

LAND COVER

Land Cover Map for Map Zones 8 and 9 Developed from SAGEMAP, GNN, and SWReGAP: A Pilot for NWGAP

James S. Kaqan¹, Janet L. Ohmann², Matthew Gregory³ and Claudine Tobalske¹

Introduction

As part of the Northwest Gap Analysis Project (NWGAP), a land cover map was generated for U.S. Geological Survey (USGS) Map Zones 8 and 9, which covers most of eastern Washington, eastern Oregon, and parts of western Idaho and northern Nevada. The map was derived from two primary components. The first was a combination of two large regional datasets: SAGEMAP covering eastern Oregon and Washington and southern Idaho, based on the 2000–2001 MLRC imagery, and SWReGAP covering the northern Nevada part of Map Zone 9. SAGEMAP and the Southwest Regional Gap Analysis Project (SWReGAP, Lowry et al. 2005) used regionally consistent geospatial data (Landsat ETM+ imagery and DEM derivatives), similar field data collection protocols, a standardized land cover legend, and a common modeling approach (decision tree classifier). The second component was a Gradient Nearest Neighbor (GNN) (Ohmann and Gregory 2002) modeling effort developed for forests and some woodlands, based on the network of forest vegetation plots in the region. These projects were integrated and improved to create the final maps, which provide information beyond what is contained in typical land cover maps. The goal of the project was to develop a land cover map and database for the area that included as much information as possible on the status of the vegetation and habitats, building from available information but applying some new techniques.

Classification Methods

SWReGAP mapped land cover for Colorado, Utah, Nevada, New Mexico, and Arizona, and was an important component of our project. The availability of the SWReGAP

map and the decline of the greater sage grouse (*Centrocercus urophasianus*) inspired Steve Knick and the USGS Great Basin Information Program to start the SAGEMAP project, to classify and map sagebrush and steppe vegetation in the West based on SWReGAP methods. For SAGEMAP, where shrub cover explains much of the variation in plant communities, a total shrub cover grid was developed to distinguish shrubland, steppe, and grassland vegetation. Following similar methodology used in trial regions of SWReGAP (Jennings et al. 1993, Huang et al. 2002) and by Washington Fish and Wildlife (Jacobson et al. 2000), overall percentage of shrub cover was estimated for each training site. Total shrub coverage was represented as a continuous variable but reclassified to five categorical types following guidelines suggested by LandFire (Rollins and Frame 2006). The continuous surface was generated using a separate classification and regression tree (CART) model.

All mapping efforts used classes based on the NatureServe Terrestrial Ecological Systems (ES) Classification (Comer et al. 2003), which focuses on natural and semi-natural ecological communities. For all mapping efforts, altered and disturbed land cover and land use classes were considered separately, based where possible on National Land Cover Database classifications and maps for nonforested areas, and on the GNN models for forested areas. Most new work involved modeling forest areas using GNN and non-vegetated and riparian ESs using CART.

Gradient Nearest Neighbor (GNN) Imputation

The Gradient Nearest Neighbor (GNN) method (Ohmann and Gregory 2002) uses multivariate gradient modeling to integrate data from regional grids of field plots with satellite imagery and mapped environmental data. A statistical model

¹Institute for Natural Resources and Oregon Natural Heritage Information Center, Oregon State University, Portland, Oregon.

²Pacific Northwest Research Station, USDA Forest Service, Corvallis, Oregon.

³Department of Forest Service, Oregon State University, Corvallis, Oregon.

is used to impute a suite of fine-scale vegetation variables to each pixel in a digital map, and regional maps then can be created for any vegetation attributes. Key advantages of GNN maps are: efficiency in mapping large areas at fine spatial and attribute resolution; analytical flexibility provided by vegetation data at the basic level of tree species, sizes, and densities; representation of full range of variability in regional maps; and maintenance of covariance structure (species co-occurrence) of plant communities. Until now, most GNN projects have emphasized mapping of forest structure. In this project we developed two GNN models: one emphasizing species composition, which we used to map forested ESs; and one emphasizing forest structure, which we used to map several forest structure 'modifiers' of the forested ESs (for example, average tree size, canopy cover). The vegetation data used in GNN modeling were from ~4,000 regional forest inventory plots installed by the Forest Service and Bureau of Land Management (BLM): the Forest Inventory and Analysis Program of the Pacific Northwest Research Station, and Current Vegetation Survey plots of the Pacific Northwest Region and BLM. For spatial data, we used mapped information on climate and topography in addition to Landsat imagery.

