Chapter 11.—Projecting Watershed Condition with Interagency Mapping and Assessment Project (IMAP) Vegetation Data and Landscape Models

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Abstract

The Interagency Mapping and Assessment Project (IMAP) is a collaboration between Federal, State, and non-government partners in Washington and Oregon to build a collection of landscape-level data and state-and-transition models for conducting mid-scale assessments (5th-field hydrologic code watersheds and larger). IMAP data and models can be used for analyzing resource decisions and their effects on important regional programs like forest health and restoration, watershed condition, species' habitats, and long-term timber supply. The state-and-transition models are initialized with current vegetation data developed from Landsat ETM satellite imagery and other spatial data. Output from the landscape models provides a means for comparing likely outcomes of alternative management strategies and disturbance regimes on forested landscapes over time horizons from one to several centuries. In this paper, we provide an overview of the IMAP program and refer the reader to original publications for additional detail. We also present examples of IMAP data and models for assessing the vegetation component of watershed condition.

Introduction

The diverse landscapes of the Pacific Northwest are managed by different owners for different objectives. However, certain key forest management questions shared by all owners include managing fire risk, wildlife habitats, old-growth forest ecosystems, rangeland conditions, supply and demand of forest products, biomass supplies and carbon budgets, and others. State and Federal agencies in Washington and Oregon are currently conducting assessments and updating forest plans. For example, Oregon Department of Forestry (ODF) plans to publish a state-wide assessment of forest conditions in 2010, and to evaluate various policy scenarios and their implications for indicators of forest sustainability, timber supply and demand, conversion of wildland forest to residential use, and water quality (http://www.oregon.gov/ODF/RESOURCE_PLANNING/Sustainable_Forest_Indicators_Project.shtml). On National Forest lands, long-term planning strategies are being focused on opportunities for improving forest health through active management in the face of increasing fire risk and insect and disease damage. Effects of management practices also are being focused on for old-growth forests, habitat for northern spotted owls, marbled murrelets, and aquatic habitat quality—monitoring of these elements is a legal requirement under the Northwest Forest Plan for lands in the range of the spotted owl.

Policymakers and the managers who implement policy objectives need tools to both evaluate alternatives and to display potential outcomes, while accurately accounting for the wide variety of values people expect from both public and private lands. The most helpful tools are easy to use and provide a robust representation of the social, economic, and environmental implications of vegetative succession, management, and natural disturbances. The Interagency Mapping and Assessment Project (IMAP) is a multi-partner collaborative effort to develop consistent vegetation data, models, and analytical tools for conducting landscape-scale mapping and projections useful for assessing current and future landscape conditions. The objective is to enhance the capability of land managers and policymakers to understand likely outcomes of future management and disturbance scenarios, for the purpose of comparing the effects of alternative policy regimes and prioritizing treatment opportunities.

The purpose of this paper is to provide an overview of the IMAP project—its organization and objectives; the vegetation data—how it is developed and applied by IMAP, and how it can be acquired for use; and to show examples of the IMAP models and data for landscape-scale watershed assessment. The reader who wants additional IMAP design details should refer to the original sources referenced throughout this paper.

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IMAP Organization and Objectives

IMAP is a program for building integrated datasets, models, and tools for conducting landscape-scale assessment, monitoring, and planning in the Pacific Northwest Region, supported by current vegetation maps and associated spatial data. The IMAP project is being implemented in Oregon and Washington. The project is led by the USDA Forest Service Pacific Northwest Research Station (PNW), and at present includes as partners USDA Forest Service Region 6 (R6), Oregon Department of Forestry (ODF), Washington Department of Natural Resources (WDNR), USDI Bureau of Land Management (BLM), Oregon Department of Fish and Wildlife (ODFW), and The Nature Conservancy (TNC).

