CANOPY COVER AND SHADE/STREAM TEMPERATURE RELATIONSHIPS

These two projects are part of a larger research effort on Land and Water Relations funded by the Oregon Legislature through the Agricultural Experiment Station at Oregon State University. The two studies highlighted are not yet complete and findings reported are preliminary evaluations of the data. They are part of our research effort to more clearly explain the relationships between shade and diurnal changes in stream water temperatures. Much of current water quality policy in state government regulation is focused on water temperature and enhancement of the amount of shade on streams is a major focus to improve water temperature for salmonids. We hope these projects will provide information helpful for designing future water temperature monitoring programs.

EVALUATION OF TECHNIQUES TO MEASURE CANOPY COVER

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STUDY METHODS

Canopy cover was measured for five Oregon streams in the summer of 2000 using three methods recommended by the Oregon Plan for Salmon and Watersheds (1999). Each stream was in a different Ecological Province as described by Anderson el. al. (1998). Vegetation along each reach selected for study was uniform based on ocular reconnaissance. Streams were visually evaluated and Rosgen (1996) stream types assigned to each stream. A general description of each stream is given in Table 1.

We measured canopy cover for each stream using a clinometer, modified spherical convex densiometer Model A and the HemiView 2.1 digital image system. All measurement protocols followed the Oregon Plan for Salmon and Watersheds (1999). Twenty transects were established across each stream perpendicular to stream flow and all instruments were used at each sampling point in the center of each stream. The location for the initial transect was selected randomly. Subsequent transects were established at distances to minimize potential overlap of images. Distances between transects varied from 50 ft to 200 ft depending on density of cover. All canopy cover measurements were taken from the transects at the center of the stream.

Table 1. Site characteristics for each location. Plant species listed are the dominant plants that provided most of the cover to each stream. Source of scientific names: Hitchcock and Cronquist (1998)

Location: Nearest city County Ecological Province	Elevation (ft) Rosgen Stream Type	Ave Bankfull Width (ft) Direction of Flow	Dominant Vegetation
Yachats Lane Coast	197 B	32.5* Easterly	Red Alder *Alnus rubra* Bong. Big Leaf Maple *Acer macrophyllum* Pursh Sitka Spruce *Picea sitchensis* (Bong.) Carr. Douglas Fir *Pseudotsuga menziesii* (Mirbel) Franco Western Hemlock *Tsuga heterophylla* (Raf.) Sarg. Western Red Cedar *Thuja plicata* Donn. White Fir *Abies concolor* (Gord.& Glend.) Lindl. 7 shrubs 20 forbs 12 grasses and sedges
Corvallis Benton Willamette	230 C	30.8 Southerly	Oregon White Oak *Quercus garryana* Dougl. Red Alder *Alnus rubra* Bong Oregon Ash *Fraxinus latifolia* Benth. Big Leaf Maple *Acer macrophyllum* Pursh 7 shrubs 2 forbs 5 grasses and sedges
Dufur Wasco The Dalles	1457 B	21.7 Easterly	Oregon White Oak *Quercus garryana* Dougl. Ponderosa Pine *Pinus ponderosa Dougl.* Douglas Fir *Pseudotsuga menziesii* (Mirbel) Franco White Fir *Abies concolor* (Gord.& Glend.) Lindl. Red Alder *Alnus rubra* Bong Western Red Cedar *Thuja plicata* Donn. 12 shrubs 9 forbs 7 grasses and sedges
Seneca Grant John Day	4839 C/E complex	9.8 Southeasterly	Bebb's Willow *Salix bebbiana* Sarg. Geyer's Willow *Salix geyeriana* Anderss. 13 forbs 7 grasses and sedges
Enterprise Wallowa Blue Mountain	3300 B	14.8 Southerly	Douglas Fir *Pseudotsuga menziesii* (Mirbel) Franco Ponderosa Pine *Pinus ponderosa* Dougl. 8 shrubs 17 forbs 12 grasses

*Wetted width

The clinometer measured the angle between the stream channel and the top of the highest vegetation at each sampling point. Four clinometer measurements were taken from the stream center at each transect; facing upstream, facing downstream and facing left and right banks. The left bank was on the left side of the observer when facing downstream. These angles were averaged and converted to percent canopy cover (90° equals 100% cover).

The densiometer is a small handheld spherical convex mirror with an engraved grid. The grid was modified according to the protocol in the Oregon Plan for Salmon and Watersheds (1999). This was done to reduce observations behind and to the sides of the observer in order to minimize overlap of canopy measured. Canopy cover measurements are a ratio of the areas reflecting cover to those reflecting sky.

The HemiView 2.1 imagery system is based on a digital camera with a fish eye lens. The images produced have a field of view of 180° vertically and 360° horizontally. Images are analyzed with GIS technology. Because the camera is geographically oriented when the image is taken, the path of the sun can be modeled and shade calculated as the percent of the field of view covered with canopy that prevents direct sunlight from reaching the point of measurement. Since the canopy is fixed and the sun is perceived to move across the sky, the percent shade changes throughout the day.

Statistical comparisons of results of measurement from each instrument were done with a randomized block design in an analysis of variance. Each instrument was compared to the other two with a paired t test using the pooled error term from the general linear model. Sampling efficiency was evaluated with Stein's two-stage test (Cook, et. al., 1962). Comparison of cover and shade from the HemiView system were made with t tests within each site and relationships between shade and canopy cover were evaluated with simple linear regression.

RESULTS AND DISCUSSION

The clinometer and HemiView imaging system both have a 180° field of view ("horizon to horizon") whereas the modified densiometer has a restricted and variable field of view, thus it measures less of the cover near the horizontal plane. Consequently the cover values calculated from the modified densiometer measurements were lower than those from the clinometer, even though both were measured from the same four points on each transect (Figure 1).

