UNIVERSITY OF CALIFORNIA
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Working in the Woods
A Guide for California's
Forest Landowners
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What Do We Own: Understanding Forest Inventory

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The Purpose of an Inventory

One of the first steps in planning any management activity on forested land is to conduct an inventory of the resources on the property. This inventory, often called a **cruise**, when used to estimate timber volume, can range from a quick walk-through "eye-ball" estimate to the carefully planned and executed timber inventory designs used for industrial and government timberlands. Most landowners opt for something in between that's accurate enough to make informed decisions at a reasonable cost. This leaflet will help you decide what type of inventory information might be useful on your property and provides guidance on interpreting some of the results.

The principal question that most timber inventories answer is what is the volume and value of the timber resource on the property. Timber inventories also answer questions about the age and size structure and species composition of the existing forest. Information about the structure of the forest helps determine appropriate forest stand treatment. While other resources and conditions can be inventoried, this is rarely done on smaller ownerships because of the cost.

Why should you bother with the cost of an inventory? That is an important question that is hard to answer except generally. Depending on the experience of the forester and the complexity of the forest, an "eye-ball" walk-through estimate might be sufficient for some management decisions - especially if the decision is to invest in a more formal inventory. If you are considering a timber harvest, you will need an accurate inventory for the Timber Harvest Plan (THP). Most management decisions should be made with the best available information. It is difficult to make an informed decision when you do not know what you own.

The formal timber inventory helps guide forest management decisions from an objective point of view. After completion of an inventory, you have an estimate of the volume, value, and structure of the forest. Management objectives can be defined in terms of volume and stand structure. One of the themes of this series is for landowners to define measurable objectives to guide the process of forest management. By carefully specifying measurable objectives, landowners have a way to carry out their land management decisions.

Can I Do My Own Inventory?

While there is nothing really complex about conducting a timber inventory, this is one task you should consider a professional forester for, in most instances, because of the need for credibility. Few people will believe numbers generated solely by a landowner. Most Registered Professional Foresters (RPFs) will insist on at least checking the inventory because their license depends on providing accurate information. An inventory is useful for the forester to get to know the property. The inventory process relies on measuring a small sample and expanding it to reflect the entire property. A very small bias, measuring the diameter an inch below breast height, or slightly overestimating the heights of measured trees, can have enormous impacts on the volume and value calculated from the inventory.

The other major reason to use a forester would be experience. Taking accurate inventory takes experience. Inventories by inexperienced foresters are checked and rechecked until the forester can be trusted to take accurate information every time. In large inventories, check cruising – remeasuring a subsample of the plots – is designed into the procedure. A landowner conducting his or her own inventory could easily make a simple

mistake that would be unlikely to be discovered until important decisions have been made with spurious information.

With that said, there is a leaflet in this series that describes how a landowner can conduct their own simple inventory. This will be useful if you just want to know what is on your land, or you would like to independently check others' figures.

The Process

The most common timber inventory technique is a stratified, systematic, random sample. So what does this mean and why is it important? The basic technique is to group similar forest stands (stratify), start at a randomly determined place (random), and measure small circular plots (sample), spaced equal distances apart (systematic). Figure 1 shows a typical timber inventory overlaid on an aerial photo.

Grouping trees of about the same age, stand structure, species composition, and location improves the information gathered by an inventory by minimizing the variability within a strata (group) and maximizing the variability between the strata. In Figure 1 we can see there are 4 vegetation types, Meadows (M), Mixed Conifers in 2 density classes, Light and Dense (MCL and MCD respectively), and Ponderosa Pine Light Density (PPL). The density class refers to the amount of ground covered by tree crowns when viewed from directly overhead. In the Dense class 80-100% of the ground is covered. In the Light class 0-40% of the ground is covered by tree crowns.

