5 ha plot should be attempted.

6. Stem Analysis and Data Collection

6.1 Principles

The process of stem analysis and data collection will allow for the calculation of actual gross, net and merchantable tree volumes.

Gross volume is understood in this study as total tree volume in bole sections of commercial size, irrespective of form, and in other tree sections of commercial size and form.

Merchantable volume is the wood volume utilizable for primary processing (sawmilling). It results from the application of utilization factors to gross volumes in each section.

Net volume is sound wood volume. It is wood volume without decay, voids or insect damage, in bole sections of commercial size, irrespective of form, and in other tree sections of commercial size and form. Net volume results from discounting the volume of decay, voids and insect damage to the gross volume. Net volume may be larger than merchantable volume, as the latter takes into account not only the volume of sound wood, but also its distribution in the section, as well as section form.

Only trees above the minimum commercial diameter for the species will be sampled and analyzed.

Logs will be regularly cut at 2.6 m length. This length is short enough to minimize errors in the calculation of log volume by applying the Smalian’s formula, while it makes possible commercial utilization of the logs.

The cross sectional area of decay and other losses in each section will be precisely determined, excluding any contiguous area of sound wood.

The utilization aptitude of the sections will be assessed and estimated taking into account the gross and net volume but also other characteristics like decay shape and distribution, as well as form and local primary processing aspects.

These procedures are not addressed to determine the biological causes of decay nor identify those organisms which produce decay in the SUA.

6.2 Materials and equipment required

The following materials/equipment are required for stem analysis:

a. Compass
b. GPS
c. 30 m or 50 m tape
d. Diameter tape
e. Thin pointed knife, blade 5 cm or larger
f. Cutlass
g. Axe
h. Chain saw
i. Felling wedges (2)
j. Small ruler starting at 0 cm
k. Metric carpenter's tape
l. Spray paint
m. Flagging tape
n. Electronic data collector
o. Hand calculator
p. Indelible felt markers or log crayons
q. Blank weather-proof sheets
r. Heavy duty stapler
s. First aid kit
t. Copy of procedures

6.3 Outline of general procedures

The sequential outline of general procedures for stem analysis involves the following tasks:

1. Identification of the tree.
2. Recording plot attributes.
3. Assessing the tree for decay indicators.
4. Marking and measuring the standing tree.
5. Falling the tree.
6. Marking and measuring the felled tree.
7. Measuring decay and voids.
8. Checking of decay indicators for hidden decay.
9. Assigning utilization factors.
10. Processing and analyzing the data.

6.4 Identification of the tree

On the 100 % inventory area, each tree is identified with the same number and other identification codes given in the inventory. This consists of a letter indicating compartment, block number, and tree number. For example, for tree number 29 of Block 888 of the Essequibo Compartment, the identification code is E-888-29. The sampled tree should be clearly identified by recording its identification code on the stump. Spray or any other paint can be used for this purpose. For trees that were excluded in the pre-harvest inventory but included in this study (see Section 5), numbering should start from 1, and an X should be added after tree number (e.g. E-837-1X).

On the non-inventoried area, compartment and block codes are used in the same way, but tree numbers start from 1 in all cases (regularly 1 to 12 on each block). For making clear in the recording that it is a non-inventoried block, an "N" will be added after tree number. For example, for tree number 7 of Block 1196 of the Kurupukari Compartment, the identification code would be K-1196-7N.

Tree species should be recorded as a part of tree identification, using the two-letter code also applied in the pre-harvest inventory.

6.5 Recording plot attributes

Plot attributes are forest type, soil type, percent slope, aspect, laterite deposits and other significant physical features (water courses, rock outcrops, etc.).

If forest type as found on the ground is different to the one on the forest map, the correct forest type should be registered and work on the plot shall still be carried out as planned. An observation should be done on the field sheet, stating this circumstance. No changes to the planned sampling should result from this.

6.6 Assessing the tree for decay indicators

Assessment of decay indicators on standing trees will allow for establishing relationships between those indicators and actual decay losses. It is important to make the assessment before any neighboring trees are felled.

