1509

MONITORING NEW FORESTRY

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Abstract. Techniques to monitor growth and mortality of live trees, and longevity of snags were developed and tested on 8 units in the Oregon and Washington Cascades where new forestry (structural retention) cuttings were utilized. Time and costs were quantified. The total area of three aggregated units and five dispersed units was 27.8 ha, with 2407 trees and snags measured on 25.1 ha of sample area. Cost of field work was approximately $4590 (4 person crew at 6 weeks) while costs of data entry, analysis and report writing were approximately $2000 (250 person hours). Monitoring is an important component of adaptive management and is essential if we are to understand the ramifications of new silvicultural systems.

1. Introduction

Past silvicultural management practices simplified forest systems, in contrast to retention silvicultural systems which seek to encourage the high variability found in forests by maintaining the complex structural and functional elements found in older forest ecosystems (Franklin, 1989). The structural elements which are retained may include green trees, snags, and coarse woody debris, under the assumption that they are essential elements in forest ecosystem complexity, biodiversity and resiliency (Franklin, 1989, 1991; Hopwood, 1991; Swanson and Berg, 1991).

The retained structural elements are generally found in two types of distribution patterns: dispersed and aggregated. Dispersed units are orchard-like with individual trees widely scattered throughout the unit, while aggregated units have closely clumped trees. The aggregated units have variously shaped elongate strips or small patches which may or may not be connected to an uncut forest. The elongate tree strips connected to uncut forest are known as peninsulas. The clumps may be thinned. The plot layout and sampling differ for the two types of setting.

Monitoring the silvicultural and ecological effects of retention cuts provide quantified data to assess whether silvicultural objectives are met and aid in defining guidelines for future cuttings. The monitoring sample design may allow other types of studies on the same stand. Additionally, monitoring is the backbone of any good adaptive management program. Examples of monitoring in forestry include: growth and yield of regeneration, growth and mortality of the leave trees, use of snags by wildlife, monitoring windthrow patterns, and tracking stand development.

The objectives of this work was to develop techniques for monitoring growth and mortality of leave trees, and the longevity of snags, in sites where structural retention silvicultural systems have been used in the Washington and Oregon Cascade Mountains. In addition, the variability in cutting unit designs was appraised. Because time and money are a major constraint in any monitoring effort, an additional objective of this work was to determine the time and costs of monitoring.

During the summer 1991, plots were established at the Cedar River Watershed, North Bend, WA; on Plum Creek Timber Corp holdings near Morton, WA and Cougar, WA; and on the Blue River Ranger District (H.J. Andrews Experimental Forest and the Mona Creek Drainage), Blue River, OR to test the monitoring system discussed here.

2. Methods

2.1. Locating and Referencing Plots

Each structural retention unit was referenced and extensively documented to facilitate remeasurement. The units were documented by establishing site reference posts, drawing maps, and verbally describing the unit layout. The location of the plots, subplots, transect layouts and plot center placements could then be easily relocated. Locating individual trees could be facilitated by retracing the sampling paths indicated on additional maps.

The dispersed units were referenced to a tagged post located near a road or other access point at the corner of the unit. The first point on the plot grid was then established 50 meters in and 50 meters up from the edges of the unit to be measured. The rest of the unit was laid out by placing posts 100 meters apart in all direction, placing posts only where the 100 meter points fall within the stand. For 100% tree and snag samples, the first subplot was only 50 meters long and 50 meters wide. The unit was then broken into 100 by 50 meter wide subplots pivoting on the established posts. A buffer zone was established where appropriate, however the usual delineating border for a dispersed setting site was usually the harvest boundary path marked when the unit was cut. The plots around the edges of such a dispersed cut may have irregular shapes and sizes.

If only a subsample of the trees in the unit was to be done, the 100 meter by 100 meter grid was laid out over the entire area and 1/10 ha (17.84 meters radius) subplots established at the grid line intersects. Care was taken in locating plots so there was minimal influence from surrounding stands.

The aggregated units were highly variable. Depending on the size and shape of the stand more than one reference post may have been used. For the elongated strips a center line was run through the aggregate of trees. Three strip plots were then run perpendicular to the center line, one at each end of the aggregate and one in the middle. Each strip plot was posted at the intersect with the center line. Distance and azimuth from the site reference post to the nearest sub-reference post at the beginning of each transect was documented. The plot dimensions are determined by laying out a rectangle stretching from one side of the strip to the other. These strip plots are a minimum of 10 meter wide, however when less than 20 live trees (five centimeters or greater in diameter at breast height) were encountered the plot width was adjusted to include at least 20 trees.

