EREN
ECOLOGICAL RESEARCH AS EDUCATION NETWORK

Permanent Forest Plot Project (PFPP)

Version 1.06
(Protocols Only)
(Appendices are available as a separate document.)

30 Aug 2014

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http://erenweb.org/

Table of Contents

Permanent Forest Plot Project (PFPP) Overview

The goal of this project is to establish a set of permanent research plots throughout the United States and Canada, that will give faculty and students access to data that they can use to address questions related to tree biomass, carbon accumulation, species diversity, invasive species, and disturbance across a range of sites and ecoregions that represent different ecological gradients.

Project participants will establish one or more permanent, 400 m² plots (20 x 20 meters) in forested areas at or near their home institutions. The protocols have been designed with the goal that work can be conducted as part of a normal class laboratory or as part of student independent research projects. All trees within the measurement plots will be identified and their diameters' measured. Additional plot and tree data will be recorded as well. Tree diameters will be remeasured over time to calculate growth, mortality, biomass, and carbon sequestration. Data will be entered in an online database that will then be accessible to all participants. Educational modules will be developed for use with the database so that faculty can utilize the dataset with students in their classes.

Key to the success of this project is that all researchers will use the same protocols so that all data are comparable. Anyone who is interested in following the protocol and adhering to EREN's Data Sharing Policy is encouraged to participate in this collaborative project by setting up their own sites and contributing to the online database. If you are not yet an EREN member, visit http://erenweb.org and sign up!

Changes from version 1.05 (30 July 2012) to version 1.06 (30 Aug 2014)

New Plot Variables: **Site Web Link** (p. 16, optional); **Data Quality Assurance** (p. 16, required); **PlotDataUpdates** (p. 17, required); **Soil Texture** (p. 12, optional); **Distance to Edge** (p. 14, optional); **Border Type** (p. 14, optional); **Border Width** (p. 14, optional) **Border Aspect** (p. 14, optional); **Border Slope** (p. 14, optional)

Changes in existing Plot Variables: Uses are requested to record number and name for **Bailey's Ecoregions** (p. 9).

New Tree variable: Tree Damage (Optional for PFPP but required for the EAB subproject) (p. 25).

Changes in existing Tree Variables: Soundness Tree Variable made optional (p. 24); Added new Inv_Status options (FS, MS, DD); Tree numbers can now range from 1.0 to 99999.99 (p. 21).

New Small Stem Variable: Notes (p. 26; This variable allows users to add their own small stem data. Allows up to 100 characters, and can include commas.)

Text only changes:
Addition of a Table of Contents
Clarification of Plot Month and Plot Year updating frequency (p. 10).
Added emphasis on checking units and time interval when entering precipitation data (p. 10).
Clarification of what is meant by "Soil Order" (p. 11).
Clarification of what to enter in % Slope, Aspect, and Plot Description for plots located on hilltops or in saddles that have more than one dominant aspect (pp. 12-13).
Disturbance History Notes – Added information on what to include in this section. (p. 15).

Changes from version 1.05 (30 July 2012) to version 1.06 (30 Aug 2014) cont'd

Text only changes (cont'd):
>   Clarification of tree numbering requirements (p. 18).
>   Additional clarification for **Multiple Stems** (p. 21).
>   Clarification for the measurement of **Vines** (p. 19).
>   Clarification of **Inventory Status codes** for RD stems, and sprouts. (p. 21).
>   Instructions on data entry for small stem subplots that lack small stems (p. 26).
>   Instructions for filling blank cells in CSV files prior to upload (p. 29).
>   Added sections on **Frequency of Online Data Entry** (p. 28); **Administrator Responsibilities and Data Quality guidelines** (p. 29); **PFPP Subproject Variables not stored in PFPP database** (p. 26), and **Suggested Citation Format** (p. 31) for the protocols.
>   Added updated references for calculating tree biomass and carbon from tree dbh (pp. 27-28

 Plot, Tree and Small Stem Data Entry Forms Updated to include added variables.

Site and Plot Data Entry Form divided into 2 forms (Site-Plot Indoor Data and Plot Outdoor Data) to more clearly separate data collected in the forest from data that can be completed indoors, to provide some additional explanation, and to provide room for the newly added variables.

Database: Updated to reflect the new variables. Because of the new variables for both Trees and Small Stems, Researchers will need to download the new CSV templates before uploading Tree or Small Stem Data. Note that "null" should be included in ALL cells that lack data, even if the variable is optional.

Changes from version 1.04 (11 June 2012) to version 1.05 (30 July 2012)
Changes in Variables:

Four new Plot variables: Principal Investigator (p. 6); Edge Type (p. 9); Edge Width
>   (p. 9); and Edge Description (p. 9)

Text only changes:
>   Definition of Forest plot (p. 3), and Urban and Wetland plots (pp. 4 and 9)
>   Additional detail for Aspect reporting (p. 8)
>   Minimum edge width specified and descriptions of new Edge variables added (p. 9)
>   Clarification of Multiple Stem (p. 15)

Added sections: **Updating Site and Plot Data in the database** (p. 23), and **Correcting or Changing Tree Data or Small Stem Data** (p. 23)

(Note: The protocols are still being improved. Please contact Karen Kuers or Erin Lindquist *with any problems you encounter, or suggestions you have to improve the content and format. 30 Aug 2014)*

Potential Research Questions Using Permanent Forest Plots

There are a large number of research questions that could be addressed using fixed-area permanent forest plots. As the online database grows, students will be able to search for and utilize data from plots in other regions for comparison to their own results. PFPP participants are encouraged to share the hypotheses they are testing so that over time groups of faculty and students in different regions can work simultaneously on the same questions and hypotheses. Visit http://erenweb.org/project/carbon-storage-project/permanent-plot-protocol/potential-pfpp-research-questions/ for a growing list of sample research questions.

How many plots to establish?

The number of plots you establish will depend upon your research/teaching goals. A single 20 x 20 m plot could be used to demonstrate biomass and carbon monitoring techniques, to follow local plot biomass changes over time, and to provide a local vegetation comparison plot for inclusion in the PFPP database. New plots could be added in subsequent years and previously established plots re-measured. (It will take significantly less time to re-measure the plot than to establish it.)

Plot replication can provide a more robust site characterization and allow statistical analyses among and within sites. Participating faculty are encouraged to replicate plots whenever feasible. Three to five plots within each forest type, or site condition being studied could be sufficient for this purpose. For example, to compare biomass in two different local forest types, 3-5 plots could be established in each forest type. (If there is insufficient time in a single year, a pair of plots could be established each year, accumulating plots over time.)

Note: There should be a minimum of 20 m between replicate plots, or plots representing different forest conditions.

Deciding where to locate your plots

For the purpose of this project, a Forest Plot is one in which the dominant plant community consists of trees. While the trees may be in any stage of development, these protocols are most appropriate for plots containing tree stems that are ≥ 2.5 cm in diameter at a height of 1.37 m above the ground. While complementary protocols that will assess other plant groups are planned for the future, the focus of the current PFPP inventory procedure is on woody species.

Where you choose to locate your plots will depend upon the types of questions you interested in addressing, and the types of forested locations you have available. We welcome plots in any forested site. We are specifically encouraging the installation of paired plots in the following locations: urban and non-urban forests; forests with invasive plant species and forests without invasive plants; edge and interior forests; naturally regenerated and planted forests of similar species; forests with exotic insect/disease pests and those without; and wetland and upland forests. If you are in an area currently or soon to be impacted by an exotic insect or disease (e.g. emerald ash borer; hemlock wooly adelgid; thousand canker disease; oak wilt) and have forests not yet impacted, it would be helpful to install plots before the forest is attacked. For example, as of 2014, the emerald ash borer (EAB) has moved west into Colorado and south into Tennessee, Georgia, and North Carolina, and it would be helpful to have plots in ash forests to track the arrival and impact of the insect on forest structure and productivity. If you are interested in the EAB Impacts Study, you can find additional information at: http://erenweb.org/new-page/emerald-ash-borer-project/ ."

Frequency of Data Collection and Online Data Entry:

See "Frequency of Data Entry (p. 28) for information on how often to update Site, Plot, Tree, and Small Stem Data.

EREN Permanent Forest Plot Project (PFPP): Introduction to Methods

Objectives:

The purpose of this project is to use common protocols to establish and measure 400 m^2 (0.04 ha) permanent forest inventory plots that can be used to assess biomass levels, woody plant biodiversity, and/or carbon accumulation in forests located in different ecological regions, climate zones, and/or landscape positions. Once established, the plots can also be used to assess changes over time, as well as the impacts of a range of variables such as invasive species, proximity to edge, or location in urban or other impacted environments.

Materials (minimum):

1 -2 compasses per group   DBH tape (metric) (1 per student group)
Tree ID key   2-4 metric tapes at least 30 m long (per class)
Clinometer to measure canopy height
Wire Survey flags: (4 for plot corners, 6 to 25 for 5 x 5 m subplots, 100+ if used to number each tree)
List of species abbreviation codes (Appendix V)
3 Data Forms: Site/Plot Data, Tree Inventory Data, Small Stem Data
        Optional: Paper copies of the plot layout for mapping tree locations (Appendix VIII)
        Optional: aluminum nails and tags to permanently mark the trees
        Optional: Metric calipers or 2.5 cm measuring gauge for very small trees

Note: There are a variety of tools available for use in forest measurement. The following link provides a list of the most common equipment, describes their uses, and provide a link to potential suppliers.   http://ext.nrs.wsu.edu/handtools/tools/measurements/index.htm

Plot location

Plot location is critical to interpretation of the results. In addition to classifying plots as interior or edge, we are also interested in knowing whether plots are in urban forests and/or in wetlands. **Interior/Edge:** Plots located within 30 m of the forest edge are considered "edge" plots, whereas "interior" plots are those located at least 30 m from the edge of the wooded area. For the purposes of this project, a plot is **Urban** if the plot is surrounded by urban or suburban landscapes, or other patches or strips of trees located within or immediately adjacent to urban, suburban, or other residential areas. (For additional information see "Plot Variables - Urban Status, p. 14.) **Wetland** plots are those in which the soils are saturated either permanently, or seasonally. For additional information on identifying your site as a wetland you can visit the following website: http://water.epa.gov/type/wetlands/what.cfm (accessed July 26, 2012).

