PNW
Pacific Northwest Research Station

Science FINDINGS

INSIDE

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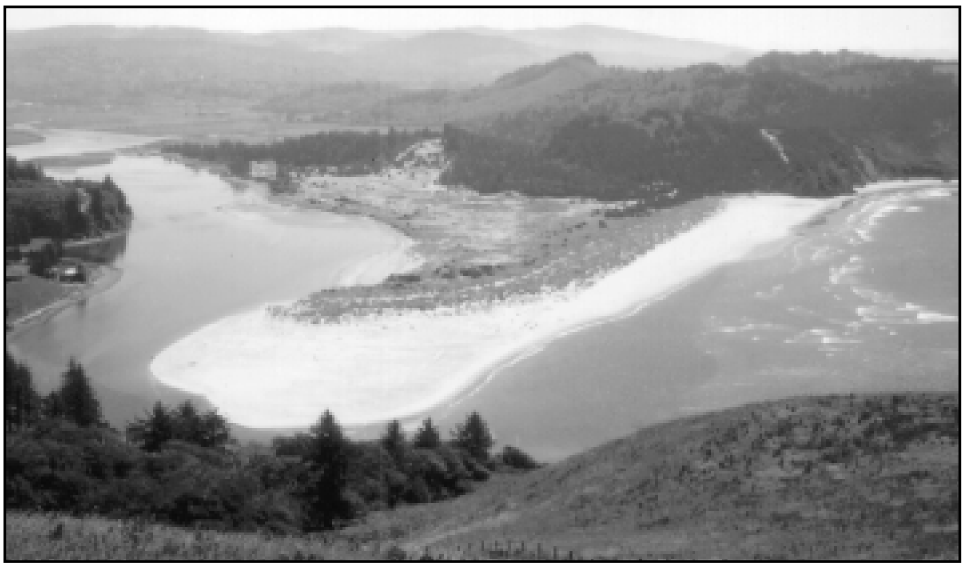
"Science affects the way we think together."
Lewis Thomas

PIXEL BY PIXEL: THE EVOLVING LANDSCAPES OF REMOTE SENSING



The CLAMS study area includes more than 5 million acres in Oregon, extending from the Pacific Ocean to the Willamette Valley fringe.

IN SUMMARY

This issue of "Science Findings" focuses on remote sensing research and how it can be used to assess a landscape. The work of PNW Research Station scientists Tom Spies and Warren Cohen and their use of satellite technology in developing the coastal landscape analysis and modeling study (CLAMS) is featured. The CLAMS study area includes more than 5 million acres in Oregon extending from the Pacific Ocean to the Willamette Valley fringe. Field and satellite data are combined to produce a picture of current vegetation and other resources in the Oregon Coast Range. The data are then used to model changing patterns of vegetation cover, wildlife habitat, and land use in the region over the next 100 years. The CLAMS study will produce the tools needed to assess sustainability of different forest and land use policies over time. The study also will help to visualize how social and ecological change will affect the landscape: useful information for land managers and land owners alike.

"Evolution . . .is—a change from an indefinite, incoherent homogeneity, to a definite, coherent heterogeneity."

Herbert Spencer 1820-1903

If you can draw an accurate picture of a single tree from 100 yards away, can you draw an accurate picture of a forest from 400 miles away? Can you extrapolate from one stand of trees to the whole landscape? Translate back from the whole landscape to the single stand?

Ah, but the questions are too simple. You might as well ask, if a tree falls in the forest, does it show up as a log on the next satellite photo?

The world of remote sensing research is furnished with high expectations, fed by lavish early promises from off-the-shelf programs, and perhaps by the odd spy movie. This is particularly true in forest resource issues, according to two PNW Research Station researchers who are acknowledged midwives to new ways of using satellite technology. "It's a strange business to be in," says Tom Spies. "People want new technologies to provide all the answers, and they're apt to believe anyone who says they can do it, before they know the details of what is and isn't possible."

Spies and Warren Cohen, forest ecologists, have spent much of the last decade trying to reconcile small groups of tree measurements from the ground—field data—with the whole-landscape imagery beamed back from satellites hundreds of miles above Earth's surface and then to apply the results with rapidly advancing fields of landscape ecology and ecosystem management.

