ENVIRONMENTAL SCIENCE JOURNAL FOR TEENS

NOVEMBER 2016

What kind of fungus are you?

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Associate Editor:
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Abstract

You may think of fungus as something gross and slimy, but it's actually an important part of the forest ecosystem! Nearly all tree species depend on a symbiotic relationship with one of two types of fungus called AM or ECM (comes from *arbuscular mycorrhizal and ectomycorrhizal*). Which fungus grows in the trees' roots determines how nutrients are cycled and many other important things.

We wanted to find a way to classify large areas of trees as either AM or ECM using information found in satellite imagery. To see if our technique worked, we compared the results of our satellite measurements with observations we made by hiking through four different forest sites across the United States.

Introduction

A symbiotic relationship is a relationship between two species that benefits both species. Trees have a symbiotic relationship with two types of fungi, AM and ECM. The two groups of trees have different characteristics – different types of leaves, different rates of leaf decomposition, and different ways of handling nutrients like carbon and nitrogen. It is useful for scientists to know what percentage of the trees in a forest are AM or ECM because it helps us understand the way nutrients move through the ecosystem (Fig.1).

The challenge is that most forests have a mixture of the two types of fungi living in the tree's roots. How can we classify them without walking every inch of forest and counting every tree? We decided to see if we could use satellite images to classify trees automatically.

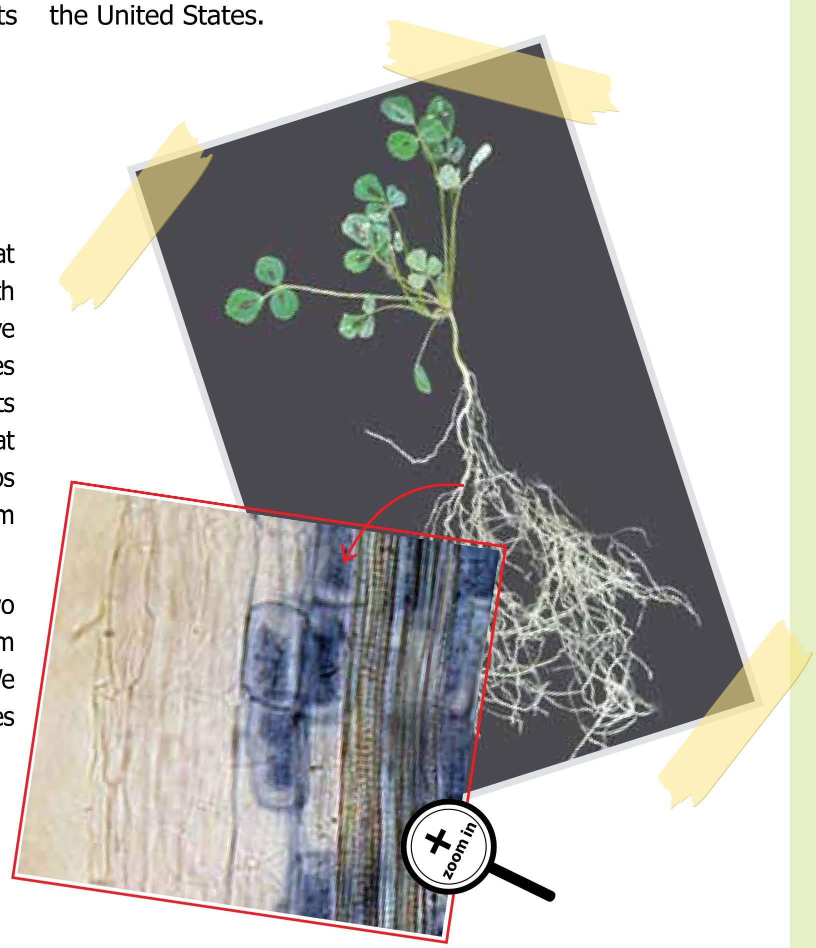

Figure 1:
Mycorrhizal fungi live in plants' root systems.

Satellite images contain much more information than just what the surface of the earth looks like. Light is emitted at lots of different wavelengths. Satellites can detect those different wavelengths for a given pixel and develop what is called a "spectral signature". Spectral signature is the measurement of the wavelengths of light, both visible and invisible, given off by an object.

We wondered if we could tell a difference between the AM and ECM trees just by looking at their spectral signature. If we could, then we'd be able to use satellite data to classify large areas of forest into AM and ECM trees. A number of other scientists have tried to develop ways to do this, but previous methods have so far been too complicated or cumbersome for a computer to do quickly.

