



Federal Ministry
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Participatory research to support sustainable
land management on the Mahafaly Plateau in
south-western Madagascar



Field Manual for Biomass Inventories in South-Western Madagascar in the Scope of the SuLaMa Project



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February 2016

This manual was developed by the SuLaMa Project Group responsible for the supervision and conduction of the biomass inventories in the scope of the SuLaMa Project. The content of the manual follows the structure of a Field Manual elaborated by Prof. Dr. M. Köhl and Dr. Matthias Scheuber (1998) and builds upon a previous version of this manual used in the REDD-FORECA project. Main contributors to this version of the field manual are:

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SuLaMa — Participatory research to support sustainable land management on the Mahafaly Plateau in south-western Madagascar
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Published by: University of Hamburg
Institute for World Forestry
Leuschnerstr. 91
21031 Hamburg
Germany

Cover picture: Jens Härtel

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1. Introduction

1.1. Objective of the manual

The field manual describes the procedure of the field work developed for biomass inventories in the scope of the SuLaMa project. It serves for the training of field crews and as a reference book during fieldwork.

The definitions given in the manual set the standard for the assessment of terrestrial sample plots. All definitions and the described procedures are binding and have to be obliged by the field crews.

1.2. Use of the field manual

It is recommended that the field crews carry their field manual with them and to use it during the fieldwork. The definitions given in this field manual are not to be changed by the field crew. The chief of the field crew is responsible for the correct conduction of the assessments on the sample plots in accordance with this field manual.

Critics and suggestions that can improve the field manual are welcome and shall be written down by the field crews and given to the responsible staff.

1.3. Preparation of the field work

Before each field sampling campaign, the field crew controls their equipment for completeness according to the equipment list in Annex 6. The team takes special care to not run out of forms, pens, paint and permanent plot markers during the sampling campaign and order substitution in advance.

Before departure to the field, the field crew controls the equipment for completeness, especially forms, list of clusters and fix-point list, permanent plot markers and paint.

For security reasons, the field team gives information about the locations of the clusters and the intended date and time it will work on each of these.

The end time of the fieldwork should be registered according to Section 2.4 when returning to the field camp.

In preparation of the field sampling campaign, the GIS-laboratory has to preload all GPS units with waypoints of the position of clusters and sample points using the naming scheme indicated in Section 1.6. Further, the GIS-laboratory creates field maps which include the position of clusters (labelled with the name of the cluster), high-resolution aerial or satellite images and auxiliary information such as roads, rivers and contour lines. High-resolution remote sensing data are freely available online using Google Earth or other online map services.

1.4. Description of the inventory method

The inventory method follows the idea of a continuous forest inventory. The samples are distributed systematically over the territory of the particular study area with a regular dot grid. The dot grid spacing for the biomass inventories may vary according to stratification of different forest types. The clusters are located at the crossing points of the dot grid lines and consist of six sample plots. In the following sections, this method is described in detail and definitions of the nomenclature are given.

1.5. Description of the dot grid

The dot grid is set by the GIS-laboratory. It is based on a regular dot grid established for the different study areas.

For the biomass inventory, the study area is stratified according to the distribution of the density and the origin of the forested area. The reason for this stratification is the different composition of the forested areas (natural and secondary forest) and different precision requirements (degraded and undegraded). Further information about stratification for biomass inventories can be found in Köhl et al. (2006) and Plugge et al. (2010).

1.6. Description of the cluster

A cluster consists of six sample plots localised in form of a rectangle with 50 m distance between the centres of two neighbouring sample plots. There are three sample plots on two 100 m long trails as shown in Figure 1.1. The centre of sample plot 1 is identical with the dot grid point. Sample plot 2 lies 50 m east (azimuth = 90°) of sample plot 1. The centre of sample plot 3 lies 100 m east (azimuth = 90°) of sample plot 1 (50 m east of the centre of sample plot 2). The centre of sample plot 4 lies 50 m north of sample plot 1 (azimuth = 0°), the centres of sample plot 5 and 6 lie 50 and 100 m east to the centre of sample plot 4, respectively.

The cluster is linked to the dot grid with sample plot 1. The position of the centre of this sample plot is identical with the crossing of the dot grid lines (dot grid point). The cluster is identified by the corresponding number on the dot grid point and the coordinates of the dot grid point. The sample plots are identified by the number of the cluster combined with the number of the sample plot as indicated in Figure 1.1.

The field work proceeds in accordance with the sample plot numbering from sample plot 1 over sample plot 2 to sample plot 3. To save time, sample plot 6 follows after sample plot 3, then sample plot 5 and finally sample plot 4. The lines that connect the sample plots are named “connecting lines” further on. Along these lines, the “cluster line information” is assessed.

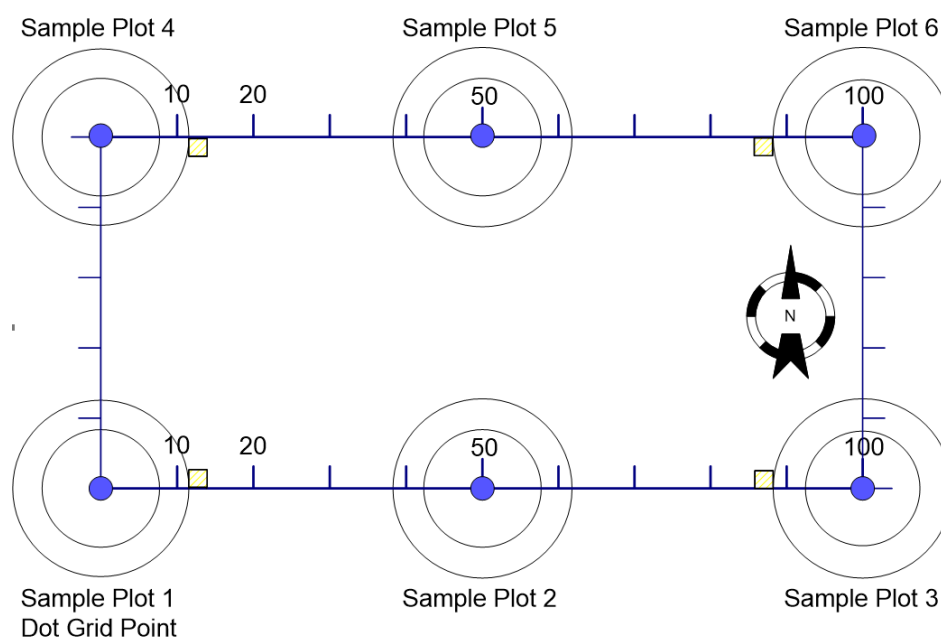
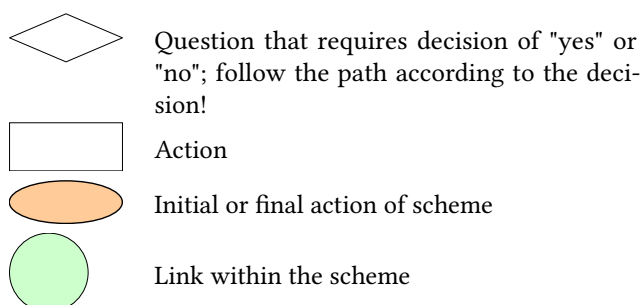


Figure 1.1.: Cluster Design in the biomass inventory.

All GPS units are to be preloaded with the coordinates of clusters and sample plots in the waypoint format to facilitate the fieldwork (see Section 2).

1.7. Description of the sample plot

The sample plot consists of two concentric circles around the sample plot centre. The external circle has an area of 500 m², corresponding to a radius of 12.62 m in level area. On this circle, all trees with a diameter at breast height (dbh) of 15 cm and more are assessed. The internal circle has an area of 200 m² and a radius of 7.98 m. Here all trees with $5 \text{ cm} \leq \text{DHP} < 15 \text{ cm}$ are assessed. The measurement procedures for both circles are described in detail in Chapters 4 and 5 of this field manual.



1.8. Procedure of fieldwork

The procedure of the fieldwork for the forest assessment within the biomass inventory is defined in the following working schemes (Figure 1.2).