Reminder: There should be a minimum of 20 m between replicate plots, or plots representing different forest conditions

Plot layout Overview

For long term monitoring, the trees need to be either mapped by location, or each tree needs to be individually tagged for repeat measurement over time (if possible it would be good to both map and tag each tree, but mapping could be done at a later time.)

There are many approaches to establishing and inventorying a 400 m^2 plot. The approach described on p. 17 is for 20 x 20 m square plots (we encourage the use of square plots), but plots could be either rectangular (10 x 40 m) or circular. Square plots can be easier to maintain long term, but take longer to establish than circular plots. A circular 400 m^2 plot should have a radius of 11.28 meters. For the small stems inventory, a circular 25 m^2 plot would have a radius of 2.82 meters.

Site Variables (These variables can be completed in the lab, either before or after establishing the study plots. Enter this data on the **Site/Plot Data - Indoor Data Form**. *Please print data carefully and clearly on the datasheets to avoid mistakes. The data should be easily readable by anyone looking at the data form.)*

Site Name: A general name of your location. It may include one or more plots (e.g. OWU, Flattop Mtn., Laurel Park, etc.) The Site name must remain constant through time.

Site Date: The date that the site is described. The site will be identified in the database using this year. *If site variables change over time, the data can be updated online by creating an additional site description that uses the same name, but has the new date.*

Ecoregion (Bailey's): Enter both the number and name of Bailey's Domain, Division, and Province.
A list of Ecoregion Domains, Divisions, and Provinces can be downloaded from the EREN PFPP website. The ecoregion can be visually determined from the following website: http://www.fs.fed.us/land/ecosysmgmt/   Alternately the Province can be determined by entering the zipcode of the location in the following website, http://www.pollinator.org/guides.htm, and the Domain and Division can be found on http://www.fs.fed.us/land/ecosysmgmt/
If you live in a region where Bailey's Ecoregions have not been delineated, record "No Domain", "No Division", and "No Province" in the three blanks.

Mean Annual Air Temperature: Record the mean annual temperature in degrees Celsius.

Mean Temperature data source: Indicate if the source is LOCAL or obtained from the WEB.

Air Temperature Source Note: If the source is the WEB, indicate the site used to obtain the data.
There are a variety of data sources for obtaining average annual temperatures. If you have access to data from a weather station close to the site, use that data and record the source as LOCAL. If you need to obtain the value, the WEB is a useful source. There are a number of possible sites from which you can obtain your data, some free, some requiring a fee. The following NOAA website (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?WWDI~getstate~USA) may require a fee for some data forms.
If you use one of the WEB sites, note the actual location for which the data was recorded. Sometime the data for smaller locations are actually reports from the nearest large city. The instructions below illustrate how to obtain weather information from two different free sites: Weather Underground, and the NOAA Coop site.

> **Weather Underground:**   http://www.wunderground.com/history/
> 1.   Type in location (city name or zip code)
> 2.   Type in date and select "submit"
> 3.   When data screen opens, select "custom" tab
> 4.   Type in any two dates as prompted. Note that they must be < or = one year apart.
> 5.   Select "go".
> 6.   Data will appear including: a) Temperature (min, max, mean) , b) Degree days (heating, cooling, growing), c) Dew point, d) Precipitation, e) Wind, and f) Sea level Pressure
> 7.   Note that you can select any time span up to and including one year (12 months) prior to your sampling date.
>
> **NOAA Coop Site:** http://www7.ncdc.noaa.gov/IPS/coop/coop.html
> The NOAA COOP site provide free, downloadable pdf files of monthly temperature and precipitation data submitted by volunteer COOP stations. The data would need to be converted to spreadsheet format and summarized to obtain annual totals, a project that could be conducted by students as part of a class activity.
> To use the COOP site, highlight the correct state, and then select "Next". Look through the available stations list and see if there is a COOP station near your forest that has data available for the time period of interest. Note that the

most recent month is generally not yet available. If there is an available station, select the station, and "Next". A list of available months and years will appear. Select the dates of interest. You can download each month as a separate pdf file. Monthly temperature and precipitation data can then be entered in excel and used to compute annual averages. (Note that the data is reported in degrees Fahrenheit and inches and would need to be converted to degrees Celcius and millimeters.

Average Annual Precipitation: Record the precipitation in mm.
Please record the average total annual precipitation, in millimeters, not in cm or inches. Do not enter the average monthly value, and please be certain to convert inches to millimeters.

Precipitation information source: Indicate if the source is LOCAL or obtained from the web.

Precipitation Source Note: If the source is the WEB, indicate the site used to obtain the data.

Length of Growing season: Indicate the length of the growing season in <u>days</u>**.**
The growing season is the number of days between last and first frost, or approximately the last and first occurrence of 0° C (freezing) overnight low temperature. You can obtain the approximate dates of the annual first and lost frost by visiting one of the following websites:
http://davesgarden.com/guides/freeze-frost-dates/
http://www.accuracyproject.org/w-FreezeFrost.html

Growing Season Data Source: Record the source used to obtain the growing season length.

<u>Plot Variables –Indoor Data Entry</u> *(These variables can either be determined from records, online data sources, or laboratory analysis of samples collected in the field. This data should be entered in the **Site/Plot Data - Indoor Data Form.** Some of these variables (e.g. precipitation) will change from year to year, requiring the creation of a new Plot record when new Tree Data is added to the database. In addition, if a plot is significantly disturbed or modified the Plot information should be updated. See "Updating/Editing Site and Plot Data", page 30.)*

Plot Name: Provide a name for the plot that includes 6-12 characters, no spaces. The Plot name must remain constant over time.

Principal Investigator (PI): Name of the official contact(s) for tree data collected for this plot.
Include the full name (or names) of the key individual(s) responsible for coordinating plot selection, layout, and data collection for the plot. PIs will typically be faculty members, or other researchers, who are directing student participants. We encourage all PIs to become EREN members and registered PFPP Database Researchers. Anyone with questions concerning the Plot data, or planning use of the data in a publication, will be referred to the PIs listed in the database.
It is possible to add additional PIs whenever Plot data is updated and trees are remeasured in the future. (See "Updating/editing Site and Plot Data" p. 30.)

Plot Year: Report the year in which the Plot variables were measured.
All uploaded tree data will be associated with a Plot Year and Plot Month. Plot data should be updated each time new tree measurements are taken. The data can be re-entered using the same plot name with the updated year and month. (See "Updating/editing Site and Plot Data" p. 30.)

Plot Month: Report the month in which the Plot variables were measured.
Plot data can be entered up to 2 times per calendar year...once before the growing season begins, and once after the growing season ends. Plot data should be updated each time new tree measurements are taken. The data can be re-entered using the same plot name with the updated year and month. (See "Updating/editing Site and Plot Data" p. 30.)

Forest Origin Year: Record the Year of Origin for the forest (yyyy; Leave blank if unknown).

The year of origin is the year that the forest was planted, or year in which the dominant/codominant canopy trees began their aboveground growth after some type of disturbance or change. If you are unable to determine the age of the stand from records, increment cores, or known disturbance history, leave this blank.

Using an increment borer to determine tree age and the year of stand origin: If you have an increment borer, you can core one or more of the canopy trees to determine the age of the overstory. Subtract the number of rings at breast height from the current year to determine the Year of Origin. There are a number of good online descriptions of using increment borers to extract increment cores to determine tree age. Most purchased increment borers come with instructions. They can be purchased from equipment retailers such as Forestry Suppliers and Ben Meadows. See also the following document for obtaining and using increment cores to determine tree age:
http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr25.pdf

Forest Age Information Source:

If you have written or oral records concerning the origin of the forest stand in which the plot is located, circle **WRITTEN or ORAL,** and record the known **Forest Origin Year** above. If you used an increment borer to determine the age of the overstory, circle **MEASURED,** and record the year of origin derived from your increment core. If you have a general idea of approximately how old the forest stand is, circle **ESTIMATED,** leave the origin year blank, and include what you know in "Forest Stand Notes". If you were unable to determine the age of the stand, leave the origin year blank, and select **AgeUNKNOWN**.

Forest Origin Type: Indicate if the stand was PLANTED, NATURALLY REGENERATED, or its origin is UNKNOWN.

Forest Stand Notes:

Please add any information regarding the origin of the stand that could prove helpful in analyzing the tree data. This might include information obtained from forest management records, personal knowledge of the disturbance event that gave rise to the current forest, prior agricultural activity, or other potentially useful information regarding site history and origin.

Forest Size : Circle the approximate size (in hectares) of the Forest in which the plot is located.

If it is an isolated patch, indicate whether the patch is **< 1 ha,** or **1-10 ha**. If it is a larger forest tract, indicate whether the extent of the forested area is **11 – 100 ha**, or **> 100 ha**.
*See Appendix III for a method of using **Web Soil Survey** to calculate forest area.*

Soil Order: Record the Soil Order for your plot.

Enter the soil order for your plot. Please select enter one of the following 12 soil orders: **Alfisol, Andisol, Aridisol, Entisol, Gelisol, Histosol, Inceptisol, Mollisol, Oxisol, Spodosol, Ultisol, Vertisol**.

