Woody Debris Research Protocol:
Long Transects

CTFS Global Forest Carbon Research Initiative
Version November 2009

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Illustrative photos are included at the end of this document. You may want to exclude these photos when printing by printing only pages 1-12.

Introduction

The objectives of the these inventories of fallen CWD (coarse woody debris, diameter at least 200 mm) and FWD (fine woody debris, diameter 20 - 199 mm) in which samples are collected are (1) to contribute to the database used to calculate the total pool of woody debris in the plot and (2) to enable development of models that will be used to calculate dry mass of woody debris from data on diameters and penetrometer measurements taken in inventories without destructive sampling (as in the study of CWD dynamics). This inventory with destructive sampling is carried out on long transects that should not be used again for quantifying the amount of woody debris, as the destructive sampling will influence the amount of woody debris encountered in the line in subsequent years. This inventory can in principle be conducted without the companion study on "CWD dynamics", but the methodology has been optimized for their joint application.

The Excel workbook that accompanies this document contains relevant datasheets (please note that the workbook has several worksheets for different aspects of the work – see the "tabs" at the bottom of the page in Excel).

Sampling Design

The necromass of fallen woody debris is estimated using line-intersect surveys in which pieces of woody debris that intercept the transect are measured at the point where they cross the transect. If a given piece crosses the transect twice, it is measured at both intersections (Photo 2). The transects are all oriented parallel to one edge of a plot. In a 50 ha plot, the transects are speced 100m apart, with the first transect initially located 40 m from one border (Figure 1). In smaller plots, the transects should be spaced more closely to achieve the same total distance transect length (5 km).

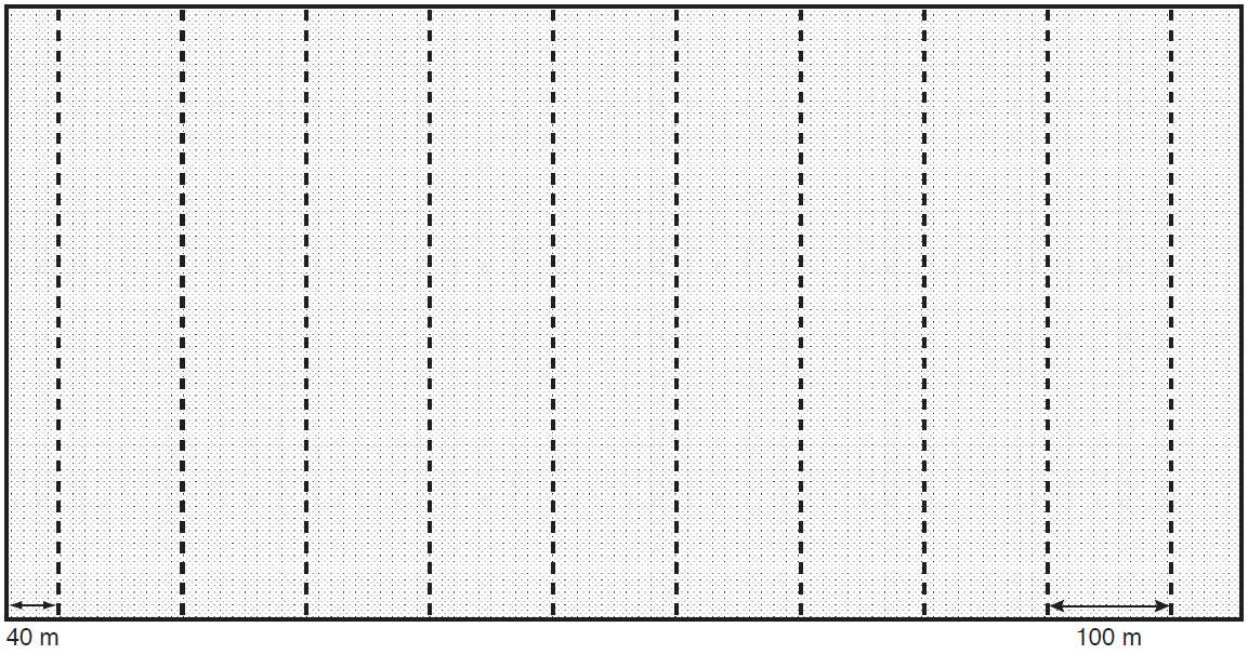

Figure 1. The layout of the transects (dashed lines) in a 1000 x 500 m plot. The edges of the plot are shown with solid lines.

