# RESOLUTION OF SMALL-GROUP SELECTION IN FOREST PLANNING MODELS

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ABSTRACT.—Forest planners must make tradeoffs between size and complexity of planning models and the accuracy of predictions. Modeling small-group selection poses particular difficulties because of inherently high spatial resolution and probably high temporal resolution. In addition, small-group selection is likely to be a recently adopted technique imposed on an already heterogeneous landscape; long complex conversion periods are required before regulation. This paper discusses some of the techniques that can be used to incorporate small-group selection into forest planning models in the context of tradeoffs between accuracy and simplicity. Possible modifications from even-age planning techniques that may be needed include (1) approaches to inventory, (2) projections of growth and yield, (3) tracking of individual units through space and time, and (4) classification of forest structure. Current knowledge limitations on how small-group selection affects wildlife, aesthetics, and growth may temper the need for complex modeling approaches.

## INTRODUCTION

Early in this century, Carl Schenck described small-group selection as cuts, from 0.4 - 1.2 ha in size, that could be "roundish, oval, square, etc. as the case may be, usually coinciding with a geological feature" (Schenck 1905). He noted disadvantages to the group selection method such as scattered operations and the need for an intricate system of permanent roads. For these and other reasons, small-group selection has never been used extensively in the United States. However, in recent years, there has been increasing interest in the method. The small openings of group selection are similar to small-scale disturbance by wind, insects or root disease (Tappeiner et al. 1997), leading some people to view small-group selection as a silvicultural system well suited to ecosystem management. In 1992, a strategy that would have greatly increased the use of small-group selection was considered for National Forests in the Sierra Nevada region (Fiske et al. 1992). If small-group selection becomes more prevalent, planners will need to anticipate issues involved in modifying forest planning models to incorporate this system.

Forest planning models are used to develop information about the consequences of different alternatives for forest management. Incorporating small-group selection into forest planning models poses some problems. First, less information is available on biological, ecological, and economic effects of small-group selection than is available for methods such as clearcutting Second, small-group selection has an inherently high degree of spatial and temporal resolution, leading to potentially greater complexity in planning models. In this paper, we discuss the respective merits of different approaches to planning for small-group selection, and use some 20 years of group selection at Blodgett Forest Research Station (Univ. of California - Berkeley) to illustrate the potential problems and opportunities.

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## CHOICES FOR MODEL RESOLUTION

Daniel et al. (1979) define a stand as a "reasonably homogenous unit that can be clearly differentiated from surrounding stands by its age, composition, structure, site quality, or geography". However, by convention, the term *stand* is applied to an area of group selection, rather than to the individual groups. Smith (1986) suggests that this convention arose before the advent of air photos, when mapping stands on the ground made it too time consuming to delineate very small areas.

In what Smith refers to as *balanced* uneven-age management, an equal proportion of a stand's area is in each age class; in his discussion of uneven-age management, the distinguishing characteristic between single-tree selection and small-group selection is that the area of an individual patch of same-age trees is larger under small-group selection (Smith 1986). With balanced uneven-age management, there is a continuum of management from single tree selection to even-age management that differs by the size of individual openings in the canopy cover. The boundaries defining group selection might be placed at opening sizes from 0.10 to 1.00 ha, with single tree selection being anything smaller and even-age management being anything larger.

If an uneven-age stand is balanced, then it can also be perceived as a small version of a regulated forest under even-age management. In this case equal productive areas are occupied by each age/size class ranging from 0 through R, where R is the rotation age or largest tree size class. As the site quality of a stand managed under small-group selection is presumed homogenous, harvest volumes in a regulated state would be the same under either volume control or area control. As with area regulation for even-age management, the percent of area harvested at each entry is equal to the rotation age divided by the time interval between entries. For example, using an 80 year rotation with a 10-year entry interval, an eighth of the stand's area would be put into small group cuts at each entry; for a 100 ha stand with a desired group size of 0.5 ha, 25 individual group cuts would be placed at each entry.

Hann and Bare (1979) recognized that linear programming (LP) models could model either even-age systems, uneven-age systems, or a mixture of systems with equal facility. Yet there can be some differences in the size of the model created. As an example, consider converting a homogenous forest area to either (1) single tree selection or (2) an even-age silvicultural system, where planning periods are 10 years and after regulation both systems have the oldest trees in an 80-year age class. Modeling the even-age system would require eight decision variables to represent each initial entry. With a 10 year cutting cycle, the single tree selection system would be represented with a single decision variable. In the representation of the even-age system, groups of trees of the same age are treated as individual variables, and in the representation of the uneven-age system, groups of trees of different ages are treated as individual variables. Modeling for uneven-age management can create significantly smaller LP models.

