FIELD MANUAL ON GROUND TRUTHING AND TREE INVENTORY

[PD 239/03 Rev.1 (F)]

Development and Installation of a Forest Resources Monitoring System (FORMS) by Utilizing the Forest Canopy Density (FCD) Model Developed in ITTO Project PD 60/99 Rev.1 (F)

JANUARY 2007

Department of Environment and Natural Resources
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Acronyms and Abbreviations

CALABARZON	Cavite, Laguna, Batangas, Rizal and Quezon Provinces
CENRO	Community Environment and Natural Resources Office
DAB	Diameter Above Buttress
DBH	Diameter at Breast Height
DENR	Department of Environment and Natural Resources
FCD	Forest Canopy Density
FCDM	Forest Canopy Density Mapper
GIS	Geographic Information System
GPS	Global Positioning System
ITTO	International Tropical Timber Organization
JOFCA	Japan Overseas Forestry Consultants Association
PENRO	Provincial Environment and Natural Resources Office
QPL	Quezon Protected Landscape
SFM	Sustainable Forest Management
UTM	Universal Transverse Mercator
WGS	World Geographic System

Foreword

The pilot application of Forest Canopy Density Mapper (FCDM) in the Department of Environment and Natural Resources (DENR) Region IV CALABARZON, Philippines evolved from the need to streamline and systematize the gathering and management of important forest sector data. The use of FCDM, an image analysis semi-expert remote sensing software developed by previous ITTO project respond to the opportunity in the improvement of information gathering methods by utilizing satellite imagery analysis. It supports logical decision–making , formulation and well-planned interventions in forest conservation, development and management. The application of FCDM provides mechanism that support efficient management of forest resources enabling decision makers to access information on the actual status of forest conditions in real time. The use of satellite imagery data coupled with digital mapping are viable alternatives to the outmoded systems currently in use.

The ground truthing operation is essential to determine the actual status of the ground cover relative to FCD output. It should be noted that satellite data do not present the identification of the forest and groundcover type. It only depicts information as to the degree of forest class density in stratified manner.

The conduct of ground truthing has the following activities, i.e. plot establishment, canopy and ground readings, tree inventory and analysis. This series of data gathering from map to ground situation analysis is the first-of-its-kind of FCDM application in the country. The process can be improved through time and pose as a challenge to researchers and policy makers as FCD technology will be a common and cost-effective tool for planning and decision-making.

It is hoped that this Field Manual will help validate the accuracy of forest canopy density on the ground and provide the means to determine the interventions required in forest rehabilitation and management geared towards SFM.

Acknowledgments

On behalf of the Department of Environment and Natural Resources (DENR), Region IV CALABARZON, we acknowledge with profound gratitude, the assistance, support and contributions of various DENR offices, i.e. Provincial Environment and Natural Resources Offices (PENROs), Community Environment and Natural Resources Offices (CENROs), Forest Management Bureau (FMB), National Mapping and Resource Information Agency (NAMRIA), Local Government Units (LGUs) as well as officials and staff of the funding institution, the executing and cooperating agencies for the successful implementation and completion of the Project, entitled "Development and Installation of a Forest Resources Monitoring System (FORMS) by Utilizing the Forest Canopy Density (FCD) Model Developed in ITTO Project PD 66/99 Rev.1(F)."

We are specifically grateful to the International Tropical Timber Organization (ITTO) represented by its Executive Director, Dr. Manoel Sobral Filho, for providing the funding support and thereby allowing the FORMS Project to become a reality.

Our heartfelt gratitude is also extended to Japan Overseas Forestry Consultants Association (JOFCA) whose expertise and support have been shared with us in the groundtruthing activities. To Dr. Emmanuel R.G. Abraham who contributed the topic on the procedure of groundtruthing and likewise, introduced the use of densitometer equipment for canopy and ground reading. Special mention is due to Mr. Susumu Miyatake, who assisted the project staff in the establishment of groundtruthing plots.

We are also grateful to the unselfish support and participation of the following technical personnel for the conduct of ground truthing works, namely: Foresters Ernesto Jocson and Oliver Olivo from Regional Office, Luningning Morales, from PENRO Batangas, Norberto Capacio from PENRO Laguna, Victorio Ombajino and Nina Veloso from PENRO Quezon, respectively, and Antonio Abijay from PENRO Rizal. Special thanks to Ms. Liza Cabrera, Chief, MIS Section, Planning and Management Division (PMD) for her unselfish assistance in the final preparation of the Field Manual in digital format.

We also express our deep appreciation to Dr. Merlinda R. Manila, Project Coordinator and concurrent OIC-Chief, Forest Resources Development Division, with her unrelenting dedication and tireless work, she pioneered the groundtruthing study in the country through FCD technology using satellite imageries.

Finally, we are also indebted to all who shared their insights, wisdom, and expertise, in one way or another, during the implementation phase of the project.

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FIELD MANUAL ON GROUND TRUTHING/TREE INVENTORY

INTRODUCTION

The imlementation of the DENR IV-ITTO project at the CALABARZON region using the Forest Canopy Density (FCD) Ver. 2, a semi-expert remote sensing software developed by previous ITTO project prompted the establishment of the testing plots at Quezon Protected Area Landscape (QPL). The plots were established to conduct ground truthing as a result of FCD operation. The Forest Canopy Density (FCD) map showing the stratified forest density class range from 1-100% served as guide in the selection of sampling plots. The establishment of testing plots was made to ensure that FCD data showed on the map have correlation on the ground.

The validation and measurement of FCD class range was made possible through the use of GRS Densitometer which was used to measure the status of crown density and ground cover. The establishment of transect line forming a diamond shape within the 20m x 50m plot, two (2) diamond shape plots were laid on the ground at 20m x 20m sub-plots. The two sub-plots cover 0.1 hectare.

On the same plot (20m x 50m), a timber inventory was conducted to determine the number of trees and volume of timber. The inventory was also done in an attempt to generate volume data that can represent the density of the forest crown cover.

The conduct of these various ground truthing techniques and timber inventory is the first mini-research type of activity undertaken by the project in an anticipation to predict the actual location of the remaining forest of the country including the calculation of timber volume. The results of this simple study will be useful in decision making as to the degree of resource utilization and development within the protection and production forest.

The ground truthing operation is essential to determine the actual status of the ground cover relative to FCD output. It should be noted that satellite data do not present the identification of the forest and groundcover type. It only depicts information as to the degree of forest class cover in stratified manner.

Ground truthing is a pre-requisite to effective management of forest cover. The process entails verification of stand existing in the area. It also provides information on the extent of forest cover and the degree of rehabilitation to be undertaken.

