

Field Manual for Permanent Sampling Plot Establishment and Re-measurement



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Introduction

Forests cover roughly about 61.6 % of Belize's national territory (Cherrington *et al.* 2012). Forests in Belize are categorized based on their parent material, they include: Limestone, Santa Rosa, Pleistocene, Toledo Beds and Volcanic forests. Each of these forests is further categorized based on elevation gradients. Birth, growth and death dynamics within these forest types are defined by biotic and abiotic influences overtime. Observation in growth rates, change in biodiversity, human impact and effect of climate change are some of the dynamics that can be measured through effective forest monitoring.

The Forest Monitoring Network of Belize (FORMNET) allows the standardized monitoring of forest in Belize. FORMNET was established as part of the Forest Planning and Management Project (FPMP) in 1992. FORMNET is composed of 30 permanent sampling plots (PSPs) scattered over Belize's protected areas. Since its establishment, only a few of the PSPs have been re-measured.

A PSP is a sampling plot that is made permanent by undertaking several protocols. Permanent monuments are utilized to demarcate the perimeter of the sample plot. Within the PSP standard measurements are made to allow comparison over time. Trees within a PSP are enumerated. The point of measurement for DBH of trees marked to allow re-measurement at same point in the future. Both biotic and abiotic aspects within a PSP are measured. Tree DBH, crown position, crown form, presence of climbers on trees, wood density of trees, tree height, vine cover, coarse and fine woody debris, slope and aspect of terrain, as well as the true location of the tree are observed within a PSP. These measurements are conducted in a standardized form highlighted in this field manual.

The objective of this field manual on PSP re-measurement is to highlight the methodology employed to work within a PSP. This manual solely concentrates on data collection on trees within a PSP. Both liana and woody debris work were excluded. In this manual we observe work on trees in three categories: measurements within the PSP, photographing of specimens from PSPs, and voucher preparation.

1.0 Measurements within the permanent sampling plot

1.1 Establishing new plots

The objective of PSPs is to monitor changes of forests over time. Therefore, new PSPs should be established in areas which take into account forest type, climatic conditions, and geographic location. Four general criteria should be considered when establishing a new PSP: the parent material and soil type must be homogeneous, the PSP must be accessible, the PSP must be far enough from human disturbance and the PSP must have sufficient long term institutional support (Phillips and Baker, 2006). PSPs should be established in a randomly stratified manner to ensure the representation of several forest types and to prevent biased ideal forest conditions.

A PSP must represent 1ha of the forest (100m x 100m plot). The borders of PSPs should be established along their true bearings, i.e. all borders should face their true cardinal orientation. Working within the plot after border demarcation generally follows the proceeding guidelines.

1.2 Established plots

Access to an established PSP can be accomplished with the aid of 1:50,000 topographic base maps. The original demarcation schedules should be used to locate the plots. Schedules describe the UTM coordinates of the origin and the bearing of tie-lines which lead to plot corners. Plot relocation can be accomplished with a high-sensitivity GPS receiver (Garmin GPS Map 60CSx) and lensatic compass. Upon the location of the north-west corner, its NAD27 UTM coordinate should be recorded within 8 m of its true location. The north-west corner should also be used as the reference location for the plot. Plot-relocation can only be confirmed when all corner posts have been located and its spatial configuration in relation to each other (i.e. bearing and distance) corresponding to the original layout (Figure 5). All four corner posts should be either 4x4 or 3x3 inches wooden (Manilkara zapota) posts with painted white tops. In cases where plot has been recently surveyed, 6 inch or 2 inch PVC pipes can be expected as the corner posts.

1.3 Plot layout

After plot re-location has been confirmed, plot layout can be re-established by re-opening the boundaries of the plot. Since the plot has been aligned to the cardinal points using true bearings, magnetic adjustment and adjustment for annual declination should be made using the updated correction factor. These new bearings are to be recorded on the plot re-location

field sheet. A 100 m tape can be stretched between posts to guide the clearing of the plot boundary. Vegetation should only be cut from the outside of the plot so as to minimize disturbance to trees inside the plot. Wooden pegs, cut from outside of the plot are to be placed at carefully measured 20 m intervals along each of the boundary lines with the aid of a compass. These wooden posts mark the start of the internal sub-plot lines at 20, 40, 60 and 80 m (see plot layout *Figure 1*). Once the perimeter of the plot is opened and the 20 m markers are in place along the four sides, the internal sub-plot lines can be opened east to west beginning from the southern boundary of the plot. No vegetation clearing should occur on the internal sub-plot lines. A measuring tape is stretched from east to west of the most southern, east wooden marker to begin demarcation of subplots (*Figure 1*). Another measuring tape is then stretched from south to north of the most eastern southern wooden marker to meet the east to west tape at consecutive 20 m intervals. At each meeting point the two tapes should be pulled tight to converge exactly on the north-west corner of the 20 x 20 m sub-plot. At the meeting point of the tapes, a 1.5 inch PVC pipe is to be laid. This process should then be repeated until all 25 sub-plots are established (*Figure 2*).

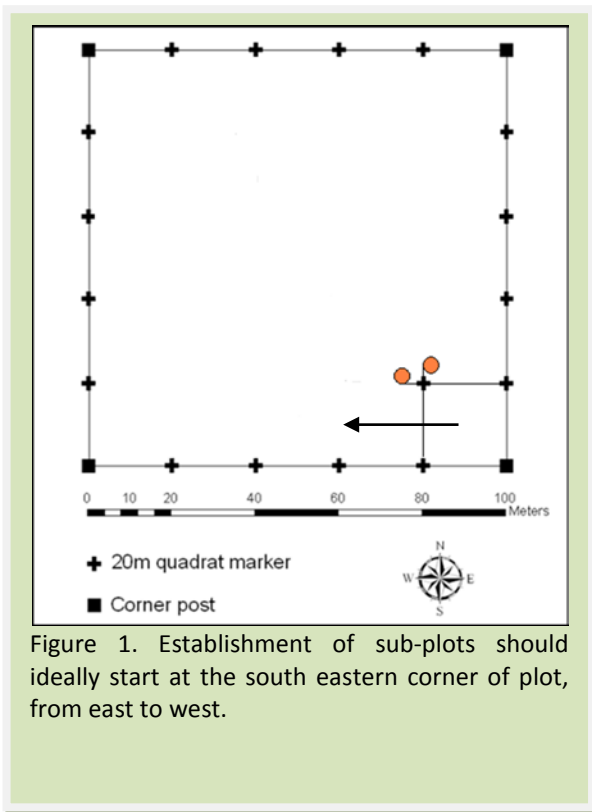


Figure 1. Establishment of sub-plots should ideally start at the south eastern corner of plot, from east to west.

