

Metal Band Dendrometer Protocol

CTFS Global Forest Carbon Research Initiative

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Materials checklist

(For details on these materials and names of potential suppliers, see the section on *Specifications and Suppliers for Materials*.)

1. Diameter measuring tape (1 per person)
2. Wooden stick 1.4 m long, with marks at 1.0, 1.1, 1.2, 1.3 and 1.4 m (1 per person)
3. Ladder (1 per team)
4. Clipboard and datasheets (1 per person)
5. Permanent marker (1 per person)
6. Tree marking paint
7. Small container and brush for paint (1 per person; nail polish bottles work well).
8. Heavy-duty lever hole punch (1 per person)
9. Digital calipers (1 per person)
10. Snips/heavy-duty scissors (1 per person)
11. Stainless steel banding (length equal to tree circumference plus 8-20 cm, depending on tree size – see below)
12. Stainless steel springs (1 per tree; length of 38, 76 or 127 mm depending on tree size – see below)

Preliminary Observations

1. Locate the designated tree using the information on the maps and datasheet.
2. If the tree is dead or presumed dead (missing), record this under notes using the usual plot codes. For BCI, these are D for Dead, followed by:
 - S = Dead trunk still standing
 - C = Dead trunk lying on ground
 - T = Tree missing, tag found
 - N = Both tag and tree missing
3. Examine the stature and condition of the tree; record any special cases under “Notes” on the datasheet. For BCI, use the following standard plot codes where relevant, and also record if there are “Thorns” or “Bark peeling”:
 - B = buttresses extending to 1 m or higher
 - M = multiple stems
 - L = leaning
 - Q = stem broken above 1.3 m
 - X = stem broken below 1.3 m
 - I = irregular stem
4. Assess and record the crown condition of the tree using the following categories:
 - 4 = 75-100% of the crown is intact (no or few branches lost)
 - 3 = 50-75% of the crown is intact
 - 2 = 25-50% of the crown is intact
 - 1 = 0-25% of the crown is intact (most of the crown is gone)
5. Evaluate and record the crown illumination index (CII) of the tree. The different values are defined as follows (Figure 1):
 - 5 = crown completely exposed (to vertical light and to lateral light within the 90 degree inverted cone encompassing the crown)
 - 4 = full overhead light ($\geq 90\%$ of the vertical projection of the crown exposed to vertical light; lateral light blocked within some or all of the 90 degree inverted cone encompassing the crown)
 - 3 = some overhead light (10-90% of the vertical project of the crown exposed to vertical light)
 - 2 = lateral light ($< 10\%$ of the vertical project of the crown exposed to vertical light; crown lit laterally)
 - 1 = no direct light (crown not lit directly either vertically or laterally)