The purpose of this Field Manual is to provide guidance in the conduct of crown and ground cover measurements and timber inventory as a result of Forest Canopy Density technology. It is recommended that further studies should be undertaken to improve the methodology and create opportunity to enhance the data generation and be able to respond to the fast changing information technology.

1. FIELD WORK PREPARATION

The conduct of ground truthing is similar to the conduct of timber inventory in a given area. The essential factor to a fruitful ground truthing activities depends on the availability of personnel, budget, planning, coordination, equipment and instrumentation.

1.1 Planning, coordination and control

The preparation of a rectified printed FCD and topographic maps is equally important in conducting ground truthing. It is of utmost relevance that pre-identified sample plots representing various FCD class ranges are printed in large scale for easy identification of pixel value location on the ground.

The pre-determined sample plots on the FCD map, the number of plots to be established can easily be estimated. Experienced has shown that it takes a well trained team to establish two (2) plots of 20m x50m under average terrain condition for two (days) for densitometer reading, tree tagging, tree height and diameter class measurement.

1.2 Field inventory teams

The Team Leader aided by a technical assistant tasked to undergo ground truthing should be a Forester with training on Remote Sensing and ground truthing or timber inventory. The team has to be assisted by two (2) laborers. The laborers should be hired locally as they will also serve as guide in the area and assist in the identification of tree species. The team leader is responsible for the attainment of all activities required to be done and safekeeping of quality data records. The members of the team should be oriented by the Team Leader as to the use of equipment and measurements and tasks to be done.

1.3 Equipment and instrumentation

Ground truthing is carried out with the support of various equipment and instruments to aid in data collection. With the advent of information technology, global positioning system (GPS) is a must as a tool in locating the correct position of the sample plot. The GPS should have a feature that can give data on elevation, least error and should be downloadable in the computer. A sunto compass is recommended and is also of equally important to support GPS when satellite tracking lines are not operational due to dense forest crown cover. Other relevant pieces equipment are clinometer for use to measure tree height, diameter tape to measure diameter class and meter tape to measure the distance of the plots.

2. THE GROUNDTRUTHING METHOD

2.1 Site selection for sampling plot

Before going to field works, identify plots on the FCD map. Overlay location of FCD plots onto the topographic map to determine the terrain and accessibility of the plot. Guided by the FCD class range, choose sample plots based on the number of pixel value. It should be noted that the higher number of same pixel value, the easier to find the area on the ground. A magnified FCD map printed in A3 size bond paper showing the sample plot in a number of pixel size is a must (see Photo No. 1). With the use of GPS, locate the area on the ground. It should be noted that the GPS must always be calibrated and set to a WGS projection.

2.2 Plot Demarcation

The ground truthing design complements the FCD appearing in the stratified forest covering different classes and uses sampling units on a series of sample plots according to class range to be sampled. The adoption of the combined sample plots represents the canopy density and the probability of the number of trees per hectare with a diameter ranging from 5 cm and up. Ground truthing design ensures pieces of information collected for a sufficient qualitative and quantitative description of the forest resources.

The establishment of ground truthing plots comprised as follows:

(a) Guided by FCD map and a calibrated GPS, locate the target area to determine potential areas to establish sample plots (areas of varying canopy cover).

(b) Undertake a field reconnaissance of landscapes or sites to aid if necessary.

(c) Identify and select sample plots, taking note of their coordinates.

(d) Using GPS and compass, demarcate the FCD class area on the ground the 20m x 50m plot following direction covering size of the pixel reflected on the FCD map as shown on Figure 1.

(e) All corners of the plot demarcated shall be marked by a flagging tape (cor. 1,2,3 and 4).

(f) Layout a modified diamond shape on the plot using meter tapes as shown in Figure 1.

(g) Enclosed the demarcated plot using the 50-meter tape purposely to guide the recorder in the meter interval and direction of the line.

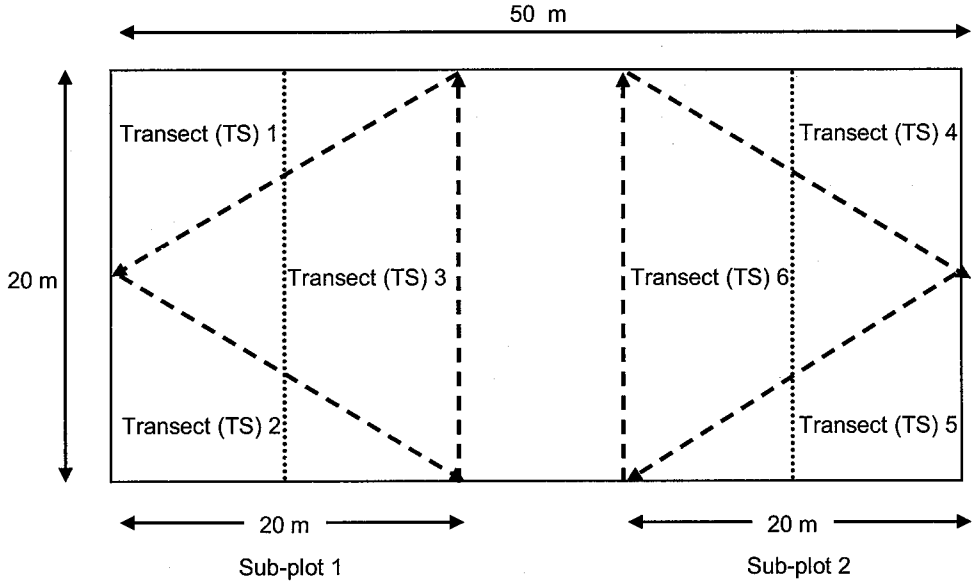


Figure 1. Schematic diagram of a sample plot size with Diamond shaped layout transect for canopy and ground cover measurements

2.3 Canopy Cover Measurement

The GRS Densitometer is to be used to determine crown cover measurements. The Densitometer is used with the point-transect method of sampling. It is a tool that uses a mirror to project a view of the sample location point in the canopy above to the person holding the instrument on the ground. Likewise, GRS Densitometer can be aligned to give an exact vertical line-of-sight into the canopy. Mounted inside the viewing tube are two bubble-line level vials. The recorder can simply sight through the unit until the vial's bubles are both level, then record the characteristics of the feature that covers the point when the 'dot' is centered on the circle (please see Photo No. 2).

The crown cover measurements had been carried in the demarcated plot as follows:

(a) Walk along each transect (TS) and using the GRS Densitometer, record whether the canopy reading is open sky or leaf/vegetation and whether the ground reading is vegetation or others (e.g.bare soil, rock, or litter, etc.) for every meter.

