

# **Litterfall Monitoring Protocol**

CTFS Global Forest Carbon Research Initiative

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**Materials for trap construction, monitoring, and maintenance****Supplies required for construction of 1 trap station**

1. PVC piping for the aboveground trap (note – for all piping for litter traps, use the type of PVC designed for pressurized water lines not the type for electrical conduit, and use piping with an outer diameter of 15 mm (or 0.5 inches=12.7 mm)
  - a. Standard design (requires no “right angle outs”, which are harder to find)
    - i. 6 m of PVC pipe. Ideally this is precut into
      1. 2 pieces 1.6 m long (for 4 legs, cut to fit in field) and
      2. 8 pieces sized so that 2 pieces connected by a T and with elbows on the end measure 70.7 cm from pipe center to pipe center; see Figure 2 (depending on the type of PVC, the necessary length can vary from 32-34.5 cm)
    - ii. 4 PVC “tees”
    - iii. 4 PVC “elbows”
  - b. Alternative design (somewhat more stable, but requires “right angle outs”)
    - i. 6 m of PVC pipe cut into
      1. 2 pieces 1.6 m long (for 4 legs, cut to fit in field)
      2. 4 pieces sized so that a piece with right angle outs on the ends measures 70.7 cm from pipe center to pipe center (depending on the PVC, 66 - 69.5 cm long)
    - ii. 4 PVC “right angle outs” (a right angle out joins three pieces of PVC pipe to make the corner of a cube)
2. PVC piping for the ground trap (as above, 15 mm or 0.5 inches, for water lines):
  - a. 2.8 m of PVC pipe, cut into 4 pieces sized so that a piece with elbows on the ends measures 70.7 cm from pipe center to pipe center (67-69.5 cm)
  - b. 4 PVC “elbows”
3. Two 1-m pieces of 6 mm (0.25 inches) rebar (concrete reinforcing bar) (to anchor aboveground trap)
4. Something to secure the ground trap
5. One 122x122 cm (4x4 feet) piece of window screen (with a mesh size of 1.2 mm)
6. 4 m of telephone wire or plastic-and-metal twist tie material, cut into 20 20-cm pieces (for tying window screen to PVC frame)
7. Four durable cloth bags each about 80 cm deep and 40 cm wide, ideally two of one color and two of another (see Fig. 1).
8. Optional: fluorescent orange (or other brightly colored) spray paint (for painting the PVC pipe of the ground trap, to make it more conspicuous)

**Total supplies required to construct and maintain 100 trap stations for 4 years**

1. Supplies for construction of 112 trap stations (see above)
2. An additional 120 122x122 cm pieces of window screen (mesh size 1.2 mm) (more or less may be needed depending on climate)
3. An additional 100 m of wire, for repairing damaged window screens with patches

Equipment required for trap construction and maintenance

1. Saw or tool for cutting PVC pipe (must have one that is portable for use in field to cut legs to fit)
2. Hammer for driving rebar into ground
3. Bubble level – to check that the aboveground traps are level and to measure slope
4. Measuring tape to measure slope
5. Wire cutters for cutting wire
6. Permanent markers for marking trap numbers on PVC and on cloth bags
7. Scissors – for cutting window screen into patches for repairing damaged screens

Equipment required for collecting, drying and sorting litter

1. Heavy-duty clippers for cutting large leaves, palm fronds and branches up to 20 mm in diameter
2. Measuring tape or ruler 50 cm or longer, or a custom-cut 50-cm long piece of wood
3. Dial calipers
4. Clipboard and pen or pencil.
5. One plant dryer (for pre-drying sopping wet litter)
6. One large drying oven set at 65 C for at least three days after each collection (ideally located within an air-conditioned laboratory because the oven will last longer)
7. Four plastic bowls 30-40 cm in diameter (see Fig. 1)
8. One electronic balance accurate to at least 0.1 g
9. Filter mask (to wear while sorting dried litter – see Fig. 1)



Figure 1. Left: Omar Hernandez with cloth bag for collecting and drying litter and mask to wear while sorting litter. Right: Plastic bowl used for sorting litter and balance used for weighing litter.

