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FEATURE

A Land Use Puzzle: Piecing Together How Forests, Croplands, and Residential Neighborhoods Interact with Climate

Alexandra Contosta

Earth's surface is like a giant reflector. Sometimes, the reflector is clean and bright, like an open field after snowfall, causing most of the incoming solar radiation to be returned to space. Other times, the reflector is very dirty, as in black tar roof tops and roadways, causing most of the sunlight to be absorbed and reradiated as heat near the surface. In most cases, the reflector is somewhere in between.

How well a surface reflects incoming sunlight is called its *albedo*, and albedo plays a major role in determining the amount of heat trapped in Earth's atmosphere. The higher the albedo of a surface, the more sunlight is reflected back to space. If all sunlight entering Earth's atmosphere returned to outer space, then our planet would be so cold that life could not exist. If all of the light was absorbed and reradiated as heat, then Earth would be too hot to support life as we know it. It turns out that the "just right" temperature of our planet is, in part, regulated by the albedo of plant life that covers about 20% of its surface.

The albedo of vegetation is not uniform across Earth, however. Grasslands and croplands have higher albedo than forests, and even within forests, deciduous trees have higher albedo than evergreens. This makes some intuitive sense as bright green grass should reflect more light than the dark green of a pine forest. However, most of the difference in the albedo of vegetation has to do with colors our eyes cannot see in the near infrared portion of the electromagnetic spectrum. Because grasslands and croplands reflect more light to the atmosphere, they can have a cooling effect on regional and global climate. By contrast, forests absorb more light and therefore can have a warming effect. If we replaced all of the forests of Earth with grasslands, the change in albedo could have a small cooling effect of about 0.3°C on the planet's temperature (Bala and others 2007). Changes to albedo could have local impacts as well, as land cover change could also affect surface temperatures locally by as much as 1°C (for example, Stohlgren and others 1998).

But albedo is not the only thing that matters when thinking about how plant cover might influence climate. Take surface heat flux, for example. When Earth's surface absorbs sunlight instead of reflecting it, some of the resulting energy is reradiated by either heating the air above the surface or by causing water to evaporate from soils, water bodies, and plant canopies. Called evapotranspiration, this phase change of liquid water to water vapor prevents heating on the landscape, much like the cooling effect of perspiration evaporat-

ing from your skin. Areas covered with houses and roads do not have as many plants performing photosynthesis and releasing water to the atmosphere. As a result, most of the solar radiation absorbed in residential areas reenters the atmosphere as something called “sensible heat,” which can be both measured and felt. This is one of the reasons why urban environments are so much warmer than their forested counterparts. You can sense the difference in temperature if you walk a mile down a city block in the summer versus a mile on a trail in the woods. The city block will be much warmer.

Land cover can also influence climate through the storage and release of carbon. This is important because most carbon in the atmosphere occurs as carbon dioxide (CO₂), a greenhouse gas that traps some of Earth’s heat. In fact, most land management policies addressing climate change focus on ways to keep carbon out of the atmosphere by sequestering it in soils and plant biomass. The net carbon balance of an ecosystem is the difference between the amount of carbon stored in plant biomass and soils versus the amount of carbon lost through root and soil microbial respiration of CO₂.

A mature hardwood forest typical of my corner of New Hampshire, for example, has a positive net carbon balance. It can hold about 250 megagrams of carbon per hectare in the leaves, stems, and roots that comprise its living biomass (Jenkins and others 2002). This is roughly equivalent to the mass of fifty cars parked on an area the size of a football field. If you cut down a forest and convert it to a residential development, most of its stored carbon is lost to the atmosphere where it has a warming effect on climate. Some of this carbon loss occurs as people burn harvested wood, and the rest takes place over longer periods as leaves, branches, and stumps decompose and harvested wood products decay.

In addition to the loss of aboveground carbon storage, physical disturbance of soils during land use change exposes long-protected organic matter to the air, where it can be decomposed by soil microbes and lost as CO₂. Even when soils are stable, they naturally emit greenhouse gases as plants respire and soil microbes decompose organic matter. Temperature and moisture, which are two of the primary controls on soil CO₂ loss, vary from a forest to suburban lawn. For example, the warmer conditions in a lawn environment receiving direct sunlight might cause higher soil CO₂ fluxes as compared to lower fluxes from a cooler, shaded forest floor. However, lawn soils are often drier than forest soils, in part because they lack a thick leaf litter layer to protect them from evaporative moisture loss. During droughts, when temperatures are high but water is scarce, soil CO₂ fluxes might be lower in lawns than in forests due to moisture stress.

If all of this sounds complicated to you, then you are beginning to get a sense of why comprehensive studies of land cover, land use change, and climate impacts at the local scale are needed in the scientific literature.

Here on the seacoast of New Hampshire, my colleagues and I are trying to address that need. Over the past three years, we have been quantifying the ways that our local forests, farms, and housing developments interact with climate. We are measuring albedo, surface heat, carbon storage, and greenhouse gas emissions in the residential, agricultural, and forested portions of our landscape. We are then converting each of these measurements into a common denominator, “radiative forcing,” that allows us to determine how each cover type either contributes to or offsets climate change.

Although our study takes place on the New Hampshire seacoast, our area is like many other rapidly suburbanizing landscapes across the United States. Population growth over the past fifty years has resulted in a 60% loss of farmland and forests and a corresponding increase in residential and commercial areas. In this scenario, the phrase, “smart growth” is usually applied to prevent urban sprawl associated with rapid development. For us, “smart growth” might also be a way of crafting land use policies that balance the food, housing, and recreational needs of local communities with the ability of the surrounding landscape to mitigate climate change.

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