PNW
Pacific Northwest
Research Station

Science FINDINGS

INSIDE

issue one hundred thirty eight / january 2012

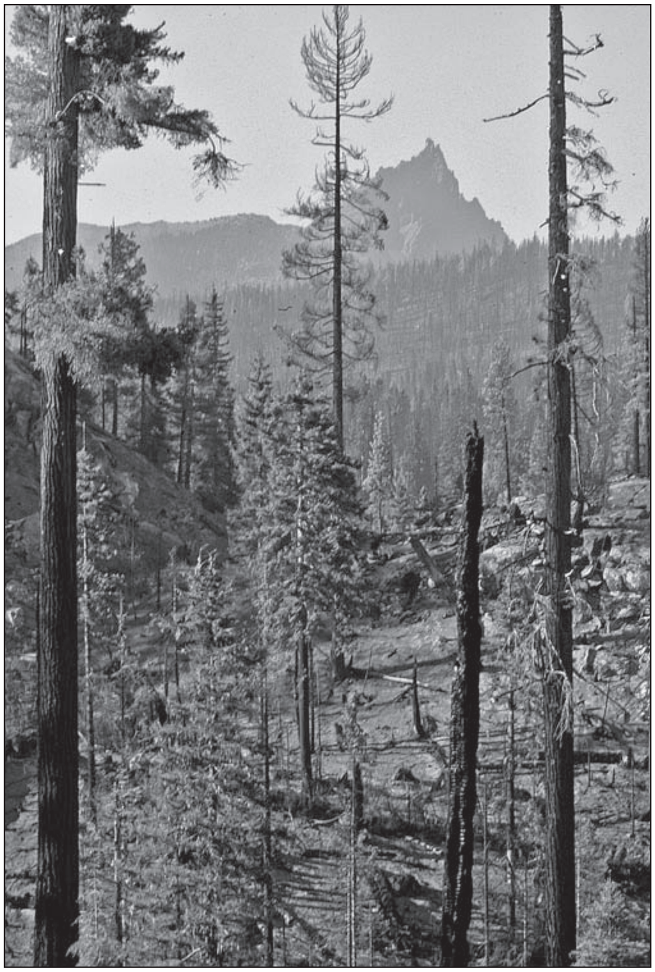
"Science affects the way we think together."

Lewis Thomas

Mapping Older Forests: Satellites, Statistics, and Boots on the Ground

"Our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible, and legally responsible."

—President Bill Clinton, directing the creation of the Northwest Forest Plan, 1993



Tom Iraci

In the past 15 years, fire was the leading source of disturbance in old-growth forest on federal land managed under the Northwest Forest Plan.

IN SUMMARY

The 1994 Northwest Forest Plan (NWFP) established a common management approach across federal land within the range of the northern spotted owl. It also established a monitoring framework to track, among other things, the Plan's effectiveness at maintaining and restoring late-successional and old-growth forests.

Station scientists Janet Ohmann and Warren Cohen contributed to the recently published 15-year report by the Interagency Regional Monitoring Team on the status and trends of these older forests of the Pacific Northwest. Ohmann, Cohen, and their colleagues used a novel mapping approach that integrates satellite imagery, time-lapse technology that tracks forest disturbances on an annual basis, and field surveys to provide a wealth of data on stand structure and composition previously unavailable to land managers.

The 15-year report also identifies disturbance trends across all forested lands in the region, which provides public and private land managers with a broader understanding of landscape patterns across multiple land ownerships. The amount of older forests on federal lands has remained fairly stable since implementation of the NWFP. Most loss stemmed from wildfire. On nonfederal land, timber harvests were the leading disturbance resulting in diminished areas of older forest.

The Pacific Northwest Region is using these data and mapping techniques to provide information to national forest planners as they revise their 10-year forest plans.

What's the status of older forests in the Pacific Northwest? It's been 18 years since the landmark Forest Plan for a Sustainable Economy and Sustainable Environment (commonly known as the Northwest Forest Plan or NWFP) became the guiding management plan for 24 million acres of federal land within the range of the northern spotted owl in Washington, Oregon, and northern California.