The following six decay indicators have been mentioned in Guyana, mainly with tree description purposes. A two-letter code has been proposed within the GFC for these and other tree characteristics in a recent draft document (GFC, 2006). The reduced list below includes that code:

- BC Broken top with coppice crown
- BT Broken top, no crown present
- DF Defoliated crown
- FU Fungus on stem
- RT Rot in stem
- SL Stem slashed for rubber collection

Other decay indicators are also considered important, added to the list and given a code:

- RB Large rotten branch in crown
- OS Open scar
- CS Closed scar
- SO Sounding
- TE Termite nest on stem

These eleven indicators will be used in the study. Further indicators will be added before or during the study if found appropriate. This is a preliminary classification, and for data analysis purposes certain close indicators could be grouped (e.g. BC and BT). The same preliminary character of these categories may result in some of them being not discrete, and certain overlapping may be expected. However, only one indicator should be registered for the same indication of decay.

The general idea/guideline for indicators that describe stem damage, such as scars and broken tops, is that at least four years must have passed since the damage was produced. While this period cannot be proved with exactitude, the concept should be taken into account in the assessment.

Important: Indicators that are directly related to logging damage will not be taken into account in the study, as logging in the SUA is very recent and could not have any incidence on present decay. For this reason, two indicators which could be important in other situations are not being used here: Felling damage in crown (FC) and felling damage on bole due to skidding or falling tree (FS).

For each indicator on the standing tree, except for sounding and defoliated crown, the height should be estimated and recorded. For termite nests, fungi and rot in stem, slashed stems and scars, lower and upper heights (in m to the nearest dm) and average width (in cm to the nearest mm) should be recorded. Remember that for trees on slopes, the standard practice is height distances measured from high side ground level.

A reassessment of the decay indicators will be made for the felled tree, working on those indicators already identified on the standing tree, but also on those that were hidden in the crown or the stem, or not visible for any reason on the standing tree. When convenient, measurements on indicators identified on the standing tree may be taken on the felled tree. However, only those indicators that were not identified on the standing tree should be registered in the assessment of the felled tree.

General procedures for assessing decay indicators include recording the indicators for all sample trees, entering the correct codes, estimating the position of each decay indicator on the stem to the nearest 0.1 m, using a minus sign (-) for heights below high side ground level, and recording indicators for all measurable crown branches from the base of the tree to the utilizable top of the crown branch or leader. If the decay indicator appears in clusters, such as more than 10 or 20 fungi on a bole over a 6 m length, it can be recorded as one item, making a note on the situation.

The following definitions should be considered for decay indicators:

Broken top is produced when an external force or condition causes the top of the tree to break away from the main bole. Wind, as well as mechanical damage from other falling trees, may cause broken tops. The length to the break should be recorded.

A *defoliated crown* (not related to the deciduous or semi-deciduous character of a tree species) may be a sign of decay in old and diseased trees.

Fungus on stem refers to the fruiting bodies of stem decay fungi and is a reliable indicator of decay. It should affect the bole or leading crown branches for being considered..

Rot in stem appears as visible stem wood decay affecting wood consistency. This indicator includes rot in leading crown branches. The study will define whether this indicator can stand as a different indicator to *open scar*. The latter would be due to the action of external forces on the decay area. If rot is not visible, an open scar should be registered.

Stem slashed for rubber collection is found on many Bulletwood (*Manilkara bidentata*) trees. The study may allow for a better knowledge about the influence of this practice on wood decay in this species, although this will depend on the availability of slashed bulletwood trees in the plots.

Large rotten branches in crown refer to those with a diameter greater than 15 cm at the base. They have signs of heart rot and typically appear as short, rotten branches on overmature trees at the top or crown. They should not be confused with secondary branches that have died dominated by other branches or by other normal causes.