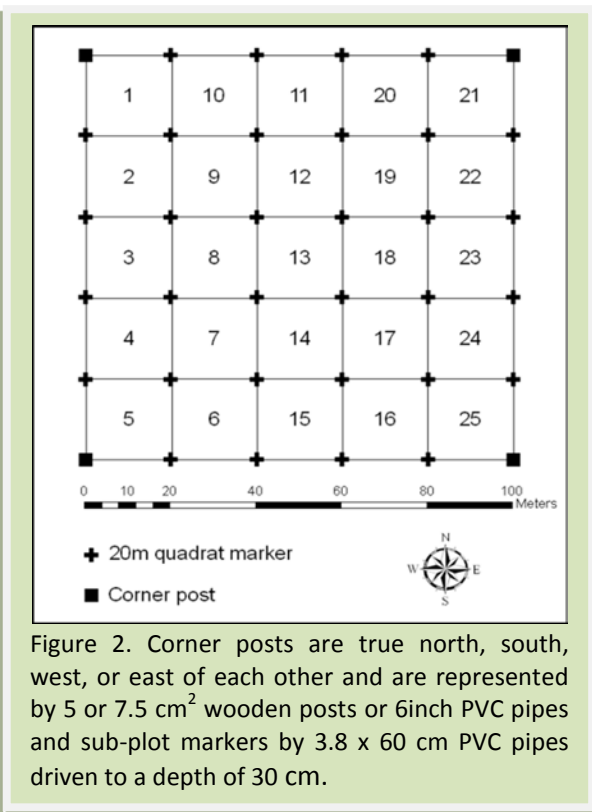


Figure 2. Corner posts are true north, south, west, or east of each other and are represented by 5 or 7.5 cm² wooden posts or 6inch PVC pipes and sub-plot markers by 3.8 x 60 cm PVC pipes driven to a depth of 30 cm.

1.4 Borderline Trees

Trees on the perimeter of the plot are of major concern compared to trees on the perimeter of internal sub-plots. In established plots, it is important to determine if the tree along the perimeter bears a tag; if so, the tree is located within the plot. If the tree does not bear a tag, then it is likely that it is a new recruit. Each tree which does not bear a tag and lies on the perimeter of plot needs to be assessed on an individual basis. The tree must be included within the plot if:

- The geometric center of its bole at 1.3m is within 20.2 m, perpendicular from the nearest sub-plot line.
- The geometric center of its base is within 20.2m, perpendicular from the nearest sub-plot line.
- The geometric center of its bole at 1.3m lies within the plot when sighted with a compass at a 20m marker located 40m from the tree. (Bird 1998).
- More than 50% of its roots and buttress lie within the plot when viewed from a compass at a 20m marker located 40m from the tree.

The tree must meet at least 3 of the 4 criteria to be included within the plot. In cases where the line of sight is obscured by a tree, the first two criteria should be used to determine the inclusion of perimeter trees. Trees along the perimeter which are not to be included within the plot are to be slashed with an "X" on the bole facing the interior of the plot to indicate exclusion.

1.5 Method of working within plot

Tree measurement in PSPs must always commence at the north-west sub-plot and then proceed south and then north again; in a zigzag fashion, following to the numerical sequence in *Figure 2* (Bird 1998). Work in sub-plot 1 should start at the north-western corner, heading in a clockwise direction (Bird 1998). To demarcate sub-plot border, tag on trees should be placed facing the internal sub-plot borders (Phillips *et al.* 2009). When work is completed within the sub-plot (the north-west corner reached), the sub-plot should be walked diagonally to ensure that no tree is missed (*Figure 3*). Sub-plot 2

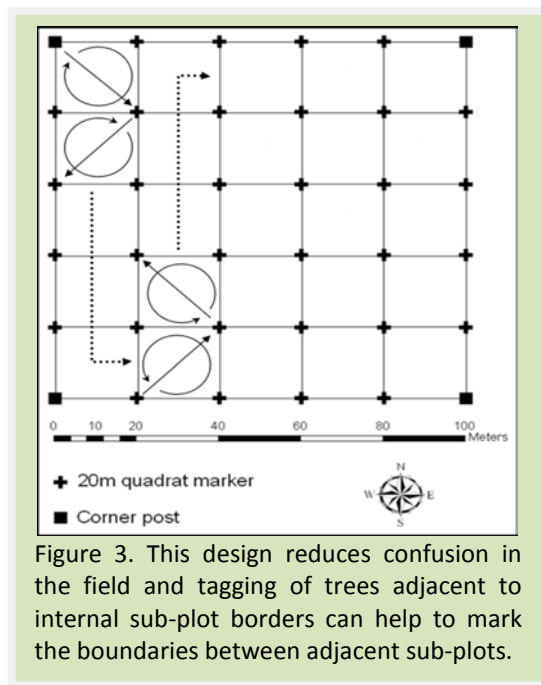


Figure 3. This design reduces confusion in the field and tagging of trees adjacent to internal sub-plot borders can help to mark the boundaries between adjacent sub-plots.

should then be enumerated starting in the north-east corner heading in a clock-wise direction. Once the starting point is reached, the sub-plot should be walked diagonally through the center to inspect for missed trees. The following sub-plot therefore is to be enumerated starting again from the north-west corner. Once the southern boundary of the plot has been reach, work in the next column should start from the south-west corner of the adjacent sub-plot. The same systematic method is to be observed heading north but this time in an anti-clockwise direction within sub-plots (*Figure 3*).

1.6 New tree/recruit location

Location of new trees should be recorded within each sub-plot as x,y coordinates, i.e. eastings and northings - the perpendicular distance in meters from the nearest westerly internal sub-plot line (x) and the nearest southerly internal sub-plot line (y), respectively. The reference point will therefore always lie at the southwest corner post of each sub-plot, and since the plot is aligned with true bearings, tree coordinates will be aligned with true bearings and hence with the UTM grid system. To locate trees, two 20 m tapes originating from the westerly boundary should be laid out on the ground along the north and south boundaries of each sub-plot. Similarly, two parallel 20 m tapes originating from the southerly boundary should be laid out along the east and west boundaries. Using this system, x,y coordinate measurers can move about on parallel sub-plot perimeters to obtain the most advantageous point of measurement and be within 10 m of any given tree. The distance of the geometric center of tree base should be observed with the aid of a compass adjusted to true bearings from the closest perpendicular x and y axis. This produces x,y coordinates within 10 cm (*Figure 4*).

