Basic Truths for Planning and Executing an Inventory

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Abstract.—A number of basic truths are presented. The importance of carefully developing the objectives for an inventory is stressed. The use of permanent plots and temporary plots is covered. The necessity of obtaining a representative sample, training effectively, and collecting quality data is discussed. The future direction for forest inventories is suggested.

Thomas Edison said, "There is a better way for everything. Find it." An examination of the program for this meeting shows that through the many and varied speakers and their subjects we have the opportunity for better ways. We also have that opportunity as we share ideas with each other during breaks and activities throughout this conference.

We have the responsibility to be good stewards of our natural resources while working to meet our organization's objectives. We must have adequate data to properly manage these resources collected in a cost-effective and credible manner.

Today I will share some of my concerns and thoughts as well as the ideas of some of my forest inventory friends as I discuss basic truths of the planning and execution of a natural resource inventory.

My comments will primarily pertain to large-scale forest inventories. Natural resource inventories have become more and more complex. Foresters have traditionally put the emphasis on collecting data to manage the forest. The forest is composed of stands which are frequently referred to as polygons. A stand is defined by unifying characteristics such as species composition, age, tree size, and density. Normally, any measurable characteristic of the stand is put on a per unit basis. Thus, most inventories have been made to gather timber data. It is obvious that we have a growing need for information on wildlife, water, recreation, forage, and other non-timber values. This need has stimulated the development of integrated multiresource inventories. The non-timber values are usually much more difficult and expensive to assess than the timber values and are not well understood.

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OBJECTIVES

Whether we are looking for water on Mars or designing a comprehensive inventory system, we must carefully determine our objectives. Regardless of the resource we are interested in, we must determine what data to collect to reach our objectives. We need to find out what information is available and which procedures and methods to use in obtaining the data that must be collected. Once we know these, we should ask if we have the finances, personnel, and time to achieve our objectives. All field procedures should be thoroughly tested before implementation. It is important to develop a plan for compilation and analysis before making the first field measurements and to test the compilation system.

A basic truth that may be overlooked is that the original objectives of the inventory often change between the time they are planned and the time they are executed. After the inventory has been completed, unanticipated questions may arise. It is most difficult to reassess data to answer questions the inventory and data collection were not designed to answer, again stressing the importance of proper planning. Save all data at the raw level for future recompilation. Do not throw anything away and do not round or classify until it is absolutely necessary.

Resource inventories must be adequately designed to reach the intended objectives. Sometimes the inventory is overdesigned, which causes it to be inefficient in achieving the planned use of the data. In designing the inventory, it is important to recognize that there are areas where little change occurs over time and other areas where changes are so rapid that the inventory information is soon outdated.

Sometimes it is most difficult to collect all the data needed to reach a given objective. A case in point is "The Oregon Plan for Salmon and Watersheds." This plan is designed to restore the healthy function of Oregon's natural aquatic systems. A speaker discussed this at a recent forestry meeting. He used the example of a Chinook salmon. At the end of his presentation he was asked the question: "since a Chinook salmon spends most of its life in the ocean, what effort is being made to learn what happens to the salmon during that time?" His response after a reflective moment of silence was to tell a story. A man was down on his hands and knees under a light pole at night. A person came along and asked him what he was doing. He replied that he had lost his glasses. The next question was "where did you lose them?" His response was "over there." Why are you looking here? It is the only place I can see.

This emphasizes another basic truth. We need to thoroughly examine what the goals are for the inventory. We could develop nearly perfect stream habitat for salmon, yet accomplish little if we do not know what effect changes in the ocean conditions, fish harvest, or predators might have on the number of salmon returning to rivers and streams. In addition, we need to properly monitor salmon counts in the rivers before and after habitat restoration, as well as compare salmon counts in rivers that have had little or no disturbance with counts in rivers that have had degradation.

In planning for any natural resource inventory, we must have adequate knowledge of the population to be sampled and especially its dynamics. This knowledge is critical in designing a sampling system that will give a representative sample. This is difficult enough for forest populations that do not move. However, the problem is greatly compounded for animal, bird, and fish populations that have such varied patterns of movement.

RESOURCES

It is essential to have recent aerial photographs at a reasonable scale, current maps, trained personnel, proper equipment and computer capability to properly process the inventory data into information. The development of efficient field data recorders capable of functioning under a wide range of field conditions, including the ability to do editing in the field, has greatly enhanced the entire data recording process. Increased computer capacity makes it feasible to store more detailed data rather than just summaries. Actual stand tables or tree lists are particularly helpful for such activities as commercial thinning, midterm harvest planning, and preharvest timber cruising. Computer software programs need to be designed to meet the needs of the inventory system and not be just convenient for the programmers.

