Implementation and Interpretation of Management Recommendations for the Northern Goshawk

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Introduction

This document presents our best current understanding and approach in implementing the Kaibab NF Land and Resource Management Plan (Plan) as amended in 1996 to address the Management Recommendations for the Northern Goshawk in the Southwestern United States (MRNG) (Reynolds et al. 1992.) In the early 1990s, a group of professionals within the Kaibab National Forest (and to a lesser degree from outside of the Forest) studied the MRNG and provided interpretations based on the "intent" and sound biological concepts. The Plan was amended in 1996 to reflect this intent. The ideas presented here simply represent an attempt to provide for consistent implementation of the Plan across the Forest and from one project to the next.

Appendix A contains some concepts, ideas, and unique characteristics of the MRNG and how they are reflected in the Plan. These are the basis for the management approach discussion that follows. However, please recognize this not meant to be a total interpretation of all the recommendations, nor does it provide any required direction.

Appendix B describes the principles behind the arrangement and tree densities in the Plan standards and guidelines and presents one way to comply with them.

Management Approach and Discussion

Described herein is an approach for attaining the Desired Conditions (DCs) outlined in the Plan as standards or guidelines. To determine need for treatment, it is important to be able to describe existing conditions so they may be compared to DCs. In the past this has been done through an interpretation of the stand data that derived a vegetative structural stage (VSS) for the entire stand. This was mostly adequate when the Plan DCs were for a forest of even-aged stands of different densities and ages less than 120 years across the landscape, with some old growth blocks set aside for older trees. The 1996 Plan amendment changed the DCs in goshawk habitats in some fundamental ways, consistent with recommendations in the MRNG. Table 6 (pg 17) in the MRNG describes interspersion of VSSs, large trees, and an herb/shrub understory, as the most important habitat attributes for most goshawk prey species. Management on a group basis (½ to 4 acres), featuring within stand structural diversity that would greatly increase interspersion compared

to even-aged management.[1] This poses a problem of evaluating the existing conditions down to ½-acre groups. Maps displaying stand averages (VSSs) are useful[2]; however, they reveal little about the treatment needs of the individual groups, but mapping the spatial distribution of group VSSs would be cost-prohibitive.

One approach is to determine VSS for each sample point. VSSs can be calculated meaningfully when there are enough points.[3] Generally a large area (a PFA, FA or "audit unit") will be reliably represented; however, there are not enough points at the stand level to be confident of predictions.[4] An evaluation of differences between existing and desired VSS proportions and densities could then be carried out to determine a need for change.

It may also suffice to simply note needs for particular areas during field reconnaissance, based upon the differences between Plan DCs and existing conditions.

A useful end product of whatever process is used would be an estimate of the percent of each VSS (at the group scale) for the assessment area and an indication of the departure from Plan DCs. As discussed in Appendix A (#7), the VSSs most important to species diversity and numbers are the two ends of the spectrum (VSS 1-2 and VSS 5+). This approach would yield estimates of the amount of each VSS and whether we are deficit in VSS 1-2, VSS 5+, or both.

For ponderosa pine, the Plan generally supports treatments that aim to maintain and enhance within-stand diversity on a group basis (1/2 to 4 acres) by using group selection and thinning of groups to create essentially even-aged groups with a "rotation" (200+ years) for each group of trees. For areas of one acre or more that are regenerated, reserve trees (3-5 per acre in pine) are to be retained. Reserve trees may effectively "escape" from the rotation, continuing to grow and become as old as physiology and natural disturbances permit.

One systematic approach to identify the need for change is to determine if there are shortages for the groups of VSS 1/2 and/or for the groups of VSS 5/6. Based on this analysis, the acres to be regenerated are estimated. If the groups of VSS 5s and 6s compose less than 40% of the area evaluated, then all groups of 5s and 6s perhaps should be maintained in that state. (An exception could be for treatment of dwarf mistletoe, but groups dominated by large trees – and even individual large trees - become increasingly important as their prevalence decreases). This does *not* imply that no groups of VSS 5or 6, or individual large trees should be cut. All VSS 5s and 6s over existing smaller trees that could be managed as groups of VSS 2 through VSS 4 might be removed (except for the reserve trees) to release these groups but this would be uncommon when there are relatively few acres occupied by VSS 5s and 6s.

The identification of "groups" is a fairly subjective task. A clump within a stand where the individual trees are closer together than the individual trees around them is easily spotted. These are subgroups or variations within a group and

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[1] In the Plan, these DCs are captured on pages 27 (uneven-aged stand conditions dominated by large, old trees), 29 (range and proportion of VSS), and 43 (group selection and group size range.)

[2] Regional and national protocols for processing field-sampled vegetation no longer calculate VSS for uneven-aged stands because of the low utility and misleading information the calculation would convey for these stands.

[3] Stand exams are usually designed to obtain an SE% of 20% (67% confidence) for trees per acre at the stand scale. Subdividing the tree profile into six classes raises the SE% considerably for trees per acre in each of the tree classes. Further, presence of trees in a particular diameter class does not make the corresponding VSS necessarily present. Nonetheless, trees are arranged in a groupy pattern and a large number of plots are more likely to represent the true distribution of VSS than stand averages.

[4] Audit units were developed by North Kaibab RD biologists to assign areas outside of PFAs to specific goshawk territories before the Plan was amended in 1996. Since the MRNG recommends assigning 5400 acres of FA to each goshawk PFA and the density of PFAs on the district precludes this, Theissen polygons were set up to assign the actual available FA to each PFA. Conditions within each of these polygons are "audited" for existing conditions in planning treatment needs. The amended Plan does not identify FAs; instead it provides guidance for habitats outside of PFAs. Audit units may still be useful in delineating portions of these areas to describe departure from Plan DCs.

are particularly important to recognize with VSS 4+.[5] Residual basal areas within groups are described in tables in Appendix B for both the PFA and the FA by cover type. These are based on desirable occupancies measured by SDI, but derive from and meet the guidelines for canopy closure in the Plan. On way to greatly increase diversity within groups of VSS 4+ is to manage for tree clumps with open interspaces. These open interspaces allow room for developing root systems necessary to grow and maintain medium-sized to very large trees with canopy interlock within the clumps. To retain this clumpiness within groups over time, it is important to thin by focusing cutting or leaving individual clumps rather than seeking optimal spacing for individual trees. "Focus" does not mean exclusion of good sense, however. Intermediate and suppressed trees within a clump often contribute little to canopy cover; thinning these trees will leave the dominant and co-dominant trees with space to increase their canopy volume and rate of diameter growth. Further the MRNG specifically refers to "thinning from below" and favoring larger, thriftier trees (Figure 10, pg. 23).

One way to gain an understanding of this concept is to observe the stocking of a group of large and old ponderosa pines first hand in the forest. Most people may not recognize the group as one group but as a number of smaller (closed canopied) clumps. Inspecting the interspaces between these clumps will generally show little regeneration of robust trees and little herbaceous growth because these interspaces are fully occupied by the root systems of the clumps. The size of the individual stems is directly proportional to the amount of available growing space. Since the DC includes groups of 24"+ trees across 20 percent of the area, then groups of VSS 1-3 must be quite open: moisture-limited Southwestern ecosystems are unlikely to ever produce groups of 24"+ trees with a continuous closed canopy when they are young. If there is doubt about what is required to grow large tree groups in their likely lifetimes, modeling may help (See Appendix 5 in the MRNG.) The growth and yield model in the Forest Vegetation Simulator for the Southwest is based upon research with a high coefficient of determination for diameter growth (98% in ten years).

Clumps and groups with a nearly closed canopy can and often do exist adjacent to what appear to be openings because their root mass can gather more moisture and nutrients in that circumstance. It is important to distinguish these interspaces from areas available for robust regeneration (VSS 1). In fact, frequent disturbance with mechanical thinning or fire will have to occur to maintain these areas as openings. A high degree of clumpiness is beneficial, as well.