The concept of an interagency partnership was born from a need to foster cooperation on important landscape management issues affecting different agency entities and landowners at different scales. Ideally, planning efforts on lands with a variety of management objectives would all share a common collection of landscape data and models, to help ensure comparable answers to common resource questions. For virtually all landowners, a singular resource perspective is no longer suitable (Barbour et al., 2007a). The IMAP vision is to provide data and models capable of representing a variety of important management and policy scenarios, with sensitivity to both current and potential disturbance agents. The ability to model changes in regional fire risk under climatic warming scenarios, with attendant impacts on timber supply and carbon emissions is an example. Furthermore, a landscape perspective recognizes that regardless of which entity is conducting resource planning, analyses need to be landscape-level, multi-resource, and multi-owner in nature (Lettman and Hemstrom, 2008).

Landscape Modeling Approach

IMAP is designed for mid- to broad-scale assessment (individual 5th-field hydrologic code watersheds and larger). It uses wall-to-wall current vegetation data to populate an initial landscape, from which projections of future landscape conditions are made.

IMAP uses a state-and-transition modeling approach for projecting the effects of disturbance and management on landscape vegetation dynamics. This model type treats vegetation as combinations of broad cover types and seral states linked together by transition pathways resulting from natural disturbances, management actions, or growth and development. State and transition models are fairly easy to understand and use, are applicable at multiple spatial scales, and provide a reasonable representation of vegetative dynamics and responses to management and disturbance.

We use the Vegetation Dynamics Development Tool (VDDT) developed by ESSA Technologies (Beukema and Kurz, 1995; ESSA Technologies Ltd., 2005) to project how forest vegetation transitions between states in reaction to management and disturbance. A VDDT model simulates the probability of each acre being affected by natural succession or disturbance, moving each acre between linked states. The vegetation cover type/structure state classes, pathways describing movement between states, and transition probabilities (the stochastic frequency with which movement between states occurs in the model) are parameters established through expert knowledge and empirical data and models. Movements between states result either from changes due to successional dynamics such as regeneration, growth, and competition, or changes driven by disturbances—human management such as harvest activities and land use conversion, or natural disturbances such as wildfire and insect attack. Model projections are performed in a Monte Carlo environment for evaluating, displaying, and comparing outcomes on the landscape due to alternative management and disturbance scenarios.

Vegetation Data

For modeling purposes, a landscape is divided into environmental strata called potential vegetation types (PVTs) that describe particular combinations of environment, disturbance agents, and growth potential (Hemstrom et al., 2007). A VDDT model is designed for each single PVT within a study region (example, table 1).

Using a map of existing vegetation, the landscape to be modeled is initialized by assigning each acre within a PVT into state classes defined by cover type (defined by dominant tree species) and structural stage (defined by the average diameter of the dominant tree canopy, percentage canopy coverage, and whether single- or multi-storied) (table 2). In IMAP, consistent vegetation data are created using Gradient Nearest Neighbor (GNN) imputation. GNN uses tree-level data collected on Forest Inventory and Analysis (Forest Inventory and Analysis Program, 2006) and Current

Table 1. An example of the set of VDDT models defined by potential vegetation type. This one is in the 14-million acre Blue Mountains project area of northeastern Oregon.

Potential vegetation type	Predominant cover types
Xeric ponderosa pine	ponderosa pine; western juniper
Dry ponderosa pine	ponderosa pine
Dry Douglas-fir	ponderosa pine; Douglas-fir
Dry grand fir	ponderosa pine; Douglas-fir/grand fir
Cool moist mixed conifer	Douglas-fir; grand fir/Engelmann spruce; western larch/lodgepole pine
Cold dry mixed conifer	grand fir; Engelmann spruce/subalpine fir; lodgepole pine/western larch
Whitebark pine	whitebark pine

Table 2. Standard structure classes that along with disturbance history, define states in the IMAP VDDT models.

Tree size (DBH—inches)	Class description
1.0 to 4.99	Young tree
5.0 to 9.99	Pole tree
10.0 to 14.99	Small tree
15.0 to 19.99	Medium tree
20.0 to 29.99	Large tree
30.0 and larger	Giant tree
Canopy closure (percent)	**Class description**
0 to 9.9	Non-stocked
10 to 39.9	Open
40 to 69.9	Medium
70 to 100	Closed
Canopy Layers	**Class description**
1	Simple
2 or more	Multiple

Vegetation Survey (Max et al., 1996) inventory plots on forested lands, coupled with satellite imagery and other spatial data to populate 30-m raster maps with plot data (Ohmann and Gregory, 2002). The resulting vegetation map, along with other spatial layers used to stratify the study region by ownership and land allocation, define the initial conditions that assign acres to state classes for VDDT modeling.