Abbreviations:

DGP Dot grid point = Cluster Number

SPC Sample plot centre

FLL Forest limiting line

Used symbols and their meaning:

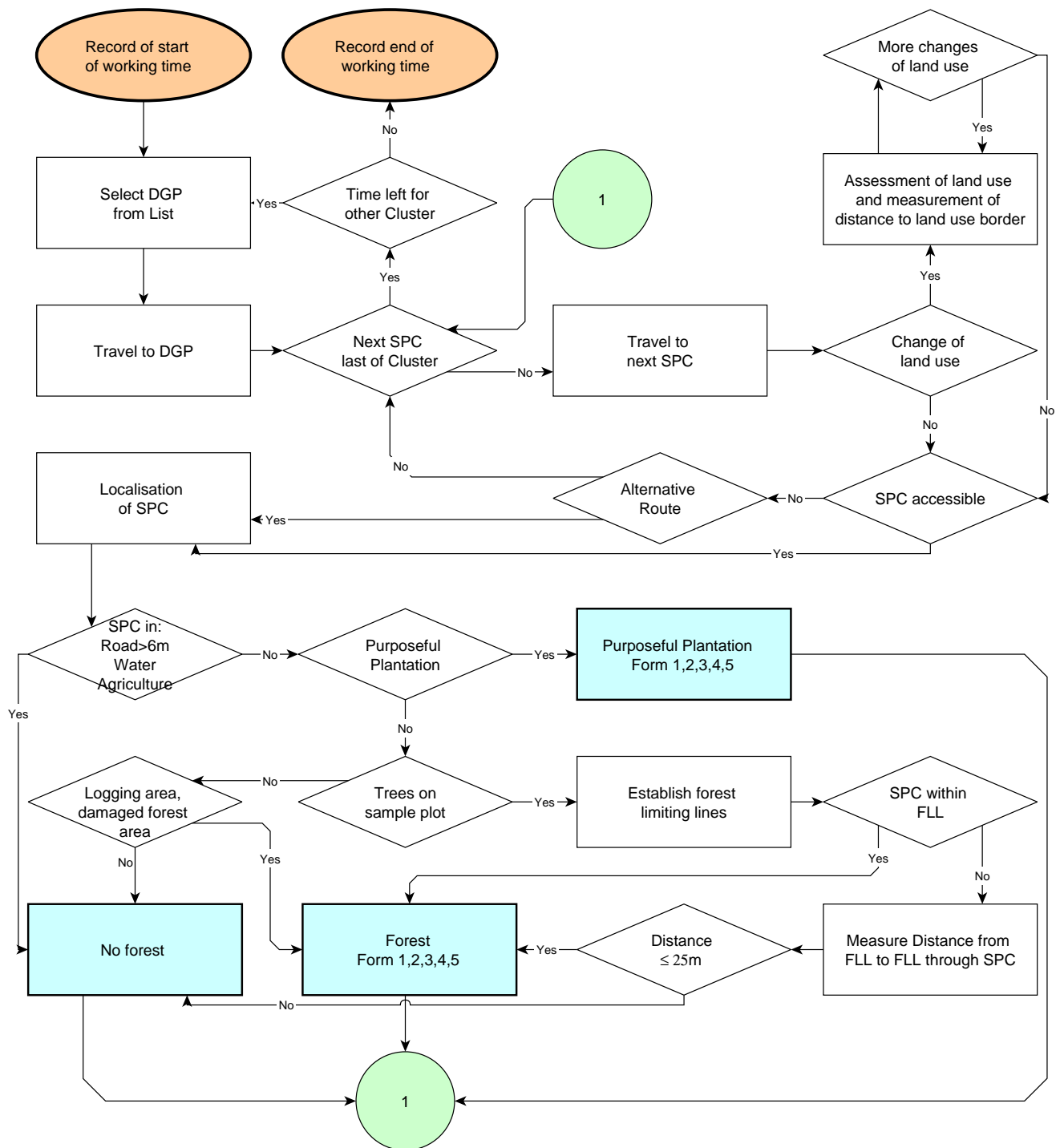


Figure 1.2.: Procedure of field work for the forest assessment and decision about the actual land use on the sample plot centre

2. Localisation of the cluster

This chapter gives the definitions of all attributes assessed within Form 1 (Appendix A).

Each day before starting the field work, the field crew leader should plan the route to the cluster based on the field maps prepared by the GIS-laboratory. Local guides who are familiar with the area should be consulted during this step, as they can often offer valuable information. In the field, clusters and sample plots are located using a preloaded GPS units prepared by the GIS-laboratory.

2.1. Cluster number

Definition: The cluster number is the executive number of each cluster and identical with the number of the dot grid point (crossing of the dot grid lines).

Specification: The number goes from 1 to the total number of dot grid points of the biomass inventory, according to the dot grid list provided by the GIS-lab.

Remark: All dot grid points within the study area are included in the numbering and not only the “fieldwork-points”.

2.2. Dot Grid Point Coordinates

Definition: The coordinates of the dot grid point (centre of sample plot 1 of the cluster) are defined by the coordinate system lines used for the biomass inventory.

Specification: The x-coordinate (first number) and y-coordinate (second number) are available in the preloaded GPS units.

2.3. Date

Definition: The date on which the field work is conducted has to be noted.

Specification: The date is given as:

- day (2 figures, e.g. 01 = first day of the month)
- month (2 figures, e.g. 01 = January)
- year (4 figures)

2.4. Working time

Definition: The working time is the total time consumption for the field work on one cluster, measured from the start of the field work (departure from the field camp) until the end of the field work (arrival at the field camp).

Specification: The exact time is to be given in hours (24-hours-system: 08 = 8 am) and minutes.

2.5. Team number

Definition: The team number is the number code of each field crew.

Specification: The number is given according to the field crew list.

2.6. Team members

Definition: The names of the field crew members who conduct the fieldwork on the specific point and are responsible for the completeness and accuracy of the measurements are given.

Specification:

1. The name of the chief of the field crew is given. The chief has the responsibility for the correct execution of the field work in accordance with the procedures and attribute definitions as given in this Field Manual. He fills in the forms and controls them for completeness.
2. and 3. The name of the auxiliary staff of the field crew is given. The auxiliary staff is responsible for correct measurements.

Remark: No field crew member conducts fieldwork on his own for security reasons. The team organises its fieldwork on its own within the general planning and according to the instructions.

2.7. Magnetic misleading

Definition: The magnetic misleading is the angle between magnetic north and the north of the map given by the coordinate system of the map.

Specification: The magnetic misleading is given as described on the map in minutes and seconds. Eastern misleading is indicated by ‘–’, western misleading is indicated by ‘+’.

Remark: The magnetic misleading is subject to variation. If the annual change is given in the map, it has to be taken into consideration. In compasses or bussols without built-in correction facility the magnetic misleading is subtracted in the case of eastern misleading and added in the case of western misleading.

2.8. Cluster layout

Definition: The cluster layout shows the geographic localisation of the cluster elements (sample plots and connecting lines). See Figure 1.1.

Specification: All borders of land use (natural forest, forest culture, no forest area) are marked along the connecting lines of the sample plots. Additionally, roads and watercourses are to be drawn into the sketch when they are crossed by the connecting lines.

2.9. Cluster line information (land use)

Definition: Information assessed along the connecting lines of the cluster regarding the land use or the change of land use.

Specification: All crossing points of the connecting lines with land use borders are measured during the localisation of all sample plots. Land use is divided into forest (natural forest including open forest, planted forest, shrub forest) and no forest according to the land use definitions in Chapter 3.4.

start Number of the sample plot that was assessed last.

aim Number of the sample plot that will be assessed next.

distance from Position on the connecting line, where the measurement starts (centre of the last sample plot or crossing of land use border), given in metres and decimetres.

to Position on the connecting line, where the measurement ends (crossing of next land use border or sample plot centre), given in metres and decimetres.

1 forest Land use is natural forest.

2 purposeful plantation Planted, artificial forest, forest cultures.

3 agriculture Land use is for the purpose of agriculture.

other Other land use than defined above; description of land use.

2.10. Cluster line information (human impact)

Definition: Information assessed along the connecting lines of the cluster regarding the visibility and amount of human impact on the forest.

Specification: The type of human impact, the amount of human impact in percent of the remaining stand, the form of human impact is noted and the concerned species is defined.

- Type:
 1. Degradation for fuelwood/charcoal
 2. Degradation for construction wood or precious woods
 3. Degradation for agriculture
- Amount:
 1. barely degraded (<33%)
 2. notably degraded (>33% and <66%)
 3. severely degraded (>66%)

4. not degraded
- Form:
 1. by hand
 2. with an axe or handsaw
 3. with a chainsaw or other professional device
 4. fire
 - Species: The name of the species is given.

3. General sample plot information

In this chapter, the definitions of all attributes assessed in Form 2 (Appendix B) are given in order to characterise the general and geographic situation of the sample plot.

3.1. Sample plot number

Definition: The sample plot number is the number of the sample plot of one cluster.

Specification: The sample plots of a cluster are numbered from 1 to 6 according the cluster layout (Figure 1.1), starting with 1 at the point that is identical with the dot grid point. Sample plot 2 lies 50 m east (azimuth = 90°) of sample plot 1 and sample plot 3 lies 100 m east (azimuth = 0°) of sample plot 1. Sample plot 4 lies 50 m north of sample plot 1 and sample plots 5 and 6 are located 50 and 100 m east to sample plot 4, respectively.

3.2. Altitude over sea level

Definition: The altitude of a sample plot point is its height (z-) coordinate.