A rough example of this is in the Pearson Natural Area, Fort Valley Experimental Forest. There, groups of large ponderosa pine exist without regeneration directly under the group. But dense young trees exist all around the groups well beyond their drip-line, pressing ever closer as each individual large tree dies. The interspaces needed by these large trees are being lost to an encroachment of the regeneration and a higher rate of mortality is being induced due to the competition. Traditionally we would have removed the overstory to release the poles, but the DC described in the Plan is to create or maintain 40% of the area dominated by groups of VSS 5s and 6s. So, in this case, we may instead remove the poles away from the mature trees.

There may generally be four types of mechanical treatments (applied to groups) prescribed to progress toward the DCs: thinning, release, tending, and regeneration. At the DC, stands will consist of even-aged groups and there will be less need for release.

- Situations occur where *releases* (removal of some larger, older trees from over younger trees) may be desirable; particularly where they are covered by groups of large trees is not deficit in the landscape.
- Existing groups of VSS 2 through 4 may receive the needed management either through a *thinning from below* (removing smaller-diameter trees from groups) or a release (leaving the reserve trees, if needed).
- *Tending* (either pushing back competing regeneration or by cutting out suppressed trees from within the group)

[5] Clumps have no meaning in the Plan in relation to goshawk habitat standards or guidelines, except in nest areas. Patches have no meaning in the Plan for any goshawk standard or guideline. Both terms are used here simply to help describe a possible management approach to implement the Plan. For purposes of this paper, "clumps" range in size from two adjacent trees to perhaps 1/4 -acre of trees, while "groups" are made up of clumps of similarly-sized dominant trees up to two acres. "Patches" are made up of groups of similarly-sized trees from two to several acres.

may be desirable for existing clumps and groups of VSS 5 and 6). Suppressed trees are generally few in number and are those that are deformed and are not very suitable for snags. Once again, if the VSS 5B+ presence is less than 40%, great care about the amount of release prescribed for existing regeneration should be taken: is the highest value to release a potential VSS 2 group or is it to push back or remove the smaller trees from a VSS 5 group? It is important for markers to identify where each group is during implementation: It is very easy to release a clump (less than ½ acre) of regeneration within a VSS 5 group when perhaps the regeneration should be removed to maintain the VSS 5.

- Assuring adequate areas in *regeneration* ([creation of] openings that produce luxuriant understory vegetation and tree seedlings) exist is important to maintain a DC that is sustainable over time in forest that is suitable for timber production. Perhaps 8%-10% of the area in groups on a 20 year entry may be needed. To select areas for regeneration, the first priority may be to assure regeneration in existing openings. This may simply require site preparation or some expansion of the opening to create favorable regeneration conditions. The second priority may be where there is needed treatment for dwarf mistletoe. The Plan provides guidance for controlling (not eliminating) dwarf mistletoe in GAs 2, 10 and 13 on page 43, including even-aged regeneration methods.[6] If after taking care of these two priorities regeneration is still needed, then locations may be chosen based on creating a relatively even distribution across an area. At this time and particularly on the south Kaibab RDs, groups of VSS 5+ usually do not have to be cut to provide for regeneration, because other VSS are usually in "surplus". When there is a deficit of VSS 5+, regeneration can be encouraged adjacent to an existing group of VSS 5+, perhaps in VSS 3 or 4. The key is that an adequate number of acres are regenerated regularly to move the forest toward a balanced age-class distribution.

The 1996 Plan Amendment removed minimum thresholds for hiding or thermal cover in timbered areas and the need for thermal cover for both elk and deer has been called into question by research. (Duncan 2000, Freddy 1986). These habitat components are still considered to be important by many biologists however, and they are provided for by the very nature of the Plan DCs for goshawk habitats. With irregular spacing and the maintenance of groupiness, thermal cover is likely to be present in dense tree groups covering 60% of each stand. Hiding cover may need more site-specific attention. Growing seedlings and saplings in open conditions will help maintain full, live crowns. In many cases thinning may occur too late and the crowns will have already risen, losing the characteristic needed for effective hiding cover. In addition to the use of coniferous species, hiding cover can be supplied by other species such as aspen and oak and can be supplemented by broken topography and control of road access. Open conditions in groups of VSS 1 and 2 will encourage the development of larger shrubs than are often currently present in capable sites. The amount and location of hiding cover that should be maintained may be determined during project analysis.

Traditionally, thinning has been implemented seeking even tree spacing, reducing or removing clumpiness from stands. To retain or recreate the clumpiness suggested by the MRNG and other scientific sources, it may be necessary to manage for greater variation at very small scales. Applying irregular spacing when the trees groups are approximately 8" dbh or larger could be effective. Prior to this, most trees may be evenly spaced, but consider retaining some two- or three-tree clumps with only a few feet of spacing; these may grow into large-tree clumps with boles leaning away from each other – a structure evident in historic ponderosa pine forests. For trees groups less than 8" dbh, one approach that is being tried is to thin from below with an upper diameter limit. This favors the dominant trees and the clumpiness that is inherent in a natural stand. Another approach is to thin from below selecting individual stems until a desired BA is reached. Still another approach is to select the "dominants" and "co-dominants" for leave trees. Application of fire may be effective in many cases. This is very site specific and prescriptions must be applied on a specific basis using the existing condition. Some areas won't need thinning at this time; others may be retained for hiding cover. But, it is important to consider all areas within a project and do what is needed to progress toward DCs.

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[6] In some cases, the shortest time to desired uneven-aged stands dominated by large, old trees may be through regenerative activities that create even-aged stands in the short run, but allow for eventual development of tree groups healthy enough to develop into VSS 6.

The structure of VSS 4 groups is critical to achieve and maintain the DCs - essential for mycorrhizal development and for squirrel nesting cover. The management approach here is to grow trees with robust live crowns that will close up their canopies in clumps within groups as they grow into VSS 4. Typical groups of VSS 4 in an FA would have an average residual BA in the low 60s (ft^2-ac^{-1}), however, they would contain clumps that will maintain a closed canopy with a much higher stocking, such that average canopy cover across each group meets Plan guidelines. Space between the clumps would be open, maintaining most of the live crown on the outside of the clump. Using basal area as a guide to marking is difficult because of the variation being created and the small size of the clump. Markers can key on clumps and use BA for the trees that are around the clumps. The number of clumps may be based on a spacing interval of approximately twice the diameter of the clump. These clumps can occur in roundish groups or in stringers determined by the conditions found at the site.

Stocking within the clumps may be controlled by simply spacing individual trees averaging 10 to 12 feet apart (with some nearly touching and others much farther apart) or by removing only suppressed and intermediate stems. Clumps of approximately 7 to 10 large trees found on the Fort Valley Experimental Forest that have never been thinned have a spacing of around 20 to 25 feet with lots of variation. An additional thinning at the VSS of 5 will approximate this condition at VSS 6.

There are several habitat concerns that should require less specific management emphasis now with the desired conditions captured in the Plan standards or guidelines for goshawk and Mexican spotted owl habitats than they did in the pre-1996 Plan. That plan emphasized resource outputs, even-aged management, with 120-year rotations and evenly-spaced residual trees. Inherently, characteristics of the current approach tend to provide for:

- interspersion of VSS;
- cover;
- interior dwelling species;
- old growth;
- migration corridors;
- snag recruitment;
- wildlife trees; and,
- visual quality objectives.

Previous Plan adjacency requirements assured that treatments would not essentially enlarge stands and reduce diversity. Under the current Plan, derived from the MRNG recommendations the DC is to obtain within stand diversity by managing on a group basis.

A common habitat concern that is often raised in the context of old growth is for “interior dwelling species”. Interior dwelling species require large areas of closed canopy forests. An example would be the temperate rain forests of the Northwest where fire occurred infrequently. In the Southwest most forests evolved with frequent, low-intensity fire seldom, if ever, occurred with a dense canopy across large areas. Although they cover small areas of the Region, the exceptions of spruce-fir and the higher elevation mixed conifer forests should be noted. Frequent-fire adapted forests are more open with clumps or groups of trees in a closed canopy state. No native wildlife species should require closed canopy conditions except perhaps in upper-elevation mixed conifer and spruce-fir. The management indicator species for old growth on the Kaibab is the northern goshawk. The current Plan standards and guideline that this management approach follows were specifically developed for the goshawk and its prey species.