First, we need to take a sample of the trees to obtain an understanding of what kind of forest we have to work with. A sample is chosen at random from the entire forest so that we can use the theories of probability and statistics to infer from a few well-chosen samples, information about the forest as a whole. Measuring trees is difficult and expensive. The goal is to reduce the number of trees that you measure, but still have enough information to make informed decisions.

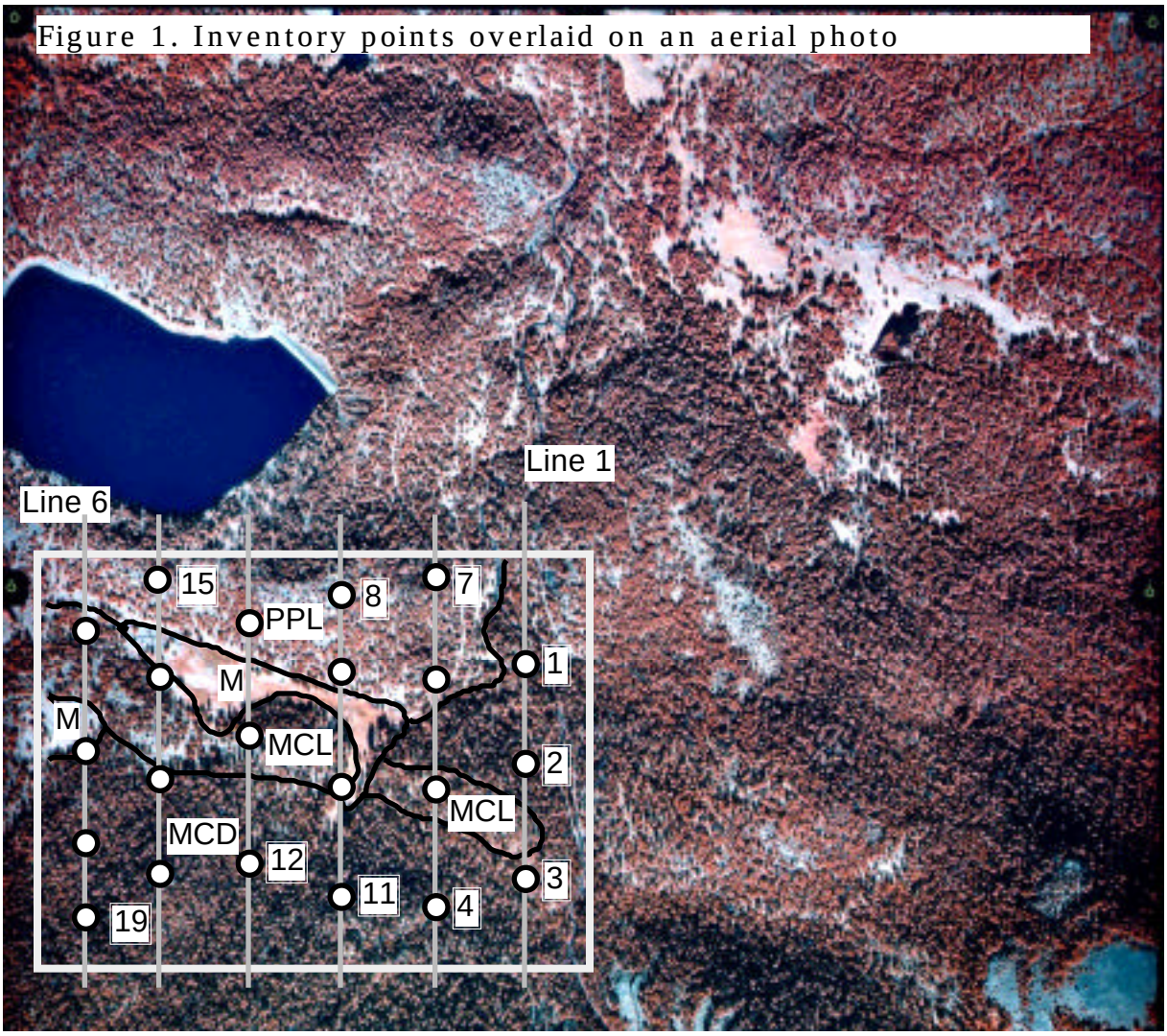
Statistical theory limits some of the specific ways in which we can take plots. In order to use cost-efficient methods, we need to make sure that the individual sample points are selected randomly. Otherwise, we might bias the sample by just measuring the biggest and best parts of the stand. By selecting a random starting point and systematically laying out the rest of the sample plots, we satisfy the statisticians while still maintaining an efficient sample. While there are many different methods for selecting sample points, the systematic plots ensure that you sample the entire property.