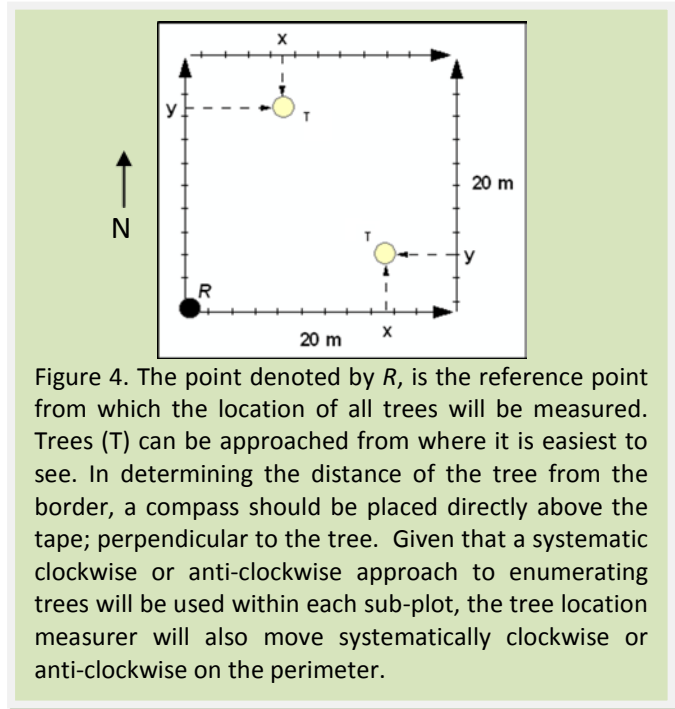


Figure 4. The point denoted by R, is the reference point from which the location of all trees will be measured. Trees (T) can be approached from where it is easiest to see. In determining the distance of the tree from the border, a compass should be placed directly above the tape; perpendicular to the tree. Given that a systematic clockwise or anti-clockwise approach to enumerating trees will be used within each sub-plot, the tree location measurer will also move systematically clockwise or anti-clockwise on the perimeter.

1.7 Tree identification

Prior to measurement, trees should be identified to the species level wherever possible. However, expert taxonomical inspection suggests that errors in species identification are

substantial in plots; especially for lesser known species. In previously established plots, it is assumed that taxonomical identification during past enumerations was suspect for all non-timber species, i.e. all lesser known trees. Indigenous knowledge should be used to identify trees by common names and botanical samples should be obtained for each tree identified in this manner. Trees which are neither identifiable to species nor common name are to be classed as unknowns and numbered sequentially. Botanical samples of these unknown species must be collected. All botanical samples collected should be photographed and labeled by plot, e.g. plot x, unknown 1,...i (see section 2). Where possible; voucher specimens consisting of foliage, flowers and fruits, should be prepared for later identification at a reputable herbarium (see section 3). Tree bark, leaves, flowers and fruits along with a short description of all lesser known and unknown species should also be compiled in a manual, updated daily and used in the field to aid in maintaining consistency in identification. In this manner, the total number of taxonomically different trees (i.e. species) can be determined reliably and efficiently. The hierarchy of taxonomical efficacy expected in plots is presented in *Figure 5*.

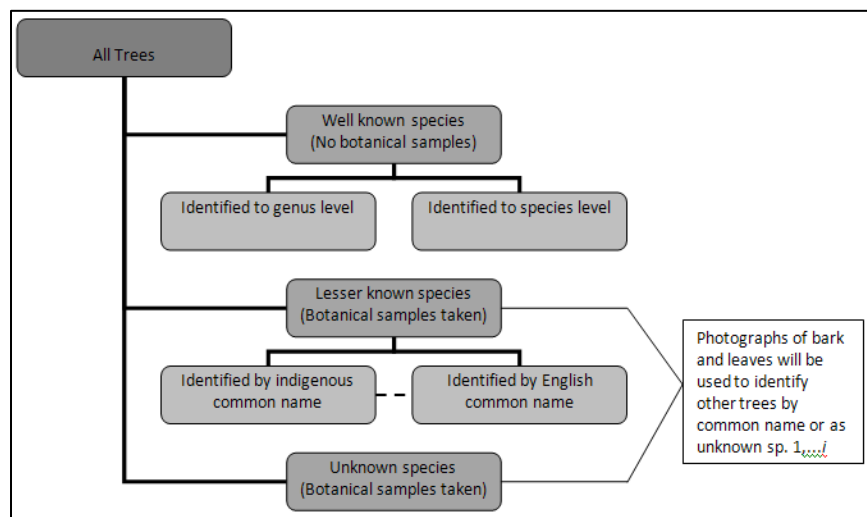


Figure 5. It is expected that the majority of trees should fall into the first two levels. Trees falling into the second and third levels should be identified to either family, genus or species level post-fieldwork at a reputable herbarium. The result of the herbarium exercise will inform the categorization of species into functional groups based on a literature review.