Modeling for small-group selection could conceivably use either approach. In typical planning models, modelers decide whether to work with individual stands or with stand-types. In planning for small-group selection, they must choose between four options for what is to be the highest level of spatial resolution:

1. groups
2. stands
3. group-types, or
4. stand-types.

Higher resolution will lead to larger planning models, so that the most compact model will be produced by using stand-types as the basic land unit. However, the level of resolution can affect accuracy of predictions. For a planning model used to predict economic outputs, timber volumes, and changes in vegetation structure, the predictions are dependent on inventory, initial land classification, projection of growth and yield, acres harvested by entry, assumed economic coefficients, and method of structure classification. To discuss each of these points, we use as an example 20 years of small-group selection at Blodgett Forest Research Station, located in the mixed conifer region of the Sierra Nevada.

## UNCERTAINTY OF PREDICTIONS

### Inventory

As small-group selection has not been widely used, it is likely to be imposed upon stands that have had a different past management regime. If no groups of different ages currently exist, it would take at least one rotation to convert the stand to a balanced state. In order to maintain the same level of accuracy, sampling intensity for forest inventory has to increase with increasing variation of the stand. Thus a sampling design suitable for the stand at the start of the conversion period may not be suitable for the same stand at the end of the conversion period.

The 1200 ha Blodgett Forest has a permanent inventory system with 0.04 ha plots located at 120 m. intervals throughout the forest. Less than 162 ha are currently managed with group selection. The permanent regularly spaced inventory system works well for the areas of the forest managed with single tree selection and even-age management, but is less suitable for small-group selection management, due to its gradual conversion to high spatial variability. Systematic sampling methods can be biased when applied to populations with periodic variation. Small-group selection is particularly prone to bias because of uniformity of size and spacing of the group cuts. Blodgett's permanent regularly spaced sampling system estimates inventory for the residual stand well, but may not capture changes from group cuts (Fig. 1). In this case, the sampling system is most suitable for low resolution modeling with stand-types, and least suitable for high resolution modeling which would be better served with stratified sampling.

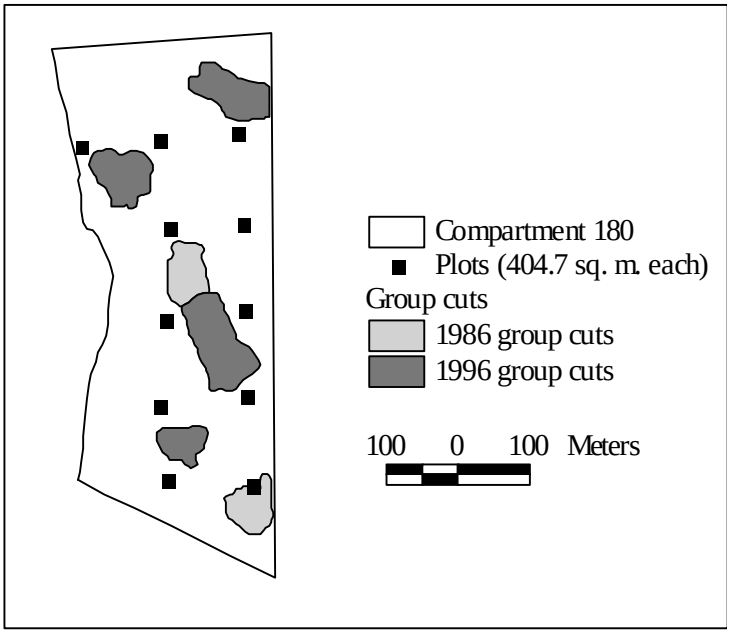


Figure 1. Inventory plots and two sets of group cuts for compartment 180 at Blodgett Forest Research Station

### Initial Classification

Typical methods of stand delineation (air photo interpretation or remote sensing with digital image classification) will often distinguish individual groups. When individual groups are distinguished, sophisticated programming could be needed to get a classification method to recognize a pattern of group cuts as a unique stand. Because a small-group selection stand consists of patches of differently sized trees, even classification by ground mapping or air photo interpretation will not be able to distinguish all edges.

