Disturbance and Canopy Gaps as Indicators of Forest Health in the Blue Mountains of Oregon

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Abstract.—Disturbance profiles, indices based on both spatial and non-spatial statistics, are used to examine how small-scale disturbances and the resulting canopy gaps disrupt ecosystem patterns and processes in selected stands in the Blue Mountains of Oregon. The biological meaning of many indices remains undefined for small scale disturbance phenomena, but their disturbance profiles could eventually be used to assess current and desired forest conditions and suggest actions to meet specific management objectives. These profiles can be determined for plots representing desired conditions associated with specific management objectives, to establish a range of variability for forest health indicators, and to monitor the progress of disturbances used as silvicultural tools.

DISTURBANCE AND CANOPY GAPS

Canopy gaps are discrete openings in forest canopies caused by small scale disturbances (Watt 1947). Most natural, small-scale disturbances are so well integrated into community dynamics that they are considered keystone processes for maintaining the health or integrity ecosystems. Tree mortality and the resulting distribution of gaps, snags, coarse woody debris, and recolonizing vegetation are important factors in determining biodiversity, wildlife habitat, scenic quality, recreation opportunity, timber volume, water yields, and various ecological functions. Canopy gaps and the agents that cause gaps influence many different forest resource values. They reduce timber production by reducing stand uniformity and create forecasting and scheduling problems by causing miscalculations in prediction models.

Gaps may also positively influence other ecosystem components, such as wildlife species, by increasing the amount of available habitat for organisms dependent on coarse woody debris, openings, or edges.

Gaps in the forest canopy created by disturbance agents harbor the preponderance of coarse woody debris in a typical forest stand. These logs, stumps, and snags are key habitat components for many species comprising the primary cavity-excavating guild of birds and the small animal fauna of these forest sites. Chickadees, nuthatches, voles, mice, chipmunks, and other species of these groups contribute to biodiversity and biomass of a forest site and also play an important ecological role as prey of predatory wildlife species that are often rare or sensitive. Quality habitat for the primary excavators and small mammals is often defined by the availability of specific kinds of coarse woody components. Thus, forest canopy gaps, their origin, and the structure and composition of their interiors can directly impact the biodiversity of forest landscapes.

With an increasing understanding of small-scale disturbance these natural processes could be used as additional silvicultural tools for generating and maintaining desired future conditions. These conditions include species composition, stem density, tree size, type and abundance of snags and

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logs, and canopy structure. Small-scale disturbances are particularly useful for increasing within-stand diversity and decreasing large-scale pulses in mortality and regeneration.

FOREST HEALTH

What is forest health? The answer to this question will, in large part, determine how we measure and quantify indicators of health. No matter how one defines it, or even if one agrees with the concept, the term "forest health" is now used almost daily in discussions about natural resource management because it is something that almost everyone can identify with. We know what it is to be healthy ourselves and we want our forests to be healthy as well. One way of measuring forest health would be to look at the ability of a forest to meet management objectives. Under this approach, a healthy forest could be described in this way: "A desired state of forest health is a condition where biotic and abiotic influences do not threaten resource management objectives now or in the future" (U.S. Department of Agriculture, Forest Service 1993).While this definition can be considered highly utilitarian, other definitions focus more on aspects of ecosystem function. In this viewpoint, a healthy forest is an ecosystem in balance; a fully functional community of plants, animals and their physical environment (Monnig and Byler 1992) where the major components of ecosystem function vary within a range of known, specified parameters.

The most useful and popular definitions seem to combine the two views. In essence, we design our management goals to include, or be dependent on, functional ecosystems. The challenges we face are to define and measure the indicators of forest health, as well as the attributes of functional ecosystems, that will be useful in helping us recognizes when forest and stands are unhealthy and why.

