

Tree Data (TD) Sampling Method



EXECUTIVE SUMMARY

The Tree Data (TD) methods are used to sample individual live and dead trees on a fixed-area plot to estimate tree density, size, and age class distributions before and after fire in order to assess tree survival and mortality rates. This method can also be used to sample individual shrubs if they are over 4.5 feet tall. When trees are larger than the user specified breakpoint diameter; diameter at breast height, height, age, growth rate, crown length, insect/disease/abiotic damage, crown scorch height and bole char height, are recorded. Trees less than breakpoint diameter and taller than 4.5 feet are tallied by species-diameter-status class. Trees less than 4.5 feet tall are tallied by species-height-status class and sampled on a subplot within the macroplot. Snag measurements are made on a snag plot that is usually larger than the macroplot. Snag characteristics include species, height, decay class and cause of mortality.

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INTRODUCTION

The Tree Data (TD) methods were designed to measure important characteristics about individual trees so that tree populations can be quantitatively described by various dimensional and structural classes before and after fires. This method uses a fixed area plot sampling approach to sample all trees that are within the boundaries of a circular plot (called a macroplot) and that are above a user-specified diameter at breast height (called the breakpoint diameter) are sampled. All trees or shrubs below the breakpoint diameter are recorded by species-height-status class or species-diameter-status class, depending on tree height. The TD method is appropriate for both inventory and monitoring.

The TD sampling methods were developed using fixed-area sampling procedures that have been established and accepted by forestry professionals. Field sampling and the data collected are similar to that in ECODATA.

The fixed area plot used to describe tree characteristics in the TD methods is different than the standard timber inventory techniques that use plot-less point sampling implemented with the prism. We use the fixed area technique for many reasons. First, the plotless method was designed to quantify stand characteristics using many point samples across a large area (e.g., stand). This means that the sampling strategy is more concerned with conditions across the stand than within the plot. Second, plot-less sampling was designed for inventorying large, merchantable trees and is not especially useful for describing tree populations - especially within a plot - because the sampling distribution for the plot-less methods under-samples small and medium diameter trees. These small trees are the ones many fire managers are interested in monitoring, for instance in a restoration project. Similarly, canopy fuels are not adequately sampled using plot-less techniques because there is insufficient number of trees in all age classes to obtain realistic vertical fuel loadings and distributions. Finally, there are many ecosystem characteristics recorded at each FIREMON macroplot and the origin and factors that control these characteristics are highly interrelated. For example, shrub cover is often inversely related to tree cover on productive sites. Plot-less sampling does not adequately allow the sampling of tree characteristics that influence other ecosystem characteristics, at the plot level, such as loading and regeneration. The expansion of trees per area estimates from fixed-area plots is much less variable than density estimation made using plot-less methods. The contrast between point and fixed area plot sampling is really a matter of scale. Point or prism sampling is an efficient means to get stand-level estimations but it is inadequate for describing tree characteristics within a plot.

Many characteristics are recorded for each tree. First, the species and health status is recorded for each tree. Then, structural characteristics of diameter breast height (DBH), height, live crown percent, and crown position are measured to describe physical dimensions of the trees. Age and growth rate describe life stage and productivity. Insect and disease evidence is recorded in the damage codes. A general description of dead trees is recorded in snag codes. Fire severity is assessed by estimates of down hill bole char height and percent of crown scorched. There is one column to build user-defined codes for each tree, if needed. Each tree above the breakpoint diameter gets a tree tag that permanently identifies it for further measurements.

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Besides being used to inventory general tree characteristics on the macroplot, the TD method can be used to determine tree survival or fire-caused tree mortality after a burn and used describe the pre- and post-burn tree population characteristics by species, size, and age classes. Values in many TD fields can be used to compute a host of ecological characteristics of the tree. For example, the tree's DBH, height, and live crown percent can be used to compute stand bulk density for modeling crown fire potential.

There are many ways to streamline the TD procedure. First, the number of measured trees can be lowered by raising the breakpoint diameter. A large breakpoint diameter will exclude the individual measurement of the many small trees on the macroplot. Next, age estimates of individual trees can be simplified by taking age in broad diameter and species classes. Last, the FIREMON three-tier sampling design can be employed to optimize sampling efficiency. See the sections on **User Specific TD Sampling Design** and **Sampling Design Customization** below.

SAMPLING PROCEDURE

The sampling procedure is described in the order of the fields that need to be completed on the TD Data form. The sampling procedure described here is the recommended procedure for this method. Later sections will describe how the FIREMON three-tier sampling intensity classes can be used to modify the recommended procedure to match resources, funding, and time constraints.

This method assumes that the sampling strategy has already been selected and the macroplot has already been located. If this is not the case, then refer to the FIREMON **Integrated Sampling Strategy** and for further details.

Preliminary Sampling Design

There is a set of general criteria recorded on the TD Data form that are the basis of the user-specified design of the TD sampling method. Each general TD field must be designed so that the sampling captures the information needed to successfully satisfy the management objective within time, money and personnel constraints. These general fields must be decided before the crews go into the field and should reflect a thoughtful analysis of the expected problems and challenges in the fire monitoring project.

See **How To Customize Plant Species Codes** if you are not planning on using the NRCS Plant species codes.

Plot size selection

There be as many as three nested fixed plots in the FIREMON TD methods. First, the macroplot is the primary sampling plot and it is the plot where all live tree population characteristics are taken. Next is the snag plot, which may be larger than the macroplot and it is used to record a representative sample of snags. Often, the incidence of snags on the landscape is so low that the macroplot area is not large enough to describe snag populations. The snag macroplot is allows more snags to be sampled. Last is the subplot where all seedlings are counted. This is smaller

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than the macroplot and is provided to streamline the counting of densely packed seedlings. All of the plots are concentrically located around the macroplot center.

Macroplot area

The size of the macroplot ultimately dictates the number of trees that will be measured, so large plot sizes usually take longer to finish because of the large number of trees on the plot. However, some ecosystems have widely spaced trees scattered over large areas so that large plot sizes are needed to obtain statistically significant estimates. There have been many studies to determine the optimum plot size for different ecosystems with mixed results. We offer the following table to help determine the plot size that matches the fire monitoring application. Unless the project objectives dictate otherwise, use the median tree diameter and median tree height - for trees greater than breakpoint diameter - to determine the size of your macroplot (table TD-1). Enter the macroplot size for the TD method in Field 1 of the TD Data Form

Table TD-1. Use the median tree diameter and median tree height to determine the size of the sampling macroplot.