Component processes of a GNN model are as follows (fig. 1).

1. Vegetation data in the form of live tree lists by species, heights, and diameters, snags, logs, understory, and fuels collected in the field on regional inventory plots.

2. The plot data are coupled with spatial data from remotely sensed and other sources. Along with Landsat ETM spectral bands and transformations, environmental and disturbance gradients used as explanatory variables include precipitation and temperature means and seasonality from climate models, ownership, geology and soils maps, and topographical attributes—slope, aspect, and elevation. At present, GNN vegetation maps are complete for Washington and Oregon using Landsat imagery from 2000 to 2001.

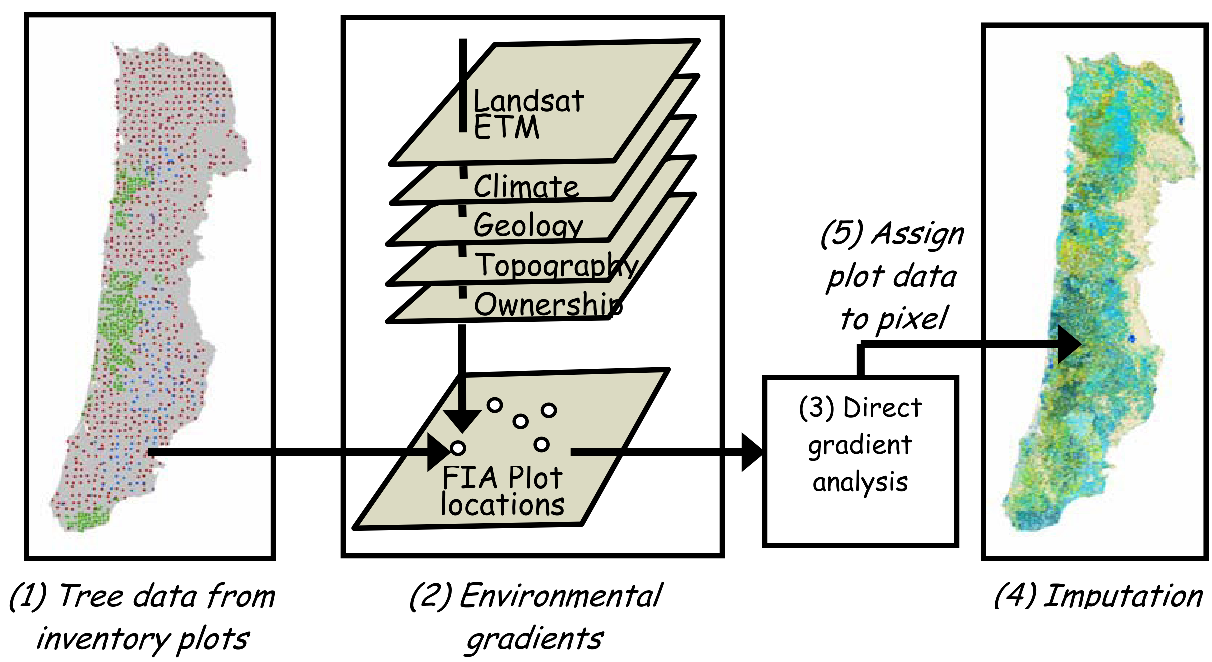

Figure 1. Overview of Gradient Nearest Neighbor (GNN) imputation approach. See text for number explanations.

3. A statistical procedure—direct gradient analysis—correlates the plot and spatial data to fit a model in multivariate gradient space.

4. For every individual 30-m pixel, the gradient model is used to identify the unique field plot that is the best “match”, given its combination of explanatory attributes. This plot is assigned, or “imputed,” to the pixel.