A *scar* is an injury caused by external forces that damage the cambium or heartwood of the tree, exposing the tree to wood-decay fungi. A *scar* can occur anywhere on the main stem, leading crown branches or root collar of the tree. The position should be recorded. Scars on other branches should not be recorded. The register shall indicate whether it is an *open scar*, meaning the wood is exposed, or a *closed scar*, meaning that the bark has grown over the injury. Old fire scars should be recorded. If *rot in stem* appears together with an *open scar*, registering only the rot should be satisfactory.

Sounding is a positive response (sound) to the action of hitting a standing tree stem for investigating presence of internal voids and rot.

Termite nest on the stem is considered an indicator of decay by loggers in Guyana. While termites may destroy wood in living trees, in most cases their colonies nest in portions of standing trees that are already dead, rotten or affected by other causes. This indicator has been found frequently associated to *sounding*. In these cases, both indicators should be recorded. *Termite nests* on large crown branches (greater than 15 cm at the base) are also indicators. Termite nests on other branches are not considered indicators.

6.7 Marking and measuring the standing tree

In the same way as decay indicators are assessed on the standing tree, it is important to complete those regular measures of the standing tree before the falling begins. This ensures that this information is collected in the same conditions as those found during inventory work.

The high side of the tree should be marked, and heights above high side should be marked around the bole with paint at 0.3 m and 1.3 m. At those heights, diameter outside bark (DOB) should be measured. DOB is measured with diameter tape, ensuring that tape is at right angles to the trunk.

DIB is obtained by calculating double bark thickness (DBT) and discounting it from DOB. For this purpose, bark is measured at opposite sides of the tree stem at each height. Points with atypically thin or thick bark should be avoided. Both of the bark thicknesses at each height are measured and registered. It is possible to measure bark thickness at 0.3 m and 1.3 m on the standing tree, and for this reason these fields appear on the standing tree section of the field sheets. However, these bark measurements may be taken on the sections once the tree has been felled, and doing it in this way may be simpler. During data processing they will be added together to obtain the DBT and DIB values.

If bark is missing on part of the stem, an average DBT value should be estimated. For example, if bark is missing from 30% of the circumference, bark should be measured from the portion with bark and a 30% reduction should be applied to each bark thickness value.

The case of trees buttressed at breast height

When the tree is buttressed at breast height, the point of mensuration (*pom*) for the tree diameter, which is regularly at 1.3 m height (where diameter at breast height or *dbh* is measured), is moved to 30 cm above the end of the buttress. This point should be marked, as well as the point of the end of the buttress, and the point where the faller will do the cut attempting to maximize the utilization of commercial volume of the tree (new stump height). These heights should be registered to the nearest 0.1 m.

If the new *pom* cannot be reached, tree diameter at that height should be measured on the felled tree. In this case, painting a measured reference height at some distance above the cutting point is recommended, for facilitating height measurement of end of buttress and *pom* after felling.

If the new *pom* is very high, the part of the bole between the stump (actual cutting height) and the end of the buttress might include more than one section, and should be treated for measurement purposes as the rest of the bole, with 2.6 m length standard sections and other procedures as described at 6.9 below.

DOB and bark of those heights should be measured. At heights where an influence of aerial roots (“wings”) exists, diameters should be measured after bucking and by taking two measurements (long and short axes) on the central ellipse, disregarding wing extensions. The average measurement would be DIB. For registering DOB on the field sheets or data collectors, the two bark measurement values should be added to this value.

The case of trees buttressed at stump (0.3 m) height but below breast height

In this case, the point of mensuration (*pom*) for the tree diameter, which is regularly at 1.3 m height, is not changed. However, the 0.3 m height is not necessarily maintained as the “default” stump height. A more realistic stump height, where the faller will do the cut, is marked as the new stump height, and this will be the base of the first section for the analysis. Diameter and bark thickness at this stump height should be measured on the stump after felling. Procedures for dealing with aerial roots were already described in the preceding paragraph. All heights should be registered to the nearest 0.1 m.

