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Research Station

Science FINDINGS

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"Science affects the way we think together."
Lewis Thomas

INSIDE

Can We Store Carbon and Have Our Timber and Habitat Too?

"All government—indeed, every human benefit and enjoyment, every virtue and every prudent act—is founded on compromise and barter."
—Edmund Burke, statesman, 1729–1797

H.J. Andrews Experimental Forest, Oregon. Older trees store more carbon than younger trees. However, the amount of carbon being stored increases more rapidly in young forest than in older ones. Scientists assessed tradeoffs among various management scenarios with differing emphasis on carbon storage, timber production, and habitat for various bird and mammal species.

IN SUMMARY

With the passage of the Multiple Use Sustained Yield Act of 1960, the U.S. Forest Service has managed its 193 million acres of forest and grassland for multiple uses, including timber, watersheds, and wildlife. Using today's terminology, some of these purposes are considered ecosystem services, which encompass a breadth of benefits provided by forests, including their ability to absorb and store atmospheric carbon, a greenhouse gas linked to climate change.

National forests are now working to mitigate climate change, but the tradeoffs involved in managing for multiple ecosystem services are not well understood. Using landscape-scale datasets of forest vegetation, carbon storage estimates, and wildlife habitat profiles, scientists with the U.S. Forest Service Pacific Northwest Research Station simulated the effects of various management plans on timber harvests, wildlife habitat, and carbon storage in forests of the western Cascade Range.

They found that ecosystem services may be complementary, competitive, or neutral (e.g., a change in one service has little effect on other services). For example, carbon sequestration is potentially competitive with timber harvests and creating wildlife habitat for the western bluebird, but can be complementary to maintaining habitat for the northern spotted owl and the red tree vole. By using this tradeoff-management framework, land managers will have a better understanding of the multiple ecosystem services a management plan may provide.

We ask a lot of our national forests. They are our recreation destinations, while providing habitat for numerous wildlife and plant species. They are a source of timber that supports jobs for rural communities and our cities' water supplies. And they are vital in our nation's efforts to address climate change. "Forests store most of the carbon on the Earth's surface, so forests are really important from a carbon perspective," says Warren Cohen, a research forester with the U.S. Forest Service Pacific Northwest (PNW) Research Station.

The 2012 Forest Service Planning Rule requires the agency to mitigate and adapt to climate change. One solution is increasing the amount of carbon stored on national forests; however, national forests are not managed for a single use. The Multiple Use Sustained Yield Act of 1960 requires that national forests be managed for multiple uses, including "outdoor recreation, range, timber, watershed, and wildlife and fish." The challenge land managers face is writing forest management plans that address carbon storage and provide for these other ecosystem services.

What's unknown is the effect of favoring one ecosystem service over another. For example, how would favoring carbon storage affect timber production and wildlife habitat? Although harvesting trees decreases the volume of carbon stored on the landscape, maintaining an older forest capable of storing higher volumes of carbon does not provide suitable habitat for wildlife species that require younger forests or the open conditions created after a wildfire and harvest. Decreasing timber harvests on national forests to increase carbon storage in forests also could have a negative impact on timber-dependent rural economies, and increase pressure on private industrial timberland owners to maximize production to fulfill the market demand for wood products.

This knowledge gap between policy and the production of ecosystem services has been of interest to Tom Spies and Jeff Kline, scientists with the PNW Research Station, since they worked on the Coastal Landscape Analysis and Modeling Study. That project, which ran from 1996 to 2002, sought to understand how forest policies within the Oregon Coast Range affected the ecology of the landscape and the economic decisions of timberland owners. After the project's conclusion, Spies and Kline realized further research was needed to better understand the interaction of ecosystem service tradeoffs and management decisions. The 2012 Planning Rule provided just the opportunity.

KEY FINDINGS

- Forest management plans can be designed to deliver multiple combinations of ecosystem services on federal lands. The disturbance interval and harvesting intensity of these plans can affect carbon storage, the level of timber harvests, and wildlife habitat.
- When managing for carbon storage, tradeoffs exist between timber harvests and habitat for wildlife species, depending on how often harvests are conducted, the scale of the harvest, and the habitat needs of the widlife species affected.
- The carbon-habitat relationships vary from competitive to complementary and reflect niche breadth and specific species' needs. Managing forests in the western Cascade Range for high levels of carbon storage produces habitat for the northern spotted owl, olive-sided flycatcher, and red tree vole, but these conditions may not be suitable habitat for the Pacific marten, pileated woodpecker, and western bluebird.
- On industrial forest lands, management plans that call for 40- to 80-year rotations with wildlife tree retention represent a small fraction of management options that can deliver multiple ecosystem services.