The traditional view of old growth as a continuous closed canopied forest of large old trees simply is not sustainable in the Southwest where most forests evolved with frequent fires. Old growth standards and guidelines in the Plan and as presented here would seek to maintain a “flow” of large old trees across the landscape both spatially and temporally. They seek to mimic (but do not replicate) forest conditions that occurred prior to European settlement where large old

trees occurred in clumps/groups across a landscape of open forest. The Plan requires a minimum of 20% of the landscape to be allocated to old growth as depicted in a table of old growth habitat characteristics, although the guidelines suggest 40% of the landscape be in groups of large trees (plurality of basal area in tree groups with 18"+ dbh). These groups of large trees may meet the needs for all "old growth dependent" wildlife species, providing old growth on 40% of the landscape.

"Migration corridors" are commonly considered in landscape analyses for several wildlife species. In order for wildlife species to occupy a landscape they must have the habitat components that enable them to move across the landscape. Since some species cannot move across large openings these could "fragment" the habitat, limiting movement. The Plan standards and guidelines for uneven aged management limit fragmentation by managing for diversity on a very small scale - managing openings and groups of trees with all components represented regularly across each landscape unit. Therefore, at the DC, there is little need for specific vegetative management for "migration corridors". The presence and frequent mechanized use of open roads or cross-country travel could be much more important to fragmentation for many wildlife species.

The Plan includes some DCs about flows of habitat components (such as snags) across the landscape both spatially and temporally. It may be that most of the functions that snags currently provide were present in green trees with defect prior to fire suppression and systematic cutting of trees with "defect". (Ganey 1999)For snag habitat retaining trees with defects likely to become cavities, such as green trees with spiked tops, lightning scars, large cat-faces, and other, similar attributes that may provide habitat for cavity nesting species across the landscape may help meet this DC. In addition, reserve trees (i.e., 3-5 large trees in ponderosa pine) retained during group-selection regeneration treatments of one acre or more, supplementing the 40% of the landscape that would be fully stocked by large trees in groups may provide snag habitat as trees in these areas die. So not only are snags retained, but their recruitment may be assured across the landscape.

In the pre-1996 Plan, visual quality objectives often were difficult to reconcile with even-aged timber management, especially in "retention" areas in the foreground. However, the Plan emphasis now on interspersion of small groups (and openings) with lots of variety at human scales across the landscape, matches the desired stand structures in the Plan with "Retention" visual quality objectives.

APPENDIX A

A guideline on page 28 of the Plan refers to the MRNG for “for scientific information on goshawk ecology and management which provide the basis for the management guidelines.” This appendix is an attempt to encapsulate some of the key concepts from the MRNG. There are also a few practical suggestions on how implementation of the Plan standards or guidelines that derive from the MRNG may be attained (management approaches).

1. The standards and guidelines developed from the MRNG are applied to all our forested ecosystems except where Mexican spotted owl habitat requirements or site-specific species requirements take precedence. There are basically three types of management areas: Nest stands/replacement nest stands, post-fledging family areas and foraging areas.
2. The recommendations imply rather frequent disturbances controlling tree density and structure should be applied, based on the potential of the site, as a management strategy throughout the ecosystem (including areas outside of the suitable timber base).
3. The intent is to maintain a flow of large old trees across the landscape both spatially and temporally. “Large” is not completely defined but will depend on the site. Most pine sites are capable of growing trees over 24” dbh in less than 200 years at the stocking levels shown in Appendix B charts.
4. In order to maintain the area and density of large old trees the forest will become "regulated" (i.e., vegetation manipulation will be necessary to ensure enough acres of each age class are present at all times to maintain the oldest age class).
5. The primary reason for regeneration is to replace large old trees over time. Regulation will be accomplished through the regular recruitment of seedlings over time with each entry. Planned entries within an assessment area for timber harvest should be at 20 year or greater intervals. Fire disturbances may be more frequent. This includes all treatments. Exceptions would be for small-scale operations to catch latent infections of dwarf mistletoe, burning, planting, etc.
6. Any reduction (i.e., does not regenerate, maintain overstocked stands, etc.) in growth will reduce the amount (acreage) of large old trees that will be possible.
7. The structural stages with the greatest importance for prey habitat are: the early stages (1 & 2) where an herbaceous and/or shrub layer and hiding cover are present; and, the later structural stages (4+). VSS 3 has little direct biological importance and is necessary primarily as an intermediate stage as VSS 2s grow to 4s. The time that a given area is in VSS 3 may be minimized by maintaining the maximum growth rates.
8. Deep live crowns are important for hiding cover, diversity, cone production, and tree vigor. The maintenance of robust live crowns is essential for attaining and maintaining the DC.
9. It is important to have a robust herbaceous-shrub layer present; this layer provides most of the plant diversity in PP forests, at least.
10. Interlocking crowns are important in the older age groups (VSS 4s and larger).
11. It will be necessary to have open grown trees from seedlings to the middle of the VSS 3 class (8" DBH) to develop an herbaceous-shrub layer and live interlocking crowns in the VSS 4 class. How thinning is carried out in the VSS 3s is critical to the eventual development of interlocking crowns in the older age classes. Irregular spacing of trees beginning with mid-VSS 3 is critical to developing groups with interlocking crowns in the VSS 4+ classes.
12. To further develop the size desired for the VSS 6s, trees in VSS 4/5 groups will have to be thinned. Thinning may be on a clump basis (having fewer clumps), maintaining the interlocking crown condition in the remaining clumps within the group.
13. Stand Density Index (SDI), a relative measure of stocking, can be used to understand regulation of tree densities. It is assumed that there is a reasonable correlation between given SDI values and canopy density by species at the group level. Maximum SDI is independent of site (soils) where light is limiting. It is assumed in the southwest where

moisture is limiting that SDI may not be completely independent.

14. It is the intent of the recommendations to achieve and maintain healthy forest conditions, that include insects and diseases at endemic levels. Insect and disease outbreaks may be addresses based on current forest conditions and the shortest pathways to DCs. For example, treatments may depart from the described recommendations to deal with high infection levels of dwarf mistletoe.

15. Hiding cover will be provided by growing seedlings and saplings in an open grown condition (full live crown development) and letting the crowns grow together in late VSS 3s, development of hardwoods and shrub species, along with other practices such as road closures, which can relieve some of the need for (security) cover.

16. Thermal cover will be provided with the interlocking crowns in tree groups in VSS 4+ in coniferous forest and in groups of other tree species, such as aspen and oak.

17. Group sizes are defined in the recommendations from 1/2 to 2 acres. The exception to this would be for mistletoe treatment which may emphasize a larger group or may require an even-aged stand prescription. Openings of 2 to 4 acres are consistent with the MRNG but have been considered an even-aged treatment, by definition.

18. Regulation may be attempted at the stand level based on the existing condition at the assessment level (i.e., the DC will be to have a balanced age class distribution at the stand level; however, consideration of various surpluses or deficits of VSS classes across the assessment area may need to be taken into account.) Due to the high variation we seek to create in each stand it will only be practical to analytically monitor progress toward DC at the landscape scale (about 10,000 acres). We can subjectively monitor progress at smaller scales.

19. At the DC, forty percent of the area would be fully stocked with VSS 5 and 6 groups having canopy cover of 40%+ (>= 35% SDI max). The remainder of the area (60%) would be occupied with VSS 1 - 4 with a residual overstory of 3 to 5 trees per acre (in a clumpy fashion) of trees >= 18” dbh.

20. Skid trails may not be classified as "permanent" but the locations should be permanent. Consider integrating skid trail layout into group boundary definition. If skid trails follow/define group boundaries, costs of control lines for prescribed burns could be reduced over the alternative and problems with felling or skidding large trees through seedlings and sapling groups can be minimized. In any case, skid trails may be planned as part of the permanent transportation system to avoid proliferation of soil compaction over time.

APPENDIX B

This appendix illuminates some concepts of silviculture and stand development that lead to the construction of the charts at the end. The charts represent a management approach that provides some measures of tree densities by size class at the group and stand (or larger) scale that should meet the applicable standards and guidelines in the Plan. Other approaches may also fully address the Plan direction. Nothing herein is intended to amend or provide additional Plan-level direction in project development.