Small, roughly circular clumps had a site reference post set near a road, a site reference post outside the aggregate, and a post in the center of the clump. In this study all the trees within the circular aggregate plots were tagged and measured. Alternative sampling schemes can be used, however, depending on the size, shape and objectives of a monitoring program.

2.2. Measuring and Describing the Stand

We developed three cards for field use to standardize the documentation of the establishment and the initial or subsequent measurements of structural retention reference stands. These were: A location card which included information about the Geological Survey maps of the areas containing the plots, verbal directions to the sites, ownership and contact persons, as well as any other information regarding access to the site and the location of the site reference posts. A map card for making detailed maps of the plot and subplot layout. And a tree measurement card including a map of the sampling path for the trees.

The tree measurements are listed in tabular form to facilitate entry into database. Tree measurements included: tag number, species, diameter at breast height (dbh), crown class (applicable for aggregated trees only), crown ratio, overall vigor, snag decay class and evidence of use, and on a subsample of 20% of the trees; height, height to lower crown, and five and ten year radial increment. A vegetation list of a 10 m^2 center plot was also included on this card.

3. Results and Discussion

We chose to document live tree growth and mortality, and snag longevity in our monitoring effort. We did not sample extensively for other characteristics such as vegetation, wildlife response, or growth and yield of the regenerating stand, but we hoped our plot layout would accomodate these other studies in the future.

The monitoring plots were established in eight units totalling 27.8 hectares, 2407 trees and snags were tagged on 25.1 ha of the sample area; three of these were aggregated and five were dispersed retention units. Much of the time was invested familiarizing ourselves with the area, then setting up and posting the sample area. Travel time was also considerable. Table I lists the different units sampled and their statistics.

We found that the time required to established the average dispersed one hectare plot (100% sample) took approximately 11.5 personnel-hours. This included laying out two 50 meter by 100 meter subplots on compass lines, posting the four corners of the hectare, flagging the lines along the two 50 meters plots, tagging, recording tree and snag conditions, measuring the average number of 75 widely dispersed live trees (> 5 cm dbh) and snags (> 15 cm dbh), and measuring the heights and growth increments of 20% of the live trees.

The amount of time required to establish any particular retention plot depended on the type of setting (i.e., whether the unit was dispersed or aggregated), the

TABLE I

Summary of unit names, locations, owners and selected statistics including unit area, area sampled, total living trees and snags sampled, time, and estimated costs (the areas contained in the strips are estimated).

Aggregated Units	
Sugar Bear Substitution, Cedar River Watershed, Seattle WA	
Total area in strips	10.5 ha
Total area sampled belt plot	1 ha
Total living trees and snags	268
Total time to establish	80 hr
Estimated costs	600 $
Suzy Q Unit, Plum Creek Timber Company, Morton WA	
Total area in strips	5.3 ha
Total area sampled belt plot	0.37 ha
Total living trees and snags	225
Total time to establish	76 hr
Estimated costs	570 $
Cougar Ramp Unit, Plum Creek Timber Company, Cougar WA	
Transects 1–3 (Plots 1–12)	
Total area in strips	6.5 ha
Total area sampled belt plot	0.88 ha
Total living trees and snags	340
Plot 13 (aggregate plot)	
Total area in plot	0.17 ha
Total area sampled approximately	0.17 ha
Total living trees and snags	100
Total time to establish	108 hr
Estimated costs	810 $
Dispersed Units (100% sample)	
H.J. Andrews Experimental Forest, Willamette National Forest, Blue River Ranger District.	
Blue Ridge Unit	
Total area sampled	4 ha
Total living trees and snags	173
Total time to establish	96 hr
Estimated costs	720 $
Interfluve 5–6 Unit	
Total area sampled	7.1 ha
Total living trees and snags	325
Total time to establish	104 hr
Estimated costs	780 $
Mendel Unit	
Total area sampled	9.8 ha
Total living trees and snags	687
Total time to establish	84 hr
Estimated costs	630 $
Blue River Ranger District	
Slim Scout 3B, Mona Creek Drainage	
Total area sampled	1.7 ha
Total living trees and snags	89
Total time to establish	32 hr
Slim Scout Unit 4, Mona Creek Drainage	
Total area in unit	2.8 ha
Total living trees and snags	ND
Total time to establish	32 hr
Total personnel hours required	64 hr
Estimated costs	480 $

number of trees and snags, how accessible and steep the unit was, the density of the understory and the amount of woody debris which had been left on the site.