5. All vegetation attributes of the plot are then assigned to the pixel. The end result is a map where each pixel is attributed with all vegetation measures collected on its matching field plot.

Because all field data from the inventory plot is assigned to the pixel, the resulting map data are rich in vegetation attributes. The pixel data can be summarized spatially and thematically to meet various analysis needs. Data joined to each pixel can be any value that can be computed or summarized from the plot data. Many attributes are stored as core values in a GNN pixel attribute table accompanying the vegetation map. Others attributes can be computed by the user from tree data in the plot database. Examples include basal area, trees per acre, percent cover, species composition, large woody debris pieces and volume per acre, indicator species presence, and many others. All GNN data are accompanied by accuracy assessments conducted at the pixel, plot, and landscape scales, and intended to guide the end user toward appropriate use of the data.

For modeling purposes in IMAP, the 30-m existing vegetation pixels are aggregated upward to watershed units (5th-field hydrologic code, units averaging about 100,000 acres). Within watersheds, strata are developed using owner/land allocation spatial data. This stratification is useful for defining and modeling different management goals. Examples are timber-suitable Federal lands, Federal wilderness or species habitat reserves, and private industrial lands managed for intensive wood production. Summarizing the acres and outputs for these owner/allocation strata within 5th-filed watersheds generates useful information about the spatial distribution of landscape characteristics, without implying pixel or stand-level accuracy. This is necessary because IMAP vegetation data are simply not sufficiently accurate at the scale of individual 30-m pixels for most analyses.

Example 1: Examining Landscape Response to Active Fuel Treatment in Central Oregon

In an IMAP analysis, the regional landscape is divided into local geographic project areas that roughly represent physiographic provinces or ecoregions. After initializing the vegetation state classes for the project area landscape, and parameterizing the state-and-transition model for the potential vegetation type, we then simulate vegetation development over one or more centuries for comparing likely outcomes of alternative management and disturbance scenarios.

IMAP data and models have been used to examine the ecological consequences of thinning and prescribed fire on reducing the risk of large, severe wildfires in eastern Oregon (Wales et al., 2007). In a similar example in the 3.8 million acre Central Oregon Landscape Analysis (COLA), public workshops were held to develop modeling scenarios that reflect current management, as well as alternative scenarios testing various levels of active fuels treatments to move Federal forests towards historical conditions, in which single-story, old-growth forests were more prevalent than at present. The proposed treatment regime included periodic reduction of stocking by pre-commercial and commercial thinning, and regular prescribed fire. Treatment objective was to reduce vertical canopy structure and understory fuels while retaining large diameter trees. For the active fuels treatment compared with no treatment scenarios, we plotted the projected proportion of open-canopied stands dominated by large trees on the landscape, as well as timber harvest levels, and susceptibility to catastrophic wildfire (Hemstrom and Merzenich, 2006).

There are 36 HUC5 watersheds within four subbasins in COLA (fig. 2). We simulated each treatment scenario with 30 Monte Carlo simulations over 300 years, and then examined the results for the area as a whole, and for three of the individual watersheds. Under active fuels treatment, HUC 206 developed the largest percentage of area in old-growth forest having an open canopy (fig. 2). HUC 307 had much more area in medium and dense canopy, and very little open-canopy, large forest. H101 was intermediate between the other two. This example is used to help the reader envision how simulation results like these might be used to guide treatment priorities across watersheds. Forest managers also might be interested in overall differences in key attributes for the entire modeled landscape—for example, proportion of the landscape by forest condition (fig. 3a), potential timber harvest levels (fig. 3b), and potential fire risk reduction (fig. 4).