The Problem

The Plan and many science sources identify "extremes" of vegetative composition or structure as being important to various forest-dwelling wildlife species. These include very dense and very open tree conditions as well as regeneration and old growth areas. Functions identified include understory productivity, thermal cover, foraging habitat (on the forest floor as well as in tree canopies), hiding cover, large snags and regeneration of trees. To provide high biodiversity, a wide range of vegetative composition and structure must be present at scales appropriate to the needs of plants, animals and fungi. How can this composition and structure desired in the Plan be provided?

The Approach

The Plan guides management of mid-aged and old-aged groups of trees toward canopy cover percent (CC%) minimums of 40 to 70, depending upon forest type and intended habitat. This is based upon science provided in the MRNG and other sources about intended functions. Functions include providing site amelioration, protection for fledglings and squirrel foraging habitat. Unfortunately, most of our data has not been collected in a way which allows us to directly measure CC%. There are several measures of relative stand density which can make a fairly good estimate of CC% and we have appropriate data available. In the early 1990s, the Kaibab NF collected canopy density (CD) with a densiometer at plot centers along with our usual stand examination data on approximately 4000 points. We have drawn a correlation between CD and Reineke's stand density index (SDI) from these points.[7]

There can be lot of variance between these two measures of density for a couple of reasons:

a) The size of the plot measured with stand exams (fixed and variable plot) and the densiometer (vertically projected cone) are not the same;

b) Interpretation of stand exam data using SDI can give an estimate of the occupancy of the site relative to its biologic potential for the species in question. It is not clear what biologic parameter, if any, is being measured with the densiometer.

Nonetheless, this is the data we have available to work with and some reasonable conclusions consistent with SDI thresholds have been drawn from the data.

Considering "Openings" in a Forest

Several studies have been done in northern Arizona and elsewhere correlating absolute tree density measures (such as basal area) with understory or forage production. We wished to develop a correlation with SDI because of its relatively high inverse correlation with understory production. A study (Deiter, 1989) on the North Kaibab Ranger District indicates relative measures of density (such as SDI) have better correlations to understory production than absolute measures, including CD as measured with a densiometer.

For "openings", it seems reasonable to assume a site should be unoccupied by trees at least to the extent it is available

[7] A study by Edminster (1987) sets an average maximum density for ponderosa pine sites of 407. However, this maximum was calculated differently than done by Reineke (1933) and others. Edminster plotted an average maximum density line through the top 2 percent of observations from Regions 2 and 3. Others plot an SDI maximum line which includes virtually all observations rather than just the top 99%. Indeed, the densest site in Edminster's data set is 492; any difference between the two methods may have nothing to do with the "actual" SDI maximum.

to produce 1/3 to 1/2 of its potential in understory. (On fescue sites, this would obviously be much higher absolute production than on a blue gramma site but the amount of the each site's potential going into forage production should be about the same.) This is consistent with a view that "openings" should fulfill that function rather than just have an absence of tree canopy. Eg. cinder pits, rock piles and gaps between tree groups are open but are not openings if they do not produce understory species in amounts comparable to what a productive local site would be capable of. By thinking of openings in this way, rather than as just an absence of a certain CD, their intended function in the MRNG at least becomes clearer.

Pearson (1964) studied forage production on sites near Fort Valley that were quite similar to those at Taylor Woods in 1967. Since he correlated forage with basal area but not with dbh or trees per acre, some reasonable assumptions need to be made about these to correlate SDI with understory production.

With Pearson predicting about 490#/ac of forage in an un-timbered (but capable of growing trees) site, we felt 200#/ac would be a good break between an "open" and a "closing" condition for this site. Using the Taylor Woods data for 1967 (Ronco, et.al, 1985) to derive SDI by basal area, a connection was made to understory production by SDI. A basal area of 40 correlates with about 200#/ac of understory production. Basal area 40 plots in the Taylor Woods data had an average dbh of 6.8" and 159 trees per acre in 1967. SDI for 200#/ac is therefore calculated as 86 or 19.1% of SDI Max. For simplicity sake, the "open/closing" threshold is set at SDI 90, or 20% of SDI Max.

This seems consistent with SDI theory since trees are thought to begin competing for space (and crowns begin to lift even in young trees) by about 25% of SDI Max. (Jack and Long 1996)

Considering "Closed" Forest

In theory, a site is fully occupied at or above 35% of the maximum SDI for a species. Adding another tree to the site results in a corresponding and proportional loss of growth from the rest of the trees on the site. Foliar biomass is also near its maximum at this point. Adding another tree to the site results in a corresponding and proportional loss of live crown from the rest of the trees on the site, although horizontal canopy cover may continue to increase. Since the Plan guidelines aim for 40 percent of the landscape to be composed of large or very large tree groups, while also seeking to have canopy densities in the medium to large trees of at least 40-70 percent, it is reasonable to manage these groups near an SDI of 35%.

For ponderosa pine sites, we found a CD of 60 corresponded with an SDI of about 158, which is close to 35% of the maximum SDI of 450 for ponderosa pine. This indicates it is probably unreasonable to expect canopy densities much higher than 60% over the extent of any group of large ponderosa pine, when the area occupied by its roots is included. This may be considered "closed" forest conditions in the dry forest environments on the Kaibab.

Point and stand VSS

A stand VSS can be calculated from stand exam information, but it has little utility in uneven-aged management because it reveals very little about differences between existing and Plan desired conditions. Inventorying individual groups of trees for VSS systematically would be a cost-prohibitive exercise and isn't necessary to make reasonable estimates of the differences between existing and Plan desired conditions.

Routines have been developed to calculate the VSS for each point in field-sampled stand exams. These can provide an approximation of the area and tree density for each VSS on a group basis for a stand or larger area. Because of the variance typically associated with stand exams, there is likely to be high standard errors for each stand. Further, points frequently will not just sample one group of trees because both groups and sample points are effectively randomly located. So, evaluating larger areas, such as each PFA will yield more reliable estimates of VSS distribution at the group scale.

Stand VSS at desired Plan conditions may usually calculate as VSS 6 with a range of densities from A-C, depending upon whether it is habitat outside of PFAs, with PFAs or nest areas within PFAs.

Density Management

There are two basic tools we have in density management to meet objectives, be they primarily for certain types of wildlife habitat, fiber production economics or visual quality. They are:

a. Size-density relationships (and indices derived from them, such as SDI; and

b. Growth-growing stock relationships.

Size-density relationships using SDI

SDI "has the potential of being a most useful tool when intensive stand management requires a refined method for regulating stand density to fit prescribed goals." (Daniel, et al. 1979. pg.262)

The principle of SDI comes from a discovery by Reineke that a single-species, fully stocked (self-thinning), even-aged stand of a given average stand diameter (Dq) has about the same number of trees per acre (tpa) as any other stand with the same four conditions. Reineke found this relationship to be independent of site quality or age over a wide range.
By observing several stands that were self-thinning (e.g. growing at their maximum biological density) across a range of average stand diameters, a curve of maximum number of tpa by diameter class was obtained for a given species. When plotted on log-log paper, this curve becomes a straight line.

After plotting maximum lines for several species, Reineke found most of these lines had the same slope, although the y-intercept was different for most species. (See Figure 1.) Since these maximum lines have the same slope (-1.605 for a plot of tpa over Dq), their location on a graph can be defined by the location of only one point on the graph. In a plot of tpa over Dq, this defining point is where the maximum line is intercepted by a projection from 10" average stand diameter (Point B).

A projection to the tpa axis from the point where the previous two lines meet is the maximum number of tpa any single species, even-aged, fully stocked site is biologically capable of growing for the species in question when the Dq is 10" dbh.

A line plotted through this maximum number of tpa where Dq is 10" dbh (Line segment A-C) is the reference curve for the species. Lines parallel to this line can be plotted which represent the same level of site occupancy all along the line (Line segments D-E, F-G and H-I) and thus can be converted into an equivalent density where Dq is 10". Thus Reineke's SDI is the number of trees per acre at a Dq of 10" (Daniel et al. 1979.)

