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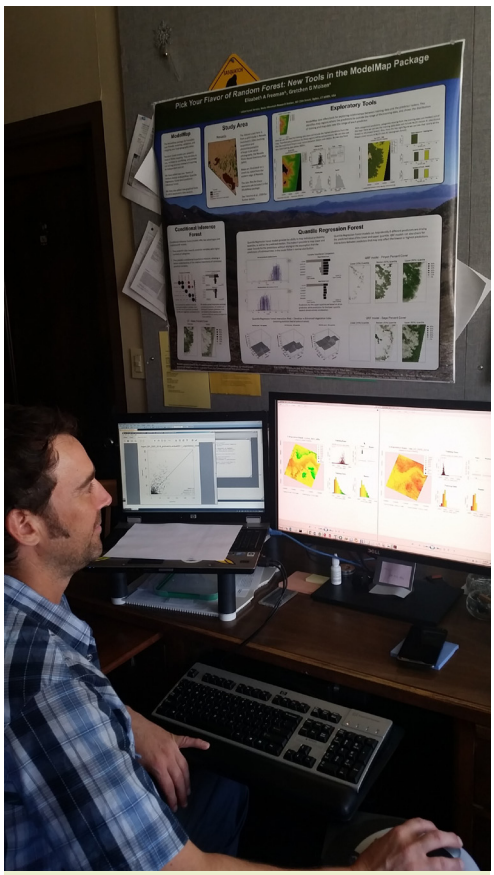
Painting a Picture Across the Landscape with ModelMap

It's been said many times that if you build a better mousetrap, the world will beat a path to your door. This quotation has been attributed to Ralph Waldo Emerson, although there's no proof that he ever used those exact words. Still, many people have taken inspiration from these words over the years, and this may be one of the reasons that more than 4,400 mousetrap patents have been filed with the U.S. Patent Office since 1836.

But every now and then, an invention comes along that is so effective that its usefulness goes far beyond what its creators intended. ModelMap software, which was created by specialists working for the Rocky Mountain Research Station, is one such innovation. ModelMap automates and simplifies the map modeling process, allowing researchers and land managers to visualize complicated geospatial data, develop predictions, and communicate it all to stakeholders and other researchers.



Charles Werstack, a biological scientist with RMRS, is using ModelMap to model Aspen Distribution in the Interior West (Photo by E. Freeman).

SUMMARY

Scientists and statisticians working for the Rocky Mountain Research Station have created a software package that simplifies and automates many of the processes needed for converting models into maps. This software package, called ModelMap, has helped a variety of specialists and land managers to quickly convert data into easily understood graphical images. The software package also includes methods to test for accuracy. A true product of the information age, ModelMap combines many existing programming tool packages to streamline creation of sophisticated models from diverse data sources, ranging from field visits to satellite information gathered over the past several decades. ModelMap use cases have ranged from forest cover and biomass to invasive plants and endangered species habitat. ModelMap can be installed from within the basic R platform or from within R Studio. Additional information can be found at https://cran.r-project.org/web/packages/ModelMap/index.html

"WE NEED A BUTTON…"

