Permanent Plots in Natural Stands in the Pacific Northwest

Sarah Greene[1], Howard Bruner[2], Kari O'Connell[2]

[1]Pacific Northwest Research Station Forestry Sciences Lab, Corvallis, OR.
[2] Forest Science Department, Oregon State University, Corvallis, OR.

The first forested permanent plot in the Pacific Northwest was established by Thornton T. Munger in 1910, nearly 100 years ago. Munger, only 26 at the time, recognized the importance of long-term field observations in understanding forest changes. Following his example, foresters and forest ecologists continued to establish plots on federal lands in Oregon and Washington for the next 80 years. These plots were primarily in natural stands, unaffected by timber harvest or other kinds of management. By 2000 the plot network consisted of over 145 plots with measurements on over 100,000 trees, spanning a range of ages of twelve centuries.

The earliest plots were established in young stands of Douglas-fir, but as more plots were established, mature and old-growth stands were represented as well. Eventually the plots were expanded to include higher elevation stands of noble fir, Pacific silver fir, subalpine fir, and mountain hemlock; lower elevation stands of coastal Sitka spruce-western hemlock and Douglas-fir-red alder; east side stands of ponderosa pine; mixed conifer stands in southern Oregon and California; and spruce-fir and lodgepole pine stands in Colorado (Figure 1). Though most of the plots were in upland stands, more recently permanent plots have been established to include riparian zones. Some of the earlier stands have been lost to timber harvest, road building, and salvage after fire or blowdown. Beginning in the 1960s, in order to provide for more permanent protection, plots were almost exclusively established on experimental forests, research natural areas and national parks.

The Pacific Northwest permanent plot program is managed through a partnership with the Oregon State University Forest Science Department (OSU), the Pacific Northwest Research Station Ecosystems Team (PNW), and the College of Forestry, University of Washington (UW). The partnership is responsible for remeasuring the plots, managing the data through the Forest Science Databank at OSU, facilitating and encouraging research use of the plots, and keeping track of publications that result from using the plots or the data. In the last 3 years there have been over 100 requests for use of the various datasets, and over 75 papers published that actually used the plots and/or data from the plots.

Data for the first permanent plots were collected in the field and then copied over in indelible ink during the winter months. One hundred years later some data is collected with hand held computers, though hard copy data sheets are more commonly used. All the data collected in the field is then stored electronically, but getting to this point has been a long and arduous task. Computers and programs for using them have changed dramatically in the last 30 years, and each data set has had to make its way through these changes. Even with the advent of computers, field plot data inevitably includes errors that can only be reconciled by human knowledge and familiarity with the field situation.

Working in permanent plots has evolved over the years with changes in field equipment and variables measured. Plots, originally surveyed using a staff compass, are now surveyed using a laser finder, a quicker and more accurate method. Tree heights first measured with an abney level and tape, then with a clinometer, can now be measured with a laser finder as well. Though field marking plots is still essential, relocation is made easier with the use of GPS. In the beginning most measurements were made in English units; now metric units are used. The necessity of copying data sheets over has been eliminated with the advent of rite-in-the-rain paper. Initially mortality data consisted of only marking a tree dead; now dead tree information includes wood decay class, probable cause of death, and evidence of pathogens or insects.

A general overview of the plot network is in Table 1. Size of plots varies; some of the older plots are an acre or less in size. The more recently established plots are a hectare or contain a number of 1/10th hectare circular plots. Remeasurement intervals vary for each set of plots; every plot in a forest type is not always remeasured. Five year remeasurement intervals are preferred. Currently all plots have GPS locations, have been well marked in the field, and include detailed directions for access. Due to increasing costs and lack of funding, some of the plots have been "put to bed," and for some the remeasurement interval has been increased. Remeasurement of understory vegetation is variable. All plots are on federal land, though the degree of protection is not consistent.

