Canopy Cover and How it Relates to Other Forest Attributes as an Indicator of Forest Conditions
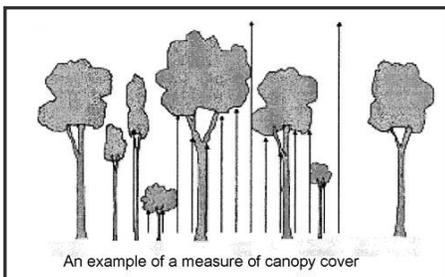
INTRODUCTION AND PURPOSE

This Fact Sheet is intended to clarify what information about forest restoration can be obtained by analyzing canopy cover or measuring canopy cover in combination with other monitoring indicators. There are four key questions that should be considered when using canopy cover as a metric to assess ecological forest restoration:

1. **What does canopy cover tell us about restored conditions?**
2. **What additional indicators are needed to ensure a comprehensive analysis of the effectiveness of management actions?**
3. **How is canopy cover measured and how accurate are measurements at different scales?**
4. **What do we know about reference condition canopy cover?**

CANOPY COVER AND FOREST ATTRIBUTES

Q: Are measures of canopy cover a useful indicator for determining if management actions have restored forest structure to within the natural range of variability?

*A: **Useful, but not without combining it with other indicators.** Canopy cover is one in a set of important variables that describe structural forest conditions. Canopy cover as a stand-alone indicator measures the proportion of the forest floor covered by the vertical projection of tree crowns. It is one of the few indicators that can be calculated at the landscape scale. However, it is not sensitive to many structural attributes, tree ages, tree size, tree density or stand basal area. This is particularly important to recognize in the Southwest where on basalt soils trees often occur in uneven-aged groups. Therefore, it is strongly recommended that a **set** of key indicators or variables are used to evaluate whether forest structure is within the natural range of variability and in turn whether forests are approaching desired conditions. Canopy cover is directly related to some forest attributes—particularly tree density and stand basal area—but is relatively poor at predicting many other attributes. As shown in Table 1 on page 2, for a given canopy cover value, forest stand characteristics may differ widely.*

An example of a measure of canopy cover

Examples

Potential fire behavior is a common forest attribute used to evaluate management alternatives. However, models used by fire managers require information on tree height, crown characteristics, and surface fuels, in addition to canopy cover, to clearly evaluate effects of management on reducing the potential for crown fire.

Wildlife species exploit a variety of forest patches with different canopy configurations. Some wildlife species are commonly referred to as "canopy-dependent." However, canopy cover by itself does not effectively capture their habitat requirements. For example, in ponderosa pine forests, the Northern goshawk (*Accipiter gentilis*) commonly nests in stands with high canopy cover. These stands are also dominated by mature or old-growth trees and located near natural drainages. The tassel-eared squirrel prefers ponderosa pine forest patches with high canopy cover, that also have interlocking tree crowns. And mule deer (*Odocoileus hemionus*) use dense, shaded stands for summer day beds, but feed in openings that support greater diversity and biomass of forage plants. In these cases, an understanding of canopy cover alone without considering tree size and arrangement would not fully indicate the forest conditions needed by these species.

CANOPY COVER AND OTHER MONITORING INDICATORS

Q: What monitoring indicators should be used to determine if management actions have restored forest structure to within the natural range of variability?

A: ***Measurements that examine stand structure, composition, and spatial pattern will provide a more complete picture of post treatment stand structure.*** *These measurements include: tree sizes (heights and diameters), tree ages, the spatial arrangement of trees, the makeup of tree species, and densities of snags and logs.*

Canopy cover (%)	Mean diameter (in)	Crown Area (ft^2)	Density (TPA)	BA (ft^2/ac)	Stand density Index	Height (ft)	Canopy Bulk Density (lb/ft^{-3})
16.7	1.57	5.81	3091	16.99	393	6.56	0.0153
16.7	3.15	17.39	1034	22.65	400	9.84	0.0092
16.7	4.72	33.00	545	27.01	404	16.40	0.0069
16.7	6.30	52.00	346	30.49	407	26.25	0.0056
16.7	7.87	73.99	243	33.11	409	32.81	0.0047
16.7	11.81	140.42	128	39.20	413	45.93	0.0035
16.7	15.75	221.23	81	44.43	416	55.77	0.0028
16.7	19.69	314.77	57	48.79	418	62.34	0.0024
16.7	23.62	419.87	43	52.71	420	65.62	0.0021
16.7	31.50	661.51	27	59.68	423	75.46	0.0017
16.7	39.37	941.19	19	65.34	426	78.74	0.0014

