(Table 2. continued)

Jan. 27-28	1	4.48	0.48	2.16	4.08	0.16	0.154
	11	3.08	0.36	1.44	2.92	0.20	0.118
	14	3.88	0.28	1.36	3.32	0.08	0.125
	15	2.76	0.32	1.08	2.76	0.16	0.115
	16	3.60	0.36	1.32	3.40	0.08	0.129
Feb. 17-20	1	10.48	0.48	1.72	4.24	0.32	0.131
	2	6.56	0.28	1.12	2.76	0.24	0.085
	3	6.24	0.32	0.96	2.84	0.40	0.081
	6	5.88	0.40	1.32	2.64	0.40	0.080
	9	4.28	0.24	1.16	2.64	0.48	0.081
	11	7.72	0.32	1.32	3.64	0.32	0.102
	12	6.52	0.44	1.28	3.20	0.44	0.084
	15	6.96	0.40	1.48	3.24	0.00	0.088
	16	6.76	0.40	1.52	3.04	0.08	0.082

Table 2 summarizes rainfall amounts and intensities for the three largest (and other) storms. The largest storm of the winter occurred on December 5-6. Total rainfall varied from 2.84 to 5.96 inches with maximum hourly intensities of 0.16 to 0.44 inches and maximum 24-hour intensities of 2.60 to 4.56 inches.

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AN INDEX OF CANOPY HEIGHT DIVERSITY

The structural diversity of vegetation is important in distinguishing stages of forest development and in the habitat selection of many animals, especially birds such as the northern spotted owl. However, layering (or diversity) is an often vaguely defined characteristic of forest stands. Several very labor-intensive techniques have been developed to measure the foliage height diversity of forest stands. These techniques include the use of vertical line intercepts with telephoto lenses and the estimation of the foliage cover of large checkerboard patterns at different heights and distances away from an observer. While these approaches may be useful for intensive analysis, they are not practical for large surveys and inventories. Another approach often used is to visually estimate the number of canopy layers in a forest. While this can be done relatively rapidly, it is subject to considerable observer bias and many forests do not sort out into discrete canopy layers. For general inventory purposes an index with the following properties is needed:

1. It should be easy to measure in the field and not be subject to observer bias.
2. It should be related to ecological function and be general enough to apply to a broad spectrum of ecological processes and organisms.
3. All other things equal, tall forests should have a higher index than short forests. Tall forests have thicker boundary layers and a greater range of microclimates and habitat structure than short forests. Tall trees influence more volume from top to ground than do short trees.
4. For forests of equal height, those with foliage or crowns occurring throughout the vertical space should have a greater index than those with foliage or crowns occurring at one or a few heights.
5. Forests with a greater volume of tree space (crown and volume beneath the crown) should have a higher index than forests with less volume of tree space.
6. The index should be capable of being scaled to the height potential of a particular forest type. For example, the index could be calculated differently for east-side lodgepole pine types than for west-side Douglas-fir types. This adjustment may or may not be desirable, but it should be possible.
7. The index should be at least partly predictable for remote sensing imagery since this is becoming one of the main methods of obtaining a first approximation of landscape-scale forest characteristics.

We have developed an index of canopy height diversity (CHD) that meets all of the above criteria. The CHD characterizes the height diversity and the volume of ecological space of trees in a stand. The ecological space of trees in a stand is defined as the sum of the imaginary cylinders surrounding individual trees with a cylinder height equal to the height of the tree and a cylinder diameter equal to the crown diameter of the tree (Figure 1). The CHD is calculated according to the following:

$$CHD = \sum_{i=i}^{N} P_i * H_i \; i \qquad (1)$$

H_i is the relative height of height class i. The relative height of a height class is computed by dividing the upper limit of a height class by the upper limit of the lowest height class.

N is the number of height classes.

P_i is the height class-cover score of the ith height class based on the proportion of the ground area that is covered by the crowns of trees with that height class. It is calculated as:

$$P_i = \begin{cases} C_i/0.3 \text{ for } C < 0.3 \text{ (Threshold)} \\ \text{else } 1 \text{ for } C >= 0.3 \end{cases} \qquad (2)$$

where C_i is the horizontal crown area of a tree within height class i and is calculated as:

$$C_i = \frac{\sum_{i=1}^{K} A_j}{AG} \qquad (3)$$

where A_j is the horizontal crown area of the jth tree with the height class i and AG is the ground area of the sample, and k = the number of trees in height class i.

