

NEW FOREST VEGETATION MAPS FACILITATE ASSESSMENT OF BIODIVERSITY INDICATORS OVER LARGE, MULTI-OWNERSHIP REGIONS

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ABSTRACT. Natural resource policy analysis and conservation planning are best served by broad-scale information about vegetation that is detailed, spatially complete, and consistent across land ownerships and allocations. In this paper I describe how a new generation of forest vegetation maps can be used to assess the distribution of vegetation biodiversity among land ownerships and land allocations at a regional scale. The vegetation maps contain detailed tree- and stand-level attributes of vegetation composition and structure for each forest land pixel in a regional landscape, which can be translated into vegetation biodiversity indicators at individual tree, species, community, and landscape levels. The new forest vegetation maps can be combined with models of stand and landscape dynamics to assess potential effects of alternative forest policies on biodiversity in future landscapes. Lastly, I discuss the importance of considering all land ownerships and allocations, including the matrix of semi-natural, managed forests, in regional biodiversity assessments.

KEYWORDS. Ecological indicators, gradient analysis, regional conservation planning, forest policy effects, Oregon Coast Range

Why Are Improved Regional Vegetation Maps Needed?

The conservation of biodiversity is globally recognized as a fundamental component of ecologically sustainable forest management (Santiago Declaration 1995). At the regional level, natural resource policy analysis and conservation planning are best served by broad-scale information about forest vegetation that is detailed, spatially complete, and consistent across land ownerships and allocations. Detailed forest vegetation maps are needed to evaluate the effects on biodiversity of current or proposed forest policies that govern the manipulation of forest vegetation and thus habitat, including policies such as the Northwest Forest Plan for federal lands, and state forest practices acts on state and private lands.

Broad-scale biodiversity assessments such as Gap Analysis (Scott et al. 1993) have not considered within-community variability in species composition (Hunter 1991), nor elements of structural complexity such as canopy layering, dead wood, and large remnant trees, that are key habitat elements for wildlife and other taxa on forest lands. These fine-scale vegetation elements are especially important in assessing the potential effects of forest management on biodiversity. The failure of broad-scale assessments to explicitly consider fine-scale elements of forest vegetation can be attributed simply to the lack of relevant vegetation data at this scale (Margules et al. 1994). Assessments have had to rely on maps of generalized forest vegetation types or stages of development derived from satellite image classifications.

Furthermore, most broad-scale conservation assessments have focused on the degree to which natural community types are represented in reserves such as national parks and wilderness areas.

Semi-natural, managed forests have not been considered, nor have nonfederal ownerships. The managed forest matrix contributes substantially to overall conservation efforts while simultaneously producing commodity values, and ideally is considered simultaneously with reserves in regional assessments (Hunter 1991, Lindenmayer and Franklin 2002). At the bioregional scale, patterns of land ownership have been shown to explain much of the variation in land management practices, and thus in current vegetation pattern as well as future trajectories of land cover change (Wimberly and Ohmann, in press; Spies et al. 1994, Turner et al. 1996, Radeloff et al. 2001, Cohen et al. 2002). Information about how vegetation composition and structure vary with land ownership therefore is essential to regional conservation planning.

In this paper I describe opportunities for regional biodiversity assessments created by a new generation of maps of forest vegetation. The maps are developed by integrating vegetation data from regional grids of field plots with satellite imagery and other spatial data to ascribe detailed vegetation attributes to each pixel in a regional map. I discuss how the maps can be used to assess the current distribution of vegetation biodiversity among land ownerships and allocations, and integrated with models of stand and landscape dynamics to assess potential effects of forest policies on biodiversity.

Desired Characteristics of a Regional Vegetation Map

A vegetation map was needed for the coastal province of Oregon as part of the Coastal Landscape Analysis and Modeling Study (CLAMS) (Spies et al. 2002). The goal of CLAMS was to develop tools and data to assess the effects of forest policies on biophysical and socio-economic responses, including biodiversity. Within CLAMS, a vegetation map was needed to describe current landscape conditions as input to stand and landscape simulation models that grow forests into the future under current and alternative forest policies. The vegetation map had to support response models for a suite of biodiversity indicators at species, ecosystem, and landscape scales, and be sufficiently detailed to be sensitive to forest management practices.

To fulfill these analytical needs, the vegetation map needed to consist of fine-resolution raster data (25-m pixels), with each pixel assigned a 'tree list' of live and dead tree densities by species and size, as well as data on understory vegetation. The covariance structure of the multivariate data within each pixel needed to be realistic, i.e. consist of species and structures known to co-occur in the real world; fine-scale vegetation pattern needed to be realistically represented; and the map needed to capture the full range of variability for the region. Ideally, spatial predictions would be ecosystem-based, accounting for relations among vegetation, physical environment, and disturbance.

