1966 (WS 1), a 25% harvested patch-cut watershed with 6% of area in roads completed in 1963 (WS 3), and a forested control (WS 2), which was not harvested. Suspended sediment was sampled during and between storms. Bedload was measured annually in a stilling reservoir.

The variation of annual suspended and bedload sediment yields among watersheds has been great. Total yield over the period 1957 to 1985 was 73,000; 10,000; and 294,000 kg/ha in WS 1, 2, and 3, respectively. Over 80% of the entire 28-years sediment production in WS 3 occurred during two days in 1964 when a series of debris flows initiated at road crossings and scoured the channel to bedrock. Excluding this event, WS 1 has produced over twice as much sediment as WS 3 in the first 20 years following cutting.

The pattern of long-term sediment production from these three watersheds reflects their mass movement history. High sediment yields in WS 1 can be attributed to accelerated debris avalanche erosion after clearcutting. Seven debris avalanches (>75 m^3 each) moved soil downslope in WS 1 between 1964 and 1972. Total sediment yield following clearcutting has steadily declined in WS 1, while sediment discharge in WS 3 has remained quite low since the 1964 debris flows. Presumably these flows removed most of the available sediment from storage in the channel and supply of additional sediment from hillslope areas has been slow.

This study points up the importance of mass erosion events in controlling rates of sediment transport in mountainous areas. Timber harvest activities may primarily affect sediment production and transport in this region by changing the magnitude and frequency of mass erosion events rather than by directly affecting supply of sediment to the stream system. Conversion of natural or old-growth stands to managed plantations increases sediment delivery to streams and may pose risks to downstream aquatic and riparian resources.

Effects of Forest Land Use on Watershed Hydrology: A Modelling Approach

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Current interest in effects of forest management and other disturbances has prompted the need to develop large-scale hydrology

models that are sensitive to land-use changes. Such models should allow researchers to investigate the effects of alternative cutting patterns on stream flows and provide managers with a tool for planning harvest activities across the landscape. We currently are developing such a model for watersheds within the H. J. Andrews Experimental Forest in Oregon. Data sets collected at the Forest over several decades include hydrologic information on basins ranging in size from 10 to 6,000 hectares, a detailed meteorologic record, and a well-documented land-use history.

A computer model developed by the junior author called the Precipitation-Runoff Modelling System (PRMS) explicitly treats land-use effects. PRMS analyzes the watershed as a mosaic of hydrologic response units (HRUs) which are characterized by slope, aspect, vegetation, soil, and precipitation distribution. A water and energy balance are calculated for each HRU and flows are routed through the stream network utilizing energy and mass balance equations. Both daily and storm hydrographs can be simulated. By partitioning the watershed into HRUs, the effects of land-use changes over part or all of the watershed can be evaluated. Because the system is modular, it can be tailored to specific landscapes and climatic regimes.

We have begun to apply and test the model using the hydrologic data sets for three small (approximately 100 ha) watersheds located in the Andrews Forest, two of which were logged during the 1960s. If the model accurately simulates the measured hydrologic response of these basins, we will examine its applicability for larger streams. Included in this effort will be an examination of the effect of rain on melting snow under different forest stand conditions. When used with Geographic Information Systems (GIS), we expect the model to be able to predict the hydrologic response to different cutting patterns. For example, we will use the model to predict the hydrologic effects of dispersed as opposed to aggregated cutting units over the landscape. This will assist resource managers in minimizing risks of floods and other deleterious hydrologic effects when harvesting old- and second-growth forests.