"With the Planning Rule's focus on storing carbon and meeting carbon goals, it occurred to me that the agency has other goals for the land that might have negative impacts on carbon storage," says Spies, who is also a forest and landscape ecologist. "I thought it was important to help clarify what those tradeoffs could be, because as a land management agency, the Forest Service rarely manages everything for just one particular objective; it has multiple objectives."

As an economist, Kline, sought to bring the often overlooked value of economics to the tradeoff-management discussion and explore all the possible combinations in which ecosystem services could be delivered, rather than focus on an either-or management approach such as simply whether to harvest. "In economics, we tend to want to look for solutions," he says. "What are the different combinations we can have, and is there a combination that we can agree on. You can't have that discussion until you have a sense of what different combinations are possible."

Although there were models that analyzed the effect of forest management activities on carbon storage, they didn't include a robust set of forest management scenarios that considered the harvest intensity or the frequency of harvests. Nor did the models account for how carbon storage affects wildlife habitat. There are a number of endangered and threatened wildlife species whose habitat is early-successional forests or forest edges, and this habitat is created following a disturbance, whether a timber harvest, windstorm, or wildfire. Spies and Kline realized a new approach was needed to analyze the interaction between carbon storage, timber harvests, and wildlife habitat, and reveal the potential tradeoffs of selecting one ecosystem service over another.

Satellites and Computer Models—A Powerful Combination

In 2011, Spies received funding through the National Aeronautics and Space Administration's (NASA's) Terrestrial Ecology Program to create such a model. The program started in 2006 with an expressed goal to, "improve understanding of the structure and function of global terrestrial ecosystems, their interactions with the atmosphere and hydrosphere, and their role in the cycling of the major biogeochemical elements and water."

This Forest Service-NASA partnership is powerful, Spies explains: "We have a lot of data on the forests, and they have the satellites, remote sensing data, and the interest in looking at global phenomena with satellites. We can bring the data and models about forests and synchronize them with remote sensing."

The remote sensing data that Spies and his team drew upon was a combination of satellite imagery (Landsat) and light detection and ranging (LiDAR). For decades, satellite imagery has captured disturbances, such as timber harvests or wildfires. LiDAR is a remote sensing method in which a laser instrument mounted on a small aircraft sends 100,000 pulses of light per second toward the ground. Once processed, these incredibly precise data can provide a detailed, three-dimensional description of the forest below, including the amount of stored carbon. "LiDAR data is a really wonderful dataset for characterizing biomass on the landscape," says Cohen. "When you connect the LiDAR data to field plots, you essentially have a map of biomass that's very high quality."

Purpose of PNW Science Findings

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

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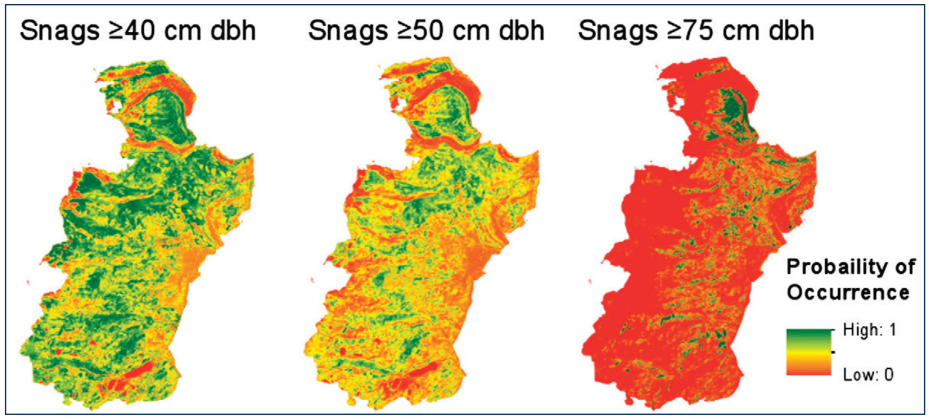
The forest vegetation and forest carbon data used in the model focused on nearly 400,000 acres in the western Cascades of Oregon. This landscape is owned by both private landowners and the federal government, and contains numerous forest types ranging from industrial timberland to mature forests. “Plus this region has been the epicenter for the tradeoffs that we’re looking at,” Cohen adds. “The tradeoff with carbon storage versus forest products is real here.”