Early attempts to describe forest health in the Blue Mountains of Oregon were at a landscape scale so the indices used to describe and quantify indicators of forest health were selected and designed to be appropriate for that scale. The results of one of the early attempts at forest health analysis are documented in the Blue Mountains Forest Health Report, "New Perspectives in Forest Health." In it the authors reported that the health of the forests in the Blue Mountains was declining. The effects were obvious: dead and dying trees. The causes were ascribed to 'decades of fire exclusion, selective harvesting of early and mid-seral trees, livestock grazing, and little influence on . . . biodiversity and long-term site productivity.' (Gast 1991). Indices used in the report were: insects and diseases, watershed health (measure of impacts by grazing), fire, long-term site productivity, and biodiversity, (table 1). Those stands with large and increasing populations of insects and diseases, a Class III rating for watershed health, increased risk of catastrophic fire, and biodiversity structure outside the range of natural variation, were considered unhealthy. Range of natural variability is a description of ecosystem composition, structure, and processes of an area, had it been minimally influenced by humans (ECOMAP 1993). This concept is tied closely to that of the functional ecosystem as it is viewed in forest health definitions. Predictive simulation models can also play a role in assessing the temporal range of natural variability, that is, how the ecosystem will change over time (Kaufman 1994). This method for assessing forest health is useful in showing, on a landscape scale, the location of forest health problems but it does not provide an analysis tool useful for assessing, predicting, or monitoring the impacts of disturbance agents at the stand level.

As part of a larger research project examining disturbance and canopy gaps in the West, the study I would like to report on here was designed to use several indices simultaneously to examine

Table 1.—Forest health profile indices for the Blue Mountains, Oregon.

Index	Units of measurement
Insects and Diseases	Acres of defoliation/Acres of mortality
Watershed condition class	Class I/Class II/Class III
Fire	Percentage of true fir/Mixed age structure/Dense, suppressed
Long-term site productivity	Not degraded/Generate products in perpetuity
Biodiversity	Ages/Structural configurations/Species combinations

how diseases, insects, anthropogenic activities and other canopy gap-forming disturbances change the structure and function of ecosystems at the stand level. One of the primary objectives was to see if this system could be used as a way of measuring indicators of forest health at a lower spatial scale than that of the Blue Mountain Report. Forest health can be described and assessed at multiple scales. For the work reported here, the focus is at the stand and tree level, even though we realize that, in order to deal with forests health issues in a holistic way, they must be described at the landscape level through vegetation mosaics and ecosystems processes. Because of our interest and expertise in identifying meso-scale disturbances, the scale we selected was that of the stand, the domain of the silviculturist.

DISTURBANCE PROFILE

Silvicultural management of stands for forest health objectives will require new methods of inventorying and characterizing forest stand attributes. According to Lunquist, Geils, and Negron (1995), these attributes must be: 1) sensitive and responsive to the effects of disturbance and recovery, 2) relate to patterns and processes for the scale at which silviculture is practiced, 3) provide linkage to higher and lower spatial scales, 4) indicate the status and trends of resource values and ecological functions, and 5) reflect and respond to management activity in modeling exercises and implementation. A disturbance profile is a combination of spatial and relational statistics (referred to here as indices) describing relationships between, among others, canopy density and structure, disturbance agents and their interactions, dead woody material such as snags and logs, and recolonizing vegetation. It is, therefore, a spatial and temporal description or fingerprint of the stand and gives us another tool to visualize an extremely complex system. Multivariate statistical methods are used to compare and contrast disturbance profiles among forest stands and to establish range of natural variability for various management objectives (Lundquist 1995). Disturbance profiles can be compared to a test used to measure human health known as a blood profile, a test that we are all familiar with from physical check-ups

Table 2.—Blood chemistry profile.