6.8 Falling the tree

The falling process is at the discretion of the expert faller, trained in directional felling and RIL techniques. The crew should move to a safe distance during the process.

Any side branches should be cut on the felled tree. It is convenient to measure and register total tree height before this operation, for making easier to identify the top.

6.9 Marking and measuring the felled tree

The tree should be cut into sections ("bucked") for measuring and analysis. Sections are named after the height of their lower cut. For example, the 0.3 m section is the 1 m log resulting from the cuts at 0.3 m and 1.3 m.

Sections are those parts in which the stem is divided for analysis and for determining gross, net and merchantable volumes. Sections make up the main bole from the height of the stump to the height of the utilizable bole, as well as parts of secondary leaders and branches with commercial size and form. Note that no part of the main bole is excluded from the analysis for bad form, but commercial form is a requirement for parts of secondary leaders and branches to be included as sections in the analysis.

The measuring tape should be run along the stem of the tree to mark sections and defects. For avoiding errors, the 1.3 m mark on the tape should be lined up exactly with the trunk breast height, or with the marked reference height described above for trees with high buttresses.

In many cases, the utilizable part of the tree will be only the utilizable bole, this is, the part of the trunk beneath the crown, up to a minimum small end diameter of 25 cm (DIB). However, large branches with good form (Utilization factor 7 or more), a minimum small end diameter of 25 cm (DIB), and a minimum 2 m length, may also be utilizable. In certain cases, two or more stems compete for apical dominance ("fork"). These situations should be taken into account in the process of marking and measuring the tree.

In the case two or more stems are separated below 1.3 m height, they are treated as different trees, a standard criterion in forest inventories.

If secondary leaders are to be measured, the primary leader should be identified. The primary leader is the tallest leader. The only exception to this rule is in the case of a broken top. In this case, the determination of the main bole is based on projecting the old broken top and comparing its size to the new leaders.

Secondary leaders (stems) and measurable branches should be identified. They will be treated equally and given a number (starting from "Secondary leader/branch 1" or "SL/B 1") and measured if the following applies:

a. Originate from the primary leader;
b. originate above breast height;
c. are alive; and
d. meet size and commercial form criteria.

A number should be assigned to a secondary leader/branch before marking the individual sections. The height of the secondary leader/branch start height should be measured and registered.

For the main bole, or that part of the primary leader beneath the crown, the base height of the live crown should be measured. Forks and epicormic branches should not be confused with the crown base, which starts where live branches cover most of the stem circumference.

The location of the utilizable top (DIB 25 cm) of the bole should be determined by estimating its location, chopping a bark window, and measuring bark thickness and calculating DBT. This calculation is made on the field, and the process also provides DOB, which is also registered with DIB.

The total length of the bole up to the utilizable top should be measured and the utilizable bole top marked with paint.

For secondary leaders/branches, location of the utilizable top should be determined by applying the same procedure as for the main bole, and marked with paint.

Sections should be marked with paint. The standard section length will be 2.6 m, and in regular cases will start from 1.3 m (*dbh*)

Section lengths may and should be adjusted to better capture the section volume, or to maximize the utilization of the tree, as it would be done on a production situation. Forked and crooked sections may produce drastic alterations of the taper. Bottoms and tops of those sections should be marked to define section lengths for those parts of the stem. Some times, changes in taper are not associated to any visible factor, and the same procedure should be used. The default section length of 2.6 m should be resumed above those sections. Residual lengths of 1 m or smaller can be integrated into an adjacent section as long as no taper change occurs.

Decay indicators should be identified and measured, recording the lower and upper height of all indicators and their average width.

After the tree is marked and the decay indicators have all been located, all the tree sections should be bucked, including the utilizable top section.

The DOB of each section should be measured, starting from the lower sections of the tree (beginning at sections above 1.3 m) and working towards the top. In the case of buttressed trees, however, the definitive tree diameter (at *pom*) is measured on the felled tree, unless the *pom* is low enough to be reached on the standing tree.