Table 1*: Median reconstructed presettlement canopy cover based on reconstructions is 16.7% (please see Table 3 on **page 4** for data). Table 1 lists possible stand structures that would support 16.7% canopy cover.*

Variable/Indicator	Unit	Attributes	Monitoring
Basal area	ft2/ac	Understory production	Field sampling, remote sensing
Tree density	no./ac	Wildlife habitat	Field sampling, remote sensing
Size distribution	no./ac/size class	Wildlife habitat	Field sampling, remote sensing
Species composition	no./ac/species	Wildlife habitat	Field sampling, remote sensing
Dead wood	no./ac.	Potential fire behavior	Field sampling

Table 2*: Key variables/indicators, their units, examples of attributes indicated, and typical monitoring methods.*

MEASURING CANOPY COVER

Q: **How is canopy cover measured and how accurate are measurements at different scales?**

A: ***There are many ways to calculate canopy cover.*** *Figure 1 below highlights a multi-age forested stand with trees denoted both individually and in groups, with open interspaces. The transect describes the canopy as it is observed along the line through the stand; the average canopy for the entire transect depicted below is 30%.*
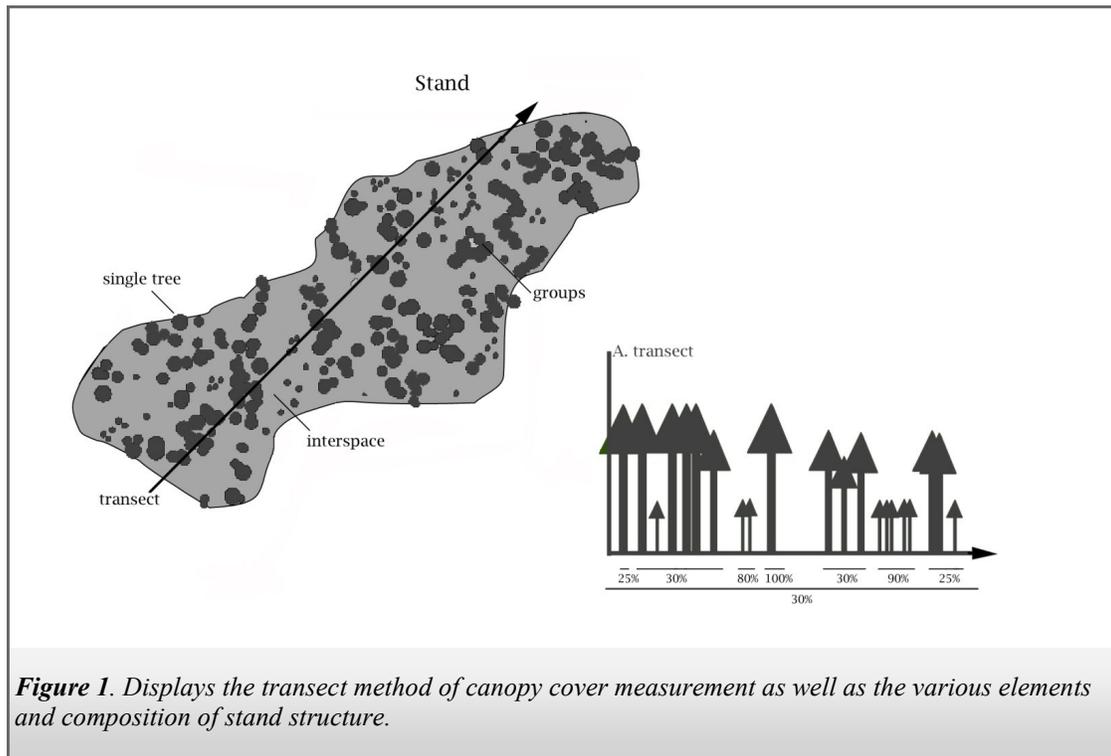

Figure 1. *Displays the transect method of canopy cover measurement as well as the various elements and composition of stand structure.*

CANOPY COVER MEASUREMENTS:

1. ***Transect Method****: canopy measured from set of points along a transect using a densitometer to look vertically from ground to sky. Canopy is analyzed as a proportion of total points hitting branch, twig or foliage. Note: Observations can be under tree canopy and still hit "openings" through tree canopy. See transect profile in lower right of Figure 1.*

2. ***Remote Sensing Method****: canopy measured from aerial imagery. Landscape categorized into canopy/ shadow/ no-canopy (opening), other. Errors exist where shadows cover canopy and where imagery is distorted or poor quality. Canopy is analyzed as proportion of total area with canopy cover, no canopy, water, rock, other. Note: generally, entire "drip line" of tree is canopy. See stand "image" in Figure 1.*