Median Tree Diameter - trees greater than breakpoint	Median Tree Height	Suggested Plot Radius	Suggested Plot Size
< 20 in. (<50 cm)	< 100 ft (<30 m)	37.24 ft (11.28 m)	0.1 ac (0.04 ha)
20 to 40 in. (<100 cm)	100 to 130 ft (<40 m)	52.66 ft (12.61 m)	0.2 ac (0.05 ha)
> 40 in. (<200 cm)	> 130 ft (<50 m)	74.47 ft (17.84 m)	0.4 ac (0.1 ha)

In general, the 0.1 ac (0.04 ha) circular plot will be sufficient for most forest ecosystems and should be used if no other information is available. A general rule-of-thumb is the plot should be big enough to capture at least 20 trees above breakpoint diameter (see definition in next section) on the average across all plots in your project. Though it is not absolutely necessary, extra measures should be taken so that plot sizes are the same for all plots in a project.

Subplot area

All seedlings - trees less than 4.5 feet (1.37 meters) tall - are measured on a subplot nested within the macroplot (figure TD-1). Use seedling density to determine the subplot size (table TD-2) unless the project objectives dictate otherwise.

Table TD-2. Use seedling density to determine the subplot radius.

Seedling density	Subplot radius	Area
Typical	11.77 ft (3.57 m)	0.01 ac (0.004 ha)
<2 seedlings per species	18.62 ft (5.64 m)	0.025 ac (0.01 ha)
>100 seedlings per species	5.89 ft (1.78 m)	0.0025 ac (0.001 ha)

Again, make an effort to keep the subplot radius constant across all plots in the FIREMON project. Subplot sampling is discussed in later sections of this document. The area of the subplot is entered in Field 2 on the TD Data Form.

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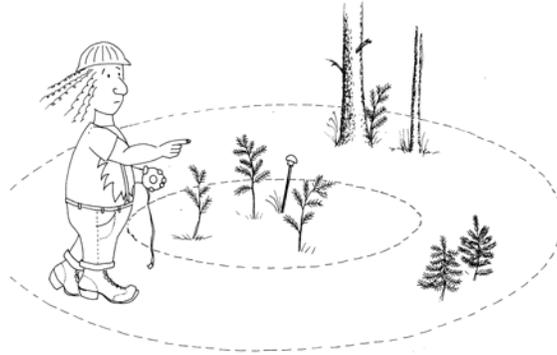


Figure TD-1. The subplot is nested inside the macroplot. The recommended circular plot shape is shown but rectangular plots may also be used.

Snag plot area

Snags are dead trees greater than breakpoint diameter. Snags can be measured within the macroplot, but often their numbers are so low that a larger plot is needed to detect changes in snag populations. A suitable snag plot size is difficult to determine because snags are non-uniformly distributed across the landscape. A good rule of thumb for sizing the snag plot is to double the macroplot diameter, which will increase the snag plot area by a factor of four. Enter the snag plot area in Field 3 of the TD form even if it is the same size as the macroplot. If snags are important to the project objectives you should chose a plot radius that will provide you with at least 20 snags, meaning the plot could be quite large.

Breakpoint diameter

Choose a breakpoint diameter that allows at least 20 trees to be measured on each FIREMON macroplot. (figure TD-2). The same breakpoint diameter should be used for all of the macroplots in the study.

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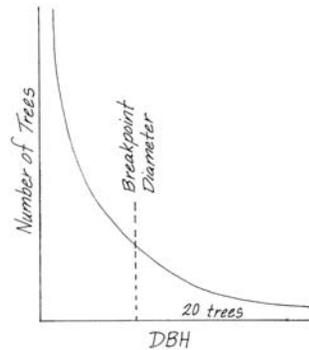


Figure TD-2. Choose a breakpoint diameter that leaves at least 20 trees in the tail of the distribution. The diameter distribution can be derived from a pilot study or estimated from previous experience.

The breakpoint diameter is the tree diameter at breast height (DBH) above which all trees are tagged and measured individually and below which trees are tallied to species-DBH classes. Selection of the breakpoint diameter must account for fire monitoring objectives as well as sampling limitations and efficiency. For example, a large breakpoint diameter (>8 in.) will exclude many small trees from individual measurements and reduce the sampling time. As long as the project objectives are very broad (e.g. 70 to 80 percent mortality of saplings) then a tally of trees below breakpoint will be sufficient. However, if the objectives are specific (determine the effect of crown scorch and char height on fire caused mortality of trees 2 in. and greater DBH) then a lower breakpoint diameter, and the associated increase in sampling effort, will be necessary. Individual measurement of small trees might be unrealistic if there are high sapling densities (>1,000 trees) on the macroplot. Selection of an appropriate breakpoint diameter requires some field experience and knowledge of the resources available to complete the fire monitoring project. In FIREMON we suggest using a 4-inch (10 cm) breakpoint diameter if no other information is available. The breakpoint diameter is entered in Field 4 of the TD Data Form.

See **How To Locate a FIREMON Plot**, **How To Permanently Establish a FIREMON Plot** and **How to Define the Boundaries of a Macroplot** for more information on setting up your macroplot.

Preliminary Sampling Tasks

Before setting out for your field sampling layout a practice macroplot and subplot in an area with easy access. Even if there are just a few trees on your practice plot, getting familiar with the plot layout and the data that will be collected before heading out will make the first day or two of field sampling less frustrating. It will also let you see if there are any pieces of equipment that will need to be ordered.

When you are ready to go into the field, consult the TD Equipment list and gather the necessary materials. Since you will probably be spending most of your day hiking from plot to plot it is

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important that supplies and equipment are placed in a comfortable daypack or backpack. Also, be sure that you pack spares of each piece of equipment so that an entire day of sampling is not lost if something breaks. Spare equipment can be stored in the vehicle rather than the backpack. Be sure all equipment is well maintained and there are plenty of extra supplies such as plot forms, map cases, and pencils.

