

# Plastic 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 with paint and brush (1 per person; nail polish bottles work well)
8. Plastic banding (length equal to tree circumference plus 35 cm per tree)
9. Seals (2 per tree)
10. Seal tightener compatible with banding and seals (1 per person)
11. Scissors (1 per person)
12. Stainless steel springs (1 per tree)
13. Digital calipers (1 per person)

*Figure 1: Plastic banding (black and yellow), springs of two sizes, seals, and a seal tightening tool. One spring size and banding color is normally sufficient.*



**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 2):
  - 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)

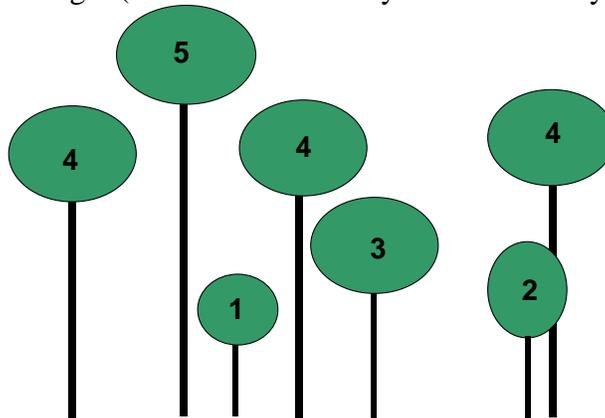


Figure 2. Examples of trees having different values of the crown illumination index.

**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.

**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. Construct and install a plastic band dendrometer of the appropriate size. *Note that all measurements are in dcm, i.e. units of cm on diameter tape (1 dcm = 3.14 cm).*
  - a. Cut a length of banding equal to  $c + 4t + 6.5$  dcm, where  $c$  is the circumference of the tree,  $t$  is length of a metal seal, and  $s$  is length of spring when not stretched (Figure 3).
  - b. Attach the seal to folded over banding as shown in Figure 3 (see Figure 4 for an image of the finished product). Note that the loops to attach the spring should be approximately 0.5 dcm long, the shorter tail should be  $s$  long, and the longer tail should be 6 dcm long.
  - c. Cut a small notch 1dcm from the seal in the longer tail (Figure 3). The depth of the notch should be approximately 10 % of the width of the band and the side closer to the seal should be cut vertically.
  - d. Cut the corners of the loops to enable attachment of the spring (Figure 4).
  - e. Install the dendrometer so that the notch is on the bottom.
  - f. Check that the band is level and goes under lianas and epiphyte roots, and adjust it if necessary.
  - g. Make sure 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.
  - h. Carefully take up slack in the band as much as possible so that the band sits tightly around the trunk.
  - i. Check that the spring is a little bit stretched (approximately 0.5 dcm longer than its resting length) and that the distance from the notch to the tip of the shorter tail is approximately 0.5 dcm.
  - j. Optional – Paint the seals and the bark of the tree above and below the seals. This makes it easy to see if there is any change in the location of the band, and can be used to camouflage the band (and protect it from theft) if the paint is similar in color to the bark.
18. Use the digital calipers to measure the distance between the end of the shorter tail and the notch (Figure 5). Place both blades of the caliper so that they touch the tree bark. Record on the datasheet. (Make sure the caliper is set to read in mm.)

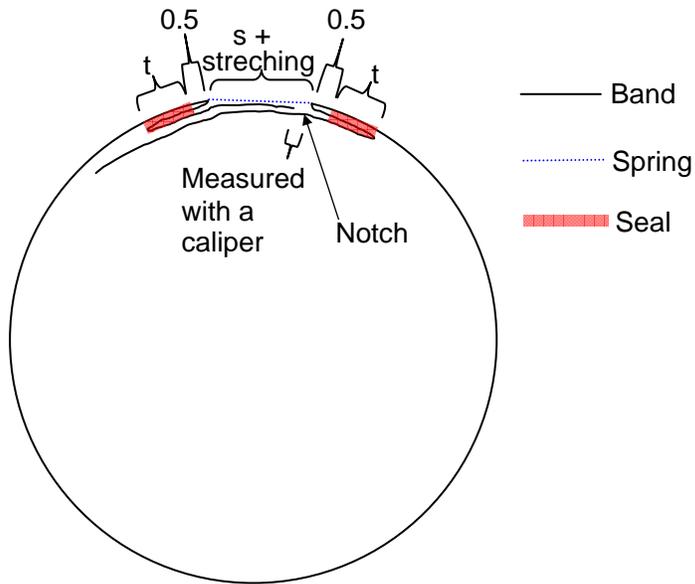


Figure 3. Schematic representation of a plastic dendrometer installed around a tree seen from above. “s” stands for spring and “t” for seal.



Figure 4: Plastic dendrometer installed on a tree. Note that the seals look quite different when fastened. The spring is attached between folded over parts of bands, with both ends of each fold cut. The notch in the lower band and the free end of the upper band are both visible beneath the spring.



Figure 5: The caliper measurement is made along the lower side of the band, extending from the notch on the bottom band to the free end of the upper band.