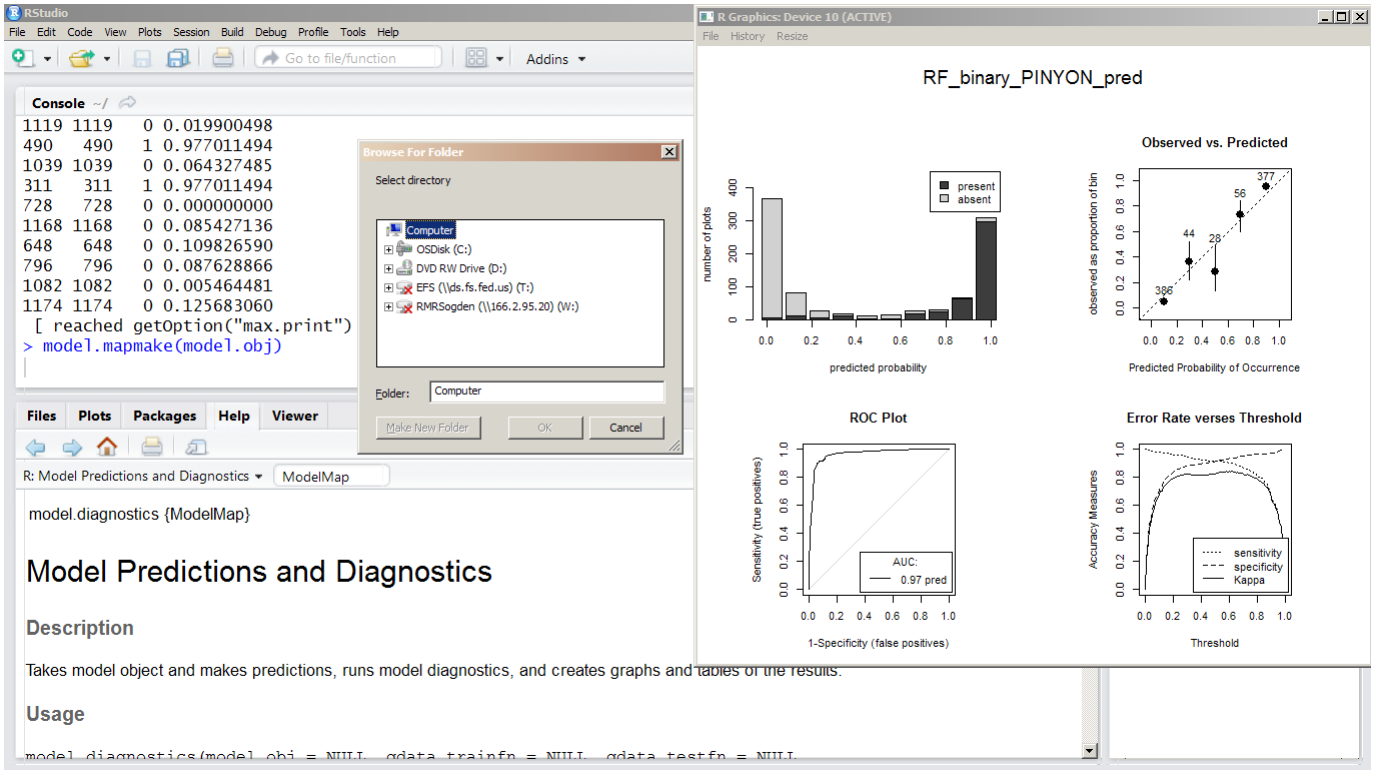
The idea for ModelMap came about 10 years ago. According to Gretchen Moisen, Techniques Research team leader for the Rocky Mountain Research Station's Inventory and Monitoring Program in Ogden, Utah, "We were sitting around the conference room table discussing all the statistical modeling steps required for making a map, and decided that we needed a 'button' to make it happen. There are a lot of details involved in mapping, and many people don't necessarily need to know all those details about how the process works." As Moisen and her team considered the problem, they realized: "We've got forest inventory data, satellite data, modeling tools, computing power … the resources were out there but we needed something to take the work away."

According to Elizabeth Freeman, ModelMap's developer and an ecologist for Rocky Mountain Research Station, "We wanted to come up with a way that we could key in the data and a map would spit out with predictions across the entire landscape, so that you wouldn't have to move from one software program to another." The result was ModelMap, which has been used by land managers and for countless mapping projects around the world. Freeman describes it this way: "ModelMap helps streamline the process of making maps from field data and also knowing how accurate they are — how much they can trust their maps. It brings all the tools into one place."

WHAT IS MODELING?

Scientific modeling is the process of creating a physical, conceptual, or mathematical representation of a real phenomenon. These models can be used to explain and predict the behavior of objects and systems, including wildlife and plant habitat, wildfire damage, and countless other applications. ModelMap uses satellite imagery and other topographic details for map generation.

Moisen explains it this way: "Picture a graph," Moisen says. "The Y axis could be something like biomass: It's



ModelMap features an easy-to-use graphical interface that can be navigated by a wide range of users. (U.S. Forest Service.)

the thing I want to map. The X axis is something I already have a map of, say elevation. If I develop a model that describes the relationship between elevation and biomass, then I can predict biomass everywhere I have elevation. That is, I can make a map of biomass. Well, of course you need more than elevation to build a good model of biomass, so we bring in other things we already have maps of, like lots of data from satellite imagery – lots of X's. We then build a 'model' to describe the relationship between the Y and all those predictor X's. We can then apply that model to create a map. It's a way to take the data you've collected at your field sites and use it to make a landscape-wide map."

FIA data collected by Jenny Turner and Laura Anzalone will be used as training data for ModelMap (Photo by E. Freeman).