### General considerations on trap design

All traps must have the specified size and shape (70.7 cm by 70.7 cm from the top of the pipe on one side to the top of the pipe on the other side, for a total area of 0.5-m<sup>2</sup>) for several reasons. First, the chance that larger leaves and pieces of fine wood (< 20 mm diameter) are sampled in above-ground traps varies with trap size and shape. Second, seed and fruit fall varies widely over very short distances (consider the behaviors of frugivores that disperse seeds). Third, experiments on BCI show that squirrels and other small arboreal vertebrates are much less likely to remove seeds and fruits from 0.5-m<sup>2</sup> traps than from smaller traps. Thus, comparisons of fine litter production among CTFS sites depend crucially upon all sites having traps of the same size and shape.

Above-ground litter trap design must meet three crucial criteria. The first is a fixed level surface (verified with a bubble level) to catch falling material. If the surface varies from level, the effective surface area is reduced by a variable amount. For this reason, traps must be rigid. The second criterion concerns the actual surface that catches and holds litter. Litter must not blow out, water must drain away, and ‘small’ particles must be retained. The final criterion is that traps must be tall enough to prevent heavy rain from splashing soil onto the captured litter. The trap design we describe here meets these three criteria. It is now in use at BCI, Luquillo, Pasoh and Yasuni, and has been proven to work well in tropical forests over the long term (the BCI study has been running for 20 years).

Ground litter traps are designed to collect large leaves and fine wood > 50 cm long. This is done because branches, palm fronds and other large leaves are often larger than above-ground litter traps and therefore slide off above-ground traps. Because different CTFS sites vary in the abundance of palms and large-leaved species, this sampling bias would lead to biased estimates of differences in litterfall among sites if above-ground traps alone were used. The ground litter trap design described here is a variation on a design uses at multiple tropical forest sites as part of the TEAM initiative of Conservation International.

### Construction of above-ground traps

Each above-ground litter trap consists of a 0.5-m<sup>2</sup> surface of window screen suspended 80 cm above the ground from a square frame (70.7 x 70.7 cm) constructed of polyvinyl chloride (PVC) pipe.

For the standard design (requiring no “right angle outs”), each side of the PVC frame is constructed by gluing two short (32-35 cm) pieces of PVC pipe together using one PVC “tee” (Fig. 2A). The square frame is completed by gluing four identical sides together using the four PVC “elbows” (Fig. 2B). The legs are glued into the third outlets of the PVC “tees” midway along each side of the square frame (Fig. 2C) – but these should only be glued into place at the permanent location of the trap in the forest.

For the alternative design, the top of the trap is a square consisting of four long (67-70) cm long pieces of PVC pipe and four PVC ‘right angle out’s glued together (Fig. 3). The legs are glued into the third outlet of the PVC “right angle outs”, but only once the trap is in its permanent location.

At the permanent trap location, the legs are cut to fit and glued into the traps, and the trap is installed on top of rebar driven into the ground. The legs should only be glued into place at the permanent location of the trap in the forest because each leg must be

tailor cut when traps are located on slopes. The square frame must be level, and this can be achieved by cutting a shorter leg on the uphill side and a longer leg on the downhill side. The following procedure works well on slopes: First, take two legs of 0.8 m length, connect them to opposite sides or corners of the trap, and place them on the ground such that they are level with each other. This leaves one place for a leg uphill of these two, and one place downhill. Second, cut the remaining 1.6-m piece of PVC into two unequal portions that are sized to match the height of the trap above the ground on the uphill and downhill sides of the trap. To insure that traps stay upright and in the same place, drive two (or four) pieces of concrete reinforcing bar (rebar) into the ground and place opposite (or all) legs of the trap over the exposed rebar (Fig. 2D). For traps on slopes, the two supporting pieces of rebar are placed under the two level legs of the trap. On very steep slopes the total length of all legs is longer than the standard for flat areas.

The window screen that catches and holds falling litter can be installed as late as two weeks before the first biweekly litter collection. We use short pieces of wire to tie a 122 cm by 122 cm (four feet by four feet) piece of window screen to the square PVC frame (Fig. 2E). (It is also possible to use cable ties to attach the window screen, but Standard plastic coated, fiberglass window screen has a suitable mesh size of about 1.2 mm. The 122 cm by 122 cm window screen hangs down inside the 70.7 cm by 70.7 cm frame so that collected litter does not blow out.

