Explore

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Carbon Sinks and Carbon Bombs

Part I
Directions
As a group, read the following article. Each section of the article should be read by a different group member. As you read, underline words that are unfamiliar. In the margin of the reading, make any necessary notes. Be sure to indicate any sections of the reading that need further clarification when the group discussion begins.

Carbon Sinks and Carbon Bombs

Courtesy of the American Museum of Natural History (2010)

Scott Goetz has studied the boreal forest of Alaska for more than two decades, but year by year, the landscape is becoming less familiar to him. Forest fires have become more frequent and intense. In severely burned areas, Goetz has seen new landscapes grow back, with fewer evergreen trees and more deciduous trees like aspen and birch. “Every time we come back, the forest has changed in some way,” he says.

Goetz is studying how climate change is affecting the boreal forest—and how, in turn, the forest may be influencing climate change. Earth's atmosphere and biosphere are intimately connected. As global warming alters the boreal biome, the resulting changes can actually "feed back" into the climate system and influence its patterns and processes. "The big questions are, will the feedbacks in high-latitude forests largely be negative so they'll mitigate additional warming, or will they be positive and exacerbate the warming?" says Goetz, a senior scientist at the Woods Hole Research Center. What his team discovers could improve the computer climate models that are used to predict the progress and effects of climate change. Currently, those models only take simplified ecosystem feedbacks into account.

Moving Carbon
About half the stuff that makes up all living things—known as biomass—is carbon. In other words, organisms are effective carbon storage vessels, or sinks. But Earth's carbon never stays in one place. Rather, it cycles through the biosphere, the atmosphere, and sediments such as fossil fuels. This process is called the carbon cycle. For millennia, the carbon cycle has been at near-equilibrium: the respiration of animals, plants, and microbes on Earth adds roughly the same amount of carbon into the atmosphere as plants take in during photosynthesis.

But when humans turn a natural carbon sink into a carbon source, as we do when we burn fossil fuels and cut down forests, we upset the balance. "What humans release on an annual basis is actually small compared to the natural carbon cycle," says Ted Schuur, a University of Florida ecologist who is studying Alaska's permafrost. "Human inputs amount to 10 billion tons of carbon a year, but plants, on the other hand, take up about 110 billion tons." But our small contribution matters. There are not enough natural carbon sinks on Earth to take in the excess amount of carbon that humans release—-so some of that extra carbon stays in the atmosphere and drives up temperatures.

Two major carbon sinks in Alaska have drawn the attention of scientists studying the role of ecosystems in climate change: the biomass of the boreal forest, and the carbon-rich layer of permafrost in the tundra soil. Significant changes in these sinks could have huge implications for the balance of the carbon cycle and the future changes in global temperatures.

Boreal Biomass

The boreal forest landscape carpets much of Siberia, northern Eurasia, and Scandinavia, along with Canada and the interior of Alaska. In North America, black spruce are the dominant trees. White spruce and deciduous aspen and birch constitute a smaller, but significant, minority in the tree population.

Scott Goetz wants to know how much carbon the boreal forest takes up as it grows. He uses satellite data to monitor the amount of light that the forest canopy absorbs, since that energy drives photosynthesis, a carbon-storing process. On the ground, Goetz tags different species of trees and tracks their growth to calculate the increase in biomass. His colleagues also estimate how much organic matter in the forest soil burns off during fires, which can influence what species grow back.

Climate change in high latitudes is prodding forest fires to increase in frequency, intensity, and the amount of area that burns. "Most of the big fire years have been in the past 10 years, with the biggest by far being 2004 and 2005," says Goetz. Burning biomass releases stored carbon to the atmosphere, which creates a positive feedback on climate change: Rising temperatures increase atmospheric carbon inputs, which further raises temperatures.

But the feedbacks, Goetz is learning, are far more complicated than that. Larger, hotter fires can burn centuries of accumulated organic matter on the forest floor. This process enriches the soil with minerals. Since deciduous trees grow better in mineral-rich soils than coniferous species, aspen and birch quickly establish themselves in the wake of more severe fires. A more-deciduous boreal forest may, for several reasons, exert a braking effect on climate change—a negative feedback. Deciduous trees tend to be more productive than conifers—they grow faster, cycle nutrients more quickly, and thus take up more CO_2. Furthermore, leaves are lighter in tone than needles and thus reflect more solar radiation back into the atmosphere. The higher albedo, or reflectivity, of deciduous trees could therefore have an overall cooling effect. In addition, deciduous trees don't burn as readily as coniferous trees do, which reduces carbon release during fires.

Goetz's data will help him determine how deciduous Alaska's boreal forest is becoming so he can calculate the net feedback potential of the forest changes. Other complexities of this ecosystem make this effort even more challenging. For example, warmer winters have allowed insects to survive for longer periods, leading to more insect damage on boreal trees. The insects affect both tree productivity and survival. In addition, Goetz has already documented drought-related browning in boreal forests, which further reduces how much carbon they can take up.

The Carbon Bomb

At the Eight Mile Lake ecological research site near Denali National Park, a treeless carpet of tundra lies low between snow-capped mountain peaks. Beautiful but barren, the tundra biome actually harbors a tremendous amount of carbon, sequestered below ground in permafrost. This permanently frozen ground covers much of the northern latitudes that is not covered by ice sheets, and contains carbon-rich matter from plants and animals that can remain untouched by decay for tens of thousands of years. But when permafrost thaws, microbes digest the organic material and release the carbon into the atmosphere as CO_2 and methane, speeding the pace of climate change. No wonder permafrost is considered "the carbon bomb."

Ted Schuur has been studying permafrost at Eight Mile Lake for eight years. He and his colleagues bore narrow holes into permafrost to measure the amount and age of its carbon. In addition, they create mini-atmospheres by enclosing and warming frozen tundra in clear plastic chambers. As the soil temperature rises, they measure changes in CO_2 exchange over time. "We're finding that permafrost's carbon pool can extend tens of meters down into the ground in some locations," says Schuur. "It's a significant accumulation." Schuur's research has discovered that there is about twice as much carbon stored frozen in permafrost soils as the atmosphere currently holds. "The next question that follows from that is how fast can this stuff come out, and how fast is it coming out now?" Schuur says.

The answer depends on how fast permafrost will thaw and how rapidly microbes can break down the organic matter, yet the expansion of shrubs in warming tundra areas could offset some of that release. Schuur's current estimates predict that at least initially, plant growth in northern latitudes will be an effective sink for the excess carbon emissions from permafrost. After a few decades, however, a greener Arctic won't be able to take up slack. Net carbon release from the world's permafrost could approach 1 billion tons of carbon per year if widespread permafrost degradation were to occur—roughly equal to the current amount added annually by tropical deforestation.

What Schuur and Goetz find could prove vital for current climate models. "Models have nothing in regard to permafrost carbon," says Schuur. They also do not currently account for forest feedbacks. "The outcome of our field measurements is that we improve our ability to make models better, and then we trust their future predictions more. Everyone wants to predict the future, which we know is impossible, but we use our scientific analysis and computer models to make our best guess."

QUESTIONS

1. Describe in your own words what a carbon sink is. What are some examples of carbon sinks?

2. How do carbon sinks become carbon sources?

3. Describe how changing a carbon sink into a carbon source could negatively affect the atmosphere.

4. How is photosynthesis a carbon storing process?

5. How has climate change produced a positive feedback loop?

6. In what way could this climate change result in a negative feedback loop?

7. In your own words, describe what a carbon bomb is.

8. What effect could climate change have on a carbon bomb?