

Science

FINDINGS

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"Science affects the way we think together."

Lewis Thomas

Water, Water Everywhere: Subtle Shifts in Soil Saturation Drive Ecological Function in Coastal Rain Forests

"A cloak of loose, soft material, held to the Earth's hard surface by gravity, is all that lies between life and lifelessness."

—Wallace H. Fuller

Most of what goes on in soil is virtually invisible to humans. We more commonly notice what soils produce rather than the soils themselves, so it can be easy to forget about the critical role they play in maintaining healthy watersheds.

"It's surprising how little people know about soils, and how they really underestimate their importance," says David D'Amore, a soil scientist with the U.S. Forest Service Pacific Northwest Research Station in southeast Alaska. "Soils are not similar—there is a very complex array of soil types on the landscape. In the United States alone, there are more than 20,000 unique types of soil, and that's a real underestimate—that's just the soils we map and identify."



Identifying wetlands in southeast Alaska can be tricky because the ground is generally wet much of the year. A recent study shows how soil color—a result of iron oxidation and reduction—can be an indicator of soil saturation.

To call attention to the essential function of soils in sustaining life on Earth, the United Nations General Assembly declared 2015 as the International Year of Soils. At the most basic level,

USDA Natural Resources Conservation Service

IN SUMMARY

New research reveals how topography, soil temperature, and subtle shifts in soil drainage are key drivers in ecosystem function in the coastal temperate rain forests of southeast Alaska and British Columbia. These studies, by Dave D'Amore and his colleagues, provide a better understanding of the influence of soil hydrology on dissolved organic carbon export and the interplay between soil saturation and tree species' response to varying soil conditions. More refined techniques for identifying hydric soils are making wetland delineation in southeast Alaska quicker, easier, and more accurate.

Identifying wetlands has been particularly tricky in these areas because southeast Alaska is relatively moist year-round. This means that wetland delineation is based on more subtle indicators. One study provides new information about how soil color can be used as an indicator of soil saturation and reduced oxidation, thus streamlining and increasing the accuracy of wetland identification. Scientists also have developed models that, based on long-term position of the water table and soil drainage, project the types of vegetation that will occur in specific landscapes. This information is proving useful for climate change adaptation planning. Other studies explore the influence of soil hydrology on the release of dissolved organic carbon into the Gulf of Alaska.

soils are formed from glacial deposits, alluvium, and weathered bedrock. After stabilizing, they capture and transform nutrients, enabling vegetation to grow. They retain, filter, and export water. And scientists are just beginning to appreciate their important role in storing and cycling carbon.

“We’re still on the cusp of a rich understanding of how soils function,” says D’Amore.

Much of D’Amore’s work focuses on the emerging science of hydropedology, which explores the inextricable link between soils and moisture. He and his colleagues have recently completed several studies that add much to the body of knowledge about how soil saturation affects forest productivity and how soils sequester and cycle carbon. Their findings provide more precise methods for identifying

KEY FINDINGS	
• Soil color can be used as an indicator for identifying soil saturation and reduced oxidation.	
• The depth of the long-term water table can be used to predict the occurrence and abundance of particular tree species and overall biomass accumulation.	
• Improved models for assessing soil saturation and dissolved carbon export provide better methods for assessing carbon budgets on a landscape.	

wetlands, predicting carbon budgets in the coastal rain forests of North America, and assessing species-specific forest productivity.

ASSESSING CARBON BUDGETS

Wetlands are capable of sequestering carbon for thousands of years, and their capacity to fulfill this function is particularly important in coastal areas. As water flows through soils, sequestered carbon dissolves and moves from the land into streams and rivers, ultimately reaching the ocean.

The world’s largest contiguous expanse of coastal temperate rainforest stretches from northern California to south-central Alaska. In southeast Alaska, thousands of relatively small watersheds drain into the Gulf of Alaska. The volume of freshwater coursing through these perennially wet forests, bogs, and estuaries is larger than the flow of the Mississippi River, and it brings with it large quantities of dissolved organic carbon.