HOW MODELMAP IS USED

One of ModelMap's more obvious applications has been in predicting where certain tree types are located, based on field site data collected through the Forest Inventory and Analysis program in combination with remote sensing imagery and digital topographic data. This has helped with many Forest Service projects, including the National Land Cover Database (NLCD). Created by the interagency Multi-Resolution Land Characteristics Consortium, NLCD provides land cover class, impervious surface information, and tree canopy cover maps for the United States.

"Take Douglas-fir as an example," says Karen Schleeweis, a research geographer for the Rocky Mountain Research Station's Interior West Forest Inventory and Analysis program in Ogden, Utah. "If it's below 3,000 feet, then there's probably no Douglas-fir; and then you factor in things like whether it's south-facing or not and the geographic location. With this information you can predict the kind of trees in an entire forest. ModelMap incorporates several existing packages to maximize accuracy. And there's also a package called PresenceAbsence, also developed by Liz Freeman, which is a diagnostics tool to analyze model accuracy. That's important because some species are easier to predict than others. Aspens are really easy to predict, but juniper detection has a much higher error rate."

"ModelMap helps streamline the process of making maps from field data and also knowing how accurate they are — how much they can trust their maps. It brings all the tools into one place." - Elizabeth Freeman

ModelMap is based on the "R" programming language. R is a sophisticated tool, but it's sometimes intimidating for new users. To address this, ModelMap incorporates a relatively easy graphical user interface. According to Moisen, ModelMap

"When we started, I was hoping the code would be helpful to a few people working on forest applications. Who would have thought it would be used for things like tracking malaria transmission risk in Swaziland?" - Gretchen Moisen

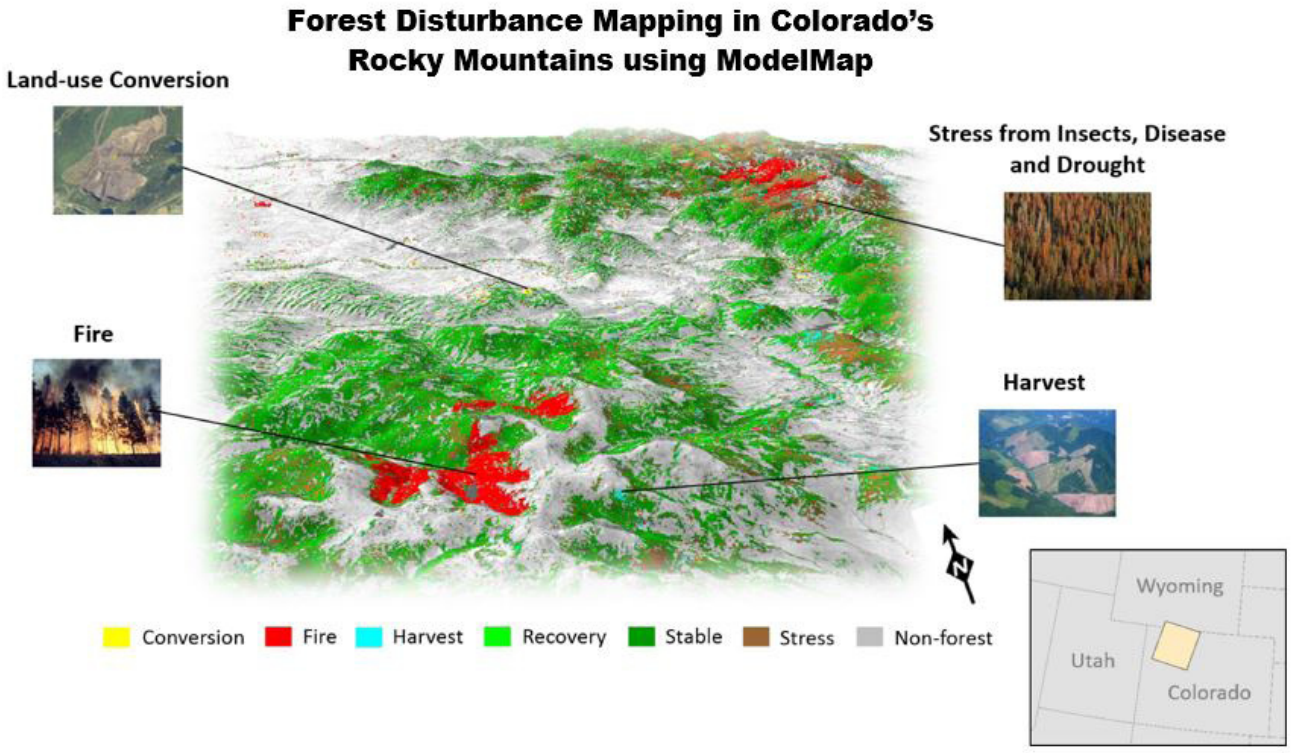
users include researchers, analysts and resource staff. "It doesn't require statistical expertise," Moisen says. "A user who has no R statistical expertise can build a model and make a map."

