Storing Carbon to Combat Global Warming May Cause Other Environmental Problems, Study

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Robert Jackson (right) and Roni Avissar in pine forest near Duke | Jim Wallace

Growing tree plantations to remove carbon dioxide from the atmosphere to mitigate global warming -- so called "carbon sequestration" -- could trigger environmental changes that outweigh some of the benefits, a multi-institutional team led by Duke University suggested in a new report. Those effects include water and nutrient depletion and increased soil salinity and acidity, said the researchers.

"We believe that decreased stream flow and changes in soil and water quality are likely as plantations are increasingly grown for biological carbon sequestration," the 10 authors wrote in a paper published in the Friday, Dec. 23, 2005, issue of the journal *Science*.

The study was funded by Duke's Center on Global Change, the National Science Foundation, the National Institute for Global Environmental Change/Department of Energy, the inter-American Institute for Global Change Research, the Andrew W. Mellon Foundation and South Africa's Council of Scientific and Industrial Research.

"I think carbon sequestration with trees will work, at least for a few decades," said Robert Jackson, a professor in Duke's Department of Biology and Nicholas School of the Environment and Earth Sciences who was the paper's first author. "But I think we're asking the wrong question.

"The question isn't just 'Can we store carbon in trees and how much do we gain from that?' The question is also 'What are the other gains and losses for the environment?' We have to be smart about our sequestration policies."

Originating in a series of meetings at the Center on Global Change, which Jackson directs, the study sought to identity those tradeoffs and benefits at locations worldwide thought likely as places where land would be converted from other uses to tree plantations for carbon sequestration.

Assessing the impact of existing conversions, the study showed that the larger water demands of growing trees rather than crops or pastures "dramatically decreased stream flow within a few years of planting," the authors wrote.

Water use within existing tree plantations of all ages resulted in average stream flow reductions of 38 percent, with losses increasing as the trees aged. Moreover, "13 percent of streams dried up completely for at least one year," the study said.

Overall, about 20 percent more of the water provided by precipitation was removed by current tree farming, the study estimated. And additional planting of trees for carbon mitigation will likely have large impacts on water resources of many nations that net less than 30 percent of what precipitation provides for their total annual supplies of fresh water, the authors predicted.

"The places that are most likely to grow trees for carbon sequestration are places where trees aren't growing now," Jackson said in an interview.

"One of the points of this paper is that those places tend to be relatively low rainfall areas. We predict we will see a decrease in stream flow particularly in these relatively drier spots that are targets for sequestration." Almost all plantation trees are heavy water using evergreen species such as pines and eucalyptus, he added.

However, the researchers said adding more of these plantations would also release more moisture into a region's atmosphere, as trees roots removed water from the soils and discharged some portions as water vapor emanating through leaf pores.

To predict whether this increased moisture might boost rainfall to counter tree water withdrawals, co-authors Bruce McCarl of Texas A&M University and Brian Murray of RTI International in Research Triangle Park, N.C. first investigated where in the United States additional tree plantations would most likely locate.

Using a computer model that projected the likelihood of such conversions in return for payments of between $50 and $100 per ton of sequestered carbon, they estimated that 72 million hectares in the Southeast and Midwest might initially convert from non-irrigated croplands and pasture to forestry at the $100 price.

Such economic incentives are provided under so-called “carbon trading exchanges” encouraged by the Kyoto Protocol and the European Union’s Greenhouse Gas Emission Trading Scheme, the study noted.

Co-authors Roni Avissar, a professor of civil and environmental engineering at Duke's Pratt School of Engineering, and his postdoctoral research associate Somnath Baidya Roy then used computer climate models of their own design to simulate how added forest moisture might affect climates in those regions.

“While a weather forecaster makes predictions about the weather for the next day or week, we instead forecast climate given other kinds of scenarios, such as changes in land use,” Roy said.

Those simulations showed no evidence that such significant land conversions could help generate more rainfall except perhaps in northern Florida and southern Georgia. In general, “unlike in the tropics, the temperate regions modeled here did not have sufficient energy to lift the additional atmospheric moisture high enough to condense and form clouds,” the study said.

“Plantations not only have greater water demands than grasslands, shrublands or croplands,” the study added. “They typically have increased nutrient demands as well.”

In order to store carbon from carbon dioxide in their tissues, trees must also remove nutrients like calcium and potassium and nitrogen from the soil, Jackson explained. During these chemical exchanges, “you leave sodium behind, which builds up in the soil to make it saltier,” he said.

Jackson’s former postdoctoral scientist Esteban Jobbágy, now at the Universidad Nacional de San Luis in Argentina, and Kathleen Farley of The Nature Conservancy, also investigated another way that forest growing might increase soil salinity in Argentina's normally treeless pampas.

There fresh water pockets just under the surface supply residents with drinking water. But that is underlain by ground water that is brackish. “After trees use that fresh water up, there’s an upwelling of saline water,” Jackson said.

“These mechanisms have been linked to more than five-fold increases in groundwater salinization in southern Australia and in the Caspian steppes of Russia,” the study’s authors wrote. Similar examples would include “Hungary’s Hortobagy grasslands, Russia’s western Siberian steppes, and the eastern Chaco croplands of Paraguay and Argentina,” the study said. “We predict that plantations could salinize soils in these locations as well if planted broadly.”

Together with nutrient removal, leaf and needle fall from plantation trees can also acidify soils, wrote

the authors. "Globally, plantation soils were more acidic in 98 of 114 cases," their study said.

In addition, the study cited cases where tree plantations might improve the environment. One example was an area of southwestern Australia where brackish water rose to the surface to contaminate soils with salt after a heavy water-using eucalyptus forest was replaced by croplands.

In this case, reforestation could lower water tables and help leach salt from soils, predicted the authors. "Widespread conversion of croplands to forest in the central U.S. farm belt may also improve regional water quality as nutrient, pesticide, and erosion runoff from crop production is reduced," they wrote.

Source: Duke University