The Sugar Bear Substitution unit was flat, but had a heavy understory of western hemlock regeneration, so that laying out the initial transect was impeded by not being able to see along the compass line. Once the belt plot were laid out, however, measuring the trees themselves proceeded rapidly. The Suzy Q and Cougar Ramp units presented similar visibility problems as well as being steep. The Mendel Unit in the Oregon Cascades was relatively open because it had been burned after it was cut ten years previously, and had not been replanted with tree seedlings. However, the access to this site was difficult due to its steepness and the number of large logs left after cutting. The Blue Ridge and Interfluve units were easy sites to establish and measure due to the open understory, the small quantity a coarse woody debris and a relatively moderate relief. The two Slim Scout units in the Mona Creek Drainage in Oregon proved the most difficult to establish because they were extremely steep, access was difficult, and a large amount of coarse woody debris was left on site. Neither of these units had been burned after they were cut six months before, so that a large quantity of leafy slash was present which reduce visibility. A estimated 612 personnel-hours were required to establish the plots in the eight units, not including travel time. Total personnel costs were approximately $4590.

The time required to design an appropriate database format and enter the tree data for future reference, to complete the maps and location descriptions, and to prepare reports took another 250 personnel-hours, costing approximately $2000. The other major expense incurred in this project were transportation costs, including the vehicle and paid travel time between sites and to the plots at each site, these costs are not estimated in this report.

Having an explicit sampling scheme prior to the field work and spending time examining the site before beginning to lay out transects and grids reduced the time required to set up the plot by minimizing the number of traverses needed to complete the establishment of the plot. We found the grid design easy to establish and should be easy to relocate.

Decisions as to the sampling patterns to use subsequently affect the type of analysis possible. Standard statistical tests of the data collected from these randomized systematic grid are valid provided the underlying populations are randomly distributed (Scheaffer *et al.*, 1986). In addition, spatial inferences can be made from systematic sampling schemes. However, aggregate retention plots within a harvested area may not represent the population of the area. Consequently, care must be taken to insure that the measured plots address monitoring objectives for the site.

Protocols and procedures for collecting the data need to be explicit prior to field work. This is to insure that the collected data is accurate, useful and sufficient without being extraneous. Previewing analysis prior to field work can eliminate unnecessary expense, as well as, identifying possible sources of variation or error to guard against. Variability in tree and snag measurements can be quite high in some retention cutting systems, so that adequate sample size is important for statistical viability. It is easier to take the extra time required in the field than returning later to pick up some needed piece of information. The added expense of revisiting the sites can be extensive. Preparation can prevent such 'holes' in the strategic plan.

Such decisions as the sampling method can have great influence on the type of analysis that is possible. Choice of the systematic grid or simple randomly sampling can be important if interpolation between points or spatial inference is of interest. Statistically, the selection of completely random points offers the most independent estimate of the samples mean. Operationally, the systematic grid is easier to establish and relocate for successive measures, is more efficient to measure (and hence cost effective), and offers spatially oriented details that are evenly spread over the population.

The statistical trade-off between sampling designs depends on the nature of the population being sampled (Cochran, 1977). The two sampling procedures are equivalent when the population is random (Scheaffer *et al.*, 1986). The harvest areas with aggregated retention may represent a periodic spatial pattern in the population that requires care when applying sampling design.

Monitoring allows a view into the system or process of interest and an analytical avenue to determine if the overall objectives are being achieved. Without a monitoring system no quantitative basis exists for assessment. Equally important is how to analyze the newly acquired information; this is a fundamental of adaptive management (Walters, 1986). Using the available information is how the best decisions are made but this is complicated by the fact that new information is being gained.

Forest stand projections are based on approximations of future conditions. New information on the growth and yield of retention stands can be incorporated into current stand models to make more accurate projections. Updating the information and adapting our management to meet the desired or planned objectives is a continuing process but has the key benefit of reducing the uncertainty around projections.

4. Conclusions

The eight sites selected for the establishment of New Forestry reference plots represent a small fraction of the sites needed to adequately examine the impact of harvesting techniques which retain a significant proportion of the original structural and functional elements of a forest ecosystem on the site. Current knowledge about the influence of the elements is primarily anecdotal, although these observations have pointed out the key variables to be tested. The protocol suggested here has been tested in the field for its efficacy and ability to examine the key variables in forest structure, live trees and snags. The ability to collect quantifiable information from monitored reference plots will help to enhance our sustained use of the whole

forest without jeopardizing biological diversity.

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