One of the studies D’Amore was involved in provides models that will better predict this movement of dissolved organic carbon throughout southeast Alaska and British Columbia’s waterways. He and his colleagues found that increased soil temperature combined with frequent water table fluctuations promote the export of large quantities of dissolved organic carbon from the area’s forested wetlands, poor fen (marshy areas consisting of dense, low growth), and upland forests throughout the region. They also found that concentration of dissolved organic carbon in streams was significantly correlated to the slope of a watershed.

Jaquie Foss, a Forest Service soil scientist with the Tongass National Forest in southeast Alaska, is using the results of these recent

studies to inform her work in the field, which includes mapping soils and identifying wetlands throughout the Tongass. She is particularly grateful to have substantial data that specifically relates to the area she manages.

“A lot of the work that has been done on carbon and wetlands and soils—and just in general—has occurred in the lower 48 states,” says Foss. “We have this mantra up here: ‘Alaska is different’—the disturbance regimes, the way water is processed, the small scale of our watersheds. It was enlightening for me to learn that our three dominant land types—poor fens, forested wetlands, uplands—behave differently but are still responsible for huge amounts of carbon moving into the waters and out to sea. I hadn’t really given much thought to the drier parts of our landscape being responsible for

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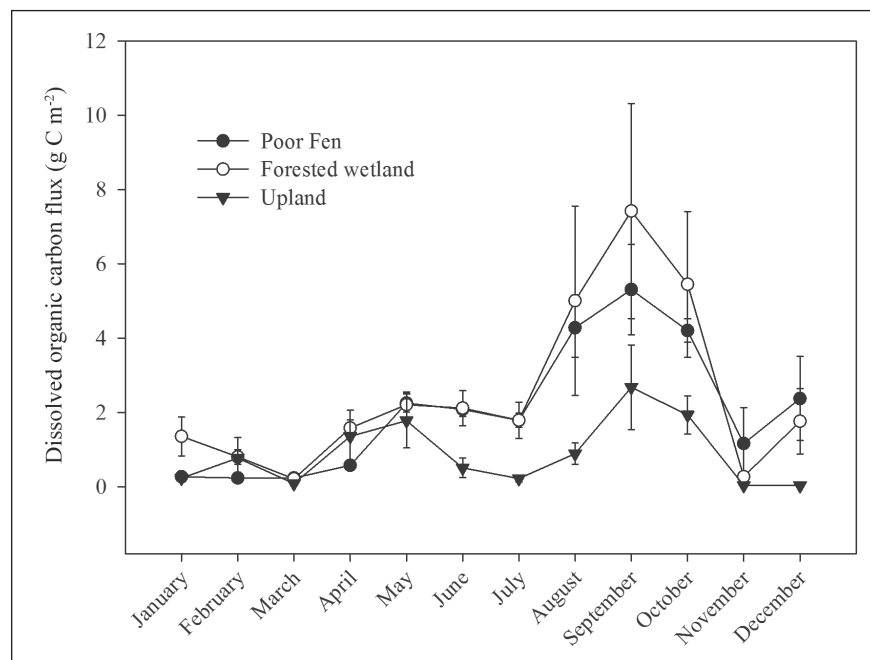
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Large amounts of dissolved organic carbon flow from the watersheds of southeast Alaska into the Gulf of Alaska, providing a potential source of energy for freshwater and marine food webs. Warmer soil temperatures combined with fluctuations in the water table promote the export of dissolved organic carbon.

D’Amore, Edwards, Herendeen et al. 2015

that much carbon moving around. It's pretty interesting that all of our landscapes are linked by hydrology, more so than I'd really considered."

Even though, as Foss points out, Alaska's watersheds are small relative to other places

in the world, they still produce a dramatic ecological impact. "Dissolved organic carbon export from Alaska's coastal temperate rain forests is among the highest in the world," says D'Amore. Excess carbon in the atmosphere and the ocean is associated

with ocean acidification and, in the long run, a warming climate. "So predicting the fate of this massive soil carbon stock under changing climate scenarios is extremely important," he says.

USING SOIL COLOR AS A TOOL FOR WETLAND DELINEATION

A key application for D'Amore's work is wetland delineation. Identifying wetlands is an important management action because it has implications for land-use planning. Wetlands have been under federal protection since passage of amendments to the Clean Water Act in 1972.