Classification methods can cause problems if the groups are very small or variable in size. Depending on the shape of the group, classification of thirty meter resolution remote sensing imagery might consistently identify groups of 0.50 ha or more, but miss groups of 0.10 ha. Classification of remote sensing imagery may not differentiate between recent clearcuts and recent group cuts without using the size of the cut as an attribute for classification. As growth of regeneration is somewhat affected by the size of openings, the ability to differentiate land in clearcuts from land in group cuts can be important.

The classification problems are most likely to occur when managers have not kept track of past harvesting and have outdated inventory information. Because of the problem of edge delineation, and the inexact typing that can occur with vegetation classification, it would probably not be efficient to keep track of groups and group-selection stands with periodic vegetation classifications. Instead, for management efficiency, it would be desirable to spatially delineate groups soon after they are first harvested, using either a global positioning system (GPS), ground mapping, or air photo interpretation, and keep that information in a geographic information system (GIS) along with the date of harvest and a record of any treatments.

## Growth and Yield Projections

Growth and yield models used to project inventory and harvest volumes typically are either whole stand models or spatially independent single tree growth and yield simulators. Either type of projection assumes spatial homogeneity for the modeled stand. Growth and yield models are not designed to model the types of patchy stands produced with small-group selection. Using the permanent plot inventory system at Blodgett with an individual tree growth and yield simulator, growth projection could take any one of three approaches:

1. To simulate the growth of individual plots in the stand (or stand-type), and then average the results.
2. To average the plots in the stand (or stand-type) to create a “representative” plot, and then simulate its growth.
3. To stratify plots by the age of groups they represent, average the plots within each age class, and simulate the growth of the averaged plots.
4. To stratify small plots within groups by distance to edge, simulate growth of individual plots, average results by strata, and weight by the proportion of area within zone of edge distance.

None of these choices is very satisfactory. For any of these approaches, the growth and yield simulator would not correctly account for competitive interactions along the edge of group cuts. Of course, using individual tree growth and yield models to simulate the growth of stands (or stand-types) always ignores effects of edge. But the problem is compounded in modeling growth of trees in a group selection system, because of the high percentage of area within the zone of edge influence.

The size of group openings affects both species composition and growth rates of regeneration (Dale et al. 1995, McDonald and Abbott 1994). A study of 8 to 12 year old regeneration in group cuts at Blodgett Forest found the highest number of seedlings ( < 1 m tall) to be located within 5 to 10 m from the edge, perhaps because of favorable microclimate and increased seedfall (Olson and Helms 1996). However, sufficient taller trees at all distances from edge occurred to make this effect unimportant. Compared to even-age plantations, regeneration in the group cuts at Blodgett includes a higher proportion of shade tolerant Douglas-fir and white fir, and a smaller proportion of shade intolerant ponderosa pine. However, sufficient regeneration of each of the six major species allows pre-commercial thinning to achieve any desired species mix.

In the group cuts at Blodgett, planted 2-year old seedlings are used to accelerate regeneration growth, although natural regeneration would be sufficient to produce full stocking. Average height growth of regeneration in group cuts is less than in even-age plantations, with the greatest effects occurring within 1/3 of overstory tree height from the edge. However, at 15 years of age, the growth of the best 200 trees per acre in the group cuts exceeds the projections of Oliver and Powers (1978) for pine plantations (Table 1). Thus from a modeling point of view, early

pre-commercial thinning allows one to greatly reduce problems caused by using even-age growth estimates for young regeneration in group cuts.

**Table 1.—Height in meters of ponderosa pine regeneration in groups, yield tables, and plantations**

| Source of growth estimate | Height at 10 years | Height at 15 years |
|---|---|---|
| Groups[a] | 4.1 | 5.9[c] |
| Groups[1] - best 494 trees per ha | 6.6 | 8.2[c] |
| Oliver and Powell (1978) - 6 ft. spacing | 3.4 | 6.4 |
| Oliver and Powell (1978)- 12 ft. spacing | 4.0 | 7.0 |
| Plantation[b] | 6.2 | 11.9 |

[a] Each value averaged from 6 groups, 10-year and 15-year measurements from different stands

[b] 10-year and 15-year measurements from different stands

[c] Differed from 10-yr groups by not having pre-commercial thin at 6 years

Although not measured at Blodgett, the edge trees in the residual stand that surround a group cut are likely to benefit from the increased growing space. McDonald et al. (1996) found that ponderosa pine, sugar pine, Douglas-fir, incense-cedar and white fir surrounding 18 and 27 m diameter group cuts all experienced significantly increased basal area growth. It was concluded that individual growth of trees adjacent to openings was influenced by tree size, distance from opening, and position of other trees (McDonald et al. 1996).