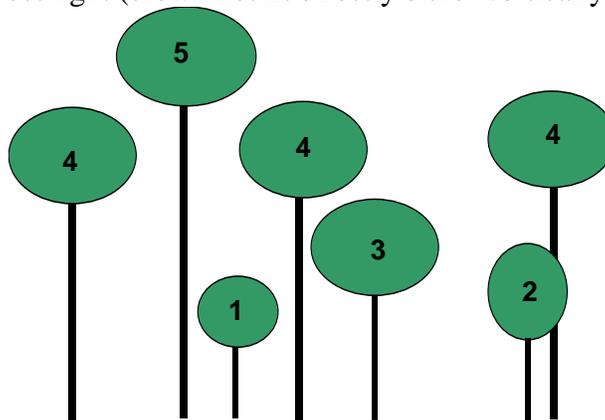


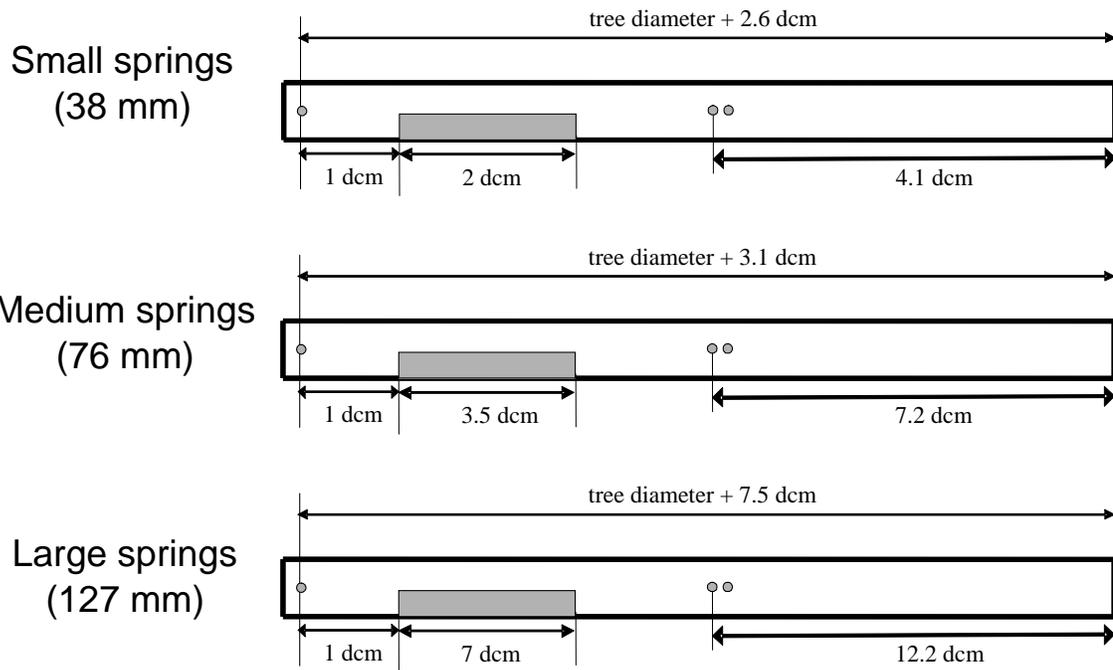
Figure 1. Examples of trees having different values of the crown illumination index.

Diameter Measurement

6. Locate the current measurement point for the main census using standard methods for the site in question. (The datasheet's POM column states this height.) For BCI, the following guidelines apply:
 - a. If the measurement point is listed as 1.3 m, there will be no paint marks on the tree. Note that in determining where 1.3 m height is,
 - i. On a slope, 1.3 m height is measured on the uphill side.
 - ii. For a leaning tree, 1.3 m height is measured along the lower side
 - b. If the measurement point is higher than 1.3 m, there will be an orange paint mark – the *highest* paint mark is the current measurement point.
7. Evaluate if the current measurement point is suitable for continued measurements with a diameter tape over the next 4 years. If it is not, choose a new measurement point. In most cases, if a measuring point is “good enough” for the main census, it is good enough for our purposes as well. But there are exceptions:
 - a. If there are stem irregularities at the measurement point that can easily be avoided by measuring at a higher or lower position, then adjust the measurement point appropriately.
 - i. First consider options up to 50 cm higher than POM, then if the current POM is at 1.3 m consider options up to 50 cm lower, and finally consider options further up.
 - ii. In many cases, stems that are irregular at the measurement point are also irregular through most of their length. In this case, just use the regular census measurement point.
 - b. If the buttresses have grown up since the last census so that they now end less than 10 cm from the current measurement point, then move the measurement point upwards.
 - i. The new measurement point should be 50 cm above the top of clearly defined buttresses.
 - ii. On many trees, buttresses do not have a clear ending. In this case, just use the main census measuring point.
8. Temporarily mark the measurement point with a permanent marker.
9. Measure the diameter of the tree at the chosen measurement point using diameter tape, and record it.
10. Paint-mark the measurement point if necessary (if not already painted, or if the paint is fading), and note on the datasheet whether the mark is newly painted or not.
11. If the measurement point is new, then measure the height of the chosen measurement point from the base of the tree (using the standard site rules for measuring on a slope and on leaning trees, for BCI as in 5a).
12. Evaluate if the tree is suitable for installation of band dendrometers. In cases where there are many thorns on the bark preventing the placement of the band, or in species known to have rapidly peeling bark, band dendrometers are not suitable. If the tree is suitable, a band should be installed as described in the next section. If it is not suitable, note this and state the reason under notes on the datasheet and go on to the next tree. ,MLK LJ