Specification: The altitude is referred to sea level and taken from the GPS unit.

3.3. Accessibility

Definition: Accessibility of a sample plot is given when it can be reached without danger of life.

Specification:

1. yes (the sample plot is accessible)
2. no (the sample plot is not accessible); The reason why the sample plot is not accessible is given.

Remark: Several routes to approach the sample plot have to be tried. Seek help and advice of local workers when the situation is not clear.

3.4. Land use

Definition: The actual land use is stated at the sample plot centre. The determination of the land use defines the amount and kind of further measurements and assessments to be carried out in the field. The definition of forest follows the definition given by the FAO (Appendix G, FAO 2005).

Specification:

0 Other: Every land use that is not specified in the following descriptions. No measurements are performed. A remark to specify the type of land use is taken.

1 Forest in strict sense is defined as vegetation consisting of forest species with the objective of timber production and various protection and other functions. The horizontal forest area has a minimum crown cover density of 20%, a minimum width of 25 m and a minimum height of 5 m. In case of forest cultures, no minimum height has to be considered.

A point is forest when it lies within forest area. The limit of the forest area is determined by the forest limiting line. This line connects those outermost trees of minimum height, whose horizontal distance from each other is less or equal to 25 m. Gaps or unstocked areas within the forest have a distance of less than 25 metres between the forest limiting lines that describe the gap (see Figure 3.1¹). If the sample plot centre lies within stocked forest area, this area has to have the minimum horizontal width of 25 m, measured from limiting line to limiting line through the sample plot centre (see Figure 3.2).

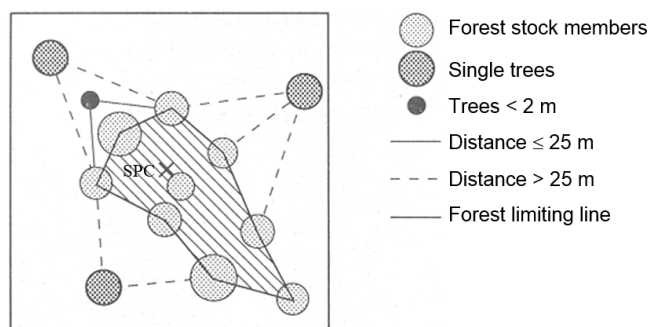


Figure 3.1.: Forest limiting line with sample plot centre (SPC).

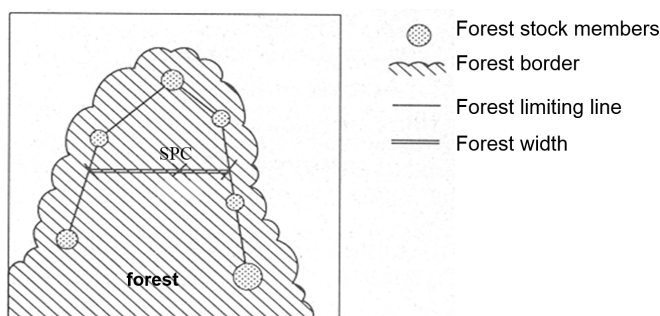


Figure 3.2.: Forest limiting line. The sample plot centre (SPC) is located in stocked forest area.

If the sample plot centre is outside stocked forest area, the maximum length of the horizontal distance from forest limiting line to forest limiting line measured through the centre is equal or less 25 m (see Figure 3.3).

2 Forest: Open Forest is defined as vegetation existing of forest species in accordance with the definition of Forest but lower density from 10% to less than 20%.

¹ All figures, except 1.1, 5.4, 5.5 and 6.1, are adopted from Stierlin et al. (1994).

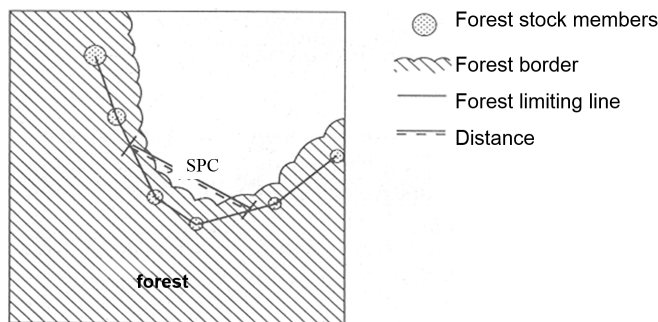


Figure 3.3.: Forest limiting line. The sample plot centre (SPC) is located outside stocked forest area.

3 Forest: Purposeful Plantations are gardens and industrial plantations as defined in Chapter 4.5.

4 Forest: Shrubs are divided in 'crawling shrubs' and 'other shrubs' (see Section 4.4). They have a minimum density (covered area) of 67% and a minimum height of 0.5 m. Measurements:

- Shrub density is measured estimated in the field.
- The sample plot centre is marked as on forest points.
- Due to the definition of shrubs, Section 4.8 is dense (4).
- In Section 4.9, the 3 prevailing shrub species are given. Additionally, all forest trees and the regeneration of forest species are assessed on the circular plot as described in Chapters 5 et 6.

5 Agriculture (no forest): Measurements are conducted if single trees or groups of trees are present on the sample plot. The reason has to be given why the point is neither forest nor shrubs or purposeful plantation.

3.5. Borders

Definitions:

- Forest edge: Border area of the forest to any other landscape element.
- Border of forest stock: The border of forest stock is given by the forest stock borderline which is connecting the outside of stems of those outermost trees that have a minimum diameter at breast height of 5 cm and build the forest edge (exceptions are afforestations, young forest, temporarily unstocked areas after storm damages or cuttings, shrubs). Gaps of less than 10 m are not taken into consideration. If the forest stock borderline is not one single straight line, but has an edge, then this point is called edge point of the line. If the forest stock borderline is one straight line crossing the sample plot, then any point on the forest stock borderline can be taken as edge point (see Figure 3.4).
- Border of accessibility: The border of accessibility is the borderline to that part of the sample plot area that is not accessible.

Specification:

1. border of forest stock

2. border of accessibility
3. no border

3.6. Border measurement

Definition: Measurement of edge point and border direction.

Specification: In case of a border (border type 1 or 2) there has to be measured:

- the distance between the sample plot centre and the edge point of the forest border line.
- the azimuth from the edge point to the sample plot centre
- the azimuth in both directions of the border line from the edge point

Remark: Exact localisation is essential for the area correction of results of those sample plots that are localised at a forest edge and have therefore not the whole area stocked with forest trees.

3.7. Sample plot centre marking (securing points)

Definition: The sample plot centre is permanently marked in order to find the sample plot in the following inventories (CFI – Continuous Forest Inventory).

Specification: The sample plot centre is marked with a permanent plot marker.

3.8. Situation sketch

Definition: The situation sketch is a hand drawn map that shows the sample plot situation with all characteristics of the sample plot and its surrounding to facilitate later relocation of the plot.

Specification: The situation sketch shows:

- sample plot centre
- characteristic items (rocks, single trees, ...)
- lines as rivers, streams, creeks, roads, paths etc.
- forest edge, forest stock border line, borders of accessibility, stand borders
- any other helpful information

3.9. Pictures of the sample plot

Definition: Pictures from the point of view of the centre of the sample plot greatly facilitate the locating of the sample plot in subsequent inventories.

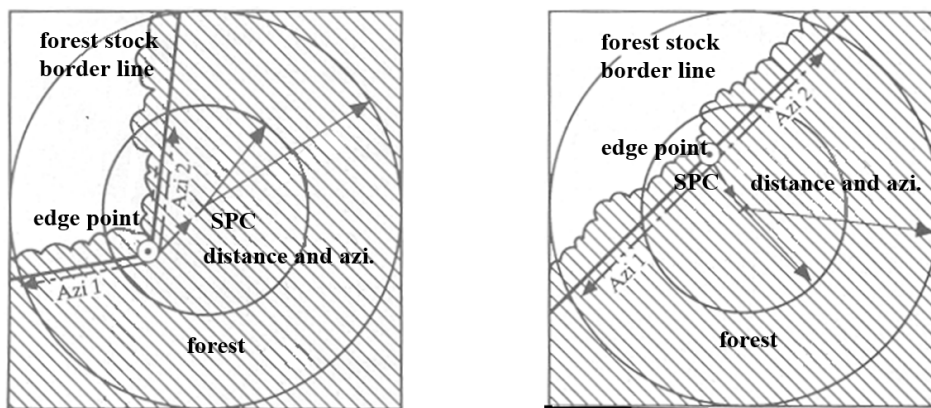


Figure 3.4.: Forest borderlines in two examples (SPC = Sample plot centre; azi = azimuth).

Specification: Overlapping pictures from the centre of the sample points in all directions are to be taken. The first picture is taken with an azimuth of 0°. Then, pictures are taken in a clock-wise direction, with each picture slightly overlapping the previous picture, until a full circle is covered. Depending on the lens type, this will result in 5–8 pictures for each sample plot.