All TD Data Forms should be copied onto waterproof paper because inclement weather can easily destroy valuable data recorded on standard copier paper. Plot forms should be transported into the field using a plastic, waterproof map protector or plastic bag. The day's sample forms should always be stored in a dry place (i.e., office or vehicle) and not be taken back into the field for the next day's sampling.

If the sampling project is to remeasure previously installed FIREMON plots, then it is highly recommended that plot sheets from the first measurement be copied and brought to the field for reference. These data can be extremely valuable for help in identifying sample trees that have lost their tree tags or have fallen over and can provide an excellent reference for verifying data measurements.

We recommend that one person on the field crew, preferably the crew boss, have a waterproof, lined field notebook for recording logistic and procedural problems encountered during sampling. This helps with future re-measurements and future field campaigns. All comments and details not documented in the FIREMON sampling methods should be written in this notebook. For example, snow on the plot might be described in the notebook, which would be very helpful in plot re-measurement.

It is beneficial to have plot locations for several days of work in advance in case something happens, such as the road to one set of plots is washed out by flooding. Locations and/or directions to the plots you will be sampling should be readily in order to reduce travel times. If the FIREMON plots were randomly located within the sampling unit it is critical that the crew is provided plot coordinates before going into the field. Plots should be referenced on maps and aerial photos using pin-pricks or dots to make navigation easy for the crew and to provide a check of the georeferenced coordinates. It is easy to mis-record latitude and longitude coordinates and marked maps can help identify any erroneous plot positions.

A field crew of three people is probably the most efficient for implementation of the TD sampling method. For safety reasons there should never be a one-person crew. A crew of two people will require excessive walking and trampling on the plot. Any more than three people will probably result in some people waiting for critical tasks to be done and unnecessary physical damage to the plot. For simplicity, we will refer to the people in the three-person crew as the crew boss, a note taker, and a technician. The crew boss is responsible for all sampling logistics including the vehicle, plot directions, equipment, supplies, and safety. The note taker is responsible for recording the data on plot forms or onto the laptop. The technician will perform most individual tree measurements while the note taker estimates tree heights. Of course, the crew boss can be the note taker, and probably should be for most situations. The initial sampling tasks of the field crew should be assigned based on field experience, physical capacity, and

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sampling efficiency. Sampling tasks should be modified as the field crew gains experience and tasks should also be shared to limit monotony.

Sampling Tasks

Define macroplot boundary

The first task to be completed is to define the boundary of the TD sampling plot. The TD macroplot should be established so that the sampling plots for all of the methods overlap as much as possible. See **How To Establish Plots with Multiple Methods**.

If you are sampling using only the TD methods, it is not so important that flags are placed exactly at the fixed distance; rather, it is more important that the trees inside the macroplot are clearly identified for sampling. This means that borderline trees (questionable trees on the boundaries of the plot) be flagged so that the tree sampler knows if the tree is inside or outside the macroplot. This is done by tying the flag on a branch on the outside of the tree (away from plot center) if the tree is inside the macroplot, or tying the flag on a branch that faces toward plot center if the tree is outside the boundaries. Avoid tying flagging to tree boles as it can lead to some confusion about whether trees are “in” or “out”. If you must flag around a bole, point the knot toward plot center if the tree is “out” or point the knot away from plot center if the tree is “in”. See **How To Define the Boundaries of a Macroplot** for more information. With either method you will need to adjust for slope as you go around the plot (see **How to Adjust for Slope**).

The snag and subplot boundaries probably don't need the extensive marking and flagging as required for the macroplot. For the snag plot, we suggest fixing a cloth or fiberglass tape to the macroplot center and proceeding out to the distance of the Snag Plot Radius. We suggest a cloth or fiberglass tape because your diameter tape will probably not be long enough. Leave the tape pulled out and start traversing the snag plot to search for snags. You will be able to determine whether most of the snags you find are “in” or “out” just by looking however, you will have to use the tape to measure snags that are on the border. If you have a second cloth or fiberglass tape this task will go quicker. You probably won't need to flag the seedling subplot because it is so small. Seedling sampling is described in detail below.

Define initial sample position

Once the macroplot has been defined and all perimeter flags have been hung, flag the tree inside the macroplot, furthest from plot center and greater than breakpoint diameter, that is closest to due north (360 degrees azimuth) from plot center. Mark it near the base so that flagging won't be confused with the plot boundary marking. This tree will be the first tree measured and will also indicate when the sampling has been completed. If tree density is high then you may want to flag the closest tree to the left of your “first” tree as the “last” tree (you will be sampling clockwise around the plot). Tie a flag at the base of the tree(s) so that it will not be confused with plot boundary trees. You may even want to use another flag color, or you may want to use tree chalk instead of a flag (figure TD-3).

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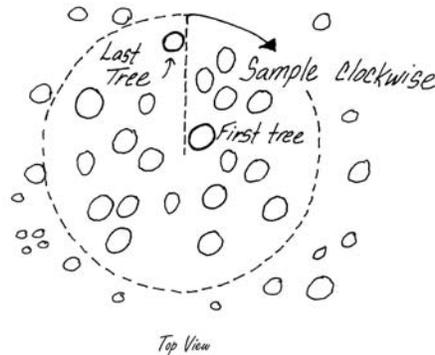


Figure TD-3. Sample trees clockwise around the plot starting with the first tree located clockwise from an azimuth of 360 degrees true north.

Sampling seedlings

In FIREMON we call trees less than 4.5 feet (1.37 meters) tall seedlings. Seedlings are sampled using a small subplot within the larger macroplot. This is done because seedlings are more numerous than larger trees so they can be sampled on a smaller area and still allow a representative sample. Trying to sample seedlings on the entire macroplot would be inefficient and time-consuming. Subplot sampling is done before individual tree measurements because repeated walking around the macroplot center by field crews may trample some seedlings and bias the tree sample.

To start your seedling counts attach the zero end of a logger's tape at plot center and walk away headed due north until you are at the distance (corrected for slope) you selected for your subplot radius from table TD-2. Once at the required distance, hold the tape just above the seedlings, then sweep clockwise around the plot, tallying seedlings by species into their respective status and height classes as you go. Use the following status classes:

H –Healthy tree with very little biotic or abiotic damage.