Dendrometer Installation

13. Decide on the location of the band dendrometer.
 - a. Default location – 10 cm above the paint-marked measurement point.
 - b. If there are stem irregularities at the default location that can be avoided by moving the location of the dendrometer, then move the installation point to the nearest possible location free of such irregularities.
14. Clean the circumference of the tree (remove mosses, loose dirt and bark, etc.) and pull lianas away from the bark at the dendrometer installation location.
15. Measure the diameter at the dendrometer installation location using diameter tape, and record on the datasheet.
16. Measure the height of the dendrometer installation point using measuring tape, and record on the datasheet.
17. Choose the spring and window size appropriate for the measured diameter and tree condition at the installation point:
 - a. $Dbh < 100$ mm, small (38 mm) spring
 - b. $100 \text{ mm} < dbh < 500$ mm, medium (76 mm) spring
 - c. $Dbh > 500$ mm
 - i. If there will be spaces between the band and the tree trunk in some areas, use medium (76 mm) spring.
 - ii. If the band will be in contact with the bark all the way around the tree, use large (127 mm) spring.
18. Construct a metal band dendrometer of the appropriate size, punching holes and cutting windows as directed below. *Note that dcm refers units of cm on diameter tape; thus each dcm = 3.14 cm.*



19. Attach one end of the spring to the middle of the band.
20. Put the band around the tree at the dendrometer installation point; attach the other end of the spring to the hole at the end of the band.
21. Check that the band is level and goes under lianas and epiphyte roots, and adjust it if necessary.
22. Make that throughout the area where the band is doubled, it sits snugly against the trunk (that is, there are no air spaces between the band and the trunk in this area). Rotate the band around the trunk if necessary.
23. Carefully take up slack in the band as much as possible so that the band sits tightly around the trunk.
24. Use the digital calipers to measure the distance between the end of the window and the trail end of the band (the actually exposed window). See figure 2 below. Record on the datasheet. (Make sure the caliper is set to read in mm.)

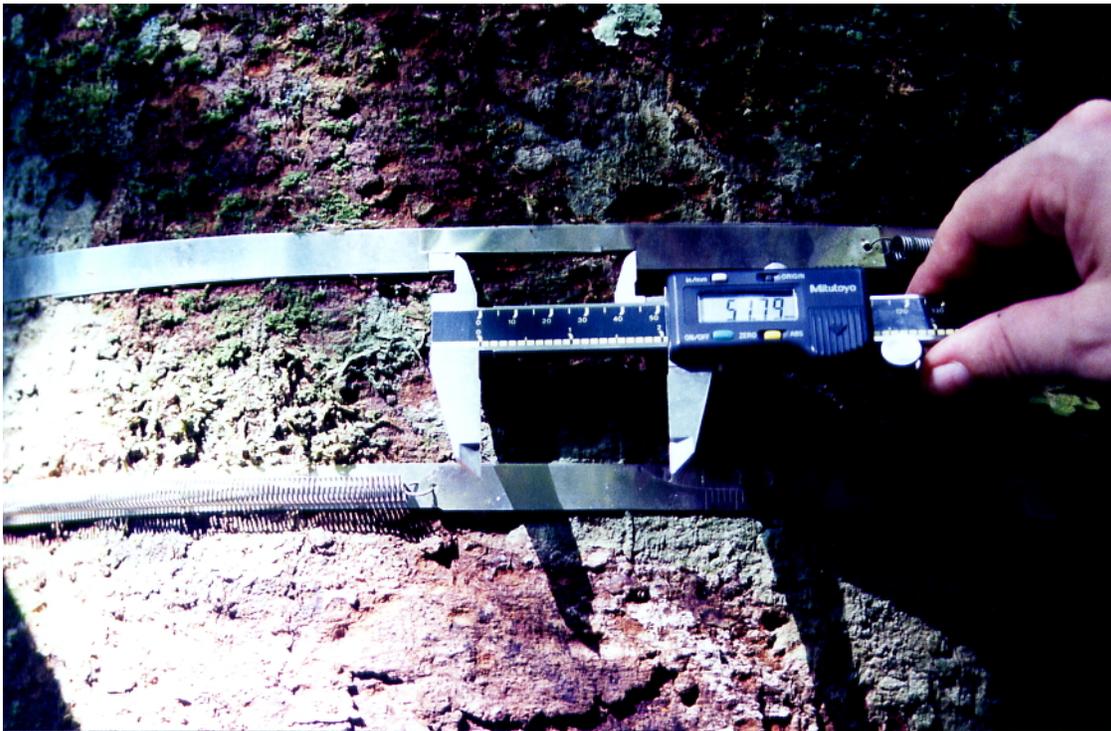


Figure 2: Picture of two band dendrometers (one above the other), and measurement of the window size of one of the dendrometers with calipers.