To simulate these tradeoffs, the scientists modified an existing model called LandCarb, which was developed by Mark Harmon at Oregon State University. LandCarb simulates carbon storage at the landscape scale in various forest types. For this effort, it was modified to include wildlife habitat models for seven species of interest to management because they are endangered, threatened, sensitive, or indicator species. These seven species—the northern spotted owl, western bluebird, olive-sided flycatcher, pileated woodpecker, red tree vole, Pacific marten, and mule deer—live in a range of habitats from early-succession to mature forests.

Also added to the model were 38 different forest management scenarios ranging from maximum timber harvest to no harvest, and 13 different harvest intervals ranging from 25 to 500 years.

Spies says it took the entire 3-year-grant period to fine-tune calculations for the programming needed to modify the LandCarb model: “It took a fair amount of time and effort to figure out what we needed to change and at what landscape scale to model. To make the model say something about wildlife, we had to modify the model to include forest structure—the sizes of the trees and the canopy cover—features that are important to wildlife.”



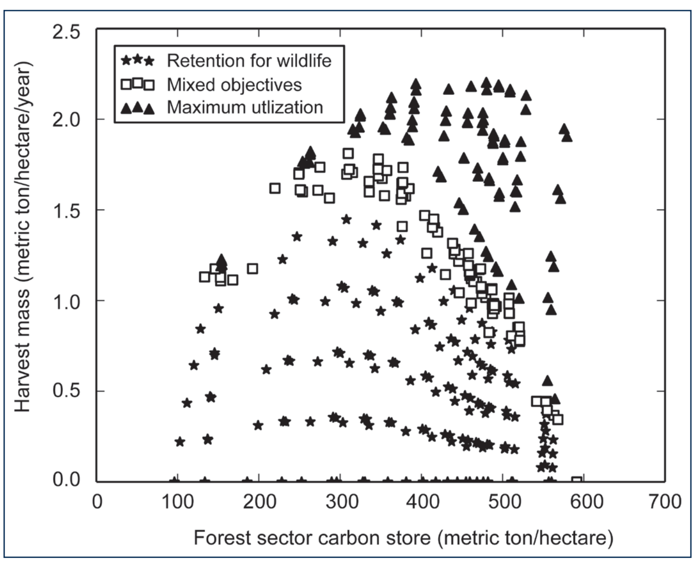
Adapted from Vogeler et al. 2016

Snag probabilities across 90,000 acres burned by the 2003 B&B Fire in central Oregon. The maps are based on data from satellite imagery (Landsat) and airborne laser scanners (LiDAR). This method can be used to map wildlife habitat—snags in this case—and forest structure, including carbon.

Many simulations of each management scenario were run from 1900 to present day. Using the remote sensing data, Cohen and his graduate students at Oregon State University compared the model’s simulations of the estimated biomass and carbon storage against the current totals to validate the results. “We then made changes to the model to make sure it’s producing a reasonable characterization of forest dynamics,” Spies says.

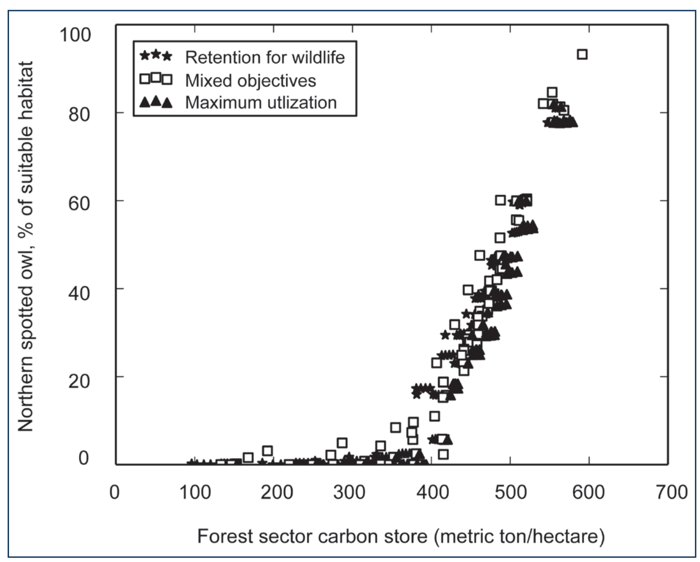
Generating accurate results, however, was only part of the challenge; the other piece was presenting the results in a way that is usable for land managers. Kline approached this challenge from an economics perspective that is a standard practice in his discipline: graphing each ecosystem service in relation to another. The result was a series of graphs displaying the joint production possibilities of carbon storage, timber harvests, and wildlife habitat, and the tradeoffs when choosing to produce more or less of each.