For more information about soil orders see: http://www.cals.uidaho.edu/soilorders/ or http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_053588 or http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447032&topicorder=2&maxto=16 . (*Soil information can be obtained by using the free android app SoilWeb at the plot, or you can also s*ee Appendix I for a description of methods to use the web to obtain the Soil Order and general Soil Classification information for your plot from the NRCS online Web Soil Survey tool. http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx *).*

Optional Soil Variables: (*See Appendix II for methods to measure these optional soil variables.)*
> **Soil pH (optional):** Record the soil pH.
> **Soil bulk density (optional):** Record the soil bulk density.
> **Soil Texture (optional):** Enter the soil texture classification for your plot. (This can be entered as the Soil Series or Soil Map Unit obtained from the NRCS Web Soil Survey tool or from the output obtained using the free android app SoilWeb, available for download from Google Play.)
> **Soil Organic matter (optional):** Record the % soil organic matter.
> **Soil Moisture (optional):** Record the % soil moisture.

Total Precipitation Preceding 12 months: Record the precipitation in mm.
> *(PPt data can often be obtained from the same web sources as Temperature data.)*

Precipitation information source: Indicate if the source is LOCAL or obtained from the web.

Precipitation Source Note: If the source is the WEB, indicate the site used to obtain the data.

Plot Variables – Outdoor Data Collection: *(These variables are recorded from plot observations and measurements. This data should be entered in the Plot Outdoor Data Form.)*

Plot shape: Indicate if the plot is Square (S), Circular (C), or Rectangular (R)
> Square plots are 20 x 20 m, Circular plots have a radius of 11.28 m, and Rectangular plots should have dimensions of 20 x 40 m.

Plot Description Date: Record the date of measurement (yyyy/mm/dd). If the data is collected over 2 or more weeks record the date the plot (not tree) field measurements were completed.

Latitude / Longitude: Record the latitude and longitude of the NE corner of the plot in the format:
> Latitude: xx.xxxxxx (decimal degrees)   Longitude: xx.xxxxxx (decimal degrees)
> (Please use at least 4 decimal places; 6 if possible)

> *Decimal degrees can be calculated from Degrees Minutes Seconds by the following formula:*
> *Decimal Degrees = Degrees + ((Minutes / 60) + (Seconds / 3600))*
> **Note that longitude values that are in the western hemisphere and latitude values that are in the southern hemisphere are recorded as negative decimal degree values. All others are reported as positive values.**
> *Example: The decimal degree representation for the location of the United States Capitol*
> *38° 53' 23" N, 77° 00' 32" W   =   38.889722°, -77.008889°   in decimal degrees*

Elevation (m): Record the elevation of the NE corner of the plot in meters

Aspect (°): Aspect is the direction that a slope faces.
> If your plot is not flat, stand in the middle of the plot and look to see which direction the slope faces. Point your compass in that direction, read the aspect in degrees, and record it as a number from 0 to 360. If on flat ground, record the azimuth as "flat". *Plots on a hilltop or in narrow valley might have two different aspects; Record the "dominant" direction as the plot's aspect, and record the second aspect with the plot description*

Slope %: Record the average % slope across the plot. If the plot is flat, % slope = 0.

Percent slope is equal to the change in elevation per horizontal distance ("Rise" over "run".) A 45% slope indicates that there is a 45 ft elevation change per 100 ft horizontal distance. One way to measure slope % is to use the % scale (left hand scale) on a clinometer. Hold the clinometer parallel with the ground (upslope or downslope), and look through the clinometers at a point that is equal to the height of your eye above the ground. (It is best to sight across the entire plot so that you get the overall slope of the plot.) Read the % slope from the left side of the scale visible in the view finder. Slope % can be > 100.

One way to do this is to pick a partner, note the point on your partner that is equal to your eye level, and then walk to opposite uphill/downhill sides of the plot and look through the clinometer, aiming at the height of your partner that is equal to your eye level. If no partner is available, identify the height of an eye level object on the uphill or downhill edge of the plot, walk to the opposite side of the plot and sight through the clinometer at the object, reading the slope from the % scale. Note: Many compasses also have scale that can be used to read slope.

Plots on a hilltop or in narrow valley might have two very different slopes; Record the slope in the "dominant" aspect as the plot's slope, and record the second slope, along with the second aspect, with the plot description.

Landscape Shape: Record the shape of the plot as predominately Planar (flat), Concave, or Convex.

Concave plots will tend to collect water, and convex plots will tend to have water runoff. Planar plots can be variable, depending upon the % slope

Plot description: Please include a general description of the plot**.**

Include such information as presence of trails, excessive vine coverage, deer browse, cover of invasive plant species, the secondary aspect of plots that are situated on hilltops or in drainages, and another other information that might prove useful in later evaluation of plot development over time. If the plot is on a hilltop or in a saddle, with 2 different aspects, make note of that here, and record the secondary aspect and slope.

Interior/Edge: Record whether the plot is Interior or Edge.

The minimum width of the non-forest area adjacent to the plot should be 10 m for the plot to be classified as edge. If the plot is at least 30 m from the forest edge select **INT** for interior**.** If the plot is 30 m or less from the forest edge, select **EDGE,** and record the actual distance in "Edge Description". For more information on the "Edge Effects" PFPP subproject protocols go to: http://erenweb.org/new-page/edge-effects-project/ .

Edge Type: Record the type of edge.

If the plot is not an edge plot, circle **"not an edge".** *(Note: When you enter data into the database Edge Type will not appear as an option if you have identified the plot as Interior.)*

If the plot is an edge plot, you will be required to select one of the following edge types to describe the condition in the area adjacent to the forest edge: **impervious surface**, **utility corridor**, **unpaved road**, **agriculture**, **old field**, **lake/river**, or **other.** (If you select "other", please specify in "Edge Description")

Edge Width: Select the appropriate width class for the edge.

Edge width refers to the distance across the adjacent patch to the next forest patch**.** If the plot is not an edge plot, circle **"not an edge".** If the plot is an edge plot, you will be required to select one of the following widths: **10 to 20 m; 20 to 50 m;** or **> 50 m.** (*Note: When you enter data into the database Edge Width will not appear as an option if you have identified the plot as Interior.)*

Optional Edge Variables: *(While optional for PFPP, These variables are required for the Edge Effects Subproject. For more information on these variables please refer to the Edge Effects Subproject Protocols: http://erenweb.org/new-page/edge-effects-project/eren-pfpp-edge-effects-study/).*

Distance to Edge: Record the distance (in m) to the forest edge from the plot corner or perimeter closest to the forest edge. If you are using a different criterion for defining the edge line, please explain under "Edge Description".

Border Type: Circle one of the following: **Straight   Convoluted   Perforated   Other**

Border Width: Circle one of the following   **<1m   1-5m   >5m**

Border Aspect: Use a compass to determine the bearing perpendicular to the general contour line of the edge nearest to this plot. Record the Aspect in degrees **(1 to 360)**.

Border Slope: Use a clinometer to determine the slope (in %) perpendicular to the general contour line of the edge nearest to this plot. *If the edge approximates 90 degrees (i.e. a cliff or bluff), report the % slope as 9999, and note this in the* **Edge Description**.

Edge Description:
Record what you know regarding the origin and longevity of the edge, along with the distance from the plot to the edge. If you selected "other" for edge type, please explain here. If you know when the edge was created, of have any information concerning how the edge is maintained, including any direct impacts on the forested edge, please include that information here, as well as any of the supplemental data required for the optional Edge Effects subproject. *(Note: When you enter data into the database Edge Description will not appear as an option if you have identified the plot as Interior.)*

Wetland Status: Indicate whether the plot is in a floodplain or wetland by selecting **YES** or **NO**.
Wetland plots are those in which the soils are saturated either permanently, or seasonally. For additional information on identifying your site as a wetland you can visit the following EPA website: http://water.epa.gov/type/wetlands/what.cfm (accessed July 26, 2012).

Urban Status: Indicate whether the plot meets the Urban forest criteria by selecting **YES** or **NO**.
Identify a forest as "urban" if it meets one of the following criteria: The plot is surrounded by urban or suburban landscapes, or other patches or strips of trees located within or immediately adjacent to urban, suburban, or other residential areas. Any plot located in or near residential or industrial locations in which the soil, or plant community has been highly or repeatedly modified by construction or other residential or industrial activities, should be classified as "urban". If you have doubts as to the classification, include your questions under "Plot Description" above.

Disturbance History: Please indicate if there is visible evidence, or recorded evidence of the following types of disturbance:

        Fire_____   If yes, record how recent, or record UNK in **Disturbance Notes**
        Insect____   If yes, record the insect, or record UNK in **Disturbance Notes**
        Disease___   If yes, record the disease, or record UNK in **Disturbance Notes**
        Wind ___   If yes, record how recent, or record UNK in **Disturbance Notes**
        Mining____   If yes, record how recent, or record UNK in **Disturbance Notes**
        Logging___   If yes, record how recent, or record UNK in **Disturbance Notes**
        Other____   If yes, please explain in **Disturbance Notes**

Disturbance History Notes: If you answered YES to any of the preceding disturbances, whether it has had a major or minor impact on the site and its vegetation, along with any details you might know as to when the disturbance occurred, the type of insect or disease, etc.

Dominant Groundcover: Which statement is most correct with respect to the plot's dominant groundcover?   L G H W M NNP FF SR none

L:	Lichen and/or mosses cover over 50% of the plot.
G:	Grass: Grass covers over 50% of the plot. (Not including Japanese stilt grass *Microstegium*).
H:	Herbaceous (native): Non-grass, native herbaceous plants cover over 50% of the plot.
W:	Woody (native): Native shrubs cover over 50% of the plot.
M:	Mixed: Grass and <u>native</u> herbaceous and woody plants combine to cover over 50% of the plot.
NNP:	Non-native plants: Non-native herbaceous or woody plants cover over 50% of the plot.
FF:	ForestFloor: Leaf/ woody litter covers over 50% of the plot.
SR:	Bare Soil/ Rock: Bare Soil/ Rock covers over 50% of the plot.
none:	None of the preceding cover over 50% of the plot.