The problem of adjusting growth projections for edge influence is compounded by changes in the nature of the edge over time. The first group cuts at Blodgett were surrounded by 60 to 80-year old forest. Group cuts that will take place near the end of the conversion period could have edges bordering either groups of 15 year old saplings or groups of 160 year old trees. The dynamic nature of edge interactions poses significant complexity if it is necessary to project growth of group selection stands with a very high degree of accuracy.

When there are no edge interactions, we have found that growth and yield simulators can be surprisingly accurate in projecting short term growth of managed 60-90 year old forest. Using the CACTOS individual tree growth and yield model (Wensel et al. 1986), a paired T-test of 79 remeasured tenth acre plots found that the projected annual volume growth was within 1.5% of measured growth (no significant difference at $\alpha$=.05). However, the CACTOS model is not designed for projecting stands beyond this age. Projection of small-group selection is complicated by the long conversion period needed to get to a regulated system. If the stand is already mature when group selection is first implemented, the last groups of trees to be harvested will be outside of the range that we can accurately estimate with current knowledge. A mitigating factor to this problem is that progressively less area will be occupied by such “beyond model data range” trees.

## Economics and Management

Harvesting costs are likely to be higher with small-group selection than with clearcutting (Schaffer et al. 1993, Kellogg et al. 1996). However, on tractor ground, increased logging costs with small-group selection may be minor compared to effects of stumpage price changes (Keegan et al 1995). All of Blodgett Forest is suitable for tractor ground; harvesting costs for small-group selection are typically more than harvesting costs for clearcuts ($70/Mbdft) and less than harvesting costs for individual tree selection ($85/Mbdft) or commercial thinning. Harvesting costs per unit volume, and damage to the residual stand, decrease when the diameter of the group opening is more than 1 overstory tree height. To minimize damage to the residual stand, a group diameter of at least 2 tree heights is preferred.

Other costs for managing small-group selection may also be higher than corresponding costs for even-age management. In some cases road system costs may be higher. At Blodgett, road costs are unrelated to silvicultural method, as the forest is covered by a permanent and well-maintained road system. Costs of planting, brush treatment, and pre-commercial thinning in group cuts at Blodgett are slightly higher than in clearcuts due to longer travel times, with travel cost increasing with crew size. In the past, a simple sketch of group location on stand maps has sufficed to prevent individual groups from becoming "lost". Periodic air photos also help ensure that all groups are accounted for and receive planned intermediate treatments. GPS units are currently being used to map group boundaries, with the resulting information becoming part of the forest's GIS database. Increased administration cost for tracking treatment of group cuts is minor. Within the past decade, average net revenue for logs delivered to the mill has more than doubled. Although there is uncertainty about the estimates of harvesting, treatment, and management costs for small-group selection, it is overwhelmed by the volatility of timber prices.

Inaccurate estimates of the size of group cuts may be a source of error in prediction of costs and revenues. The inability to estimate area harvested does not, intuitively, make a great deal of sense. A manager should be able to harvest exactly the proportion of the stand that is planned for harvest. Yet going back to Schenk's (1905) definition of group selection, it is apparent that part of the original appeal of group selection was the ability to place individual groups in particular locations. These locations may be chosen to reduce a less desired species, to remove a center of high mortality, to replace slower growing individuals, or to harvest small groups of trees with a higher economic value than the surrounding stand. If one of the desirable aspects of group-selection is the discretion given to the forester, than group cuts will vary in size, shape and location regardless of a modeling system that treats the problem as a standard conversion to a miniature regulated forest. Although the general intention at Blodgett is to use the equivalent of a 100 year rotation, past entries exemplify the variability that can occur (Table 2).