The number of each trap should be written on the top PVC pipe that will first be seen by a technician approaching the trap using a black permanent marker. The number should be followed by "A" to designate above-ground. For each aboveground trap, two cloth bags (ideally of different colors) are permanently numbered (using the permanent marker) with the trap station number followed by "A".

### **Construction of ground traps**

Ground litter traps, like above-ground traps, should be square with 70.7 cm sides (0.5 m<sup>2</sup> surface area). Ground litter traps should be constructed with four long (67-70 cm) pieces of PVC pipe and four PVC 'elbows' glued together. Small holes should be drilled in two opposite elbows of the trap for the metal stakes that will hold the trap to the ground. It is useful if ground litter traps are painted fluorescent orange to facilitate finding them under fallen litter. Each ground litter trap is placed directly on the ground 2 m from a paired above-ground trap. Each ground trap is marked with the number of the trap station plus the letter "G" to designate ground trap using the permanent marker.

For each ground trap, two cloth bags (ideally of different colors) are permanently numbered (using the permanent marker) with the trap station number followed by "G".

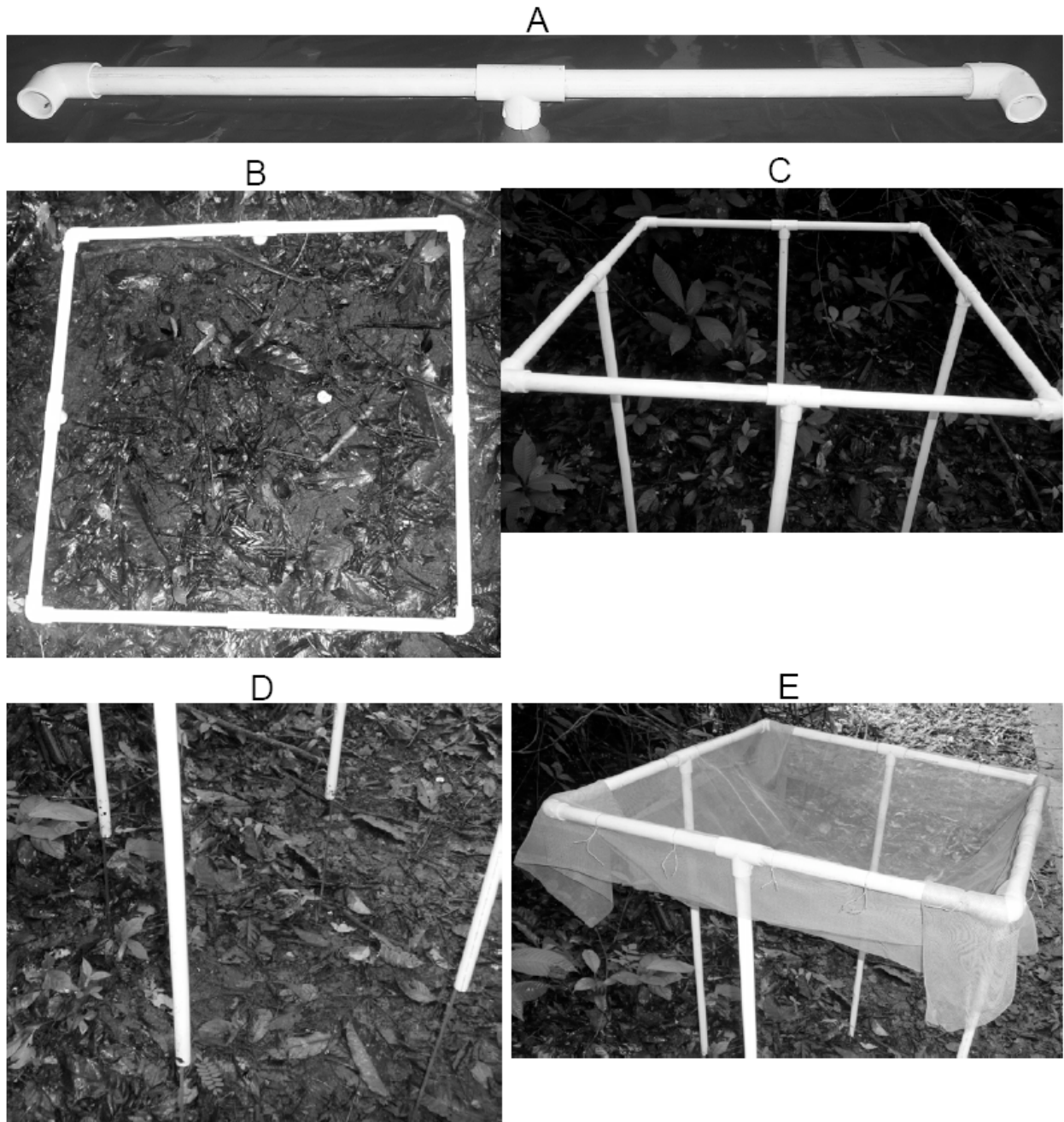


Figure 2. Construction of standard design above-ground litter traps. A. Each side is constructed by gluing two short (32-35 cm, depending on type of PVC) pieces of PVC pipe together using one PVC “tee”. B. The square frame is completed by gluing four identical sides together using the four PVC “elbows”. C. In the field, legs averaging 0.8 m long and cut to fit local terrain are glued into the third outlet of the PVC “tee”. D. Four pieces of concrete reinforcing bar (rebar) are driven into the ground leaving 50 cm above ground, and the legs of the traps are placed over the exposed rebar. E. A 122 cm by 122 cm (4 feet by 4 feet) piece of window screen is tied to the square PVC frame using short pieces of wire, with the window screen hanging down inside the frame so that collected litter does not blow out.



Figure 3. The alternative aboveground trap design, which requires “right angle outs” at the trap corners.

### **Installation of litter traps**

A pair of litter traps (one above-ground, and one ground) should be installed as close to the center of each dendrometer subplot as is feasible given vegetation, trails, and topography.