In short, to hone the benefits of remote sensing tools. Seeing whole landscapes. Consistent, repeatable, relatively inexpensive data. A big picture across multiple ownerships. A new view of ecosystems.

Clearly, an enormously complex undertaking. An undertaking that needed all of a decade to complete the fundamental research, so that it could solidly achieve the credibility it is gaining with managers in various disciplines.

KEY FINDINGS

- Satellite imagery can be used to estimate important characteristics of forest-structure and composition across large areas of the Pacific Northwest. The greater the number of forest classes we try to estimate, however, the greater the overall error. These estimates can be done at high resolution (areas of 30 yards on a side or about 0.2 acre).
- Vegetation maps derived from remote sensing can be used to estimate habitat for bird species including the northern spotted owl. There was generally good correspondence with estimates from aerial photography done by owl biologists.
- For several bird species, including the northern spotted owl, total amount of habitat rather than how it is distributed was most strongly related to bird abundance and population dynamics.
- Satellite-based vegetation maps of watersheds are useful in predicting in-channel habitat conditions for anadromous fish, and thus for locating watersheds with high or low habitat potential for conservation and monitoring efforts at landscape and regional scales.

WHAT ARE WE REALLY LOOKING AT HERE?

Remote sensing deals with energy information: the interaction of solar energy with vegetation and the understanding of how it's reflected back on its way to the satellite. Several difficulties confound mapping efforts in the Pacific Northwest region. Conifer forests have high leaf area indices, absorbing most solar energy, making these forests difficult subjects for discriminating among forest classes, particularly if researchers try to distinguish between several classes. In addition, topography has a substantial effect on satellite images, potentially contributing to over- or under-estimating certain forest age classes.

Such data shortcomings become crucial management issues when making distinctions between young and old-growth forests, for example.

"If we map something as old growth that is really mature, it can still support most old-growth species and will probably develop old-growth characteristics within 50 to 100 years, whereas mapping young as old growth would mean that some old-growth species would not find suitable habitat in the area, and it might be at least 75 to 150 years before it becomes suitable," Cohen explains.

It is important to remember that remote sensing in direct applications such as forest cover mapping is an evolving science, involving some art and intuition. It supplements plot data and field mapping, both time-consuming methods of determining vegetation cover. Remote sensing also adds to the value of highly expensive aerial photography, by its lower cost, repeatability, and wall-to-wall coverage.

"It has now been established that for some applications, satellite imagery can do just as good a job in predicting habitat and answering fundamental landscape ecology questions as aerial photographs used to do," says Spies.

So are the current 65- to- 80-percent accuracy levels acceptable? "It depends on what uses you're seeking," he says. "If you want a general overview of your lands and how they fit in the landscape, then this level of accuracy is fine. If you want to do stand-level management, then it may not be."

At present, these are standard accuracy levels for remote sensing data, according to Spies and Cohen. Indeed, an overall accuracy rate of 82 percent for their work on the west side of the Oregon Cascade Range is moderately high compared with results of other forest classification studies, they say. In addition, they can reliably estimate forest features at high spatial resolution: about 30 yards on a side, or 0.2 acre, per pixel. (Pixels are individual points that comprise an image on a screen.)

Purpose of PNW Science Findings

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

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A NEW FIELD OF STUDY

The maps represent the integration of the disciplines of remote sensing and of forest ecology—"remote ecology" is the tongue-in-cheek designation of the new field. It requires both a fundamental understanding of what remote sensing is about and a clear sense of the dynamics of landscape and forest ecology. The resulting integration gives us something we've never had before, the researchers say: good knowledge of the major forest cover types, done consistently and objectively, and relatively cheaply on a per-acre basis.

Analysis of the utility of remote sensing data is an inherent objective of the coastal landscape analysis and modeling study (CLAMS). Covering more than 5 million acres, the CLAMS study area extends from the Pacific Ocean to the Willamette Valley fringe, and contains some of the most productive timber-growing land in the country. It also contains a complex ownership mosaic that has substantially influenced landscape pattern to date, and has significant implications for future patterns.