Janet Ohmann and Warren Cohen, research ecologists with the Pacific Northwest Research Station, along with partners from the Pacific Northwest Region and at Oregon State University, tackled this question. Specifically they wanted to know how forest conditions within the NWFP boundaries had changed since the inception of the Plan. To do this, they developed several novel techniques for analyzing satellite and forest inventory plot data, verifying it, and ultimately producing maps that illustrate the effects disturbance has had on forests in the region. This information contributed to the recently published monitoring report: *Northwest Forest Plan—The First 15 Years (1994–2008): Status and Trends of Late-Successional and Old-Growth Forests.*

"Land managers have never before had this level of detailed information across such a large land base," says Ohmann. Providing this information, however, was no easy task. To develop a comprehensive picture of older forests in the region, Ohmann, Cohen, and their colleagues analyzed change across 57 million acres of federal, state, tribal, and private land. This included 19 national forests and 7 Bureau of Land Management districts.

Tom Iraci

Established in 1994, the Northwest Forest Plan was designed to preserve and restore large tracts of older forest to facilitate the recovery of such species as the northern spotted owl, marbled murrelet, and Pacific salmon.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
P.O. Box 3890
Portland, Oregon 97208

Send new subscriptions and change of address information to:

pnw_pnwpubs@fs.fed.us

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Science Findings is online at: http://www.fs.fed.us/pnw/publications/scifi.shtml

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KEY FINDINGS

- From 1994 through 2008, the amount of older forests decreased 1.9 percent—from about 7.3 million acres to 7.1 million acres—on all federal lands covered by the Northwest Forest Plan (NWFP).
- Most losses on federal lands occurred within areas designated as "reserves" under the NWFP. Ninety percent of losses in the reserves were associated with wildfire.
- Timber harvesting accounted for less than a 1 percent (about 32,100 acres) decrease in older forests on federal lands. Wildfires claimed five times that amount (about 183,800 acres) during the same 15-year period.
- The NWFP assumed that federal lands would play the primary role in maintaining or restoring late-successional old-growth forests. Monitoring results confirmed this. Within the monitoring period, the amount of older forests on nonfederal lands fell by 13 percent versus 1.9 percent on federal lands from their respective baseline estimates. Across all land ownerships, 67 percent of older forests in the NWFP area now occur on federal lands.

MAPPING UNCHARTED TERRITORY

The NWFP remains a novel management effort that spans jurisdictional boundaries in the region. Adopted in 1994, it is a record of decision that modified forest management plans for Forest Service and Bureau of Land Management land within the range of the northern spotted owl. The NWFP attempted to balance the economic needs of communities reliant on the timber industry, while also preserving large tracts of older forests conducive to the survival of several sensitive species in the area, namely the northern spotted owl, the marbled murrelet, and the Pacific salmon.

A monitoring provision in the NWFP also led to the development of an Interagency Regional Monitoring Team to track and provide periodic reports on the Plan's effectiveness. The first monitoring reports that comprehensively reviewed local economies, species population and habitat status, forest preservation, and water quality were published in 2005 and 2006 and reported effects of the Plan's first 10 years of implementation. The 15-year report that Ohmann and Cohen participated in built upon the 10-year results while incorporating the latest techniques in assessing and mapping forest changes.

"We're right on the leading edge of using new technology," Ohmann says. She and her colleagues at Oregon State University employed a statistical mapping technique she pioneered called gradient nearest-neighbor (GNN) mapping. The GNN technique incorporates satellite readings of reflections from the Earth's surface and geophysical attributes (such as elevation, slope, sun exposure, seasonal temperatures, and precipitation) with vegetation data from known, surveyed plots. Those vegetation data are then projected onto locations that share similar geographic features but have not been surveyed.

The rationale behind GNN is that similar landscapes and environmental conditions will produce similar vegetation patterns. The "gradient" part of the formula allows researchers to give certain selection criteria a greater emphasis or weight when seeking the closest match between sampled and nonsampled parts of the landscape.

"The 'nearest-neighbor' isn't necessarily what's closest geographically, but rather what's most similar in this statistically derived 'gradient space,'" Ohmann says.

Although maps of older forests existed in the 10-year report, they weren't created using GNN. For the sake of more accurate before-and-after comparisons, Ohmann and her colleagues agreed that new baseline maps from 1994 should be created using the GNN method. To do this, Ohmann used her mapping technique and made it work backwards in time, something that had never been tried before.

"The problem is there are several kinds of errors in spatial predictions," she says. "In comparing two maps for two dates, differences between the maps may be due to errors in one or both maps, rather than real change on the ground. We had to take additional measures to minimize those errors."