Secondary Groundcover: Which statement is most correct with respect to the plot's second most dominant groundcover?   L G H W M NNP FF SR none

L:	Lichen and/or mosses cover 25 – 49 % of the plot.
G:	Grass: Grass covers 25 – 49 % of the plot. (Not including Japanese stilt grass *Microstegium*).
H:	Herbaceous (native): Non-grass, native herbaceous plants cover 25 – 49 % of the plot.
W:	Woody (native): Native shrubs cover 25 – 49 % of the plot.
M:	Mixed: Grass and <u>native</u> herbaceous and woody plants combine to cover 25 – 49 % of the plot.
NNP:	Non-native plants: Non-native herbaceous or woody plants cover 25 – 49 % of the plot.
FF:	ForestFloor: Leaf/ woody litter cover 25 – 49 % of the plot.
SR:	Bare Soil/ Rock: Bare Soil/ Rock cover 25 – 49 % of the plot.
none:	None of the preceding cover 25 – 49 % of the plot.

   <u>Groundcover:</u> Groundcover includes any vegetation that is less than 1.37 meters tall, as well as leaf/woody plant litter, and/or bare soil and rock. When calculating percent coverage, exclude the ground that is occupied by tree stems, and base the calculation on the ground that is not covered by standing large or small stems (living or dead). For a diagram that us useful for estimating % groundcover, refer to Figure 1.
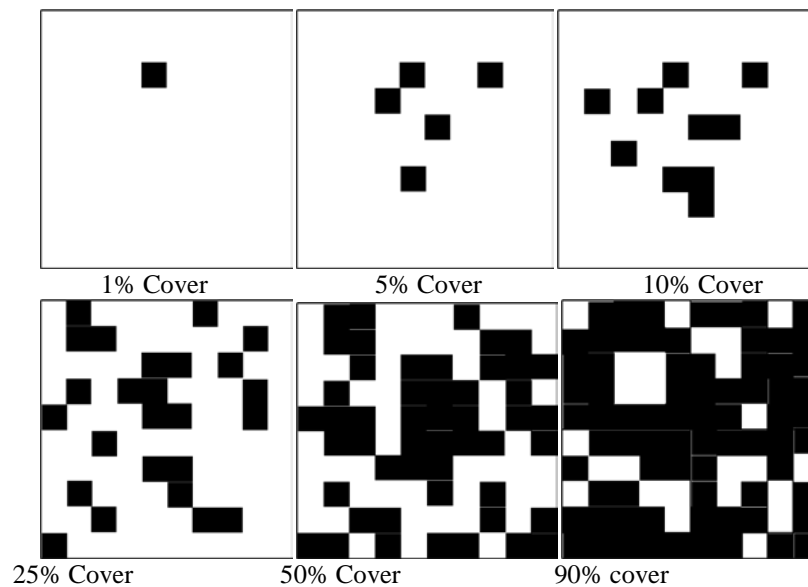
Figure 1: Diagram depicting different levels of percent to aid in estimating the Dominant and Secondary ground covers in the plot. Appendix IV included a printable handout of this diagram.

Vegetation Typical? Is the plot vegetation typical of that in the surrounding forest. **YES or NO**

Vegetation Comment: If the answer above is **NO,** please indicate how it is different.

Invasive Species? Are invasive plant species present in the plot? **YES or NO.**

Invasive Species List: If the answer to "Invasive Species?" is **YES,** please list the invasive plant species present in the plot.

Avg. Canopy Height (m):

Record the height (in meters) of the average level of the top of the canopy. Select one or more trees that make up the general level of the canopy of forest in which your plot is located and measure the height of one or more of those trees. See one of the following links for information on how to measure the heights of trees:

http://www.sewanee.edu/Forestry_Geology/watershed_web/Emanuel/Treehts.htm
http://extension.usu.edu/forestry/Kids/Kids_TreeHeightMeasure.htm
http://www.envirothonpa.org/documents/MeasuringTreeHght.pdf

Site Web Link (Optional):

If there is a web site with additional information on the study area where this plot is located, or which includes photos or additional datasets, please include that link here.

Data Quality Assurance (Required):

All datasheets must be double checked for accuracy before data is entered into the database. Scientists are also strongly encourages to check measurement accuracy by repeating measurements of a portion of the tree diameters. Indicate in the database the level of quality control (1 – 5) used with the tree data uploaded for this plot. Repeat measurements should be made by someone who has demonstrated the ability to make consistent, accurate dbh measurements.

1) All data entered in the spreadsheet have been carefully compared to the data entry sheets, and numbers have been checked to see that they are within reasonable ranges.

2) In addition to data entry checks, at least 10% of the tree diameters for the plot were measured by at least 2 people, and measurements were repeated until sequential measurements resulted in a difference of less than 0.2 cm.

3) In addition to data entry checks, at least 25% of the tree diameters for the plot are measured by at least 2 people, and measurements were repeated until sequential measurements resulted in a difference of less than 0.2 cm.

4) In addition to data entry checks, at least 50% of the tree diameters for the plot are measured by at least 2 people, and measurements were repeated until sequential measurements resulted in a difference of less than 0.2 cm.

5) In addition to data entry checks, all of the tree diameters for the plot are measured by at least 2 people, and measurements were repeated until sequential measurements resulted in a difference of less than 0.2 cm.

PlotDataUpdates (Required):
This information will make it easier to determine how plots have changed during periods between tree data uploads. Please check the boxes of each of the sections in which the current plot data differs from previous plot data information. The titles refer to the plot data categories as defined in the PFPP online Database.

| Forest Variables | Soil Data | Precipitation data | Characteristics |
| Landscape location | Disturbance History | Vegetation | |

Field Techniques: Plot Establishment and Tree Measurements

Laying out a 20 x 20 m Plot (Preferred plot shape)

Mark the NE corner of the 20 x 20 m plot. You will first set the diagonal for the plot to be certain that the final plot is square. (Note: It helps to have two compasses, four people, and four 20 to 30 m tapes. However, it can be done with only one compass, two people, and three tapes.)

One person stands at the NE corner, sets the compass for S45°W (or 225°) and directs a second person who walks approximately 30 meters S45°W and turns to face the first person. The first student then motions the second student to move right or left until he/she is exactly S45°W. If a second compass is available, the second person should set his/her compass for N45°E (or 45°) and sight back to the first corner to double check the orientation. Once the students are in agreement, a third person pulls the tape 28.28 m from the initial corner toward the second person. The two people with compasses can direct the person pulling the tape to help him/her walk the straightest path past trees and shrubs. Once the tape is straight, taut, and in the correct orientation, mark the new corner with a flag. (This is the SW corner of the plot). Leave the tape in place if possible.

Next find the NW corner of the plot by using a compass to sight due W from the NE corner, and due N from the SW corner. Pull one tape 20 meters W from the NW corner and another tape 20 meters N from the SW corner. Once the two tapes are taut, where they meet at 20 m should represent the NW corner of the plot. (If you plan to divide the plot into 5 m subplots, now is a good time to go ahead and place flags at 5 meter intervals along the N and W boundaries of the plot.)

Next find the SE corner of the plot by using a compass to sight due S from the NE corner, and due E from the SW corner. Pull a tape 20 meters S from the NW corner and another tape 20 meters E from the SW corner. (These can be the two tapes that you used to set the NW corner.) Once the two tapes are taut, where they meet should represent the SE corner of the plot. (If you plan to divide the plot into 5 m subplots, now is a good time to go ahead and place flags at 5 meter intervals along the S and E boundaries of the plot.)

To check that the plot is square, pull a tape from the SE corner to the NW corner. The diagonal should be 28.28 meters, and it should cross the other diagonal at 14.14 meters. Adjust the location of one or both of the NW and SE corners as needed.

If you placed flags at 5 m intervals along the boundary, number them 5, 10, and 15 going from N to S, and 5, 10, and 15 going from E to W. Next mark the interior 5 x 5 m subplot boundaries by pulling tapes S from the northern to the southern boundary at the 5, 10, and 15 m intervals.

Tree Numbering, Tagging, and Mapping

If you plan to number the trees, one method of involving students in the process is to initially use colored pin flags that are numbered and later replaced with aluminum tags. The method that follows assumes that you have established 5 m subplots and that there will be 4 student groups working simultaneously to measure a plot within a single laboratory period. The main purpose for the different colors of flags is to make it easy for a class with several student groups to easily see where each group should measure, and to aid in the mapping of the stems. If the entire plot will be measured by one group, the trees can be numbered and mapped in one pass, and different colored flags may not be necessary.

Tree Numbering

Assign a number to each stem so that it will be possible to relocate and remeasure the tree in a future year. Trees with multiple stems will require multiple numbers. Multiple stems can either have unique whole numbers, or may be recorded as a decimal (1.1, 1.2).

No two stems in a single 20x20 m plot can have the same number. When plots are remeasured in the future, smaller trees that grow above the 2.5 cm minimum measurement size should be given the next unused number. When a tree dies and falls to the ground, its number is "retired" forever.

The method that follows uses pin flags to number each stem.

Tagging Trees

There are a number of different methods for permanently tagging trees. Stem attachment materials (nails) and tags should generally be aluminum (or plastic cables) rather than steel (unless small staples are used) to prevent to injury people and equipment if the stem is sawn in the future, either after it dies, or as part of a harvest. Tags can be placed in the ground at the base of the tree, in the tree stem near the ground (to make them less visible), near DBH (*See pp. 22-23 for methods of positioning the tag and nail to ensure a consistent DBH measurement height*), or can be hung from small branches near the base of the tree. The method you choose will depend upon the size and age of your trees, desired investment of time and resources, and whether or not you want the tags to be readily visible. Tags will need to be checked periodically because they are often chewed on by wildlife (or removed by people). Searching the internet for images of tree labels or tree tags also can provide ideas from innovative ways that people have found to label their trees. The websites below (accessed 14June 2012) provide examples of tree tagging methods.

