

MATHEMATICAL ECOLOGY: PREDICTING THE FUTURE FOREST

Economists have been using predictive models for decades. By quantifying known variables and creating a prediction framework, they can infer future financial behavior. Predictive science, and modeling in particular, also has a valuable place in the ecological sciences. When dealing with long-lived complex systems, such as forests, quantitative models can illuminate what governs ecosystem dynamics, guiding sound management practices.

Over the past ten years, Institute forest ecologist Dr. Charles D. Canham has been engaging in mathematical ecology. By statistically modeling forest parts, and building whole-system models, Dr. Canham is unraveling how forests function. His findings on how trees interact with their “neighbors” are invaluable to informing theoretical community ecology and sustainable forestry. By building models and testing what happens when tree species are manipulated, he can ask questions like, “How many trees need to be left behind during harvesting for the forest to regenerate, and of what size?”

Dr. Canham’s interest in ecological modeling was motivated by a desire to answer ecological questions with quantitative answers, forcing him to think explicitly about how systems and relationships are defined. Once relationships are established, based on known data, they can be developed into simulation models where integrated system dynamics link functional parts. A model called SORTIE, created by Dr. Canham and colleagues, is helping to shape the way ecologists analyze forest interactions. This framework can be used to study everything from seed predation to nutrient cycling.

At any point in a forest, what is happening in the ecosystem is strongly influenced by the distribution of trees around that point. Dr. Canham has developed new statistical methods that allow him to relate the spatial distribution, sizes, and species of canopy trees to spatial variation in ecosystem processes. Traditionally, ecosystem scientists have averaged across this variation, with limited ability to predict changes in ecosystem properties as canopy composition changes. SORTIE allows scientists to make explicit links between tree population dynamics and forest ecosystem processes, facilitating predictions of how changes in canopy composition will affect ecosystem processes.

Working in a range of systems, from the northeastern U.S. to the tropics of Puerto Rico, Dr. Canham and his colleagues are using SORTIE to understand tree competition and to predict long-term forest dynamics. In the U.S., data from over 25,000 plots sampled by the U.S. Forest Service are being analyzed. Does the size of a tree influence how sensitive it is to competition and disturbance? From a forest management point of view, this question is critical. An explicit goal of this research, done with IES and University of Massachusetts graduate student Michael Papaik, is to develop guidelines for the sustainable management of northeastern forests. Sustainable harvesting is only feasible when it is economically viable. In this alternative to clear cutting forests, managers need to spare trees that have the most future growth potential.

In Puerto Rico, Dr. Canham is working with IES Postdoctoral Associate Dr. Maria Uriarte analyzing competition in a network of permanent plots managed as part of an NSF-funded Long Term Ecological Research (LTER) site. Analyzing the Puerto Rican forests, with their long history of hurricane exposure, will provide insight into the role of competition in forest recovery from disturbance.

New statistical methods, quantitative models, and ever more powerful computers are helping ecologists understand likely changes in forests of the future. There are very real limits on the ability of any

quantitative model – no matter how good the data – to predict the future of natural systems (just as economists would readily admit that their models have limits). Models are best viewed as “what if” tools that allow researchers to map out the logical consequences for forests given different scenarios of environmental change. In light of human-accelerated environmental change, predictive models are likely to play an increasingly important role in ecology.



A hemispherical photograph of a forest canopy. By gauging the amount of light hitting the forest floor, these photographs help ecologists calculate crowding in forest stands.



Drs. Charles Canham and Maria Uriarte are using savvy science and computer modeling to help predict how forests change over time.