An example might help here. Looking at Figure 1 Plots 6, 7, 8, 9, 14, and 15 are in the Light Density Ponderosa Pine Type, a 22-year-old Ponderosa pine plantation from an area harvested after a fire. All of the trees are about the same age, diameter, height, and species. Plots 5, 10, 13, 16, and 22 are in the Light Density Mixed Conifer Type (MCL). This stand was damaged by the fire, and some trees removed as salvage. It was not replanted and there is little regeneration. Plots 1-4, 11, 12, 17-21 in the Dense Mixed Conifer was not affected by the fire. It resulted from a timber harvest in the 1930s using typical practices of the day. Essentially every tree that had value was harvested. A few "seed trees" of poor form and size were left, and the area regenerated from these. The stand was initially taken over by brush, and the trees that we see today had to grow through the brush. Table 1 outlines the inventory data from these stands.

These stands are very different due to their history. It does not make sense to treat them the same way, neither does it make sense to combine their inventory information. The Ponderosa pine plantation (PPL) is doing fine. It might might need a thinning but otherwise should be left to grow. The dense conifer stand (MCD) looks ready for a regeneration harvest. At this point, it could transition to an uneven-aged stand, or an even-aged regeneration treatment could be applied. The inventory helps you decide on the treatment.

Averaging the inventory of these two stands distorts the on-the-ground information. Though it gives an average volume for the property, the average does not help with determining an appropriate management system. Most inventories are stratified, usually by timber type but sometimes by management unit.

Figure 1. Inventory points overlaid on an aerial photo



Scale: 1”=3 chains’

Each Line is 1.5 chains apart
Each Plot is 2 chains apart
Each Plot is 1/5 acre
Not all plot numbers are shown

Vegetation Types:

M	Meadow
MCL	Mixed Conifer Light Density
MCD	Mixed Conifer Dense
PPL	Ponderosa Pine Light Density