Cable tag: http://www.proaxis.com/~johnbell/equipment/equip56a.htm
Stem tags: http://www.nationalband.com/nbtplant.htm#Tree_Tags
Urban: http://www.tufc.com/pdfs/tree_labels.pdf

For temporary marking, place a pin flag at the base of each living or dead stem that is ≥ 2.5 cm in diameter at 1.37 m DBH in each 5 x 5 subplot. *(See note at the end of this paragraph.)* It helps to use four different colors of flags to mark the trees, and to use a different colored flag for each of the four subplots that make up one 5 m wide N to S transects. You will rotate the colors from one

transect to the next such that no two adjacent subplots have the same color (Figure 2). Plots 1,9,7, and 15 are one color, 2,10,8, and 16 another color, 3,5,11, and 13 a third color, and 4, 6,12, and 14 are a fourth color. If the class is divided into 4 groups, each group can be given a different pin flag color and can then flag each of the trees in the 4 plots designated to be that color.

Note: It may help to create a 2.5 cm gauge to quickly and uniformly determine which trees are ≥ 2.5 cm. It can be made by cutting a 2.5 cm wide indentation in a small block of wood or a plastic card (Figure 3). If you use a different material make certain that the edge is not sharp so that it won't damage the small stems.
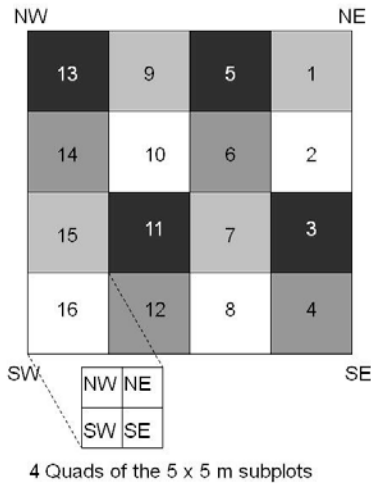

Figure 3. Sample 2.5 cm gauge for separating large from small stems.

Figure 2. 20 x 20 m plot layout, including subplots.

After all of the trees in the first four subplots have been flagged, someone can begin in subplot 1 to number the stems. Stems should be numbered sequentially throughout the entire plot so that every stem in the plot has a unique identifier. If there are multiple sprouts on a single stump, number them using decimal notation (2.1, 2.2, 2.3, etc.) After numbering all trees in subplots 1 through 4, go next to subplots 5 through 8, then 9 through 12, then 13 through 16. *(Note: The numbering might be done by the instructor or by a single group of students.)*

Treatment of Vines: Vines that are ≥ 2.5 cm dbh should be tagged and numbered, and included as individual stems in the tree inventory, even if they are running up the side of a tree. Stems that are < 2.5 cm dbh should be included in the small stem inventory. If the vines are attached to the side of a tree it may be necessary to use large calipers to measure the diameter of the tree. **(See DBH.)**

Tree Mapping

If the trees are numbered, it is not necessary to map them unless you want to also use the data to analyze species and tree distribution patterns. One approach to mapping is to have students draw the location of each stem on the map while they are conducting the inventory. This is most easily done if the square plot has been divided into 5 x 5 m subplots. Students can place a numbered dot at its approximate location within the appropriate quadrant (NE, SE, NW, SW) of each 5 x 5 m subplot. It is often easiest to do this if you have someone stand in the center of the subplot. *(See Appendix VIII for a handout with diagrams that can be printed and taken to the field for mapping tree locations.)*

An alternate approach would involve use of a compass and tape to measure the azimuth and distance to each tree from one or more specified locations within the plot. The azimuth and distance to each tree is recorded in the field and used to later draw maps in the classroom.

Note: The center of a tree's stem indicates its location. The center of the tree must be in the plot or exactly on the line to be counted.

(Tip: Once all, or most, of the trees have been tagged and numbered, student teams can begin the inventory process. If there is more than one team, each of the inventory teams can begin in separate subplots. Using the "leap-frog" approach, the first of the groups to finish inventorying its subplot would go to next unmeasured subplot. If there were 4 groups, the first to finish would go to subplot 5. The next group would go to subplot 6, and the process would continue until all of the subplots had been inventoried. If no subplots were established, the instructor could divide the total number of tagged stems by the number of groups and assign each group to inventory a specific number sequence. For example, with 100 trees and 5 groups, Group 1 would inventory trees 1 to 20; group 2 trees 21 to 40, etc.
Encourage students to record data carefully and clearly on the datasheets to avoid mistakes. The data should be easily readable by anyone looking at the data form.)

Tree Inventory procedures (Enter Data in the Tree Inventory Data Sheet):

Each group will record the following information for <u>all living and dead stems</u> that are ≥ 2.5 cm dbh (diameter at 1.37 meters). The middle of the tree should be inside the boundary for the tree to be included. Dead trees that are leaning more than 45 from vertical are not included in the tree survey as they would be included in an inventory of downed woody stems.

Subplot number/Subplot quadrant (optional):

Enter the subplot number (1-16) and the subplot quadrant (NE, NW, SE, SW) in the appropriate column of the data sheet. This information is mostly useful for quality control and rechecking individual stems. The identification of subplot quadrant can be helpful when mapping tree locations. *Note: To do the small stem inventory you will need to have some system of identifying the locations of the subplots used in the stem tally.*

Tree Number:

Only number and record stems that have a dbh ≥ 2.5 cm. Each stem in the plot needs a unique identifier (no two stems in a single 20x20 m plot can have the same number), so that it will be possible to relocate and remeasure each tree in future years. When plots are remeasured in the future, smaller trees that have grown above the 2.5 cm minimum measurement size should be given the next unused number, and given the Inventory Status of "IG" (ingrowth). When a tree dies and falls to the ground, its number is "retired" forever.

Trees with multiple stems (see **Multiple Stems** for additional information) require unique numbers for each stem in the clump that has a dbh ≥ 2.5 cm. <u>Each stem should be recorded on a separate line of the data sheet</u>. Multiple stems should be numbered using decimal notation (2.1, 2.2, 2.3, etc.). Note: Do not number any of the sprouts that are less than 2.5 cm dbh, as they would be considered "Small Stems" and would be tallied in the Small Stem Inventory at that location.

Vines that are ≥ 2.5 cm dbh should be tagged and numbered, and included as individual stems in the tree inventory, even if they are running up the side of a tree. Stems that are < 2.5 cm dbh should be included in the small stem inventory. If the vines are attached to the side of a tree it may be necessary to use large calipers to measure the diameter of the tree. (See DBH.) Measure the diameter of the vine at a height of 1.37 m.

The database will accept numbers from 1 to 99999.99. Letters are not allowed in tree names.

Multiple Stem:

Indicate for each stem if it is **S** (single stem) or **M** (part of a multiple stem tree). Individual stems and stems that fork at or above a height of 1.37 m (i.e. DBH) are considered a single stems. A tree has a multiple stem when the stem forks below DBH, giving rise to two or more stems, each of which is competing for canopy position. Do not count as a separate stem a subordinant sprout attached below DBH if it is growing more like a branch. (Figure 4 illustrates where to measure DBH on stems that fork or have other anomalies near DBH.) Only include stems for which the center of the stem at 1.37 m above ground is located within the plot boundary. (Some stems of a multiple stem tree might thus be out of the plot, and would not be included in the database.)

The diameter of each sufficiently large stem in the clump is measured separately, and each stem is given a unique decimal number (e.g. 1.1, 1.2, 1.3, etc.) If a multiple stem tree has stems that are less than 2.5 cm DBH, those stems should not be included in the Tree Inventory, but would be included in a Small Stem tally for a subplot at that location. If the small stem later attains a DBH of 2.5 cm it would be added to the database during a remeasurement of the plot. At that time the stem would be given a number of x.x, and would be coded with the Inventory Status of "IG" (See **Inventory Status**).

Species:

Record the 6 or 7 character abbreviation for the scientific name of living stems. The first 3 characters represent the first three letters of the Genus and the last 3 characters are the first 3 letters of the specific epithet for the species (GGGSSS). Example: QUEALB = *Quercus alba*. *(Appendix V contains a list of abbreviations for most species you are likely to encounter in your inventory. Note: If you have a species not on the list, please email the species to the EREN Permanent Plot contact so that it can be added to the official list. This needs to be done before you will be able to successfully upload your data to the database.)* When trees are identified to variety, or if two species would give the same, a 7th character is added to the name. If the tree is standing dead, record it as SNAG. Standing dead stems that are leaning are only inventoried if the lean is < 45° from vertical. Those with a greater lean are included as downed stems. *(Note: Please use ALL CAPITAL LETTERS when entering the species code in Excel.)*

Inventory Status Codes:

Use the following codes to indicate whether a stem is being included in the inventory for the first time, has changed condition since the last inventory, or is being removed from the inventory because it is no longer a standing tree. (Note: Once a tree is entered in a plot inventory it will always remain as a numbered stem in the inventory, even if it is removed. For that reason trees that grow into a plot are always given a new number, and no tree numbers are ever repeated in a plot. All stems in year one will be IL or ID. Subsequent plot measurements will require that the student researchers refer to the data collected in the previous inventory to complete this column.

IL – Initial Living: Initial measurement of a living tree. Only used during the first inventory of a plot. In subsequent measurements it will be coded as RL.

RL – Repeat Living: Repeat measurement of a living tree

ID – Initial Dead: Initial measurement of a standing dead tree. Only used during the first inventory of a plot. In subsequent measurements it will be coded as RD.

RD – Repeat Dead: Repeat measurement of a standing dead tree (SNAG). Once the tree falls to the ground it is no longer included in the database, and its number is retired from the plot.

FS: - Fallen Stem: Once the tree falls to the ground it may be omitted from future standing tree measurements. The tree number should not be used for any other tree in that plot.

IG – Ingrowth: Stems that were too small at the preceding inventory and have now grown large enough to exceed minimum measurement diameter. In subsequent inventories the stem will be coded as RL. (May include small stems of a multiple stem tree that have now grown over 2.5 cm dbh.)