3. ***Estimates at stand level****: stand designations are variable and user-defined. Canopy cover within stands is estimated by averaging multiple transect samples (Transect in Fig. 1 = 30%; multiple transects needed to describe a stand), or summarizing remote sensing proportions within stand designation.*

4. ***Estimates from basal area****: basal area taken at plot level is used to predict canopy cover based on published regressions.*
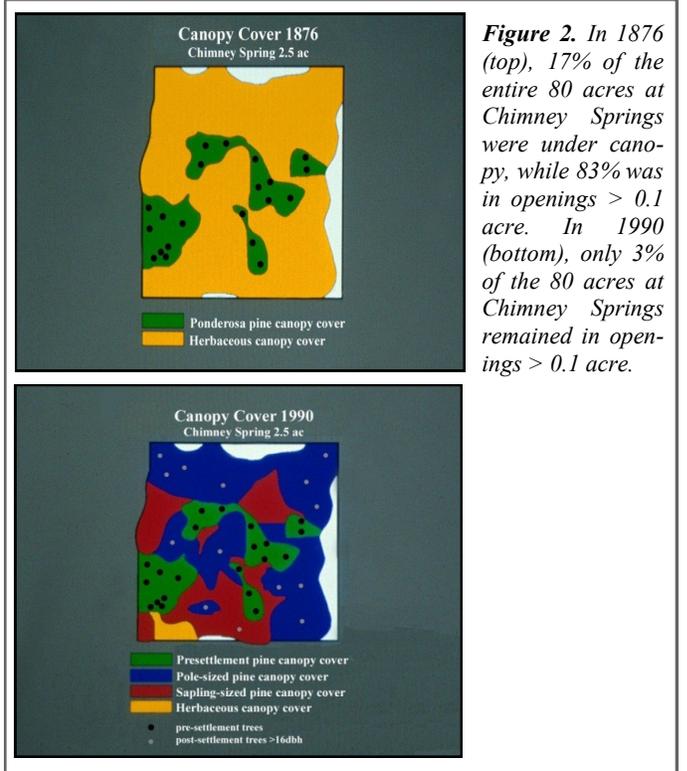
PRESETTLEMENT REFERENCE CONDITIONS

Q: What are presettlement reference conditions for canopy cover?

A: *Canopy cover determined from reconstructed sites ranged from 10% to 22% with a median of 16.7% (Table 3).* Canopy cover today is significantly greater than historical canopy cover reference conditions as depicted in Figure 2.

CONCLUSION

Canopy cover, when combined with other indicators, can provide valuable information for forest structural conditions and how current stands compare to a desired condition. However, canopy cover as a stand-alone metric does not provide an adequate tool for assessing the array of structural characteristics important in setting desired conditions for restoring forest structure.

Figure 2. In 1876 (top), 17% of the entire 80 acres at Chimney Springs were under canopy, while 83% was in openings > 0.1 acre. In 1990 (bottom), only 3% of the 80 acres at Chimney Springs remained in openings > 0.1 acre.

Cover type	Site	Method	Reference date	Canopy Cover	Citation
PP	AZ-Coconino, Gus Pearson	Standing age class	1875	21.9%	White 1985
PP	AZ-Coconino, Gus Pearson	Dendro-reconstruction	1876	19.0%	Covington et al. 1997
PP	AZ-Coconino, Chimney Springs	Standing size class	1876	17.3%	Covington and Sackett 1986
PP/PP-Oak	AZ-Coconino, Woolsey	Dendro-reconstruction	1874		Sánchez Meador et al. 2011
	S1B, Fort Valley			10.2%	
	S1A, Fort Valley			15.8%	
	S4A, Sunset Crater			14.1%	
	S4B, Sunset Crater			13.6%	
	S5B2, Coulter Ranch			16.7%	
	S5B3, Coulter Ranch			18.8%	
PP/MC	CO-Colorado Front Range, Cheesman Lake	FVS-reconstruction	1900		Fornwalt et al. 2002
	North Aspect			21.5%	
	East/West Aspect			15.7%	
	Uneven-Aged Example Stand			18.0%	
	South Aspect			12.9%	
			Mean	16.6%	
			Median	16.7%	

Table 3: Select reconstructions from ponderosa pine forests.
PP = Ponderosa pine; PP-Oak = Ponderosa pine–Gambel oak; PP/MC = Ponderosa pine, Mixed conifer

References

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