Methods

We selected four forest plots in different parts of the United States for this study, Indiana, Virginia, Wisconsin, and Missouri. Before we measured the spectral signatures of the trees using the satellite data, we walked through each forest plot and recorded information about what kinds of trees were growing in each one. We used this information later to see if the satellite data was correct.

Once we knew what kinds of tree species grew in our forest plots, we made maps to show what areas were dominated by either AM or ECM trees, or whether it was a mix of both. We also collected dead leaves and soil from the ground at our study sites and measured the chemical composition to see how the ecosystem was cycling nitrogen and carbon.

We used a statistical technique to narrow down which kinds of satellite data were most important in classifying the trees.

While we were looking at those variables, we noticed that tree growth patterns vary by location, even for trees with the same fungal association. Trees at the Wisconsin site had a much shorter growth phase than trees at the lower latitude sites like Indiana and Missouri, for example. It was important that the model we developed could account for these regional differences when making predictions about tree type, so we fine-tuned the model using half of our observed fungal association data at each site.

Finally, we tested the model using the other half of our data.

Results

The figure shows maps of each test site comparing the percent of AM trees for each plot with the fungal association predicted by the model. In most plots (77%), the model predicted the correct percentage of AM trees (Fig. 2). We tried testing the model in a number of different ways and found similar results each time.

The last step of our analysis was to use the model to predict fungal association of trees outside of our study area. Although the model did a pretty good job predicting the percentage of AM trees in the study areas, it tended to overpredict the percentage of AM trees in plots with few AM trees. The opposite was also true.

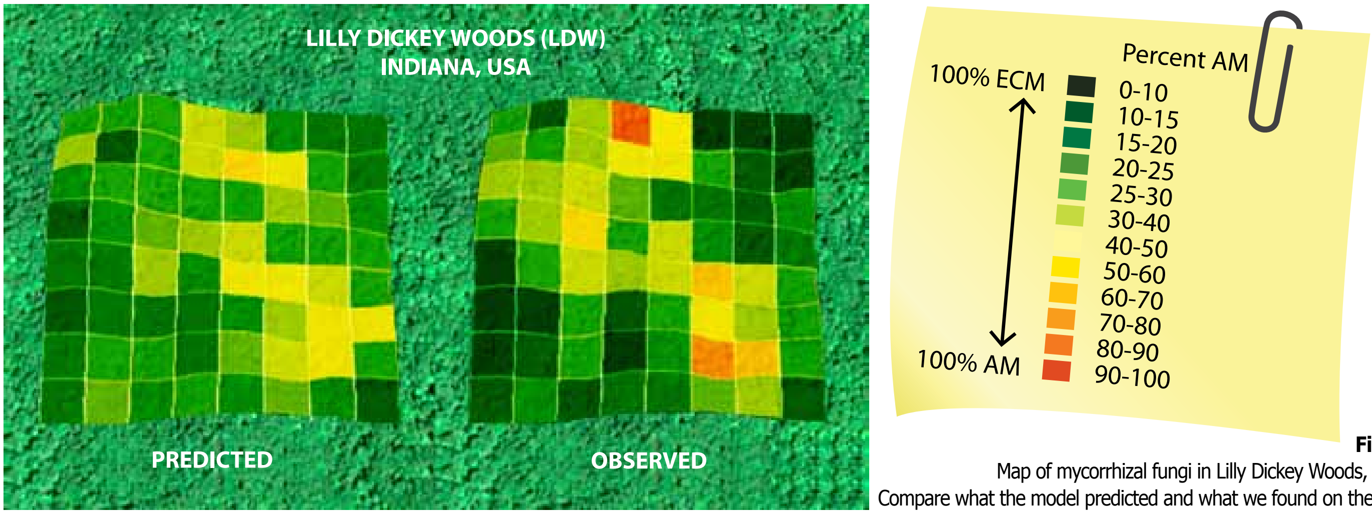

Figure 2:
Map of mycorrhizal fungi in Lilly Dickey Woods, IN, USA.
Compare what the model predicted and what we found on the ground.

Discussion

Forest composition, the species and numbers of trees growing there, have changed a lot in the last hundred years because of the way people have changed the landscape for agriculture and cities. It is important to know how changes in forest composition affect the way our forest ecosystems work. To study that, we needed a way to classify trees across a large area.

Our model uses information found in satellite images to classify trees as either AM associated or ECM associated. Even though the fungi are tiny and located underground, they have a big impact on the leaves of the tree. Things like leaf size, lifespan, color, nutrients, and structure are all influenced by the kind of fungus the tree interacts with. That's why we can tell whether a tree is AM or ECM all the way from space.