Remote Sensing of Canopy Structure in the Pacific Northwest

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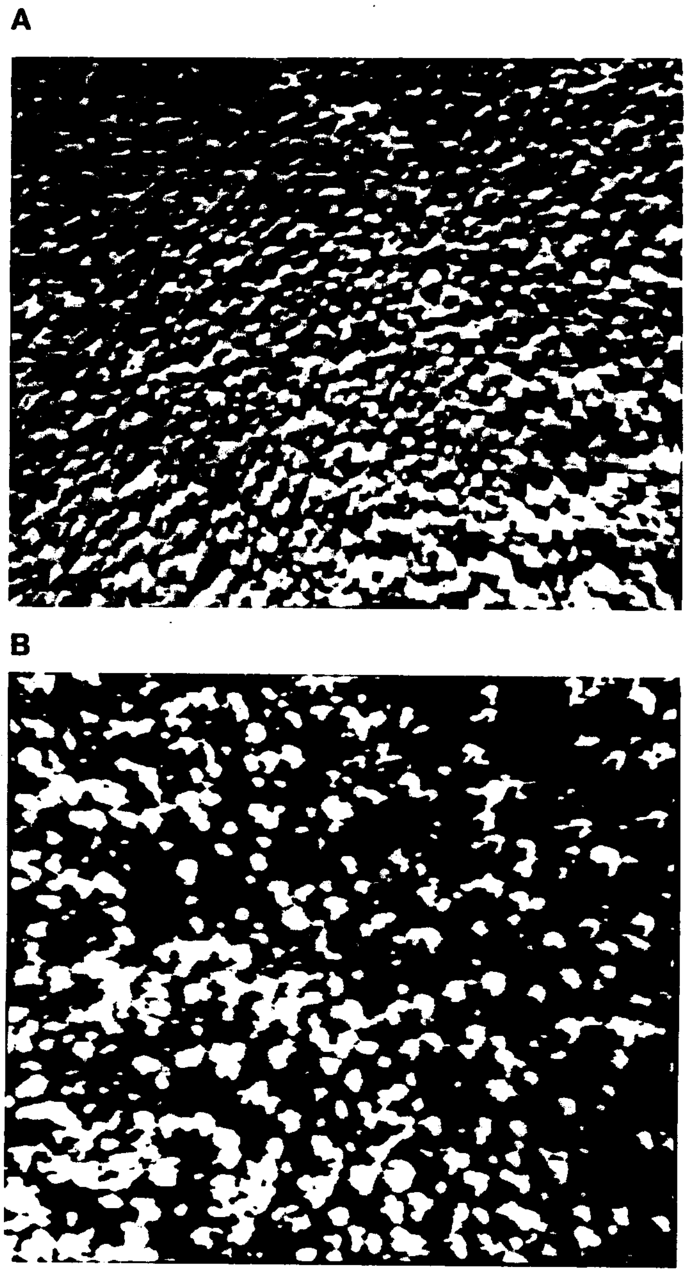
Disturbance histories and site conditions in the Pacific Northwest vary greatly. This has led to a complex pattern of canopy structures



in the conifer forests of the region. Consequently, many forest stands are mosaics of differently aged and structured patches (Fig. 1). Young and mature patches may have remnant old-growth trees emerging above the main level of canopy cover. Old-growth patches may have numerous canopy gaps in which younger, smaller trees are growing. Tall standing dead trees may be present in different numbers and there may be a variety of canopy species. Given the current debate over the amount and location of various forest structural conditions, an efficient means is needed with which to identify and quantify forest structural attributes across the landscape.

Remote sensing is a potential tool to inventory and map old growth and related structural conditions in the coniferous forests of the Pacific Northwest. Currently, however, little is known about what characteristics of forest canopy structure can be detected by remote sensing instruments. A study has been initiated to evaluate the utility of digital satellite imagery to provide information about tree size, density, and other canopy structural components. Imagery from the two commercial satellites known as Landsat (for land satellite program) and SPOT (Systeme Pour l'Observation de la Terre) will be used.