Results and Discussion

Integrated Map of Ecological Systems for Map Zones 8 and 9

We combined the GNN and SAGEMAP component grids into a single map of ESs for Map Zones 8 and 9. An example landscape in the Blue Mountains ecoregion of eastern Oregon is shown in [Figure 1](#). We also developed several modifiers of the ESs that we provided as separate grids: forest characteristics from GNN (multiple attributes joined to a single grid), and cover of shrubs, annual grasses, and perennial grasses from SAGEMAP. Examples of modifiers also are shown in [Figure 1](#).

Mapping Forested Ecological Systems with GNN

We developed two GNN-based models: (1) a 'species model' used to map 19 forested ESs in Map Zones 8 and 9 ([Table 1](#)), and (2) a 'structure model' used to map modifiers of the ESs that characterize forest structure, such as average tree diameter and tree canopy cover. We developed several accuracy assessment products to accompany the maps, addressing local (plot) and regional scales.

Table 1. Forested Ecological Systems in Map Zones 8 and 9 that were mapped using GNN.

[ESLF, Ecological System Life Form. **Ecological System geographic abbreviations:** CB, Columbia Basin; CP, Columbia Plateau; EC, Eastern Cascades; IMB, Inter-Mountain Basins; MRM, Middle Rocky Mountain; NP, North Pacific; NRM, Northern Rocky Mountain; RM, Rocky Mountain]

ESLF	Ecological System
4103	NRM Western Larch Savanna
4104	RM Aspen Forest and Woodland
4204	CP Western Juniper Woodland and Savanna
4205	EC Mesic Montane Mixed-Conifer Forest and Woodland
4228	NP Mountain Hemlock Forest
4232	NRM Dry-Mesic Montane Mixed Conifer Forest
4233	NRM Subalpine Woodland and Parkland
4234	NRM Mesic Montane Mixed Conifer Forest
4237	RM Lodgepole Pine Forest
4240	NRM Ponderosa Pine Woodland and Savanna
4242	RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
4243	RM Subalpine Mesic Spruce-Fir Forest and Woodland
4244	RM Subalpine-Montane Limber-Bristlecone Pine Woodland
4266	MRM Montane Douglas-fir Forest and Woodland
4267	RM Poor Site Lodgepole Pine Forest
4301	EC Oak-Ponderosa Pine Forest and Woodland
4303	IMB Mountain Mahogany Woodland and Shrubland
9170	CB Foothill Riparian Woodland and Shrubland
9190	NP Hardwood-Conifer Swamp

The predicted spatial distribution of ESs from GNN depends largely on how the training plots are classified into ESs. Because ESs are defined floristically based on existing vegetation, we relied on relative abundances of tree species to classify the plots, plus information on potential vegetation type and ecoregion as needed. We did not use data on understory vegetation (shrub and herb species) because these data were not yet available in a standardized database. We have now obtained these data and are using them in Map Zones 2 and 7.

In Map Zones 8 and 9, many ESs intermingle in the landscape ([Figure 1B](#)) as mosaics determined by interacting influences of physical environment and disturbance. This variation often is at a very fine scale, with field plots encompassing more than one ES. For this project we chose not to recognize within-plot variation in vegetation and ESs, and analyzed field plots as intact units. Because of this fine-scale variation, and the fact that classification to an ES often hinges on small shifts in relative abundance of the same few species in mixed-conifer forests, it is not surprising that the GNN maps contain some 'confusion' among these ESs. We conveyed this by presenting 'fuzzy' accuracy assessment statistics, where certain ESs are considered to be similar

