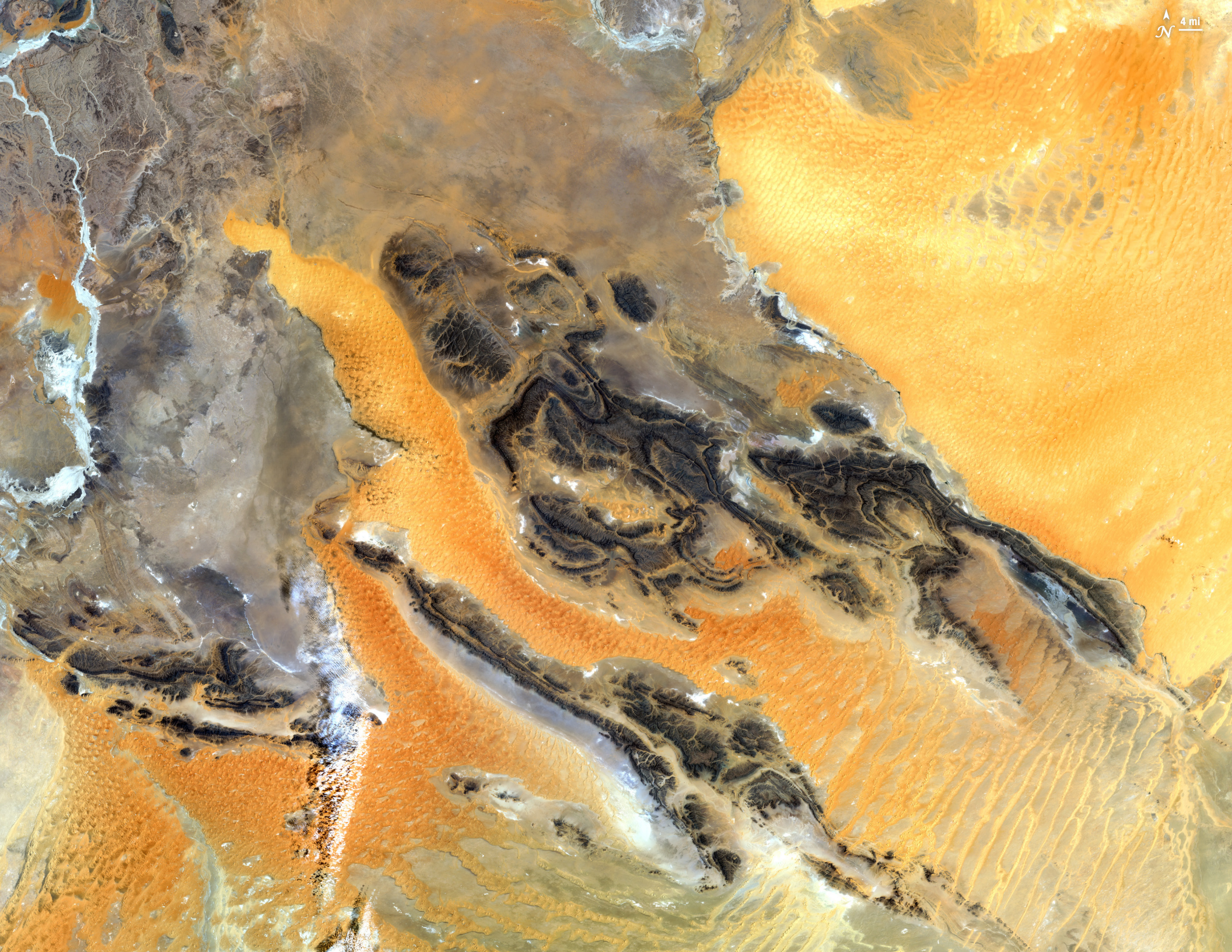
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