While SDI was developed from even-aged conditions, there is some empirical evidence it applies to other stand structures as well. Deiter (1989) found SDI to have highest high correlation to understory production on the North Kaibab RD. It seems to be quite useful in describing stocking conditions for even-aged groups in uneven-aged stands also, which Plan guidelines suggest. Also, other papers have been published suggesting the use of SDI for density control in uneven-aged management. (Long & Daniel, 1990; Cochran, 1992; Long & Smith, 2000; Lileholm et al. 2006)

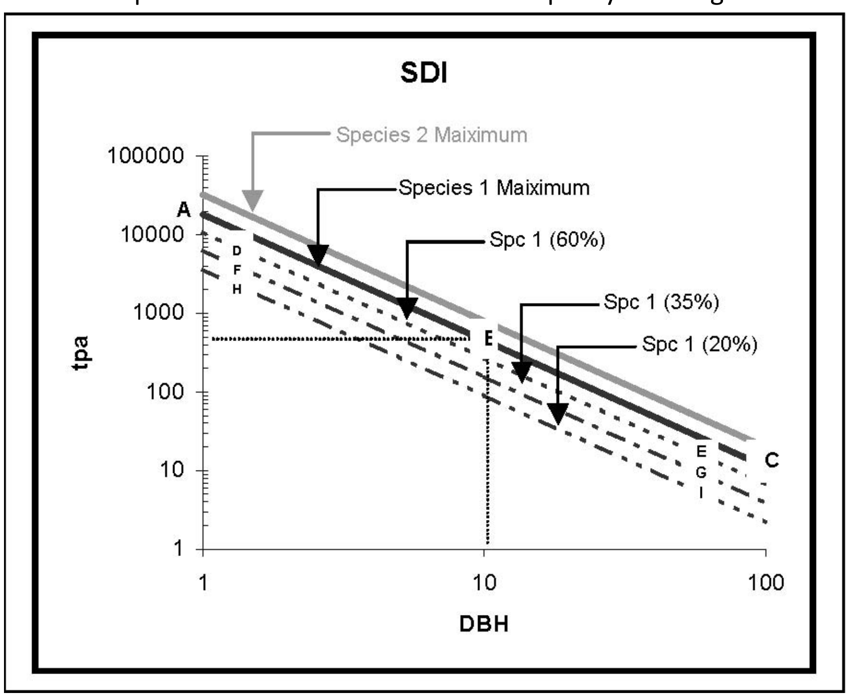

Figure 1 – Conceptual diagram of stand density index.

Several formulas are useful in understanding how SDI relates to frequently used measures of absolute density:

for a group or stand:

$$SDI = (Dq/10)^{1.605} * tpa$$

$$Dq = \sqrt{BA / (tpa * 0.005454)}$$

or

$$tpa = BA / (Dq^2 * 0.005454)$$

for an individual tree:

$$tpa = BAF / (dbh^2 * 0.005454)$$

Where:

Dq = quadratic mean diameter

dbh = tree diameter at breast height

BAF = basal area factor for the sample

tpa = trees per acre

Growth-growing stock relationships

Langsaeter's hypothesis (1941) states, "The total production of cubic volume by a stand of given age and composition on a given site is, for all practical purposes, constant and optimum for a wide range of density and stocking. It can be decreased, but not increased, by altering the amount of growing stock to levels outside this range." (See Figure 2.)

This range is referred to as zone III. "Below" this are zone I, where there is a one-for-one increase in site growth for every increase in stand volume and zone II where this effect attenuates as zone III is approached. "Above" zone III is zone IV where density-related mortality (self-thinning) occurs. Since there is a time lag between the time a tree dies and the time its neighbors occupy the available growing space, the site is growing at a rate below its potential. Zone V is the condition where the site is so over-stocked that individual trees are unable to fully reoccupy the site after neighbors die and the site remains below potential until regeneration takes up the available space.

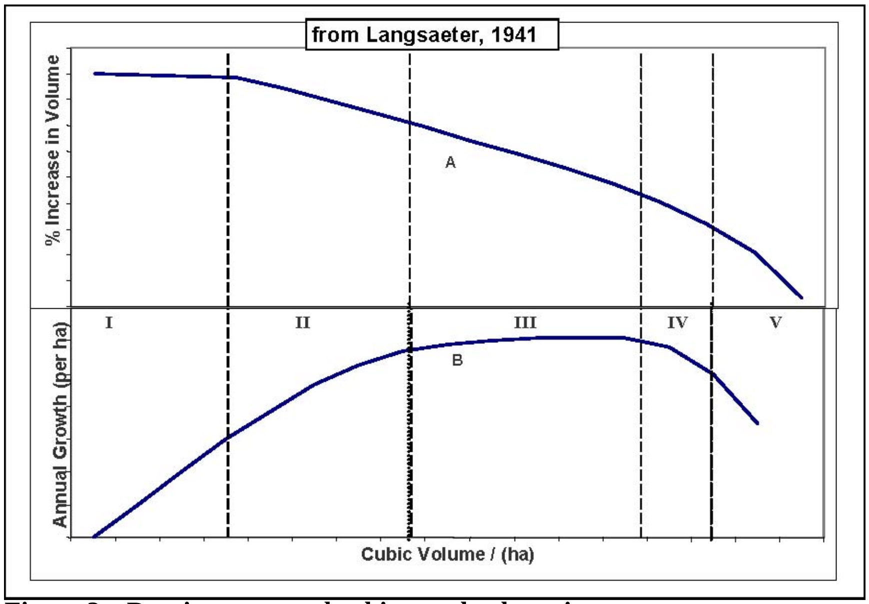

Figure 2 – Density zones and cubic stand volume increment.

In zone I, individual trees are growing at their biological potential, with no competition from their neighbors. Trees have full crowns, although some lifting will occur as they age except in very open sites. In zone II, competition is occurring but the addition of a tree to the site is not fully offset by the decrease in growth of its neighbors. Crowns have begun to lift but total foliar biomass is still increasing with additions of trees to the site. In zone III, the diminishing return has been reached; for each tree added to the site, there is a corresponding decrease in the growth of its neighbors. Foliar biomass is also constant; there is a proportional loss in individual tree crown lengths to balance the increase in number of live crowns with each tree added to the site. In zones IV and V, trees are in a weakened state and are much more susceptible to many insect and disease problems than they would be in other zones.

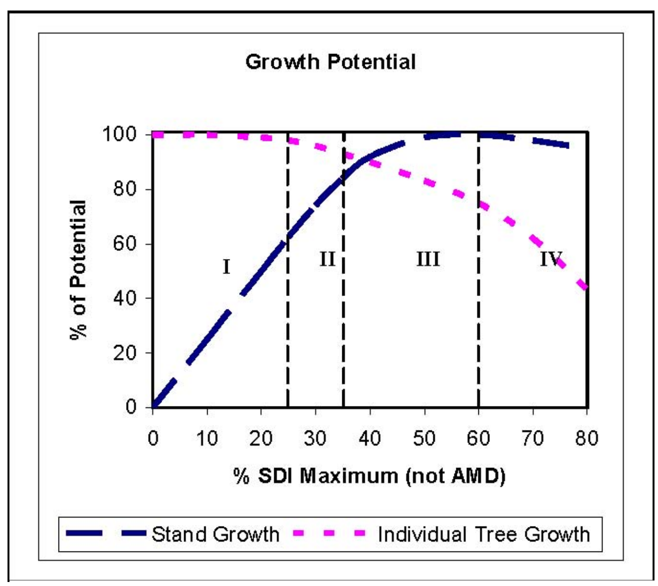

Figure 3 – Synthesis of SDI and Langsaeter's hypothesis.

Putting these two density management tools together and evaluating data from some real plots for various species, the approximate breaks between the Langsaeter zones can be

expressed in terms of SDI percents of the maximum SDI. The boundary between Zones I and II is about 25% of the SDI maximum for a species. The boundary between zones II and III is about 35% of maximum SDI. For the zone III/IV break, it is about 60% of maximum SDI.