Dendrometer Remeasurement

The band dendrometers will tend to underestimate growth in the initial period after installation, as it will generally take some time for the band to “settle”, essentially taking up slack. To determine when reliable measurements can begin, it is advisable to remeasure a subset of the dendrometers (perhaps 100) monthly for the first 6-12 months. Remeasurements of the full set can commence 3-12 months after installation, depending on tree growth rate and other factors. Bands should subsequently be remeasured at least once a year, and preferably twice a year. See the Dendrometer Overview document for additional notes on scheduling remeasurements.

When a tree is remeasured, the following procedure should be followed:

1. Locate the designated tree using the information on the maps and datasheet.
2. If the tree is dead or presumed dead (missing), record this under notes using the usual plot codes (see 2 under *Preliminary Observations*).
3. Examine the stature and condition of the tree; record any special cases under “Notes” on the datasheet (see 3 under *Preliminary Observations*).
4. Assess and record the crown condition of the tree using the standard categories listed in 4 under *Preliminary Observations*.
5. Evaluate and record the crown illumination index (CII) of the tree using the standard categories listed in 5 under *Preliminary Observations*.
6. Locate the current paint-marked diameter measurement point, and measure the diameter there with diameter tape.
7. Evaluate if the current measurement point is suitable for continued measurements with a diameter tape over the next year. If it is not, choose a new measurement point, measure the diameter there, paint-mark that measurement point, and measure its height (see 7-11 under *Diameter Measurements* above for procedures in evaluating existing measuring points and choosing new ones). Note that diameter should be measured at the old measuring point regardless.
8. Evaluate the state of the band dendrometer:
 - a. If the dendrometer has shifted, this should be recorded in the notes column, and the dendrometer should be returned to a horizontal position and tightened around the tree as much as possible.
 - b. If the spring on the dendrometer is fully extended or close to fully extended (such that it is likely to become fully extended in the following year), then this should be recorded in the notes column. In this case, the old dendrometer should be measured and a new dendrometer installed.
 - c. Any other problems with the dendrometer should be recorded in the notes column.
9. Measure the window on the old dendrometer with calipers and record the measurement.
10. If a new dendrometer is to be installed, then follow instructions under *Dendrometer Installation* earlier in this document.

