FEATURES

Looking for Lawns

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Cristina Milesi is too busy to think much about her small Northern California lawn, and it shows. She waters a little, when she can remember. Never fertilizes. She definitely doesn’t bag up her grass clippings. Where would she find the time for that? The mother of two young children, Milesi also works almost full time in the ecological forecasting research group at NASA’s Ames Research Center in California. “I have already let part of the yard go,” she says, which means some of it is a combination of bare patches and weeds.

Part of the reason Milesi has little time to be concerned with her own lawn is that she is busy thinking about everyone else’s. Since 2003, Milesi has been calculating how much of America’s land surface is lawn-covered and what impact all that grass has on our country’s water and carbon cycles.

“I think the interest in lawns started because I’m kind of an outsider,” she explains. Milesi moved to the United States from Italy in 1998. “When I first came here I lived in Montana, in a town that was surrounded by mountains. Past June, everything surrounding the town would turn brown and dry. A lot of the natural vegetation goes dormant in the summer. But then throughout our town, I would see these oases of green patches—people’s lawns. I had a neighbor who would water every day, even twice a day. It was not familiar to me." In Italy, she explains, people typically live at much higher population densities, with smaller yards that have little landscaping. "If there is grass in the yard, it is generally a mixture of clover, dandelions, and lots of other so-called weeds, able to survive the long dry summers with little additional water."

Milesi was working on her Ph.D. at the University of Montana. To finish up her required hours of classes, she signed up for an e-business class. For the class' final exam, students had to submit a proposal for an e-business. At the time, Milesi and her husband were expecting their first child. As many expectant mothers can testify, sometimes a slow, short stroll around the block is all the exercise they can manage. These strolls became the inspiration for Milesi's business plan.

"It was summer," she recalls, "and all the sprinklers were running, with the water flowing down the driveways and collecting in little rivers down the street." Sprinklers ran even on evenings when there had been a thunderstorm earlier in the day, obviously not an efficient use of water. "The e-business plan I came up with was an e-mail-based subscription service for homeowners that, based on current weather conditions and forecasts, would tell them if they needed to turn on their sprinklers and for how long."

Sprinkler runoff creates a stream on the side of a street. Irrigated lawns have a significant impact on water supplies in American cities. (Photo courtesy Cristina Milesi.)

From the business point of view, Milesi wondered how many potential customers she might find in the United States, while the ecologist in her wondered how much water could be saved if her forecasting service prevented people from watering their lawns when it wasn't really necessary. To answer either question, she needed to know how much surface area in the United States was covered by lawns.

But after hunting through published scientific research, Milesi was surprised to discover that no one had ever published an observation-based estimate of lawn surface area in the United States. Milesi couldn't stop thinking about that missing piece of information—it seemed like an important part of the ecological picture of America. So after a few months, she submitted a research proposal to the NASA Earth System Science Fellowship Program to produce a national estimate of lawn area and the impact of those lawns on ecological factors like the carbon and water cycles.

Despite big differences in climate and soil conditions across the United States, most of the grasses used in U.S. lawns aren't native to the area where they are being grown. In most parts of the country, lawns require large amounts of added fertilizer and water to survive. (Photo courtesy Cristina Milesi.)

Most people don't think about the impact of their lawns in the big ecological picture. We associate "fertilizer" or "irrigation" with food crops. We associate "carbon cycle" with fossil fuels and deforestation. But Milesi believes there are good reasons to think about the impact of lawns on the national water and carbon cycle.

For starters, she says, "This country has large variability in climate, and people are very mobile." But although we move a lot, she says, we tend to recreate the same landscape wherever we go. "Most of the grasses used in U.S. lawns aren't native to the area they are grown; many of the species come from the East, Kentucky bluegrass, for example. A lawn isn't a big deal in the northeast, but when you recreate that same landscape out West, it becomes a major ecological issue because the only way to grow those grasses is with high use of water and nitrogen fertilizer. An individual, quarter-acre lawn isn't a big ecological influence, but adding up all those quarter-acres for everyone in the country . . . We suspected that the ecological impact could be pretty big."