#### **Installation of above-ground traps:**

1. These should be placed at the coordinates corresponding to the exact centers of the dendrometer subplots, if possible. If trees, other plants, trails, or other factors make it impossible to place the trap there, then move it to the closest possible location.
2. To install the trap, first drive the rebar into the ground to anchor the trap legs.
3. Next cut the trap legs such that the trap is exactly level and the top of the trap is on average 80 cm above the soil surface. *It is very important that the trap be level, as any tilt will change the effective surface area!* It is also very important that the trap is at least 80 cm above the soil so that rain does not splatter soil into the trap.
4. Finally assemble the rest of the trap.
5. Record the coordinates of the center of the trap to within 0.1 m, the reason for moving it if this was necessary, and the tag numbers of all trees overhanging the trap.



Figure 4. Measuring the slope of a ground trap.

#### Installation of ground traps:

1. Each ground litter trap is placed directly on the ground 2 m (measured from the nearest side of each trap) from a paired above-ground litter traps and in a randomly chosen direction. Where the ground is sloped, the trap should follow the contours of the ground and also be sloped.
2. If tree trunks, tree roots greater than 10 cm high, other plants or trails make it impossible to place the trap there, move it to the closest possible location that is 2 m from the above-ground trap. Record the reason for moving the trap if this was necessary.
3. To install the trap, stake it to the ground using the metal stakes through the 2 holes at opposite ends of the trap.
4. Record the coordinates of the center of the trap to within 0.1 m.
5. Measure the slope of the trap with a bubble level and PVC pipe kept horizontally and a measuring tape kept vertically. Record the vertical distance.
6. Note the trees overhanging any part of the trap, and record their tag numbers.

#### Maintenance of litter traps

Holes develop in the window screen over time. Small holes should be patched as soon as they appear using small bits of window screen and additional wire. As the window screen develops more and larger holes, the entire screen should be replaced. On BCI, window screens are replaced on about 25% of litter traps each year. The rate at which screens need to be replaced is likely to vary among sites; some sites may need to replace screens more frequently. Screens are replaced less frequently at Pasoh and Yasuni

The trap numbers written on the traps will also fade over time and need to be rewritten approximately annually. Algae will also cover the trap numbers, which should be kept visible.