3.10. Ownership status

Definition: The ownership information is to be obtained from the district administration about the land on which the inventory area is located.

Remark: The service of the district administration may be charged. A letter of information and petition should be sent in advance.

3.11. Slope incline

Definition: The slope incline is the inclination of the slope within the sample plot area measured in percent (%). This information is important for the correction of the plot area to a horizontal area.

Specification:

- The measurements are conducted with a clinometer.
- The first measurement is conducted from the sample plot centre 15 m upward the slope to the highest point. The vision line has to be parallel to the ground. Increase is indicated by '+'. (see Figure 3.5).
- The second measurement is conducted from the sample plot centre 15 m downwards the slope to the lowest point. The vision line has to be parallel to the ground. Decrease is indicated by '-'.
- The arithmetic average of the absolute numbers of the two measurements is calculated. With this average the correction of the plot circle radius is done (see Table 5.1). The average value is rounded to full percent. Values from 0.5 are rounded up to the next full percentage.

3.12. Slope exposure

Definition: The slope exposure is the direction of the line of greatest slope decrease measured in degree.

Specification: The slope exposure is measured with a SILVA compass. It is 999 if the average slope incline (see Section 3.11) is below 5%.

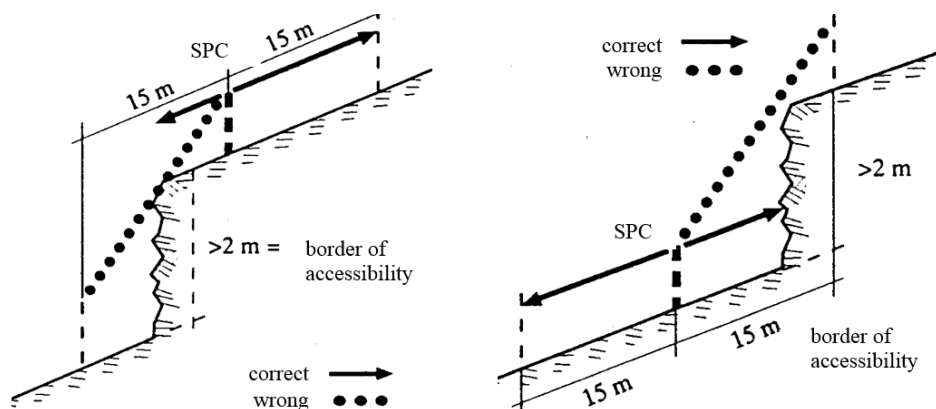


Figure 3.5.: Measurement description of the slope incline in case of a border of accessibility.

3.13. Terrain relief

Definition: The terrain relief is determined on the whole area around the sample plot.

Specification:

1. mountainous
2. level/flat

3.14. Sample plot micro relief

Definition: The sample plot micro relief is the relief of the 500 m² circle.

Specification:

1. flat (500 m² circle with a maximum inclination less or equal to 10%)
2. upper part of slope
3. middle part of slope
4. lower part of slope

3.15. Traces of erosion

Definition: Traces of erosion are visible signs of the process of erosion on the sample plot mainly caused by water.

Specification:

1. yes (visible signs of erosion exist)
2. no (erosion cannot be observed)

4. Stand information

The chapter gives the definitions of all attributes assessed within Form 3 (Appendix C) in order to describe the stand situation.

4.1. Growth location

Definition: The growth location is the general location of a stand. The information gives hints about the growth conditions.

Specification:

1. mountain (sample plot centre is located in mountainous area)
2. valley/lowland (sample plot centre is located in a valley or lowland)
3. stream-side (sample plot centre is located within an area of seasonally or occasionally floods along rivers, streams and creeks, marked by the erosion step caused by water floods).

4.2. Origin

Definition: The origin indicates the nature of the prevailing species in the stand of the sample plot.

Specification:

1. natural (developed from natural regeneration of forest tree species)
2. artificial (developed from plantation; purposeful plantations — see definition at Section 4.5)
3. mixed (mixture of natural and artificial origin)

4.3. Forest type

Definition: The forest type is specified.

Specification:

1. shrubland
2. dry spiny forest thicket
3. open spiny forest
4. dense spiny forest

The information is to be obtained on the sample plot.

4.4. Kind of shrubs

Definition: The kind of shrubs is specified.

Specification:

1. crawling (crawling shrubs with low height <0.5 m)
2. other (higher shrubs, mostly mixed of various species)

4.5. Purposeful plantation

Definition: A purposeful plantation is an artificial (man-made) plantation of forest, none-forest or fruit tree species that have an objective different from forest.

Specification:

1. Garden: Only plantations of fruit trees or shrubs are subject to the biomass inventory. Private gardens around houses are not assessed. The stock borderline of a garden is considered as the line that connects the outermost fruit trees (outside of stem) or shrubs (centre of shrub).
2. Forest Park: consists of forest tree species.
Measurements: The same measurements as on forest points are conducted.
3. Industrial plantation: Industrial plantations are plantations of forest species (*Pinus spec.*, *Eucalyptus spec.*, *Acacia spec.*, etc.) for industrial purposes.
Measurements: Industrial Plantations are assessed like forest points.

4.6. Crown cover density

Definition: The density of a stand is its crown cover area, given in percent (%) of the sample plot area measured with a dot grid of 25 points in the aerial photo. Alternatively — when no suitable aerial photos are available — it is estimated in the field.

Specification: The measured crown cover density is given. In case of estimation of the crown cover density in the field, a visual estimation of crown cover percentage is performed by the field crew leader.

4.7. Structure

Definition: The structure is the vertical layering of a forest stand on the sample plot (see Figure 4.1).

Specification:

1. simple (only one layer of trees)
2. two layers (the second layer is of young forest trees)
3. three layers (the third layer is of young forest trees, the second layer contains older regeneration growth)
4. complex (more than two layers of trees)

4.8. Underwood

Definition: The underwood density is estimated as percent (%) of the crown cover area of underwood species on the sample plot.

Specification:

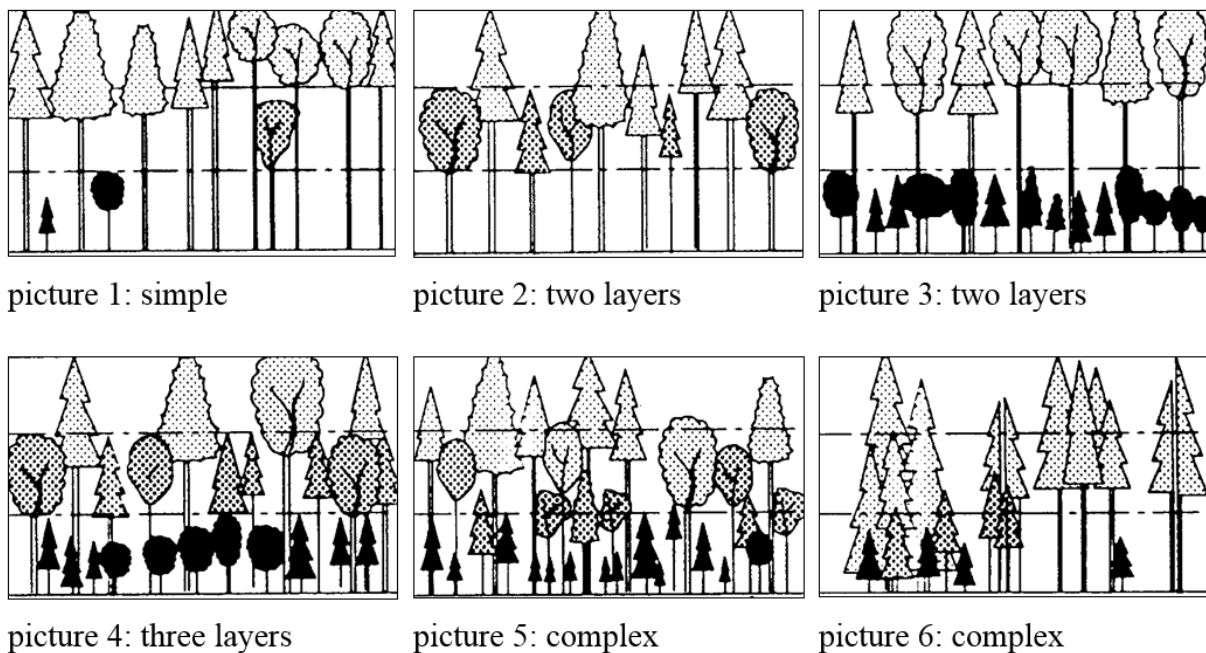


Figure 4.1.: Examples for the structure definitions one layer (picture 1), two layers (picture 2 and 3), three layers (picture 4) and complex (pictures 5 and 6).