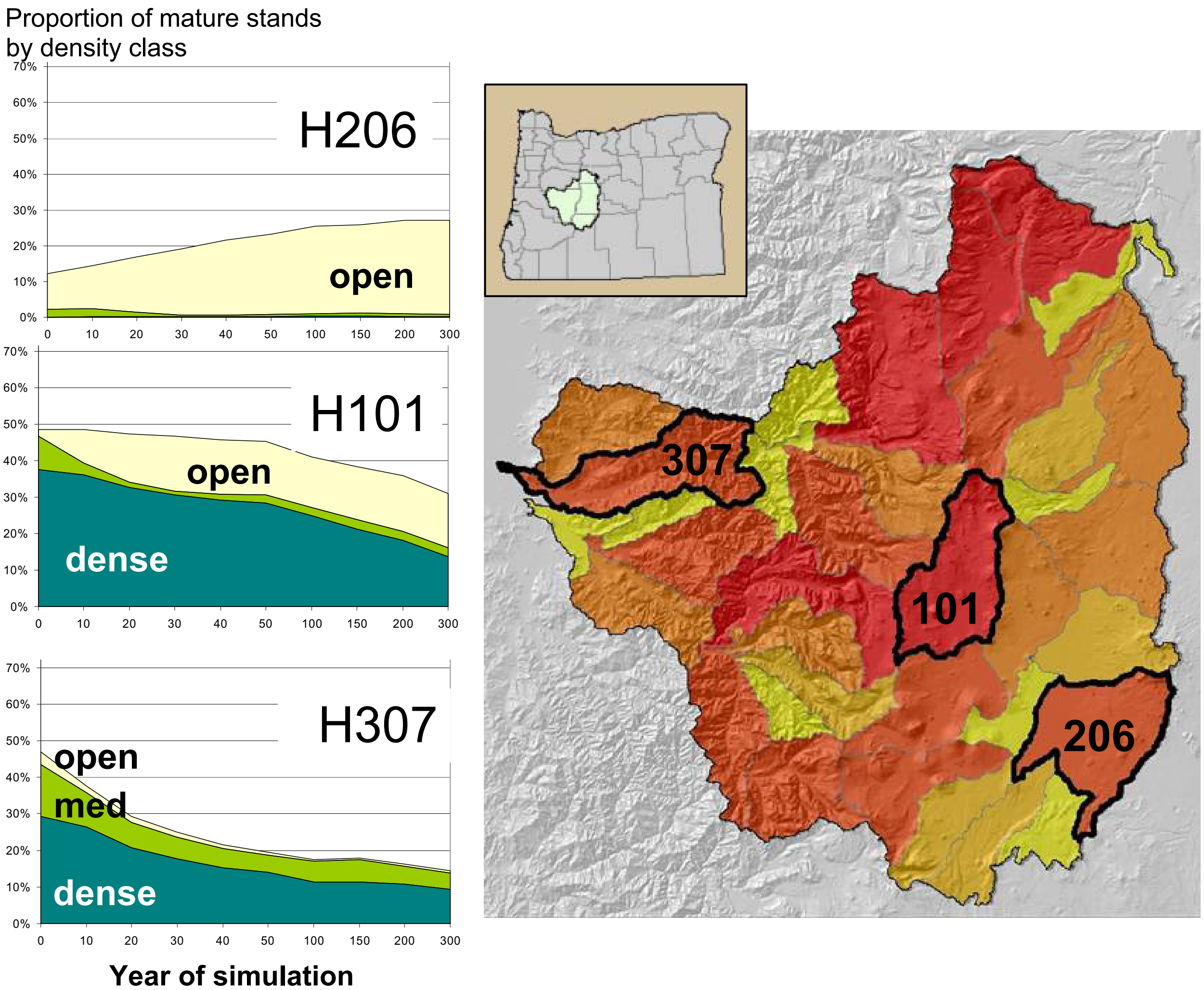

Figure 2. Simulation results for three watersheds in COLA of an active fuels treatment scenario. Shown is the proportion of mature stands in open (< 40% canopy cover), medium (40–70%), and closed (>70%) density classes after 300 years of simulated development and 30 random sequences of fire year intensity.