The GNN Method for Predictive Vegetation Mapping

The Gradient Nearest Neighbor method of predictive vegetation mapping (Ohmann and Gregory 2002) was developed to meet the analytical needs of CLAMS. GNN combines concepts and methods from similar approaches (Moeur and Stage 1995, Tuominen et al. 2003) in novel ways. Direct gradient analysis (ter Braak and Prentice 1988) and nearest-neighbor imputation (Van Deusen 1997) are used to ascribe detailed ground attributes of vegetation to each pixel in a regional landscape. Vegetation data from a regional sample of field plots are integrated with spatial data on climate, topography, geology, ownership, and Landsat TM imagery. Plot data are from regional Forest Inventory and Analysis and Current Vegetation Survey inventories (Max et

al. 1996). A multivariate gradient model is developed that quantifies relations between ground and mapped data for plots. For each mapped pixel, scores on the first several CCA axes are then predicted from the mapped explanatory variables. For each pixel, the single plot is identified that is nearest in multi-dimensional gradient space. Lastly, the measured and derived vegetation attributes of the nearest-neighbor plot are imputed to the pixel. Maps then can be constructed for any vegetation attributes measured on the plots or derived from them. Alternative gradient models can be developed to optimize prediction accuracy for particular vegetation elements.

Map accuracy is assessed using cross-validation and other methods described in Ohmann and Gregory (2002). In general, spatial predictions are of excellent reliability at the scale of a large region, where proportions of the landscape in different vegetation conditions very closely match those estimated from the systematic sample of inventory plots. The GNN maps are moderately accurate for specific sites, similar to other Landsat-based maps. The GNN maps are appropriately used in assessments that inform planning and policy decisions at regional and subregional geographic scales, and not for tactical, project-level decisions.

Defining Elements of Vegetation Biodiversity

Once a tree list has been assigned to each pixel, regional maps can be constructed for any vegetation measure directly measured on the plots or derived from measured variables. Indeed, a strength of the GNN maps is the analytical flexibility provided by the detailed vegetation data. Vegetation measures, or indicators, can be defined by the user to maximize relevance to particular questions or objectives, and can be constructed to address levels of biological organization ranging from the individual tree, to communities or ecosystems, to landscape patterns (see Noss 1990). To illustrate the capability of the GNN vegetation maps, below I describe several elements of vegetation structure and composition used in recent analyses of vegetation biodiversity of coastal Oregon.

Potential vegetation types. Spatial predictions from a gradient model emphasizing species composition can be used to map vegetation types that are defined by the presence and abundance of tree species. In coastal Oregon, species gradients are strongly associated with climate (Ohmann and Spies 1998), and Landsat variables are not used in the GNN model. Because I defined vegetation types based on presence of tree species, resulting vegetation types can be interpreted as potential vegetation types (Daubenmire 1968) at the level of tree series. The vegetation types can be thought of as an integrated expression of multiple environmental factors that interact to influence tree species composition on a site, and at this level of classification and at the regional scale are relatively insensitive to disturbance (Ohmann and Spies 1998).

Species richness. Spatial predictions from a species-oriented GNN model also can be used to map tree species richness. Richness is the cumulative number of species occurring in geographic units such as watersheds (i.e., gamma diversity, *sensu* Whittaker 1972).

Current vegetation types. Current vegetation types defined by general physiognomic features that are sensed by the Landsat data can be mapped using a GNN model that incorporates both Landsat and environmental variables. In particular, conifer and hardwood vegetation types can be discriminated.

Successional stages. Spatial predictions from a gradient model that emphasizes stand structure can be used to map vegetation classes that correspond to stages of forest development that express the effects of past disturbances. Unlike most existing regional vegetation maps, the classification rules can incorporate detailed vegetation attributes such as canopy closure, mean and variability in tree size, and characteristics of the understory or presence of legacy trees. For example, old growth can be quantified using an index¹ that considers multiple vegetation characteristics in addition to stand age, such as density of large live trees, diversity of tree sizes, and abundance of large snags and down wood.

Tree-level elements of vegetation structure. Many tree-level structures represent important habitat components for species of wildlife and other taxa. Spatial predictions from GNN can be used to map vegetation elements such as the abundance of large live trees, snags, and down wood, including a characterization of whether the trees originated in the current stand or are legacy from a previous stand removed by stand-replacing disturbance (usually clearcut harvest).