1. absent
2. thin (up to 33% of the area is covered by underwood species)
3. medium (34 to 66% of the area is covered by underwood species)
4. thick (67% and more of the area is covered by underwood species)

Remark: By definition (see Section 3.4) the density of shrubs is thick (4).

- The degree of decomposition is tested with a machete. Only those trees or stems included in the first decomposition class (freshly dead) following the classification of Albrecht (1990) are considered in this inventory.
- Fallen trees: Diameter measurements are taken on the lower end and the upper end of the fallen stem. The length of the stem is measured with a measuring tape.
- Standing deadwood: A diameter measurement is conducted at breast height and the height is measured with the VERTEX tool.
- The existence of serious forest pests or diseases is assessed (1 = yes; 2 = no).

4.9. Prevailing underwood species

Definition: The prevailing underwood species are the most frequent underwood species on the sample plot.

Specification: The species names of the three prevailing underwood species are given.

Remark: In case of shrubs, the names of the three prevailing shrub species are given.

4.10. Sanitary status

Definition: The sanitary status of a stand is assessed.

Specification:

- By definition only those fallen trees or standing deadwood is taken into consideration that can still be used for fuelwood or charcoal purposes and that exceeds a minimum DBH of 5 cm. This excludes those trees or stems that are already covered by moss or other epiphytes. Excluded are those fallen trees that exceed the sample plot with more than half of their length.

4.11. Grazing

Definition: Grazing in this inventory is any damage caused to plants by animals.

Specification: Signs of grazing on the sample plot like paths, traces, excrements, damaged trees, grazed grass, etc. are assessed.

1. yes (there are signs of grazing)
2. no (there are no visible signs of grazing on the area of the sample plot)

4.12. Grass cover

Definition: Grass cover is the cover of the sample plot with grass species in percent.

Specification: The coverage of the sample plot with grass species is estimated in percent (%) of the area.

5. Tree information

This chapter gives the definitions of all attributes assessed in Form 4 (Appendix D) in order to get information on the trees and other woody plants of a minimum diameter of 5 cm on the sample plot.

5.1. Page number

Definition: The page number is the number of the actual sheet of Form 4 (Appendix D). The information is given for control and self-control purposes.

Specification:

- current sheet number of Form 4
- total number of sheets of Form 4

5.2. Sample plot radius

Definition: The sample plot consists of two concentric circles (Figure 5.1). The external circle has a horizontal radius of 12.62 m corresponding to an area of 500 m². On this circle, all trees with dbh \geq 15 cm are assessed. The internal circle has a horizontal radius of 7.98 m corresponding to an area of 200 m². Here, all trees with 5 cm \leq DHP $<$ 15 cm are assessed. In case of a slope inclination of more than 10%, the radius has to be corrected according to Table 5.1.

5.3. Tree number

Definition: The tree number is the executive number for each tree on the sample plot.

Specification: The number goes from 1 to the total number of measured trees on the sample plot.

5.4. Azimuth

Definition: The azimuth is the angle measured from the sample plot centre to a tree referred to magnetic north.

Specification:

- The measurement of the azimuth is done with a compass to the left stem side at breast height in degrees.
- Where a correct measurement of the azimuth is not possible, e.g. because the sight to the tree is hindered, the azimuth is estimated.

Table 5.1.: Determination of the correct circle radius.

Inclination (%)	500 m ² radius (m)	200 m ² radius (m)
0-10	12.62	7.98
15	12.69	8.02
20	12.74	8.06
25	12.81	8.10
30	12.89	8.15
35	12.99	8.21
40	13.09	8.28
45	13.21	8.36
50	13.34	8.44
55	13.48	8.52
60	13.62	8.62
65	13.78	8.71
70	13.94	8.82
75	14.10	8.92
80	14.28	9.03
85	14.45	9.14
90	14.63	9.25
95	14.82	9.37
100	15.00	9.49
105	15.19	9.61
110	15.38	9.73
115	15.57	9.85
120	15.77	9.97
125	15.96	10.09
130	16.16	10.22
135	16.35	10.34
140	16.55	10.47
145	16.74	10.59
150	16.94	10.71

5.5. Distance

Definition: The distance of a tree from the plot centre is given.

Specification: The distance is measured at breast height at the left stem side in centimetre to the midst of the tree stem (callipers!) with a VERTEX (see Figure 5.2).

Remark: The distances of trees at the border of the Sample plot have to be measured carefully to see whether they are in the plot or outside. If the centre of the tree stem is exactly at the limit of the circle, the tree is measured and it is noted as a remark that it is a border tree. It will be counted only half in the calculations of the results.

5.6. Species

Definition: The name of the tree species or shrub species is given.

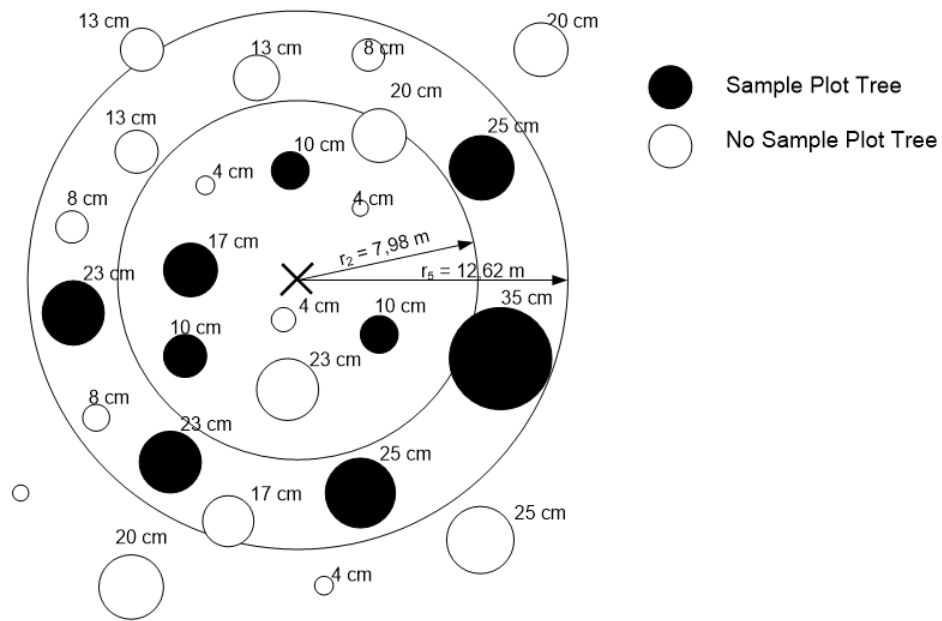


Figure 5.1.: Sample plot of the biomass inventory with concentric circles.

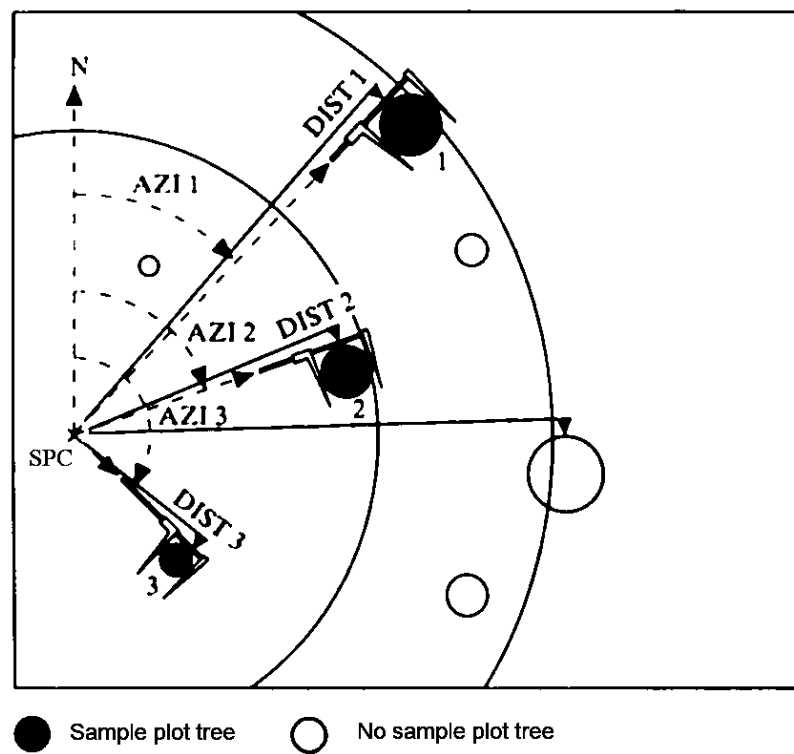


Figure 5.2.: Measurement of the distance between the sample plot centre (SPC) and a tree.

5.7. Tree diameter

Definition: The tree diameter is the diameter of a tree stem measured at breast height ((1.3 m, see Figure 5.3).