DD- Dead: Standing tree that has died since the last inventory, when it was measured as a living stem; On subsequent measurements these trees will be coded as RD.

SL- Skipped Living: Live tree that was large enough to be tallied at the previous inventory, should have been entered in the previous inventory, but was overlooked. This tree will not be included in growth increment from the previous measurement. In future measurements this stem will be coded as RL.

SD – Skipped Dead: Dead tree that was large enough to be tallied at the previous inventory, should have been entered in the previous inventory, but was overlooked. (There is no way to know if this tree died since the last inventory or died prior to the last inventory.   In future plot measurements this stem will be coded as RD.

MS - Missing Stem - It is likely that the tree has fallen. If, however, there is no confirmed evidence of the tree on the ground, then it should be coded as MS. Once a tree is coded as MS it can be omitted from the standing tree inventory in future measurements. Should it rediscovered in the future, it should be coded as SL (or SD), and should retain its original number.

Note: If sprouts develop from the base of a tree that has died, the sprouts are not added to the tree database until they reach 2.5 cm dbh. At that time they would be given a new, unique number, and would be classified as IG.

DBH:

DBH is the abbreviation for "Diameter at breast height". DBH is diameter measured at 1.37 meters above ground on the uphill side of the tree (or 4.5 ft when using English units). Record the DBH of all living and dead stems (including vines) that are $\geq$ 2.5 cm at 1.37 m. If the ground is sloped, measure on the uphill side of the tree. Trees with irregularities or swelling, or other unusual situations may require special measurements.

DBH can be measured using calipers, a special diameter tape (D-tape) that can be purchased from a forestry supply catalog, or the circumference can be measured with a regular measuring tape and the result divided by pi (3.14) to calculate DBH. *Appendix VI includes a printable handout with instructions, as well as a copy of the following diagram for measuring DBH on irregular stems.*

Vines: If a vine is attached directly to the side of a tree, it may necessary to use larger calipers to measure the tree's diameter. When measuring tree diameter with calipers it is best to take two measurements at right angles, since many trees are not completely round. *(Calipers can be purchased from a forestry supply company or could probably be made with a meter stick, wood blocks, and some creativity.)*

Methods for Accurate DBH and DBH Increment measurements:

Measurement of biomass and carbon storage and accumulation rates in forested plots requires accurate, repeatable measurement of DBH. It is thus very important to measure DBH at the exact same height on the tree each time it is measured. This may require physically marking the stem, especially when DBH is measured at a non-standard height due to one or more of the situations illustrated in Fig. 4.

It is also important that repeat measurements of DBH are carried out during approximately the same time of year. It is generally best to measure DBH during the dormant season if growth increment over time will be determined. Annual growth increments are less accurate when

measurements are taken during the active growth period, before diameter increment has ended for the year.

Some methods of ensuring accurate DBH measurements include:

1) Mark DBH with lead free tree marking paint or surveyors crayons, both of which are available online or through forestry supply catalogs. Either draw a solid or dashed line completely around the stem at DBH (1.37 m), or place a dab of paint on opposite sides of the tree stem to assure that the DBH tape is level when it is wrapped around the tree.

2) Use the tree ID tag and nail as guides for measuring DBH. The tree ID tag can be nailed to the tree (use an aluminum nail) at a defined distance from DBH, either above or below, and thus be used to assure consistent DBH measurement. The tag should be at least 2 cm above or below DBH because the nail can cause a slight swelling of the stem and influence the DBH measurement accuracy. It is also good to leave approximately 2 cm of the nail extending outside the stem to allow for tree growth and to allow a guide stick to rest on the nail. (If your plot is in a location that might be harvested at a future date, you might want to place the nail in the basal 25 cm of the stem to make certain it would not be in the path of a saw blade.) Once the nail and tag are in place, a guide stick can be created whose length is equal to the distance between the nail and DBH. A notch can be placed in the stick to allow it to be positioned on the nail and used to guide the location for DBH measurement.
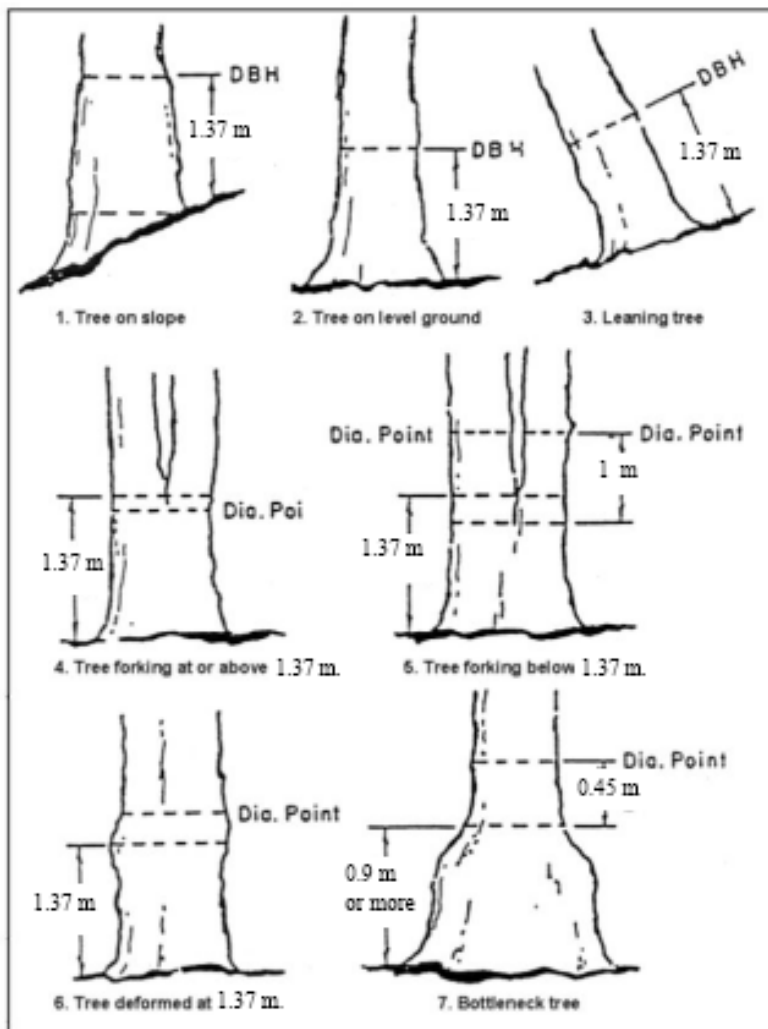

Figure 4. Location for measuring DBH in standard and irregular shaped stems. (Adapted from US Forest Service.) *A copy of this diagram is included in Appendix VI.*

3) Create a 1.37 m wooden guide and position the guide on the ground and measure DBH along the top of the guide. Note that you would still need to mark those stems for which DBH is measured at a non-standard height, and it would be important to position the guide on the same side of the tree each time a measurement was made.

4) Use dendrometer bands for continuous DBH measurement. Dendrometer bands are the most expensive method of measuring long term DBH, but can be purchased and installed on a subset of stems in the plot to allow students to follow seasonal and annual growth. The USGS has a wonderful website with instructions for constructing and installing dendrometer bands on trees: http://www.nwrc.usgs.gov/Dendrometer/index.htm
Additional information is available at: http://web.utk.edu/~grissino/dendrometers.htm

Soundness (Optional): *Rank stem soundness from 1 to 3 to indicate the degree to which the lower 5 meters of the stem is solid wood or is occupied by a hollow cavity. The three categories are (1) 95 to 100% solid wood, (2) 50 to 94% solid wood, and (3) < 50% solid wood. Make your judgment based upon the width, height, and depth of the hollow cavity relative to the entire 5 m section of the tree. (Ignore cavities above that height.) Appendix VII contains additional details.*

1) The stem appears 95 to 100% solid in the lower 5 m of the stem. Rank the tree a **1** if there is no obvious cavity into the lower 5 m section of the stem, or if there is a small crack or wedge shaped opening into the side of an otherwise solid tree. The width of the opening should generally be less than 5% of the circumference of the tree (Figure 5). Stems with small decayed sections that do not run the length of the 5 meter stem section can also fit this category.

2) The stem appears 50 to 94% solid in the lower 5 m of the stem. This stem will generally have an opening that is > 5% of its circumference, and/ or a hollow core that comprises between 5 and 50 % of the stem volume for most of the 5 meter stem section.

3) The stem appears < 50% solid in the lower 5 m of the stem. This stem will have an opening that is > 5% of its circumference, and/ or a hollow core that comprises over 50 % of the stem volume for most of the 5 meter stem section.

The thickness of the shell of wood, and the size of the opening relative to the circumference of the stem can be compared to Tables 1 and 2 in Appendix VII to estimate % stem soundness. (Fig 5).
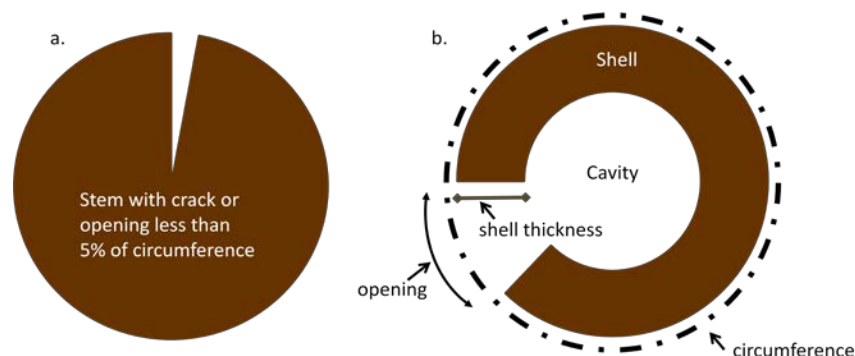

Figure 5. Terminology and images for determining the percentage of sound wood in a stem. (a) Stem with small crack. (b) Stem with an opening into a hollow cavity. Measure the length of the opening relative to the total circumference to determine the opening % size class and measure the thickness of the shell relative to the stem diameter.