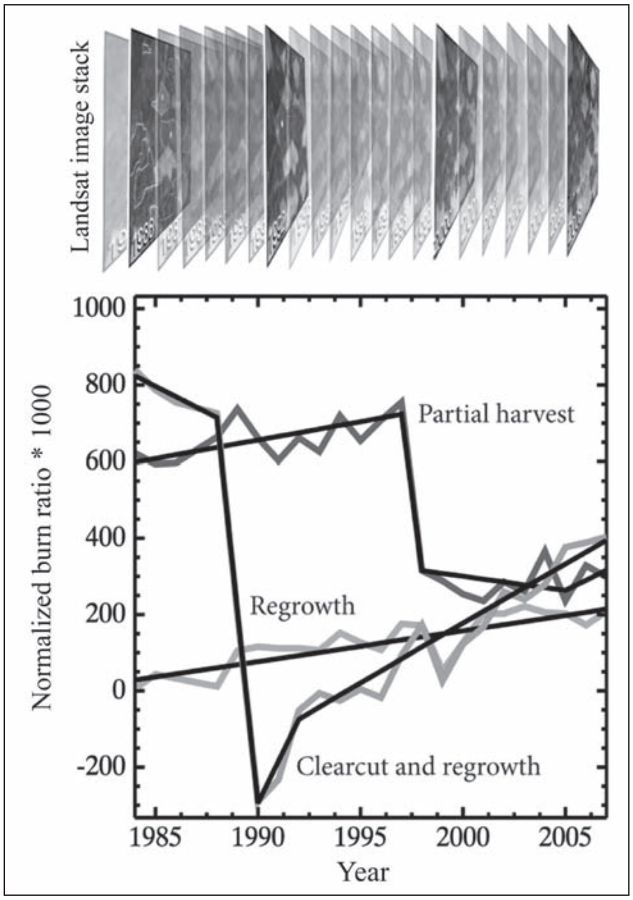
For that, she called upon the expertise of Cohen, who, with his colleagues at Oregon State University, specializes in tracking landscape and vegetation changes using satellite imagery.

LOOKING BACK IN TIME

The researchers chose 1994 and 2007 for northern California and 1996 and 2006 for Oregon and Washington for their before-and-after comparisons. Researchers then gathered Landsat satellite images taken between 1984 and 2008 from the U.S. Geological Survey.

The first Landsat satellite was launched in 1972 as a partnership project primarily between the National Aeronautics and Space Administration and the Department of the Interior. Subsequent satellites have been recording the Earth's surface data continuously ever since.

To the eye, Landsat images are a mosaic of multicolored squares representing visible and infrared reflections of the Earth's surface. In one view, vegetation typically appears in shades of yellow to blue, its brightness or hue dependent on the health and vigor of the vegetation. Soils with no or sparse vegetation typically range from red to dark brown or black, depending on moisture and organic matter content.



Changes to a landscape's vegetative cover can be analyzed through the amount of reflected light detected by satellite imagery over time. LandTrendr software assigns values to the amount of reflected light that researchers can then graph to help them determine what might be causing the changes.

Colors, however, can be distorted by cloud cover, sun angles or shading, even from variations in a forest's seasonal growth cycle. For GNN to accurately select nearest neighbors, these distortions have to be corrected.

The entire sequence of images, from 1984 through 2008, were processed through a series of algorithms in software called LandTrendr (Landsat Detection of Trends in Disturbance and Recovery) to remove the distortions. With the images now normalized through time, their colors and degree of reflected brightness could be converted into a composite score for each year. When these scores were plotted across time, the resulting line graph gave birth to a new form of Landsat image analysis called "temporal segmentation," explains Cohen.

"Landsat data has existed for a long time, but the conceptual approach used to temporally segment the spectral signatures through time is new and was the brainchild of my colleague Robert Kennedy at Oregon State University," Cohen says.

Graphed lines with abrupt breaks or sharp declines would indicate a major disturbance, such as a high-intensity wildfire or timber harvest. A more subtle or gradual decline in the graph might indicate a slower moving disturbance, such as a drought or insect infestation. Coupling GNN mapping with time-lapse sequencing not only let researchers look at how late-successional and old-growth forests were changing, but also provided clues about why these changes occurred.

"A landscape's condition is a function of the history on it," Cohen says. "Landsat data themselves can't tell you that, but LandTrendr disturbance mapping can."

As an added step to verify the accuracy of this new method for tracking disturbances, Cohen and his colleague Zhiqiang Yang of Oregon State University developed a software program called TimeSync that independently analyzed the graphical output from LandTrendr. Researchers also would compare Landsat time series images against Google Earth images as part of the TimeSync protocol. While more labor-intensive, TimeSync results were more precise and better adept at identifying smaller, more subtle changes in a landscape.