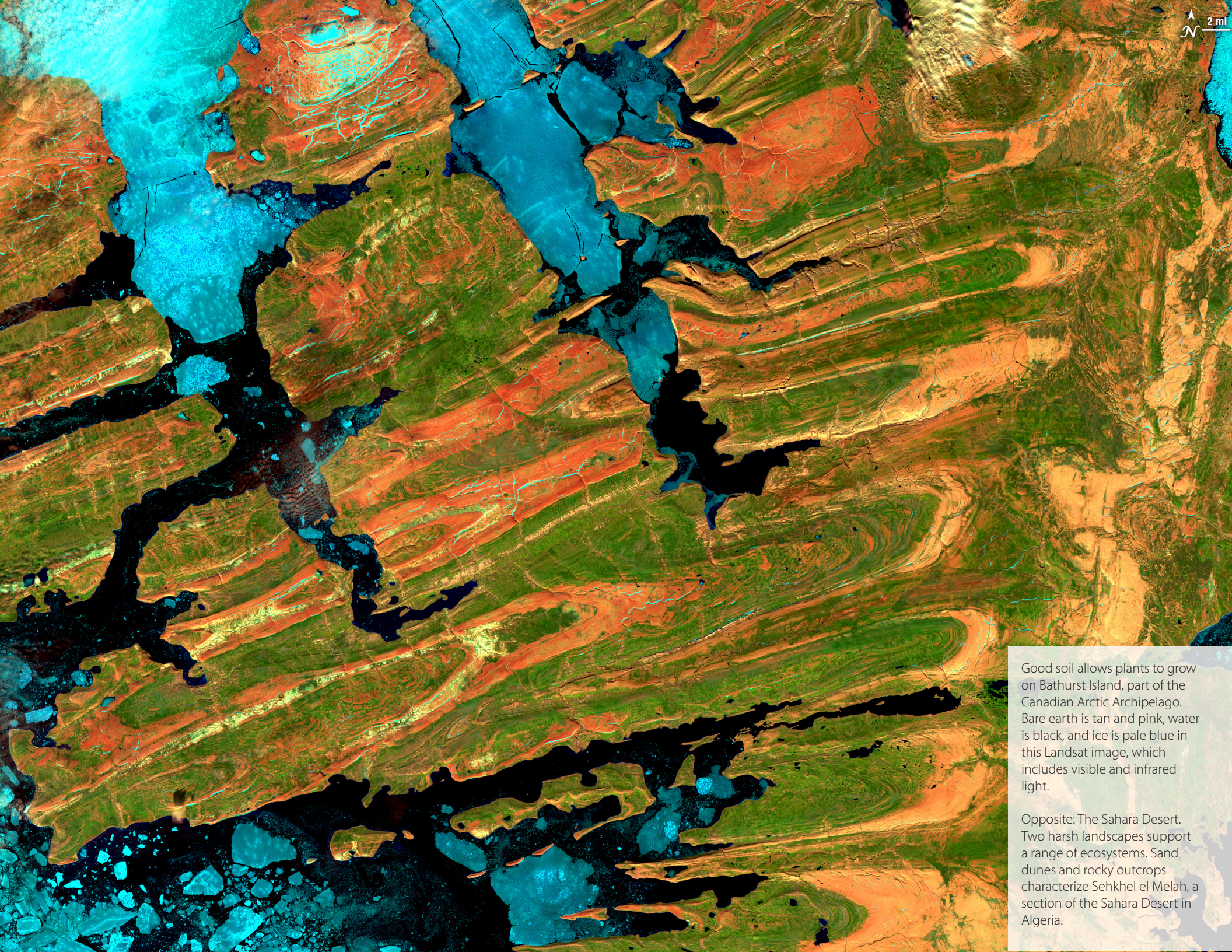