U – Unhealthy tree with some biotic or abiotic damage, and this damage will reduce growth. However, it appears the tree will not immediately die from the damage.

S – Sick tree with extensive biotic or abiotic damage and this damage will ultimately cause death within the next 5 to 10 years.

D – Dead tree or snag with no living tissue visible.

The height classes in table TD-3 are suggested but you can use any classes you choose. The Analysis Tools program assumes that the height class value recorded is the midpoint of the class. Make sure you note any size class changes in the Metadata table. Estimating height using a stick marked with the height classes will make counting quicker and easier.

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Table TD-3. Size classes for seedlings.

Midpoint Height Class (ft)		Midpoint Height Class (m)	
Class	Height Range	Class	Height Range
0.2	>0.0 – 0.5	0.1	>0.0 – 0.2
1	>0.5 – 1.5	0.3	>0.2 – 0.5
2	>1.5 – 2.5	0.6	>0.5 – 0.8
3	>2.5 – 3.5	0.9	>0.8 – 1.0
4	>3.5 – 4.5	1.2	>1.0 – 1.4

We recommend that you sample seedlings using two crew members, with one person tallying all of the seedlings on inner part of the plot and the other person counting all the seedlings on the outer part. Also, this way, when the tape encounters a tree as it is swept clockwise the sampler closest to the plot center can keep track of which seedlings have been counted so that the sampler holding the tape can move around the obstructing tree and return the tape to the proper point before the tally is resumed. Be sure to carefully search the subplot for all seedlings, no matter how small. Use the dot tally method for seedlings (figure TD-4) and when you have finished enter the counts in Seedlings table of the TD Data Form by mid-point class (Fields 31 to 34).

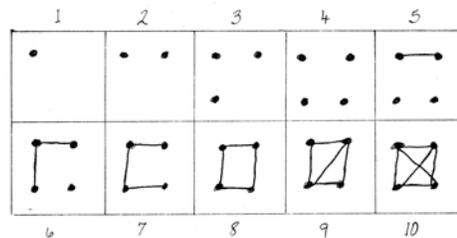


Figure TD-4. Use the dot tally method to make counts quickly with little chance of error.

Sampling seedlings by height class allows a compromise between sampling efficiency and the detail required for describing fire effects.

If a tree is broken below 4.5 feet (1.37 m) but you believe that the tree would be taller than 4.5 feet if unbroken you should still sample it as a seedling.

Saplings and mature trees

In FIREMON we divide trees taller than breast height (4.5 ft) into two groups: saplings and mature trees. Both groups are measured on the macroplot. Saplings are trees taller than 4.5 feet (1.37 m) but smaller than the breakpoint diameter and mature trees are greater than breakpoint diameter. Trees above the breakpoint diameter are tagged, measured and recorded in Table 1 of the TD Data Form. Trees below the breakpoint diameter, but taller than 4.5 feet (1.37 m), are measured and tallied in Table 2 of the TD Data Form. It is most efficient if both sampling tasks are done at the same time as the sampling proceeds around the macroplot because, especially in dense stands, it will be difficult determining which trees have been measured.

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As with seedlings, sample saplings and mature trees in a clockwise direction starting with your “first” tree. The best way to do a repeatable sample is to measure trees in the order that a second hand would hit them as it moved around the plot (figure TD-5). Sometimes this method means that you travel back and forth between the middle and outer portions of the plot and this may seem inefficient but the benefit is that you will be able to relocate trees easier at a later date if something happens to the trees or the tree tags. For example, if tagged trees are blown down by heavy winds or knocked down by other falling trees you will be able to account for their mortality by locating them, in order, around the plot.

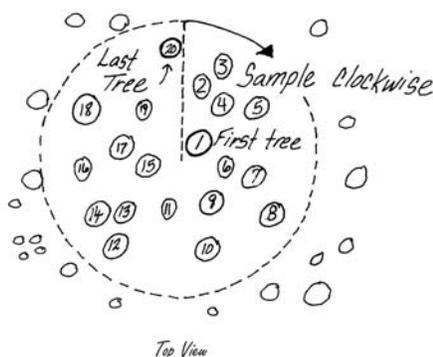


Figure TD-5. Sample trees by measuring the tree you flagged due north of the plot center, first, then move in a clockwise direction. It is easiest to sample all trees above DBH at the same time.

Once a tree is identified for measurement, the sampler must decide if it is above or below the breakpoint diameter. Usually you will be able to do this visually but use a ruler or diameter tape if the tree is borderline. We have found that it is usually less time consuming to initially estimate DBH using a clear plastic ruler rather than with a diameter tape (see **How To Measure Diameter with a Ruler**). However, if the ruler estimate is within 1 inch (2 cm) of breakpoint diameter, we recommend using a diameter tape because the diameter measurement will be more reliable.

Measuring DBH

The diameter of a tree or shrub is conventionally measured at exactly 4.5 feet (1.37 meters) above the ground surface, measured on the uphill side of the tree if it is on a slope. Wrap a diameter tape around the bole or stem of the plant, without twists or bends, and without dead or live branches caught between the tape and the stem (figure HT-6). Pull the tape tight and record the diameter. If you are only determining the diameter class then the measurement only needs to identify the class that the tree is in. If you are measuring the diameter of a mature tree then measure to the nearest 0.10 inch (0.5 cm). Large diameter trees are difficult to measure while standing at one point, so you have to hook the zero end of the tape to the plant bole (bark) and then walk around the tree, being sure to keep the tape exactly perpendicular to the tree stem and all foreign objects from under the tape. See **How To Measure DBH** for more information.

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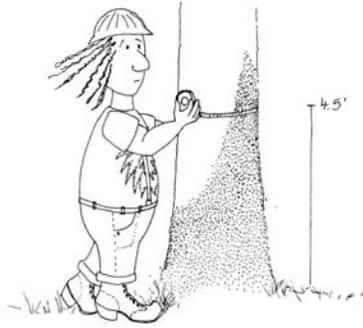


Figure TD-6. DBH Measurement. The diameter tape should carefully be pulled tight around the tree without twists or bends.