Specifications and Suppliers for Materials

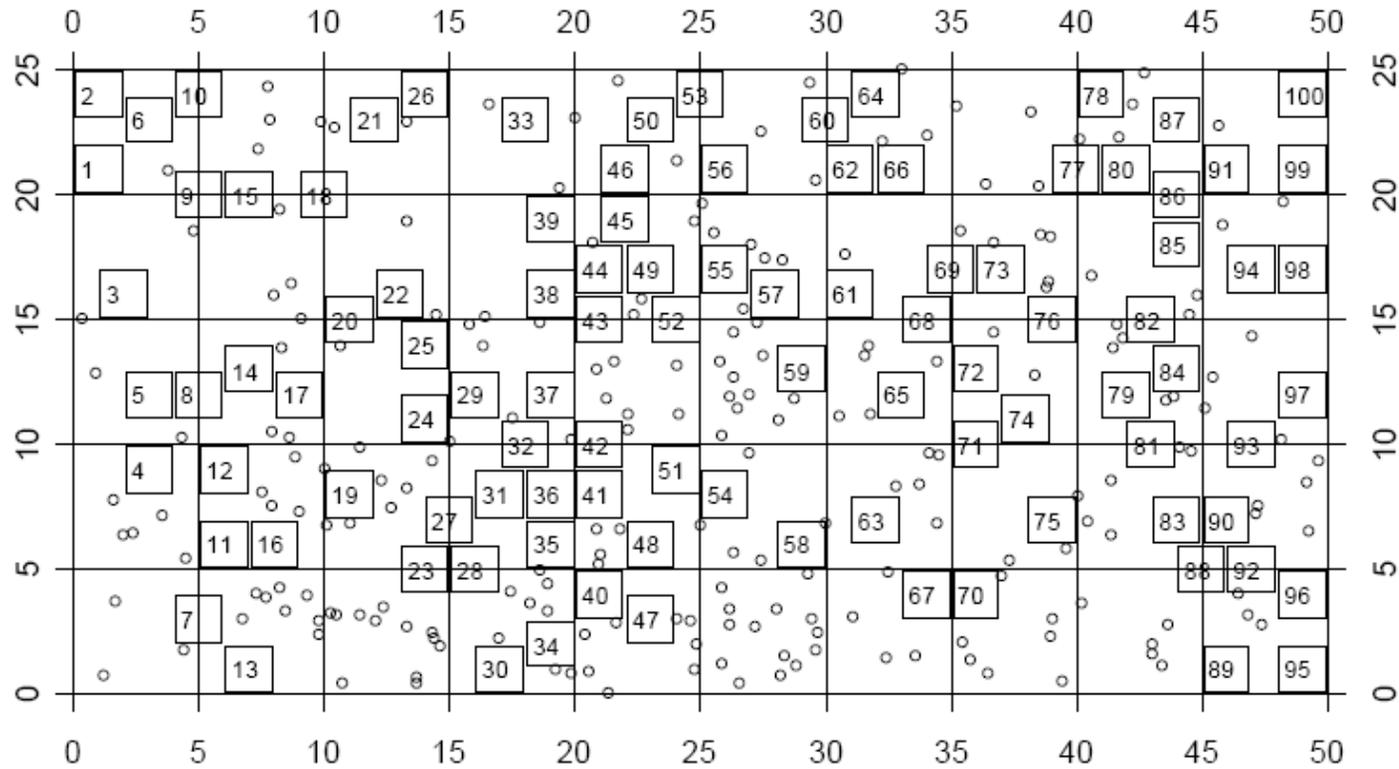
1. **Diameter measuring tape** (1 per person). Should use same kind used for regular census at the site.
2. **Wooden stick 1.4 m long, with marks at 1.0, 1.1, 1.2, 1.3 and 1.4 m** (1 per person)
3. **Ladder** (1 per team). We use a simple 3-m tall ladder on BCI. In plots where trees do not have buttresses, a ladder may be unnecessary. On plots where buttresses are rare, it may be better to simply go to all trees with buttresses as a separate campaign after covering all the other trees.
4. **Clipboard and datasheets** (1 per person)
5. **Permanent marker** (1 per person)
6. **Tree marking paint** (sufficient for painting measuring point on each tree to be censused). On BCI, we use a non-toxic blue paint suitable for outdoor use and purchased locally. There is no need to go with specialized “tree marking paints” sold by companies such as Forestry Suppliers (and indeed, not only are these more expensive, but it can take a very long time to ship them because they are considered hazardous materials).
7. **Small container and brush for paint** (1 per person; nail polish bottles work well). Specifically, we buy nail polish bottles, empty them of polish, and refill them with paint. We have found that a ketchup disperser bottle works well for holding the paint and adding it to the nail polish bottles.
8. **Heavy-duty lever hole punch** (1 per person). We ordered from mcmaster.com: Portable compact lever punch, cost \$54.74. Item # 3461A22. Portable Compact Lever Punch W/ Adj Throat 1.2 Tons Pressure, 1/4"-1-3/4" D Throat. Note that a regular hole-punch for punching holes in paper is not sufficient to punch holes in the metal banding.
9. **Digital calipers** (1 per person). We have been using Digimatic calipers ordered from forestry-suppliers.com, cost \$150, item #59601. Measuring range: 0 to 6"/0 to 150 mm. Accuracy: ± 0.001 " / .02 mm. Battery life (approx.): 2 years. We had problems with one of these malfunctioning after it became wet on a rainy day, so we recently ordered Mitutoyo Harsh Environment Electronic Caliper Number 500-672, 0-6" (0-150mm) Range from mcmaster.com for \$140. (These “harsh environment” calipers “have a sealed IP-rated housing, protecting them from water, coolant, dirt, and dust” which we hope will perform better under wet forest conditions.)
10. **Diameter measuring tape** (1 per person). Use the same model employed in the main census at the site.
11. **Snips/heavy-duty scissors** (1 per person). We have just purchased these locally. Heavy-duty office scissors work okay, but snips designed for use with metal work better.