Good soil allows plants to grow on Bathurst Island, part of the Canadian Arctic Archipelago. Bare earth is tan and pink, water is black, and ice is pale blue in this Landsat image, which includes visible and infrared light.

Opposite: The Sahara Desert. Two harsh landscapes support a range of ecosystems. Sand dunes and rocky outcrops characterize Sehkhel el Melah, a section of the Sahara Desert in Algeria.

Mapping the Western Pine Beetle

Tassia Owen

Standing at the foot of a mountain inside Sheepshead Recreation Area just outside of Butte, Montana, Sue Cummings remembers the day she married her husband 25 years ago. She recalls her casual off-white dress and the deep green of the forest. The smell of pines still brings her back to that day.

In the summer of 2011, Sue almost didn't recognize the place. The population of mountain pine beetles, which had always been present in the forest, had exploded recently due to warmer winters and drier summers. The beetles killed many of the trees that set the scene for her marriage vows. "I was sad to see the devastation of the pine beetle epidemic. Although I had seen it elsewhere, when it is somewhere you have great memories of, it hits you harder," says Cummings.

Cummings is not the only person finding beloved forests transformed of late. Outbreaks of the mountain pine beetle have swept across western forests, impacting more than four million acres. One of the best ways to see the full extent of the infestation is the National Insect Disease Risk Map. Jim Ellenwood, Frank Krist, Frank Sapio and others who developed the map use annual aerial surveys and Landsat data to measure the extent of the damage from the mountain pine beetle and to create models, which ▸

Photo Information
Opposite: From the sky, areas that are infested by the mountain pine beetle appear red compared to the bright green areas that are healthy forest and not infested. Credit: William M. Ciesla, Forest Health Management International. Below: A lodgepole pine tree infested by the mountain pine beetle, with visible "pitch outs." Credit: Padraic Ryan. Above: A mountain pine beetle is a very tiny insect, averaging around 5 mm long. Although small, the beetle is the number one insect and disease risk for forests in the United States. Credit: USDA Forest Service.

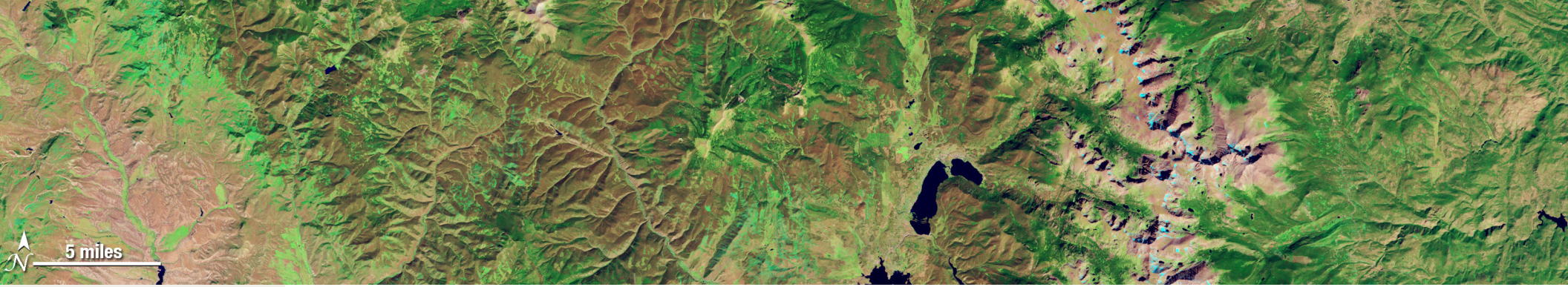


Image information
Landsat 5 acquired this image of a beetle-damaged forest in Rocky Mountain National Park on September 28, 2011. Healthy forest is dark green, while infested forest is brown. Exposed rock or bare earth is pink. Credit: NASA/USGS

are used to predict the outcome of disease and insect infestations across the United States.

Understanding the extent of a pine beetle outbreak is important because weakened and dead trees can fall in campgrounds, roads, or trails, posing a hazard to people. Fallen, dry trees are also a significant fire hazard. Land managers mitigate the hazard by removing infected trees near populated areas.

Landsat Maps Pine Beetle

Recently, the map has improved thanks to 30-meter observations from Landsat satellites. Incorporated into the map for the first time in 2012, Landsat measurements help scientists identify forests that are at risk of infection. A number of factors make forests particularly vulnerable to pine beetle infestations, including forest density, tree age, and tree type—all things that Landsat can help assess.

Landsat measures both visible and infrared light reflected from forests. Healthy trees absorb blue and red visible light and reflect infrared light. A densely forested area will reflect infrared light and absorb more visible light than a sparsely forested area. By measuring the amount of reflected light across the electromagnetic spectrum and combining that information with other significant data such as soil type, Ellenwood and his colleagues are able to determine the density of the forest. Dense forests are vulnerable because the mountain pine beetle can move more rapidly during an outbreak.