The CLAMS team—as many as 40 people representing diverse disciplines—is integrating field and satellite data to produce a complex picture of current vegetation and resources in the Oregon Coast Range, then modeling changing patterns of vegetation cover, wildlife habitat, and land use for the region over the next 100 years.

Ultimately, CLAMS will produce a set of tools for assessing sustainability of different forest and land use policies through time, for visualizing how both social and ecological change will affect the landscape—in other words, detailed dynamic mapping of the whole landscape, natural as well as human caused. In an unusual "joint learning" step for private forestry and research, landowner evaluation of modeling assumptions and simulations will improve the utility and accuracy of CLAMS tools, such as maps.

MANAGEMENT IMPLICATIONS

- Cost-effective and beneficial tools of remote sensing are now available to managers to meet the monitoring needs of the Northwest Forest Plan. Federal agencies are already incorporating these tools into monitoring at large spatial scales of old-growth, spotted owl and marbled murrelet habitat, and aquatic and watershed conditions.
- In the CLAMS project, a combination of remote sensing tools, vegetation databases, and ecological models will form the foundation of ecosystem management planning for the Oregon Coast Range, and provide a model for landscape-scale planning elsewhere.
- Knowing where and how forest habitat pattern affects abundance will give managers more options for designing landscape conservation strategies that meet both commodity and ecological objectives.

CAN WE MAP THE DETAILS?

But when you print out those colored maps showing what you think the landscape contains, and what you think it will contain in the future, something peculiar happens, the researchers say. In what Spies has dubbed the oracle effect, complete accuracy is assumed.

"A map is not unlike a photograph, in that people expect it to be real. They look for the place on it that they know, then based on the accuracy of that point, the whole map is good or bad to them," says Cohen. "It is very important to undersell rather than oversell what remote sensing can do, to point out what it can and cannot do. We have to manage expectations."

What remote sensing cannot do is guarantee the truth in every pixel.

"We are approaching the limits of the current technology in terms of exploring what spectral and spatial datasets can do for us," says Cohen. Along with some of the difficulties already mentioned, remote sensing cannot yet successfully characterize understories, standing dead trees, or small features such as narrow riparian zones, all of which, of course, remain ecologically important.

In addition, there are necessarily problems when important fine-scale features get aggregated, or lumped together in a single, coarse-grained pixel. Imagine a set of pixels in which just over half are clearcut or very young forest and the rest are old-growth and mixed deciduous stands. If they're aggregated to be all very young, the estimation of old growth and mixed deciduous goes down. In this or the reverse case, the under- or over-estimation is problematic if it happens over too large an area.

"If your pixel is so large that you start to mix old-growth and clearcut patches, and just say it's one or the other, you obviously have a fundamental pixel size problem," says Cohen. "One of our ongoing objectives in remote sensing is to explore the errors and information losses that accrue when extrapolating field data to coarse-grain (1-kilometer) surfaces."

The coarse, 1-kilometer (0.62-mile) resolution is still capable of showing gross patterns for large-scale landscape views, he points out, and was recently used in the interior Columbia River basin assessment, and in northern California. The type of imagery that produces 30-yard pixels generated for the CLAMS project, called Thematic Mapper, brings the scale down to individual stands.

WRITER'S PROFILE

Sally Duncan is a science communications planner and writer, specializing in forest resource issues. She lives in Corvallis, Oregon.