12. **Stainless steel banding** (length equal to tree circumference plus 8-20 cm per tree on which band dendrometers are to be installed, depending on tree size – see below). We have been using stainless steel banding that is 1.27 cm (0.5 inches) wide and 0.127 mm (0.005 inches) thick, which is sold as embossing tape in rolls of 6.4 m (21 feet). We buy this from mcmaster.com, item # 1598T62, \$3.75 per roll for 10 or more rolls.
 - a. Note: It is also possible to use thicker stainless steel banding that is 0.254 to 0.381 mm thick, at least for the larger trees. Indeed, this may be the preferred material for larger trees. In this thickness, stainless steel banding is commonly used for strapping street signs onto poles, and is available in rolls of 100 feet or more. We purchased some from keyesdavis.com; however, we found it more awkward to work with because of the larger rolls.
13. **Stainless steel springs** (1 per tree on which band dendrometers are to be installed; length of 38 mm (1.5 inches), 76 mm (3 inches) or 127 mm (5 inches) depending on tree size – see above). Other specifications of the springs:
 - a. Material: stainless steel (type 304, if there is a choice)
 - b. Wire thickness: 0.66 mm (0.026 inches)
 - c. Outside diameter of spring: 0.64 cm (0.25 inches)
 - d. End style: Machine
 - e. End type: Hook (if you need to specify the size of the gap, make it 0.25 cm = 0.1 inches)
 - f. Relationship of ends: Random
 - g. Finish: Plain or Passivate (if you need to specify this)

We ordered 38 mm and 76 mm springs from Lee Springs, leespring.com, who provided these quickly as standard production items (item # LE 026C 05 S for the 38-mm springs and item # LE-026C-11-S for the 76-mm springs). We ordered 127 mm springs from Gardner Springs, gardnerspring.com, and because these were made-to-order they were quite slow to be produced. It is possible to work with just the medium and small sized springs; indeed, we found that relatively few trees were really well-suited for the largest springs. In principle, longer springs allow for longer time before the dendrometer has to be replaced.

Sample Datasheets

BCI dendrometer subplot locations



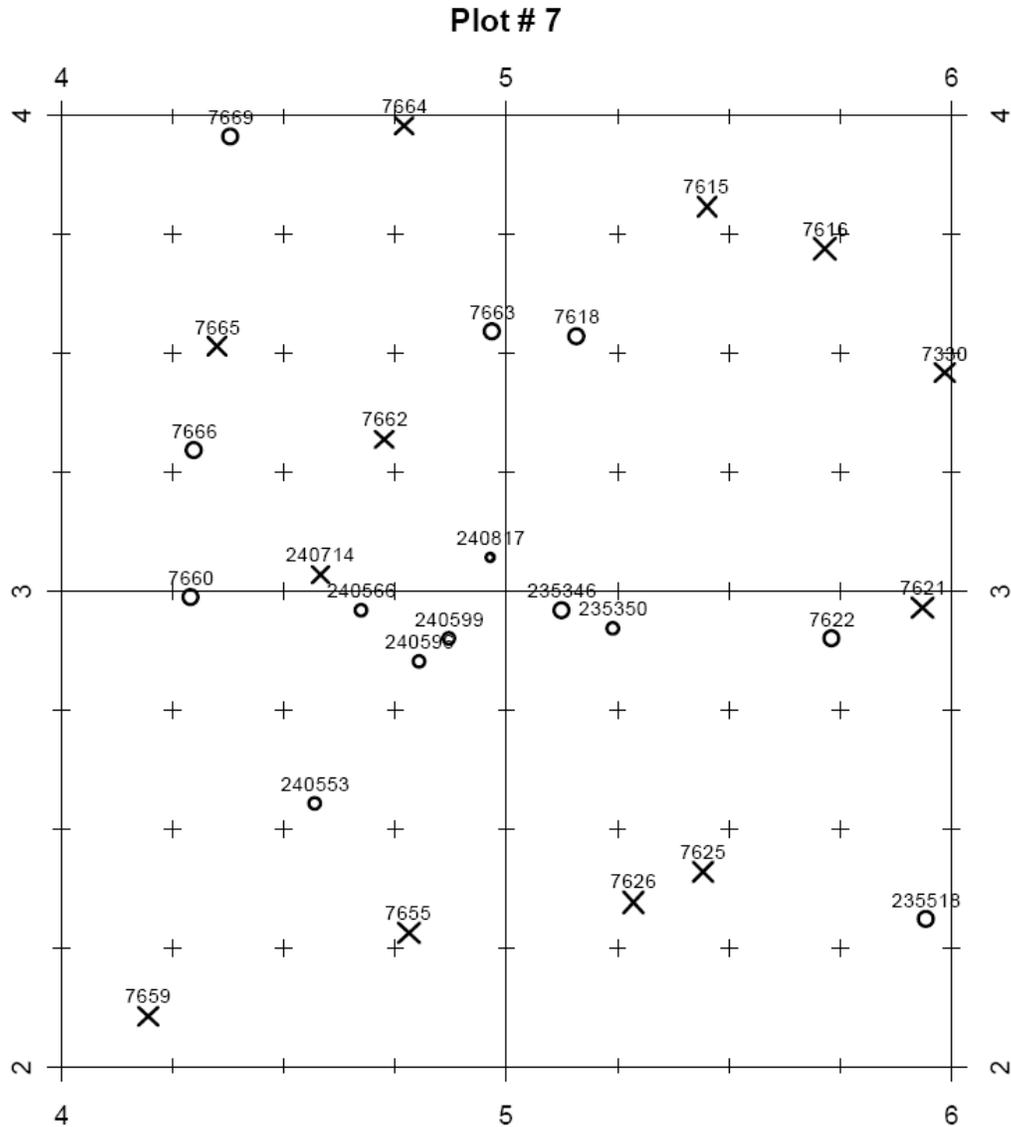
The locations of the randomly placed dendrometer subplots (squares with numbers inside), and of the large trees (>80 cm dbh) outside the subplots on which dendrometers are also to be installed (circles) on BCI. Note that dendrometer subplots can be regularly or randomly placed, depending on the site.