Specification:

- The diameter is measured with a diameter tape. For trees which cannot be measured with a diameter tape, e.g. because the presence of thorns, a calliper is used.
- When a calliper is used, it is held perpendicular to the stem axis with the axis of the calliper pointing towards the sample plot centre.
- The minimum diameter of a sample plot tree for the external circle is 15 cm, the minimum diameter for the internal circle is 5 cm.

Special cases:

- Branch or knot at 1.3 m: One diameter measurement is done above and one below the disturbance, calculating the diameter as average of the two measurements.
- Forked tree/twin stem above 1.3 m: It is considered as one single tree.
- Forked tree/twin stem below 1.3 m: It is considered as two trees. Each stem is measured separately, using the same tree number for each fork.
- Bifurcation at 1.3 m: In this case the measurement is taken below the bifurcation.
- Measurement impossible: The diameter at breast height gets the value '0' and the reason is given as remark in Section 5.17.

5.8. Tree height

Definition: The total tree height is given as the distance between the stem foot and the highest point of the tree.

Specification:

- The tree height is measured for the first 5 trees (starting at 0°).
- The measurement is executed with a VERTEX or CRITERION height measurement device to full decimetres at a minimum distance of 1 tree height.
- On slopes, the measurement is done from the hillside of the tree.
- The heights of trees with inclined stem axis are measured and a remark is given in the field form.
- If a measurement is impossible, the tree height gets the value '0' and the reason is given as remark in Section 5.17.

5.9. Crown length

Definition: The crown length is given as the distance between the first green branch and the highest point of the tree.

Specification:

- The crown length is measured for the first 5 trees (starting at 0°).
- The measurement is executed with a VERTEX height measurement device to full decimetres at a minimum distance of 1 tree height.
- On slopes, the measurement is done from the hillside of the tree.

If a measurement is impossible, the tree height gets the value '0' and the reason is given as remark in Section 5.17.

5.10. Crown shape

Definition: The crown shape is the formation of the outer limits of the crown.

Specification:

- The crown shape is assessed for every tree on the plot.
 - The shape of the crown is assumed to the idealized forms given in Figure 5.4.
1. rectangular; the length is a multiple of the width
 2. umbrella; resembles an umbrella or an upside down conical form
 3. round; the shape resembles a circle/balloon
 4. conical; the volume of the crown constantly diminishes towards the top
 5. not accessible

5.11. Crown consistency

Definition: The crown consistency assigns the shape of a crown a code describing the symmetry of the crown (Figure 5.5).

Specification:

1. round, symmetric
2. slightly one-sided
3. one-sided, asymmetric
4. not accessible

5.12. Crown diameter

Definition: The crown diameter is the average cross sectional area covered by the canopy of a single tree.

Specification:

- The crown diameter is measured at the first 5 trees (starting at 0°).
- The diameter is measured with two measurements, the first in north-south, the second in the east-west direction.
- The measurement includes only the main part of the crown, not single outreaching branches. The diameter is given to the nearest decimetre.

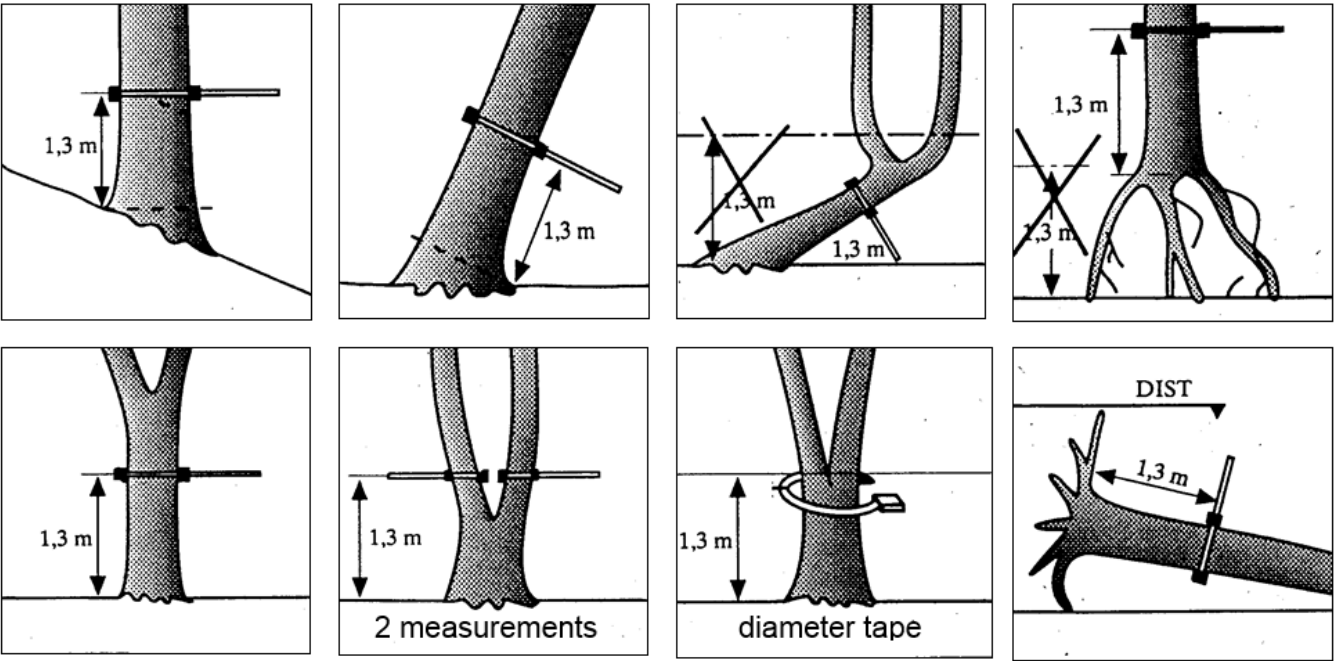


Figure 5.3.: Examples of diameter measurements.

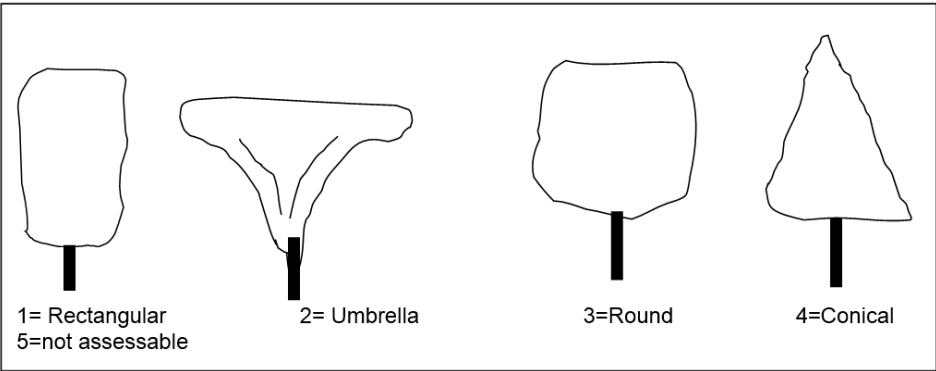


Figure 5.4.: Crown shapes

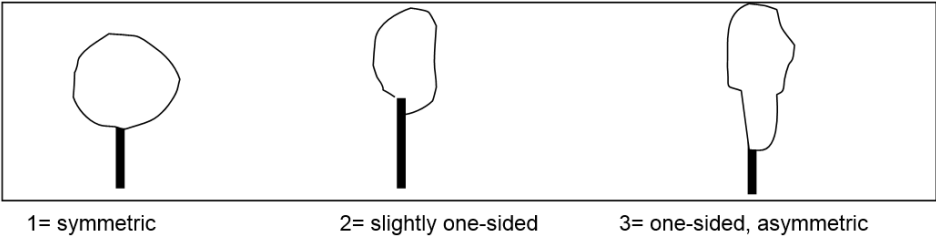


Figure 5.5.: Crown consistency

5.13. Layer

Definition: The stand is vertically divided into 3 layers of equal height. The considered tree is part of that layer in which the top part of its crown is located (see Figure 5.6).

Specification:

1. upper (tree height more than $\frac{2}{3}$ of the stand height)
2. middle (tree height between $\frac{1}{3}$ and $\frac{2}{3}$ of the stand height)
3. under (tree height less than $\frac{1}{3}$ of the stand height)

5.14. Tree class

Definition: The tree class is specified according to the definition of KRAFT in the classes 1 (highest dominating trees) to 5 (small trees under the pressure of the other trees) as shown in Figure 5.7.

Specification:

1. predominant; emerging the upper canopy layer.
2. dominant; part of the upper canopy layer.
3. co-dominant; reaching into the upper canopy layer.
4. dominated; part of the middle/under layer, not reaching the stand height.
5. suppressed; part of the under layer, not reaching into the middle/upper layer.