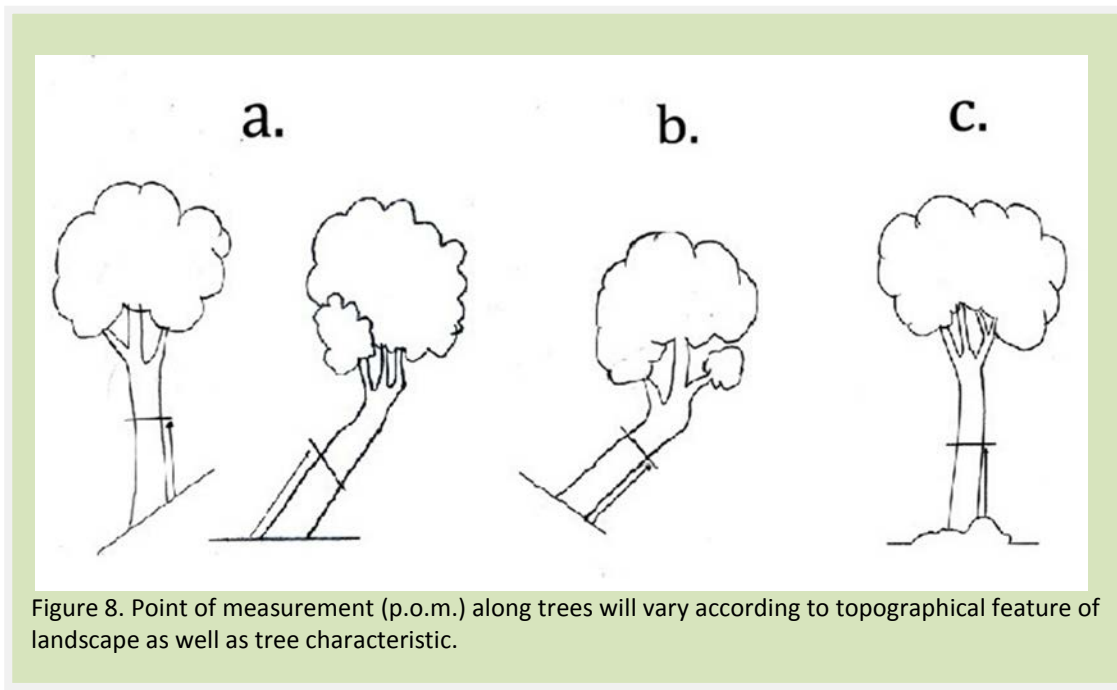
1.8 Measurement of diameter

1.8.1 New Trees

Diameter measurements should be made using fiberglass tapes and recorded to the nearest 1 mm for all trees ≥ 10 cm at 1.3 m above the soil. For saplings ≥ 1 cm but less than 5 cm, a small caliper can be used to take perpendicular measurements, the average of which is to be

recorded as the diameter. If the reading is exactly halfway between the graduations, then it must be rounded up. Stems <10 cm should only be enumerated and identified in the central sub-plot (sub-plot #13). A stick carefully measured and marked at 1.3 m in length should be used in the field to guide the point of measurement (p.o.m). To maintain consistency with previous measurements, the height of 1.3 m should always be measured on the uphill side of vertical trees on slopes (*Figure 8 a.*). Where there is a non-vertical tree on a slope, the direction

of



lean will take precedence over the slope (*Figure 8 a.*). The height of 1.3 m should always be measured along the side lowest to the ground for any non-vertical tree, be it on a slope or not (*Figure 8 b.*). For vertical trees not on slopes, but where the surrounding ground is uneven (a common situation), the height to the POM must be measured from the highest point around the tree as long as it is measured from soil (*Figure 8 c.*).

In cases where it is not possible to reliably measure diameter at 1.3 m, e.g. buttressed or stilted roots, the POM is moved from 1.3 m to immediately above the convergence of the buttress or stilts (Bird 1998). The height to the new POM should be recorded on the field sheet. Although this step differs from the RAINFOR methodology where the POM is shifted to 50 cm above the buttress, it is necessary to maintain consistency with previous measurements. In order to improve the handling of buttress growth, the RAINFOR methodology should be observed as well, and two the POM's must be measured. The handling of this situation and the coding of the resultant diameters is presented in *Table 1.*

Table 1: p.o.m change guide.

Type of POM change	Diameter Code
New (1.3 m) or old trees (original POM)	D1
Forced POM change due to buttress or stilt (Bird, 1998)	D2
Forced POM change due to slope (Phillips <i>et al.</i> 2009)	D3
<i>Note: Some old trees may have both D1 and D2 recorded if, for example, a deformity has developed at the original POM and a new POM has to be determined. Still other trees may have all tree diameters if, for example, a buttress has extended into the original p.o.m and a new p.o.m has to be determined according to both Bird (1998) and Phillips et al. 2009).</i>	

Where buttresses and stilts make POM inaccessible, a ladder can be used to make diameter measurements. Where extremely tall buttresses occur and the ladder does not allow measurement at the POM, the diameter should be estimated by reaching with tall poles to place the tape perpendicular to the main axis of the stem and readings taken from two perpendicular positions. The distance away from the tape should also be measured. Such measurements must be coded and corrected for parallax error during data post-processing; following the methodology in Phillips *et al.* (2009). Paint is then applied to the p.o.m using a paint brush on a pole and the tree should be tagged at 1.3m from the ground.

Where trees are fluted at the base, the procedure is the same as for buttressed trees. Where fluting extends along the entire stem, the diameter is measured at 1.3 m and a fluting code recorded on the field sheet.

When trees forks below 1.3 m, each stem should be measured and tagged individually. Where the fork lies at exactly 1.3 m, the stems are also to be measured and tagged individually and the new POM's taken immediately above where the stem divides. Each of the multiple stems must be given a code on the field sheet to indicate that they belong to the same root system. Where the fork occurs above 1.3 m, the POM should be marked and one measurement taken and the tree coded accordingly. Where there is a defect at 1.3 m, the diameter should be measured immediately above the defect, given that defects normally spread downward, and the height to the new POM recorded. The height to the new POM and reason for moving the POM are always recorded on the field sheet for each such tree. Before diameter is recorded any loose bark or moss must be brushed away and the POM marked with chalk or timber crayon. Climbers should *not* be cut away and the diameter tape must be passed under climbers to be in direct contact with the tree. The diameter tape is then placed perpendicular to the main axis of the stem so that its lower side coincides with the chalk mark and additional chalk marks can be made along the lower side of the tape to mark the exact POM. Once the diameter is recorded with the tape a band should be painted around the tree with the top edge coinciding exactly

with the chalk marks. Painting must be done carefully and accurately, perpendicular to the bole so that the upper margin of the painted band is exactly at the POM. Only one half of the tree circumference can be painted to save time and material. For stems <5 cm the four points of contact of the caliper is to be painted with a dot. The technique used to measure trees (*Table 2*) should be noted in the comments section of the field data sheet (*Appendix 1*).

Table 2. Codes for diameter measurement technique.