Tree type matters because, while mountain pine beetles make their home in many different species of pine trees, they prefer aging Lodgepole, ponderosa, sugar, and western white pines. The beetle spends most of its life as larvae living under the bark of trees and feeding on the inner bark and the phloem, the first layer of living tissue under the bark that carries nutrients to the different parts of the tree. The mountain pine beetle cuts off the supply of nutrients to the tree, preventing the tree from getting all of the things it needs to live. "It's kind of like it destroys the cardiovascular system of the tree," says Hecker. "Without our arteries and veins we wouldn't survive. It's the same for trees. Without the pathways for nutrients to move around the tree, it can't survive."

Landsat can help scientists determine which trees dominate in a forest because large tree stands of the same tree type look similar in Landsat images. By combining tree type and forest density, Ellenwood and his colleagues build models that predict the risk of of disease and insect infestations across the United States.

"We know there are forest health issues out there, we want to be proactive. The National Insect and Disease Risk Map gives us the ability to be proactive at a strategic level," says Ellenwood.

Responding to Pine Beetle Infestations

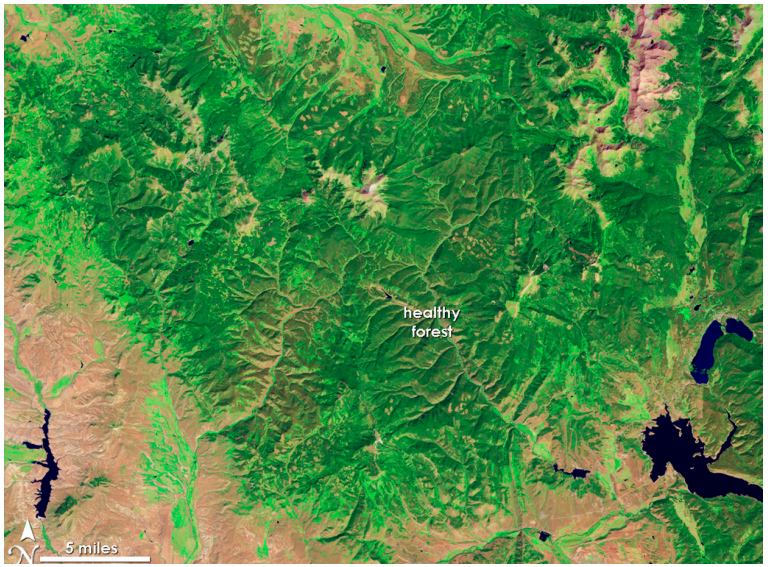
Managing bark beetle infestations is becoming more important. According to the 2006 National Insect Disease Risk Map, the mountain pine beetle is projected to destroy 750.5 million square feet basal area of pine forests by 2020. Basal area is a measure of the density and size of trees. The insect has caused similar devastation in Canada, particularly British Columbia.

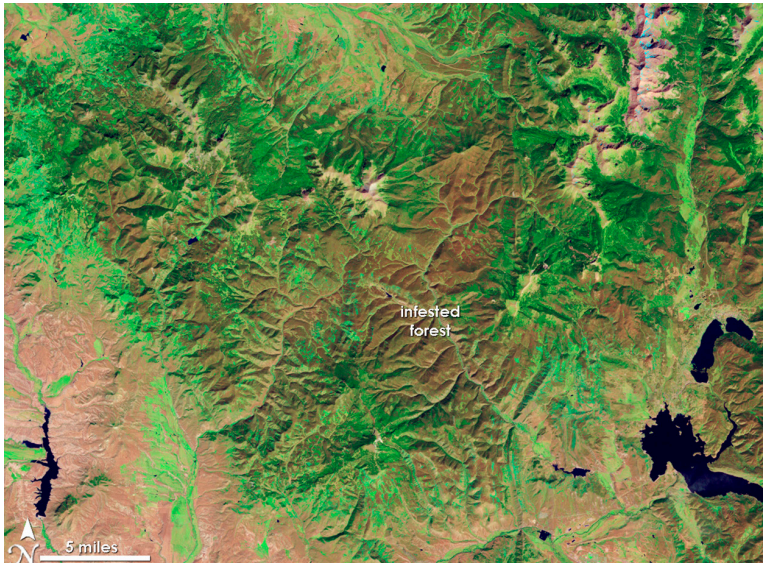
The current outbreak is epidemic due to what researchers have called the perfect storm: above normal temperatures in winter and abundant food supply. Without a cold winter there was no "hard prolonged freezing temperatures to kill the larva," according to Hecker. Also, most of the forests in the West are the same age, about 150 years old—near the maximum age for these types of forests. Since older trees are more susceptible to the mountain pine beetle, outbreaks have been extensive.