FOREST DISTURBANCE APPLICATIONS

One important application for ModelMap has been the North American Forest Dynamics (NAFD) project, a collaboration between NASA, the University of Maryland, the Forest Service's Forest Inventory and Analysis program, and many other partners. As part of the NAFD project, specialists processed historical Landsat satellite imagery data to provide an annual analysis of U.S. forest disturbance history including wildfire, floods and wind events from 1984 to 2010. This was accomplished with the help of ModelMap, which continues to be used for forest disturbance analysis.

Alexander Hernandez, an environmental scientist at Utah State University, has been using ModelMap for about 5 years to help evaluate and visualize canopy cover loss following disturbances such as fire, insect outbreaks, disease, and avalanches. According to Hernandez, "Before ModelMap was available, you'd have to take a model and go through multiple steps manually. ModelMap is very useful because you can fit your model into it, assess its accuracy, and then go forward into mapping."

Todd Schroeder, a research forester with the Forest Service's Southern Research Station, described how ModelMap's mapping function helps land managers analyze forest



ModelMap has helped land managers to visualize recent forest disturbance at a landscape scale, including large fires and conversion from forest cover to residential development. (U.S. Forest Service.)

FOREST INVENTORY AND ANALYSIS

ModelMap was created by research scientists working for the Forest Service's Forest Inventory and Analysis (FIA) program, which helps to provide the information needed to assess America's forests and to predict their land cover and condition in the decades to come. According to Michael Wilson, Interior West FIA program manager, "We provide the critical data that informs forest industry, National Forest System planners and managers as well as other agency managers, and scientists across the globe."

Although the FIA program goes back more than 80 years, its applications are more relevant than ever today: Contemporary topics include carbon sequestration, forest product employment trends, biomass availability, land cover and land use changes, pollution effects, and fire risk. As Wilson explains, "The program started with gathering baseline information, but there's more and more demand for the information that can be extracted from it."

John Shaw, biological scientist for Interior West FIA, explains that today, modern technology and new methodologies have made FIA data more useful than ever. For example, the Forest Service has enhanced the FIA program by changing from a periodic survey to an annual survey and by expanding data collection to include soil, understory vegetation, tree crown conditions, coarse woody debris, and lichen community composition. The FIA program has also expanded to include the sampling of urban trees in select cities. As Shaw says, "A lot of folks know a little about us, but their information about what we can do is dated or inaccurate. With our new annualized system we're better able to show trends over time — it might be something that hasn't even occurred to them. That kind of conversation is going to be ramping up as more national forests enter the assessment process as part of the new planning rule."

As a result, FIA works closely with many different groups around the country. According to Shaw, "What Congress asks us to do as part of the Farm Bill is to report on every state, every 5 years. We also work with national forests that are in the forest plan revision process and we work with land managers to solicit their needs for project planning purposes. They may be interested in lynx or spotted owl habitat and we can often provide the data they need so they can focus on other details like nest productivity. We can continually crunch data to see if that habitat is coming or going."

Additional information on FIA and can be found at www.fia.fs.fed.us and www.fs.fed.us/research/inventory-monitoring-analysis. FIA reports can be found at www.treesearch.fs.fed.us.

disturbance: "It's possible to fit models, evaluate performance, and produce maps using other tools, but ModelMap accelerates the process by integrating all these functions into one package. ModelMap has helped us develop maps that can track the location, timing, and type of disturbances impacting our nation's forests. With this information we can begin to better understand the social, ecological, and economic consequences brought on by these changes."

MANAGEMENT IMPLICATIONS

- Land managers today have access to far more data than ever before in history, but modeling and mapping are necessary for visualizing and communicating analytical results.
- ModelMap saves time by combining many different mapping tools and automating much of the analysis and map-generation process.
- ModelMap can help researchers and land managers predict wildlife and plant habitat, forest disturbance history, and disease transmission across landscapes.
- While it incorporates many sophisticated methodologies, ModelMap's simple graphical user interface allows it to be used by nontechnical staff who have little or no statistical or programming experience.