Property is 9 chains X 6.75 chains = 60.75 acres

22 plots X 1/5 acre/plot = 4.4 acres sampled

4.4 acres / 60.75 acres = 7.2% Sample

Plot Design and Layout

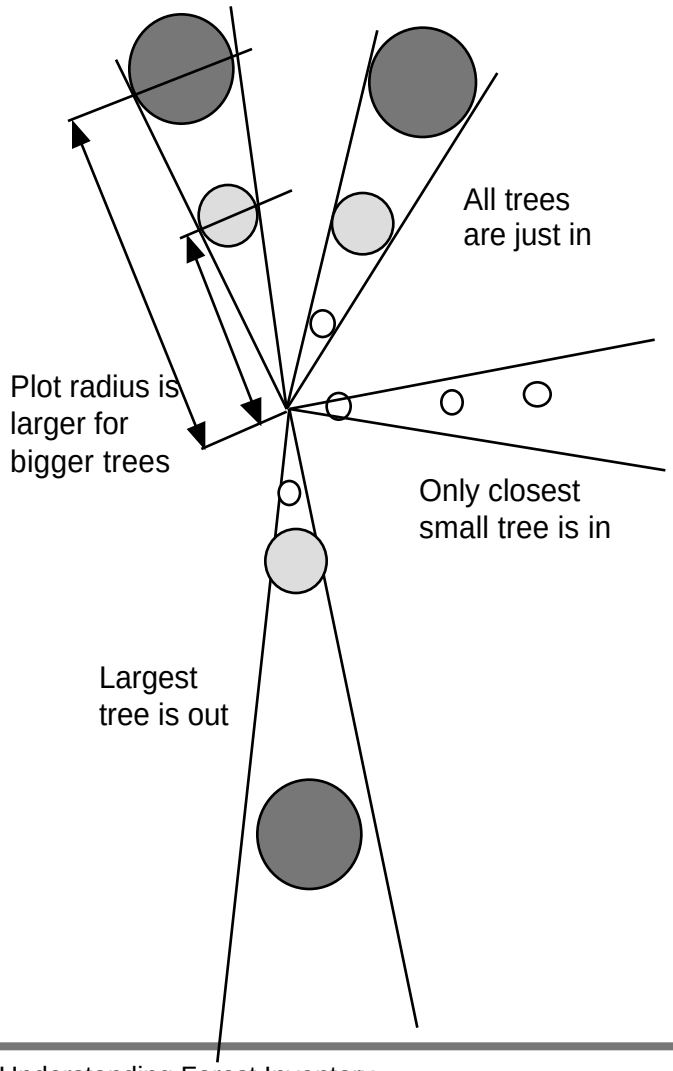
The next choice to make is the type of plots to measure. The two most commonly used plots are **fixed radius** or **variable radius** or **prism plots**.

Fixed radius plot are the easiest to picture. The forester locates the plot center using a compass and pacing. Every tree within a certain distance of the center of the plot is measured. Since you know the area of the plot, you can expand the number of trees you measure to a per acre figure. An example will help here.

A circle with a radius of 37.24 feet encloses 1/10 acre - or 4,356 square feet. Since we are measuring all of the trees on 1/10 of an acre, we assume that the other 9/10 of an acre has a similar distribution of trees. Over large enough areas, this works out very well. Thus, every tree we visit on the plot represents 10 trees per acre. You can quickly see the cost savings by measuring at most every 10th tree. You can also see a problem, unless the sample is measured with great care, errors can multiply just as quickly. Sampling also realizes cost savings because not every acre is visited. Typically, only 1 – 10% of small properties are actually measured.

Another technique is commonly used when timber volume is the primary variable of interest. **Variable radius or prism plots** use some clever geometry to further reduce the number of trees that are actually measured, while still giving an accurate picture of forest structure. Figure 2 demonstrates the theory behind variable radius plots. From the plot center, a fixed angle is projected. Trees that are larger in diameter than the fixed angle are measured, trees smaller than the angle are rejected. One result is that every tree diameter has its own plot size. Larger trees have larger plots and are more likely to be selected for measurement. This is offset by the fact that larger plots count for fewer trees per acre. Since larger trees have more volume and value, you want very accurate information on their size and distribution. Smaller trees are usually more plentiful and have less volume and value. Using a prism cruise, you can reduce the sampling intensity on these smaller trees and still get an accurate idea of how many are present.

Figure 2. Variable radius (prism) plots



The trick in using prism plots is to choose a fixed angle that will measure about 5 to 12 trees per plot. Using this method has a benefit – with a bit of algebra, you can show that every tree that is in it represents a fixed amount of basal area per acre. Basal area is an expression of the density of a forest stand and is described in more detail later. The number of square feet per acre that each tree represents is called the Basal Area Factor of the prism. Commonly used factors are 10 and 20.

The fixed angle is generated with a variety of tools. The most commonly used is a prism that shifts the image of part of the tree. Angle gages are simple and inexpensive. A real “rule-of-thumb” approximates a 10 factor prism. Hold your arm straight out at eye level with your thumb extended thumbnail turned towards your eye. Slowly sweep in a circle keeping your thumb over the center of the plot. Every tree that is wider than the fixed angle formed by your eye and your thumb is “in” and should be measured. If 12 trees are “in,” each represents 10 square feet of basal area per acre, so the stand has 120 square feet of basal area per acre at that point. Note that everyone’s thumb is a different size, and this is a very rough approximation and not suitable for an inventory. It does give a very quick estimate of basal area per acre.

