USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Northern Research Station
Rooted in Research
ISSUE 42 | NOVEMBER 2024

Soil Biodiversity from Above: Remote Sensing Finds Relationship Between Forest Structure and Microbial Diversity

Biodiversity is declining in many regions of the world. Scientists know more about the diversity of aboveground organisms (like trees, plants, and animals) because they are easier to detect and measure than belowground organisms (like bacteria and fungi). Estimating belowground biodiversity usually involves extracting and sequencing DNA from soil, an expensive process that provides information about a small area of land. Forest restoration efforts would benefit from techniques that provide belowground biodiversity data for large areas of land. In a recent study, researchers explored whether using remote aerial sensing of forest structure could estimate belowground biodiversity.

Fine roots of yellow birch (*Betula alleghaniensis*) viewed under a dissecting microscope. Note several species of ectomycorrhizal (ECM) fungi colonizing the tips of the root system; many ECM species can associate with the roots of an individual tree simultaneously. USDA Forest Service photo by Ashley Lang.

Previous studies have shown that plant communities and soil microbial communities are often closely associated. However, it's not known whether forest structural diversity, the three-dimensional volume and arrangement of trees and plants within a forest, might relate to microbial diversity in soil. To explore this question, Ashley Lang and Grant Domke, scientists with the U.S. Department of Agriculture, Forest Service, Northern Research Station, and colleagues ran a study to determine whether LiDAR (light detection and ranging), an aerial remote sensing method used to measure forest canopy structure, might also be able to estimate soil diversity in large, forested areas.

Sensing Structural Diversity

Forest structure that is more diverse often translates to greater habitat diversity, which can support more types of life both above and below the ground. Greater structural diversity might also indicate higher forest productivity because variability in tree height can allow for more access to sunlight and therefore more photosynthesis overall.

To test the relationship between forest structural diversity and soil biodiversity, Lang, Domke, and the research team used data from 38 central hardwood forest plots in Indiana. Aboveground, they looked at tree inventory data. Using LiDAR, they measured forest structure (canopy density, variability, and height). Belowground, they measured soil chemistry from soil cores and analyzed microbial DNA from the cores to estimate bacterial and fungal diversity.

KEY MANAGEMENT CONSIDERATIONS

- Remote sensing of forest structure was used to estimate characteristics of microbial communities in central hardwood forests in Indiana and shows some promise for estimating belowground biodiversity across large landscapes.
- Diversity metrics of forest structure from remote sensing correlated with the overall composition of soil bacteria, ectomycorrhizal fungi, and total fungi communities.
- Canopy vegetation density was related to the diversity of ectomycorrhizal fungi, but soil properties, including pH, carbon-to-nitrogen ratio, and iron were shown to be better predictors of some microbial communities than remotely sensed metrics of forest structure.

The researchers knew that some types of fungi are linked to specific tree species and soil carbon stocks. For example, arbuscular mycorrhizal fungi create structures inside plant cells that help exchange carbon and nutrients. These fungi play a crucial role in nutrient uptake for plants. Ectomycorrhizal fungi also play a crucial role in nutrient uptake by forming structures around plant roots. Some specific types of ectomycorrhizal fungi may be associated with higher soil carbon stocks.

Soil Microbial Diversity and Forest Structure

The researchers found that forest structural diversity metrics related to indicators of microbial diversity. Forests with denser canopies and more varied structure tended to have more diverse ectomycorrhizal communities and more bacterial and overall fungal diversity. And although the relationship between forest structure and microbial diversity is not yet fully understood, it may be related to the age of the forest: older forests often have more structural diversity and may also have more diverse ectomycorrhizal communities.

Fruiting body of the ectomycorrhizal fungus *Amanita flavoconia*. *A. flavoconia* commonly associates with the roots of Eastern hemlock (*Tsuga canadensis*) and red spruce (*Picea rubens*) trees. USDA Forest Service photo by Ashley Lang.

The team also found that the remote sensing technique was most useful for estimating ectomycorrhizal fungi diversity, which was less well predicted using soil measurements. For other microbial communities, soil properties like pH, carbon-to-nitrogen ratio, and oxalate-extractable iron (which represents the reactivity of mineral soil), were better predictors of microbial diversity than forest structural diversity. The connections between soil properties and ectomycorrhizal fungi were inconsistent. Together, soil properties and LiDAR data may help scientists understand soil biodiversity patterns in forests.

Biodiversity Across Broad Scales

Even though remote sensing technology like LiDAR provides relatively low-resolution data, the researchers found correlations between LiDAR data and soil microbial diversity in the central hardwood forests of Indiana. "The fact that a pattern was discernable—even within that rather narrow ecosystem type—is kind of shocking," Lang says of the team's discovery.

Lang notes that the study of soil carbon and the role of microbes is rapidly evolving and hopes that these research findings can ultimately help estimate soil carbon based on forest canopy structure. "Using remotely sensed information to understand microbial community composition would be a big step forward," says Lang, "so that, when we one day have a clear picture of how microbes cycle carbon, we will be able to create the full link." Scaling up soil biodiversity estimates using LiDAR can help scientists cover more ground, identify areas where soil biodiversity is likely to be high, and guide forest restoration efforts.

PROJECT LEADS

Ashley Lang is a postdoctoral scholar with the Forest Inventory and Analysis (FIA) Carbon Science Group, Northern Research Station.

Grant Domke is a research forester with the Forest Inventory and Analysis (FIA) research work unit, Northern Research Station.

Jenna Zukswert is the author of this Rooted in Research Science Brief.

FURTHER READING

Lang, Ashley K.; LaRue, Elizabeth A.; Kivlin, Stephanie N.; Edwards, Joseph D.; Phillips, Richard P.; Gallion, Joey; Kong, Nicole; Parker, John D.; McCormick, Melissa K.; Domke, Grant; Fei, Songlin. 2023. Forest structural diversity is linked to soil microbial diversity. Ecosphere. 14(11): 14e4702. https://doi.org/10.1002/ecs2.4702.

Forest Service Research and Development works with partners to deliver the knowledge and tools that land managers need to sustain the health, diversity, and productivity of our Nation's forests and grasslands for present and future generations. The Northern Research Station (NRS), one of seven FS R&D units, is rooted in the geography of the Northeast and Midwest. NRS science supports a sustainable future.

For questions on Rooted in Research, please contact Andrea Brandon-Hennig. Technical editing by Carol Hollar-Zwick. Design and layout by Jeremy Siegrist.