"In the regulatory world, a wetland is under a very different management designation than a non-wetland," says D'Amore. Any disturbance activities, such as road building, ditching, infilling, or logging, are considered potentially harmful to the natural function of a wetland and are specifically controlled through a robust permitting process.

Unfortunately, identifying wetlands in temperate coastal rain forests like those in southeast Alaska and British Columbia is exceptionally challenging because the land is always relatively moist. "Essentially, we end up asking ourselves what is wet and what is not-so-wet," says D'Amore. "Defining the line between wet and not-so-wet has been very difficult, so what we've tried to do in soils is come up with features that identify the presence of water."

One of those features is color. D'Amore and his colleagues linked measurements of soil saturation with soil color.

Soils in the rain forests of southeast Alaska contain oxidized iron, so they tend to be red and reddish brown. When the soil is wet, the iron is reduced. "It gains an electron and turns into a mobile form of iron and is moved out of the soil matrix into the soil solution, so the soil becomes less red," says D'Amore. "You get duller colors."

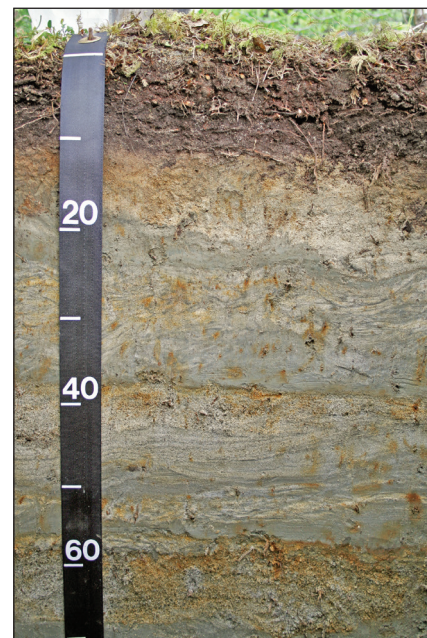
Unfortunately, it's not as simple as that, because the water table fluctuates seasonally, which causes the iron to oxidize again before it leaves the soil completely. This creates mottling—red colors mixed with gray colors. Soil scientists use the term redoximorphic to refer to soils that have these types of colors and water table dynamics.



This research helps calibrate the field guide to hydric soils used by practioners in the field.



The active surface horizon and the inactive sub-surface horizons of this organic soil are clear in this photo. Water flows freely through the surface carrying dissolved carbon to nearby streams.



The color of this soil, dull gray with red mottling, indicates that the soil alternates between very wet and dry. The iron in it has been leached from the gray areas and redeposited where there are just traces of red. This soil sample is derived from an alluvial deposit of silt near the Mendenhall River in Juneau.

Dave D'Amore

Dave D'Amore

USDA Natural Resources Conservation Service

“Redoximorphic features are color patterns in the soil formed by the oxidation and reduction of iron and/or manganese caused by saturated conditions within the soil,” says D’Amore. “You get the gray, dull browns, and bright reds together. These features make it difficult to identify whether the soil is wet or not-so-wet, unless you have some kind of calibration.”

It takes training to be able to specifically identify soil features in the field. A publication called *Field Indicators of Hydric Soils in the United States* guides Forest Service soil scientists in this task. “Research like mine helps calibrate that guide—we provide new indicators,” says D’Amore. “Color features are calibrated so that a person going out into the field doesn’t have to measure soil moisture, which is a time-consuming and costly process.”

Another feature that can be used to predict wetland soils is landscape position, or slope. D’Amore’s team analyzed specific sites for iron depletion and concentration and then tied that to slope position and water table depth, providing a gradient cutoff for soils that are most likely hydric (very wet). Combined with visual soil indicators like color, the process of wetland delineation is greatly improved.

“This makes my job a lot easier,” says Foss. “Typically, the soils I would consider gray are the somewhat poorly drained soils; they’re intermediate between the land that’s very clearly wetland—the bogs—and the non-wetland, steep forested slopes. It’s easy to tell one from the other. But in that intergrade between, it’s very difficult to determine. I can use Dave’s findings to guide where I go to

begin to determine whether it’s wetland or not. Now I know that when I see a specific color, it’s tied to a specific chemical process that is or isn’t hydric. So that’s really helpful.”