There are some advantages in prism cruises over fixed plots in the amount of time it takes to measure a smaller number of trees, automatically calculating basal area per acre, and applying shortcuts to office calculations.

Items That Are Measured

The purpose of the inventory determines exactly what is measured. You should have an idea of why you are conducting the inventory and what kind of information that you expect and need to make management decisions.

Species is almost always indicated. Sometimes species are grouped according to what can be sold. Ponderosa pine and Jeffrey pine are often grouped as yellow pines. Red fir and white fir as Fir. Generally, it is better to record the exact species in the field and later group the results.

Diameter at Breast Height (DBH) is usually measured for timber inventories. Because of the root swell at the base of a tree, we measure diameter exactly 4 1/2 feet above the ground on the uphill side of the tree. Trees that fork below 4 1/2 feet are measured as 2 trees. Trees with unusual swellings at 4 1/2 feet are measured slightly above or below the swelling to get a more accurate idea of the tree’s true size.

Height is often but not always measured. Accurately measuring height takes a great deal of time per tree. Height is estimated by first carefully measuring a certain horizontal distance from the tree. Then the angle between the top and bottom of the tree is measured. Using trigonometry, you can calculate the tree’s height. Because of the time it take to measure heights, height is sometimes estimated by the number of logs in the tree or by measuring a small sample of heights.

Site Quality is usually indicated by site index or site class. Site quality expresses the potential for the land to grow trees. In California, site quality is often expressed by Site Class ranging from 1-5 with 1 being the best. Site Class and quality are important in making management decisions. Better sites are easier to manage. They are more forgiving of mistakes, and trees just grow faster. Site Class 3 land, typical of many smaller parcels, is at the lower limit of where you can produce timber economically. There are, of course, other values that can be found on lower site quality lands like wildlife habitat, livestock grazing, and some specialty forest produces. Site quality might be expressed by site index which predicts the height of the biggest trees in a stand at various ages.

Age and Increment can be a guide to treatments of all types, thinning, pruning, or harvest. The age of a stand is determined from historical records, counting rings from stumps, or counting rings using an increment borer. The increment borer drills a small hole in the tree and extracts a core. The tree's age can be estimated by counting its rings. The increment borer also allows you to estimate recent growth. The diameter growth over the last 5 or 10 years are measured to see how fast the tree is growing.

Defect is often stated a percent of the total volume. Most individual trees have scars, rot, or crooked stems that reduce their value for lumber.

Values That Are Calculated

Trees Per Acre helps describe the structure of a stand. When stands are young, they will have many trees per acre, 1,500 or more. As they mature, some of them die, and by the time they are harvested, there may be only 100 to 200 trees per acre.

Basal Area is the area of an acre that has tree trunks on it. Usually basal area is reported in square feet per acre. If you cut off every tree on an acre cleanly at 4 1/2 feet above the ground – breast height – and measure the area at the top of the stump, and add that number up over the