Code	Description
<i>These codes will be applied next to the recorded diameter.</i>	
0	Normal measurement with diameter tape or caliper
1	Ladder with diameter tape
2	Perpendicular tape held up by poles (parallax error applies)
3	Perpendicular tape due to stranglers (parallax error applies)
4	Visual estimate

Adapted from Phillips *et al.* (2009)

1.8.2 Old Trees

Relocating old trees may be difficult given the length of time since the last census (13 years for test plots and 19 years for some control plots). Two means of verification can be used to identify old trees. First, a tree tag will confirm the presence of a tree at the last census. However, some tags may have been ‘eaten’ by trees through radial growth and others may have been ‘eaten’ or popped off by climber growth. Others may have been deliberately removed especially where plots are near to hunting trails. The second means of verification will attempt to by-pass the use of tree tags. Plot maps can also be used to identify old trees by location, species and diameter. If the species and location correspond to plot records and the present diameter is greater than the diameter recorded at the last census, then there is a high probability that the tree was present at the last census. This approach is especially useful for saplings which have grown to large trees. Diameter measurements of old trees, i.e. trees measured at the last census must be taken at the original POM. The presence of the white paint band will guide the placement of the diameter tape. If the white band is not visible due to bark shedding, but the tree is tagged, the POM should be taken at 30 cm below the nail. If neither the paint or nail is visible, but it is confirmed to be an old tree, the original protocol for locating the POM must be used. If the old POM has shifted by unusual vertical growth (inferred only after confirmation that no POM changes were made in the original measurement), the diameter and height at the painted POM is to be recorded and a new POM at 1.3 m established.

For buttressed, stilted, fluted, or deformed trees where the irregularity has spread to the POM a new POM should be established as for new trees following both Bird (1998) and Phillips *et al.* (2009). For the sake of clarity, diameter recorded on new or old trees at the original POM following Bird (1998) will be coded as D1, where the POM has to be shifted but still in accordance with Bird (1998) it will be coded as D2, but where the diameter is recorded in accordance with Phillips *et al.* (2009) it will be coded as D3 (Table 1).

1.9 Tagging trees

All measured trees within the plot should be numbered with an aluminum tag. Old trees will keep their old tags and for those trees whose tags are no longer visible, new tags should be issued. As far as possible, trees are to be numbered consecutively throughout each plot as per the method of working. For trees ≥ 5 cm diameter the tags should be nailed into the stem 30 cm above the POM using 100 mm aluminum nails driven into the stem at 45° from vertical. For saplings less than 5 cm in diameter tags are to be tied around the stem with tying wire. In addition to the painted band, a vertical strip of paint should be placed on each sapling to help with future re-location. Newly issued tags must not possess a number already present in the plot. Deciduous trees may appear dead to the untrained eye; therefore, careful checks need to be made to confirm if the cambium beneath the tree bark is still live and it consequently tagged.

1.10 Tree height

In each sub-plot, the two trees with the largest and smallest stem diameters must be selected for height assessment to establish height-diameter relationships. A total of 50 trees must be observed within the entire plot ($n=50$). This method is preferred over an equal sample number in each 10-cm diameter class (*sensu* Phillips *et al.* 2009) because the number of trees in the smaller diameter classes will typically be disproportionately greater than the larger trees. This method of selection therefore creates a random weighted sample and captures the variability in tree size better than a random systematic design. It also results in a larger (pre-determined) sample size compared to Phillips *et al.* (2009) since it may be difficult to find equal number of trees in each 10-cm diameter class. Crown point height, defined as the height to the first major live branch, should be measured to the nearest 50 cm using a clinometer. Since the intent is to develop the 'ideal' height-diameter relationship, all leaning, rotten, broken, forked below 5 m, fallen, or re-sprouted trees are to be excluded (Phillips *et al.* 2009).

1.11 Climber presence

All trees within the plot must also be coded for the degree of strangulation by climbers. The codes presented in Bird (1998) following Synnott (1979) will be used (Table 3).

Table 3. The Synnott climber code classification

Code	Description
1	Tree free from climbers
2	Climbers on main stem only, crown free
3	Climbers in crown but main stem free
4	Climbers on main stem and in crown
5	Whole crown smothered by climbers, and present on main stem

From Bird (1998)

1.12 Crown position

Crown position must be assessed for every tree measured. The methodology follows the five-point system developed by Dawkins and illustrated in Bird (1998). For ease of reference the classification system is presented in Figure 9.

The Dawkins crown position classification	Code	Description
	5	Crown plan exposed vertically, and free from competition at least within the 90° inverted cone subtended by the crown base.
	4	Crown plan fully exposed vertically but adjacent to other crowns of equal or greater height within the 90° cone.
	3	Crown plan partly exposed vertically but partly shaded by other crowns.
	2	Crown plan entirely vertically shaded but exposed to some light due to gap or edge.
	1	Crown plan entirely shaded vertically and laterally.

Figure 9. System of classification for crown position of trees in plots.

1.13 Crown form

Crown form must be recorded for all trees measured within the plot. The five-point system developed by Dawkins and illustrated in Bird (1998) will be used (Figure 10).


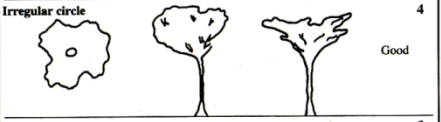



The Dawkins crown form classification	Code	Description
	5	The best size and development generally seen.
	4	Very nearly ideal, silviculturally satisfactory, but with some slight defect of symmetry or some dead branch tips.
	3	Just satisfactory, distinctly asymmetrical or thin, but capable of improvement if given more room.
	2	Distinctly unsatisfactory, with extensive die-back, strong asymmetry and few branches, but probably capable of surviving.
	1	Definitely degenerating or suppressed, or badly damaged. No true crown present.

Figure10. System of classification for crown form of trees in plots.

1.14 Palms

Only palms ≥ 10 cm diameter at 1.3 m will be enumerated in the plot. In a given hectare of forest, palms ≤ 10 cm in diameter can be too abundant to measure in any reasonable amount of time. All palms ≥ 10 cm diameter should be measured, mapped and tagged. Where the POM is obstructed by the presence of fronds no diameter needs be recorded. Such individuals will be assessed as immature since fronds emerge from the stem below 5 m (Bird 1998). Individuals where fronds emerge from the stem above 5 m can be classed as mature and diameter recorded in the standard manner.

1.15 Missing, dead or damaged trees

If a tree on the plot map or in the plot record is not found or has died, the reason should be determined and recorded. The tree should first be measured for diameter according to the standard method. The cause of death or disappearance should be coded according *Table 4*. These codes are neither similar to Bird (1998) nor Phillips *et al.* (2009) but were redesigned to be applicable to hurricane impacted forests. For example, additional codes relating to hurricane damage or mortality have been added. Any tree which died broken or broken but not dead needs to be measured to the height at which the breakage occurred. All dead or missing trees should first be flagged on the data sheet by a 1 in the comments section followed by the appropriate code or codes.

