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Researchers Explain Nitrogen Paradox in Forests

Stanford, CA— Nitrogen is essential to all life on Earth, and the processes by which it cycles through the environment may determine how ecosystems respond to global warming. But certain aspects of the nitrogen cycle in temperate and tropical forests have puzzled scientists, defying, in a sense, the laws of supply and demand. Trees capable of extracting nitrogen directly from the atmosphere often thrive where it is readily available in the soil, but not where it is in short supply. Now scientists from the Carnegie Institution have explained the paradox by recognizing the role of two other factors: temperature and the abundance of another key element, phosphorous.

Benjamin Houlton and Christopher Field of the Carnegie Institution's Department of Global Ecology, with two other co-authors,* published their results in the June 18 online edition of *Nature.*

Nitrogen in the form of dinitrogen (a molecule made of two tightly bound nitrogen atoms) makes up nearly 80% of the Earth's atmosphere, but few organisms can directly convert dinitrogen into biologically useful nitrogen compounds. Nitrogen fixation, as the process is called, requires the enzyme nitrogenase, possessed by specific types of bacteria. Some of these bacteria live symbiotically in the roots of certain plants, such as legumes, giving these plants a "built-in" nitrogen-fixing capability.

"You would expect that nitrogen-fixing species would have a competitive advantage in ecosystems where nitrogen is in low supply, but not where nitrogen is abundant, because fixation is energetically very costly to an organism," says Houlton, lead author of the paper. "And in fact that's the way ecologists have found it works in the open ocean and in lakes. But in forests nitrogen-fixing tree species are scarce in the temperate zone, even though the soils have limited amounts of nitrogen. On the other hand, nitrogen-fixing trees can make up a significant part of tropical lowland forests, despite the overall nitrogen-rich conditions."

One part of the solution to the puzzle, the researchers found, is the nitrogen-fixing enzyme nitrogenase. A survey of diverse species and bacterial strains across different latitudes and environments showed the strong influence of temperature on the enzyme's activity. A consequence is that in cooler climates more of the enzyme is needed to fix a given amount of nitrogen. The high cost of producing the enzyme offsets the benefit of nitrogen fixation in temperate forests, despite low-nitrogen soils.

In tropical forests, it's the link between nitrogen and phosphorus that explains the abundance of nitrogen-fixing species. "Many tropical [forest] soils are severely depleted in phosphorus, even where nitrogen is relatively abundant," says Houlton. "The extra nitrogen added to the soil by nitrogen-fixers helps mobilize phosphorus, making it easier for roots to absorb. That stimulates the growth of these plant species and puts them at a competitive advantage, despite the energetic cost of nitrogen fixation. It's really quite striking how simple the economics of nitrogen fixation fall out, once you consider the link between the nitrogen and phosphorus cycles in the tropics"

"Put together, these two factors give us a coherent picture of what was formerly a very enigmatic distribution pattern for nitrogen-fixing trees in plant communities," says Field, director of the Department of Global Ecology. "The more we understand about these essential ecological processes, the better we'll be able to manage Earth's ecosystems in the coming decades, especially in the face of unprecedented climate change."

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