Forked trees should be noted in the damage codes discussed in later sections. Forked trees often occur in tall shrublands or woodlands (e.g. pinyon juniper) where trees are clumped due to bird caches or morphological characteristics. Many tree-based sampling techniques suggest that diameter be measured at the base rather than at breast height, but we feel this may bias an estimate of tree mortality by not counting survival of individual stems. Moreover, basal diameters may not adequately portray canopy fuels for fire modeling.

Trees are “live” if they have any green foliage on them regardless of the angle at which they are leaning. If a tree has been tipped or is deformed by snow make all the measurements but use the damage codes described below to record the nature of the damage.

Sampling saplings

Saplings are recorded in species-diameter-status class groups rather than as individuals. As mentioned above we suggest using a 4-inch (10-cm) breakpoint diameter. Tally trees by the diameter classes in Table TD-4. The Analysis Tools program assumes that the diameter class value you record is the midpoint of the class. Make sure you note any size class changes in the Metadata table.

Table TD-4. Diameter classes for saplings.

Midpoint Diameter Class (in.)		Midpoint Diameter Class (cm)	
Class	Diameter Range	Class	Diameter Range
0.5	>0 - 1	1.2	>0 - 2.5
1.5	>1 - 2	3.8	>2.5 - 5
2.5	>2 - 3	6.2	>5 - 7.5
3.5	>3 - 4	8.8	>7.5 - 10

Note that no age or growth characteristics are recorded for trees below breakpoint diameter. The only fire severity attribute assessed from these data is tree mortality by species-diameter class.

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Once a tree is determined to be below the breakpoint diameter the sampler must 1) estimate diameter to the appropriate diameter class, 2) determine the species of the tree, 3) identify the tree status, and 4) estimate height to nearest 1 foot (0.3 meter). Tree diameter is most easily estimated using a clear plastic ruler (see **How To Measure Diameter with a Ruler**). A diameter tape can be used but it is often cumbersome when diameters are less than 4 inches (10 cm). Once the diameter class, species, status, counts and average heights have been determined, record them in Fields 24 to 28, respectively. Optionally, average live crown percent can be recorded in Field 29 using the classes in table TD-5. Record the class based on the percent of the tree that has live foliage growing from it, from the top of the live foliage to the ground.

Height and live crown percent are challenging to estimate because their values must represent all trees within the species-diameter-status class combination. The best way to do this is to look at the first tree, assign it to a species-diameter-status class, visually estimate height to the nearest 1 foot (0.5 meter), estimate live crown percent class and record the estimates in the Saplings table of the TD Data Form. As more trees in the same species-diameter-status class are found, the note taker must adjust the average height and average crown ratio of the class. Methods for measuring height and live crown percent are discussed in detail in Measuring Structural Characteristics in the next section.

Sampling mature trees

Mature trees are those with a diameter at breast height that is greater than or equal to the breakpoint diameter.

Tagging the trees -- If you are doing a monitoring project you should tag all of the mature trees on your macroplot so that they can be identified in the future. (If you are simply doing an inventory they do not need to be tagged). There are two methods for tagging the sample trees depending on whether you are using steel or aluminum tags. The tag number is recorded in Field 5 on the TD Plot Form.

We suggest using steel casket tags because they will not melt during the heat of the fire. Nail the casket tags to the tree using high-grade nails that also won't melt during fires. Each tag should be tightly nailed to the tree bole with just enough pressure to prevent it from moving, but not so tight that the tag is driven into the bark. If the tag is allowed to move or twirl in the wind, the movement might wear through the nail and the tag could fall off. Nail the tags at breast height with the tag facing toward plot center. This is done so that each tree can be identified while standing in one place and will make relocating the plot center easier. It will also reduce macroplot travel, which can cause compaction and seedling trampling. If the trees are going to be cut, nail the tag less than one foot from the ground, facing plot center. This will leave the tags available for post treatment sampling and will keep them out of the sawyer's way if the trees are cut with a chainsaw.

Unfortunately, casket tags are expensive and the steel tags and nails can damage saws so they should not be used if the trees you are tagging will eventually be harvested. As an alternative to steel tags, nail aluminum tags at DBH on the downhill side of all the mature trees using

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aluminum nails. Putting tags on the downhill side of the trees will help keep them out of the hottest part of the flame and help keep the tags and nails from melting. Pound the nails in at a downward angle, until the tags are tight but not driven into the bark. Typically, some of the tags will be melted by the fire but by using tree characteristics (species and DBH, primarily) and the clockwise sampling scheme you should be able to relocate all the mature trees. Occasionally, the head of the nail will melt off and the wind will blow the tag off the angled nail, so you may be able to find the tag lying at the base of the tree.

Although it is not recommended, sometimes it may be necessary to remove some branches with a hatchet or bow saw so that the tag can be firmly attached to the tree. If needed, remove just the problem branches. Removing too many branches may influence the tree's health and/or modify the fuelbed around the tree.

Measuring General Attributes -- Record the general characteristics of the tree (species and health) in the next set of fields. These characteristics allow the stratification of results and provide some input values needed to compute crown biomass and potential tree mortality.

Enter the species of the tagged tree in Field 6 and the tree status in Field 7 of the TD Data Form. Tree status describes the general health of the tree. Use the following tree status codes:

H – Healthy tree with very little biotic or abiotic damage.

U – Unhealthy tree with some biotic or abiotic damage, and this damage will reduce growth. However, it appears the tree will not immediately die from the damage.

S – Sick tree with extensive biotic or abiotic damage and this damage will ultimately cause death within the next 5 to 10 years.

D – Dead tree or snag with no living tissue visible.

Tree status is purely a qualitative measure of tree health but it does provide an adequate characteristic for stratification of pre-burn tree health and for determining post-burn survival. Remember that trees marked as dead (code D) indicate the tree was sampled on the snag plot.

Measuring Structural Characteristics -- Five important structural characteristics are measured for each mature tree: DBH, height, live crown percent, crown fuel base height and crown class. These structural characteristics are used to assess a number of fire-related properties such as canopy bulk density, vertical fuel ladders, height to the base of the canopy, and potential fire-caused mortality. These characteristics can also be used to compute the input parameters needed by the fire growth model FARSITE (Finney 1998) and FOFEM (Reinhardt and others 1998).