The mountain pine beetle can rapidly kill millions of trees during an outbreak, leading to large changes in ecosystems west of the Mississippi River. In fact, of all insects and diseases that impact forest health, the mountain pine beetle is the largest threat to healthy western forests. "It's like a wildfire moving in slow motion," says Hecker.

This "slow moving fire" can give rise to actual fire. Acres of dead, dry trees can be fuel for wildfire. To minimize both fire risk and the potential for damage or injury from falling trees, land managers remove downed trees from recreation and camping areas. Since fires can affect water quality, land managers also take action if a beetle-affected area is in a community's watershed. Fire destroys forests and causes the soil to repel water. Both effects allow topsoil to erode down watersheds, clogging waterways with sediment and debris and affecting water quality.

Insects and diseases impact both the forest and the animals that live there, and Landsat data are helping scientists assess how much ecosystems are changing as pine beetle outbreaks spread. When trees that are brown, red, and dead replace lush green trees, birds, squirrels, nuthatches, grouse and porcupines disappear. Voles, ▸





Before and after images from the Landsat 5 satellite reveal beetle damage in Rocky Mountain National Park in Colorado. In 2005 (image on top) the healthy forest appears bright green, but in 2011, (image on bottom) many of the bright green areas were replaced by a drab brown, indicating portions of the forest that have been attacked by the mountain pine beetle. Image comparisons allow land managers to identify areas that may be impacted by infestations. Credit: USGS/NASA's Earth Observatory

Photo Information
Above: The mountain pine beetle lives under the bark of trees, feeding on the inner bark and the phloem. This cuts off the supply of nutrients to the tree, eventually killing it. Credit: USDA Forest Service

Photo Information
Above: Land managers remove trees killed by pine beetles to minimize the hazard of a tree causing damage as it falls. Removing infected trees near roads, campground, or other populated areas is the normal response to an outbreak. Credit: USDA Forest Service
Opposite corner: Chipmunks are among the animals that move in to areas infested by mountain pine beetle. Credit: Acrylic Artist
Following full-page image: One ecosystem gives way to another as altitude changes at Maroon Lake in the White River National Forest, Colorado. Credit: USDA Forest Service.

salamanders, mice and chipmunks move into the coarse woody debris left by the mountain pine beetle. These animals churn the debris like a farmer churns compost helping air, water and nutrients to infuse the soil, while these animals assist in replanting by inadvertently moving seeds through the soil.

Terrestrial Ecological Unit Inventory

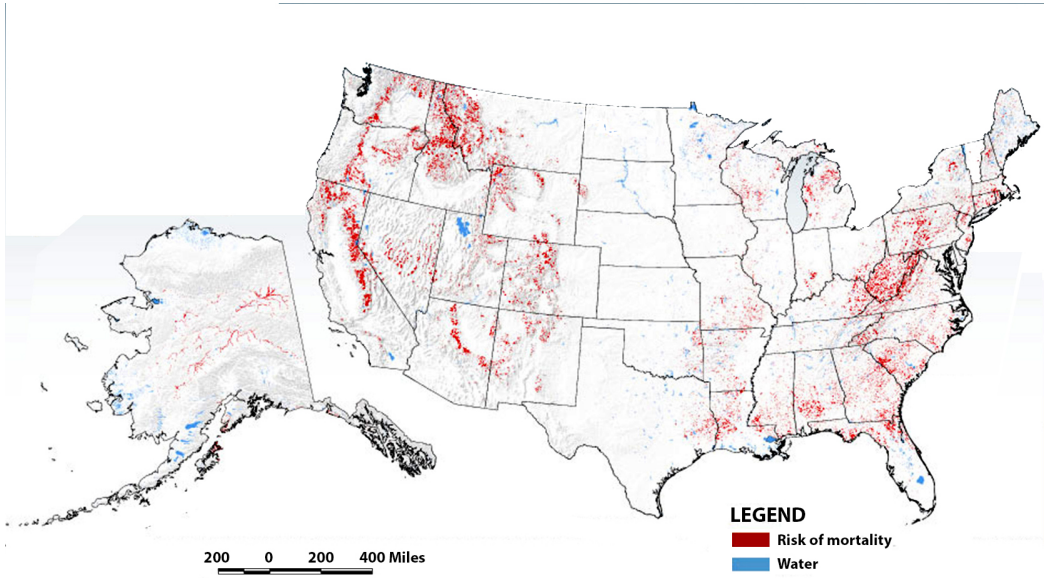
To understand the extent of changing ecosystems, scientists at the US Forest Service Terrestrial Ecological Unit Inventory program use Landsat data to merge soils and vegetation information, which can then be used as indicators of animal populations. Using Landsat measurements of both infrared and visible light, scientists are able to identify the different soil and vegetation types that mark unique ecosystems.