### **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 the Materials**

*Note: Sample springs, plastic banding, and seals are available from CTFS upon request. These can be useful in obtaining and evaluating locally available materials. The plastic banding in particular is available in different sizes and composition, and not all banding is suitable for use with dendrometers.*

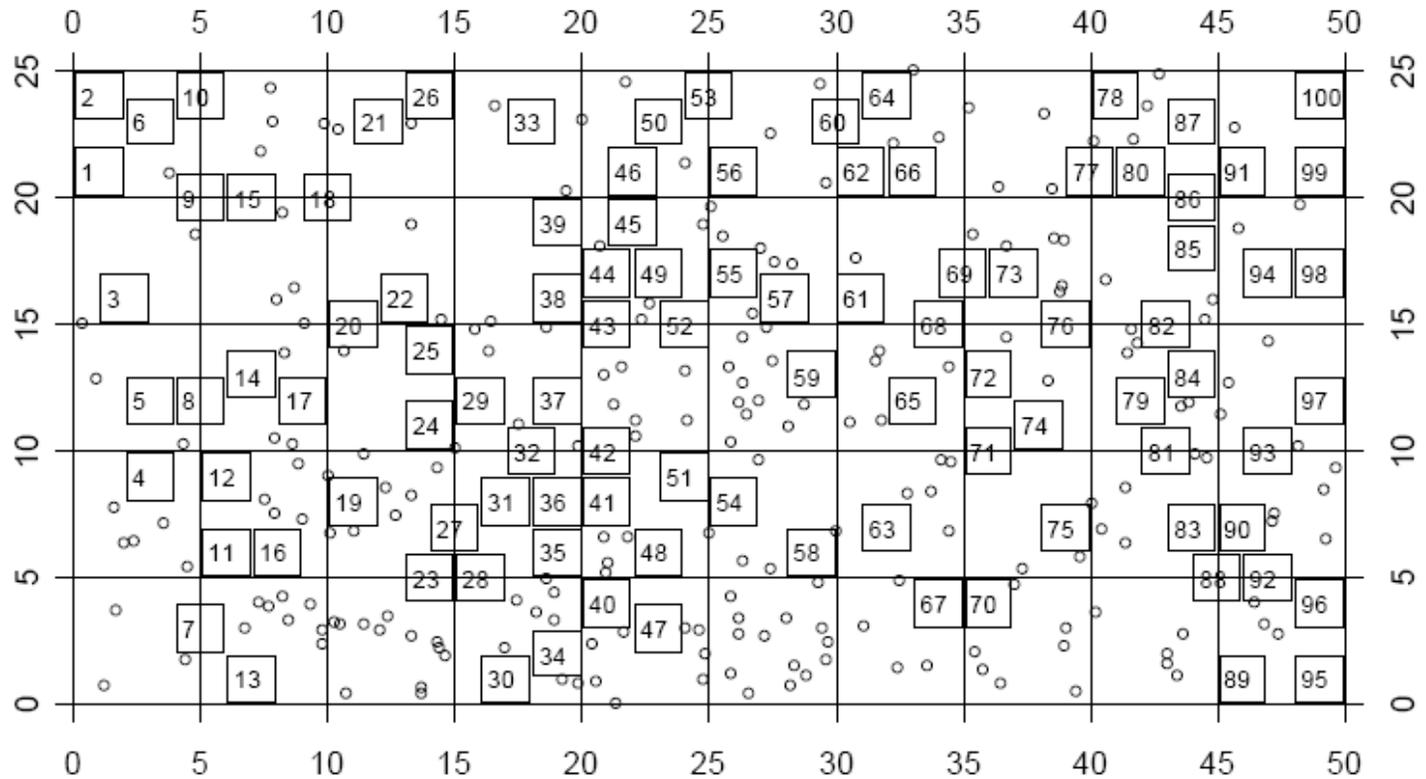
1. **Diameter measuring tape** (1 per person). Should use same kind used for regular census at the site.
2. **Wooden stick 1.4 m long, with marks at 1.0, 1.1, 1.2, 1.3 and 1.4 m** (1 per person)
3. **Ladder** (1 per team). We use a simple 3-m tall ladder on BCI. In plots where trees do not have buttresses, 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**. On BCI, we use a non-toxic blue paint suitable for outdoor use and purchased locally. There is no need to purchase specialized “tree marking paint” 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 with paint and brush** (1 per person; nail polish bottles work well). Specifically, we buy nail polish bottles and refill them with paint. We have found that a ketchup dispenser bottle works well for holding the paint and adding it to the nail polish bottles.
8. **Plastic banding** (length equal to tree circumference plus 35 cm per tree). In general, narrower banding (15 mm wide or less) is preferable. In areas where theft, vandalism, or aesthetics is a concern, banding that is closer in color to that of the tree bark is preferable. In areas where these are not a concern, banding in a contrasting color may be preferred as banded trees can be located more quickly for field work on remeasurements.
9. **Seals** (2 per tree). Ideally they should be 25 mm or shorter especially if trees
10. **Seal tightener** (1 per person). Needs to be compatible with the banding and seals. Should be as small as possible to facilitate transportation. Need to be compatible with the banding and sealer and should therefore all three should preferably be bought from the same dealer. These are very common packaging material and can be purchased from dealers around the world. For example transpack.co.uk is selling these under the heading “PP Strapping and accessories 12mm”.
11. **Scissors** (1 per person). These are for cutting the plastic banding. Heavy-duty office scissors work well.
12. **Stainless steel springs** (1 per tree). *It is very important that the springs be made of stainless steel, to prevent corrosion.* The springs should be approximately 6 cm long when not extended, have wide hooks suitable for connecting to the plastic banding, and have the capacity to be stretched to at least 20 cm without breaking. Two or more different size springs can be used for different size classes