Dave D’Amore

Dark organic matter incorporated into soils often masks color patterns making hydric soil interpretations difficult without accompanying measurements of soil saturation and reduction.

PREDICTING VEGETATIVE GROWTH IN MOIST CLIMATES

One of the major challenges for forest managers in southeast Alaska is determining how well specific tree species will grow on a certain patch of land. “Models for that have been very elusive,” says D’Amore. “The Forest Service is striving to come up with productivity maps across this landscape.”

As Foss mentioned in relationship to soils, it’s also relatively easy to predict vegetative growth at either end of the spectrum: where big trees stand on drier, well-drained areas versus marshy areas that host water-loving grasses and no trees at all. It’s in the strong gradient between wet and not-so-wet that the challenges occur.

“Trying to figure out what is wet and is stunting or limiting the ability of trees to grow, and where it’s not-so-wet and trees can grow really well, is actually very difficult to find on a landscape, because it occurs on such a small scale,” says D’Amore. “The way we’ve mapped the forests and the soils in the past, it doesn’t capture those subtle changes across the landscape.”

So, in addition to helping to map hydric soil types, the studies D’Amore was involved with show how soil saturation and refined knowledge about plant competition can enable land managers to better predict vegetative cover.

“We found a zone in the soil where, if the water table persists at a certain depth, you tend to have limited growth. And if the soil water is below that depth, you tend to have better growth,” he says. “The long-term position of the water table can influence the biomass that is found on a site.”

This finding is allowing forest and soil scientists to develop models to help identify predicted areas of higher and lower forest productivity. “Right now, we’re building a tool using what we call a saturation index, where we can map the depth of the water table across the landscape using geographic information, specifically topography,” says D’Amore. “We



Dave D’Amore

Wetland or just wet land? It can be difficult to delineate wetlands based on the vegetation alone. Skunk cabbage, growing in the foreground at the site pictured above, is a clear indicator of wetlands. The surrounding forest does not have this vegetation indicator but may also be saturated near the soil surface much of the year and meet jurisdictional wetland requirements.



Dave D’Amore

The presence of shore pine growing in this open wet site reflects the trees’ inability to compete for light with other conifers in forested conditions, rather than a preference for wet soil. An improved understanding of the physical and chemical influences on forest vegetation is helping advance fundamental plant ecology and forest management in coastal rainforests.

have a much better understanding of where the water is in the soil and how that controls the aboveground vegetation.”

Previous wetland delineation relied heavily on species distribution to determine wetland status, but D’Amore’s collaborative studies specifically looked at species’ distribution in light of hydopedological factors and found that the presence of a particular species may not be the most accurate determinant of wet versus not-so-wet.

“When you see shore pine here, it’s most likely in a wetland, but that’s not because of preference for those saturated soil conditions—it’s their inability to compete for light in forested upland conditions,” says Foss. “And the findings suggest that, while you do occasionally find western hemlock—which is quite common here—in wetland areas, this species typically prefers to be outside of saturated soil conditions. So this research could potentially change the indicator status for wetland delineation. In my opinion, it will give us a much more accurate representation of the landscape in southeast Alaska.”



LAND MANAGEMENT IMPLICATIONS



- Wetlands can be precisely identified by using improved measurements of anaerobic soil conditions and hydric soil indicators.
- The depth of the water table can be used to predict areas of higher and lower forest productivity. A saturation index is in development that will map water table depth across the landscape based on topography.
- Improved modeling of dissolved organic carbon export allows for more accurate estimation of carbon sequestration.

As the climate along the coastal region of North America changes, landscape features are adapting through natural processes. Previous multidisciplinary studies to which D’Amore contributed have linked the slow decline of yellow-cedar in the region to the effects of a warming climate, specifically because of the species’ shallow root system. Yellow-cedar is found on the landscape in the in-between zone between wet and not-so-wet. A more complete understanding of the hydrology is allowing researchers to identify where

yellow-cedar is growing now and where it is predicted to grow in the future.

“This information can be used in yellow-cedar conservation and management,” says D’Amore. “Being able to identify where drainage occurs across the landscape is a key tool and management need.”

“How can I live my life stepping on this stuff and not wonder at it?”

—William Bryant Logan

FOR FURTHER READING

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