(b) Start GRS Densitometer reading at corner of subplot 1 transect-1 -3 and corner TS-4 going to the direction of TS-5 and TS-6.

(c) The assigned Densitometer holder does the canopy reading both from the canopy and ground in a moderate voice allowing the recorder to hear the reading for data entry in the FCD GT1 form (see Table 1).

(d) At the end of the recording for 2 sub plots, compute the canopy reading. as well as the average of the two(2) sub plots.

(e) Record all crown density and ground reading following prescribed FCD GT1 form (see Table 1).

2.4 Tree Inventory

After the canopy cover measurements activity, timber inventory follows to determine timber volume and other stand characterisitics such as species composition, basal area, mean diameter and stand density. The plot is to be subdivided into five (5) subplots to ensure all trees from 5 cm dbh and up were identified, measured and recorded.

2.4.1 Tree identification and Marking

The conduct of timber inventory inside the plot start with tree identification and marking with data entries in FCD GT2 form (see Table 2). All trees 5cm dbh and up bear consecutive number using a label and a bronze (1/2) nail attach on each tree. The group conducting a tree inventory compose of a recorder, specialist on tree identification performing dbh measurement, tree height measurement recorder (with clinometer) and one laborer responsible for fixing the calibrated rod serving as reference for tree height measurement. Following the demarcated plot for canopy cover measurements, the 20m x 50m plot is subdivided into five (5) sub-plots. An imaginary transect line is drawn to ensure systematic tree inventory (Figure 2) data recording.

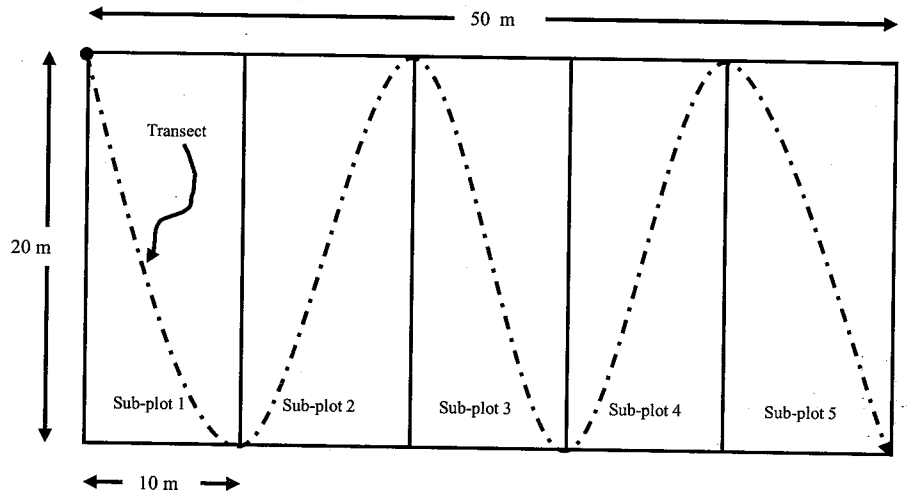


Figure 2. Schematic diagram of timber inventory sample plot

2.4.2 DBH Measurements

The diameter is expressed as diameter at breast height (dbh). The dbh is the average stem diameter, outside bark, at a point 1.3 above ground as measured from uphill side of the stem (see Figures 3 and 4). The dbh is measured in full centimeters using a diameter tape.

When bulges, swellings, depressions, branches or other abnormalities occur at breast height, the diameter is measured just above the abnormality at a point where it ceases to affect normal stem form. If a tree forks immediately above breast height, the diameter is measured below the swell resulting from the fork. When a tree forks below breast height, the stems are considered as separate trees. On leaning trees, the breast height must be determined along the axis of the stem. If a tree is buttressed beyond breast height, the diameter is measured 30 cm above the end of buttress. The dbh is measured in full centimeters with the aid of a diameter tape.

Prior to the measurement, all vines and climbers, as well as all other hindrances that may impede the proper use of diameter tape at the point of measurement on the stem must be removed, but not necessarily to cut. The tape is wrapped around the stem, carefully leveled at breast height, and tightened.

Unlike, other trees, strangler figs need a different approach. No diameter is measured, and neither tree nor log quality is assessed. The only parameter to be measured, regardless of their size, is the total height.

2.4.3 Tree Height Measurements

To carry out tree height measurements, select trees representing one tree for each dbh class in each sub-plot.The total height of a tree is the linear distance along axis of the stem from the ground level to the tip of the tree crown. Under prevailing poor sighting conditions, accurate height measurements are not seldom impossible, and at any rate prohibitively time consuming. Hence, the total height is ordinarily determined in full meters through ocular estimates. The quality of the ocular estimates is kept high through occasional comparisons with instrumental measurements.

The total height is measured using a clinometer. The team leader positions himself at a known horizontal distance from a tree to be measured, at a point from where he can see both the tip of the tree crown and at the base of the stem. The horizontal distance between the tree crown and the base of the stem. The horizontal distance from

the tree and the observation point should be closed to the estimated total height. For ease of computation, it is recommended to use distances that are multiples of 10 m. From the observation point, the team leader carries out two clinometer readings: one aiming the tip of the tree crown, and another aiming the base of stem. From the observation point, team leader carries out a first clinometer reading (e.g. +18%) while aiming at the tip of the tree crown, and a second clinometer reading (e.g. - 12%) while aiming at the base of the stem (see Figure 5).

Measure the tree height (total and merchantable) of the sample tree following the method discussed in log tree height measurements, merchantable height, and tree quality. Record all data in prescribed FCD GT3 form (see Table 3).

2.4.4 Merchantable Height

The merchantable height of a tree is the linear distance along the axis of the stem from the assumed stump height (i.e. 50 cm above ground, or end of buttress) to the first big branch. A clear bole of more than 3 m prolonging the stem above the first big branch must be included. The merchantable height is determined for trees with dbh/ dab of 35.0 cm and above.

As for total height, the merchantable height is ordinarily determined in full meters through ocular estimates and occasionally verified by instrumental measurements (see Photo No. 2).

2.4.5 Tree Quality

The tree quality is assessed for trees with dbh/dab between 5.0 and up.