of trees if desired (in particular, smaller springs are advantageous for use on trees less than 10 cm in diameter). We have tested extension springs LE 031D 09 S from leespring.com and they have been appropriate.

13. **Digital calipers** (1 per person). We have been using 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" and have been performing without malfunctioning.

**Sample Datasheets and Maps**

**BCI dendrometer subplot locations**



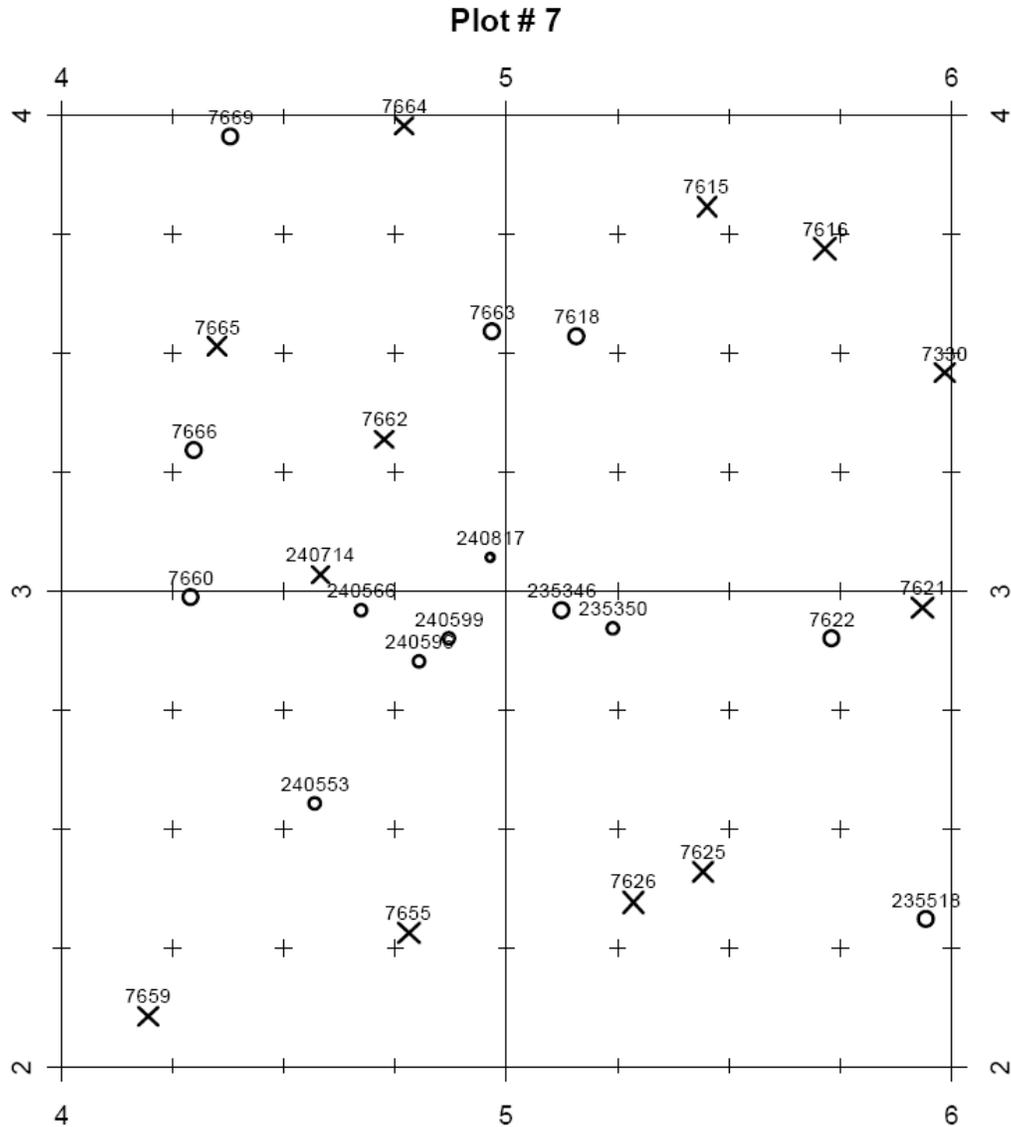
*The locations of the randomly placed dendrometer subplots (squares with numbers inside), and of the large trees (>80 cm dbh) outside the subplots on which dendrometers are also to be installed (circles) on BCI. Note that dendrometer subplots can be regularly or randomly placed, depending on the site.*

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.*