Test	Result	Reference range
Glucose	98	70–115 mg/dl
Urea Nitrogen	17	7–25 mg/dl
Creatinine	1.1	0.7–1.4 mg/dl
Bun/Creat Ratio	15.5	10–24
Protein, Total	7.0	6.0–8.5 g/dl
Uric Acid	4.6	4.0–8.5 mg/dl
Iron, Total	127	25–170 mcg/dl
Cholesterol, Total	194	<200 mg/dl
Cholesterol, HDL	31	>45 mg/dl
Cholesterol, LDL	133	<130 mg/dl

(table 2). In much the same way that a blood profile measures different blood components and compares current levels with a range of acceptable or optimum values, the disturbance profile looks at certain stand and gap components and compares them to a range of expected values. In order to make a meaningful diagnosis of the state of human health doctors need to know what the acceptable range of values is for each specific variable. So to when we attempt to estimate the health of stands we need to know whether or not the idex values we measure fall within an acceptable range, a natural range of variability. As used in disturbance profiles, range of variability could indicate minimum and maximum values acceptable for a specific management objective or the range of those variables we measure in functional ecosystems. One way to obtain this information would be to compute disturbance profiles for unmanaged, but disturbed, stands and determine the range of natural variability associated with natural disturbance regimes.

BLUE MOUNTAIN PLOTS

In order to test the utility of the disturbance profile concept, four 4-hectare areas (200 m × 200m), called plots, were established in the Five Points drainage northwest of the town of La Grande, Oregon in the Wallowa-Whitman National Forest. We then gathered data on four classes of indicators that we thought would be useful in establishing a forest health disturbance profile, canopy density, disurbance pathways, dead and down wood, and recolonizing vegetation.

Each plot was overlain with a 5m x 5m grid and at each grid coordinate an instrument called an optical densiometer was used to make estimates of canopy density. Variograms generated from these readings were used to compose two-dimensional diagrams of canopy density called patterned isopleths or gapograms. Threshold levels for differences in canopy density were set during data analysis to mimic stand conditions so that the openings indicated on the gapograms would relate to canopy gaps we could identify in the field. The units of measurement for this element of the profile are: canopy density and gap location, size, and shape.

After gapograms for each plot were generated they were used to locate individual gaps on the ground. An interdisciplinary team composed of forest pathologists, entomologists, wildlife biologists, and foresters then navigated to each gap, marked the gap boundary, and determined the disturbance pathway or pathways which had created that gap. The etiology of canopy gaps can be complex because cause/effect relationships are often not obvious. Two or more disturbance agents commonly interact to cause gaps. Measurements for this component were: predisposing factors, killing agents, and tree response. Each gap was also inventoried for dead and down woody material and recolonizing vegetation. The measurements for woody material included species, decomposition class, dbh of snags, and length of logs. Measurements for recolonizing vegetation were: abundance (percentage of ground covered) by vegetation layer.

Since the results of the fieldwork were not yet available we were unable to compose a profile for these paticular stands. When we do, however, we feel that the resulting disturbance profiles will serve as useful sources of values for ranges of natural variability of our selected indicators in unmanaged, disturbed (except by recent fire events) stand in the Blue Mountains.

MANAGEMENT USE

Managers will eventually be able to use disturbance profiles to help establish forest plan standards and guidelines . Ranges of index values would have to be constructed for various resources. The desired future condition for maintaining these resources might require forest landscapes or stand that have a certain combination of index values (profile) falling within the range of natural variability as described in the forest plan, (an example of a profile with hypothetical values for ranges of natural variability is provide in table 3). Existing stands would then be inventoried for actual values in each index and the existing and potential suite of disturbance agents. Disturbance network models would then be consulted to determine what manipulations could be done to make adjustments to the index values to more closely bring the stand towards the desired future condition

Table 3.—Disturbance profile.

Disturbance Index	Actual Value	Range of Natural Variability
Dominance	2.23	2.0–2.3
Canopy density	45%	0–60
Fractal dimension	2.56	2.5–2.7
Number of gaps	23	18–30
Contagion	3.5 (high)	2.5–3.0
Average gap area	16	15–20
Variogram range	450	400–500
Number of edges	40	50–75
Number of gaps	21	25–40
Shannon Weaver index	2.45	2.0–5.0
Shrub vegetation layer	80% cover	60–90

We believe that in the near future, application of the disturbance profile concept will be a useful tool for land managers interested in maintaining healthy, functioning ecosystems through the use of natural disturbance agents. In the future we anticipate using other technology such as remote sensing, among others, that will make gathering the necessary inventory data to develop disturbance profiles more expeditious.

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