Measuring of DOB should be done with diameter tape to the nearest 0.1 cm. Two opposite bark thicknesses should also be measured and registered for obtaining DIB. At the bottom of every section, a 5 cm thick cross-section (a “cookie”) should be cut. On the face of each cookie, the cumulative length and the tree number (and, if it applies, the secondary leader/branch number) should be clearly written. DOB and bark thickness should be measured at the bottom of every section. <u>This means that the top DOB of a section (and its bark thickness) is measured at the bottom of the following section, not at the end of the lower section</u>. The DOB, if possible, should be measured before the “cookie” is cut. Bark thickness can be measured on the cookie, on its lower face.

When measuring DOB of irregularly shaped cross-sections, the irregularity should be “smoothed out” by the sampler. The sampler should assess the overall section taper for making this decision. However, this does not apply if the cause is decay. If the distortion is due to decay resulting in missing wood, then the decayed portion should be “rebuilt” and DOB measured to the edge of the “rebuilt” portion.

Tree DOB is measured on the standing tree and is not re-measured after bucking. The only exception is the case of trees with high buttresses, where tree diameter is measured at the point of mensuration (*pom*) on the felled tree.

6.10 Identifying and measuring decay

The process of stem analysis and data collection should allow for the calculation of actual gross, net and merchantable tree volumes (see definitions in Appendix I). In the process of identifying and measuring decay, this means that the cross sectional area of decay and other losses in each section shall be precisely determined, excluding any contiguous area of sound wood. This will provide the net volume, free of decay.

Subsequently, a utilization (U) factor will be estimated and registered for every section. This factor should reflect the real aptitude of the section for being utilized, taking into account the net volume but also characteristics like decay shape and distribution. This last aspect is discussed below in Section 6.12.

The decay of wood is caused by wood-rotting fungi. The three stages of decay are incipient, advanced and final. Measurements, however, should be taken only on the advanced and final stages of decay.

In the *incipient* stage, only changes in color can be observed. Some stains, however, may be produced by organisms which are not related to decay.

At the *advanced* stage of decay, the strength of the wood has been affected, it is easily broken or even crumbled between the fingers. It appears soft, or different to the adjacent regular of the wood, when tested with a knife.

In the *final* stage of decay, destruction of the wood may be complete.

Multiple infections may occur in the same tree, like butt rot caused by fungus accessing through roots, stem rot caused by fungus entering through a scar, and top rot due to a broken top.

Decay should be identified in every section. Starting with the bottom-most section, the surface of the cookie should be examined for discolored or decayed wood. Areas of possible decay should be outlined, and every section cookie scrutinized for decay. Fiber strength should be checked with a knife, focusing on the areas initially outlined.

Decay should be measured in each section. A sharp pointed knife should be used to pick at the wood fiber on the radial edge, to determine length and strength of the wood fiber where decay is apparent or probable. Due to the subjectivity of this test, it is important to compare fiber strength with that of sound wood areas. Advanced decay should be easily identified in most cases. However, care must be taken for identifying advanced decay when incipient decay is adjacent or present in any form. It is important to remember that incipient decay should not be measured. Only final and advanced decay indicated by the presence of weak wood fibers are to be measured.

If the decay boundary is not obvious, or irregular, the cross-sectional boundary of the decay should be delineated with a marker. Any areas of sound wood within the decayed area should be identified.

Decay may appear in irregular shapes and distributions. This poses the problem of expressing the decay area in a simpler way, allowing for expedite recording while not losing much exactitude in the process. An alternative which has been used is to “coalesce” the decay area (bringing it together so as to form a one whole) into a more regular elliptical shape for measuring the long and short axes (British Columbia Ministry of Forests and Range, 2006).

For measuring decay, decay should be recorded for every section in which it occurs throughout the tree, from the bottom to the top. If the decay ends in a section and then occurs elsewhere in the tree, it has to be separately recorded.