Spies says it was interesting to see how variable some of the relationships were among carbon, wildlife, and wood. “The plotted results weren’t all the same shape of curve, and revealed for the first time the possible combinations of carbon, wood, and habitat that can exist for any management objective.” Adding such combinations can give land managers a glimpse of where they have flexibility, options, and constraints.



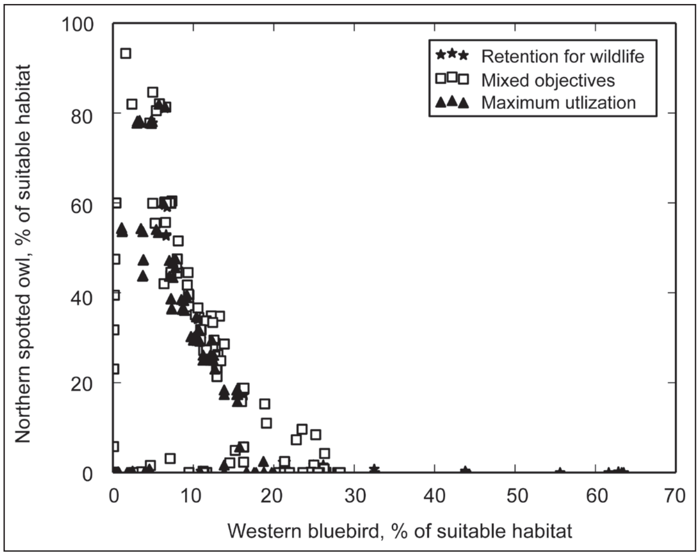
Adapted from Kline et al. 2016

This graph displays the joint production possibilities for annual timber harvest mass and forest sector carbon store. Each point represents a combination of harvest and carbon storage that results from a specific management scenario. Scientists modeled three types of management scenarios that emphasized wildlife habitat, maximum timber production, or a mix of the two.



Adapted from Kline et al. 2016

Joint production possibilities for northern spotted owl and carbon storage resulting from simulated management scenarios. Northern spotted owls prefer multistoried mature forests, which also tend to store more carbon. This means that providing northern spotted owl habitat and carbon store are “complementary” in regards to joint production possibilities.



Western bluebirds prefer vegetation conditions typical in young forests, whereas northern spotted owl prefer multistoried mature forests. Because of these differences in habitat preferences, the two species are considered "competitive" in regards to joint production possibilities. Managers generally cannot produce more habitat for one species without reducing habitat for the other species.

In the case of timber versus carbon, the team found scenarios that could provide for both carbon storage and timber harvests on private industrial forest lands and national forests. Currently, on many industrial forest lands, trees are harvested on a 40- to 80-year rotation. Depending upon the landscape and the objectives, adopting a 75-year-rotation cycle could fulfill the multiple objectives of both carbon storage and timber harvests.

The results also revealed that a management focus on storing carbon could result in complementary, competitive, or neutral tradeoffs for the seven wildlife species. A management plan focused on maximizing carbon storage, which may call for no harvests and maintaining mature forest conditions, is complementary to creating habitat for the northern spotted owl and the olive-sided flycatcher. In contrast, the western bluebird's preference for a low percentage of tree canopy cover with standing dead trees (snags) requires frequent disturbance to maintain the open forest conditions. Currently, a longer rotation period is applied on national forests; this scenario competes with creating habitat for the western bluebird as well as the mule deer, which also requires habitat with little tree canopy cover. Creating open conditions would require frequent harvests or disturbances, while retaining snags for the western bluebird. This management regime would not store as much carbon on the landscape as would longer rotations.

Using Multiple Disciplines to Tackle Complex Issues

While working as a research forester with the U.S. Forest Service Northern Research Station, Richard Pouyat grappled with similar issues concerning how urban forests could be managed to deliver multiple ecosystem services. When Pouyat later became the agency's national program lead for air and soil quality, he learned about Spies' team's tradeoff model at a conference. "I realized that this is the way we need to be going, especially in the National Forests System where, by statute, we are to manage our national forests for multiple uses," Pouyat recalls. "In the past, we used the term multiple use, and now it's not only multiple use—it's also value and ecosystem services."