Crown Class (optional): Record the crown class as: **(DC)** DOMINANT/CODOMINANT,
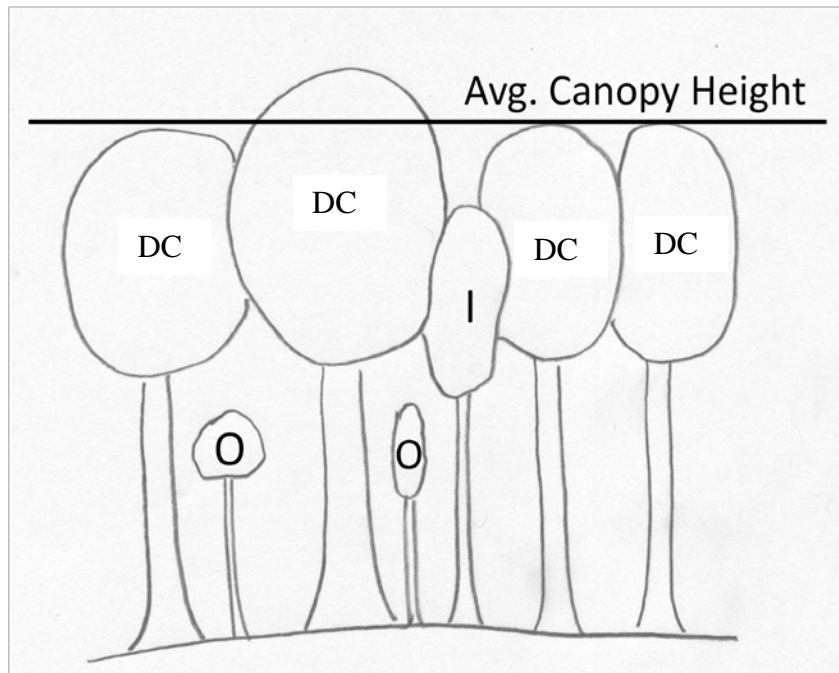**(I)** INTERMEDIATE, or **(O)** OVERTOPPED.

Figure 6. Diagram of trees in the Dominant/Codominant (DC),
Intermediate (I), and Overtopped (O) canopy positions.

Dominant / Codominant (DC): These trees form the general level of the main canopy, as well as those individuals that stick up above the general level of the canopy. All of these stems get full sun from above and some from the upper sites.

Intermediate (I): The tops of these trees extend into, but do not reach the top of the canopy. They receive full sun only from directly overhead.

Overtopped (O): Sometimes referred to as suppressed, these trees are entirely below the main canopy and do not receive any direct overhead sunlight.

Height (optional):

Measure and record the height of **(CD) Dominant/Codominant** trees (those that comprise the canopy of the forest) to the nearest 0.1 meter (Figure 6).

See one of the following links for information on how to measure the heights of trees.
http://www.sewanee.edu/Forestry_Geology/watershed_web/Emanuel/Treehts.htm
http://extension.usu.edu/forestry/Kids/Kids_TreeHeightMeasure.htm
http://www.environthonpa.org/documents/MeasuringTreeHght.pdf

Tree Damage (optional for PFPP, required for EAB Impacts Study):

Record the single best value for each tagged tree if it has any of the following characteristics:
- U   Uprooted
- SL   Snapped below breast height (BH, 1.37 m)
- SH   Snapped above BH
- B   >50% of the branches in the canopy are broken off
- L   Leaning and hung up on other trees
- F   Another tree is leaning on and substantially bending or breaking it
- AF   Another ash is leaning on and substantially bending or breaking it
- NA   None of the above (Damaged, but does not fit any of the above types. Describe in the comments.
- NONE   No damage
- null   Data not collected

(Note the use of capital letters for all but "null".)

Notes: (Optional):
Use the notes column to record tree specific information that may be helpful for future data interpretation. For example, if you are unable to measure all trees in a plot in a single day, you can use the notes column to identify those trees that were measured at a different time than the general tree measurement date. For trees that are SNAGs, you might indicate the actual species in this column, or you might include information about leaning trees or SNAGS, or Soundness call that are somewhat questionable.

Small Stem Inventory: *Stems that are > 1.37 m tall, but less than < 2.5 cm. Record this information on the Small Stem Data sheet.*
To obtain an estimate of the number of small stems < 2.5 cm dbh that occupy the plot, randomly select three 5 x 5 m subplots, or circular 25 m^2 plots (radius = 2.82 m). If you did not establish the 5 x 5 m subplot grid, randomly select three locations within the plot and establish square 5 x 5 meter subplots, numbering them 1 though 3. Permanently mark the corners of each of the subplots so that they can be remeasured in the future. (Note: You may select to measure all 16 of the subplots if you want 100% small stem inventory.)
Record the following information for each of the subplots measured:

Subplot number: If you established 5 x 5 m subplots during the plot layout, record on the datasheet the subplot number for each of the three tallied subplots. If you establish new 25m^2 subplots, record the appropriate number for each.

Is the small stem plot density typical of the overall plot? Answer YES or NO.

Species: Enter the appropriate 6-7 letter code for each small stem species in the subplot (see Appendix V). Use capital letters only. Use "UNKSPP" for unknown species, "OAKSPP" for unknown oak species, etc. If a subplot lacks small stems, record "No_Stems" in the species column and "0" in the stem tally column.

Small Stem Tally: Count the number of the stems that are at least 1.37 meters tall, but less than 2.5 cm in diameter, that exit the ground within the boundary of the three subplots. This tally should also include small stems (not included in the tree inventory because they did not meet the 2.5 cm minimum dbh) attached to multiple stemmed trees that did meet the minimum dbh requirement and were recorded in the tree inventory for the 20 x 20 m plot. If a clump of small stems is located on the subplot boundary, only include the individual stems that exit the ground within the subplot boundary. Do not include stems that exit the ground outside the subplot boundary. There is no need to measure the diameter of any of the small stems (although you may choose to do so for your own purposes).

Notes: Enter additional comments, or data, that may be useful for later interpretation of the small stem information. Up to 100 characters may be used, and commas are acceptable. This space can be used to record site or subproject specific information about specific subplots.

PFPP Subproject Variables (not included in the Database)
Some new EREN projects that utilize the PFPP plots may require additional variables that are not included in the database. For an updated list of those variables, and information on the subprojects, visit the EREN website ACTIVE PROJECTS page: http://erenweb.org/new-page/

As of Aug 2014, the following additional Plot variables are needed for the EAB Subproject:
Name of nearest major undivided roadway (State or Federal);
Distance to nearest major undivided roadway;
Name of nearest major (divided, 4-lane or more) roadway (State or Federal);
Distance to nearest major divided expressway;
Distance to nearest stream or river;
Width of stream or river at point closest to plot;
Distance to nearest railroad corridor;
Distance to nearest shipping port;
Distance to nearest distribution center or manufacturer receiving goods on foreign pallets;
Distance to nearest campground (State, Federal, or Private).
   For more information on these variables please refer to the EAB Subproject Protocols:
http://erenweb.org/new-page/emerald-ash-borer-project/ .

Calculated and Derived Variables

   The following variables can be directly calculated from the tree data. The online database will include the Site, Plot, Tree Inventory, and Small Stem data obtained from this instruction set, but will not include the following variables which can be derived from the measured data. The choice of variables to calculate will depend upon your specific teaching or research objectives.

Basal Area:

   Basal area (BA) of a tree is equal to the cross sectional area of the tree stem measured at 1.37 m (DBH). It is calculated using the equation: $BA\ (m^2) = DBH^2\ (cm)\ x\ 0.00007854$. The basal area of the plot (m^2) is equal to the sum of the basal areas of all of the stems in the plot. While the total basal area of the 400 m^2 plot could be used for comparison, it is more typical to report basal areas on a per hectare basis to facilitate comparison among plots of different sizes. Divide the sum of the BA for the plot (m^2) by the area of the plot in ha (400 m^2 / 10,000 m^2ha^{-1} = 0.04 ha) to obtain BA in m^2ha^{-1}.

Biomass:

   The biomass of the entire tree (or of specific tree parts) can be estimated from the DBH using allometric equations developed either for the species or for a group of similar species. Biomass is reported as kg (or Mg) ha^{-1}.   We suggest using one of the following publications to estimate tree biomass from dbh:

1) Jenkins, J.C., Chojnacky, D.C., Heath, L.S., and Birdsey, R.A. 2004. Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species. Gen. Tech. Rep. NE-319. Newtown Square, PA. USDA Forest Service Northeastern Research Station. 45p. [1 CD-ROM] (Accessed 1 Aug 2014 from http://www.treesearch.fs.fed.us/pubs/7058).

   The following website includes a link to the publication, as well as excel and pdf copies of the tables from the publication: http://www.uvm.edu/~jcjenkin/?Page=biomassdatabase.html (Accessed 14 June 2012) A list of additional references for vegetation biomass analysis can also be found at the following web address: http://www.sewanee.edu/Forestry_Geology/watershed_web/links2.html (Accessed 1 Aug 2014)

2) Chojnacky, David C.; Heath, Linda S.; Jenkins, Jennifer C. 2014. Updated generalized biomass equations for North American tree species. Forestry. 87: 129-151. (Accessed 1 Aug 2014 from http://www.treesearch.fs.fed.us/pubs/45402).

Carbon Storage:
　　Carbon (C) storage is estimated from tree biomass using the % C present in plant tissues. If exact measurements are not available, the value is commonly estimated to be 45 - 50% of plant biomass. It is reported as kg C ha^{-1}. (See http://www.fao.org/forestry/17111/en/). Additional carbon calculations tools can be obtained from http://www.nrs.fs.fed.us/carbon/tools/ .