More Lawns than Irrigated Corn

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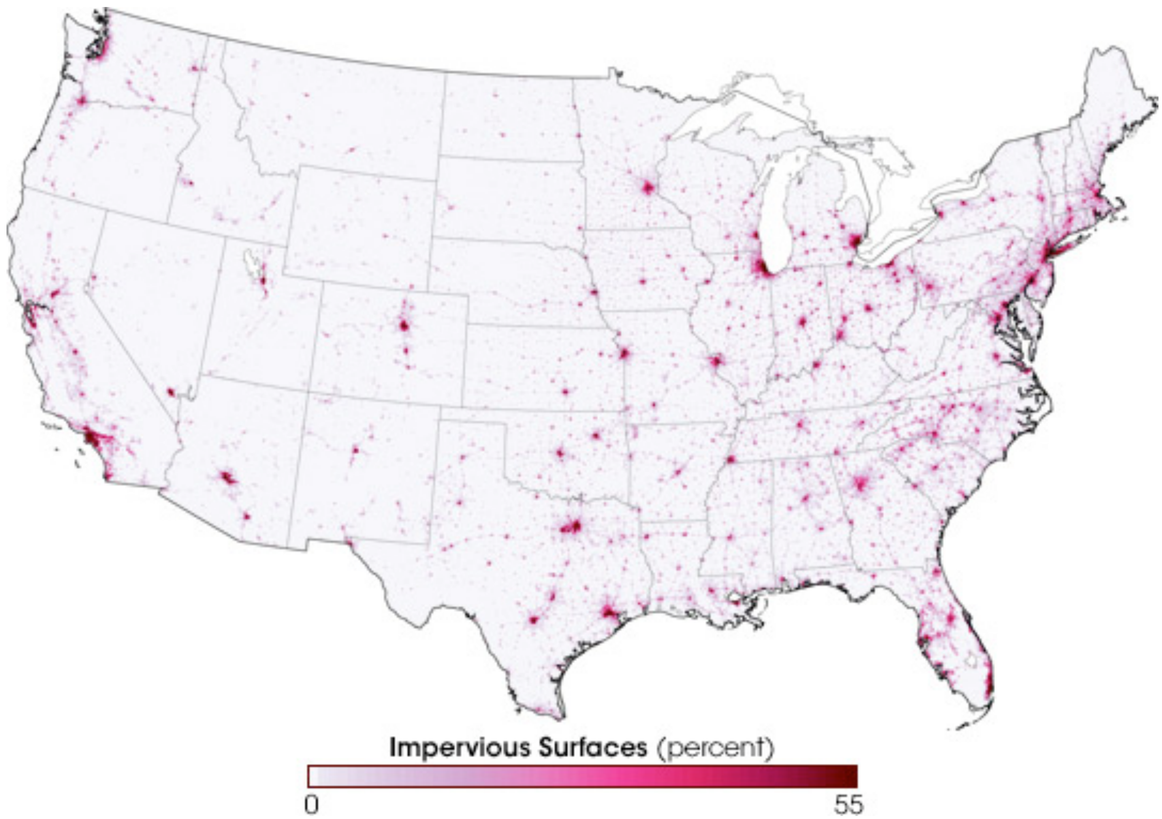
Although there was little in the way of published research on estimating U.S. lawn area, the research group Milesi was studying and working with at the University of Montana had a lot of experience with using satellite data to observe and model natural ecosystems like forests and grasslands. At first, it might seem like creating a national map of lawn surface area ought to be an easy task to accomplish with satellites. Unfortunately, the scale of most lawns is smaller than most satellites can observe. The satellites that can identify such small areas only observe small areas at a time, and the images they collect are expensive. It would cost too much to buy and take too long to analyze the large number of high-resolution (very detailed) satellite images or aerial photos that someone would need to buy to map every lawn in the country.



Impervious surfaces cover a large percentage of urban land area. The map above shows increasing percentage of impervious surfaces in darker shades of pink. Among the data used to identify impervious surfaces are satellite observations of city lights at night. (Map by Robert Simmon, based on data from Chris Elvidge, NOAA National Geophysical Data Center.)