Landscape pattern. The spatial arrangement of various vegetation conditions in the landscape can have important implications for wildlife habitat and ecological processes. Landscape metrics can be readily calculated from GNN maps by applying a ruleset to raster data using a moving window (e.g., see McComb et al. 2002), or by calculating aggregate spatial properties of the entire study area of geographic subregions such as watersheds.

A Continuum Approach to Regional Biodiversity Assessment

Once vegetation biodiversity indicators have been defined and mapped, the distribution of vegetation elements among ownerships and land allocations in a region can be assessed by intersecting the layers in GIS. Rather than considering only reserves, ownerships and land allocations can be classified along a continuum of management emphasis from biological conservation to commodity production. In this way, contributions of all components of a regional landscape to overall biodiversity can be accounted for. Indicators of vegetation biodiversity can be summarized for any geographical units for which GIS coverage is available, such as watersheds or ecoregions.

Implications for Simulation Modeling and Policy Analysis

The GNN maps of current vegetation provide the basis for simulating stand and landscape dynamics into the future under alternative forest policies (Spies et al. 2002). Potential future landscape conditions can be used to assess policy effects on indicators of vegetation and wildlife biodiversity over time. Trends in many biophysical responses of interest could not be assessed without the vegetation detail and fine-scale spatial heterogeneity in the GNN maps. For example, the maps enable application of wildlife habitat capability models that target very specific vegetation elements, such as snags for cavity-nesting birds, or the spatial juxtaposition of these elements in the landscape (see McComb et al. 2002). The map detail also allows the simulation of effects of specific silvicultural practices that target these vegetation elements. Research and technological advances on many fronts, including the new vegetation maps discussed in this paper, have ushered in a new era of regional assessments. Regional assessments now have the potential to be spatially complete and of unprecedented spatial resolution and floristic detail. By

¹Spies, T. A. and R. J. Pabst. Unpublished data.

portraying vegetation as multiple continuous variables, effects of specific management practices that target tree, stand, and landscape scales can be more realistically simulated. Collectively, these changes represent a major shift in how regional analyses are conducted and how inference is drawn for management. The multi-ownership perspective, especially when coupled with the forest dynamics perspectives of the landscape simulations (Spies et al. 2002), can reveal biodiversity threats and benefits that are not readily visible in analyses of single ownerships or a single point in time. In multi-ownership regions consisting of natural and semi-natural managed forest, all lands contribute to overall biodiversity.

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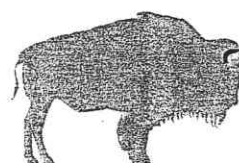
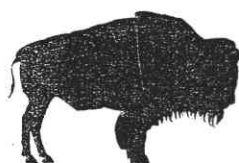
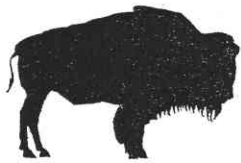
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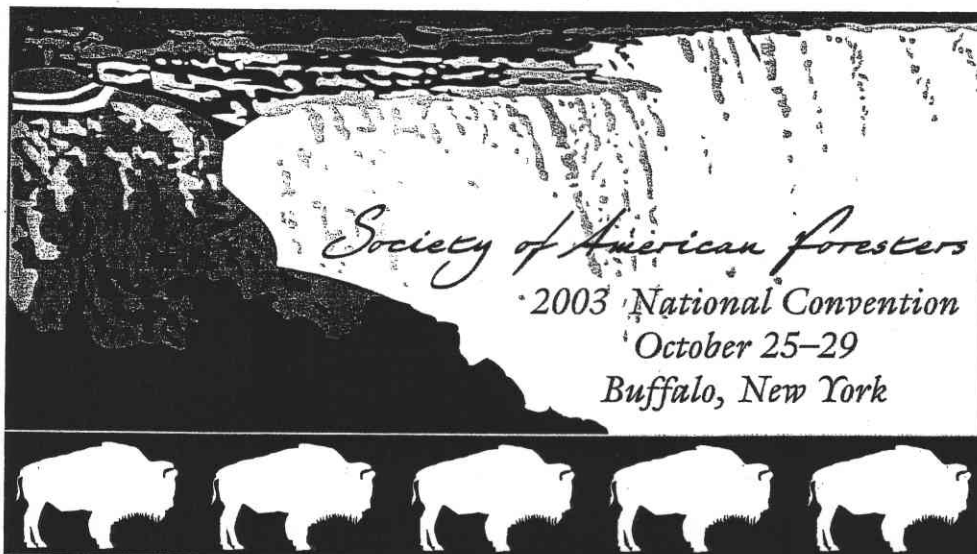
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