Potential crop tree	:	straight and cylindrical bole without visible defects and/or fork
Other sound tree	:	trees with quality and vitality to qualify as potential crop tree, but belonging to other species and/or not having the required growing space
Defective tree	:	trees with considerable bark damages down to the cambium or trees with deep wounds beyond the cambium threathened by rot
Defective tree	:	trees with center rot or trees with consoles of polyporous fungi

2.4.6 Log Quality

The log quality is assessed for all 5m logs (the top portion of the merchantable bole must measure at least 3m to be considered a log) of the tree with a dbh/dab of 35.0 cm and above. It is expressed as a combination of classes relating separately to the straightness, the roundness and the visible defects of the logs. The following classess are distinguished:

Straightness
- straight, logs that have neither a sweep nor a crook with a departure of at least half the small end section diameter (see Figure 6. Sweep and Crook)
- swept, logs with a sweep, i.e. departure of the center line of the log from a straight line joining the centers of both end sections and at least half the small end section diameter (see Figure 6)
- crooked, logs with a crook, i.e. departure of logs with a sweep, i.e. departure of the center line of the log from an extension of the center line of the straight portion of at least half the small end section diameter (see Figure 6)

Roundness
- cylindrical, logs without any pronounced concave face, and without any diameter measuring more than 25% longer than its smallest diameter (see Figure 7)

Visible defects
- none, sound logs without live or dead branches, swellings, bulges, cracks or bark damages
- minor defects, logs having either up to 4 live branches with a diameter of less than 5.0 cm, or superficial bark damages/deeper wounds that will likely heal, or climbers that slightly affect tree form and growth, or minor bulges/swellings, or scars, or small knots, or any combination of not more than 3 of the cited minor defects
- defective/cull, logs with either a combination of more than 3 minor defects, or more than 4 live/dead branches with a diameter of less than 5.0 cm, or live/dead branches with a diameter of more than 5.0 cm, or considerable bark

damages down to the cambium, or big bulges, swelling, knots, or climbers clearly affecting tree form and growth, or any signs of rot, or consoles of polyporous fungi, or any combination of these defects.

3. DATA COMPILATION, CONSOLIDATION AND PROCESSING

3.1 Data encoding

3.1.1 Using Excel, develop the appropriate tabular formats corresponding to the field notes.

3.1.2. Encode the data, ensuring that values and species names are encoded correctly.

3.1.3 Review the encoded data using the raw data and make the necessary corrections as required.

3.1.4 There should be three data sets: (a) tree inventory, (b) sample tree height measurements, (c) canopy density.

3.2 Data consolidation

3.2.1 Conduct Field inventory data collection by subplots.Merge all subplots data into one worksheet for each plot to come up with a master tree inventory list containing plot number, subplot number, tree number, fork number, tree number, dbh, species and remarks.

3.2.2 If the sample encoded data did not include dbh and species, incorporate these data now into the raw data which should include the following fields: plot number, subplot number, tree number, dbh, species, clinometer readings of tree top, crown base (merchantable height), pole top and pole base in percent, pole length, alpha (the height to which the base of the pole was placed) and remarks.

3.2.3 Compute the heights (total & merchantable) of the sample trees according to the following formulas:

$$H = \left[P_L * \left(\frac{R_H - R_{PB}}{R_{PT} - R_{PB}} \right) \right] + \alpha$$

Where

H = Height (in m), to the desired point (total height or merchantable height

P_L = Length to pole (in meters)

R_H = clinometer reading (in %) to desired height (H)
R_{PT} = clinometer reading (in %) to pole top
R_{PB} = clinometer reading (in %) to pole base
α = the height to which the base of the pole was placed IF not the same as base of the tree

3.2.4 Use consolidated canopy GRS Densitometer readings to determine canopy cover using the following formula:

$$C = \left(\frac{N_C}{N_T}\right) * 100$$

Where

C = canopy cover (in %)
N_C = number of readings indicating leaf/vegetation
N_T = Total number of readings made

4. DATA ANALYSIS FOR TIMBER VOLUME

(a) You need the processed data set of sample trees. Determine and segregate sample trees according to species, i.e. Dipterocarps and Non-Dipterocarps.

(b) Compute the timber volume of the individual sample trees for each plot according to the appropriate parameters for the equation currently used (BFR, UPCF, USAID. 1963. Regional Volume Equations and Tables for the Philippine Timber Species):

$$V = b(D^2H)$$

Where:

V = merchantable volume (m3)
D = diameter at breast height (cm)
H = merchantable height (m)
b = appropriate parameter

(c) Using Excel, plot all the data (regardless of species) into a graph with dbh on the x-axis and timber volume on the y-axis. Add a trendline to get equation relating dbh to timber volume (use non-linear trendline, $Y=aX^b$) and show R^2 value to evaluate fit (see Figure 3).

(d) Using the values of parameters *a* and *b,* compute the timber volume of all the individual trees inventoried in each of the plot. Sum up individual volumes to obtain total plot volume. Divide the value by 0.1 ha (plot size) to obtain volume per hectare of each plot. You may segregate your data by desired dbh classes to compute timber volume of trees with dbh 20 cm and above or trees with dbh 30 cm and above, etc.

(e) Compute other plot characteristics such as species composition, dbh structure, basal area, stem density, etc. using standard procedures to obtain other important plot characteristics needed to explain your results.

(f) Repeat procedure (a) to (e) for all plots.

5. DATA ANALYSIS SUMMARY

(a) Using the outputs of all previous phases, prepare a table summary containing data on timber volume, canopy density and other plot characteristics.

(b) Using Excel, plot desired timber volume (e.g. dbh of 20 cm or more; dbh of 30 cm or more, etc.) against canopy density (canopy density on x-axis; volume on y-axis)

(c) Evaluate the graph. Add the most appropriate trend line to obtain the regression equation. Check R^2 for best fit (see Figure 8).

(d) Depending on the strength of the relationship, the parameters of the regression equation may be used to estimate timber volume for canopy density for the study area (see Figure 9). It should be noted that such estimation, unless supported by adequate number of plots with very strong relationship, should be used with caution. The regression equation may be used as a predictor equation subject to strength of the relationship.

6. EQUIPMENT/TOOLS FOR FCD GROUNDTRUTHING

List of eqipment/tools are listed hereunder (see sample Figure 10):

1. Topo map (1:50,000)
2. FCD map
3. Magnified FCD map showing its value and coordinates
4. GPS
5. Meter tape (50 meters)
6. Compass (sunto)
7. Clinometer
8. Bolo
9. Medical kit
10. Hard folder
11. Pencil
12. FCD data forms
13. Bush Jacket
14. Digital Camera
16. Tripod
17. GRS Densitometer
18. Pen for tree marking
19. Flagging tape/Ribbon