EVERY PICTURE TELLS A STORY

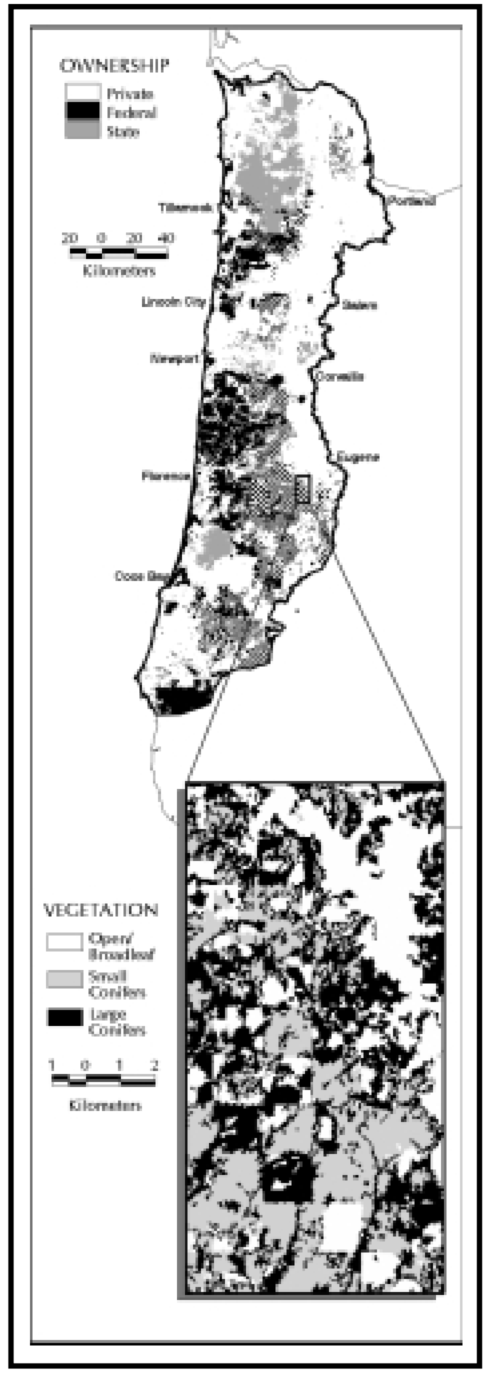
Where the resolution is this high, there are significant stories about landscape and habitat emerging, stories that become startlingly clear once the maps are printed.

Forest fragmentation, that classic Pacific Northwest landmark, leaps out plainly from every watershed. A major concern in forest ecosystem management, fragmentation raises questions about effects of edge density, effects of distribution of forest patches on habitat, and biodiversity in general. With landscape assessment and monitoring capabilities now within reasonable cost, fragmentation effects can be closely watched.

Already, one area of study supplemented by remote sensing data and crosschecked with aerial photographic data, suggests that for the bird species examined, including the northern spotted owl, landscape features related to fragmentation were not strongly related to the abundance or population dynamics of these species, according to Spies.

"In other words, the rather surprising finding is that total amount of habitat rather than geographic pattern of habitat was most strongly related to bird occurrence," he says. He notes that this finding may simplify some aspects of ecosystem management planning, allowing managers more options for designing landscape conservation strategies that meet ecological objectives as well as commodity objectives. But he is quick to add that further studies are needed to corroborate this finding.

After all, a lot of policy decisions will hang on just such outcomes of the use of remote sensing.



Ownership patterns and example of vegetation map produced from remote sensing for the Oregon Coast Range. Note the "checkerboard" pattern of ownership and how it is reflected in the vegetation.

MONITORING APPLICATIONS

A highly subjective process of landscape analysis was used by the Forest Ecosystem Management Assessment Team (FEMAT) leading up to the Northwest Forest Plan (NWFP). What remote sensing can do includes more objective habitat assessment and continuous monitoring, crucial elements in the plan.

The NWFP designates specific land allocations and management guidelines. "The primary intent is to create an interconnected system of forest reserves capable of maintaining viable populations of old-growth associated species," Spies explains. Late-successional reserves provide the backbone for the regional conservation strategy, and the aquatic conservation strategy transcends all allocations.

"All we had to work from for FEMAT was general zoning maps. We had no models to show spatial relationships—how things fit together over a large area with diverse ownerships. Certainly nothing dynamic through time," says Spies. "Translating our remote sensing work into the CLAMS project meant adapting some of what had been done before, and rapidly learning more as we developed an intensive focus on 'getting the maps right.'"

The CLAMS project will use habitat models for several wildlife species, reflecting the range of habitat conditions available in the Coast Range, and to simulate how those conditions may change through time. Habitat models will include the northern spotted owl, the marbled murrelet, and elk, as well as several species of salmon. Collaborators on aquatic habitat include Kelly Burnett and Gordie Reeves at the Corvallis Lab, and Martin Raphael on owl habitat at the Olympia Lab.

"The questions that arose in the FEMAT process forced us to think about change," Cohen recalls. "Habitat change is something we should be able to monitor easily in a disturbed context, because it becomes immediately obvious in the imagery."