Tree DBH is measured using a diameter or logger's tape. Be sure to measure DBH on the uphill side of the tree with the diameter tape perpendicular to the tree stem and directly against the bark. Measure DBH to nearest 0.1 inch (0.2 cm) and record in Field 8 on TD Data Form. (See **How To Measure DBH**).

Measure tree height from the ground level to the top of the bole or highest living foliage, whichever is higher, to the nearest 1 foot (0.5 meter) and enter the height in Field 9 of TD Data

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Form. Tree height is commonly measured with a clinometer, but it can be measured with laser technology or other surveying techniques (i.e. transit) if that equipment is available and the crew has had adequate training in using that technology (see **How to Measure Plant Height**).

Live crown ratio (LCR) is the percent of the tree bole that is supporting live crown based on the distance from the ground level to the top of the live foliage – not to the top of the bole. The LCR assessment is used as an indication of tree vigor and crown material for tree growth (e.g. in the Forest Vegetation Simulator). The illustrations in figure TD-7 show four trees with different crown characteristics. Tree A has a crown that, hopefully, will be the most common crown form you will see. Tree B is missing live foliage from the upper part of the crown (the area may be filled with dead branches and needles) and tree C is missing foliage along one side of the stem. Estimate LCR by visually redistributing the live tree crown evenly around the tree so the branches are spaced at about the same branch density as seen along the bole and form the typical conical crown. In the instance of recent abiotic or biotic damage use the Damage and Severity Codes described below to improve the crown fuel estimates. Record LCR in Field 10 on TD Data Form using the classes in table TD-5.

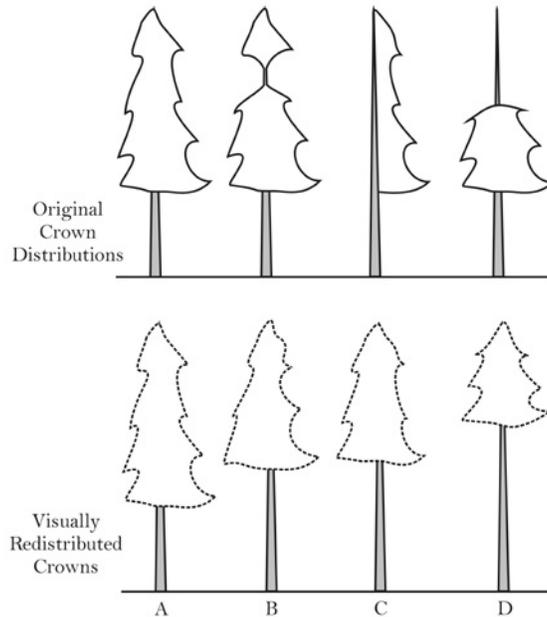


Figure TD-7. To estimate LCP visually rearrange the tree branches so that they are distributed evenly around the tree bole then estimate the percent length of the total tree stem that those branches would occupy. In this illustration the LCP class of trees A, B, C, and D are 70, 50, 50 and 30, respectively.

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Table TD-5. Use these classes to record live crown percent and crown scorch.

Code	Live crown percent
0	Zero percent
0.5	>0-1 percent
3	>1-5 percent
10	>5-15 percent
20	>15-25 percent
30	>25-35 percent
40	>35-45 percent
50	>45-55 percent
60	>55-65 percent
70	>65-75 percent
80	>75-85 percent
90	>85-95 percent
98	>95-100 percent

Sometimes, you'll see a lone live branch at the bottom of the crown that doesn't appear as part of the crown, and in these cases you can ignore the branch's contribution to LCP.

Crown Fuel Base Height (CFBH) is important for assessing the risk of crown fire. In Field 11 record either the height of the dead material that is sufficient to carry a fire from the lower to the upper part of the tree crown or, if the dead fuel is insufficient, the height of the lowest live foliage. The dead material may include dead branches associated with mistletoe infection, lichens, dead needles, etc. This is probably the most subjective field of the TD assessment. We suggest that this information should not be collected unless there is a knowledgeable crew member available that can consistently estimate CFBH. He or she should also record in the Metadata table the characteristics used for their assessment so that it can be made the same way in future sampling.

Optionally, users can record height to live crown (i.e. ignore the dead component) to limit some subjectivity. Height to live crown is defined as the height of the lowest branch whorl that has branching in two quadrants – excluding epicormic branches and whorls not part of the main crown - measured from the ground line on the uphill side of the tree. If you decide to estimate height to live crown instead of CFBH be sure to note that in the Metadata information.

Crown classes (Field 12) represent the position in the canopy of the crown of the tree in question and describe how much light is available to the crown of that tree (figure TD-8).

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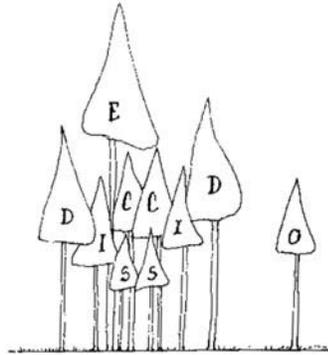


Figure TD-8. Use this illustration of crown classes to help you describe the crown class of the tree you are measuring

There are six categories describing crown class:

- O – Open grown**, the tree is not taller than other trees in the stand but still receives light from all directions.
- E – Emergent**, the crown is totally above the canopy of the stand
- D – Dominant**, the crown receives light from at least three to four directions
- C – Codominant**, the crown receives light from at least one to two directions
- I – Intermediate**, the crown only receives light from the top
- S – Suppressed**, the crown is entirely shaded and underneath the stand canopy

Crown class may be used for data report stratification, but it is also an important variable in the computation of tree biomass and leaf area.

Measuring Tree Age Characteristics -- Age characteristics allow better interpretation of the fire monitoring data by identifying important age and growth classes and using them for results stratification. In addition, growth data allows direct comparison of the change in growth rate as a result of the fire.

Tree age is estimated by extracting a core from the tree at stump height (i.e., about 1 foot above ground-line) on the downhill side of the tree using an increment borer. Rings on the increment core can be counted in the field or counted later in the office.