Landsat and SPOT imagery contain data on the reflective properties of Earth's surface features. For these data to be useful, forest patches with different structures, such as young and old growth, must reflect solar energy differently from each other. Some stand structural conditions are inherently more spatially variable than other stand conditions. As such, the more spatially variable forest patches may be expected to exhibit more spatially variable reflectance properties. On remotely sensed images, differences in spatial variation of reflected energy appear as differences in image texture. Thus, analytical tools with which image texture can be related to structural conditions are desirable. We are experimenting with a variety of analytical tools that can be used to evaluate, and capitalize on, image texture. These include semi-variograms (a geostatistical

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Fig. 1. Two distinctly different types of conifer forest structure in the Pacific Northwest: A) A 130-year old mature patch of densely-stocked and moderately-sized Douglas-fir trees. This patch has a continuous canopy layer and the trees are relatively uniform in size; B) A 450-year old patch of old growth having a multi-storied canopy. The upper canopy layer consists of large Douglas-fir trees and is broken by an abundance of canopy gaps containing smaller western hemlock trees. These aerial video images were acquired by Rich McCreight in an ultra-light aircraft in 1989 over the H. J. Andrews Experimental Forest in the central Oregon Cascade Mountains.

technique useful for evaluating the scale of spatial dependence and textural complexity), fractal dimensions (a tool for describing the scale of spatial pattern), textural algorithms (measures of local reflectance variation), and a model of canopy reflectance (this is variance driven and can provide estimates of tree size and density).

Responses of Vertebrates to Stand and Edge Type in Managed Forests of the Oregon Coast Range

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Timber management activities are supplanting natural disturbances as primary determinants of forest structure in the Pacific Northwest. These activities are often more intense and less variable than natural disturbances. Hence, managed forests are likely to have less structural complexity within stands and more uniformity in stand size, shape, and dispersion across landscapes than do natural forests (Franklin, J. 1990. A new forestry in the Pacific Northwest. *American Forests* Nov./Dec., pp. 37–44).

Accordingly, it is widely assumed that managed plantations support fewer vertebrate species than do natural forests. Moreover, the fragmentation of natural stands by timber harvest is hypothesized to reduce the availability of habitat for forest interior species. Unfortunately, few studies in the Pacific Northwest have examined habitat and vertebrate community patterns in natural and managed stands of similar age. Also little known is whether any animal species specialize on forest interior habitats and thus are likely to be sensitive to forest fragmentation.

We are studying forest structure, vertebrate communities, and edge effects in managed and natural forests in the Oregon Coast Range. The objectives are to: (1) describe forest structure within young forest plantations (2–8 yrs), older plantations that have achieved canopy closure (25–30 yrs) and natural mature forest (90–140 yrs); (2) quantify the types and configurations of vegetation used by each wildlife species within these forest types at the microhabitat and stand levels; and (3) determine potential vertebrate response to stand size and edge characteristics by quantifying the abundances of animal species, as a function of distance from stand edge, for two types of edges: open-canopy plantation/natural mature conifer edges and closed-canopy plantation/natural mature conifer edges.

Three study sites have been established for each of these two edge types. At each site, three parallel transects were placed perpendicular to the edges, each extending 260 m into the plantation and 400 m into the natural forest. Vegetation structure and composition, and animal abundance (birds, small mammals, amphibians, and reptiles) are sampled at 20 m intervals along the transects. The second and final year of field sampling was concluded in July 1990 and data analyses are now in progress.

The results of this work are expected to provide insights on the influence of stand and edge type on plant and animal community structure. Such insights will offer guidance on strategies for maintaining native plant and animal diversity in managed forests.

Responses of Wildlife Habitats to Forest Management and Climate Change: A Modeling Approach

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Biological diversity has emerged as a major environmental and scientific issue because: species are seen as economically and aesthetically valuable; patterns of diversity may serve as indicators of system response to climate and land-use change, and some organisms may strongly influence system functioning. The challenge for scientists and land managers is to develop techniques to study and manage biological diversity. We are modifying the forest succession model ZELIG (T. M. Smith and D. L. Urban. 1988. Scale and resolution of forest structural pattern. *Vegetation* 74:143–150) to study how vascular plant and vertebrate communities in the northwestern United States respond to land-use practices and climate change within forest stands and landscapes.

Like its parent model FORET (H. H. Shugart. 1984. *A theory of forest dynamics.* New York: Springer-Verlag), ZELIG simulates forest dynamics by accounting the establishment, annual diameter growth, and mortality of each individual tree on small model plots.

We are modifying the model by adding a subroutine that classifies