The long-term data from these plots have advanced the state of general ecological knowledge and have provided invaluable information for managers. A number of examples taken from Table 1 illustrate these points. The Douglas-fir plots include the plots originally established by Thornton Munger in the early 1900s and a

Figure 1. Remeasuring permanent plot in old-growth Sitka spruce-western hemlock stand, Neskowin Crest Research Natural Area. Plots established in 1979.

network of permanent plots, established in the 1970s mostly within and around the H. J. Andrews Experimental Forest, to provide typical examples of many major forest communities commonly found in Oregon's central-western Cascade Mountains (Figure 2). Data from the earliest-established plots were initially used to help build the first Douglas-fir yield tables that were used for over half a century to calculate potential growth in young stands of Douglas-fir (McArdle and Meyer 1930). More recently, long-term records (up to 82 years) from 20 permanent plots in Douglas-fir stands were used to examine the implications of an extended rotation length (as proposed by the Northwest Forest Plan (USDA and USDI 1994)) for development of old-growth structures and for timber production (Acker et al. 1998). This analysis showed that longer rotations may not always result in large declines of timber growth; they can also provide structural characteristics similar to old-growth forests.

The Douglas-fir plot data have also been used to help improve the accuracy of another set of permanent plots, the Forest Inventory Analysis (FIA), which has established plots on private lands in a grid across the United States. FIA plot design was based on a study of cost-efficiency for estimating tree density, basal area, and volume in forests of Maine and New Jersey. The ability of this plot design to provide desirable information for Pacific Northwest old-growth forests was unknown. Long-term data collected in the Douglas-fir and true fir plots were used to assess the accuracy of this plot design. Tree spatial locations from stem maps and long-term records of mortality and coarse woody debris (CWD) accumulation were used to simulate the effect of different plot sizes on the accuracy of measuring density of large live trees and snags, tree mortality, and tree species richness in mature forest stands in the Pacific Northwest. This analysis revealed that in order to monitor late-successional forest attributes in this region within an acceptable level of accuracy, the national FIA plot size needed to be expanded for the measurement of live trees and snags (Gray 2003).

In the late 1970s scientists began to collect data on amount, size and decay class of CWD, both standing and down, in most of the permanent plots throughout the region. These data from the Douglas-fir and spruce-hemlock plots were eventually used by natural resource managers to determine how much, what type and what age of CWD should be left to improve wildlife habitat after timber harvest and thinnings.

With increased concern about global climate change and the possible role of forests in sequestering carbon dioxide, much recent research using data from the permanent plots

Figure 2. Thornton T. Munger remeasuring one of the Douglas-fir permanent plots, some time in the 1920s.

has focused on forest carbon dynamics. For example Smithwick et al. (2002) approximated an upper limit on carbon (C) storage in the PNW by estimating total ecosystem carbon (TEC) stores of 43 old-growth forest stands from the permanent plot network in five distinct biogeoclimatic provinces. They suggested that the upper bound of C storage in forests of the PNW exceeds current C stores, presumably due to a combination of natural and anthropogenic disturbances. This result indicates a potentially substantial and economically significant role for forest C sequestration in the region.

The alder conifer plots, both pure and in mixtures, were established on an abandoned homestead in the early 1930s by researchers interested in the role of red alder in the development of coniferous stands on the Oregon coast. Long-term measurements eventually revealed that the nitrogen fixing alder provided little added volume to the coastal Douglas-fir stands because the stands were already nitrogen rich. In other less fertile sites in southern Washington and British Columbia, long-term plots revealed that mixing alder with the young conifers actually increased volume. In addition, these plots have been used by scientists studying the role of mycorrhizal fungi on Douglas-fir and red alder roots. Scientists have studied soils under these pure and mixed alder-conifer plots, looking at soil properties and soil chemistry, the role of soil organic matter in driving changes in soil pH, and the long-term effect of red alder on soil fertility (Trappe et al. 1968). More recently the data have been used to look at self-thinning and how density and the alder conifer mixture affect that process. Finally, the once accepted notion that red alder would begin to break up and die after age 60 is proving wrong as the alder continues to increase in volume past the age of 80.