Thus, if producing the largest individual trees possible is desired, management should retain sites in zone I. If producing the largest trees possible without giving up any foliar biomass is the goal, management should range near the break between zones II and III. If there is a dire need of immediate hiding cover in a grassy understory habitat type, consider leaving the target areas in the upper part of zone III.

Several publications using SDI to evaluate and manage wildlife habitat or establish ecological relationships have come out in the past several years. (Smith & Long 1987; McTague & Patton 1989; Moore and Deiter 2001; Lilleholm et al. 2006). There is a good discussion of Reineke's SDI and work by Langsaeter in "Principles of Silviculture", by Daniel, Helms and Baker. Most silviculturists have a copy of this text.

Predicting Vertical Crown Projection Canopy Cover Using Basal Area on the Kaibab National Forest

The Forest Plan contains guidelines for managing canopy cover. These guidelines vary by forest type and northern goshawk habitat status. Table 8 presents the values (minima, except where a range is presented) in goshawk habitats:

Table 1 – Canopy cover guidelines in the Forest Plan. The values are minimums, except where ranges are shown.

VSS[1]	Habitat[2]	Ponderosa Pine	Mixed Conifer	Spruce-fir
1-3	PFA and FA	na	na	na
4	PFA	1/3: 60 2/3: 50	60	60
	FA	40	1/3: 60 2/3: 40	1/3: 60 2/3: 40
5	Nest	50 - 70	50 - 70	50 - 70
	PFA	50	60	70
	FA	40	50	60
6	Nest	50 -70	50 - 70	50 - 70
	PFA	50	60	70
	FA	40	60	60

[1] – VSS is Vegetation Structural Stage. It refers to groups or larger patches of trees with an assigned VSS based upon trees within the diameter range with the plurality of basal area or stand density index in the group or larger patch.

[2] – Habitats are Post-fledging family Area (PFA); Foraging Area (FA – habitats outside of PFAs); and, Nest (Nest areas within PFAs).

The Kaibab National Forest Land Management Plan (Plan) has a definition for canopy ("[t]he more or less continuous cover of branches and foliage formed collectively by the crown of adjacent trees and other woody growth") that is not explicit about how to measure it. A Plan guideline in goshawk habitat management states, "Refer to USDA Forest Service General Technical Report RM-217 entitled "Management Recommendations for the Northern Goshawk in the Southwestern United States" for scientific information on goshawk ecology and management which provide the basis for the management guidelines." (Reynolds, et al. 1992) In this reference, canopy cover is defined as "the percentage of a fixed area covered by crowns of plants delimited by a vertical projection of the outermost perimeter of the spread of the foliage." Assuming no consistent alignment of tree canopy in any direction, this is equivalent to a line-intercept method of measuring tree canopy cover.

In project evaluation and implementation, it is inefficient to measure canopy cover this way (Fiala, et al. 2006) so an inference has been made to basal area by considering information from two studies:

- The first study is of canopy cover at Taylor Woods (Oliver, 2005 and Edminster, 1993) that correlated canopy cover to basal area in two-acre groups of trees. The methods used to measure canopy cover were moosehorn and spherical densiometer. There are significant and relatively consistent differences between the two methods across a range of basal areas, with the densiometer showing a higher correlation to basal area (r^2 of 0.91 and 0.78 for densiometer and moosehorn, respectively.) Neither method is directly equivalent to the canopy perimeter projection in Reynolds, et al. 1992.
- The second study (conducted in the western Oregon Cascades) compared five canopy cover estimation techniques, including line-intercept, spherical densiometer, moosehorn and a Forest Vegetation Simulator extension. (Fiala, et al, 2006) This study noted fairly consistent differences in results between the techniques across stand conditions and management history, including:

    1. The moosehorn generally provided the lowest estimates of canopy cover of ground-based methods while the densiometer generally had the highest cover estimates.

    2. Cover estimates made with FVS generally were lower than estimates of the ground-based methods. This was also found in another study in Montana (Applegate, 2000).

    3. Aside from light- and heavy-thin stands, line intercept cover estimates were significantly higher than FVS estimates.

    4. Compared with the moosehorn estimates, FVS cover values did not differ in the young stands, but were significantly lower in mature and old-growth stands.

    5. Although the methods differed in their absolute stand-level variability in cover levels, their relative rankings of variability among stand-structure types were similar and it was possible to translate estimates among the methods.

Relative differences between the canopy cover estimates at 70% and 40% for both densiometer and moosehorn versus the line-intercept were graphically evaluated using figures from Fiala, et al. 2006. See Figure 4.

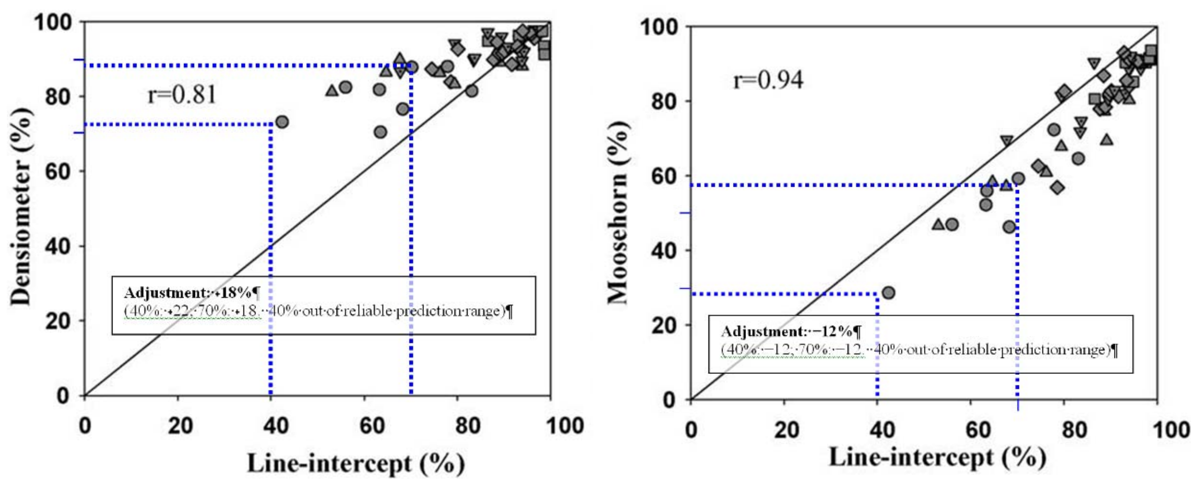

Figure 4 - Excerpts from Figure 2 in Fiala, et al., 2006 (with 40% and 70% canopy cover annotations and adjustments): Comparisons of mean stand-level percent canopy cover for [three] ground-based canopy estimation methods in this study.

The results of this graphical evaluation are presented in Table 9. Table 10 establishes "rules" to apply values from Table 9 to the Taylor Woods results graphically; imputing a line relating line-intercept canopy cover to basal area.

Table 2 – Canopy cover adjustments from densiometer and moosehorn methods to the line-intercept method.

canopy cover	method	adjustment from line-intercept
70	densiometer	+18
	moosehorn	-12
40	densiometer	+22
	moosehorn	-12

Table 3 – "Rules" for imputing a line-intercept canopy cover value to Taylor Woods.

canopy cover	distance between densiometer and vertical scope (moosehorn) lines
60	2/3 the total distance between the corresponding ba values from the densiometer value
40	1/2 the total distance between the corresponding ba values from the densiometer value