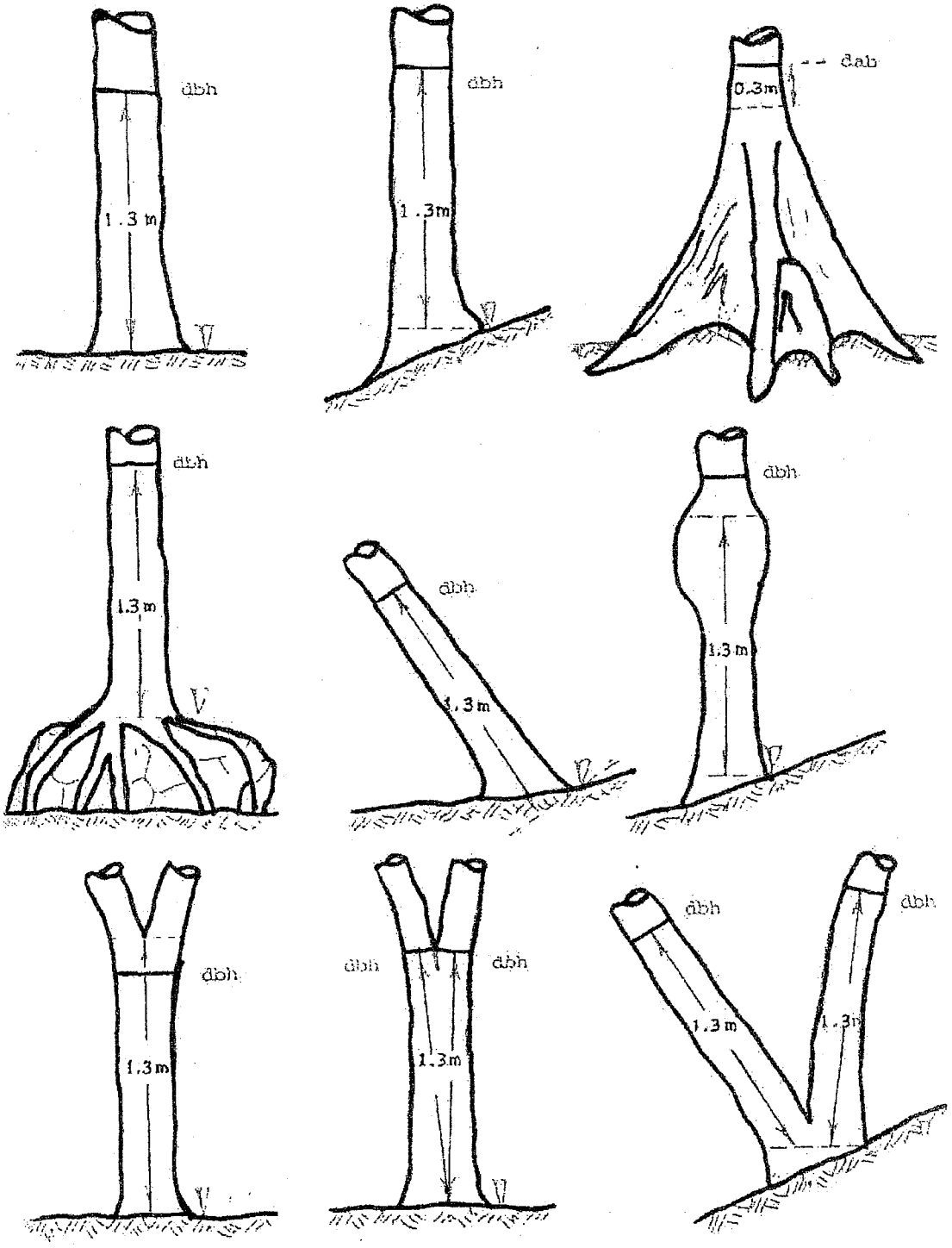


Figure 3. Diameter Measurements

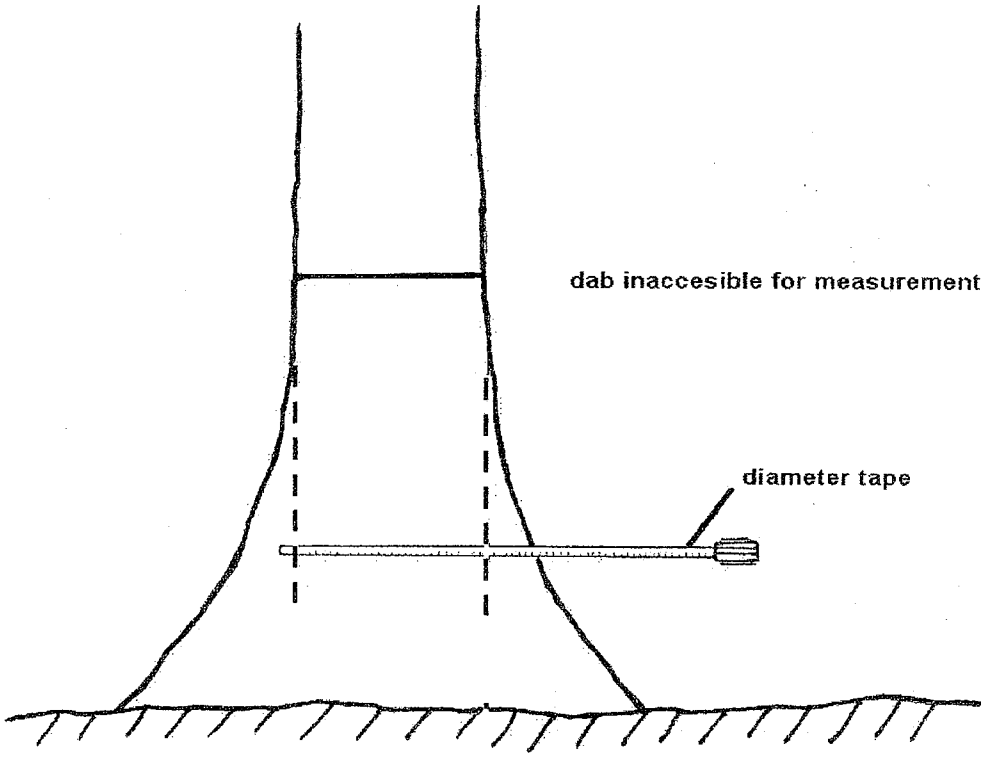


Figure 4. Diameter Estimates

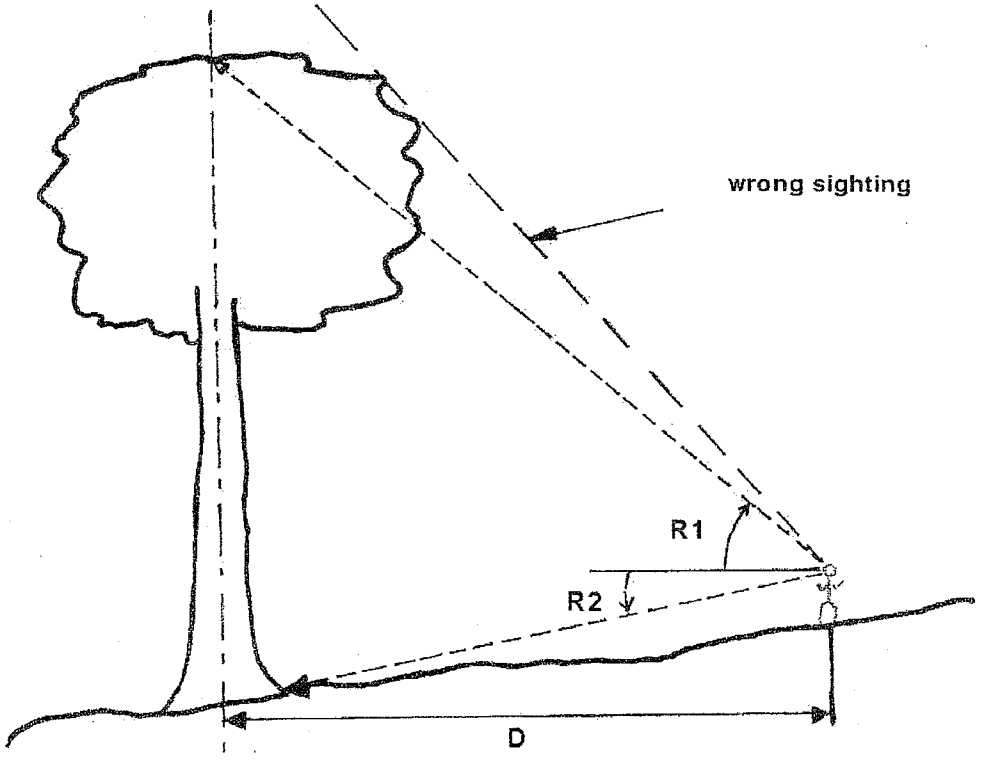


Figure 5. Measurement of Total Tree Height

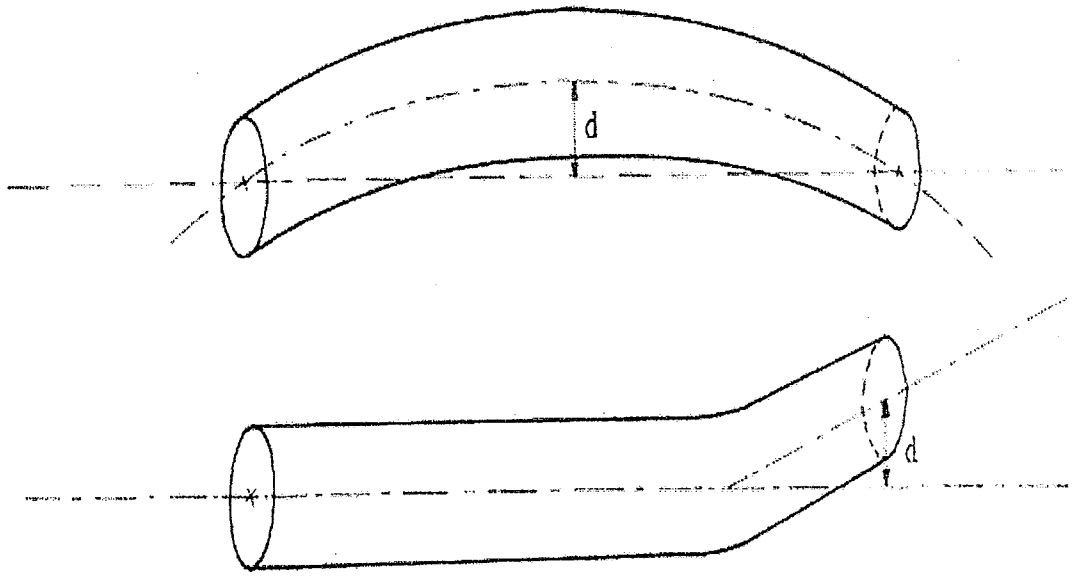


Figure 6. Sweep and Crook

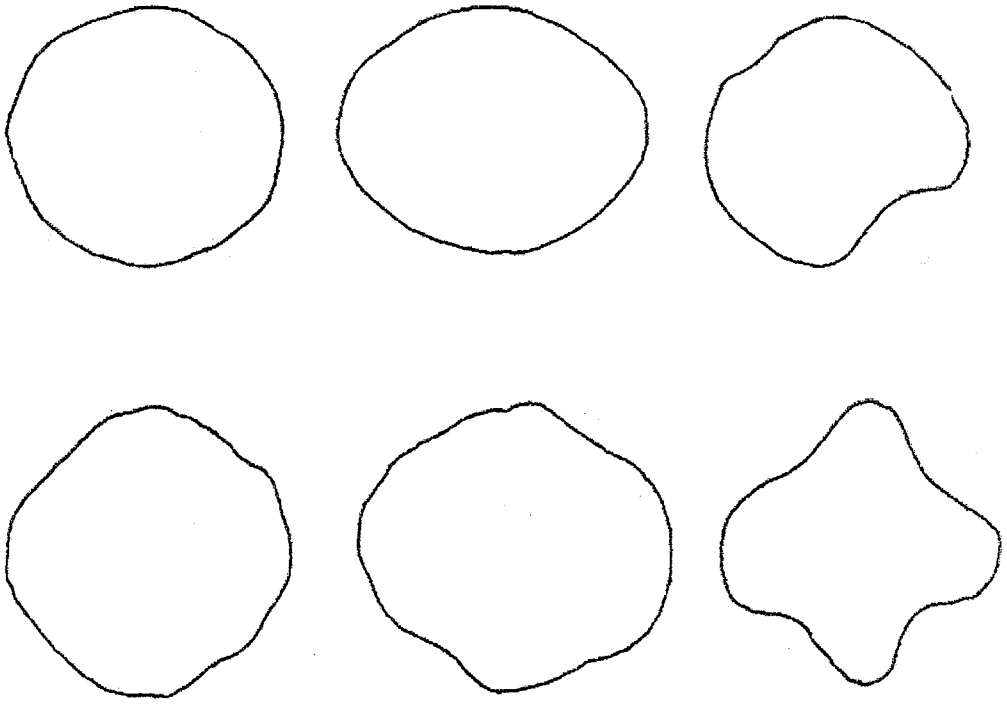


Figure 7. Log Roundness

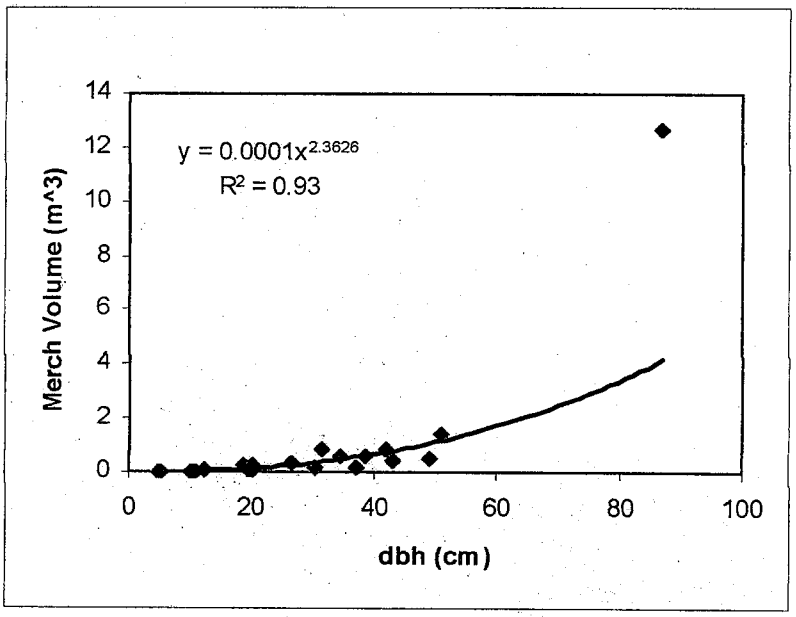


Figure 8. Sample output of regression of volume on dbh.

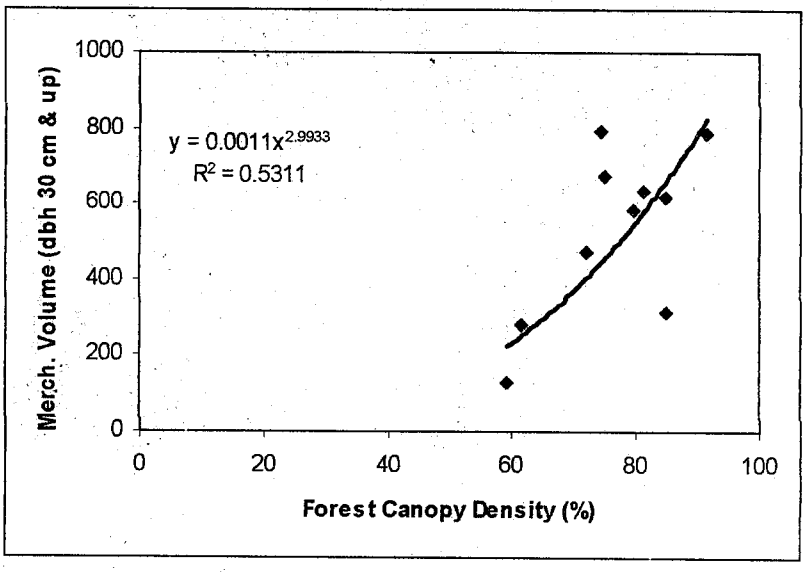


Figure 9. Sample graph showing the relationship between canopy density and volume.