The Terrestrial Ecological Unit Inventory was developed in the 1990s in an effort to coordinate the efforts of a number of scientists who study different parts of an ecosystem. Traditionally soil scientists study soil, botanists study plants, and biologists study animals, but in fact "the flora and fauna meld all of the pieces together to make a habitat or ecosystem," says Bob Benton of the US Forest Service's Remote Sensing Application Center in Salt Lake City, Utah.

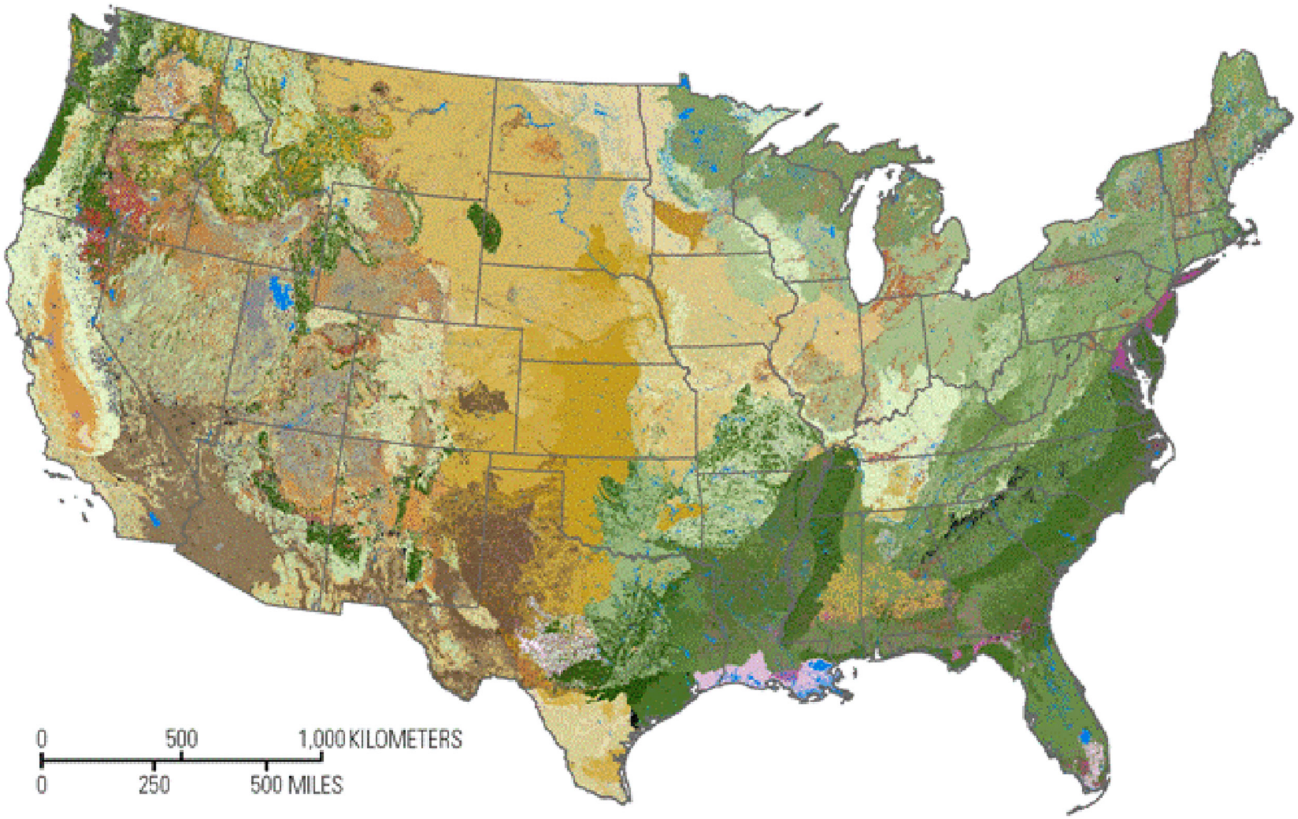
Once Benton and others classify ecosystems using Landsat and other remote sensing data, scientists from the regional offices go into the field to verify that the landscape patterns are indicative of the type of ecosystems thought to be present.