Technician Name _____

Day__ Month__ Year__

q20	lx	ly	dbh	species	tag	POM ht	codes	use	Crown condition	Crown illumination	New paint (Y/N)	Height paint (m)	Diam paint (mm)	Type dend (B/D)	Pos dend NESW	Height dendro (m)	Diam dendro (mm)	Measure dendro (mm)	Notes
402	3.9	2.1	625	TAB1RO	7659	4	B	yes											
402	5.8	19.7	453	TRI2TU	7660	1.3	*	yes											
402	11.4	11	225	ALSEBL	240553	1.3	*	yes											
402	13.5	19.2	218	POUTRE	240566	1.3	*	yes											
402	15.6	5.6	781	POUTRE	7655	3.2	B	yes											
402	16.1	17	202	TRI2TU	240596	1.3	*	yes											
402	17.4	18	182	TET2PA	240599	1.3	*	yes											
403	6	5.9	418	GUATDU	7666	1.3	*	yes											
403	7	10.3	429	VIROSU	7665	3.8	B	yes											
403	7.6	19.1	428	QUARAS	7669	1.3	*	yes											
403	11.6	0.7	362	DIPTPA	240714	2.7	B	yes											
403	14.5	6.4	421	TAB2AR	7662	3.5	B	yes											
403	19.3	1.4	80	APEIME	240817	1.3	*	yes											
403	19.4	10.9	425	AST2GR	7663	1.3	*	yes											
403	15.4	19.6	413	QUARAS	7664	2.95	B	yes											
502	2.5	19.2	263	TRI2TU	235346	1.3	*	yes											
502	4.8	18.4	175	VIROSE	235350	1.3	*	yes											
502	5.7	6.9	696	GUAPST	7626	3.95	B	yes											
502	8.8	8.2	605	ALSEBL	7625	4.24	B	yes											
502	14.6	18	462	PRI2CO	7622	1.3	*	yes											
502	18.9	6.2	365	GUATDU	235518	1.3	*	>=400?											
502	18.7	19.3	750	BROSAL	7621	5.2	B	yes											
503	3.2	10.7	445	PRI2CO	7618	1.3	*	yes											
503	9	16.2	486	APEIME	7615	3	B	yes											
503	19.7	9.2	537	BEILPE	7330	3	B	yes											

Sample dendrometer installation datasheet (with data from subplot #7 on BCI).



Sample map of a dendrometer subplot (corresponding to the sample datasheet). Circles mark trees measured at 1.3 m height, x's mark trees measured higher. The numbers on the axis give the 20x20 plot coordinates, with 20x20's delineated by lines, and the 5x5's by plus signs (+). The numbers above the circles and x's give the tree tags.