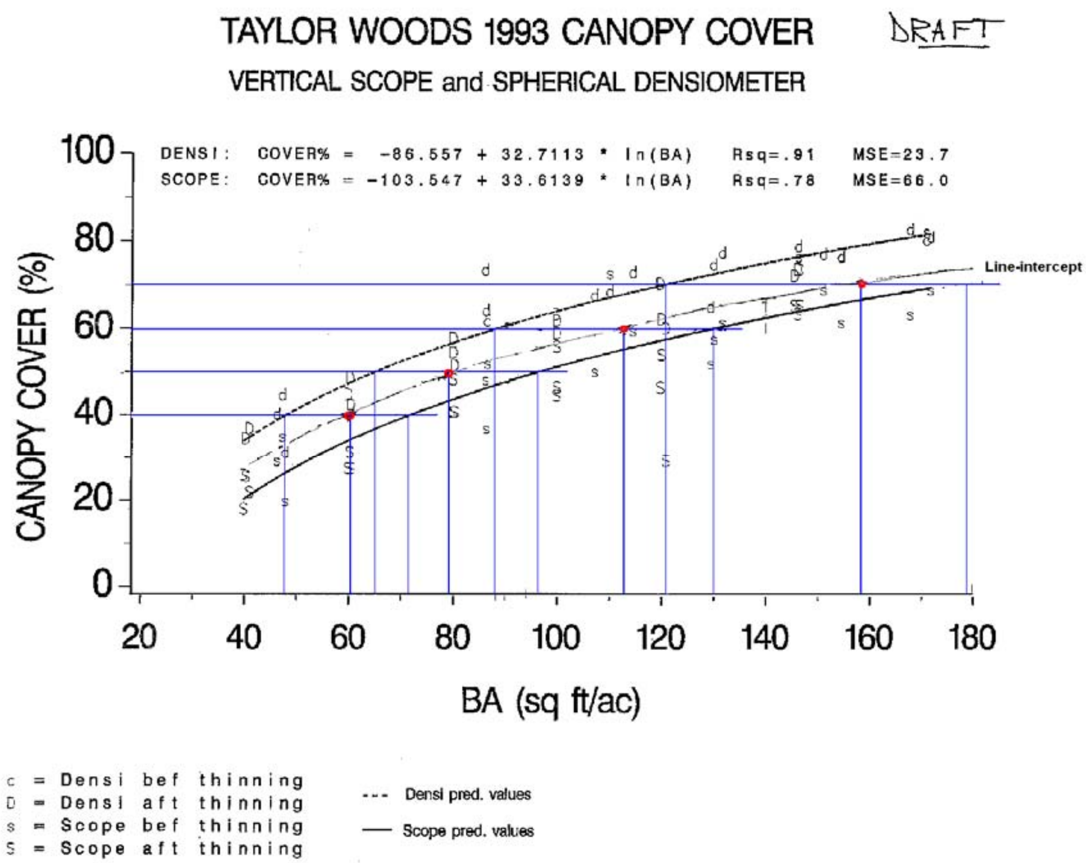

Figure 5 – Taylor Woods study correlating basal area to spherical densiometer and moosehorn canopy cover estimation methods. The imputed line-intercept method is also shown.

Table 4 – Basal area and predicted canopy cover with the line-intercept method.

basal area	canopy cover
60	40
79	50
113	60
158	70

A line through these two points of the same form as the densiometer and moosehorn lines was drawn and used to derive a relationship between line-intercept canopy cover levels applicable to the Plan guidelines and basal area. See Figure 6 for the imputed line. Table 11 presents four points along the curve.

The imputed values of canopy cover are higher than those derived from a moosehorn (vertical scope) and lower than those obtained from a spherical densiometer. The Forest Vegetation Simulator's COVER extension (and the very similar or identical values predicted by the Stand Visualization Simulator) is very likely to predict lower values than the line-intercept method (equivalent to the MRNG method.)

These values of basal area are taken to be the best available science for predicting canopy cover percent defined in Reynolds, et al. 1992, in ponderosa pine forest on the Kaibab NF. These values are also used for estimating canopy cover in the mixed and spruce-fir types because no better information is readily available at this time.

Desired Conditions (Minimum of Range)

Several standards or guidelines in the Plan provide direction that may be used to construct stocking tables of minimum desired group and stand characteristics in goshawk habitats. These could be thought of as possible conditions to aim for immediately after a management action, since the forest is expected to increase in size and density over time after treatment and it may be at least ten and perhaps thirty years before another management action to control density and structure is implemented.

The following charts represent a management approach that incorporates the standards and guidelines about several live structural attributes in goshawk habitats. Figure 4 has shading that provides a key demonstrating how the standards or guidelines were used to construct the charts and Table 1 provides some explanation of fields in the tables. For example, the Plan call for uneven-aged management (standard), that should be done with group selection(guideline), that should create or maintain six VSS classes in certain proportions (guideline) and should have some minimum canopy densities (guideline). Because it isn't clear what would represent a "minimum" condition for VSS distribution (since it must add up to 100 percent in any case) the mean distribution in the Plan guideline is presented here.

Unshaded portions of the key chart below do not incorporate and standards or guidelines, because none exist that sufficiently direct conditions applicable to these charts. However, the numbers presented in unshaded areas either facilitate the attainment of desired conditions that are contained in standards or guidelines, are informational or display a mathematical relationship between the DCs and the unshaded attribute.

A yellow highlight is displayed in the "Stand or Larger Basis" section, "SDI" column for the cell with the greatest SDI. This determines what VSS number a stand would have with the tree densities displayed. At the DC, all stands may be VSS 6.

One of the most common confusions people have about the Plan direction is erroneously applying it to stand averages when the intent is that they generally apply to groups within stands. This is the case for goshawk habitats and old growth management. A major part of this may stem from our pre-1996 Plan's even-aged management paradigm and

language commonly used in the MRNG and other documents that refer to stand or site conditions, without distinguishing between “stand” (a management unit) and “site” (an area without explicit management direction or size.) At that time, stands were to be generally managed for a homogeneous condition of a single-storied VSS. Diversity of structure would be attained between stands, rather than within stands. The current Plan seeks uneven-aged stands, with most structural diversity occurring within each stand as groups of trees that are a different VSS than their neighbors. The primary flow of structural diversity over time occurs as groups change VSS while stands and the larger landscape are, or generally grow into and then maintain a multi-storied VSS of 6 – dominated by large-old trees, but with all six VSS’ proportionally represented in groups.

DESIRED CONDITION

Moderate/High Sites - Ponderosa Pine - Post Fledgling Family Area

DBH class	% of Stand Area	Mean DBH	VSS	Group basis Mean CC %	Group basis Mean SDI	Group basis Mean tpa	Group basis Mean BA/Ac	Stand or larger basis Mean tpa	Stand or larger basis Mean BA/Ac	Stand or larger basis Mean SDI
<1	10	0.1	1	na	0	512	0	51	0	0
1-4.9	10	3	2	na	60	414	20	41	2	6
5-11.9	20	8.5	3	na	120	156	61	31	12	24
12-17.9	20	15	4	56	150	78	96	16	19	30
18-23.9	20	21	5	63	165	50	121	11*	27	37
24+	20	27	6	67	172	35	139	8.2*	33	40
sum	100							158.8	93	137

*====== Note on stand basis =======

Leave 4 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included in the tpa for dbh classes >= 18".

Dq = 12.6

SDI = 155.8

VSS: 6 B-MS

- [Blue] **S&Gs – VSS for groups (1 – 6) and dbh range for stands and larger areas.**
- [Green] **Guidelines (pgs 28-30 & 43) – VSS distribution and range. Canopy cover in VSS 4-6. Group selection system.**
- [Yellow] **Standards (pg 27) – uneven-aged stand conditions. Retain reserve trees.**
- [Hatched] **S&Gs – Old growth (pgs 32 – 34) – allocation [20%], pattern, flow [groups], Table 15 attributes [size, density & age].**

Figure 6 – Relationship between Plan S&Gs and the following DC (minimum) tables.

Since basal area is much easier to evaluate in field implementation than canopy cover, a relationship between basal area and canopy cover was developed and is presented at the end of this appendix.

Table 5 – Explanation of selected field values in the tables.