Table 1. Inventory Summary example					Per Acre			Total
Type	Species	Avg. DBH	Basal Area	Trees Per Acre	Cubic Foot Volume	Board Foot Volume	Acres	
		in.	sq. ft. / ac.	#	MCF	MBF		MBF
Meadow							5.2	
MCL	Ponderosa Pine	9.5	26.7	48.4	0.9	4.5		
	Douglas Fir	9.0	24.8	44.6	0.7	3.5		
	Other Conifers	8.8	19.7	28.3	0.4	2.9		
	Hardwoods	12.0	6.4	12.1	0.1	0.0		
	TOTAL	9.8	77.7	133.4	2.2	10.8	8.5	92.0
MCD	Ponderosa Pine	7.2	84.0	152.0	2.9	14.0		
	Douglas Fir	6.3	78.0	140.0	2.3	11.0		
	Other Conifers	6.7	62.0	89.0	1.2	9.0		
	Hardwoods	11.0	20.0	38.0	0.4			
	TOTAL	7.8	244.0	419.0	6.8	34.0	34.8	1181.5
PPL	Ponderosa Pine	4.5	112.0	675.0	0.8			
	Douglas Fir							
	Other Conifers							
	Hardwoods	2.0	22.0	72.0	0.1			
	TOTAL	3.2	134.0	747.0	0.9		12.2	0.0
Grand Total		7.0	151.9	433.1	3.3	14.9	60.8	1273.5

acre, you would get the basal area in square feet per acre, an important indicator of density. It combines average diameter and number of trees per acre into a single number that can be used for many purposes. There is a very good relationship between basal area and volume that is used for quick estimates. There are guides that set target basal areas for certain stand management options. Basal area is related to many wildlife habitat and aesthetic concerns, giving an objective measurement to guide management activities.

Volume represents the bottom line of most inventories. How much timber is out there? In California, volume is expressed in thousands of board feet (MBF). The volume of standing trees is calculated to predict the number of boards that it could produce. To account for the round edges and the waste generated by sawing, many log rules have been developed. Tables are available for most species using various conversion factor. In California, the Scribner rule is the most common and is required for Timber Yield tax when you have a harvest.

Volume is increasingly being reported in thousands of cubic feet (MCF), especially on federal timberlands. This reflects the fact that more of a tree is used than just flat boards. Most modern timber inventory software reports both cubic and board foot volumes.

The Value of timber can change dramatically over short periods of time. Though a discussion of forest economics appears in another leaflet, a brief mention will be useful here. The value to the landowner is often reported as stumpage, that is the value of a log sitting "on the stump." Stumpage is a great way to compare competitive bids for your timber. In a stumpage price, all costs of logging and marketing are taken out of the equation, and the price given can be multiplied by the volume present to get a bottom line return.

One source of average stumpage values is the Harvest Value Schedules published twice a year by the State Board of Equalization, Timber Tax Division. The Harvest Value Schedules are the Board's best estimate of return to the landowner given location, timber quality, timber quantity, and harvesting method. The Harvest Value Schedules will give you an independent ballpark estimate of the value of your timber.

estimate of the value of your timber.

Special Inventories

Fuels: Landowners are rightly concerned with fire. Most often the person who does the cruise will give a professional evaluation of fire risk based on experience. There are procedures, typically piggybacked on a timber inventory, that can objectively assess the amount and potential flammability of fuels. Another leaflet in this series provides specific information.

Wildlife Surveys are more difficult to conduct than timber cruises. Mostly, because animals move around, and are very good at hiding while trees tend to stay on one place. You have to target specific wildlife species using their behavior to get an accurate count.

Birds are a great example. Songbirds are inventoried using a line plot method similar to timber inventories. Biologists walk along a known path stopping at set distances. There, the biologist will listen for a set period of time – identifying song birds by their calls. This works fine for song birds in the day time but is inadequate for birds that don't sing or that are active at night. The inventory has to take this biology into account. Spotted owls are assessed by visiting plots and actively calling the birds by hooting. The owls are territorial and will respond to the intruder and come to investigate.

Fish are surveyed by walking stream segments with a specially designed battery pack. The biologist temporarily stuns the fish with an electric current, so they can be counted.

Wildlife habitat is the actual variable most often inventoried. The types and arrangement of vegetation, information gathered in a timber inventory, can tell you a great deal of what kind of wildlife may be present. By manipulating habitat, a landowner can encourage or discourage particular species. Knowing the specific biology of the animal you are interested in is the key to wildlife inventory.

Designing and conducting an inventory that objectively describes what you own is an crucial step in being able to effectively manage your property.

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