Coring trees to determine tree age is a time-consuming procedure that often requires over 50 percent of the sampling time. There are many reasons for this. First, there is a lot of time and effort involved in coring the tree, especially large trees, and often you will need to take more than one core per tree in order to get a usable core because of rot or because you missed the pith. Next, it is difficult to get comfortable when drilling at stump height because the sampler is stooped over in an unpleasant position. Certainly, you do not want to have to core every mature tree on your FIREMON macroplot, so the question is how many samples are enough? We suggest that one tree per species per 4 inch (10 cm) diameter class be cored if you are sampling

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at the Level III - Detailed intensity. The FIREMON project manager can increase the diameter class width to 8 inches or 12 inches (20 cm or 30 cm) to further limit coring time on the plot. Enter the tree age in Field 13 of the TD Data Form for each of the trees that were cored.

Growth rate should be determined for those trees that are cored for age however the growth rate core should be taken at DBH because the age core, taken at stump height, is not a good indicator of growth rate. Remove a core that is deep enough to allow you to measure the last 10 years growth. Growth rate is the distance between the cambium and tenth growth ring in from the cambium, measured to the nearest 0.01 in. (0.1 mm) (figure TD-9).

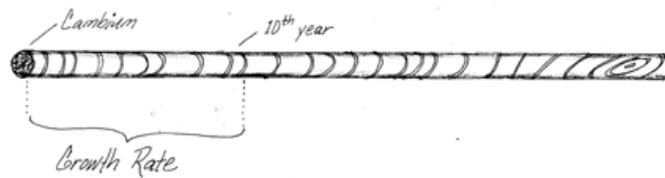


Figure TD-9. Tree growth rate is determined by measuring the last 10 years growth.

If changes in growth rates are a critical part of the monitoring effort (check sampling objectives), then more trees need to be cored for growth rate. If growth rate is an important facet of the fire monitoring project, we suggest that all tagged trees be cored to determine the 10-year growth increment. Enter the growth rate in Field 14 on the TD Data Form.

Measuring Damage and Severity -- This information may not be essential for determining the effects of prescribed and wildland fires, however, it can be useful for describing, interpreting, and stratifying monitoring results. We recommend that these fields be completed for most fire monitoring applications.

Biotic/Abiotic Damage and associated Severity Codes are entered in Fields 17 to 20 in Table 1 of the TD Data Form. These codes describe and then quantify the degree of damage by biotic (e.g. insect, disease, browsing) and abiotic (e.g. wind, snow, fire) agents for the mature trees. Additionally, you will be able to use the Abiotic codes for snags. The extensive list of damage and severity codes is presented in the **Damage and Severity Code Appendix**. These codes are the same ones that are used in the USDA Forest Service Common Stand Exam Guide. For your FIREMON project we suggest that you go through the appendix, select of codes that are important to your location and project objectives, and take a printed list with you in the field. If your project requires you to collect Damage and Severity Codes, as a minimum you should use the ones presented in table TD-6. You can add your own codes if needed but be sure to document them in the FIREMON Metadata table. When trees exhibit multiple forms of damage record the damage with the greatest severity first, then the damage with the second greatest severity.

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Table TD-6. Record tree and snag damage using these codes or select a code from the set listed in the **Appendix A: NRIS Damage Categories, Agents, Severity Ratings, and Tree Parts Damage and Severity Code Appendix.**

Damage Code	Description	Severity Code
00000	No Damage	No Damage
10000	General Insects	101 – Minor – Bottlebrush or shortened leaders or <20% of branches affected, 0 to 2 forks on stem or <50% of the bole with larval galleries 102 – Severe – 3 or more forks on bole, or 20% or more branches affected or terminal leader dead or 50% or more on the bole with visible larval galleries.
19000	General Diseases	191 – Minor – Short-term tree vigor probably not affected 192 – Severe – Tree vigor negatively impacted in the short-term
25000	Foliage Diseases	251 – Minor – <20% of the foliage affected or <20% of crown in brooms. 252 – Severe - >20% of the foliage affected or >20% of the crown in brooms.
50000	Abiotic Damage	501 – Minor – <20% of the crown affected, bole damage is <50% circumference. 502 – Severe - >20% of the crown affected bole damage is >50% circumference.
90000	Unknown	900 – 0-9% affected 901 – 10-19% affected 902 – 20-29% affected 903 – 30-39% affected 904 – 40-49% affected 905 – 50-59% affected 906 – 60-69% affected 907 – 70-79% affected 908 – 80-89% affected 909 – 90-99% affected

We recognize that it would take a great deal of field experience to identify each of the damaging agents present in a tree. There are classes at local colleges or USDA Forest Service offices to learn insect and disease identification. However, if the FIREMON crew does not have experience in the identification of biotic and abiotic damage sources, then do not fill out these fields.

Measuring Fire Severity -- There are two fire severity measurements that are specific to the TD sampling method and apply to the mature trees. The first severity measurement is bole char height, which is the height of continuous char measured above the ground, the on the downhill side of the tree, or on flat ground the height of the lowest point of continuous char (figure TD-10). It is often used to quantify potential tree mortality and some mortality prediction equations use bole char height as an independent variable. Measure char height with the logger's tape or

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cloth tape, holding the tape on the downhill side of the tree and measure to the top of charred part of the bole keeping the tape exactly vertical to the tree. Be sure to measure vertical height. Do not measure along the tree bole, which might be tempting if the tree is leaning. Record bole char height to the nearest 0.1 foot (0.3 m) in Field 21 of the TD Data Form.



Figure TD-10. Measure char height on the downhill side of the tree.

Percent of crown scorched (PCS) is another fire severity measurement that directly relates to tree mortality. It is extremely difficult to estimate because the sampler often does not know if some of the charred branches were alive prior to the fire. However, estimates of PCS to the nearest 10 percent class are usually adequate for use in mortality equations so the bias introduced by dead branches should not cause major problems.

Estimate PCS by trying to rebuild the tree crown in your head, and then estimate the amount of live crown volume that was damaged or consumed by the fire. The foliage could have been entirely consumed, or scorched black or brown with needles/leaves still attached to the branches. Enter percent crown scorched in Field 22 of the TD Data Form using the classes in table TD-5.