MAPPING BIOMASS FOR CARBON ASSESSMENTS

ModelMap has also been used by Sean Healey, a research ecologist working for the Rocky Mountain Research Station in Utah. Healey led a team that developed a forest carbon management support tool called ForCaMF (Forest Carbon Management Framework). "It's an effort by Forest Service Research & Development and the Office of Sustainability and Climate Change to support the National Forest Service in mandated carbon assessments," Healey says, adding, "We want to know where the forest is, where the biomass is, where the carbon is. We collect these forest inventory plots, but when you combine that with satellite data you can paint a picture across the landscape." This is where ModelMap came in. Healey explained, "We used Landsat and FIA field data to map biomass across each national forest using ModelMap. National Forest personnel now know how much carbon has been affected by harvest, fire, insects, and other disturbances."

Healey's team began using ModelMap to help with this project about four years ago, saving a significant amount of time. Healey explained, "ModelMap packages tools that are already available in R and makes them much easier to use. It probably saved us a couple of weeks of work. It's not new technology, but it does make it much easier for a user to feed in the information and get the results they need."

KEY FINDINGS

- After recognizing that converting models into maps can be a laborious process, Rocky Mountain Research Station scientists and statisticians developed ModelMap, which combines a suite of modeling and mapping tools while simplifying and automating the process.
- By combining modern data processing power and unprecedented geographic data availability, ModelMap provides land managers and other users with a powerful tool to quickly and accurately visualize the connection between models and the landscape.
- ModelMap use has been more extensive than expected, with more than 20,000 downloads reported so far and use cases far beyond what its developers initially envisioned.