INVENTORY USERS

It is my experience that the people responsible for managing the area being inventoried should be heavily involved in all phases of the inventory. I have seen too many cases where the inventory was not used or not properly used when local personnel were not involved in the planning and execution of the inventory. Every possible effort should be made to have communication among those responsible for the field work, those analyzing the data, and the users. A periodic review of the inventory system by the inventory personnel and the users of the inventory is most important. This type of review also needs to be done whenever significant changes are being made in the inventory system. This is a particular problem with an ownership change. The new owner may have different objectives or have a different emphasis. Changes in measurement techniques, utilization standards, and type of inventory make it most difficult to integrate an existing inventory with a new one. This is also true when there are new or changing inventory requirements. This supports the concept that everyone has a vested interest in the inventory system.

MEASUREMENT CYCLE

An important issue needing careful consideration is the measurement cycle. A general session in this conference is devoted to annual forest inventory systems. This indicates the interest in a short measurement cycle. Rotation length and the extent of activities occurring have a major impact on the length of the measurement cycle. Some organizations collect data less frequently during that part of the rotation where little activity occurs. Another suggested method is to inventory a percentage of the ownership each year. For example, if the measurement cycle is 5 years, 20 percent of the ownership is inventoried each year. This makes it possible to have a permanent highly trained inventory staff. The inventory can be updated annually by using a model to project that part of the ownership that has not been measured. Again, it is essential to have the necessary funds, recent aerial photos, and trained personnel.

FOREST INVENTORIES

There are two major types of forest inventories: continuous forest inventory (CFI) and in-place or stand-based inventory. Considerable effort has been made since World War II in carrying out forest inventories. Many of us are anxious to hear what Ed Frayer and George Furnival have to say about the history of extensive forest inventories. There was considerable emphasis on permanent sample plots in the 1950's. Generally, the periodic remeasurement of permanent sample plots is effective in assessing changes in forest stands over time. Permanent plots are particularly useful in assessing changes due to growth, mortality, species composition, and catastrophic events. However, a CFI system is not effective without adequate financial support and trained personnel. These plots were often painted so that they were highly visible. As a result, sometimes these plots were treated differently than the surrounding area and the plots were no longer representative of the population.

14One of the major problems associated with permanent sample plots has been the change in the type of plot and in plot cluster configuration between measurements. I am aware of one organization that spent considerable funds to monument fixed-area plot clusters for relocation. They never remeasured the plots because they changed to a variable-plot cluster. These types of changes under the best of conditions make comparisons difficult. There has been considerable discussion about the merits or lack thereof in using variable plots as permanent plots. Actually each of the methods can be used effectively.

Plot clusters containing from 3 to 16 subplots have been used. The USDA Forest Service used three 1/5-acre plots and then changed to 10 sample points when they switched from fixed plots to variable plots. Recently the Forest Service's Forest Inventory and Analysis (FIA) program changed from variable plots to fixed plots. FIA has the responsibility for the inventory of the nation's forest and related resources. For plot clusters, the biggest cost is getting to the first subplot. There is considerable gain in measuring additional subplots while there. However, the most efficient plot cluster size is generally considered to be three to five subplots. There is a tendency to collect additional data while at the cluster location—the "as long as you are there" syndrome—which often proves to be not cost effective. It is particularly true with plot clusters. There has also been considerable discussion of what to do when one or more subplots fall in a different type. The latest recommendation is to not move these subplots.

Stand-based inventories do not measure changes as efficiently as a CFI system, but they do give better estimates of stand conditions. Plots not permanently marked for relocation are less costly. Thus, many organizations have opted for a stand-based inventory.

Various procedures for locating sample plots or points within a polygon have been in use over time by different organizations. Some have run a line of plots through the area that was judged to be representative of the area. One inventory forester instructed his crews to cover at least 70 percent of the polygon. A grid helps to eliminate bias due to plot location. A square pattern grid is most appropriate to use when the polygon is small and there is considerable variation throughout the area. However, some type of a rectangular pattern gives more sample plots for the distance walked compared to a square grid. Using a grid also tends to give a more representative sample.