Sampling snags

There are two fields on the TD field form that are specific to snags: snag decay class and primary mortality agent. Snags progress through a series of stages after the tree dies, from standing with red, dead needles still attached to a well decayed stump. As the snag passes through these stages they function differently in the ecosystem, thus it is important to record snag decay class so the ecosystem characteristics can be quantified. Enter the appropriate snag decay class code from table TD-7 into Field 15 of the TD Field Form.

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Table TD-7. Determine snag decay class using these descriptive characteristics.

Snag Code	Limbs	Top of Bole	Bark	Sapwood	Other
1	All present	Pointed	100% remains	Intact	Height intact
2	Few, limbs	May be broken	Some loss, variable	Some Decay	Some loss in height
3	Limb stubs only	Usually broken	Start of sloughing	Some sloughing	Broken top
4	Few or no limb stubs	Always broken some rot	50% or more loss of bark	Sloughing Evident	Loss in height always
5	No limbs or limb stubs	Broken and usually rotten	20% bark remaining	Sapwood gone	Decreasing height with rot

Snag characteristics, for example wildlife preference and snag persistence, can be greatly influenced by the mortality agent so it is important to try and identify what killed the tree. This can be difficult for snags that have been standing for a few years as it is generally accepted that after five years you cannot determine the cause of mortality with any certainty. Also, typically there is more than one mortality agent. In FIREMON we suggest recording the primary cause of mortality. For instance, a fire may injure a tree enough to cause stress, which will, in turn, reduce its resistance so that it cannot effectively protect itself from beetle attacks and then the beetles introduce a fungus that eventually kills the tree. In this case the primary (first) agent of mortality is fire. If you can determine the primary cause of mortality for the tree record in Field 16 using the codes in Table TD-8. If you cannot determine the primary cause of mortality use the U code.

Table TD-8. Use these mortality codes to identify the primary (first) cause that killed the tree.

Mortality Code	Description
F	Fire caused
I	Insect caused
D	Disease caused
A	Abiotic (flooding, erosion)
H	Harvest caused
U	Unable to determine
X	Did not assess

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Precision Standards

Use these precision standards for the TD sampling.

Table TD-9. Precision guidelines for TD sampling.

Component	Standard
DBH	± 0.1 in./0.25 cm
Height	± 1 ft/0.3 m
Live crown percent	± 1 class
Live crown base height	± 1 ft/0.3 m
Crown class	± 1 class
Age	± 10 percent of total years
Growth rate	± 0.01 in./0.1 mm
Decay class	± 1 class
Mortality code	Best guess
Damage code	Appropriate category
Severity code	± 1 severity class
Char height	± 1 ft/0.3 m
Crown scorch	± 1 class
Count	± 10 percent of total count
Average height (saplings)	± 1 ft/0.3 m
Average live crown percent	± 1 class

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SAMPLING DESIGN CUSTOMIZATION

This section will present several ways that the TD sampling method can be modified to collect more detailed information or streamlined to collect only the most important tree characteristics. First, the suggested or recommended sample design is detailed, then modifications are presented.

Recommended TD Sampling Design

The recommended TD sampling design follows the Recommended FIREMON Sampling Strategy and is listed below:

Breakpoint diameter: 4 inches (10 cm)

Macroplot Size: 0.1 acre (0.04 ha) [37.24 ft radius, (11.28 m)]

Subplot radius: 11.77 ft (3.57 m)

Measure all fields EXCEPT Growth Rate, and only measure Age for one tree for each species-4 in.(species-10 cm) diameter class.

Streamlined TD Sampling Design

The streamlined TD sampling design follows the Simple FIREMON sample strategy and is designed below:

Breakpoint diameter: 6 in. (15 cm)

Plot Size: 0.1 acre (0.04 ha) [37.24 ft radius, (11.28 m)]

Subplot radius: 5.89 ft (1.78 m)

Only measure Fields 1-11, Fields 20-21, Fields 21-32.

Do not measure Table 1 fields Age, Growth Rate, Damage, Damage Severity, Snags.

Comprehensive TD Sampling Design

The comprehensive TD sampling design follows the Detailed FIREMON sampling strategy and is detailed below:

Breakpoint diameter: 4 in. (10 cm)

Plot Size: 0.1 ac (0.04 ha) [37.24 ft radius, (11.28 m)]

Subplot radius: 5.89 ft (1.78 m)

Measure all fields, but measure Age for one tree in each species-4 in. (species –10cm) diameter class. Measure growth rate on all tagged trees but only drill deep enough to measure 10-year record.

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User-specific TD Sampling Design

There are optional fields in each of the TD Field Form tables called Local Code. These will allow the sampler to record some local characteristic that is important to evaluating fire severity and effects. For example, a sampler might be concerned about the height of dead branches above the ground to describe the vertical fuel ladder. Or, maybe the sampler wishes to describe the value of the timber in this tree (e.g., sweep, crook, broken top) for salvage reasons. The Local Code field allows the sampler to design the TD Data Form to local situations and objectives. These codes must be recorded in the FIREMON meta-database to ensure that future users know their meaning.

There are many ways the user can adjust the TD sample fields to make sampling more efficient and meaningful for local situations. First, be sure the plot is big enough and the breakpoint diameter is large enough to get an ecologically valid sample. Use the 20 tree threshold for most cases (each macroplot should contain at least 20 trees above breakpoint DBH) but that should be adjusted based on the advice of local experts. Next, be sure to measure age and growth rate often enough to get a meaningful description for the plot, but not so detailed that it subsumes all sample time.

Use the Local Code for any other characteristic that is of interest in fire monitoring. Note that there is only one field so measuring two tree characteristics will take some creative thinking. For example, you could combine both measurements into one code. For example, the code 11 might indicate a code 1 for tree taper and a code 1 for timber value.

Sampling Hints and Techniques

Many times the sampler will encounter more trees than the Mature Trees table can accept. Another plot sheet can be started and the note taker can record at the top of the form that this is the second page of two (or maybe more?). It would be better if the TD plot sheet were copied to both sides of the waterproof paper. That way, the two or more plot sheets do not need to be attached for organization. The same situation happens when there are more species below breakpoint diameter than the Seedling or Sapling tables on the TD Data Form can accept. Again, if this happens, start another TD Data Form.