Table 4. Codes for dead or missing trees showing corresponding old codes.

Code	Description (more than one code may apply)	Bird (1998)
All dead or vanished trees will first be coded with a 1 in the comments column. Bird (1998) used a code of DT instead of 1.		
DA	Died alone	-
DG	Died in a group	-
DS	Dead standing with branches intact	-
F	Felled naturally (uprooted)	-
FH	Felled by hurricane	-
FA	Felled (anthropogenic)	T
KB	Killed standing (broken) by natural tree fall, branch fall, or liana weight	-
KBH	Killed standing (broken) by hurricane (tree fall or wind snap)	-
KF	Killed by fire	-
KI	Killed standing by liana competition	-
KL	Killed by lightning	-
KR	Killed during road building or log extraction	E
KS	Killed standing by strangler	-
KU	Killed by unknown	U
KW	Killed by weight of liana (use in combination with F or KB)	-
V	Vanished	U
VP	Vanished but presumably due to poor mapping	U
X	Caused death of other tree by natural fall or hurricane fall	-

Adapted from Bird (1998) and Phillips *et al.* (2009)

1.16 Tree description

Each tree which is measured also needs to be assessed for a variety of additional characteristics such as alive or dead, physical condition, defects, phenotypic manifestations, and damage. The list of codes and corresponding description for live trees is presented in *Table 5*.

Table 5. Codes for living tree condition showing corresponding old codes.

Code	Description (more than one code may apply)	Bird (1998)
DT	Dead tree	-
AF	Alive fallen	-
AH	Alive with rot in stem (hole)	RT
AR	Alive partially rotten (no hole)	RT
AS	Alive with strangler fig	-
BC	Broken top >1.3 m, but with coppice crown	BC
BS	Broken <1.3 m	-
BT	Broken top > 1.3 m, no crown present	BT
BU	Buttressed tree	BU
CD	Crown defoliated by insect or other cause	DF
DB	De-barked, bark as been lost over part of the stem	DB
DC	Damage in crown caused by other falling trees or branches	FC
DS	Damage on stem due to falling tree	FS
DU	Diameter measurement unreliable (used in combination with 2-4 in Table 6)	DU
FA	Major fork above POM, but below half tree height	FA
FB	Major fork below POM	FB
FD	Fire damage present on tree bole	FD
FL	Fluted bole	FL
FU	Fungus present on tree bole	FU
L	Lightning damage	-
LS	Leaves shed (deciduous)	-
LT	Leaning tree and/or supported by other trees	LT
N	New tree	-
N	Near death, declining	-
PC	Palm fronds cut	PS
PI	Immature palm. Fronds emerge from stem below 5 m	PI
PM	Mature palm. Fronds emerge from stem above 5 m	PM
S	Is a strangler	-
SS	Stem slashed for chicle collection	SL
ST	Stilt roots	ST
TB	Termites present on bole or roots	-
TC	Termites present in crown	-
TF	Tree in fruit	SE
TW	Tree in flower	FW
US	Very bad bole form with no utilization value	US

Adapted from Bird (1998) and Phillips *et al.* (2009)

1.17 Site codes

The bio-physical conditions within each sub-plot must also be described using the system of codes detailed in Bird (1998) and presented in *Table 6*.

1.18 Aspect

The aspect of the terrain refers to the direction to the orientation of a slope. The aspect of each sub-plot should be assessed and recorded according to eight directions based on the four cardinal points.

Table 6. Sub-plot site codes. These codes correspond with the old codes.

Code	Description
CT	Climber tangle on top of pole-sized re-growth
DW	Dry watercourse
FI	Recent fire
FL	Recent flooding evident
GA	Natural gap formed by tree fall
LO	Past logging evident
RK	Rocky outcrops
RS	River or stream
SW	Occurrence of swamp conditions
TI	Ground dwelling termite mound present
TP	Truck-o-pass
TS	Tree stumps
WT	Windthrow

Adapted from Bird (1998)

1.19 Canopy openness

The canopy openness in each sub-plot should be measured using a spherical crown densiometer (convex model A, Forestry Suppliers Inc.). This equipment measures the percentage of overhead space not occupied by canopy using a series of dots on a concave mirror. Four readings need be taken according to the four cardinal points and averaged to produce one reading.

1.20 Vine cover

The percentage of each sub-plot covered by vines to a height of 5 m also needs to be visually estimated.

1.21 Re-sprouting

On standing, but broken trees with coppiced crowns (*Figure 10, b, d, and f*), or fallen trees (*Figure 10, a*), the parent stem and all re-sprouts ≥ 10 cm diameter at 1.3 m should be enumerated. For all re-sprouts on fallen or standing trees, the POM should be taken at 1.3 m from where the re-sprout is attached to the parent stem (Phillips *et al.* 2009), this measurement following any curve in the re-sprouted stem. For fallen new parent trees the p.o.m should be taken horizontally from the base of the stem, while for fallen old parent trees the original p.o.m should be used. Re-sprouts must be counted as separate individuals if they emerge at any point along a standing or leaning parent stem whose original canopy is alive. If the parent canopy is dead, multiple re-sprouts should be counted as multiple stems (*Figure 10, c and e*).

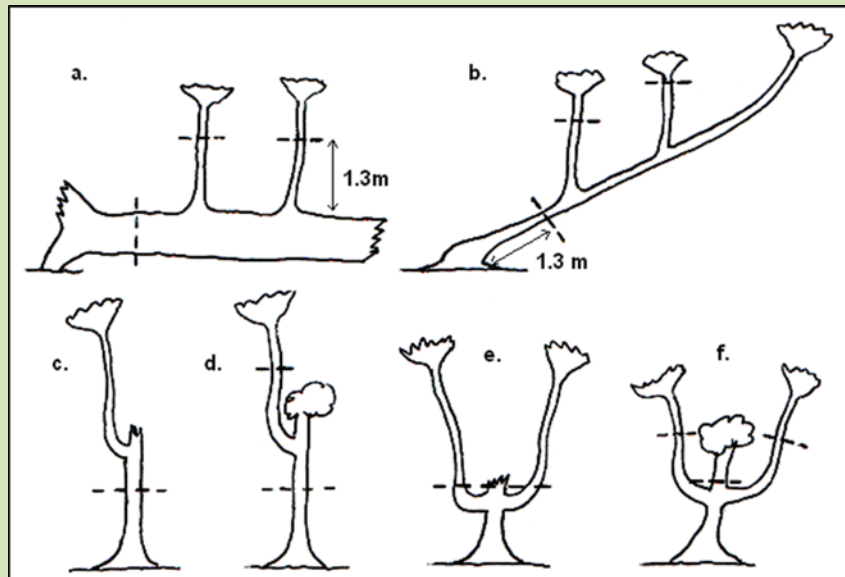


Figure 10. Illustration showing the different types of re-sprouting expected in plots. Six different re-sprouting scenarios are expected to be common in the hurricane impacted plots. All parent stems and re-sprouts in this illustration are ≥ 10 cm. The dashed lined represents the p.o.m.