5.15. Damage

Definition: The damage of a tree is described by its location and cause.

Specification:

- Damage Location:
 1. root
 2. stem
 3. branches
 4. leaves
- Cause of Damage:
 1. natural (fire, flood, storm, etc.)
 2. Human
 3. Animal
 4. diseases and pests

5.16. Utilization of species

Definition: The utilization, which is assessed on the species level, gives information about the uses of a tree species. For each new tree species encountered during the inventory, local guides are consulted about uses of that species.

Specification:

1. construction wood
2. firewood

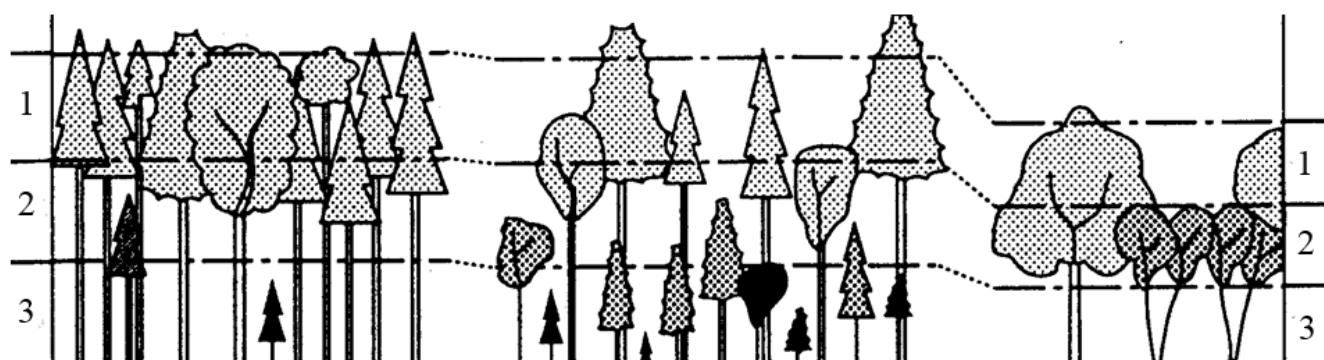


Figure 5.6.: Upper (1), middle (2) and under layer (3) in a forest stand.

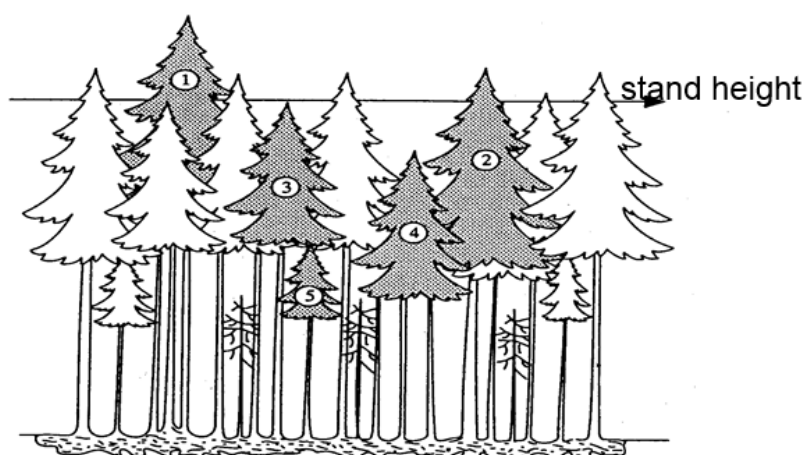


Figure 5.7.: Example of the five tree classes according to KRAFT.

3. medicinal (bark, leaves or wood can be used for medicinal purposes)
4. cultural (used during rituals)

5.17. Remarks

Definition: In the field 'Remarks', all observations of importance are given, especially referring to problems with measurements that could have caused errors, values that are given by estimation, or special cases that are thought to be not within the definitions.

6. Young forest / underwood information

This chapter gives the definitions of all attributes assessed within Form 5 (Appendix E) in order to get information about the young forest trees with a minimum height of 0.1 m up to a maximum diameter of 5 cm. Additionally, all other woody plants are assessed. The assessment of the data is carried out on four 3×3 m squares.

6.1. Localisation of the 3×3 m squares

The information about the undergrowth and young forest are gathered at four 3×3 m squares which are located directly outside of sample plot 1, 3, 4 and 6 on the connection line between two sample plots. All 3×3 m squares are situated inside the imaginary rectangle of the connection lines of the cluster. Each single square is demarked with a coloured tape on the ground while assessed. The squares are attached to the eastern borders of sample plot 1 and 4 and to the western borders of sample plot 3 and 6 (see Figure 6.1).

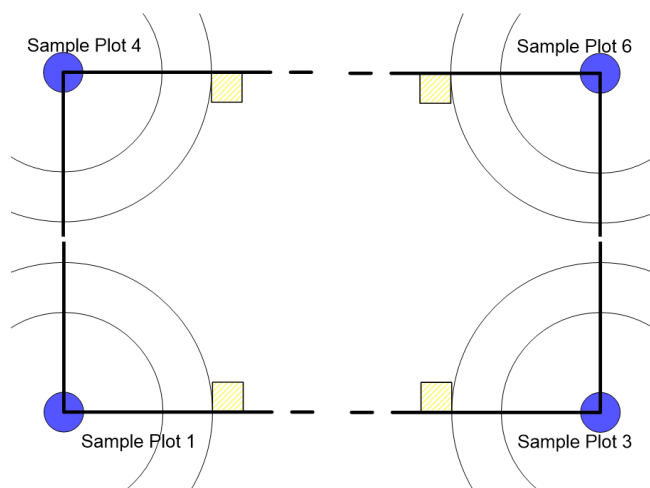


Figure 6.1.: Localisation of the 3×3 m squares.

6.2. Underwood density

Definition: The underwood density is estimated as percent (%) of the crown cover area of underwood species on the 3×3 m square.

Specification:

1. absent
2. thin (up to 33% of the area is covered by underwood species)
3. medium (34 to 66% of the area is covered by underwood species)
4. thick (67% and more of the area is covered by underwood species)

Remark: By definition (see Section 3.4) the density of shrubs is thick (4).

6.3. Prevailing underwood species

Definition: The prevailing underwood species are the most frequent underwood species on the 3×3 m square.

Specification: The names of the 3 prevailing underwood species are given.

Remark: In case of shrubs, the names of the three prevailing shrub species are given.

6.4. Nature of the young forest

Definition: The origin of the young forest trees is given.

Specification:

1. natural regeneration
2. artificial forest
3. natural and culture (there is natural generation together with an artificial forest)

6.5. Young forest class

Definition: The young forest trees are divided into 5 classes depending on height and diameter. The young forest plants are assessed according to their nature (seed or vegetative) and reliability (strong or weak). In class 5, all woody species (not only forest species but also shrub species) are assessed to get information on the biodiversity.

Specification:

1. 0.10 to 0.49 m
 2. 0.50 to 0.99 m
 3. 1.00 to 1.49 m
 4. 1.50 m to 4.9 cm dbh (including all woody species!)
- seed: the plant originates from seed
 - veget.: the plant is of vegetative origin
 - s: strong plant
 - w: weak plant

Appendix A.

Example of field form 1








Field Form 1: Localisation of the Cluster					
Cluster Nr.:		Date:		Time:	
Team Members:				Team Number:	
Map Nr.:					
Magnetic Misleading:		gon			
Dot Grid Point Coordinates:	X:			Y:	
Altitude of Dot Grid Point:		m			
Fix Point Number:					
Fix Point Coordinates:	X:			Y:	
Fix Point Altitude:		m			
Description of Fix Point:					
Description of route FP to SPC:	Azimuth	Distance	New Fix Point		
Change of direction	gon	m			
Change of direction	gon	m			
Change of direction	gon	m			
Change of direction	gon	m			
				Human Impact	
Cluster Line Information:	Description	Distance	Land Use	Type/Amount	Form/Species
Start:	SPC-Nr:	0 m			
Aim:	SPC-Nr:	m			
Distance from:	SPC-Nr:	0 m			
Distance to:		m			
Distance from:		m			
Distance to:		m			
Distance from:		m			
Distance to:		m			
Distance from:		m			
Distance to:		m			
Distance from:		m			
Distance to:	SPC-Nr:	m			
Remarks:					

m = Meter, SPC = Sample Plot Center

Field Form 1 corresponds to Chapter 1 of the Field Manual. Required information is described there in detail

Appendix B.