In other words, whether a young stand is clearcut again after 50 years, or a mature stand is allowed to persist on the landscape until it becomes old growth, or a fire blows through the Siuslaw National Forest (in the Oregon Coast Range), will not only be easy to see in a satellite picture, but also will strongly affect habitat status in those areas.

PLANNING ACROSS WHOLE LANDSCAPES

"Where you can take a whole landscape in the future depends heavily on the constraints the current landscape places on you," Spies explains. "An existing pattern can take up to 200 years to change. For example, if you look for old growth on BLM [Bureau of Land Management] lands in the Oregon Coast Range, you find very little in the northern part, because of fire and logging history."

Knowing what the rest of the landscape looks like, as CLAMS now allows, can help prioritize restoration and watershed management planning, taking wildlife effects into account. For example, Spies points out how private lands contribute open areas and broadleaf forests between large tracts of late-successional forests.

"This mixture of conditions could support both late-successional species and those requiring open and closed forests together for feeding and nesting. This example also illustrates how connectivity of late-successional forests within a watershed will depend on management objectives of intervening ownerships as well as the configuration of reserve parcels," he says.

Now that remote sensing has proven it can provide a solid base of information about forest structure across all ownerships, it is becoming a primary tool in developing new approaches to compatible vs. competing forest uses, according to the researchers. Along with vegetation databases and ecological model applications, it forms the foundation for forest ecosystem management planning in the CLAMS region of the Coast Range.

It serves also as a model for how to conduct landscape-scale planning, monitoring, and analysis in other parts of the Pacific Northwest. "Several of the techniques we used to process the remote sensing images and build wildlife habitat models are being incorporated by management agencies into their monitoring strategies, and into pilot effectiveness monitoring efforts by the Siuslaw National Forest and BLM," says Spies.

Satellite-based vegetation maps also will be useful in predicting in-channel habitat conditions for anadromous fish. Results of a study in the Elk River watershed suggest that percentage of large conifers (>30 inches average diameter) in the upper reaches, and the amount of early successional vegetation in the watershed, related closely to amount of large wood in pools within streams. Work continues on developing the ability to locate watersheds with high and low salmonid habitat potential for conservation and monitoring efforts at both landscape and whole province scales.

PUSHING THE TECHNOLOGY

With existing shortcomings in remote sensing capabilities, Cohen and Spies have naturally looked ahead to what's coming down the technology pike. Clearly, new technologies will improve accuracy in general, Cohen says. Better characterization of forest structure will improve researchers' ability to say given a certain mappable forest class, this is the range of conditions within it.

"The lidar system will allow far more detailed forest characterization, because unlike field data, which you get by looking up and seeing the bottom of things, and these satellite data, which you get by looking down and seeing the top of things, it can look through things," he says. "It may be able to distinguish between conifer and deciduous canopies, brush vs. tree conditions, and we'll be able to get a clearer picture of the understory."

The lidar technology uses concentrated, high-power optical waves to penetrate all the way through the forest, sending signals every time it hits something until it hits the ground. Standard remote sensing sends signals only from the surface of objects—the first thing it hits.

"New technologies, as always, will allow us to answer new questions, along with old questions, and some we haven't even thought about yet," says Spies. "We'd like to understand canopy layering a lot better, since it's such an important part of the ecological story. We have questions about radiation from the canopy, the movement of energy in there, and how the owl uses it, for example."

Of course, he notes, remote sensing will never replace on-ground management, simply supplement it. It will continue to provide an improving view of "this invisible place" that is the landscapes surrounding the stands we manage.

With the 10 years of fundamental research behind them, both researchers feel they are now in a position to direct remote sensing research to get out in front of some of the hot issues coming to the fore in forest policy. The link of remote sensing with ecological knowledge has become a powerful new branch of science.

Who knows? In time, when that tree falls, it might show up as a log on the next day's satellite image.

> *"Forests are inherently vulnerable to conflict. . . . Everything that happens to the forest affects every segment of the forest industry and everyone on the planet."*
>
> "Reinventing the Forest Industry," Jean Mater 1915-

FOR FURTHER READING

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