**Table 2.—Percent of compartment area harvested by entry**

| Comp. | Entry A | | Entry B | | Average over two entries |
|---|---|---|---|---|---|
| | Date | % of area | Date | % of area | % of area |
| 50 | 1985 | 7.4 | 1996 | 11.9 | 9.7 |
| 180 | 1986 | 3.7 | 1996 | 10.6 | 7.2 |
| 270 | 1985 | 6.3 | 1995 | 7.5 | 6.9 |
| 380 | 1985 | 14.8 | 1995 | 5.0 | 9.9 |

Part of the variability shown in Table 2 was deliberately chosen to compensate for patches of advanced regeneration that existed before the first set of groups cuts. If a stand is already "patchy" before implementation of the group system, managers can either account for this when they plan the location and size of group units (for example, see Heald and Haight 1979) or keep to an area-regulation approach by harvesting equal areas at each entry. The manager may also wish to deviate from an area-regulated group system if working with a mixed-species type. At Blodgett, only ponderosa pine and sugar pine need openings at the sizes of small-group selection in order to successfully regenerate and grow. Other species (Douglas-fir, white fir and incense cedar) regenerate successfully with single tree selection. Thus a manager might want to manage a stand with a mixture of larger openings (small group selection) for patches dominated by pines, and smaller openings (single tree selection) to regenerate shade tolerant species. With this mixed silviculture approach, planners can still choose to model either by groups or by stands, but will need to think through the problems of estimating growth and future forest structure.

## Classification of Forest Structure

As with initial land classification, inventory systems, and projection of growth and yield, the projection of future forest structure can be set at either the resolution of individual groups or at the resolution of group-selection stands.

California forest practice rules currently recommend the use of the California Wildlife Habitat Relationships (CWHR) system (Airola 1988) to help assess impacts of forest management on wildlife habitat. Unfortunately the classification system does not currently make a distinction between a multi-canopied stand that is spatially homogenous, and the spatially heterogeneous multi-canopied stand produced by small-group selection. Thus by this system, small-group selection stands would be classified as the same type as an equivalent single tree selection system.

One could consider a group selection stand to consist of an assemblage of habitat types corresponding to even-age management: i.e., set resolution of forest structure at individual groups. If the composition of future forest structure is evaluated within the linear programming model through the use of tracking rows, the model will not be able to distinguish between even-age management and small-group selection. As the size and pattern of forest harvest units can have important ecological consequences (Franklin and Forman 1987), this treatment will also be unsatisfactory.

One possible approach would appear to be to create a new set of classes of forest structure to account for the types produced by small-group selection. Yet although one of the benefits of group selection may be that it mimics fine scale natural disturbances (Tappeiner et al. 1997), there has been little research to assess the impacts of small-group selection on wildlife habitat or ecological processes. The problem of what level of resolution to use for classification of the forest structure produced by small-group selection is tempered by an inability to predict how the forest structure can be related to either wildlife populations or other ecological effects.

## CONCLUSION

The ideal resolution for small-group selection in a linear-programming based forest planning model will depend on the types of consequences that must be predicted, the degree of accuracy desired for those predictions, the inventory information available, the available methods for projection of growth and yield, and the time and personnel available for modeling. In general, setting model resolution at the level of individual groups will not be practicable given the increase of model size and the prohibitive cost of collecting information at this scale.

Growth and yield modeling will probably require modeling by individual group type, given the lack of spatially dependent models that could correctly account for edge effects. Some calibration or adjustment of outputs may be advisable, to decrease predicted growth of regeneration and increase predicted growth of older groups. If group types need to modeled individually by growth and yield models, outputs for group types would need to be combined if the linear programming model resolution was to be set at the level of stands or stand-types. Given the extra expense of this processing, it may be preferable to simply set LP model resolution at group types.

We believe that one of the desirable characteristics of the small-group selection system is the latitude practitioners of silviculture have to make fine-scale decisions about the placement and size of harvest units. Thus, for small ownerships, there is some conflict between the need to allow for flexibility and the need to predict accurately. Uncertainty is undesirable for planning, but the flexibility that generates uncertainty is a desirable trait of the small-group selection silvicultural system. Viewing the conversion of forest to a small-group selection system as conversion to a “balanced” stand is conceptually useful, but likely to be inaccurate for small areas.

We have included the small-group selection units into Blodgett’s planning model, using group-types as the basis for growth and yield modeling, and stands as the resolution in the LP model. Modeling small-group selection was more time consuming and more difficult than modeling the other silvicultural systems. It was also less accurate in prediction of growth, harvest, and future forest structure type. Yet the difficulty of planning and administration for small-group selection is a minor consideration compared to other factors that influence the selection of the appropriate silvicultural system.

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