Materials Needed in the Field

1) Compass
2) Large caliper (0-1270 mm; e.g. Haglöf Mantax)
3) Small caliper (0-50 mm)
4) Permanent marker
5) Chainsaw (long blade)
6) Fuel for chainsaw
7) Hand saw with stiff blade
8) Hand pruner
9) Ax (small one-hand model; e.g., Fiskars 8-inch hatchet)
10) Portable balance (0 – 2500 g; e.g. Pesola Model 42500)
11) Leather gloves (if needed against animals)
12) Plastic bags of various sizes
13) Penetrometer and spare parts (Figure 2; available from CTFS)
14) Nonpermanent marker
15) Piece of cloth or tissues
16) Ruler (preferably 200 mm long and modified to start exactly at 0 mm)
17) Clipboard
18) Datasheets
19) Pencil

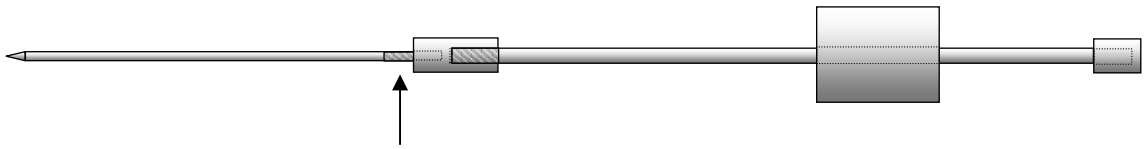

Figure 2. A penetrometer , an instrument to assess the hardness of dead wood that was developed by the CTFS Global Forest Carbon Research Initiative and Milton Garcia in 2008. It is 0.6 m long when assembled and is made of stainless steel. Nuts can be screwed onto the instrument at the location indicated by the arrow, in order to mark exactly the extent of 200 mm of penetration and to adjust the mass of the instrument if necessary.

Note: The penetrometer needs to be checked at the start of every day of field work to make sure that the tip is sufficiently sharp (it should be sharp enough to make marks on a fingernail) and that the moving weight and the surfaces it contacts are clean. It should be sharpened with a file and/or cleaned with a cloth if necessary. In addition, the penetrometer and portable balance both need to be checked in more detail and potentially adjusted at the beginning and end of any period of measurements, and at least every 2 weeks in the interim. Please see the section on "Evaluation and Adjustment of the Equipment" later in this document for details.

Defining Fallen Woody Debris

Before detailing the protocol for measuring pieces of fallen woody debris that intersect the transect, we need to define what is included in this category. Here, we define fallen woody debris as dead wood and bark on the forest floor that is at least 20 mm in diameter (diameter here refers to the width of the cross-section of the piece). This includes wood and bark from trunks, branches, buttresses, and even roots if above-ground. It does not include standing dead trees. The remains of woody debris are considered soil or below-ground woody debris and not included as fallen woody debris if the material is powdery (particle diameter less than 5 mm) and gravity has flattened the remains so that the height of a cross section is estimated to be less than 20 % of the width, or if the piece is not visible without digging (as if roots are covered in soil after uprooting). When a piece has always been split into several pieces (e.g. *Ficus*) or has split during the decomposition process, these pieces are considered one piece if they are continuous or nearly continuous in the cross-section – specifically, if there is less than 10 mm of void space between different parts (Photo 1). A piece is not considered fallen woody debris if it is not supported in at least three locations by its branches or stem touching the ground or other pieces of fallen woody debris (thus, for example, dead branches that are hanging from the canopy and do not touch the ground are not considered fallen woody debris).

Fine Woody Debris (FWD) Measurements

The transects are divided into sections of 20 m. Pieces of fine woody debris, are measured only in a 1-m subsection of each 20-m section. For consistency, this 1-m subsection should always be on the same end of each section; for example, always the southern end. Henceforth, we will refer to this as the "bottom" end of the section.