SAMPLING PRECISION

It is important to establish a sampling precision level needed for the overall inventory. This precision level should be appropriate for meeting the objectives of the inventory. A much lower precision level is needed at the polygon level, but the precision must be high enough so that the results are useful. We need to be mindful that it requires four times as many sampling units to reduce the sampling error by 50 percent. We often neglect to determine the critical components of what we are measuring. We should have reasonable estimates of the coefficient of variation of these critical components so that they can be sampled at an appropriate precision. In some cases, polygon size rather than the variation within the polygon has been used for determining sample size. Samplers need to develop the ability to estimate the coefficient of variation.

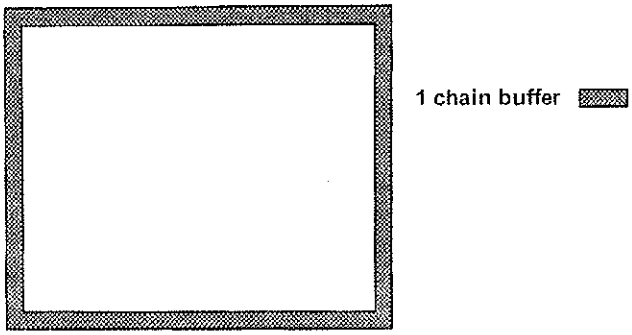
Surprisingly, many software programs do not calculate the sampling error and coefficient of variation for the component parts. Too many inventory foresters do not understand the difference between sampling error and coefficient of variation. It is important to know by checking actual data rather than to rely on what is commonly believed within an organization. In one project, we examined the coefficient of variation of an item for several samples. The coefficient of variation ranged from 2.5 to 6.7 percent. Thus, only a few observations were needed compared to the considerable time and effort the company was spending. Something that should be done more often is to change an item and observe the effect. If nothing important has changed, it is obvious that the system is insensitive to that measurement.

STRATIFICATION

There is considerable precision gain in classifying (stratifying) resource populations into homogenous units. In a forest inventory, the unit is a stand of similar characteristics. The purpose of stratifying is to reduce the variation within the polygon and to increase the precision of the population estimate. Sometimes there is a tendency to overstratify. We need to be mindful that it is necessary to accurately determine the acreage of each stratum or the gain in precision is lost due to incorrect acreage.

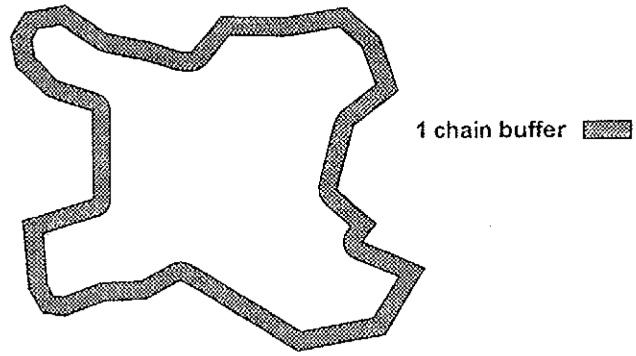
EDGE EFFECT

Another basic truth in forest sampling involves obtaining a representative sample of the outer edge of a polygon. There is often considerable difference in stand conditions between the perimeter of a polygon and its interior. Sometimes inventory foresters insist on moving in two chains before taking a plot. A one-chain-wide area on the perimeter of a square 40-acre unit represents 19 percent of the 40 acres (fig. 1). It is obvious that the perimeter of a polygon increases as the shape of the polygon becomes more and more irregular. Figure 2 shows an irregular shaped area 10.1 acres in size. A one-chain-wide area on the perimeter is 46.5 percent of the total area. Figure 3 shows an irregular shaped area 30.1 acres in size. A one-chain-wide area on the perimeter is 27.9 percent of the total area. Thus, these two areas would need to have 46.5



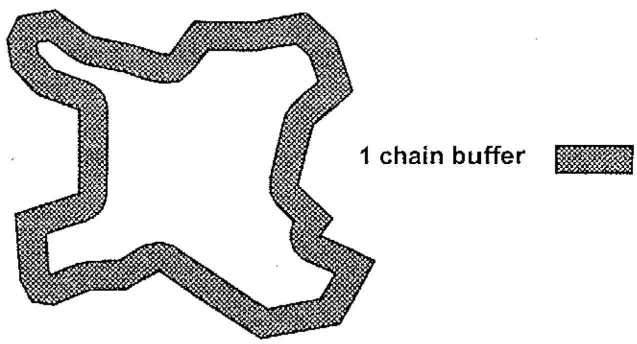
40.0 total stand acres
32.4 acres inside buffer
7.6 acres in buffer
19% in buffer

Figure 1.—*Illustrates a square 40-acre unit. A one-chain-wide area on the perimeter represents 19 percent of the unit.*