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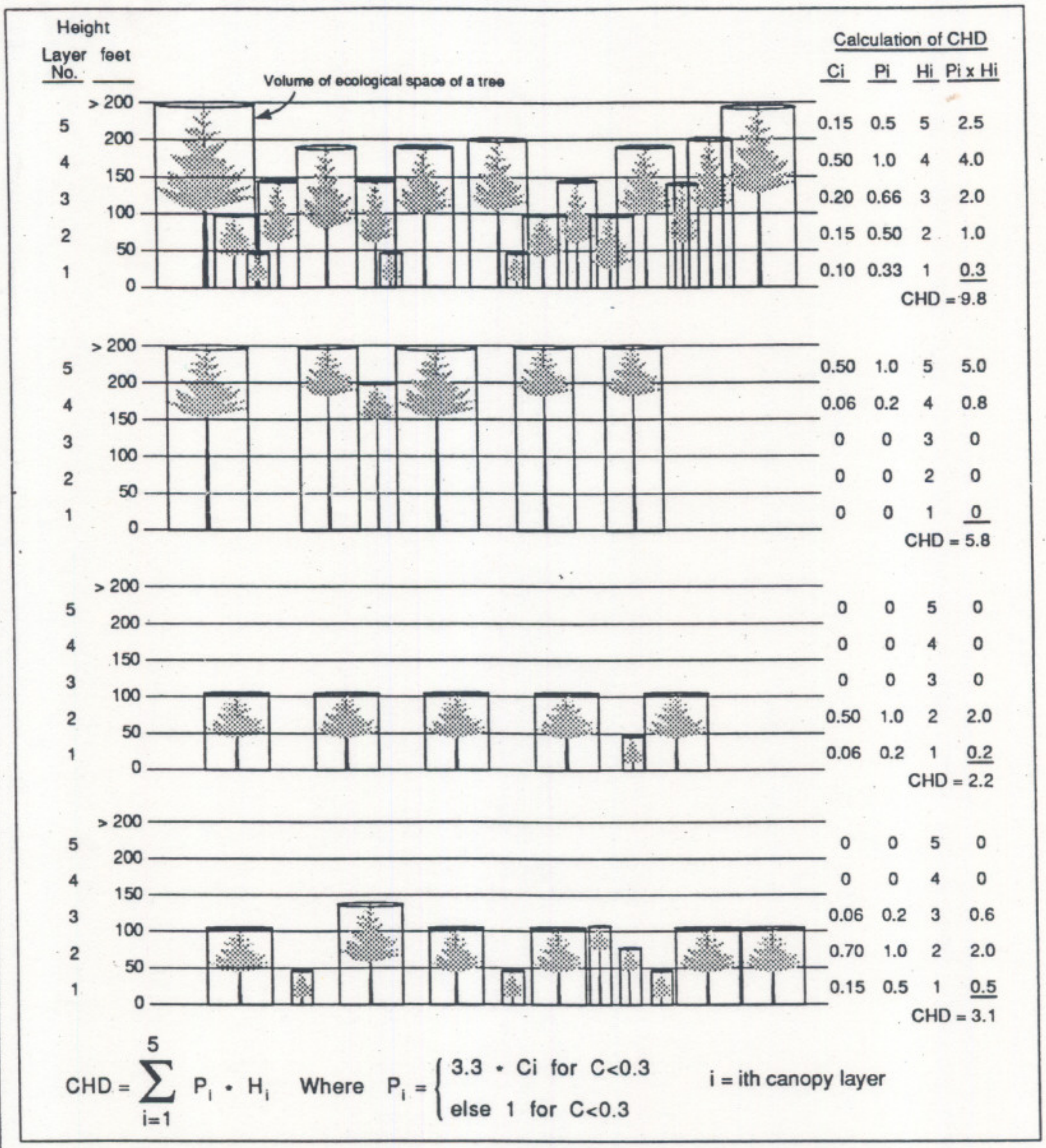

Figure 1. Examples of canopy height diversity calculations for stands with different structures.

The horizontal crown area of the tree (A_j) can be measured directly in the field or estimated from dbh data. The ground area proportion threshold (0.3 in equation 2 above) is the proportion of ground area covered by tree crown area at which the height class is considered to reach its full occupancy. The threshold can vary from <0.1 to 1.0. We determined the threshold empirically using the old-growth survey data set to examine how the relationship of the index to age changed as a function of different thresholds. We found that 0.3 seemed to produce a CHD that was most sensitive to differences in stand development in a chronosequence of sample stands ranging in age from 30 to over 900 years.

We have used height classes of 0-16m, 16-32m, 32-48m, 48-64m, and 64-80+m for west-side Douglas-fir stands. Smaller or more numerous height classes could be used with different forest types and objectives. Resolution for young stands may be limited. The relative heights of these five classes are 1,2,3,4, and 5. (Figure 1).

The maximal score for a stand is 15. In the old-growth data set, stands that were less than 100 years old had an average score of about 4 with a range from less than 1 in clearcuts to about 6 in some tall and complex young stands in the Coast Range. Stands 100 to 200 years old had an average score of about 7.5. The score was about 10 on dry or poorly stocked, low productivity sites, and ranged to over 14 on moist sites with tall emergent Douglas-firs and well-developed middle layers of western hemlock.