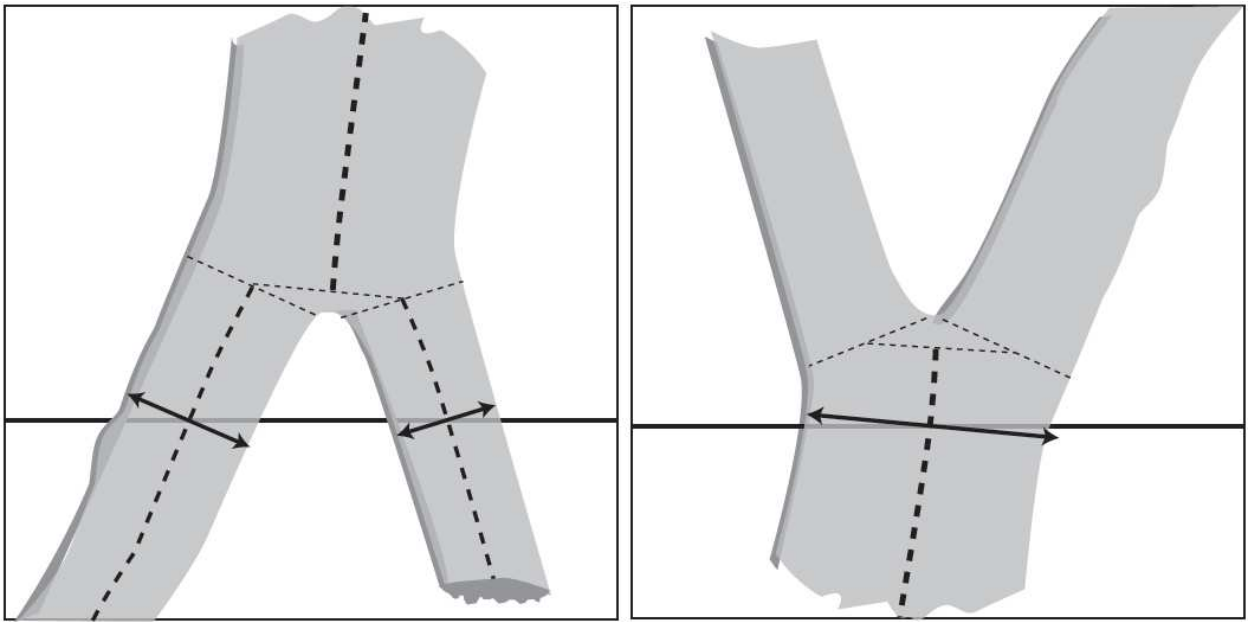

Figure 3. The central axes (shown with thick dashed lines) of a piece of woody debris run through the centroids of the cross-section. When a piece of woody debris branches, the central axis splits as shown. Note that the lower axis stops on the line running between the lower ends of the upper axes. Depending on the location of the transect, shown here by solid line, the piece is measured at either one or two places. Left: two measurements (arrows). Right: one measurement. Note that the measurements are made exactly at the intersection with the transect – deformations are not avoided.

At the bottom end of each transect section, observe whether the first 1 m includes any pieces of woody debris having a diameter of 20-199 mm at the intersection point (Figure 3). For any candidate pieces, check whether the intersection point of the transect and the central axis of the piece of woody debris really is displaced less 1 m from the bottom end of the transect section by using the scale of the large calipers. Remember that the 1 m should be measured horizontally (not parallel to the ground). Use calipers to measure the diameter of the piece of woody debris; specifically, measure the "width" of the piece when looking down on it, measuring perpendicular to the central axis of the piece (Figure 4).

A sample of each piece is then taken and transported back to the lab for oven-drying and weighing. For relatively solid pieces of FWD, cut a slice of approximately 30 mm thick with a chainsaw, a hand saw or a hand pruner. Make the cuts parallel to the diameter measurements and vertically (Figures 4 and 5). Use the small calipers to measure the thickness of the slice at two opposite sides, and record both measurements. Determine a unique sample code for that sample (e.g., the coordinates of the transect segment, plus a number for the order of the sample within that segment) and record it on the datasheet. Then pack the sample in a plastic bag (including any pieces that break off during sawing), mark the sample code on the bag with a permanent marker, and carry the bagged sample to the laboratory.