Cell Text or Column Reference	Cell Reference	Explanation of value
DBH Class		For groups, the class with the greatest SDI is the VSS for the group. For stands, this simply represents a range of diameters in which all trees in the stand are placed.
% of Stand Area		This represents the area occupied by groups within stands or larger areas.
Group Basis Mean; CC %	VSS 1, VSS 2, VSS 3	There are no Plan standards or guidelines for CC %.
	VSS 4	Example of calculation of minimum, using guidelines for PP PFA: Minimum should = 53% (.333 * 60% + .667 * 50%)

Cell Text or Column Reference	Cell Reference	Explanation of value
	VSS 5, VSS 6	Example of calculation of minimum, using guidelines for MC PFA: Minimum should = 57% (60% in PFA - 420 ac - & 50% - 70% in Nest stands - 180 ac.)
Group Basis Mean; SDI Column	VSS 1	Less than 10% SDI Max. Group dominated by grasses, forbs and shrubs.
Group Basis Mean; SDI Column	VSS 2	13% SDI Max - Trees are not competing with each other - crowns full. Understory luxuriant.
	VSS 3	27% SDI Max - trees are beginning to compete with each other. Groups gradually close as they grow through this VSS class, eventually reducing understory production to minimal levels as VSS transitions upward.
	VSS 4	33% SDI Max - group area is (or nearly is) fully occupied by trees. Eg. Any increase in individual tree growth is fully offset by a reduction in group growth. Understory production rapidly declining. Mychorrizal activity rapidly increasing.
	VSS 5	37% SDI Max - group area is fully occupied by trees but still at relatively low risk from complete bark beetle mortality. Competition between trees creates/maintains some with intermediate tree crowns.
	VSS 6	38% SDI Max - group area is fully occupied by trees but still at relatively low risk from complete bark beetle mortality. Competition between trees creates/maintains some with intermediate tree crowns.

The following tables have been modified a number of times since the original version in 1992. In the latest changes, a canopy cover column was added to the group basis, displaying how the Plan guideline applies. The table for PP PFA is an embedded spreadsheet, allowing a user viewing a Microsoft Word version of this document to see how formulas work, to evaluate other scenarios and to view comments.

An SDI column was added to the stand or larger basis to aid in displaying how stand VSS is calculated, although there are no Plan standards or guidelines about stand VSS. It should also be noted that the Plan does not contain any direction for retention of reserve trees in PFAs, but this is in the document the Plan standards and guidelines are based upon as a recommendation. The recommendation is incorporated in the PFA tables here, though it is not actually a Plan standard in PFAs.

Earlier changes allowed for movement of % in each VSS over time; and, increased residual BA of large trees as a result of leaving 35 reserve trees over groups converted to VSS 2-4 in addition to those already left over VSS 1, and, expanding to include other cover types.

These tables are for sites with a site index >= 55. Modeling for sites with lower site indexes might show a need for lower tree densities to attain the desired size class distribution within the physiological capability of the forest.

Table 6 - Ponderosa Pine - Post-fledging Family Area

DBH class	% of Stand Area	Mean DBH	Group basis					Stand or larger basis		
					Mean				Mean	
			VSS	CC %	SDI	tpa	BA/Ac	tpa	BA/Ac	SDI
<1	10	0.1	1	na	0	512	0	51	0	0
1-4.9	10	3	2	na	60	414	20	41	2	6
5-11.9	20	8.5	3	na	120	156	61	31	12	24
12-17.9	20	15	4	56	150	78	96	16	19	30
18-23.9	20	21	5	63	165	50	121	11	27	37
24+	20	27	6	67	172	35	139	8.2	33	40
sum	100							158.8	93	137
====== Note on stand basis =======								Dq* =	12.6	
Leave 4 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included as 1.2 tpa in each of the two dbh classes >= 18".								SDI* =	155.8	
								*Includes trees >= 1" dbh only.		
								Stand VSS:	**6**	**B-MS**

Table 7 - Ponderosa Pine - Foraging Area

DBH class	% of Stand Area	Mean DBH	Group basis					Stand or larger basis		
					Mean				Mean	
			VSS	CC %	SDI	tpa	BA/Ac	tpa	BA/Ac	SDI
<1	10	0.1	1	na	0	512	0	51	0	0
1-4.9	10	3	2	na	44	304	15	30	1	4
5-11.9	20	8.5	3	na	77	100	40	20	8	15
12-17.9	20	15	4	41	96	50	61	10	12	19
18-23.9	20	21	5	52	115	35	84	8	20	27
24+	20	27	6	57	123	25	99	6.2	25	31
sum	100							126.0	66	97
====== Note on stand basis =======								Dq* =	12.7	
Leave 4 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included as 1.2 tpa in each of the two dbh classes >= 18".								SDI* =	110.1	
								*Includes trees >= 1" dbh only.		
								Stand VSS:	**6**	**B-MS**

Table 8 - Mixed Conifer - Post-fledging Family Area

DBH class	% of Stand Area	Mean DBH	Group basis Mean					Stand or larger basis Mean		
			VSS	CC %	SDI	tpa	BA/Ac	tpa	BA/Ac	SDI
<1	10	0.1	1	na	0	594	0	59	0	0
1-4.9	10	3	2	na	70	481	24	48	2	7
5-11.9	20	8.5	3	na	139	181	71	36	14	28
12-17.9	20	15	4	60	174	91	111	18	22	35
18-23.9	20	21	5	67	191	58	140	13	31	42
24+	20	27	6	69	200	41	161	9.3	37	**46**
sum	100							183.9	107	158

====== Note on stand basis =======

Leave 4 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included as 1.2 tpa in each of the two dbh classes >= 18".

Dq* = 12.5
SDI* = 179.0

*Includes trees >= 1" dbh only.

Stand VSS: **6** **C-MS**

Table 9 - Mixed Conifer - Foraging Area

DBH class	% of Stand Area	Mean DBH	Group basis Mean					Stand or larger basis Mean		
			VSS	CC %	SDI	tpa	BA/Ac	tpa	BA/Ac	SDI
<1	10	0.1	1	na	0	594	0	59	0	0
1-4.9	10	3	2	na	51	352	17	35	2	5
5-11.9	20	8.5	3	na	90	116	46	23	9	18
12-17.9	20	15	4	47	111	58	71	12	14	22
18-23.9	20	21	5	56	133	41	98	9	22	31
24+	20	27	6	60	143	29	115	7.0	28	**34**
sum	100							145.8	75	110

====== Note on stand basis =======

Leave 4 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included as 1.2 tpa in each of the two dbh classes >= 18".

Dq* = 12.6
SDI* = 126.0

*Includes trees >= 1" dbh only.

Stand VSS: **6** **B-MS**

Table 10 - Spruce-fir - Post-fledging Family Area

DBH class	% of Stand Area	Mean DBH	Group basis Mean VSS	CC %	SDI	tpa	BA/Ac	Stand or larger basis Mean tpa	BA/Ac	SDI
<1	10	0.1	1	na	0	762	0	76	0	0
1-4.9	10	3	2	na	89	617	30	62	3	9
5-11.9	20	8.5	3	na	179	232	91	46	18	36
12-17.9	20	15	4	67	223	117	143	23	29	45
18-23.9	20	21	5	73	246	75	180	19	45	61
24+	20	27	6	74	256	52	207	14.0	56	69
sum	100							240.1	150	219

====== Note on stand basis =======

Leave 12 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included as 3.6 tpa in each of the two dbh classes >= 18".

Dq* = 13.0
SDI* = 248.5

*Includes trees >= 1" dbh only.

Stand VSS: 6 C-MS

Table 11 - Spruce-fir - Foraging Area

DBH class	% of Stand Area	Mean DBH	Group basis Mean VSS	CC %	SDI	tpa	BA/Ac	Stand or larger basis Mean tpa	BA/Ac	SDI
<1	10	0.1	1	na	0	762	0	76	0	0
1-4.9	10	3	2	na	66	452	22	45	2	7
5-11.9	20	8.5	3	na	115	149	59	30	12	23
12-17.9	20	15	4	60	143	75	91	15	18	29
18-23.9	20	21	5	64	171	52	125	14	34	46
24+	20	27	6	67	183	37	148	11.0	**44**	**54**
sum	100							191.3	110	159

====== Note on stand basis =======

Leave 12 tpa >18" when regenerating and removing overstory (where groups are to be managed as VSS 1 through VSS 4.) These "reserve trees" are included as 3.6 tpa in each of the two dbh classes >= 18".

Dq* = 13.2
SDI* = 180.4

*Includes trees >= 1" dbh only.

Stand VSS: **6** **C-MS**

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