Decay is always measured as an elliptical form, either solid shaped or ring –shaped. For the solid shape (for practical purposes, in this case radial and scattered decay is coalesced into a solid shape), the diameter should be obtained, measuring at right angles and registering the long and short axes of the ellipse. For the ring-shape, diameter is measured in the same way, but recording for each axis the inner and outer measures.

Once the shape is decided, it cannot be changed. For this reason, the spatial evolution of the decay should be observed in the sections. Note that for a ring-shaped decay which evolves into solid-shape decay, the cross-section of the latter can be measured as ring-shaped by artificially recording negligible inner diameters of 1 mm for both axes.

Voids, which are spaces with no wood within the sections, not due to decay, as well as insect damage, should be measured in the same way as decay. The circumstance should be registered.

Decay length is measured by registering the lower and upper heights of the decay in each section, relative to high side ground level.

If the decay is not visible at both ends of a section, decay length should be determined by making a regular series of intermediate bucks, as follows: The first buck should be made halfway along the section. If the decay is still evident, another buck should be made halfway along the half section. In this case, if decay is still present, the end of the decay should be considered to be at the “clean” end of the section, and registered at its end with a default value of 0.1 cm for the two diameters of the ellipse. If decay is not present, the end of the decay should be taken as the height of the last cut, and the same default values utilized. Note that if decay is not evident on the first buck halfway along the section, another buck is also needed to better define the end of the decay along the section. Section lengths larger than 50 cm should be checked in this procedure. This means that in some cases a regular 2.6 m section may be cut into four parts for measuring decay. Intermediate bucks can be done by cutting a wedge shaped piece out of the section, without cutting through the section.

Bad form: Within a selected tree, one or more particular sections may be non-utilizable or partially utilizable due to bad form such as crook, sinuosity or any other deformities. Those sections should be assigned a utilization factor as shown in 6.12.

6.11 Checking of decay indicators for hidden decay

All decay indicators below the utilizable top must be cut into and checked for hidden decay unless decay is already evident after the regular bucking of the sections.

The section should be bucked halfway along the decay indicator. If decay is present, it should be measured on the buck. Intermediate bucking should be performed as required to determine the length of the decay in the section.

6.12 Assigning utilization factors

For each section, utilization factors, expressed as percentage utilization factors when decay is present in a section through its total length (0%, 70%, 80% and 90%), are assigned for different shapes, distributions and grades of decay as follows:

Solid shape decay

Decay grade	*Utilization (U) (%)*
Decay on more than 30% of the section, or decay affects less than 30% but due to its particular shape its area of influence is more than 30% *	0
Marginally utilizable	70
Intermediate	80
Decay present with minimum or little effect on U	90

Diffuse/scattered decay

Decay grade	*Utilization (U) (%)*
Decay area of influence + 30% of the section *	0
Marginally utilizable	70
Intermediate	80
Decay present with minimum or little effect on U	90

Star/radial shape decay

Decay grade	*Utilization (U) (%)*
Decay area of influence + 30% of the section *	0
Marginally utilizable	70
Intermediate	80
Decay present with minimum or little effect on U	90

Ring shape decay

Decay grade	*Utilization (U) (%)*
External ring border beyond 40% of log radius and ring circumference + 50% complete	0
Marginally utilizable	70
Intermediate	80
Decay present with minimum or little effect on U	90

* *Note that "area of influence" is not the strict decay area that was previously coalesced into solid elliptical shape for measuring purposes. It is a larger section area where both decay and sound wood can be found but from where no wood products free of decay can be extracted.*

Experience indicates that it is not realistic to assign "utilizable" utilization factors below the 70% factor for sections where decay is present throughout their whole length. The proportion and distribution of sound wood in what would be those grades, together with uncertainties on decay distribution within the log and associated risks, has strong implications on the economy of transporting and primary processing of those logs. This results in those logs being considered non-commercial logs in the present market and wood processing conditions in Guyana.

Utilization factors should be assigned to each section in the field. They are the only field entries which can be reviewed, and eventually modified, after data processing is concluded. Data processing results might affect decay grades related to total and % decay area. Any review of U factors should include a review of the stored relevant "cookies".