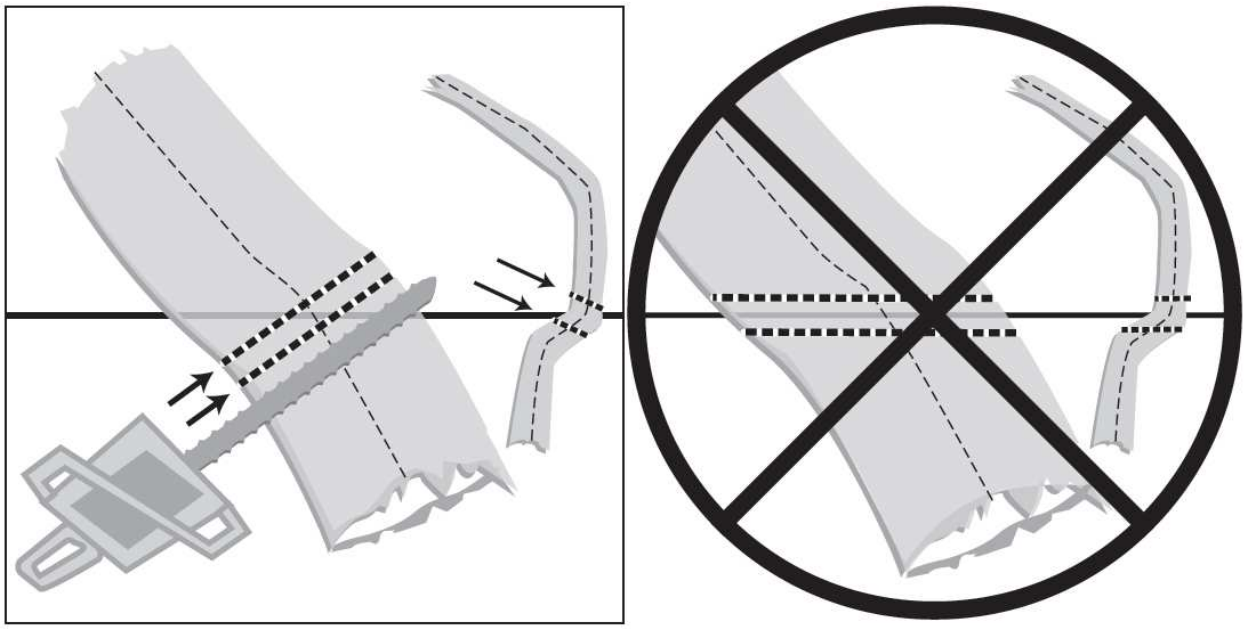

Figure 4. In this view from above, two pieces of woody debris intersect a transect (thick solid line). The central axis of the pieces are shown in thin dashed thin lines. Diameter measurements are taken perpendicular to the central axis at the point of intersection (not shown). Cuts for the sampling (thick dashed lines) are made parallel and on both sides of the diameter measurement locations. The correct cuts are shown at left (at right an example of what NOT to do).

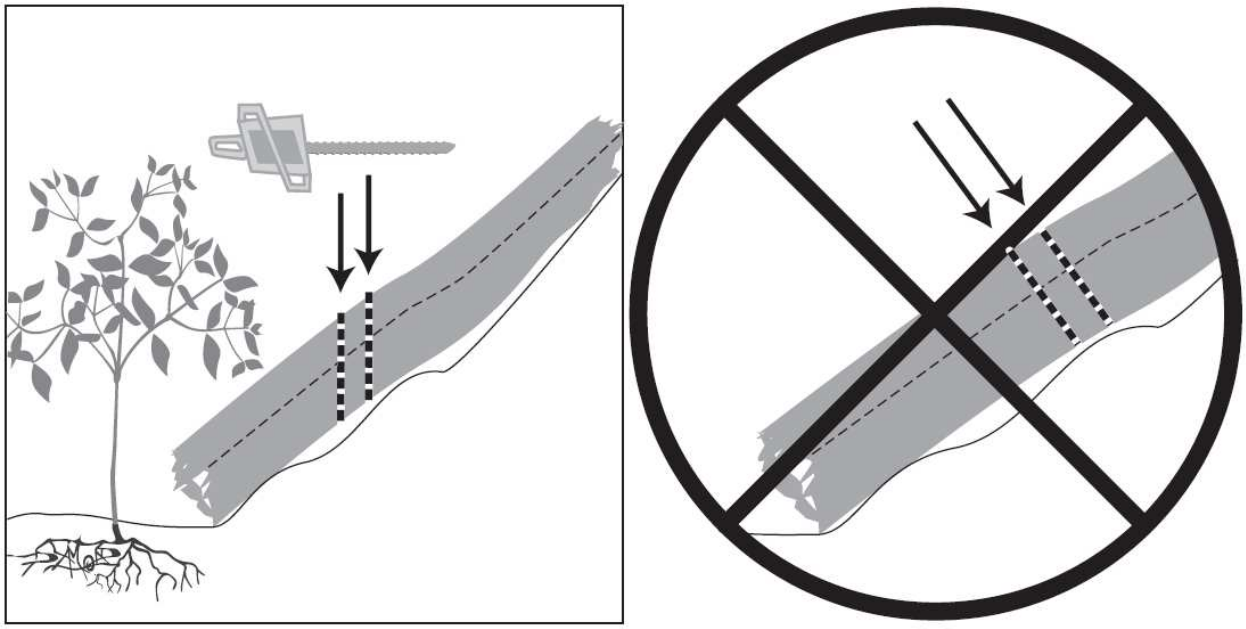

Figure 5. A side view of a piece of woody debris from which samples need to be taken. Because of the slope, the piece does not lie horizontally. The cuts for samples (dashed lines) should always be taken vertically, regardless of the sample inclination. The correct cuts are shown at left (at right an example of what NOT to do).

For friable pieces of FWD from which it is impossible to cut a solid slice, make two parallel cuts to extract a section/slice approximately 100 mm long into a plastic bag. If the piece is too friable for its thickness to be measured with calipers, then measure the width of the gap (if sawdust from the end cuts themselves is not included, then the width of the saw blade should be recorded as well, and twice this width should be subtracted from the width of the gap to obtain the width of the sample). Take great care to include all relevant pieces that fall to the ground.

Coarse Woody Debris (CWD) Measurements

Pieces of CWD, defined as pieces having a diameter of at least 200 mm at their intersection with the transect, are measured and sampled along the entire lengths of all transect sections. Measurements are made of diameter, orientation, state of decay, and hardness, and a sample is collected.