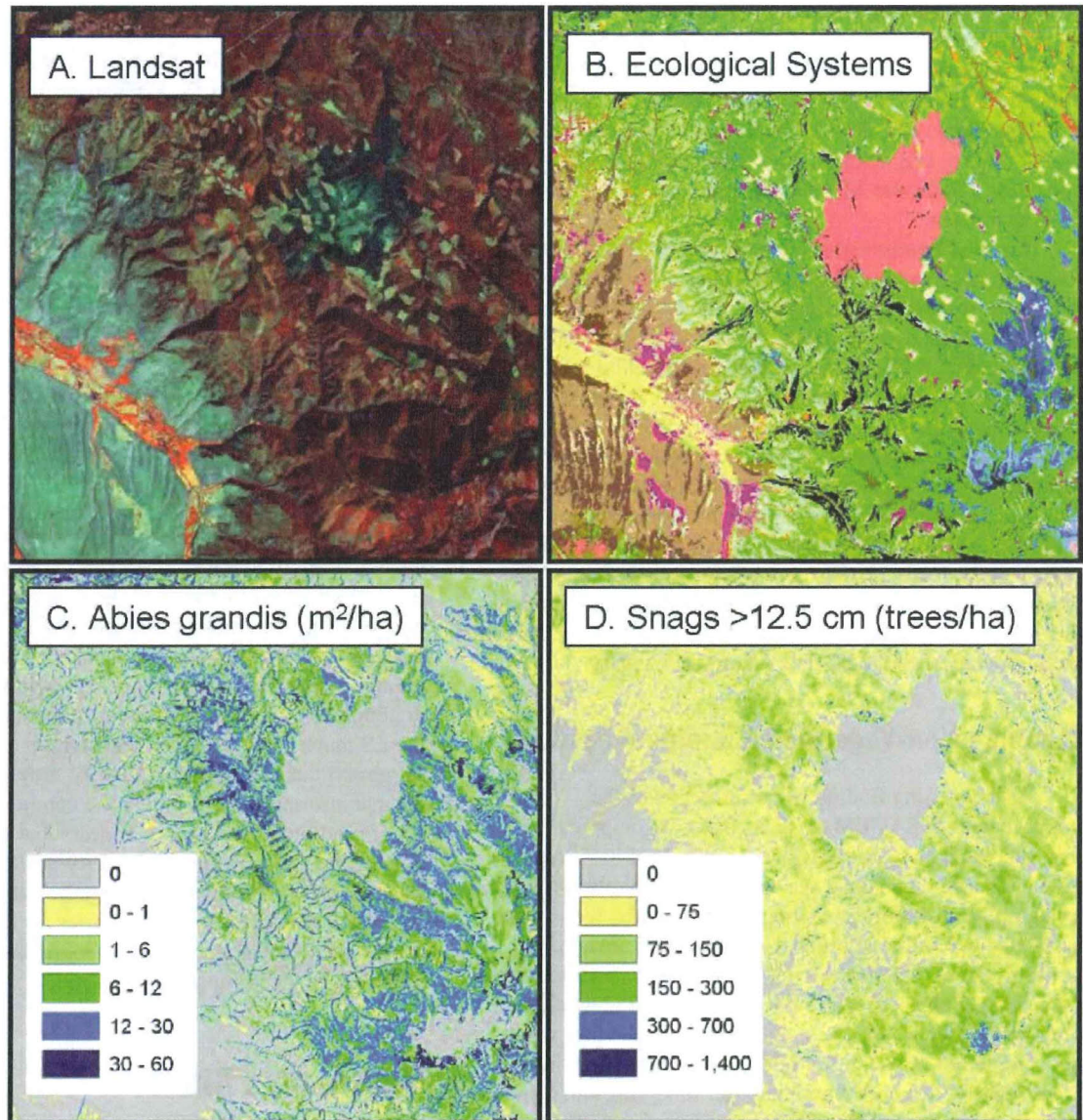


Figure 1. An example landscape in the John Day basin in eastern Oregon (location shown as blue square in inset map). *A.* Landsat imagers, summer 2000. *B.* Ecological Systems (legend not shown) combined from GNN and SageMap. *C.* Abundance (basal area) of *Abies grandis* from GNN species model. *D.* Snag density from GNN structure model.

and hence 'correct' in a fuzzy sense. We also had difficulty mapping several ESs that are rare in the landscape and lack sufficient plot data, primarily riparian and other hardwood types such as aspen and mountain mahogany. We applied some local editing to the final integrated forest/nonforest ES map to 'burn in' some of these ESs from the SAGEMAP or SWReGAP grids.

Another difficulty that faces all land cover mapping projects relying on Landsat imagery is the discrimination of forest from nonforest. Disturbed forest sites (for example, recently clearcut or burned) are not readily distinguished from true shrublands or grasslands, and areas of naturally sparse trees (for example, juniper woodland) cannot be distinguished from grasslands and shrublands that lack tree cover. We expect there is confusion in our maps among the forest and nonforest ESs (as can be seen in [Figure 1](#)) but this has not been quantified.

We used Landsat-derived variables in the GNN model of forest structure but not in the GNN species model. Prediction accuracy for individual species and plant communities (and hence ESs) was actually reduced when Landsat variables were included. This is because a nearest-neighbor plot can be selected for a map pixel based on similarity in forest structure (the primary forest vegetation 'signal' in the Landsat data) whereas species composition may be a poor match for the location. In the GNN model of forest structure, including two-date Landsat variables resulted in slightly better accuracy for most measures of forest structure, but introduced fine-scale heterogeneity ('salt-and-pepper') to the maps that we deemed undesirable. Until we can explore the reasons for this result, we opted to provide a GNN map of forest structure modifiers based on single-date (summer) imagery.

