Microsoft

AI for Earth Grantee Profile

Conservation Science Partners

Forest disturbance detection and hydrologic response

Summary

Forests in the western United States are suffering increasing tree losses due to several causes, including droughts from climate change, wildfires, and beetle infestations. This loss of trees is a serious problem not only for maintaining carbon storage, but also for the availability of water resources, as forests play an important role in replenishing local watersheds. A regional-scale analysis of forest disturbances and their impact on water resources changes is necessary to better understand and manage these issues.

With recent advances in AI, machine learning, and cloud computing, it's now possible to combine satellite imagery at medium and high resolutions and analyze this data to see how the forest cover across the region changes from disturbance events. Additionally, that analysis can be correlated to water supply records to understand those impacts as well. Through the insights gained from this study, local communities, regional organizations, and the federal government can better manage and protect these vital resources.

Protecting forest and water resources with AI

Forests play an important part in the global carbon cycle, removing up to 2 billion tons of carbon from the atmosphere annually. But when trees are killed and decompose, their carbon gets released back into the atmosphere. Although new trees grow rapidly, reclaiming most of that carbon, they are also more vulnerable to threats that would kill them and release the carbon again. (See "Climate Change and the Re-Greening of Puerto Rico".) Thus, managing forests to protect them from disturbances that cause extensive harm, such as wildfires or insect infestations, can be an important part of controlling or reducing carbon emissions.

> Approximately 75 percent of the world's accessible freshwater for agricultural, domestic, urban, industrial, and environmental uses comes from forests.

Forests are not only a pathway to reducing carbon emissions, but they also provide many other valuable ecosystem services, such as purifying drinking water. According to the United Nations' Food and Agriculture Organization, "approximately 75 percent of the world's accessible freshwater for agricultural, domestic, urban, industrial, and environmental uses comes from forests." Forested lands are known to absorb rain, refill underground aquifers, slow storm runoff, reduce flooding, and maintain soil stability. Conversely, when forest areas die off, the local watersheds are affected. In drier climes, losing the tree canopy means increased evaporation and less drinking water availability; in wetter climes, more erosion and flooding occurs.

In the United States, forests cover over a third of all land, totaling about 749 million acres including significant portions of the western US. The effects of climate change have been seen in recent years through the record-setting high summer temperatures, accompanied by increasing drought and severe wildfires. This has been in part responsible for some of the most severe forest mortality events in recent history, threatening our water resources as well.

Monitoring changes to the forest cover over time

As a doctoral candidate at Montana State University, Tony Chang studied forest disturbances in the western United States related to climate change and human causes such as fires. In particular, he examined how the changing climate affected the potential future distribution of white bark pine, an alpine tree species in the Rocky Mountains, and the distribution of mountain pine beetle, which is one of the primary disturbance agents in the region. Joining the Conservation Science Partners (CSP) as a David H. Smith Postdoctoral Fellow (one of the primary conservation biology fellowships in the United States), Chang wanted to extend his research to the greater western United States—and also find a way to make it relatable to the average person, living in seemingly distant urban areas. The key to make that connection is the relationship between the forests and the water supply; Chang needed to demonstrate that beetle infestations and wildfires in one year, causing major losses of trees, would mean a reduction in urban water availability in the following year.

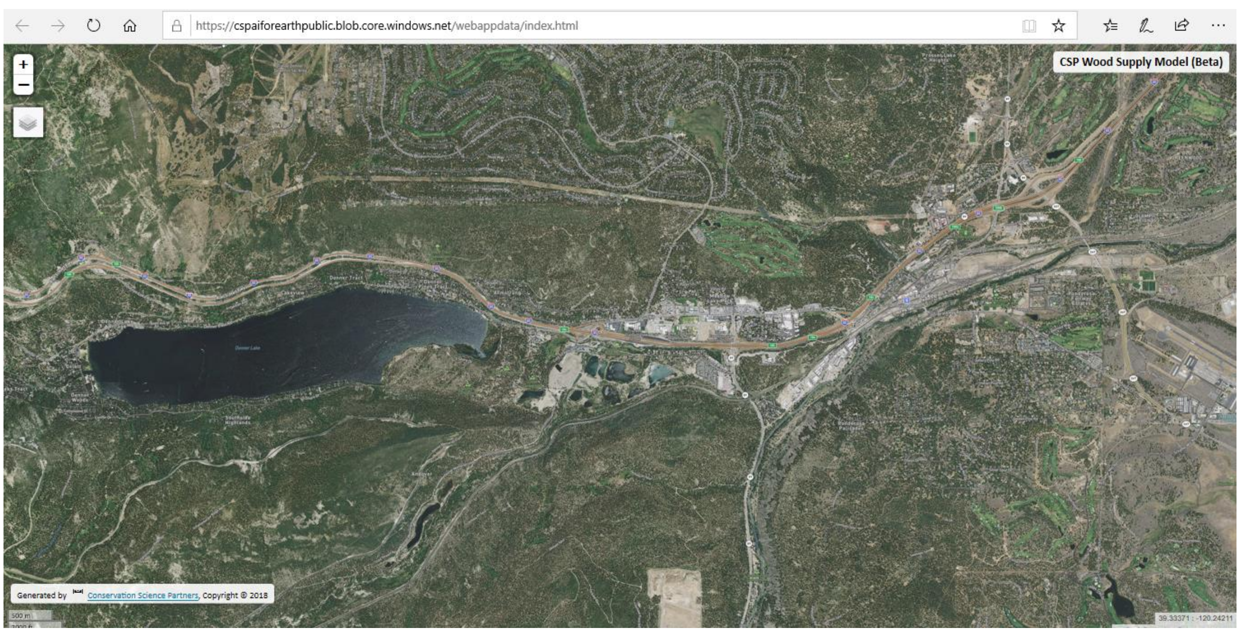
Until recently, this analysis could not be done easily on a wide scale. The US Geological Survey (USGS) and NASA produce Landsat satellite imagery covering the US, but at a 30-meter resolution—a football-field-sized area. While those images are taken often enough to show aggregate changes over time, whether due to the seasons or disasters such as fire, the resolution is too coarse for accurate identification; a grove of dead trees would look the same as a field of dead grass. However, since 2003, the National Agricultural Imagery Program (NAIP) has been producing an annual photo survey of the entire United States at one-meter resolution, high enough to identify individual trees by type (conifer or deciduous). Combining these two resources would allow determination of how much tree mass and canopy cover has been lost, and even the cause of death, whether from fire or beetle infestation or another disturbance.