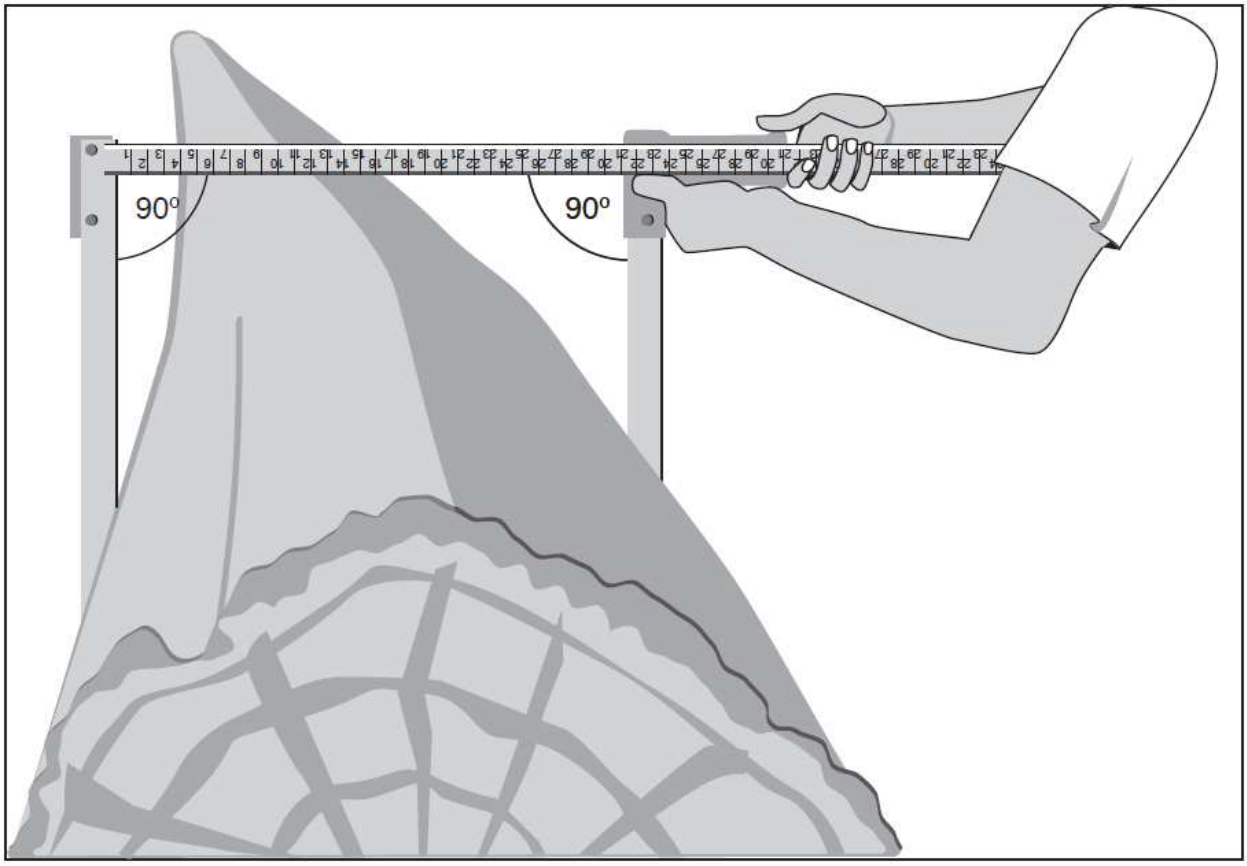

Figure 6. The diameter of a piece of coarse woody debris is measured using a large caliper. Because the two blades of the calipers bend easily, care must be taken to apply the correct amount of force so that the blades remain parallel. (This can be practiced by measuring diameters of small objects such as sticks, placing them at various positions between the blades while observing whether the blades are parallel.)