FCD GT 1 (Canopy Measurement)

Plot No. : **Sub-plot No. :**
Location :
Elevation :
Topography :
Vegetation Type :
Coordinates :
Legend :

Canopy Reading: L (leaf); S (sky)
Ground Reading: X (vegetation); X1 (roots); X2 (forest litter); X3 (stone/rock); X4 (dead wood); X5 bare soil

Transect Number	Tree No.	Canopy Reading	Ground Reading	Transect Number	Tree No.	Canopy Reading	Ground Reading

Computation:

Canopy reading = No. of Sky/No. of Transect x 100%

Ground reading = No. of Vegetation/ No. of Transect x 100%

Table 1. FCD Ground Truthing Form 1

FCD GT2 (Timber Inventory)

Plot No. :
Location :
Elevation :
Topography :
Vegetation Type :
Coordinates :

Tree Number	DBH	Species	Tree Number	DBH	Species

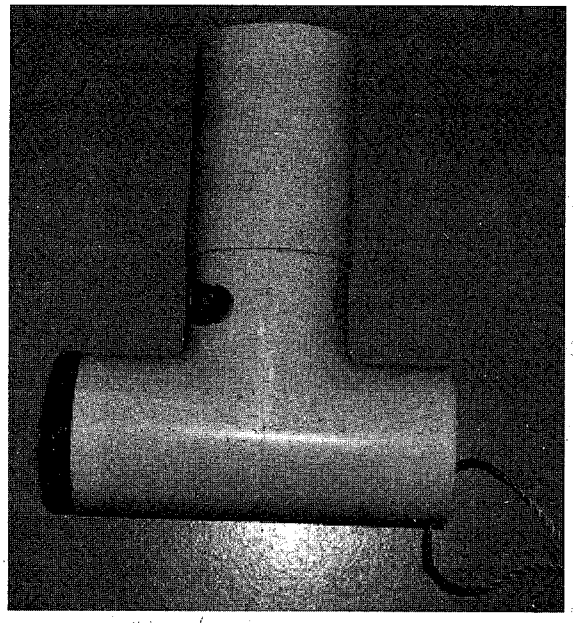
Table 2. FCD Ground Truthing Form 2

FCD GT3 (Sub-Inventory for Tree Height)

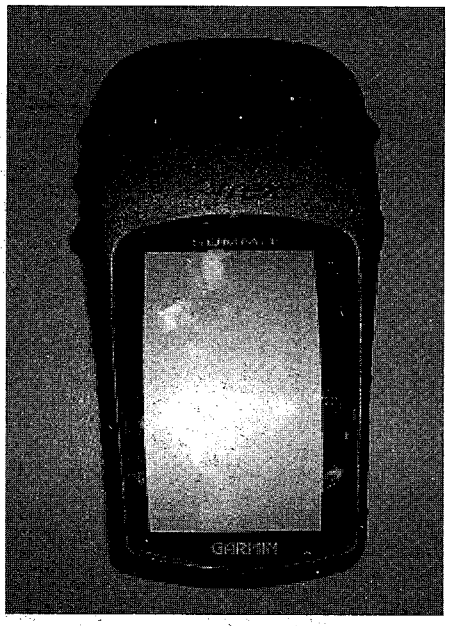
Plot No. :
Location :
Elevation :
Topography :
Vegetation Type :
Coordinates :

Plot No.	Sub-Plot No.	Tree No.	DBH (cm)	Total Height (m)	Tree Top(%)	Crown Base (%)	Pole Top(%)	Pole Base(%)	Pole Length(%)	Remarks