In addition, falling trees or branches may occasionally knock over an above-ground trap and break part or all of the PVC frame of an above-ground or ground trap. Such traps should be repaired immediately and reinstalled in their original locations, or in the nearest possible location if debris makes placement in the original location impossible (any change of location, and the date of the change, should be recorded precisely). On BCI, 1-2% of traps need to be replaced each year. To enable a quick response when such events occur, materials sufficient for construction of at least 2 extra traps, and pre-cut into the right sizes, should be kept on hand at all times.

**Field methods for litter trap monitoring****Materials to take to the field**

1. A set of cloth bags, one for each ground trap and one for each above-ground trap, each marked with the trap number and code (A or G).
2. Heavy-duty clippers for cutting large leaves, palm fronds and branches up to 20 mm in diameter where they overlap the edges of ground traps.
3. Measuring tape, ruler, or simply a custom-cut 50-cm long piece of wood to evaluate whether items are longer than 50 cm or not.
4. Plastic dial calipers to evaluate whether and where branches are 20 mm in diameter.
5. Supplies for patching minor damage to window screen in aboveground traps: small patches of window screen and wire
6. Clipboard, datasheets and pen or pencil for recording problems with traps, and for recording new tree falls and branch falls in the subplots in which the traps are located.

**At each above-ground trap**

1. Assess whether the trap is in good condition for collecting litter. Specifically check for the following problems:
  - a. Holes: The window screen has any hole large enough to allow litter to pass through. Some judgment must be used. A small will allow small seeds to pass through, larger holes will allow leaves to pass through, and a hole near the lowest point of the wire mesh is worse than a hole high on the side of the mesh. The trap contents should not be collected if a hole might have allowed leaves to pass through. All holes should be repaired immediately or the entire wire mesh might be replaced.
  - b. Blocked: The trap is blocked by a large fallen object such as a palm frond or very large leaf, which can block and redirect subsequent litter fall away from the trap.
  - c. Tilted: The trap is tilted enough to substantially change the effective trap surface area. Animals and falling branches sometimes tilt traps changing the effective surface area (although this rarely happens when trap legs are mounted on concrete-reinforcing bars as described above).
  - d. Broken: The trap is in pieces. Falling trees or branches sometime obliterate traps entirely.
2. Record the condition of the trap on the datasheet (Good, Holes, Blocked, Tilted, Broken).
3. If the trap is not in good condition, the litter should be discarded, and the trap should be repaired. In the case of holes, blocked, or tilted the repair should happen immediately. Broken traps should be repaired or replaced as soon as possible using the extra trap supplies in the station.
4. If the trap is in good condition, litter should be collected:
  - a. Palm fronds, leaves, and small branches larger than 50 cm in length (measured directly from one end to the other) are discarded from the trap, as these are collected in the ground traps (they are not reliably captured in the above-ground traps).

- b. Woody branches are cut where their diameter is 20 mm, and the part with a diameter larger than 20 mm is discarded as it is defined to be woody debris.
- c. All other material in the trap including parts hanging out but not touching ground is transferred directly to the cloth bag marked with the same number and code (A) as the trap.



Figure 5. A knot is tied in the litter bag to prevent litter from coming out. (Note that this is preferred over using a bag with a drawstring, as closures with a drawstring can leave an opening through which material can be lost.)

#### At each ground trap

1. Assess whether the trap is in suitable condition for collecting litter. Specifically check for the following problems and record if present:
  - a. Treefall/Branchfall: A tree trunk or branch greater than 10 cm in diameter has fallen over the trap or close enough to it to block items from falling into the trap.
  - b. Broken: The trap has broken. In this case record what is needed to repair the trap.
2. If there has been a treefall or branchfall, then
  - a. Relocate the ground trap, following the same guidelines as under trap installation above. That is, move the trap to the closest possible location that is, if possible, approximately 2 m from the above-ground trap.
  - b. If you can relocate the trap, then record “Treefall” or “Branchfall”, “Trap relocated”, and “No collection” on the datasheet, and record the coordinates of the center of the trap in its new location.