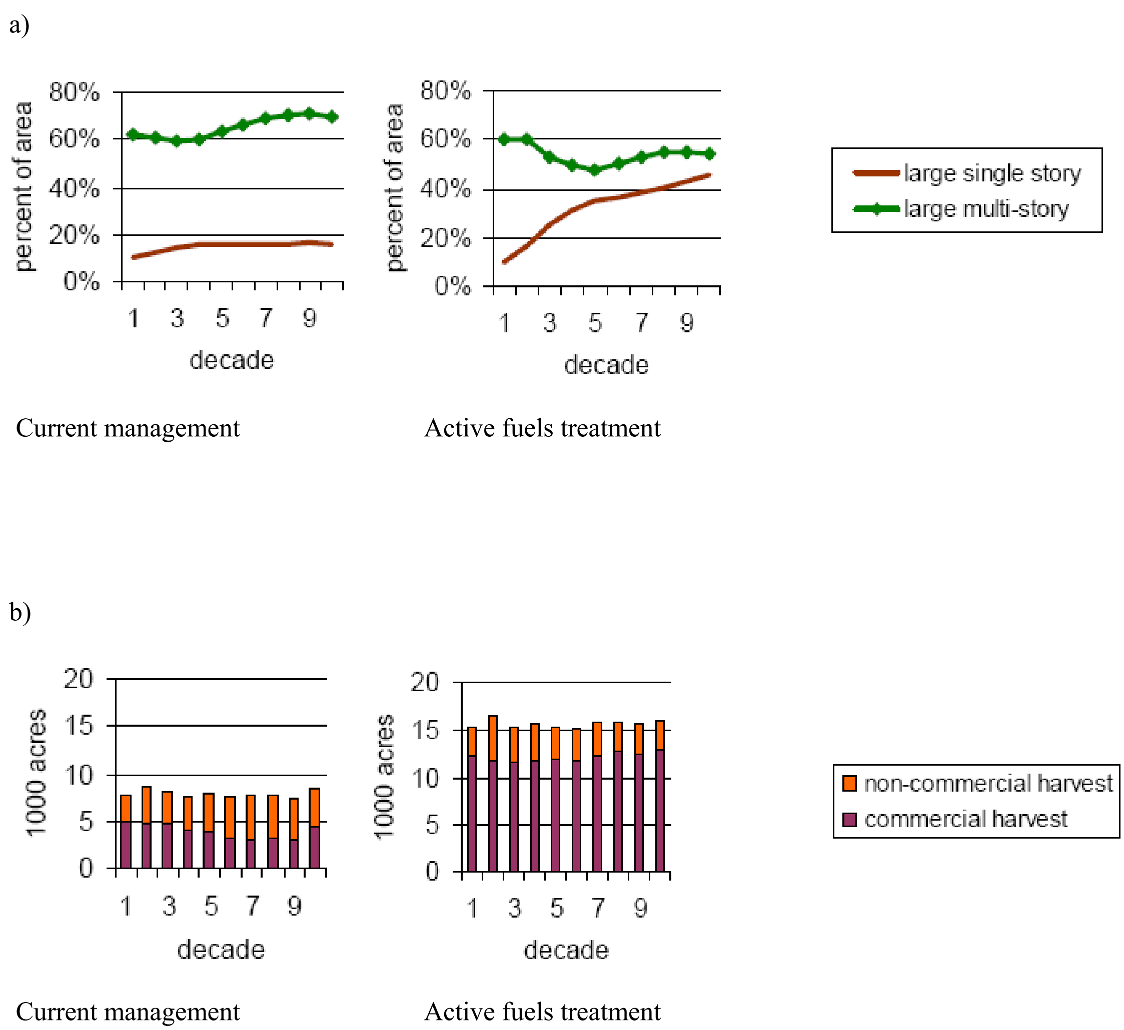

Figure 3. Summary results for COLA current management vs. an active fuels treatment scenario outlined in the text as Example 1. a) Percent of the COLA landscape occupied by single-storied and multi-storied old forest. b) Acres of timber harvested.