Pouyat became a proponent of the tradeoff model, advocating for its value to other researchers. He anticipates other researchers eventually using the model once it is modified for specific landscapes. "If we want to use these multi-decisionmaking tools, they have to be adjusted for various ecosystems, and that adds to the challenge," says Pouyat, "but once you have a working concept for a tool, making those adjustments for each system will be easier than starting from scratch."

The project also demonstrates to researchers the value, and necessity, of incorporating multiple disciplines when developing tools to help policymakers and land managers answer complex questions. It is the visualization of tradeoffs that Pouyat says is really important for the use of this new tradeoff-management framework. "The team's work was able to show visually how you might be able to manage for multiple objectives, looking at the interplay of endangered or threatened species and various timber harvesting techniques," he says. "This is exactly what we need to do, and managers need to have these tools to be able to manage for all those objectives, which are required from our national forests."

"When we present this research, people don't immediately recognize it as economics," Kline explains. "A lot of times when people think of economics, they think economics is just putting dollar value to things, and that's just not the case. Economics is really a way of thinking and addressing problems by thinking about what it is people want from the landscape and finding ways to deliver that."

Tom Spies

This aerial view shows a multiownership landscape of the western Oregon Cascade Range with Mount Jefferson in the background. Plantations in the foreground are private industrial lands and the taller forests and meadow in the mid ground are on federal lands. Each vegetation type has different capacities for carbon storage, wood production, and wildlife habitat.

Although remote sensing data have been used by Forest Service scientists for decades, it is only recently that the agency has actively used landscape-level datasets when addressing management issues. "Our study was one of numerous studies that have helped the agency appreciate the role of remote sensing," Cohen says. "The agency has been pretty aggressive about going after remote sensing applications. At the national level, the agency is developing a landscape-change monitoring system that's based on NASA's and U.S. Geological Survey's Landsat data, which is what we used."

Another important takeaway that might easily be overlooked owing to the complex remote sensing data and tradeoff graphs is the landscape-level approach Spies and his team used to tackle ecological questions that can help inform policy decisions about ecosystem services. A subdiscipline of ecology since the late 1980s, landscape ecology looks at the landscape as a whole rather than at the plot level. Only now, however, are land managers starting to incorporate landscape-level views into management decisions.

"Carbon management is potentially a complex problem and you can easily misunderstand it if you don't apply a systems' approach and think at a landscape scale," says Spies. "This approach we think helps reveal the true nature of the ecosystem—carbon, wood, and wildlife habitat relationships. It helps understand what is a complex and multiscale problem."

"Conservation means the wise use of the earth and its resources for the lasting good of men."

—Gifford Pinchot, first Chief of the U.S. Forest Service

LAND MANAGEMENT IMPLICATIONS

- A tradeoff-management framework defines long-term potentials for managing forests to produce carbon, timber, and habitat across multiple ownerships.
- The framework also fulfills the need for information that describes potential timber and wildlife habitat tradeoffs resulting from national forest policies and forest management plans designed to store carbon. The analysis for forests in the western Cascade Range identifies joint production possibilities for multiple ecosystem services.
- Ongoing debates about managing Pacific Northwest forests often focus on growing mature forests or timber harvesting. There are a broader array of management regimes and management variables that could lead to a wider range of possible management outcomes.

For Further Reading

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Science

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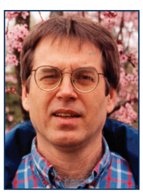
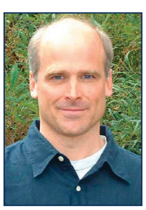
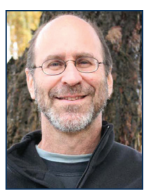


THOMAS SPIES is a research forester and forest and landscape ecologist with the Pacific Northwest Research Station. His research addresses landscape dynamics in mixed-severity fire regimes, forest policy effects, coupled human and natural systems, tradeoffs among carbon and other ecosystem services, and old-growth forest conservation on fire-prone landscapes.



JEFFREY KLINE is a research forester and economist with the Pacific Northwest Research Station. His current research examines the effects of population growth, land use, and climate change on forests and their management, as well as related changes in how the public uses and values forests.



WARREN COHEN is a research forester with the Pacific Northwest Research Station. His primary focus is translating remote sensing data into useful ecological information, particularly analyzing and modeling vegetation structure and composition across multiple biome types.

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