Carbon Sequestration Rate:
　　Carbon sequestration rate is calculated as the difference in carbon storage measured at two different times, generally in increments of years (1, 5, or other). It is reported as kg C yr^{-1}.

Forest Type:
　　The plot can be classified into different forest types based upon the composition of species inventoried. The cover type is traditionally based upon the basal area of trees comprising the majority of the canopy, and the name includes the one, two, or sometimes three species predominant species. By convention, a species must make up at least 20% of the stand's basal area to be included in the name.
　　A more complete description of standard US forest cover types can be found in the following publication.

Eyre, F.H. (ed.)1980. Forest Cover Types of the United States and Canada. Society of American
　　Foresters. 148 pp.

　　The publication is available for purchase from the Society of American Foresters website:
http://store.safnet.org/ (Accessed 14 June 2012)
　　The pdf below includes a list of forest cover types include in the publication.
 http://el.erdc.usace.army.mil/emrrp/emris/EMRIS_PDF/ForestCoverTypes.PDF
　　The following website includes a list of forest cover types used by the US Forest Service in the National Forest Inventory and Analysis (FIA).
http://www.fs.usda.gov/detailfull/r5/landmanagement/gis/?cid=fsbdev3_047974&width=full

Frequency of Online Data Entry
 Site Data: Once at the beginning, and then only when there is a major change in the forest type
　　(large disturbance). For many sites this data will never be changed after it is entered for the
　　first time.
Plot data: Plot data should be updated whenever you upload new tree data. Follow the instructions in
　　the **Online Data Entry Procedure** section for duplicating the former plot file, giving it a new
　　target year and month. Then edit only variables that have changed (e.g. date, precipitation,
　　soil, invasive species, etc...)
Tree Data: Tree data should generally not be added more than once each year, and it would be fine
　　to only uploaded data every 2 - 3 years (even 5 could be OK). Some subprojects, however,
　　may require annual sampling. Please see protocols for individual subprojects for sampling
　　intervals.

Online Data Entry Procedure

When you are ready to enter the data online, go to www.erenweb.org under Research/ Permanent Plot Project, or Data/Permanent Plot Project where you will find links to the online database along with additional data entry and data retrieval instructions.

To enter Data online, your institution must be registered with the online database, and someone(s) from your institution must be registered as your Institution's Administrator(s). To register your institution, and identify a site administrator, please email one of the PFPP Project's current Lead Scientists, whose names and contact information are included on EREN's PFPP webpage. Include in your email the name of your Institution, the city and state in which it is located, the name of the Administrator, and the Administrator's email address. Once the Lead Scientists have processed your request, the Administrator will receive an email with instructions for logging on to the database. (Note: This may take more than 24 hours, so please do this well in advance of the day that you hope to be able to enter Site/Plot/Tree data.)

Once an Administrator has been registered for your Institution, the Administrator is responsible for creating and entering Site information (only an Administrator can create Sites for an Institution), registering other Users (Administrator or Researcher) who can enter, edit, and upload Plot, Tree, and Small Stem data to the PFPP Database website. All Administrators for an Institution can register Researcher for that Institution, approve tree and small stem data that has been uploaded to the database, and delete uploads to correct mistakes. (Note: Approval is confirmation that the data has undergone quality control measures and is ready for inclusion in the database. All tree data must be approved by an Administrator before it becomes a permanent part of the database. Please see "**Administrator Responsibilities**".)

In addition to the Researchers who can enter Plot data and upload Tree and Small Stem data, other individuals can register with EREN as Users, and they will be able to Query the database and download data. Users who download data may be asked to complete a form indicating the intended use of the data.

Site and Plot Data are entered directly into the online PFPP Database. Each Site is identified by Name and Year, and each Plot is linked to a specific Site/Year, and is identified by Plot Year, Plot Month, and the Plot measurement date.

Tree and Small stem inventory data will be uploaded to the PFPP Database as two separate CSV files. Blank CSV files for each can be downloaded from the PFPP Database website and used in Excel to enter the Tree and Small Stem Inventory Data. *Note: To enter Tree or Small Stem Inventory Data you will need to be able to identify the Site Name and Site Year, as well as Plot Name, Plot Year, and Plot Month before you will be able to upload the data.*

The upload file must contain the exact column headings in the same sequence as the template file. The database does not allow blank cells in the CSF files. Fill all blank cells with "null" prior to uploading the data.

Administrator Responsibilities

Administrators are responsible for making certain that all data entered in the database have been check for accuracy. This is especially important given the intended long term use of the datasets. The data will be available online for use by other faculty and students who need the assurance that the data they use has undergone standard quality checks. **Administrators should make certain that all Site, Plot, Tree and Small Stem data is checked both before and after it has been entered into the database.**

Tree variables that most often have mistakes, and that are especially critical for data analysis include the species abbreviation codes, inventory codes, and DBH measurements. Carefully check both the decimal place and the numbers in the DBH measurements for accuracy, especially numbers

that appear to be outside the range of the rest of the data.) It is not uncommon for undergraduates to measured circumference rather than diameter, and to report data in mm rather than cm.

Plot variables most often entered incorrectly include longitude (it should be negative in North America), precipitation (check that units are mm per year, and not cm, inches, or mm per month, growing season length (this must be a positive number)

When a plot is created in the database, the user will be asked to indicate the level of quality control used to assess data quality for the data uploaded to the plot. See the **Data Quality Assurance** Variable (p. 16) for a definition of the 5 levels.

Updating/editing Site and Plot Data

Site Data: Site data can be edited by Root Users and Administrators if a correction needs to be made after data entry. To edit Site data, go to "Administration", "Site Management", and select "Edit". Highlight the Site record to be edited, select "Edit", make the necessary changes, and save the changes. *(Do not change the site name.)*

While the Site variables are not likely to change much over time, if there is a major change in one of the Site variables that needs to be input for analyzing future tree data (e.g. changed growing season length, average annual temperature, etc.), a new Site record should be created for the Site, and all future data should be linked to the new record. Administrators have two options for updating the Site record: 1) Create a new record from scratch, or 2) duplicate the record and update only the variables that need to be changed. In either case it is critical to *maintain the exact same Site Name*.

To "Create" an updated Site record, under "Administration", "Site Management", select "Create" Site. Re-enter all of the data, inputting the new year and all the Site variables. If you opt to "Create" a new Site record it is very important to use the *exact same Site Name*.

To use the "Duplicate" Site option to create a new Site record, under "Administration", "Site Management", select "Edit" Site, highlight the row containing the Site record that you want to update, and select "Duplicate". You will be asked to provide a target year for the new record. Enter the desired year, select "Go", and the new Site record will be created. Highlight the duplicate row, select "Edit", and you will be able to change and save the values that need to be updated. Future Plot and Tree data should be entered/uploaded using this NEW Site description year for reference. *(Note: It may be safer to duplicate and edit a site than create a new record. It is critical that the Site Name remains the same for long term data analysis. Only one Site record can be created for any given year.)*

Plot Data: Plot data can be edited by Root Users, Administrators, and Researchers if a correction needs to be made after data entry. To edit Plot data, go to "Administration", "Plot Management", and select "Edit". Highlight the Plot record to be edited, select "Edit", make the necessary changes, and save the changes. **(*Do not change the Plot name.*)**

Plot variables change more regularly than do Site variables, and a new Plot record should be created each time new Tree data is added to the database. (No more than 2 records should be entered for a given Plot in any calendar year.) As with Site management, Administrators have two options for updating the Plot record: 1) Create a new record from scratch, or 2) duplicate the record and update only the variables that need to be changed. In either case it is critical to *maintain the exact same Plot Name*.

To "Create" an updated Plot record, under "Administration", "Plot Management", select "Create" Plot, and enter all of the data. Re-enter all of the data, inputting the new year and month and all the Plot variables. If you opt to "Create" a new Plot record it is very important to use the *exact same Plot Name*.

 To use the "Duplicate" Plot option, under "Administration", "Plot Management", select "Edit" Plot, highlight the row containing the Plot record that you want to update, and select

"Duplicate". You will be asked to provide a target year and month for the new record. Enter the desired year and month, select "Go", and the new Plot record will be created. Highlight the duplicate row, select "Edit" and you will be able to change and save the values that need to be updated. Future Tree data should be entered/uploaded using this NEW Plot description until a new Plot record is entered. *(Note: It may be safer to duplicate and edit a Plot than create a new record. It is critical that the Plot Name remains the same for long term data analysis.)*

Correcting or Changing Tree Data or Small Stem Data

Uploaded Tree data from their Institution is always available for Administrators and Researcher to view. While it is not possible to correct Tree data or Small Stem data within the database, Researchers have a window of time in which to delete tree or small stem data after it has been uploaded. Once the data has been approved by an Administrator, however, only Administrators or Root Users can delete Tree or Small Stem data files. If you discover a mistake in your Tree Data after it has been approved, and do not have the role of Administrator, please contact an Administrator from your Site so that the uploaded file can be deleted. Once it is deleted, you will be able to upload a corrected replacement file of the same data.

Using PFPP Data

Use the Query Tool on the PFPP Database to select sites for which you wish to access and download data. Data will be downloaded in the form of CSV files. Once you register as an EREN user, data is freely available for class and other non-publication uses. Users who download data may be asked to complete a form indicating the intended use of the data.

Publication Guidelines

Should you wish to use EREN PFPP data in a publication, please check the online Authorship guidelines posted on the EREN website (www.erenweb.org), and contact one of the PFPP Lead Scientists.

Suggested Citation Format:

Kuers, K., Lindquist, E., Dosch, J., Shea, K., Machado, J., LoGiudice, K., Simmons, J., and
    Anderson, L. 2014. EREN Permanent Forest Plot Project (PFPP) Version 1.06. 30 Aug 2014.
    Accessed from http://erenweb.org/ .