Scientists established permanent plots to observe long-term growth and mortality of an old-growth mountain hemlock forest in the Torrey-Charlton Research Natural Area in 1976. A 10,000-acre wildfire that burned some of these plots in 1996 provided a serendipitous opportunity. Scientists were able to examine the effects of fire on the early successional dynamics of a mountain hemlock forest and to compare vegetation development against a 20-year baseline of old-growth plots. Forest development has been slow, especially in the areas of greatest fire severity. Total seedling density in the most severely-burned plots in 2002 was only 4% of seedling density in unburned plots. Chronosequence studies for this high-elevation system suggest colonization by lodgepole pine initially after wildfire with mountain hemlock slowly replacing the pine to become the climax tree species (Dickman and Cook 1989). Post-fire conifer recruitment was dominated by mountain hemlock and had only very limited lodgepole pine presence.

Data from the permanent plots in the Pacific Northwest have been used by scientists and managers around the country to address basic and applied questions in forest ecology and management. These plots provide reference conditions and long temporal scales not yet represented in the Forest Service FIA, Current Vegetation Survey and Forest Health Monitoring programs. Continued measurement of established long-term plots is especially important given that conclusions drawn from short-term observations do not always accurately describe long-term processes. The permanent plot program will continue to provide invaluable information on long-term forest dynamics as climate, natural disturbance, and forest management issues change.

In the past, new management concerns and new scientific questions have been brought to these remeasured plots and their long-term databases. Some of the questions that activated Munger and his colleagues in the 1920s remain important. In the future, if we sustain this legacy of applied science, these plots will be there to help managers and scientists to respond to as yet unanticipated new questions.

References

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Table 1. Permanent plots in forest stands in the Pacific Northwest, administered by Forest Science Department, Oregon State University and Pacific Northwest Research Station, USDA Forest Service.

Forest type	Number of plots	Years plots established and number of plots	Number of measurements	Variables measured	Range in elevation (m)	Ecoregion	Land ownership	Current age range (years)	Plots with tree stem maps
Douglas-fir	82	1910 - 1940: 34 1971 - 1979: 44 1980 - 1981: 2 1990: 2	13	Tree DBH, mortality, height; understory vegetation; soil description; elevation, slope, aspect	61 -762	Coast Range, OR; Olympic Peninsula, WA; Western Cascades, OR & WA	Forest Service, National Park Service	120 -1200	46
Hemlock-Spruce	20	1935: 11 1978 - 1984: 9	11	Tree DBH, mortality, height; understory vegetation; soil description; coarse woody debris; elevation, slope, aspect	125-402	Coast Range, OR; Olympic Peninsula, WA	Forest Service, National Park Service	85 - 270	8
True Fir	28	1972: 3 1976 - 1978: 22 1980 - 1981: 3	7	Tree DBH, mortality, height; understory vegetation; soil description; elevation, slope, aspect	1018 - 3100	Coast Range, OR; Olympic Peninsula, WA; Western Cascades, OR & WA	Forest Service, National Park Service	66 - 325	22
Mountain Hemlock	3	1976, 1981, 1996	6	Tree DBH, mortality, height; understory vegetation; soil description; elevation, slope, aspect	1469 - 1660	Western Cascades, OR	Forest Service	250 - 340	0
Alder-Conifer	5	1937	11	Tree DBH, mortality, height; understory vegetation; soil description; elevation, slope, aspect	152 - 183	Coast Range, OR	Forest Service	80	0
Ponderosa Pine	5	1938: 2 1981 - 1982: 3	7	Tree DBH, mortality, height; understory vegetation; soil description; coarse woody debris; elevation, slope, aspect	850 - 1400	Eastern Cascades, OR	Forest Service	300+	4
Spruce-Fir	5	1938	6	Tree DBH, mortality; coarse woody debris; elevation, slope, aspect	2840 - 2900	Rocky Mountains, CO	Forest Service	350	0
Mixed-Conifer and Giant Sequoia	6	1983	4	Tree DBH, mortality, height; understory vegetation; soil description; coarse woody debris; elevation, slope, aspect	2012 - 2440	Westside Sierra Nevada Range, CA	National Park Service	300 - 1000+	6

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