We tried other diversity indices, including Simpson's diversity index based on basal area in different height classes and tree density in different height classes, and found that they did not perform as well as CHD in characterizing structural development along a chronosequence. For example the correlation of the Simpson's diversity index based on basal area in a height class with stand age was 0.68 while the correlation of CHD with stand age was 0.85. While stand age is not necessarily the best criteria for comparing the value of different indices, for natural stands it is a good reflection of overall trend in stand development. We think the key to the index is basing it on crown diameter rather than basal area or tree density. The crown diameters are key elements for habitat structure, and the relationship between dbh and crown diameter is an asymptotic curve. Consequently, indices based on basal area give too much weight to trees with large dbh's whose crown diameters do not change much with increasing dbh. Interestingly, the standard deviation of tree dbh in a stand was highly correlated with stand age (r = 0.19) in a sample of 29 stands and can be predicted with the highest R^2 (0.82) of any stand attribute in the remote sensing regression models we have developed. Unfortunately, the standard deviation of dbh is not as easily linked to ecological process and habitat conditions as CHD, although it may be a good indicator of diverse stands.

CHD can be calculated from tree dbh measurements and a rough knowledge of dbh-height relationships and dbh-crown area relationships. CHD is based on the ecological assumption that a tree occupies a volume of ecological space and that this space consists of the crown, the bole, and the volume beneath the crown to the forest floor. This ecological space affects the habitat of canopy dwelling organisms, organisms using the tree bole, and organisms and processes affected by the cover microclimatic conditions underneath the crown of a tree. A tall forest would receive a higher score than a short forest because it has more habitat space and a

greater range of microclimates contained within it. Crown volume alone is often measured and associated with bird habitat. We have not used it in this index because: (1) we're not sure how well it can be estimated from dbh; (2) it is more time-consuming to measure in the field; (3) it does not reflect the entire volume of ecological space influenced by a tree; and (4) we think that measures of it would probably be correlated with ecological space volume.

The other apparent value of the CHD is that it is relatively predictable from satellite imagery (R^2 of .53 for SPOT imagery alone and an R^2 of 0.66 for a model combining SPOT and TM imagery). We have tested it for the central western Cascade Douglas-fir type only and would like to expand the model building to other locations and forest types.

At this time, we consider the CHD to still be in a state of development. We do not consider it a replacement for more detailed characterization of canopy diversity or a replacement for understory (shrub and herb layers) diversity measures which require ground-based sampling. We welcome suggestions and criticisms.

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OF INTEREST

JUST WHEN CAN WE EXPECT RECOVERY? UPDATE ON THE NEW ALSEA WATERSHED STUDY (NAWS)

Introduction

Estimating the potential impact of a land use practice on the water resource requires information on background stream water quality and quantity. It also requires an understanding of the system response to a given set of controls. Without knowledge of these responses, a land use manager cannot hope to assess the magnitude or duration of potential impacts to water resources from land use activities.

The New Alsea Watershed Study (NAWS), now in its third year, addresses the concept of post-harvest recovery in forested ecosystems. This research is designed to provide a better understanding of long-term water quantity and water quality dynamics in managed coastal Oregon forests.

The Original Alsea Watershed Study

The original Alsea Watershed Study (AWS) (1959-1973) considered the effects of timber harvesting practices on hydrology, water quality, stream habitat, and fish populations. The original study utilized three small watersheds, Needle Branch (71 ha), Deer Creek (304 ha), and Flynn Creek (203 ha). These basins are tributary to Drift Creek. Stream gauging weirs were constructed in 1958-1959, and monitoring began in 1959. Roads were constructed on Needle Branch and Deer Creek in 1965. Logging took place from March through October 1966. Post-treatment monitoring continued until the fall of 1973. Needle Branch was completely clearcut, with no vegetative buffer strip or other stream protection. Deer Creek was treated with three clearcuts of about 25 ha each, with a vegetative buffer strip left along stream channels. Flynn Creek was left undisturbed and served as the untreated control watershed for assessment of treatment effects in Deer Creek and Needle Branch.

The AWS had 7 years pre-treatment data, 1 year for treatment (timber harvesting) and 7 years of post-treatment data. Departures from the pre-treatment regressions between the control watershed (Flynn Creek) and the treatment watersheds were used to assess treatment effects. Study results were used to develop state forest practices legislation and are still utilized by teachers and researchers. Several publications document study results (see suggested readings): a summary, a retrospective by the original principal investigators, and a compilation of AWS and more recent Alsea research.

The New Alsea Watershed Study

No efforts outside the original study were made in the Alsea area until 1989. Reactivation of the Alsea water resources monitoring program provides a unique opportunity to assess the hydrologic recovery and long-term effects of silvicultural treatments on water and water-related resources. Currently, the water resources monitoring program is independent of biological monitoring, but a salmonid inventory was recently completed.

Flynn Creek is now designated a Long-term Research Natural Area by the USDA Forest Service to be used to characterize undisturbed coastal Oregon ecosystems. Forest regeneration on Needle Branch has been unmanaged except for some precommercial thinning in 1981. This forest thinning is not considered to affect water resources or the fishery resources.

Deer Creek had a second timber harvesting entry of 20 ha in 1978, and two units totalling approximately 22 ha were logged in 1987 and 1988. The multiple entries in Deer Creek provide the opportunity to assess our ability to predict hydrologic recovery and to identify potential cumulative watershed effects.

Some of the questions addressed by our research include:

1. Has the annual water yield from Needle Branch returned to pre-treatment levels 26 years after harvest?

2. What is the long-term effect of timber harvesting on peakflows?

3. What is the long-term effect of timber harvesting on summer lowflows?