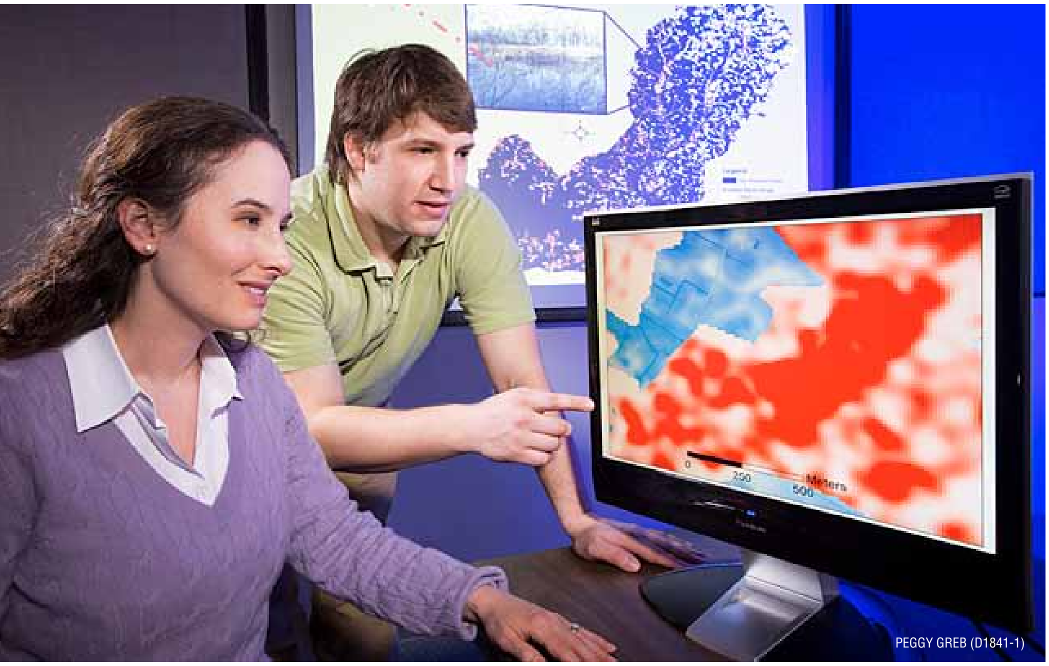
FORESTED WETLANDS
IN THE CHESAPEAKE BAY WATERSHED

USDA Forest Service ecologist Megan Lang uses a global positioning system to determine an area's exact location while ARS soil scientist Greg McCarty measures soil moisture at the location. Information on soil moisture is used to determine the accuracy of wetland maps produced using LiDAR and radar.



Megan Lang and University of Maryland graduate student Robert Oesterling compare forested wetland maps for relationships between low (blue) and higher (white) elevations on one map and wet (red) and drier (white) spots on the other map. The maps were created with two remote-sensing technologies, one using laser light (LiDAR, or light detection and ranging), the other radio waves (SAR, or synthetic aperture radar).

A clear view through the trees. That's what soil scientist Greg McCarty and USDA Forest Service ecologist Megan Lang have been working towards as they pioneer the merging of two remote sensing technologies to map forested wetlands in the Chesapeake Bay Watershed.

McCarty and Lang are based at the ARS Henry A. Wallace Beltsville Agricultural Research Center in Maryland, and they conduct research on the bay's Eastern Shore, which is located on the Delmarva Peninsula that juts between the bay and the Atlantic Ocean. Delmarva is an acronym for Delaware, Maryland, and Virginia—the three states that make up the peninsula.

The two scientists are the first to apply LiDAR (light detection and ranging) to forested wetland mapping. They are also among the few researchers to report combining the laser technology with a similar technology, a form of radar (radio detection and ranging) that relies on advanced technology called a "synthetic aperture radar" (SAR) sensor.

A Tale of Two Sensors

Both SAR and LiDAR are active sensors in that they transmit their own energy. Long-wavelength microwave energy is used by SAR, while shorter wavelength laser energy is used by LiDAR. Both sensors use the time it takes for the signals to travel to the wetlands and the strength of the returning signal to help detect the presence, extent, and, in some cases, depth of water.

SAR is currently collected by satellite-mounted sensors, allowing for more frequent image collections over large areas. LiDAR sensors are usually flown on airplanes, so the imagery is collected much less frequently, but it has greater spatial resolution.

SAR is best for spotting short-term changes in water levels, such as flooding or short-lived pools of water, while LiDAR is better for producing highly accurate maps of flooding and understanding the surface-water flow paths in landscapes or recording changes over long time periods.

SAR sensors are not restricted by clouds or even most rainstorms. That is important when collecting data during rainy periods, when wetlands really show up. The imagery also makes it practical to monitor wetlands year-round, day or night.

Both LiDAR and SAR can literally see the wetlands through a forest canopy. Most bay-area wetlands are forested, as are half of the wetlands in the United States.