Recognizing tree conditions with machine learning

Another factor making this possible is the advancement of AI, machine learning, and cloud computing. Even when limiting the data to just one section of the Rockies, such as northern California, processing the dataset is still tasking for most on-premises computer systems. Cloud computing datacenters offer an affordable means to scale to the largest datasets. Similarly, complex deep learning algorithms are now capable of automated, accurate pattern recognition and classification with an efficiency that could never be done manually by humans. Thanks to a Microsoft AI for Earth grant, Chang and colleagues at CSP were able to gain access to all these computing resources on the Microsoft Azure platform.

For this project, CSP is using an Azure Data Science Virtual Machine to build a deep convolutional neural network using the Keras API front end for TensorFlow. To train this model, CSP has gained access to the US Forest Service’s [Forest Inventory and Analysis] (FIA), an on-the-ground samples of trees in the United States, including species, size and canopy, and health. Correlating this information to the NAIP photos enables Chang to train the model to identify what different kinds of trees look like in different conditions, from healthy to dormant to dead. Because the FIA dataset includes plots of trees on private land, Chang pre-processes it to strip out the location data before moving it to Azure Blob Storage for the machine learning process.

With the model already fit to a dataset for the California and Nevada Rockies, the biomass can be estimated every year when the new NAIP image set is released. The model was already used to do a prediction for 2016, which can be seen demonstrated in a [beta web app]. Even without linking the forest biomass data to the water supply, this analysis still produces useful information for communities and governments in the region. For



Conservation Science Partners Wood Supply Model

instance, the increasingly severe wildfires in California have shown that the overgrowth of small-diameter trees needs to be better controlled, to reduce fire danger. Through this analysis, communities can identify areas where the underbrush needs cutting, and even work with biomass power plants to do the cutting and use the material for fuel. Local fire departments, regional wilderness management organizations, and the federal government also benefit from this information.

Moving forward

Now that the forest canopy and biomass changes can be accurately and repeatedly measured, CSP can also begin to address the second question, determining the effects of forest disturbances upon the regional watersheds. By linking the forest data to cumulative flow rate data from USGS gauge station records from before and after a disturbance, an analysis can be run to provide insights for conservation planning, and even for adapting forest and water management to future climate changes. Both the forest biomass and watershed analyses will initially be applied to all of California and eventually extended to the entire western United States.

Azure also offers a third advantage to CSP—and the scientific community in general: reproducibility. The entire workflow for the project, from the algorithm code to the operating environment to the processors, can be made available in a single package as an Azure Data Science Virtual Machine. That means other scientists anywhere in the world could clone the virtual machine instance, provide their own data for analysis, and get the same results. Chang foresees that the benefits of having this reproducible packaged workflow for dealing with huge datasets will make moving to cloud computing a necessary next step for the ecological sciences.

About Tony Chang

Tony is an ecological data scientist with a background in forest modeling, species distribution modeling, data visualization, and big data analysis. He specializes in applying machine learning techniques to ecological issues, including climate change and forest disturbances. Tony has 12 years of combined field- and research-based conservation experience with numerous federal agencies and NGOs. He also brings a novel perspective on ecological system modeling with his background in mechanical engineering. A 2013–2017 NASA Earth and Space Science Fellow, he is a 2017 recipient of the David H. Smith Conservation Research Fellowship from the Society for Conservation Biology.

Tony Chang, a David H. Smith Data Scientist at Conservation Science Partners [Photo courtesy Tony Chang]

About Conservation Science Partners

Conservation Science Partners (CSP) is a 501(c)(3) nonprofit collective established to meet the analytical and research needs of diverse stakeholders in conservation projects. CSP connects the best minds in conservation science to solve problems in a way that's comprehensive, flexible, and service-oriented. CSP engages nonprofits, foundations, universities, agencies, and other partners to address critical questions in conservation biology and landscape ecology. Along with its core staff, CSP draws on a network of professionals from a wide range of disciplines.

Resources

Websites

Conservation Science Partners website
CSP Chimera RCNN Model web app (beta)

Publications

Chang, T., Rasmussen, B. P., Dickson, B. G., & Zachmann, L. J. "Chimera: A Multi-Task Recurrent Convolutional Neural Network for Forest Classification and Structural Estimation." *Remote Sensing*, 11(7), 768. March 29, 2019.

Documentation

Krajick, Kevin. "Climate Change and the Re-Greening of Puerto Rico." *State of the Planet*. Earth Institute, Columbia University. March 22, 2018.

Steve Nix. "U.S. Forest Facts on Forestland: Forestry Land Trend Data in the United States." ThoughtCo. August 13, 2018.

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