"When you create a map, you need some way to assess its quality," Cohen says. "TimeSync relies on human interpretation. LandTrendr has an automated process for finding change. Decisions are made statistically to find changes that are meaningful, but the process can result in incorrect answers. The value of human interpretation is we can integrate a lot of information on the fly, so we can see the same signal and interpret it in a different way. Human integration of complex data is more accurate."

For the 15-year monitoring report, Cohen's team used TimeSync to sample the mapped area independently to determine if and when changes happened. They compared those samples to the same locations generated from LandTrendr and found an 82-percent agreement rate across the full range of mapped changes.

Jeremy Fried

The amount of older forests estimated using gradient nearest-neighbor mapping was corroborated by estimates derived from Forest Inventory and Analysis ground surveys taken from 2001 to 2008.

DEFINING "OLDER FORESTS," ASSESSING CHANGES

For consistency, the researchers defined older forest the same way in the 15-year monitoring report as in the 10-year monitoring report: stands of trees where the average conifer diameter was 20 inches or larger and conifer canopy cover was 10 percent or more. This definition also mirrors the one used in the 1993 Forest Ecosystem Management Assessment that laid some of the groundwork for the NWFP.

"It's important to note the definition used for older forests because it was those measurements or dimensions that drove our results," Ohmann says. "A more ecological definition that incorporated measures of the diversity of tree species and sizes, as well as the presence of snags and downed wood debris, would have resulted in different findings."

Comparing the bookend dates of 1994/1996 and 2006/2007, researchers estimated a slight decline of older forests on federal lands from about 7.3 to 7.1 million acres. Despite the reported slight net loss of older forests on federal lands, the results are encouraging, says Ray Davis, lead monitor of old forests for the Interagency Regional Monitoring Team.

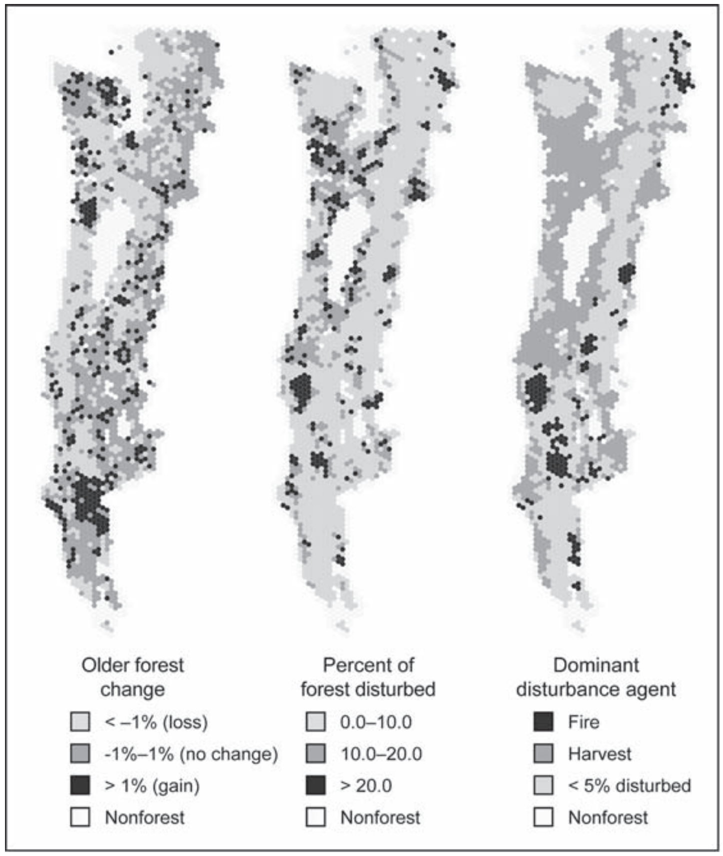
"The downward trend that preceded the Northwest Forest Plan has been reduced on federal land," he says. "And the losses since the Plan's implementation have been less than anticipated."

Researchers also note in the report that because the amount of change is so small in relation to the territory analyzed, it's also possible that some of the estimated losses might have been a reflection of errors inherent in the mapping method as opposed to real changes on the ground.

When the NWFP was implemented, some timber harvesting and periodic large-scale disturbances were anticipated, Davis explains. Results from the disturbance mapping indicate that most of the losses have been from large wildfires. Wildfires also were associated with 90 percent of older forests lost on land set aside in the NWFP as "reserves."