1.22 Fallen live trees

Fallen trees need to be checked carefully to determine if they are still alive, as with standing deciduous trees. Fallen live trees will be enumerated as per standard procedure.

1.23 Strangler lianas

Strangler should be issued a separate tag from the host tree. Loose and separate lianas are to be enumerated as per standard procedure. At advanced stages of liana parasitism, the entire bole of the tree can be engulfed with little or no portions visible. This presents a problem for measuring the liana as the shape of the stem will not allow diameter to be measured. An estimate of the percentage of bole surface covered by the liana needs to be made first to deal with this problem. Second the thickness of the liana should be measured at the POM where possible. If the entire surface of the bole is engulfed at the POM, liana thickness should be estimated from the mean liana thickness. Third, the diameter of the parasitic complex must be measured and POM determined as per standard procedure. During volume calculation correction should be applied to account for the volume of the tree bole and the un-covered space on the exterior of the tree bole.

To separate liana and host tree volume, the total volume should first be calculated using the diameter of the parasitic complex, and subtracted from this will be the volume calculated from the diameter of the host tree which will be determined by subtracting '2 x liana width'. The difference will be the total volume of the liana outer shell and this will then be corrected by multiplying by the decimal percent of bole covered by liana.

1.24 Strangled live trees

In some cases trees may be strangled by multiple stems of the same liana and in extreme cases the liana stems may merge into each other forming a blob covering most if not the entire surface of the stem. If the tree is still alive, it will be impossible to lift the liana stems to accurately measure tree diameter. In cases where the tree bole is still visible, the diameter of the tree can be estimated by holding the tape (on standard side) perpendicular to the main axis stem at the p.o.m and readings taken from two perpendicular positions. The tree should be painted and tagged in the standard manner. Such measurements need be coded and later corrected for parallax error during data post-processing. In cases where the liana stem has entirely engulfed the tree at the POM, tree diameter should be estimated and coded as unreliable.

2.0 Photographing specimens

It is recommended that a digital single-lens reflex (DSLR) camera be used for photographing of leaves, bark, flower and fruit (when possible). DSLR cameras capture more detail and allow manipulation of settings for photographing maximization. Additionally, DSLR cameras allow the attachment of macro-lenses to maximize photographing objects at a longer distance and increase detail. In cases where the species is unknown, detailed photographs should be taken. This includes specific features such as inflorescence, fruiting, seeds, stipule, stipule scars, auxiliary bud, terminal bud, leaf arrangement, pellucid glands, hairs, leaf venation, and bark colour (upon slash) amongst others. Effective photographing of specimens is governed by three features of a DSLR camera aperture, shutter speed and ISO. These are interrelated and only through practice can photographing be mastered. Though the automatic setting for photographing is recommended for beginners, the "manual" setting is recommended as it enhances detail in picture.

2.1 Aperture

Aperture on the camera controls the amount of light entering the lenses. A low aperture allows maximum light to enter the camera where a high aperture allows minimal light to enter. A low aperture yields a low depth in field (detail on object in focus will be captured where the background is blurred). A high aperture on the other hand allows for a greater depth in field (detail is captured both on the object in focus and the background). Aperture in DSLR cameras is measured in F-stops. A low aperture of F-stop 22 is recommended for photographing specimens under forest canopy.

2.2 Shutter speed

Shutter speed on the other hand determines the amount of time at which the 'film' is exposed to light. When in the automatic mode, the shutter speed is adjusted according to aperture. When in a low aperture mode, shutter speed is fast as light is abundant. Conversely at a high aperture mode, the shutter speed is slower as little light enters the camera. A slow shutter speed at a low aperture 'blows-up' the photograph because excess light over exposes the image. Similarly, a fast shutter speed at a high aperture obscures the photograph because not enough light enters the cameras. A high shutter speed should also be used to reduce blurring of photographs. When in the manual mode, with a low aperture of F-stop 22, a shutter speed of 1/200 should be used to photograph specimens under forest canopy.

2.3 ISO

The ISO of a DSLR camera defines its sensitivity. Sensitivity in this case refers to the resolution or the amount of pixels/grains present in a photograph. A high ISO setting means that the resolution of the image is low, i.e. less pixels/grains are larger hence less in a photograph. A low ISO is the reciprocal; the photograph contains more pixels/grains and therefore has a higher resolution. High ISO is important in low lit environments as the 'film' must capture as much light as possible and low pixilation does this more effectively as less surface area is exposed to light. Low ISO is typically used in well-lit environments as sufficient light enters the camera to target every pixel. An ISO of 100, a shutter speed of 1/200 and an aperture of F-stop 22 should be used to maximize photographing of plant characteristics under forest canopy.

2.4 Flash Feature

The flash feature of the camera should be used to effectively photograph leaves. The flash feature allows the demarcation of leaf boundaries by filling shadows on the background and effectively highlights the dark fields. However, the reflectance of camera flash on waxy laminae may hamper the quality of the image. Therefore, the ISO, aperture and shutter speed of the camera should be increased to address this issue. The bole of the tree should always be photographed without flash. This will require adjustment of aperture when not enough light penetrates the lower canopy.

2.5 Managing photographs

Photograph should be stored in their raw (.raw) format to avoid loss of detail. Processing and management of photographs can be achieved with Adobe Lightroom. Adobe light room allows for filtration of photographs, grain enhancement, contrast adjustments and brightness control amongst others. Additionally, Adobe Lightroom allows strings of data to be attached to the photograph. This is important as each photograph is unique to a tree, sub-plot, plot and tree tag (these should attached on the photographs to facilitate relocation).