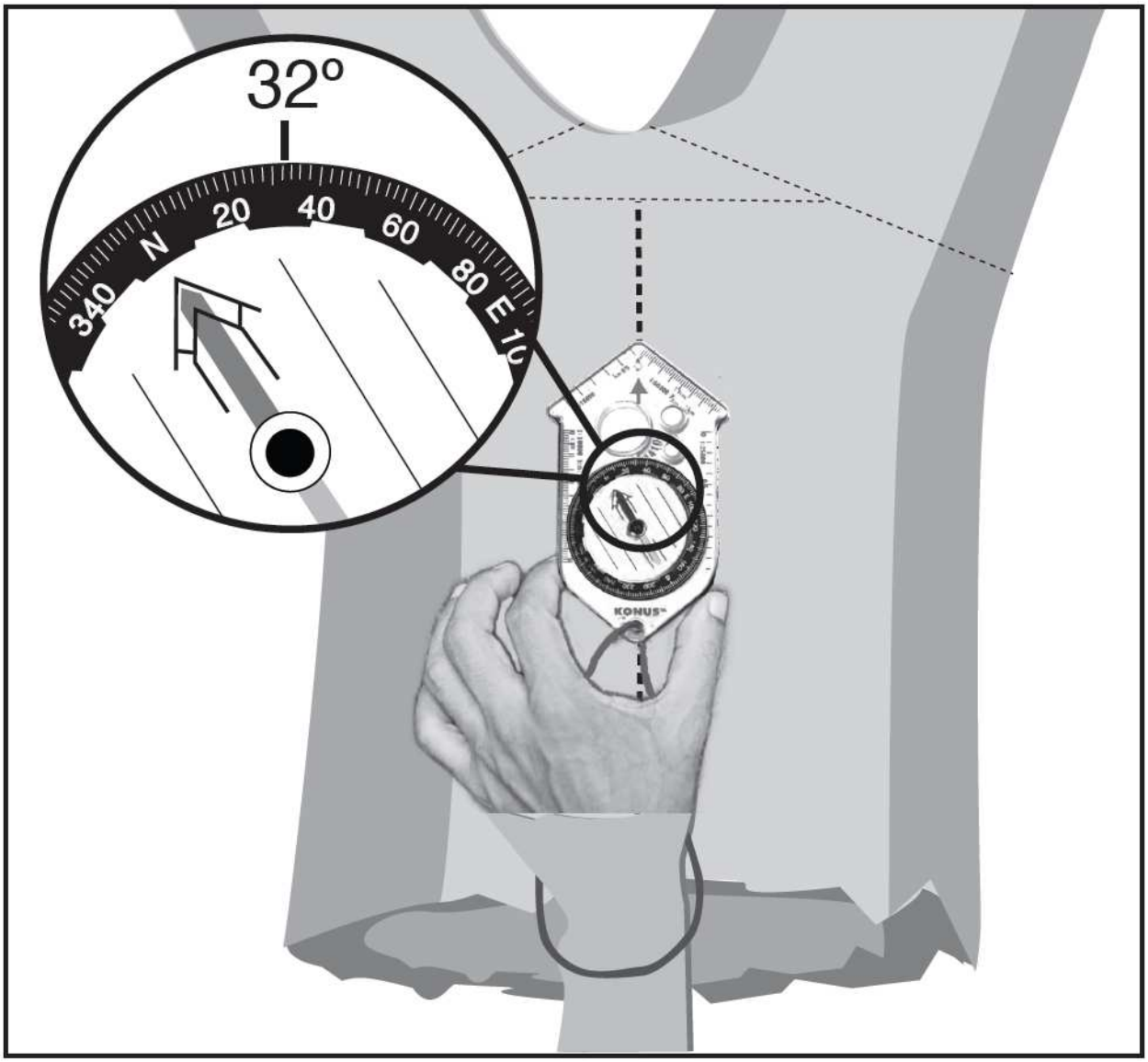

Figure 7. The orientation of a piece of coarse woody debris is assessed by placing the compass so that the compass points from the larger to the smaller end of the piece. Then turn the dial so that the needle pointing to magnetic North falls in between the fork printed on the dial and read the direction (32°in this case).

Diameter. For pieces 1270 mm or less in diameter, the diameter is measured using a large caliper (Figure 6). For pieces greater than 1270 mm in diameter (and thus greater than the maximum width that can be measured using calipers), hold two long straight items (caliper blades, rulers, or just sticks) vertically to define the opposite edges of the piece of wood at the point of measurement, and then measure the distance between them. As the very large pieces potentially represent a large proportion of total necromass they should be measured as precisely as possible.

Orientation. The orientation of the central axis of the piece is measured with a compass. The direction relative to magnetic north is measured pointing from the larger to the smaller end of the piece, and recorded to the nearest degree (Figure 7).

State of decay. Observations of the state of decay are based on the whole piece, not just the area of the intersection. Record whether over half of the original of leaves are attached and whether over half of the bark remains attached.

Hardness. The hardness of each piece is assessed using the penetrometer (Figure 2). At each piece of CWD, the penetrometer should be held vertically at the highest point of the cross-section of the piece at the intersection of the transect, and then the moving weight should be dropped 250 mm 20 times (Photo 2). Mark the lowermost part of the penetrometer that did not penetrate the piece of woody debris with a nonpermanent marker and then remove the instrument from the piece of woody debris by hitting the moving weight upwards. Measure the distance of penetration with a ruler, recording the distance from the penetrometer point to the lower end of the mark. If the instrument penetrates 200 mm in less than 20 hits, record the number of hits needed to reach 200 mm. In the very exceptional case when the height of the cross-section of a piece of coarse woody debris is not 200 mm and the penetrometer touches the soil on the twentieth hit or before record the number of hits as if the penetration would have been 200 mm. After taking the measurement, wipe the pen mark off the penetrometer with a cloth or tissues.

Sample collection and measurement. Then take a sample for transport to the laboratory and oven-drying. The sample should be taken at the intersection with the transect, and should be cut perpendicular to the main axis and vertically, as with samples of FWD (Figures 3, 4 and Photo 3). A chainsaw should be used to take the sample. Up to nine cuts with a chainsaw might be needed to get a slice if the diameter of the piece of woody debris is larger than the length of the blade of the chainsaw (Figure 8). Note that the samples do not have to be taken on the same day that the measurements are made (another team could come back later with a chainsaw for larger pieces), but any delay should be recorded, and samples should not be taken more than two weeks after the measurements as significant decomposition between the two events would bias the results.