"The large reserves under the Northwest Forest Plan were designated as places to maintain and restore older forests, but that's where the losses have been the highest," Davis says. However, the reserve system was designed to be large enough to absorb these disturbances and still function for habitat connectivity across the owl's range, he adds.

Those losses should be offset as forests continue to mature, Davis continues. "I think we are just too early in our monitoring to expect—let alone detect—significant forest growth that will replace these losses," he says.



The Northwest Forest Plan covers 57 million acres in Washington, Oregon, and California.

This map sequence shows change in area of older forest (left) over the 15-year monitoring period, the proportion of forest disturbed (middle), and the predominant cause of disturbance (right).

"For now, we should be focusing on the losses, with the knowledge that the gains will come."

Ohmann agrees. "We're talking about older forests, so you have to take that into consideration," she says. "These are slow processes; you're not going to see a lot happen in 10 or 15 years in terms of forest conditions that take decades to centuries to develop."

Janet Ohmann

Near real-time, cross ownership mapping of forest disturbances, such as fire, provides valuable information to land managers developing management plans.

A WEALTH OF DATA

The maps created for the monitoring report were based on two variables used to define older forests. However, the gradient nearest-neighbor method captures and projects many more forest attributes collected through onsite field surveys, such as individual tree species, size and age, as well as the presence of standing and fallen dead trees.

"GNN data have more than 100 forest vegetation attributes, and any one—or combination—of those attributes can be turned into a map," Davis says. "The whole premise behind creating the data was to support Northwest Forest Plan monitoring, but it has much more potential use. It's so unique."

It hasn't taken land managers long to recognize the value of the data. Ayn Shlisky, the regional forest planning analyst for the Pacific Northwest Region, is using the maps and associated information. She is sharing it with national forest representatives as they revise their respective forest plans that will guide each forest's land management direction for the next 10 to 15 years.

"The underlying technology for developing these maps is cutting-edge," Shlisky says. "They've made a huge contribution to forest planning."

Much of forest planning revolves around determining a desired condition for the forest, and then developing a strategy that results in that desired state, Shlisky explains. "By having empirically derived data, we're able to more accurately project how management actions may affect the future landscape," she says. Even by taking into account forces of nature that seem out of the control of land managers.

Integrating the disturbance mapping with the GNN data has been a real boon for forest planners, Shlisky says. "Knowing that wildfire is the number one cause for losses of older forests in federal reserves can help land managers make concrete land management decisions," she says. "By looking at historical fire data and knowing the average frequency and size of fires, you can decide that you might want a certain amount of prescribed burning, or to suppress fire in a certain area, or thin certain stands (of trees) to make them more fire resistant."

And because the maps now contain data for both federal and nonfederal sites, forest planners can consider how their management decisions might fit into a broader landscape.

"Having wall-to-wall maps encompassing all ownerships that are seamless and consistent is rare, but valuable," Davis says. "What happens on adjacent areas often has effects and consequences on neighboring lands."

LAND MANAGEMENT IMPLICATIONS

- Wildfire was the most significant agent of change in older forests on federal lands. This information may contribute to land management decisions regarding fuel treatments and fire suppression.
- Extensive mapping of forest dynamics allows policies and management prescriptions to be kept relevant by adapting to observed forest change across all land ownership in near real time.

> *"We can now send instruments of all kinds into the ionosphere, and by transmitting their readings back to ground stations, obtain information which could not possibly be learned in any other way."*
>
> —Sir Arthur C. Clarke
> *Wireless World* magazine, February 1945

FOR FURTHER READING

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Landscape Ecology, Modeling, Mapping and Analysis. www.fsl.orst.edu/lemma/. Repository of maps and data collected for the 15-year monitoring report.

Laboratory for Applications of Remote Sensing in Ecology. www.fsl.orst.edu/larse/. Contains research and links to remote sensing tools and data.

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WARREN COHEN is a research ecologist in the Resource Monitoring and Assessment Program of the PNW Research Station and director of the Laboratory for Applications of Remote Sensing in Ecology, a collaborative project supported by the PNW Research Station and Oregon State University. His primary focus is translating remote sensing data into useful ecological information, particularly analyzing and modeling vegetation structure and composition across multiple biome types. He is a courtesy faculty member in the Department of Forest Science at Oregon State University and serves on the Landsat Science Team in support of NASA and the U.S. Geological Survey.

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