Mapping Non-Vegetated Ecological Systems

An interesting finding of our project was the improvement in SAGEMAP data gained by mapping the non-vegetated ESs. The SAGEMAP plot locations were selected based on a landscape analysis of variables (climate, topography, elevation, and distance from roads) thought to be related to ES distributions. Non-vegetated areas were not sampled by SAGEMAP nor SWReGAP, which focused on vegetated areas. In particular, mostly barren lava flows, cliffs and canyons, ash beds, playas, and sand dunes were not sampled or mapped. For NWGAP, we modeled these areas separately, generating points for modeling and accuracy assessment using ancillary data. For example, ash beds provide habitat for a large number of rare, endemic plant species, and contain points from threatened and endangered species databases. This allowed us to identify many small ash beds on the imagery, which we used as training points. Cliffs and canyons were modeled using new 10-meter digital elevation

models, and the results corresponded exceptionally well to the large known cliff and canyon areas. The sum total of these non-vegetated areas is not very large, but their inclusion greatly improves the map's depiction of wildlife habitat. The accuracy of mapping these non-vegetated types is high enough (97 percent, Kappa of 96 percent; Kagan et al. 2006), and the time demands of independently modeling them is low enough, that adding this step to mapping arid landscapes seems exceptionally useful.

Mapping Riparian, Forest Structure, Weeds, Shrub Cover, and Conditional Variables

We were fortunate to have more than 3,000 riparian plots from a 12-year interagency effort to attribute riparian plant associations to different basins, stream orders, and valley types. Using data on the plant communities from the ESs and knowledge of the riparian vegetation, we were able to attribute the riparian plots to an ES and develop a separate riparian model and map. To model riparian ESs, we used a buffered, 1:24,000 layer for perennial streams, the valley profile created from a 10-meter DEM, the Landsat imagery, and a large riparian plot database. While the riparian grid has not been widely tested, it initially looks quite good.

By using GNN to develop modifiers of forested ESs, and by including the weed and shrub covers from SAGEMAP, we were able to provide new kinds of information describing the condition of many mapped ESs. This information is particularly important because habitat condition describes how wildlife use areas as strongly as the ESs themselves. For instance, to map a species such as the Vaux's swift, which require older trees and snags, grids showing average diameter or abundance of snags and woody debris are more useful than the ES maps showing what forest type is present. Initially, we suggested that it might be relatively simple to integrate the diverse information describing the condition of habitats into a set of modifiers. However, it appears that turning the ancillary information into a habitat suitability index usable over the five-state NWGAP area is likely to be very difficult, because suitability for different species varies, as does suitability for a single species over a very large geographic area. This clearly indicates the need for standards.

References Cited

- Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, S. Pyne, M. Reid, K. Schulz, K. Snowand, and J. Teague. 2003. *Ecological systems of the United States: A working classification of US terrestrial systems*. NatureServe, Arlington, Virginia.

- Huang, C., B. Wylie, C. Homer, L. Yang, and G. Zylstra,. 2002. Derivation of a Tasseled cap transformation based on Landsat 7 at-satellite reflectance. *International Journal of Remote Sensing* 23(8): 1741-1748.
- Jacobson, JE. and M.C Snyder. 2000. *Shrubsteppe mapping of eastern Washington using Landsat satellite thematic mapper data*. Washington Department of Fish and Wildlife, Olympia, WA. Available from http://wdfw.wa.gov/wlm/research/papers/shrubsteppe_map/shrubsteppe_map.pdf
- Jennings, M.D. 1993. Natural terrestrial cover classification: Assumptions and definitions. *Gap Analysis Technical Bulletin* 2. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow.
- Kagan, J.S., IA. Ohmann, MJ. Gregory, C Tobalske, J.C. Hak, and J. Fried. 2006. *Final report on land cover mapping methods, map zones 8 and 9*, PNW ReGAP. Institute for Natural Resources, Oregon State University, Corvallis, OR.
- Lowry, J.H, Jr., R.D. Ramsey, K. Boykin, D. Bradford, P. Comer, S. Falzarano, W. Kepner, J. Kirby, L. Langa, J. Prior-Magee, G. Manis, L. O'Brien, T. Sajwaj, K.A. Thomas, W. Rieth, S. Schrader, D. Schrupp, K. Schulz, B. Thompson, C. Velasquez, C. Wallace, E. Waller and B. Wolk. 2005. *Southwest Regional Gap Analysis Project: Final report on land cover mapping methods*, RS/GIS Laboratory, Utah State University, Logan, Utah.
- Ohmann, J.L., and MJ. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest neighbor imputation in coastal Oregon, USA. *Canadian Journal of Forest Research* 32:725-741.
- Rollins, M.G. and CK. Frame. 2006. *The LANDFIRE prototype project: nationally consistent and locally relevant geospatial data for wildlandfire management*. Gen. Tech. Rep. RMRS-GTR-175. Fort Collins: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 416 p.