3.0 Voucher preparation

3.1 Field data collection

Specimens collected in the field can range from leaves to fruits and inflorescence. A separate field book should be used to take notes on voucher specimens. The first data to be recorded on the field note book is the collector's name (recorded as initials and last name) and collection

number. Second, the date of collection needs to be recorded. Third, the GPS location of the parent tree should also be recorded. This should be accompanied by a detailed description of the specific location of the tree i.e. on a slope, along a stream, along a trail, sub-plot # etc. The final data that should be recorded is a detailed description of the tree. Details that must be included are those that cannot be assumed from the specimen and those that will be lost when the specimen is processed for herbarium collection. The height of the tree should be recorded. The taxonomy of the tree should always be recorded at the lowest level where possible; family, genus, species or common name. Features that will not be seen once the specimen is dry, such as leaf and inflorescence colour, presence of sap, bark colour, fruit colour, scent and other unique feature should be recorded. This data can then to be used to create a herbarium label.

3.2 Processing of voucher

Specimens collected from the field should be pressed in two fold paper having a dimension of approximately 29cm x 43cm. Local newspapers are ideal for this purpose. The herbarium press bag should also be of the same dimension. The first layer of material to be placed on the surface of the herbarium press plank is aluminium corrugate or card board. The purpose of this layer is to provide circulation of air between specimens and to efficiently distribute heat along the specimen during the drying process. A layer of blotting paper should then be placed above aluminium or cardboard. Blotting paper allows the absorption of moisture from the specimen and prevents its breakage. The final layer to be placed is the paper/newspaper leaflet; in which the specimen should be placed. Specimens collected are to be trimmed to fit exactly within the dimension of the newspaper leaflet. Evidence of trimmed stems should be kept. i.e. about 1 cm of the branch is left attached to the main stem (*Figure 11 a*). The lower right and upper left corners should be left free of specimen for the attachment of a herbarium label and an extra material envelope respectively (*Figure 11 b, c*). All branches and stems must be visible. Leaves obstructing stem can be rearranged to ensure that the branching system of the specimen is evident (*Figure 11 d*). The underside of at least one of the leaves should be displayed (*Figure 11 e*). This can be accomplished by twisting a leave to the underside . All inflorescence and fruiting material must be visible (*Figure 11 f, g*). If the specimen is too big to fit on the newspaper leaflet, it can be twisted or broken (*Figure 11 h*). When the specimen has been secured between the newspaper leaflets, the collector's initials and collection number should be written with a permanent marker on one of the corners to facilitate identification. A second blotting paper should then be placed on top of the newspaper, followed by another aluminium corrugate or card board. This process should be repeated when pressing other specimens.

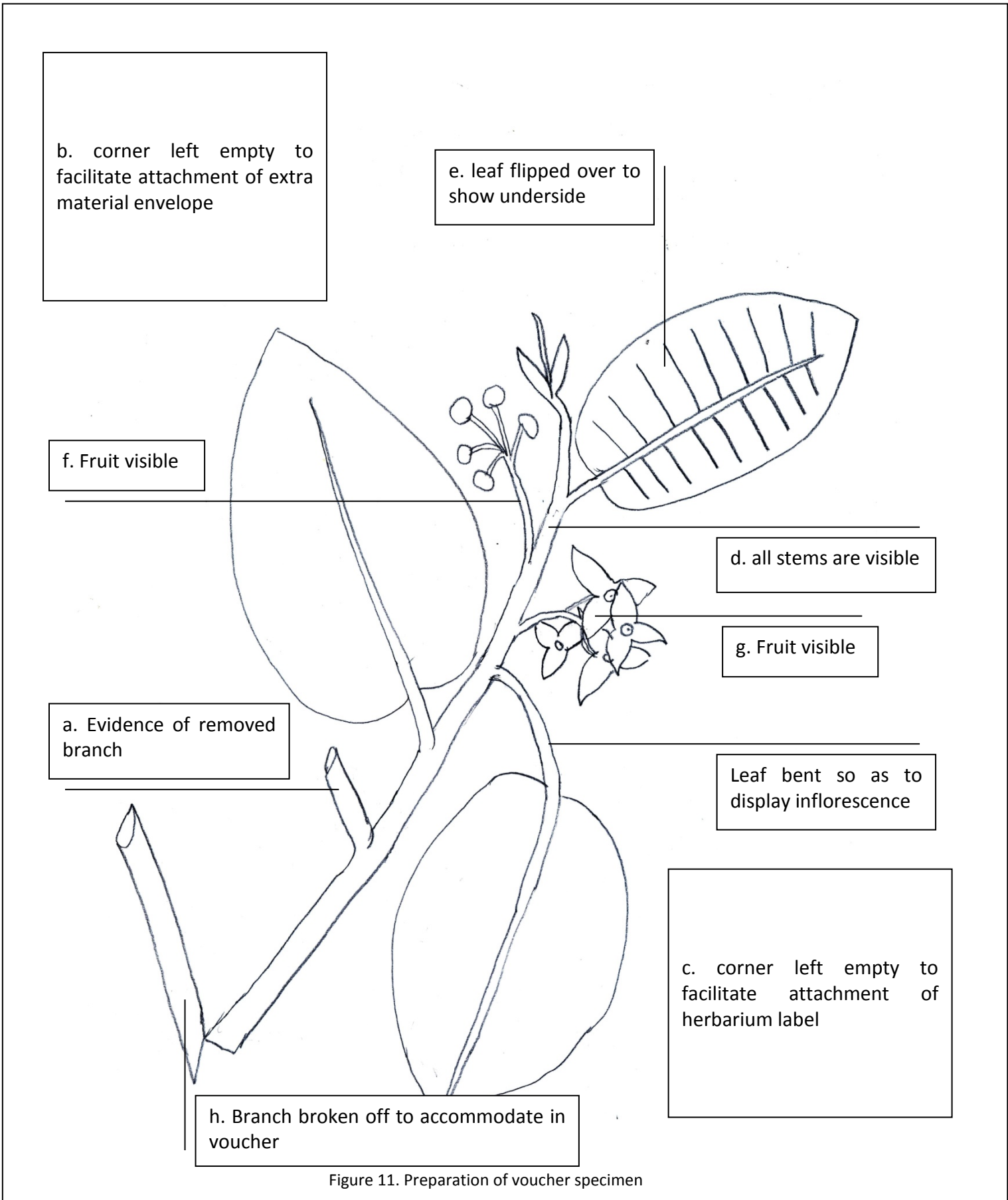


Figure 11. Preparation of voucher specimen

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