Example of field form 2

Field Form 2: General Sample Plot Information									
Sample Plot Number: <input type="text"/> Accessibility: <input type="text"/> SP Altitude: <input type="text"/> m									
Land Use: <input type="text"/> <i>1=forest; 2=open forest; 3=plantation; 4=shrub; 5=other</i>									
Borders: <input type="text"/> <i>0=no border; 1=forest border; 2=access border</i>									
Border Measurement:		Dist / Azi 1	Dist / Azi 2	Dist / Azi 3					
		m/ g	m/ g	m/ g					
SP Centre Coordinates:		X: <input type="text"/>		Y: <input type="text"/>					
SPC Variation:		Distance		Azimuth					
		m		gon					
Securing Points:		Distance	Azimuth		Description				
Securing Point 1:		<input type="text"/>	<input type="text"/>		<input type="text"/>				
Securing Point 2:		<input type="text"/>	<input type="text"/>		<input type="text"/>				
Securing Point 3:		<input type="text"/>	<input type="text"/>		<input type="text"/>				
Securing Point 4:		<input type="text"/>	<input type="text"/>		<input type="text"/>				
Ownership Status:		<input type="text"/>							
Slope incline:		<input type="text"/> %		Exposure	<input type="text"/> gon	<i>999 if incline < 5%,</i>			
Sample Plot Micro Relief		<input type="text"/> <i>1=mountainous; 2=level/flat</i>							
Terrain Relief		<input type="text"/> <i>1=flat; 2=upper part; 3=middle part; 4=lower part</i>							
Traces of Erosion		<input type="text"/> <i>1=yes; 2=no</i>							
Situation Sketch:		<i>includes: SPC; Securing Points; rocks; rivers; roads; borders; etc...</i>							
Legend:									
 Sample Plot Centre  River, Creek  Securing Points  Border  Single Tree  Rock  Road, Pathway									
Other Symbols:									

Field Form 2 corresponds to Chapter 2 of the Field Manual. Required information is described there in detail

Appendix C.

Example of field form 3

Field Form 3: Stand Information																																																												
Growth Location:			1=mountain; 2=valley/lowland; 3=stream-side																																																									
Origin:			1=natural; 2=artificial; 3=mixed																																																									
Forest Name:			1=conifer; 2=conifer dominated; 3=broadleaf dominated; 4=broadleaf																																																									
Kind of Shrubs:			1=crawling; 2=other																																																									
Purposeful Plantation:			1=Garden; 2=Park; 3=Forest Park; 4=Industrial Plantation																																																									
Crown Cover Density:			%																																																									
Structure:			1=simple; 2=two layers; 3=complex																																																									
Prevailing Forest Species:			Age:																																																									
Underwood Density:			1=absent; 2=thin; 3=middle; 4=thick																																																									
Prevailing Underwood Species:																																																												
Sanitary Status:	<table border="1"> <thead> <tr> <th colspan="2">Fallen Trees</th> <th colspan="2">Standing Deadwood</th> <th>Pests</th> </tr> <tr> <th>d_lower / d_upper</th> <th>length</th> <th>DBH</th> <th>height</th> <th></th> </tr> </thead> <tbody> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td>1=yes; 2=no</td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> <tr><td>/</td><td>m</td><td>cm</td><td>m</td><td></td></tr> </tbody> </table>		Fallen Trees		Standing Deadwood		Pests	d_lower / d_upper	length	DBH	height		/	m	cm	m	1=yes; 2=no	/	m	cm	m		/	m	cm	m		/	m	cm	m		/	m	cm	m		/	m	cm	m		/	m	cm	m		/	m	cm	m		/	m	cm	m				
Fallen Trees		Standing Deadwood		Pests																																																								
d_lower / d_upper	length	DBH	height																																																									
/	m	cm	m	1=yes; 2=no																																																								
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/	m	cm	m																																																									
Forces on the Stand:	wind	landslide	rockfall	fire	flood	grazing																																																						
	wild animals	anthropogen	Other:																																																									
	0=not existent; 1=weak; 2=middle; 3=strong																																																											
Resistance:	species	h/d	crown length	crown form	axis	root																																																						
	height	gaps	structure	sanitary																																																								
	1=weak; 2=middle; 3=strong																																																											
Viability:			1=weak; 2=middle; 3=strong																																																									
Grazing:			1=yes; 2=no																																																									
Grass Spread:			%																																																									
Degradation:	Type	Amount	Form	Species																																																								
	1=fuelwood; 2=construction; 3=precious	0=not; 1=rarely; 2=notable; 3=severely	1=hand; 2=tool; 3=profession al																																																									

Field Form 3 corresponds to Chapter 3 of the Field Manual. Required information is described there in detail

Appendix D.

Example of field form 4

Field Form 4: Tree Information							
Radius:		inner	outer	Page Nr.: /			
		m	m				
General Information:							
Tree Nr:	Azimuth	Distance	Species	Layer	Class	Marketability	Damage
1	gon	m					/
2	gon	m					/
3	gon	m					/
4	gon	m					/
5	gon	m					/
6	gon	m					/
7	gon	m					/
8	gon	m					/
9	gon	m					/
10	gon	m					/
11	gon	m					/
12	gon	m					/
13	gon	m					/
14	gon	m					/
15	gon	m					/
16	gon	m					/
17	gon	m					/
18	gon	m					/
19	gon	m					/
20	gon	m					/
				1=upper; 2=middle; 3=under	1=predominant; 2=dominant; 3=co-dominant; 4=dominated; 5=surpressed	1=industrial; 2=semi-industrial; 3=firewood; 4=medicinal	1=root/natural; 2=stem/human; 3=branch/animal; 4=leaves/pest
Tree Measurement:							
Tree Nr:	d1,3	d_7	Height	Crown length	Crown diameter	Crown shape	Consistency
1	cm	cm	m	m	m		
2	cm	cm	m	m	m		
3	cm	cm	m	m	m		
4	cm	cm	m	m	m		
5	cm	cm	m	m	m		
6	cm						
7	cm						
8	cm						
9	cm						
10	cm						
11	cm						
12	cm						
13	cm						
14	cm						
15	cm						
16	cm						
17	cm						
18	cm						
19	cm						
20	cm						
						1=rectangular; 2=round; 3=umbrella; 4=conical	0=n.a.; 1=symmetric; 2=one-sided; 3=asymmetric
Remarks:							

Appendix E.

Example of field form 5

Field Form 5: Young Forest / Underwood Information			
Underwood Density:		1=absent; 2=thin; 3=middle; 4=thick	
Prevailing Underwood Species:	1	2	3
Nature of Young Forest:		1=natural regeneration; 2=culture; 3=mixed	
Young Forest Class:			
Class	Amount	Origin	Viability
1 = 0,10 to 0,49 m			
2 = 0,50 to 0,99 m			
3 = 1,00 to 1,49 m			
4 = 1,50 to 4,9 cm dbh			
5 = 5,0 to 9,9 cm dbh			
		seed (artificial) veget (natural)	s = strong w = weak
Remarks:			
Field Form 5 corresponds to Chapter 5 of the Field Manual. Required information is described there in detail			

Field Form 6: Sample Core Information				
Tree Species:				
Tree Number	Distance	Azimuth	DBH	Sample Description
1				
2				
3				
Remarks:				
Field Form 6 corresponds to Chapter 6 of the Field Manual. Required information is described there in detail				

Appendix F.

Equipment list

Nr.	Equipment	Recommendation/Description	Amount/Group
Measuring Equipment			
1	Compass	Suunto KB14 Precision or likewise	2
2	GPS	Garmin GPSMap 64, Garmin GPSMap 78s	1
3	Clinometer	Suunto Clinometer	1
4	Diameter Tape	FS Steel Measuring Tape	1
5	Caliper	Mantax Aluminum 80 cm	2
6	Pentaprism Caliper	JIM-GEM Pentaprism	1
7	Measuring Tape 20m	Spencer	1
8	Flag Tape	Stripe Vinyl Flagging	1
9	Dendrometer	Vertex III or IV with auxiliary equipment	1
10	Altimeter	Thommen TX 22	1
11	Ranging-Poles		min. 3
Additional Equipment			
12	Iron/Plastic Tubes	Marking the Plot Center	Depends on Nr. of Plots
13	Clipboard		
14	Waterproof Pens		
15	Field Forms		Depends on Nr. of Plots
16	Maps		1 Mapbook/Group
17	Field Manual		1 Copy/Group
18	Waterproof Bags	For all electronic Equipment	
19	Spray Paint		
20	Batteries		
21	Camping Equipment		
22	First Aid Kit		

Appendix G.

Forest definition (FAO, 2005)

Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.

Explanatory notes

1. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum of 5 m *in situ*. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10% and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate.
2. Includes areas with bamboo and palms provided that height and canopy criteria are met.
3. Includes forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest.
4. Includes windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m.
5. Includes plantations primarily used for forestry or protection purposes, such as rubber-wood plantations and cork oak stands.
6. Excludes tree stands in agricultural production systems, for example in fruit plantations and agroforestry systems. The term also excludes trees in urban parks and gardens.

The term is mainly related to FRA 2005 Reporting Table T1.

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