Towards a new generation of vegetation models

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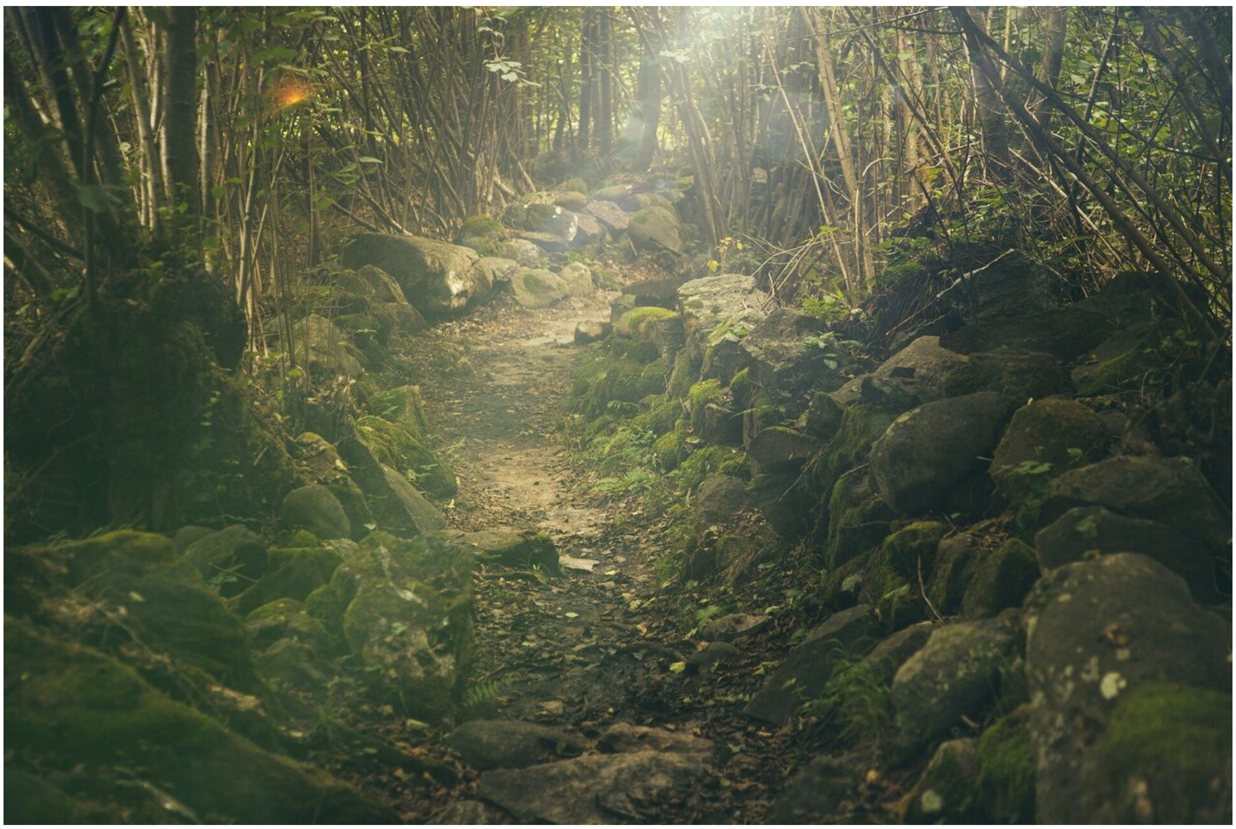

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Plants and vegetation play a critical role in supporting life on Earth, but there is still a lot of uncertainty in our understanding of how exactly they affect the global carbon cycle and ecosystem services. A new IIASA-led study explored the most important organizing principles that control vegetation behavior and how they can be used to improve vegetation models.

We rely on the plants that make up our planet's ecosystems to release oxygen into the atmosphere, absorb carbon dioxide (CO_2), and provide habitat and food for wildlife and humans. These services are critical in the future management of climate change, especially in terms of CO_2 uptake and release, but due to the many complex, interacting processes that affect the ability of vegetation to provide these services, they remain difficult to predict.

In an IIASA-led perspective published in the journal *Nature Plants*, an international team of researchers endeavored to address this problem by exploring approaches to master this complexity and improve our ability to predict vegetation dynamics. They explored key organizing principles that govern these processes—specifically, natural selection; self-organization (controlling collective behavior among individuals); and entropy maximization (controlling the outcome of a large number of random processes). In general, an organizing principle determines or constrains how components of a system, such as different plants in an ecosystem or different organs of a plant, behave together. Mathematically, such a principle can be seen as an additional equation added to a system of equations, allowing one or more previously unknown variables in the system to be determined and thereby reducing the uncertainty of the solution.

A lot of research has gone into understanding and predicting how plant processes combine to determine the dynamics of vegetation on larger scales. To integrate process understanding from different disciplines, dynamic vegetation models (DVMs) have been developed that combine elements from plant biogeography, biogeochemistry, plant physiology, and forest ecology. DVMs have been widely used in many fields including the assessment of impacts of environmental change on plants and ecosystems; land management; and feedbacks from vegetation changes to regional and global climates. However, previous attempts to improve vegetation models have mainly focused on improving realism by including more processes and more data. This has not led to the expected success because each additional process comes with uncertain parameters, which has in turn caused an accumulation of uncertainty and therefore unreliable model predictions.

"Despite the ever-increasing availability of data, and the fact that vegetation science, like many other scientific fields, is benefitting from increasing access to big data sets and new observation technologies, we also need to understand governing principles like evolution to make sense of the big data. Current models are not able to reliably predict long-term vegetation responses," explains lead author Oskar Franklin, a researcher in the IIASA Ecosystems Services and Management Program.

The study found that by representing the principles of evolution, self-organization, and entropy maximization in models, they could better predict complex plant behavior and resulting vegetation as an emerging result of environmental conditions. Although each of these principles had previously been used to explain a particular aspect of vegetation dynamics, their combined implications were not fully understood. This approach means that a lot of complex variation and behavior at different scales, from leaves to landscapes, can now be better predicted without additional understanding of underlying details or more measurements.

The authors expect that apart from leading to better tools for understanding and managing the biosphere, the proposed "next-generation approach" may result in different trajectories of projected climate change that both policy and the general public would have to cope with.

More information: Organizing principles for vegetation dynamics, *Nature Plants* (2020). DOI: 10.1038/s41477-020-0655-x , www.nature.com/articles/s41477-020-0655-x

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