30.1 total stand acres
21.7 acres inside buffer
8.4 acres in buffer
27.9% in buffer

Figure 3.—*Shows an irregular shaped unit 30.1 acres in size. A one-chain-wide area on the perimeter represents 27.9 percent of the unit.*



10.1 total stand acres
5.4 acres inside buffer
4.7 acres in buffer
46.5% in buffer

Figure 2.— *Shows an irregular shaped unit 10.1 acres in size. A one-chain-wide area on the perimeter represents 46.5 percent of the unit.*

and 27.9 percent of the sample plots, respectively, in each of these areas to have a representative sample. It is my opinion that most of us are not aware of the magnitude of the problem of edge effect. These various sized and shaped polygons illustrate the large percentage of the total area that a one-chain-wide area on the perimeter represents. This certainly points out the difficulty of obtaining a representative sample of the area on the perimeter of a polygon. It also illustrates the challenge of achieving a representative sample in odd shaped areas such as riparian zones.

ACCURATE MEASUREMENTS

Regardless of the inventory system used, accurate measurements are critical. Personnel should be highly trained and conscientious. The only way to achieve uniform results is through intensive and continuous training of field crews. In addition to training, accurate field measurements depend on quality instruments and their careful use. It is important to check instrument accuracy before going to the field. Along this line, it is preferable to use full-time field personnel rather than part-time crews. Likewise it is desirable to make accurate measurements rather than estimates and judgment calls. Generally it is better to make fewer accurate measurements rather than a greater number of estimates. Those conducting resource inventories need to be on the watch for improved equipment. The challenge is to obtain the most efficient equipment to meet the resource inventory requirements. It is also important to develop written procedures that ensure consistent measurements. In addition to having carefully written procedures, it is essential to precisely document all analyses and results. It is critical to report the reliability of all statistical data. This is often neglected in reports by secondary users, which can lead to faulty conclusions. Another problem is when inventory information is interpreted and used for purposes other than that for which it was designed. The followup to training is an effective auditing program. Foresters call this check cruising although most others refer to it as quality control. The auditing program is used to see if the person knows the procedures and how to make and record all the needed measurements. This is usually accomplished by accompanying the person while the work is being done under various conditions. The second aspect could be referred to as an independent audit. This is done by visiting a small percentage of randomly selected plots. It is important to understand which errors in measurements cause significant changes in the results. For instance, errors in diameter measurements have small consequences compared to height measurements for computing volume in variable plot sampling. Yet, there is a tendency to carefully check diameters since it is easy to do. The point is that the items that cause change in results must be checked, not just the ones that are easily checked. The concept is that the inventory person knows that any given plot can be checked regardless of location. This means you do not check only the plots close to the road. This encourages consistent high performance.

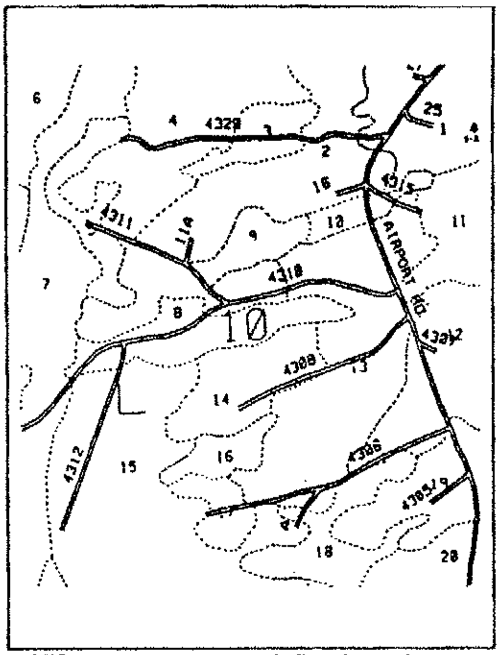
FOREST HEALTH MONITORING

We hear much about forest health monitoring (FHM). Activities associated with forest health monitoring include protecting sensitive areas, planting riparian zones, reforestation, controlling erosion, rehabilitating streams, thinning overstocked forests, disturbances affecting the health of the forest ecosystem, and restoring wildlife habitat. Achieving success in inventorying these activities requires considerable planning and clearly defined objectives. There are many challenges such as selecting attributes to monitor to detect change, choosing a sampling design, and determining sampling intensity.
A basic truth is that there is much to be gained by having uniform procedures and standards throughout an organization. However, some of the objectives of Forest Inventory and Analysis and Forest Health Monitoring are different. It is my opinion that FIA and FHM should not sacrifice important objectives of one or the other in the process of standardizing procedures.