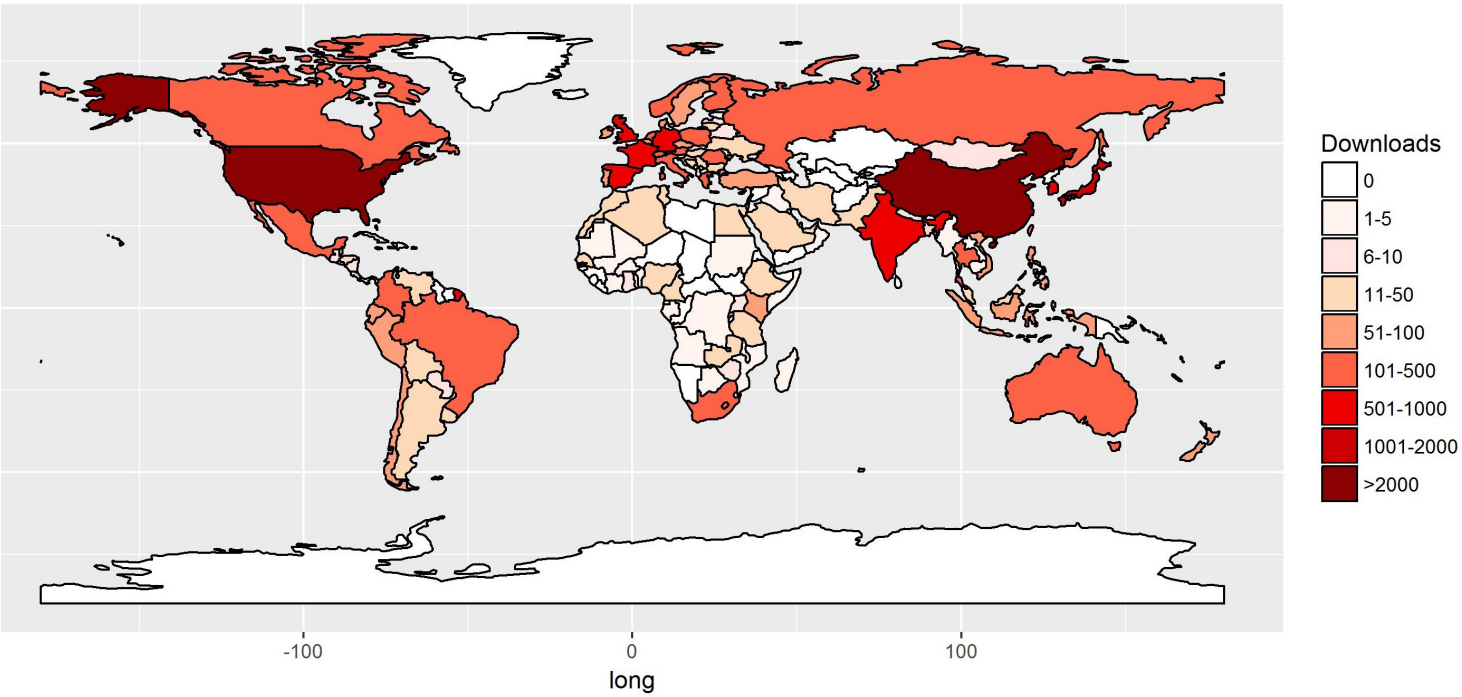
MAPPING ANALYSIS NEAR AND FAR

While ModelMap was developed to map forest characteristics, one of the biggest surprises the ModelMap development team has encountered is the software's wide range of uses. In addition to its use in forest research, ModelMap has been used to track malaria risk in Swaziland and identify suitable winter habitat for the aquatic warbler, a small, threatened bird that spends its winters in West Africa. Another use has been to help identify likely locations for invasive saltcedar trees and shrubs on the Bighorn River in Montana. ModelMap has also been used to model changes in land use in and around Kunming, China. Located in southwest China, Kunming has undergone tremendous growth and development in the past century, resulting in major changes to the city's land cover.

According to Moisen, "When we started, I was hoping the code would be helpful to a few people working on forest applications. Who would have thought it would be used for things like tracking malaria transmission risk in Swaziland? We recently figured out how to find out who's downloading the software, or at least from which country. It turns out it's been downloaded more than 20,000 times, all over the world. We're obviously not collaborating with all these people, but it's been very interesting to see how many times it's being used, and for what purpose they're using it."

FROM THE MOUSETRAP TO THE WOODS AND BEYOND

Although Ralph Waldo Emerson probably never said anything about building a better mousetrap, he did say something similar, and it still applies to ModelMap, especially considering that the software's usefulness has extended far beyond U.S. national forests, for which it was created. What Emerson said was this: "If a man has good corn or wood, or boards, or pigs, to sell, or can make better chairs or knives, crucibles or church organs, than anybody else, you will find a broad hard-beaten road to his house, though it be in the woods."



Estimated ModelMap downloads by country, 2013-2016. ModelMap has been downloaded more than 20,000 times, in countries spanning the globe. (U.S. Forest Service.)

FURTHER READING

- Freeman, E.A.; Frescino, T.S.; Moisen, G.G.. 2016. **ModelMap: An R package for model creation and map production.** Vignette for the ModelMap package. https://cran.r-project.org/web/packages/ModelMap/vignettes/VModelMap.pdf.
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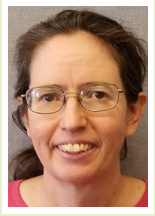
- Freeman, E.A.; Moisen, G.G. 2008. **PresenceAbsence: An R package for presence absence analysis.** Journal of Statistical Software. 23 (11). www.treesearch.fs.fed.us/pubs/29484.

SCIENTIST PROFILES

The following scientists and statisticians were instrumental in the creation of this Bulletin.

RMRS Scientist Profiles



ELIZABETH FREEMAN is an ecologist for the Rocky Mountain Research Station's Forest Inventory and Analysis program in Ogden, Utah. Elizabeth's passion is discovering patterns and structures in data and numbers. The lead developer of ModelMap, Elizabeth is currently working to develop new R tools for modeling and visualization. Projects include developing shiny web applications to facilitate interactive use of Forest Inventory and Analysis data, and R coding for mapping forest disturbance through time. Elizabeth has a master's degree in quantitative ecology and resource management from the University of Washington and a bachelor's degree in applied mathematics from the University of California, Santa Cruz.

GRETCHEN MOISEN is a research forester and the Techniques Research team leader for the Rocky Mountain Research Station's Inventory and Monitoring Program in Ogden, Utah. By finding ways to integrate remotely-sensed information with inventory and monitoring estimation procedures, her work helps to improve the quality, efficiency, and breadth of nationwide forest analysis and forecasting. Gretchen has a doctorate and a master's degree in statistics from Utah State University as well as a bachelor's degree in forestry from the University of New Hampshire.

TRACEY FRESCINO is a forester/geographic information system analyst for the Rocky Mountain Research Station's Forest Inventory and Analysis program in Ogden, Utah. Tracey's current projects include aerial photography analysis for collection of forest inventory data, development and integration of tools for automating estimation and mapping routines, and the study of projected climate change impacts on western North American conifer trees. Tracey has a master's degree in fisheries and wildlife from Utah State University and a bachelor's degree in environmental science from the State University of New York College of Environmental Science and Forestry.

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