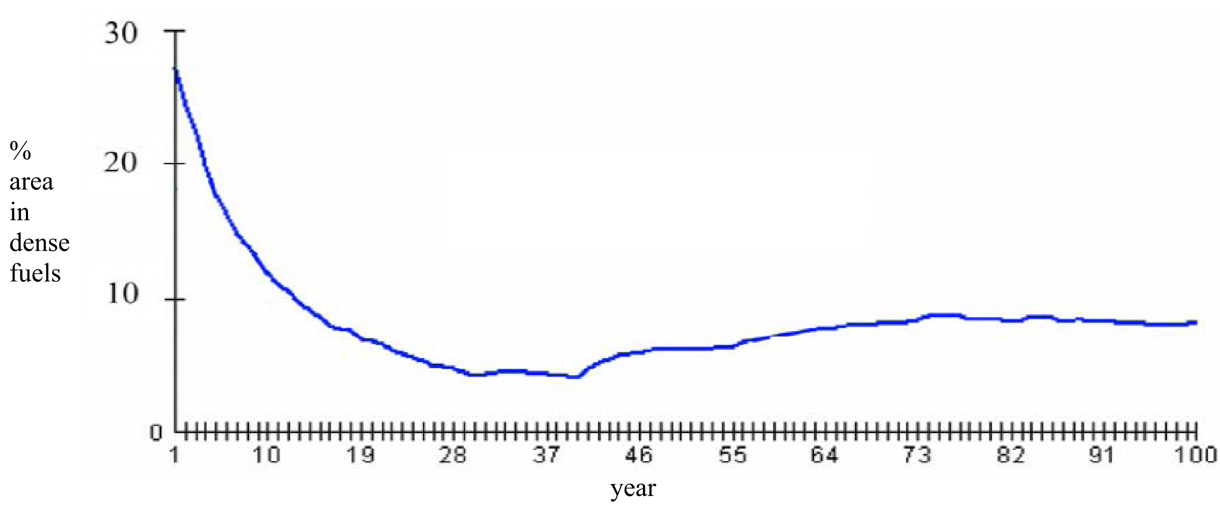

Figure 4. Change in dense fuels over time with aggressive fuel treatment. Based on simulation results for COLA study.

Example 2: Estimating Amounts and Distribution of Large Woody Debris

Large woody debris data are standard inventory attributes collected on FIA and CVS inventory plots and stored as core attributes of the GNN pixel database. In this example from the Oregon Coast Range, Ohmann et al. (2007) used the current vegetation data to summarize the amount of large woody debris by 5th-field HUC. They found that the distributions of large woody debris in this landscape were strongly correlated with disturbance history and ownership patterns, and only weakly with environmental gradients such as climate. Snag volume was most abundant in older forests, and diminished in young managed forests (fig. 5). Furthermore, although down wood volume was persistent in all age classes, log volume was highest in the oldest forests. The GNN vegetation data supported an assumption of increasing snag and log densities as seral condition moves from youngest to oldest forest.