As one may expect, it is difficult to tell exactly what types of flora and fauna are in an area from the satellite image. "Nature seems to abhor sameness," says Bob Benton. Scientists are able to make educated guesses, but the ground verification process brings more certainty to their mapping, leading to a better catalog of the existing ▸

Mapping Insect and Disease Risks with Landsat



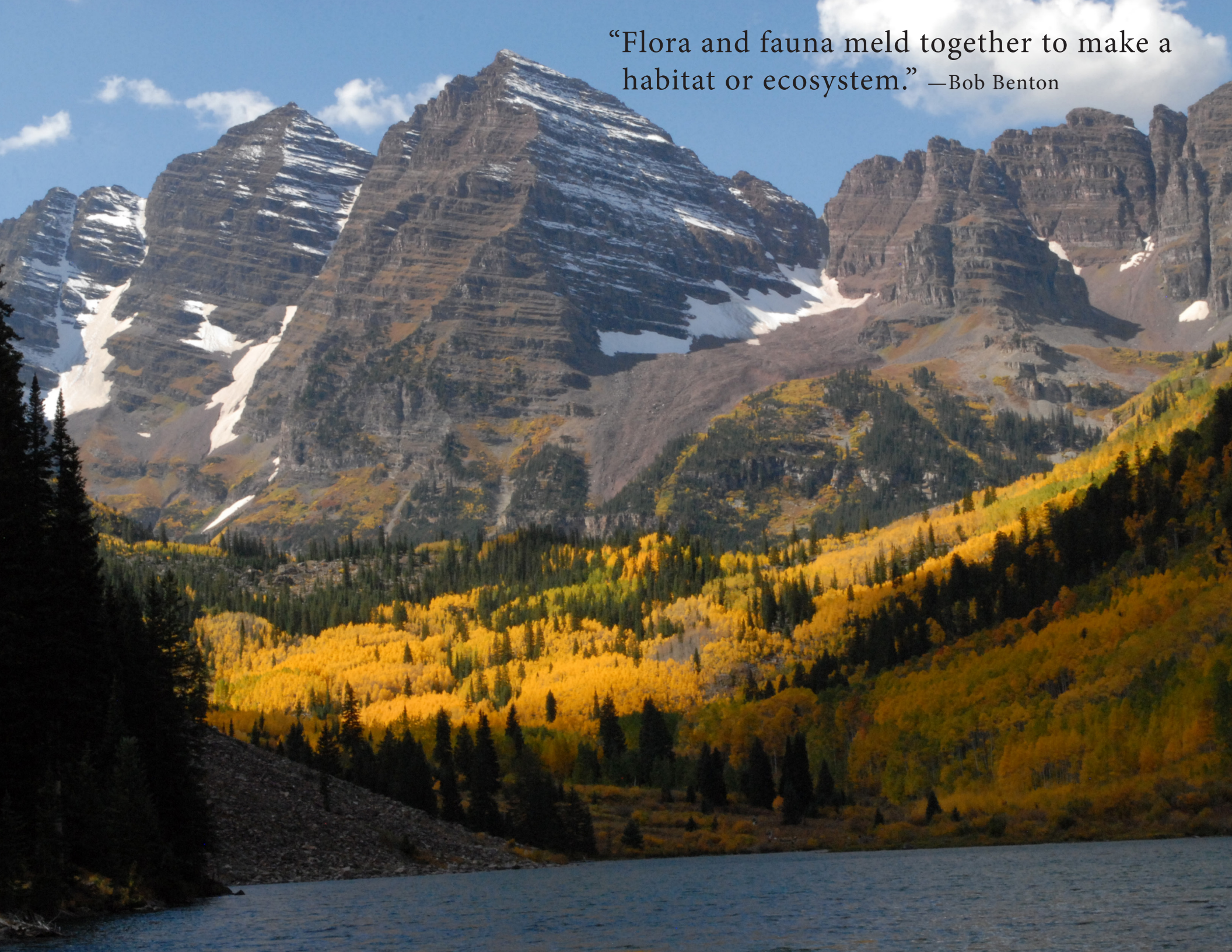
The National Insect and Disease Risk Map (NIDRM) is generated from many data sources, including Landsat, 2006. Credit: USDA Forest Service