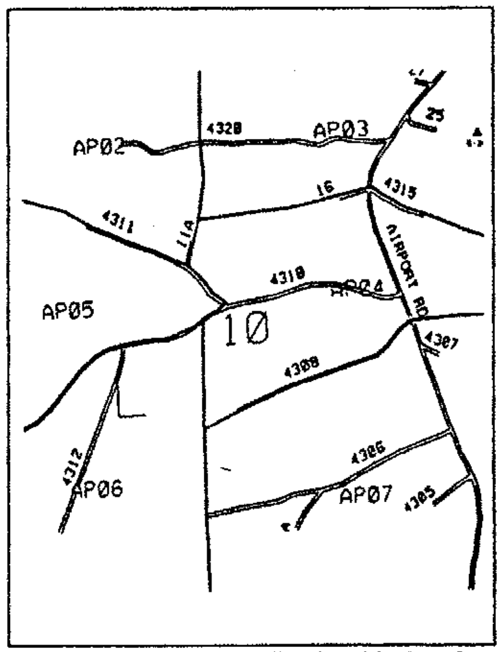
HARVEST UNIT-BASED INVENTORY

A basic truth associated with harvest units is that the harvest unit boundaries are often changed from the time they are selected until the harvest is completed. This causes many problems. One possible solution is the adoption of a harvest unit-based inventory.

In the 1980's, the Simpson Timber Company examined what they wanted from their inventory system. Management asked the inventory department to evaluate the long-term effect of various cutting scenarios on the future supply and quality of wood that would be available to their mills (Naccarini 1990). Figure 4 compares their former cover type map with their new harvest unit blocks.



In 1978 a cover type was defined as a homogeneous stand of timber with similar species, stocking, age and site class.



Today, cover types are defined as blocks of timber that are expected to be managed as one unit in the future.

Figure 4.—*Compares Simpson Timber Company's former cover type map with their new harvest unit blocks.*

"The harvest unit information is maintained by our Geographic Information System. Each unit has a unique identification number which ties directly to our silvicultural activity tracking system, long term harvest scheduling system, log accounting system, and of course, our entire forest inventory system. The harvest unit database stores the characteristics of each unit, such as, primary species, average site index, total age, relative density. Species information including trees/acre, quadratic mean diameter, and current volume/acre are also stored within this table. The system also keeps track of the projected volumes at the scheduled year of harvest." (Naccarini 1995). The harvest unit-based inventory is working well for the Simpson Timber Company. The system implies that the operational foresters are able to define future harvest units with reasonable accuracy. Many companies have had problems stemming from changes in planned harvest unit boundaries.

GEOGRAPHICAL INFORMATION SYSTEM

GIS should be considered for what it has to offer to enhance your current inventory system. Initially GIS was oversold. The maps looked great but the emphasis was on maps rather than integrating the inventory data. In the system are two databases, one being the resource inventory database that describes what is there. The other is the spatial coordinate data showing where it is located. All other applications are derived from these two components. These two components can be organized into separate layers that describe such things as the road system, water drainages, stand polygons, ownership, and planimetric and topographical features.

GIS software allows map features to be combined in various ways. These maps can be made at almost any scale. In the resource database would be such things as volume per acre, basal acre per acre, and any other stand information. GIS combining spatial and tabular databases makes possible the selection of all stands available for a certain activity such as thinning or harvesting, according to whatever criteria or distinguishing features you might want to use. Combining the map and resource bases, GIS is a highly effective tool for analyzing and establishing short- and long-range plans. In addition, GIS is valuable in keeping an inventory system current.

FUTURE DIRECTION FOR RESOURCE INVENTORIES

The basic truth here is that we are always striving for better ways to carry out an inventory. The three papers being presented later this morning discuss the very large forest resources inventory being conducted by the British Columbia Forest Service. This inventory certainly suggests the direction for future resource inventories. The province was divided into about 40 regions. An estimate was made of the volume in each polygon based on the data from the previous inventory. Approximately 200 polygons were selected in each region from an ordered list with a random start. Data are collected within each of the selected polygons. The total of all the estimates from all the polygons within a region are adjusted by the relationship between estimated and the measured data from the selected polygons. This British Columbia inventory is an excellent way to conduct a forest resources inventory.

CONCLUDING REMARKS

In conclusion, I encourage each of us to accept Thomas Edison's challenge, "There is a better way for every thing. Find it." May the things you learn and discuss during this conference help you find better ways to carry out your responsibilities.

ACKNOWLEDGMENTS

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