In addition to their different spectral signatures, we also found that dead leaves from the two types of trees behave differently in the way they decompose and put nutrients like nitrogen and carbon back into the soil. Knowing what kind of trees are in a particular forest helps us understand how the forest functions. In particular, scientists want to know how forests store away carbon, which in its gas form (carbon dioxide) has a big impact on our climate.

Conclusion

Although it's not perfect, we developed a useful new way to classify trees based on their fungal association. Our model correctly identified 77% of tree types at our four test sites. Other scientists can use our model to identify fungal associations in trees all over the world. Has the way our forests handle carbon and nitrogen changed in the last hundred years? What does that mean for our climate, now and in the future? Our model is an important step towards investigating those questions.

Glossary of Key Terms

AM *(arbuscular mycorrhizal)* fungi – type of mycorrhizal fungi which penetrates the cortical cells of the roots of a vascular plant. AM fungi produce filaments called hyphae which are highly-branched and short-lived. Thus, AM hyphae increase surface area to scavenge for available nutrients (especially phosphorus) but do not actively decompose organic matter or weather minerals. Most land plants form this type of association (Fig.3).

ECM *(ectomycorrhizal)* fungi – type of mycorrhizal fungi which do not penetrate their host's cell walls. ECM fungi produce filaments called hyphae (also called "mycelium" when bundled together) that extend well beyond the root surface in order to mine soil organic matter and soil minerals for nutrients. Ectomycorrhizas form between fungi and the roots of only around 2% of plant species - all of them woody.

Hyphae – long, branching filamentous structure of a fungus. In most fungi, hyphae are the main mode of vegetative growth, and are collectively called a mycelium.

Mycorrhiza – a symbiotic association between a fungus and roots of a vascular plant. The fungus colonizes the host plant's roots, either intracellularly as in arbuscular mycorrhizal fungi (AM), or extracellularly as in ectomycorrhizal fungi (ECM). The tree exchanges carbon for nutrients with the mycorrhizal fungi.

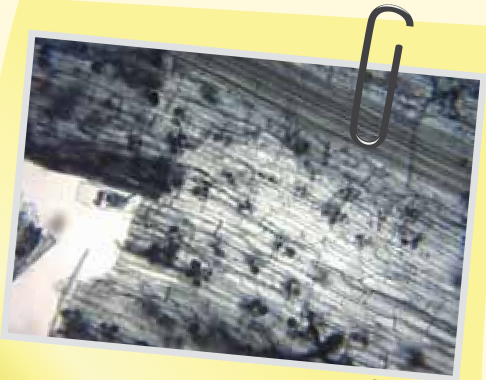

Figure. 3
AM (arbuscular mycorrhizal) fungi

Symbiotic relationship – a relationship between two species in which they live together. If the symbiotic relationship is beneficial to both parties, we call it mutualism.

Spectral signature – a measurement of the wavelengths of light, both visible and invisible, given off by an object

Check your understanding

1. Why was it important for the scientists to gather data on the ground by walking through each section of forest and recording tree species?

2. Just like we recognize visible light with our eyes, satellites are able to detect all different kinds of light, or wavelengths of energy both visible and invisible. Do you know of other ways humans are able to detect different wavelengths of energy?

3. AM and ECM fungi have a "symbiotic relationship" with trees. What are some other examples of symbiotic relationships?

4. The scientists said that the way trees process nutrients, both from the air to the leaves and from the leaves to the soil, is important for understanding the effect of forests on the earth's climate. How do trees remove carbon dioxide from the atmosphere? What happens to it?

5. Given the importance of trees in the forest ecosystem, what are some negative consequences of deforestation (or, the cutting of forests for agriculture or industrialization)?

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Smithsonian Center for Tropical Forest Science (Forest Global Earth Observatory) contained the global forest-plot network that includes the four forest plots used in our paper

http://www.forestgeo.si.edu/

Landsat Science (NASA):
http://landsat.gsfc.nasa.gov/

Acknowledgements: Funding for the remote sensing analysis was provided by the US Department of Energy Office of Biological and Environmental Research Terrestrial Ecosystem Science Program; the US National Science Foundation Ecosystem Science Program; Indiana University's Research and Teaching Preserve; and Indiana University's Office of the Vice Provost for Research. JBF carried out the research at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration, and at the University of California at Los Angeles. Government sponsorship acknowledged