Terrestrial Ecosystems

- Forest and Woodland Ecosystems
- Herbaceous Ecosystems
- Shrubland Ecosystems
- Steppe/Savanna Ecosystems
- Woody Wetland Ecosystems
- Herbaceous Wetland Ecosystems
- Sparsely Vegetated Ecosystems
- Water

Landsat data helps scientists define the extent of seven different ecosystems in the United States. Maps are available at http://rmgsc.cr.usgs.gov/ecosystems/usa.shtml Credit: USGS



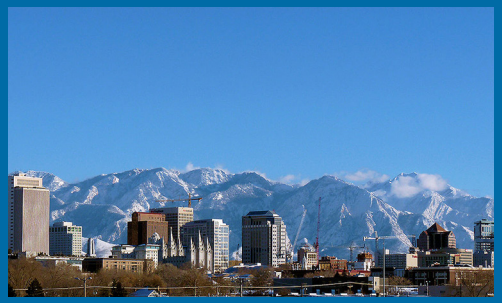
"Flora and fauna meld together to make a habitat or ecosystem." —Bob Benton

ecosystems in the inventory. The Terrestrial Ecological Unit Inventory's "purpose is to give Forest Managers and people who make decisions, a scientific basis to anchor their decisions," says Benton.

When faced with tough choices land managers are able to use inventories like the Terrestrial Ecological Unit Inventory to say, as Benton stated, "This is how I made my decision, it's consistent and this is how it is adapted to the land."

As people Like Sue Cummings continue to spend time at recreation areas and hiking through forests, they will continue to see the land change. Through improved monitoring and better models more proactive measures can be taken to mitigate the effects of insects and disease and to gain a better understanding of the ecosystems that they affect. ■

Meet Bob Benton, Inventory Coordinator for the Terrestrial Ecology Unit



Salt Lake City, Utah

Bob Benton
Inventory Coordinator
Terrestrial Ecology Unit
U.S. Department of Agriculture Forest Service

"Expect that 10 years from now, you won't be doing what you think you'll be doing," says Bob Benton, Terrestrial Ecology Unit Inventory Coordinator at the Remote Sensing Applications Center of the United States Forest Service, when asked if he has any advice for people just starting their careers. "Whatever you're doing now won't be there 10 years from now and you'll have to be relevant in some other way."

Benton is no stranger to changing careers. After spending most of his life working in the banking industry as the Chief Information Officer with Associates First Capital Bank, he hit a crossroads. Citigroup bought the bank and he could choose to relocate to Baltimore, Maryland or to stay and try to find work in Salt Lake City, Utah. He chose the latter, going back to get his master's degree at 58 years old.

Attending classes, surrounded by students that were the same age as his children, wasn't something that he or most people think they'll be doing at a time when many are preparing for retirement. "I was the oldest intern," says Benton about his time interning at the Remote Sensing Applications Center. After completing his master's degree with a focus on remote sensing, Benton reentered the workforce, working his way up from intern to management.

Benton works with a number of researchers, but his background in business gives him a fresh perspective. "They [researchers] break down the pieces." Benton on the other hand, "looks at how things work in aggregate, not how things work in particular." Working with a great group of researchers, Benton is "working towards a common outcome." After a very circuitous route, Benton enjoys what he does and is able to spend time playing in the outdoor playground of ski areas and mountain hikes nearby Salt Lake.

Satellite Data Requirements:

8-day revisit (4-day preferred)

5-30 m resolution

Vis, NIR, SWIR

Global coverage

Archive continuity & consistency

Free, unrestricted data

≤ 5% radiance calibration

12-bit bit data digitization

See inside back cover for more information