For smaller diameter pieces, take a full slice, measure and record its thickness at two opposite points, place it in a plastic bag marked with a unique sample code recorded on the datasheets, and transport the whole slice to the laboratory.

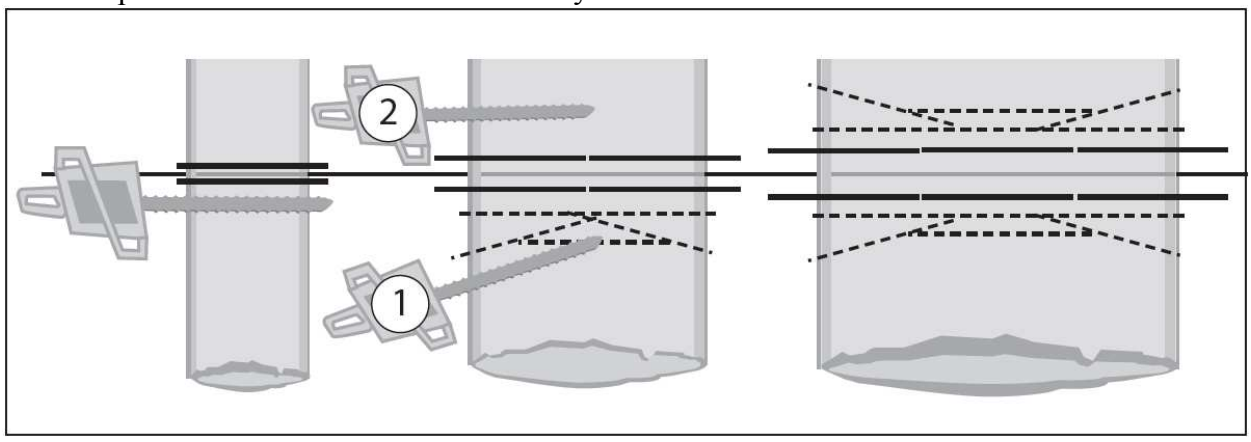

Figure 8. Three pieces of woody debris viewed from above. The dashed lines are the support cuts made with chain saw before making the final cuts (solid lines). The piece on the left has a diameter smaller than the length of the chain saw blade, the middle piece has a diameter 1 -2 times the length of the blade, and the piece on the right has a diameter more than 2 times the length of the blade. Note that the slice should be thicker for pieces of greater diameter as the relative inaccuracy caused by uneven surface resulting from combining several cuts can thus be reduced. Ideally the chain saw blade should be longer than the greatest diameter encountered along the transects so that all cuts can be made simply as on the left.

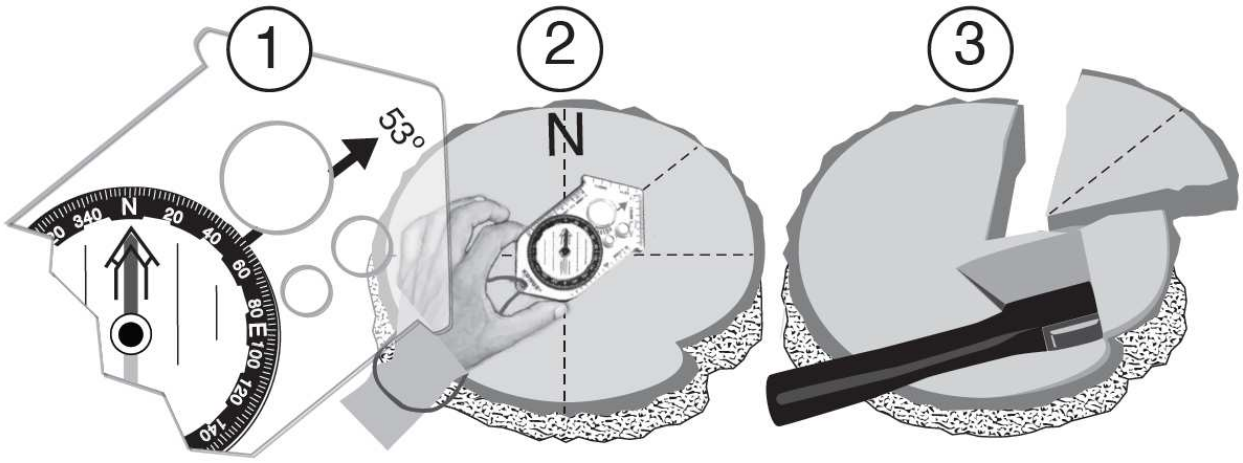

Figure 9. If the condition of the wood is very variable in different parts of a slice, it is important that the sample taken is chosen at random. One way to do this is to 1) take a compass and turn the degree dial randomly (to 53° in this case), 2) place the compass on the slice such that the needle falls in between the fork printed on the dial, and 3) then take a sample in the direction indicated by the main arrows. The easiest way to take a sub-sample from a disc is to use a small ax. Take care to include all pieces from the chosen sector.