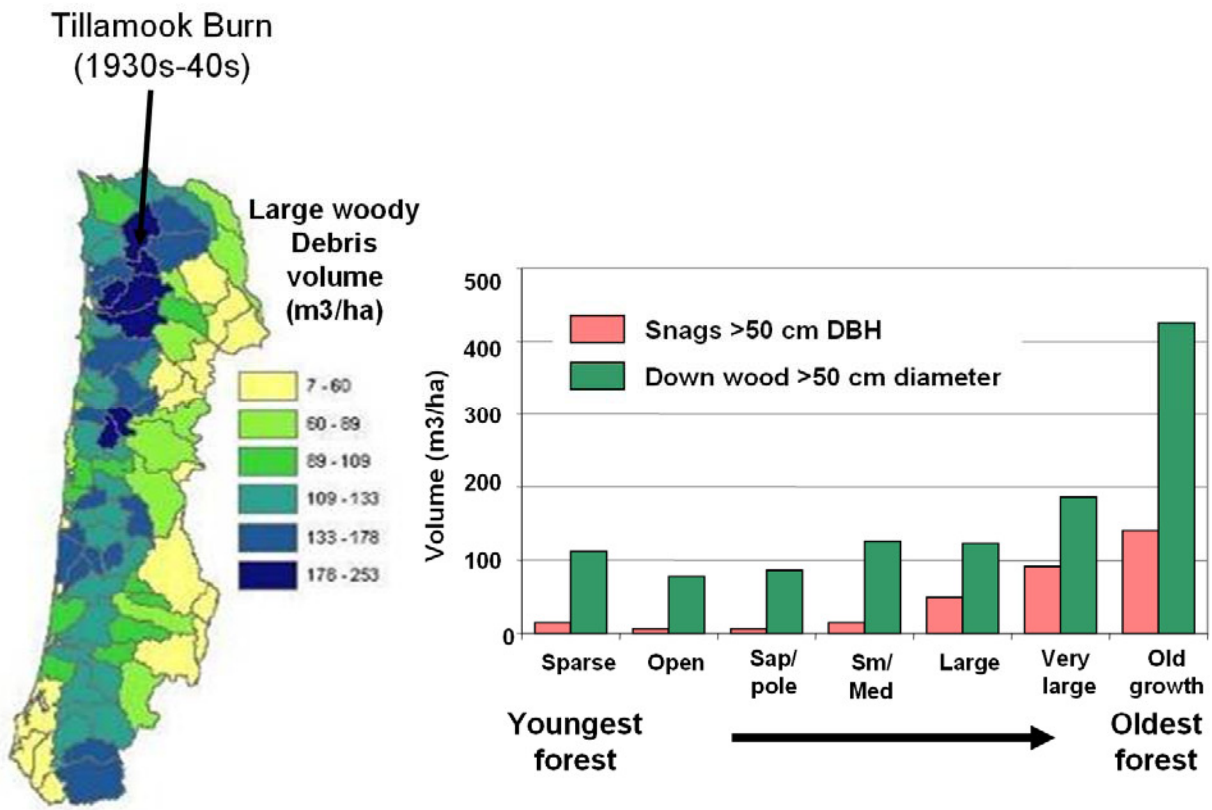

Figure 5. (left) Volume of large woody debris in the Oregon Coast range, by HUC5 watershed. (right) Large woody debris volume by forest age and structure.

Additional IMAP Examples from Published Literature

Wondzell et al. (2007b) used the IMAP state and transition model approach to evaluate the effects of disturbance and management on channel morphology and riparian vegetation in the Grand Ronde River basin in eastern Oregon. Their results linked declines in habitat quality for Pacific salmonids with degradation in riparian vegetation and channel conditions associated with Euro-American settlement. Other linked projects include an economic analysis of restoration projects (Barbour et al., 2007b), and the influence of native and non-native ungulate herbivores on forest structure (Vavra et al., 2007). Wondzell et al. (2007a) have summarized these studies as an integrated research package around riparian and stream ecosystems in the Upper Grand Ronde River watershed.

Acquiring the GNN Data

IMAP data for Washington and Oregon and supporting information can be downloaded from PNW's website (http://www.fsl.orst.edu/lemma). In Oregon, all map data available at the time of this writing are based on 2000–2001 imagery. In Washington, map data for NE Washington are based on 2000 imagery. In addition, GNN maps based on 1996 and 2006 imagery will be available in early 2009 for western Washington and western Oregon, and for 1994 and 2007 imagery for northwestern California (in the range of the Northern spotted owl).

The plot databases, data dictionary of the detailed attributes, map metadata, and accuracy reports are posted along with the GNN vegetation coverages. Map quality is reported using a number of quantitative assessments at the pixel, plot, and landscape scales. These include cross-validation, confusion matrices, kappa statistics, root mean square errors, observed vs. predicted value scatterplots, map vs. plot sample area distributions, map vs. plot sample area variation, and error maps. All these quality measures are intended to guide the end user toward appropriate use of the data.

Conclusion

IMAP data and models are continuing to be developed by the interagency IMAP partners. Data, models, and results for Oregon will be complete in 2010 and policy scenarios evaluated for a state-wide assessment to be published by ODF. Concurrently, IMAP data and models for Washington are proceeding and planned for completion around 2012. Please contact any of the authors for additional information on current IMAP projects.

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