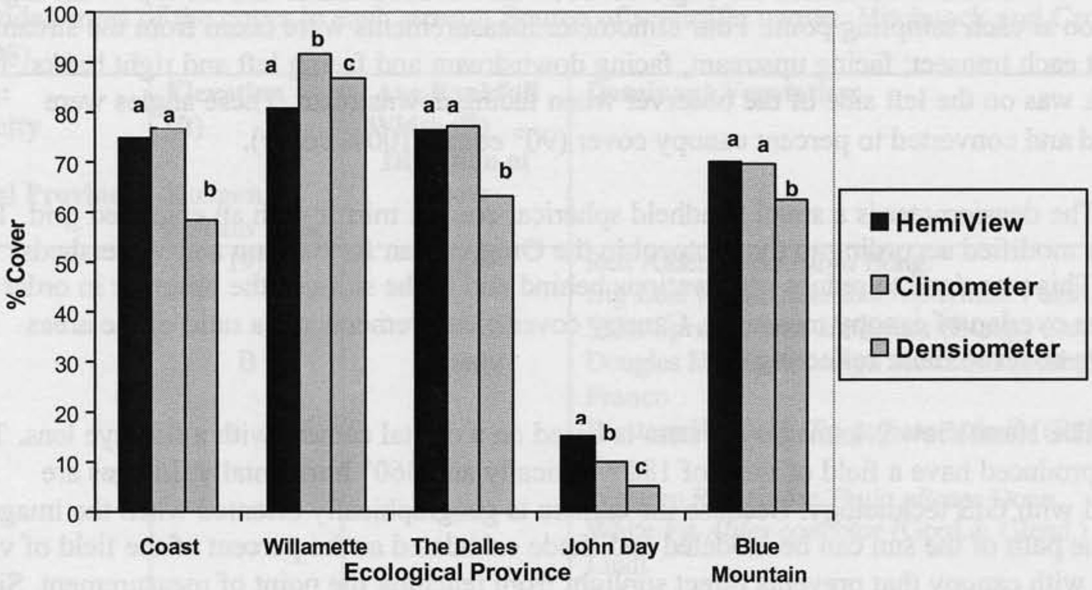

Figure 1. Comparison of measurement techniques across sites. Comparisons within sites with a different superscript are significant at $P \leq 0.05$.

Cover values calculated for the modified densiometer were also lower than values measured by the HemiView imaging system, except in the Willamette Ecological Province. In the latter case, the tree canopy nearly covers the entire stream but has numerous small openings. The difference between results from the two instruments is probably due to sampling error that would be higher for the densiometer.

Comparison of cover values calculated for the clinometer and HemiView imaging system showed no significant differences for three sites which each had about 70% canopy cover. In the John Day Ecological Province the stream we studied had significantly more cover when measured with the HemiView imaging system than when measured with the clinometer (Figure 1). In the Willamette Ecological Province the results were reverse, with significantly more cover measured with the clinometer than with the HemiView system. We think these differences highlight the higher accuracy of the HemiView imaging system for quantifying canopy cover. In the John Day stream most cover was topographic. The occasional willow at a sampling location was likely to be included in the HemiView image and recorded. The four points sampled with the clinometer would more likely miss the occasional willow yielding a lower cover value. In the Willamette Ecological Province stream, the very high canopy cover was from deciduous trees with many small openings. These were ignored using the clinometer protocol but each small opening was evaluated in the HemiView protocol. These differences due to sampling error should be evaluated when selecting an instrument to evaluate canopy cover.

Relative sampling efficiency in terms of numbers of samples required to meet specific reliability, varied among techniques and locations (Table 2). The most efficient instrument was the hemispherical imagery system and the densiometer was least efficient. The John Day site, with very low and variable cover, was difficult to sample with high reliability using any instrument. On the other sites, which had 70% to 80% cover, each technique had acceptable levels of efficiency.

Table 2. Sample size required to sample within 10% of the mean at 95% confidence.

Instrument	Coast Ecological Province	**Willamette Ecological Province**	The Dalles Ecological Province	**John Day Ecological Province**	**Blue Mountain Ecological Province**
Clinometer	20	6	18	256	16
Densiometer	38	10	42	2045	32
Hemispherical Images	4	1	4	68	6

Relationships of cover versus shade were highly site specific, with each site having a different regression model. The best relationship was for the stream in the John Day Ecological Province with $R^2 = .90$. the other streams had R^2 as low as .23. The relationships were not significant in the Willamette Ecological Province stream. Shade calculations were based on annual average values of radiation. We would expect different results if shade calculations were for specific days or times of day.

SUMMARY

When sampling is conducted within the limits of each instrument all three were reliable. Hemispherical imagery was most consistent between measurements. The clinometer and modified densiometer are rugged instruments suited to rough field conditions. They are well adapted to measure canopy cover in mid-ranges when rapid collection and analysis of measurements are needed.

Interpretation of measurements will vary among the instruments used. The densiometer is more suited to measure cover when the area directly over the stream is of the most interest, like the potential for litter to fall into the stream. The clinometer and hemispherical imagery systems are appropriate to measure cover related to landscape features, like solar radiation and shade relations.

Measurements of canopy cover vary with instruments used and each of the three instruments evaluated have benefits and limitations. The kind and quality of data needed should be a factor in selecting the technology to use.

Shade is a factor that includes both the amount of canopy cover and orientation of the canopy in relation to direct solar radiation. Canopy cover values are not equivalent to average annual shade values.