For larger diameter pieces, carrying and drying full slices is overly laborious and time-consuming, and may exceed oven capacity. In these cases, a sub-sample of the full slice should be taken for transport to the laboratory. For pieces that are relatively solid, first cut a slice approximately 30 mm thick with a chainsaw. Use small calipers to record the thickness at 2 opposite sides of the slice, or at 4 points if the thickness is very uneven, and record all measurements. Then weigh the full slice with a portable balance (Photo 4), first attaching a plastic bag to the hook and taring the balance to zero with the bag. If the mass is over the maximum of the portable balance, break the slice into several parts and weigh each separately, recording all on separate rows of the datasheet.

One wedge, ideally weighing 200-1000 g, is chosen before cutting at random to take back to the lab (Figure 9). To break the slice into parts, place the slice horizontally and use an ax to cut wedges (pie pieces). It is important that the sample taken back to the lab is packed tightly so that no water (and thus weight) is lost by evaporation between the time of collection and the time the sample is processed in the laboratory.

For friable CWD, use the same methods as with friable FWD except if the slice is too large to be carried to the laboratory. In this case, weigh the whole slice, mix it and scoop wood from different parts of the bag for form a sample to be taken to the lab.

There are several situations in which cutting a slice is problematic. If the piece of CWD is for example stuck between three trees, is bent and under tension is should not be cut due to security reasons unless the chain saw operator is familiar with resolving such situations. Similarly if the intersection is several meters above the ground the slice should not be taken. The intersection could be covered by living lianas and the slice could not be taken without killing them and the slice should therefore not be taken. However, in all cases estimate the diameter even if it cannot be done accurately and record the experienced problems as notes. If taking the slice due to hardness of the wood is difficult, special equipment (e.g. chain saw chains) should be used as excluding the hardest pieces would lead to a bias.

Laboratory Measurements of the Samples

Materials needed:
1) Drying oven
2) Paper bags
3) Permanent marker
4) Laboratory balance (0.1 g precision)
5) Datasheets
6) Pencil

Samples should be weighed immediately after collection, to avoid any mass loss due to the risk of drying. After weighing there is less urgency but decomposition would bias the results and several days of weighting is not acceptable in warm conditions. The colder the temperature is the less decomposition occurs. The samples can be stored in a freezer for months without problems.

Then place the sample in a paper bag with relevant labeling and the bag in a drying oven and dry at 60ºC to constant weight. The drying is likely to take 5-30 days depending on the size and initial wetness of the pieces and the conditions in the oven. Thus, it is important to take multiple weights per sample (separated by at least a day) until constant weight is obtained. Record the final dry weight to the nearest 0.1 g.

Evaluation and Adjustment of the Equipment

Portable Balance

The accuracy of the portable balance should be evaluated in the laboratory before and after each period of measurements, and at least every 2 weeks while it is in continuous use.

The following materials are needed:

1) Portable balance
2) Laboratory balance
3) Weights of known mass (e.g. a water container with a capacity of 3 liters)
4) Datasheets
5) Pencil

Masses close to the maximum and minimum that the portable balance measures and 10 – 20 masses in between should be weighed using both the portable balance and a calibrated laboratory balance. These data will be used to later correct field measurements taken with the portable balance.

Penetrometer

The penetrometer should be adjusted before and after each period of measurements, and at least every 2 weeks while it is in continuous use.

The following materials are needed:
1) Penetrometer and spare parts
2) Ruler or measuring tape that can measure 300 mm
3) Metal file

First, check that the tip of the instrument is sharp enough to make a mark on a fingernail. If it is not sufficiently sharp, then sharpen it using a metal file.

Second, establish a clear mark 200 mm from the tip of the penetrometer. Ideally, this is done using as many nuts as required screwed into position (Figure 2).

Third, check that the moving weight moves 250 mm. If the movement is more the weight should not be dropped from its uppermost possible location but e.g. a finger should be kept in between the moving weight and the top part of the instrument.

Photo 1. These remains of a stem or large branch are still woody debris as the pieces are solid enough to be lifted. Powdery remains are woody debris only if their height is more than 20 % of the width of the cross-section. The central group is one piece of coarse woody debris as all the small pieces are connected. The few pieces in the right separated from the central group are individual pieces of fine woody debris.

Photo 2. The hardness is assessed with a penetrometer. A nonpermanent marker is used to mark the depth of penetration before removing the instrument from the woody debris.

Photo 3. It is important to check with a hanging object (e.g. compass) that the cuts are vertical. For example in the photo the cut was not vertical and therefore cause underestimation.

Photo 4. The samples of coarse woody debris are weighed in the field with a portable balance (model in the photo different from the one mentioned in “Materials Needed in Field”).