The sensitivity of radar's microwaves to water makes SAR ideal for detection of hydrologic patterns in wetlands, although this research demonstrates that LiDAR is also up to the task—and with even greater spatial resolution.

More Accurate Wetland Maps

With the synergy between the two sensors, McCarty and Lang have created wetland maps that are about 30 percent more accurate than existing maps that use aerial photographs, a standard method for wetland mapping. This synergy also made it possible for them to develop new techniques to monitor wetland flooding and soil moisture as it varies through time. This information can be used to map wetlands and estimate the ecosystem services that wetlands provide society—such as filtering out pollutants, controlling floods, cycling nitrogen and other nutrients, storing carbon, and providing wildlife habitat.

"The combined sensors can greatly improve understanding of ecological services that wetlands provide and will likely have bearing on the management and conservation of wetland ecosystems in agricultural landscapes nationally," McCarty says.

Together, the two sensors can detect wetlands and identify their ecological benefits. As one example, Lang points to combined LiDAR/SAR maps that show water flow: In one part of the map, the surface water is flowing into a ditch and then into the Choptank River—a major Chesapeake Bay tributary—with little filtering of pollutants. To the right of that area, water flows into a forested wetland, where nutrients, sediments, and pesticides

Using a global positioning system, ARS soil scientist Greg McCarty locates a wetland study site.

may be removed before entering the river. Lang can even track how well these forested wetlands can remove pollutants through time. This information would not have been available from less advanced images, like aerial photography.

Wetlands Not Separate After All

Combining SAR and LiDAR gives such a clear view of wetlands that McCarty and Lang have found that many depressional wetlands on the Delmarva Peninsula are often connected to each other, to waterways, and to the bay by an intricate network of other wetlands, drainage ditches, intermittent streams, and ponds. Lang and McCarty have mapped networks that carry water and possibly pollutants to the Choptank River.

Many of these depressional wetlands were thought to be hydrologically isolated from each other, from perennial streams and rivers, and from the bay, so the Clean Water Act did not offer them the same regulatory protections as other wetlands.

The advent of new technology has made this work possible. LiDAR topographic mapping is spreading from state to state. New LiDAR and SAR sensors are being developed, along with advanced computer software and models to process data. The fine-resolution LiDAR data that is used by McCarty and Lang was provided by the Canaan Valley Institute in Morgantown, West Virginia, in partnership with the ARS Pasture Systems and Watershed Management Research Unit in University Park, Pennsylvania. These two organizations are currently working with McCarty and Lang to extend LiDAR to other applications, including the prediction of in-field soil moisture variations.

Chesapeake Bay Watershed Is Test-Bed for Improved Wetland Monitoring

The scientists are working with USDA's Natural Resources Conservation Service in the Choptank River Watershed as part of the Mid-Atlantic USDA Wetland Conservation Effects Assessment Project. This project is a test-bed for new landscape-monitoring tools and technologies that will be used for national applications. It partly funds Lang's and McCarty's research.

The flat topography of the Choptank River Watershed causes poor drainage, so farmers have built an extensive network of drainage ditches.

Lang says, "Until recently, people have not fully appreciated the valuable services wetlands provide to society, and this has led to the loss of vast areas of wetlands. Maryland has lost about 75 percent of its wetlands, and we estimate that the Choptank Watershed has lost well over half of its historic inland wetlands. But the wetlands that remain serve critical roles in maintaining water quality, regulating greenhouse gases, and providing habitat. The information that SAR and LiDAR provide can be used to best manage the native wetlands that remain and reduce the impact of agriculture on the bay."

The maps created by McCarty and Lang show changes in wetlands caused by ditches, other construction, farming, and weather. By tracking the impact of extreme weather on wetland water levels, they can predict how climate change will affect wetlands and their ability to provide vital services, like improving water quality, in the future. In this way, the maps also help identify how these changes may affect the health of the bay.

LiDAR can also be used to create digital elevation models. These maps have a three-dimensional-like effect, showing likely flow paths and where water may pool. The maps are accurate for elevation differences as small as 6 inches. These small differences can add up to big changes in flat landscapes like the Delmarva.

Even Bare Trees Block Aerial Views

"With aerial photography, it's almost impossible to see wetlands when deciduous trees have leaves, and it's very difficult to see many types of wetlands even when the leaves are gone. The tree branches and their shadows are often enough to hide wet soil, ditches, and ephemeral streams," Lang says.

With the combined sensors, the "view" through the trees is so thorough that it even "sees" wildlife habitat, such as small pools that form each spring where many invertebrates spawn, including endangered species. These vernal pools serve as refuges for other animals, such as frogs and toads. The pools also help maintain unique vegetation—even endangered plants—by providing moisture for seed germination.

The research adds vital information to the Chesapeake Bay cleanup and state and national wetland regulation debates.—By **Don Comis,** ARS.

This research is part of Water Availability and Watershed Management, an ARS national program (#211) described at www.nps.ars.usda.gov.

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