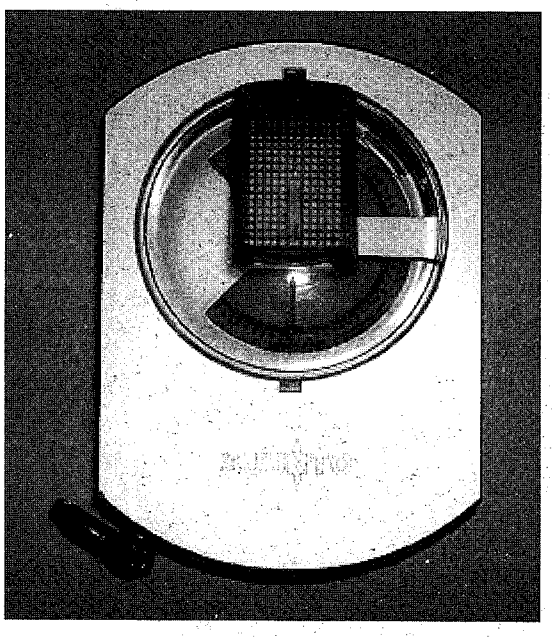
Table 3. FCD Ground Truthing Form 3



GRS Densitometer



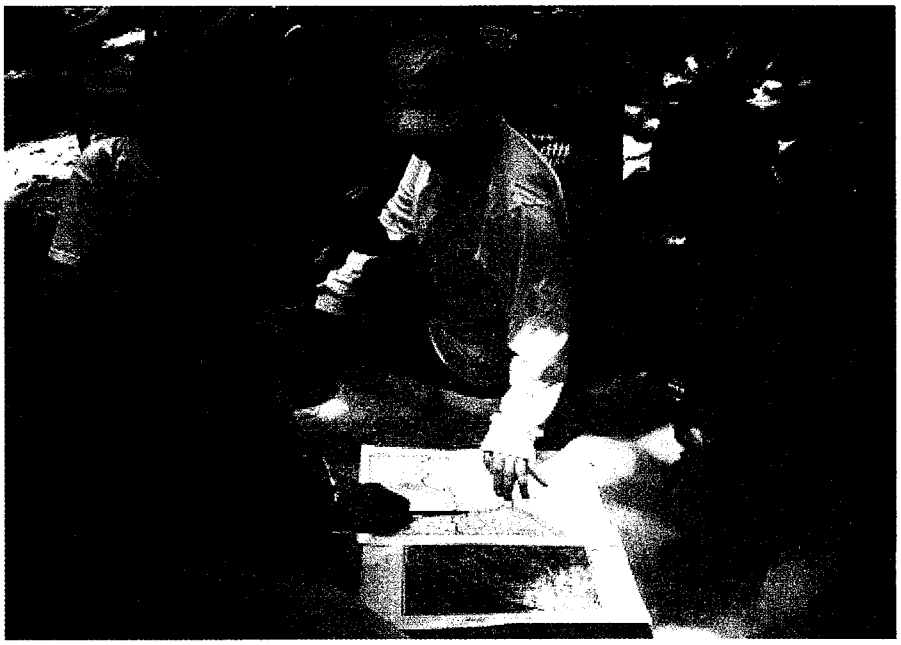
GPS



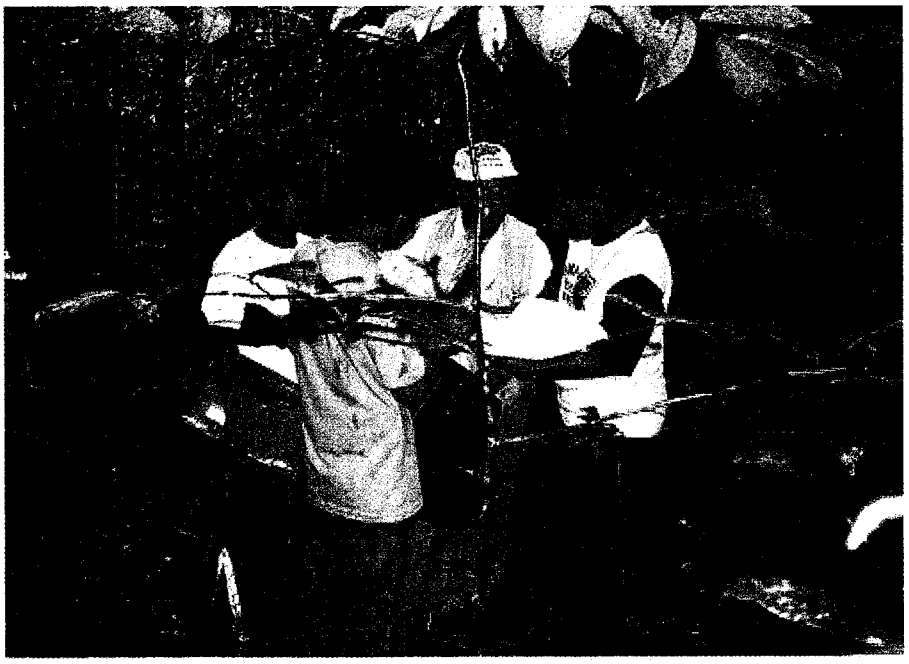
Clinometer

Compass

Figure 10. Equipment Sample for Ground Truthing/Tree Inventory

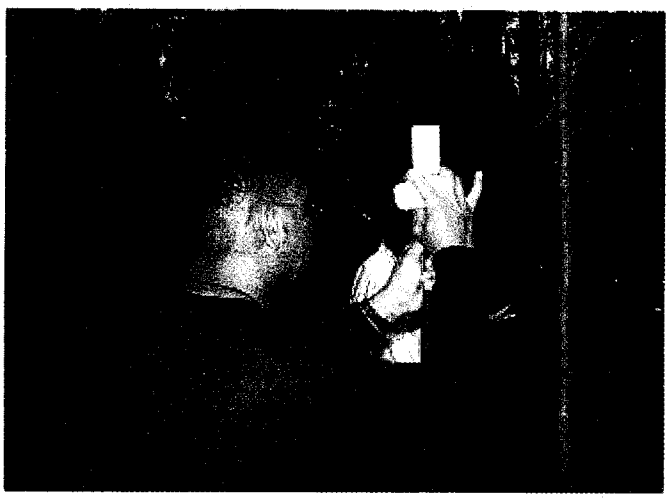


Pre-identification of plots using FCD Map



Assessment/Finalization of plot location

Photo No. 1. Pre-identification/establishment of Plots



Crown density reading by GRS densitometer

DBH measurement using a diameter tape

Tree height measurement using clinometer aided by a range pole

Photo No. 2. Canopy Cover and Tree Measurements

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