For each section, utilization factors should also be assigned when a bad form defect or insect damage or void is present throughout the section, as follows:

Bad form

Form defect grade	*Utilization (U) (%)*
Major sinuosity or deformity	0
Marginally utilizable	70
Intermediate	80
Form defect present with minimum, little effect on U	90

Insect damage

Damage grade	*Utilization (U) (%)*
Damage area of influence + 30% of the section	0
Marginally utilizable	70
Intermediate	80
Damage present with minimum or little effect on U	90

Voids

Void grade	*Utilization (U) (%)*
Void area of influence + 30% of the section	0
Marginally utilizable	70
Intermediate	80
Void present with minimum or little effect on U	90

In all cases (decay, bad form, insect damage or void) utilization factors below 70 and above 0, always rounding up to the nearest 10%, may be assigned when the problem is totally restricted to a specific length of the section.

Utilization factor 100, indicating the section is fully utilizable, should be applied in all cases in which no decay nor any other defect or loss is present.

In all cases in which a reduced (below 100) utilization factor is applied, the cause of the reduction should be registered, as follows: Decay (D), Form (F), Insect damage (I), or Void (V). Only the preeminent cause should be registered. Form is preeminent over other causes. Note also that presence of insects in a void or decayed area does not necessarily mean that insect damage has occurred.

6.13 Analyzing the data

Data analysis is based on the assumption that sample trees are selected without bias, and involves the statistical analysis of several relationships:

- Estimated volumes and actual gross, net and merchantable volumes.
- Wood utilization factors and observable decay indicators.
- merchantable volumes and *dbh*, utilizable bole length and decay indicators.

The design of the study will allow for analyzing the probable influence of other variables, such as forest type and soil, on the parameters which are the subject of the study.

The analysis will be made for a few selected species of high interest and for all commercial species as a group. As trees are selected for the study in a stratified random sampling (this is, random sampling within previously defined strata), and with a higher inclusion of trees of the high interest strata (i.e. certain species and, probably, size classes), interpolating results to the group of commercial species requires the utilization of “weights”, multipliers needed to account for variable sample selection probabilities. These weights take into account the actual distribution of species and size classes in the forest, according to the results of the 2003 forest inventory.

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Appendix I. Definitions

The following are definitions for the purpose of this study.

Bole: The part of the trunk beneath the base of the crown, this is, where branching commences.

Decay: Wood loss or damage caused by wood-rotting fungi. The three stages of decay are incipient, advanced and final. In this study, however, only the advanced and final stages of decay are considered and registered. In them the strength of the wood has been affected (advanced stage) or the wood has been destroyed (final stage). Mere changes in color, which could be related to an incipient stage of decay, are not considered.

Gross volume: It is understood in this study as total tree volume in bole sections of commercial size, irrespective of form, and in other tree sections of commercial size and form.

Merchantable volume: Wood volume utilizable for primary processing (sawmilling). It results from the application of utilization factors to gross volumes in each section.

Net volume: Sound wood volume, or wood volume without decay, voids or insect damage, in bole sections of commercial size, irrespective of form, and in other tree sections of commercial size and form. *Net volume* results from discounting the volume of decay, voids and insect damage to the *gross volume*. *Net volume* may be larger than *merchantable volume*, as the latter takes into account not only the volume of sound wood but also its distribution in the section, as well as section form.

Sections: Parts in which the stem is divided for analysis and for determining gross, net and merchantable volumes. Sections make up the main bole from the height of the stump to the height of the utilizable bole, as well as parts of secondary leaders and branches with commercial size and form. Note that no part of the main bole is excluded from the analysis for bad form, but commercial form is a requirement for parts of secondary leaders and branches to be included as sections in the analysis.

Utilizable bole: The part of the trunk beneath the crown up to a minimum small end diameter of 25 cm (DIB).

Void: Space with no wood, not due to decay; it may include ingrown bark.

Weights: Multipliers needed to account for variable sample selection probabilities.