- c. If the trap cannot be moved because it is trapped under the treefall or branchfall, then record “Treefall” or “Branchfall”, “No collection” and “Trap needs replacement” on the datasheet.
3. If the trap is broken but can be fitted together and positioned properly for litter collection, then proceed with litter collection. Otherwise record “No collection” on the datasheet and go to the next trap.
4. To collect litter from a ground trap:
  - a. Scan the trap for appropriate items, recalling that these traps are for collecting palm fronds, large leaves, and branches longer than 50 cm in length that are not reliably captured in the above-ground traps. (Note that branches whose diameter is greater than 20 mm in the entire area of the trap are not of interest.)
  - b. For each palm frond, large leaf, and appropriate branch that is longer than 50 cm in length, cut off parts that are outside the edges of the trap.
  - c. Cut each branch where its diameter is 20 mm, and discard the part with a larger diameter.
  - d. The remaining parts of palm fronds, large leaves, and small branches are transferred directly to the cloth bag marked with the same number and code (G) as the trap.

**Laboratory methods for litter trap monitoring**

Upon returning from the field, the cloth bags are placed directly into the drying oven if the litter is reasonably dry. If the litter is very wet at the time of collection, such that water is dripping from the bags, then the wet bags should first be placed in a plant dryer or hung from a clothesline to air dry before being transferred to the drying oven. (The placement of dripping wet bags of litter in the drying oven will shorten the lifetime of the oven considerably and could destroy the electronics in the oven immediately!). The material is dried in an oven at 65C until constant mass is attained (typically 72 hours or longer). Note that sorting and weighing should occur immediately after taking the material out of the oven, as the material will gradually take up water from the air (and increase in mass) if it is left in air with a relative humidity above 0%.

After drying, litter from the above-ground traps is separated into leaves (including petioles and rachis, as well as nonwoody tendrils), fine wood (< 20 mm in diameter, including bark and woody tendrils), reproductive parts (flowers, fruits, seeds and their supporting structures or pedicels), and other material (caterpillar frass, dust, dead insects, etc.). Epiphylls, mosses and fungi are not separated from leaves and wood. Petioles are included with leaves, and pedicels are included with reproductive parts. Bark is included with woody litter. Each of the separated samples is weighed to the nearest 0.1 g.

Dried litter from ground traps is separated into leaves and wood. Each of the separated samples is weighed. Any dirt should be cleaned off of these samples prior to weighing (this should not be necessary for aboveground traps, where mud is unlikely to splash on the litter). The wood sample is then returned to the oven (in a paper bag marked with the trap number and code) for another 24 hours and re-weighed and this is repeated until constant mass is attained (the weight is the same two days in a row).

Note that the number of cloth bags is double the number of traps to make it possible to store material for one collection cycle when necessary (electrical outages prevent drying, etc.). Ideally material should be dried as much as possible (at least in a plant dryer) before being stored, and then stored in a plant dryer, a refrigerator or at least in air conditioning, to reduce decay.

**Datasheet specifications for litter trap installation, collection, and contents**

The following pages show sample datasheets for litter trap installation, collection, and contents.

Technician \_\_\_\_\_

Tube length in cm (kept horizontally to measure slope) \_\_\_\_\_

above trap x	above trap y	ground trap x	ground trap y	date	trap number	final above trap x	final above trap y	final ground trap x	final ground trap y	slope (vertical distance in cm)	trees overhanging above trap	notes
20	20	18	20									
20	60	18	60									
20	100	18	100									
20	140	18	140									
20	180	18	180									
40	20	38	20									
40	60	38	60									
40	100	38	100									
40	140	38	140									
40	180	38	180									
60	20	58	20									
60	60	58	60									
60	100	58	100									
60	140	58	140									
60	180	58	180									
80	20	78	20									
80	60	78	60									
80	100	78	100									
80	140	78	140									
80	180	78	180									
100	20	98	20									
100	60	98	60									
100	100	98	100									
100	140	98	140									
100	180	98	180									

CTFS Carbon Litter Trap Installation

Technician: \_\_\_\_\_

Census Number \_\_\_\_\_

Trap number	Date	Aboveground trap notes	Ground trap notes	Treefall and branchfall notes
101				
102				
103				
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Technician \_\_\_\_\_

Census Number \_\_\_\_\_

Trap number	Date	Aboveground Leaves (g)	Aboveground Reproductive (g)	Aboveground Woody (g)	Aboveground Other (g)	Ground Leaves (g)	Ground Woody (g)
101							
102							
103							
104							
105							
106							
107							
108							
109							
110							
111							
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