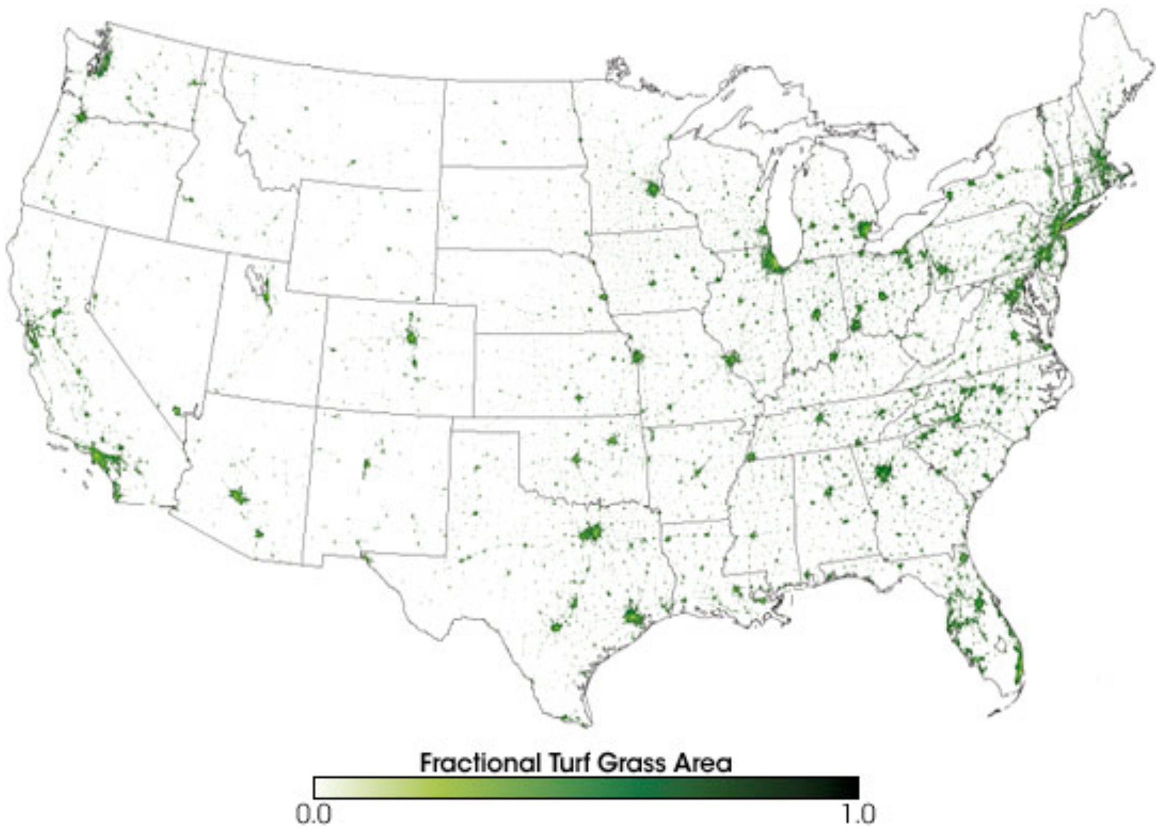
Instead, Milesi needed to identify a relationship between lawn area, which she didn't know, and some other characteristic about urban areas that was either already known, or at least easier to estimate from satellite images. She and her colleagues worked backward from the assumption that amount of lawn area would decrease as the amount of impervious surface increased. Impervious surfaces are surfaces that don't absorb water, such as roads, roofs, parking lots, and sidewalks.

Researchers predicted lawn surface area in urban and suburban settings from impervious surface area. In general, as impervious surface area such as roads and parking lots increases, lawn area decreases. Milesi and her team refined the predictions using aerial photography over different urban landscapes, such as this industrial location in Chicago. (Image courtesy Chris Elvidge.)

Milesi and her colleagues combined the information about the distribution of urban areas from the U.S. Geological Survey's National Land Cover Database, which is based on Landsat satellite data, with nighttime city light data, which are collected by a Department of Defense satellite, and analyzed and made publicly available by the National Ocean and Atmospheric Administration. It turns out that the brightness of nighttime lights in an area is a good indication of how much impervious surface there is. That isn't surprising when you think about where we put lights in a city—along roads, sidewalks, and in and around buildings.

The amount of impervious surface area changes from one part of a city to another. This residential area of Chicago is quite different from the industrial area shown above. However, Milesi and her colleagues found that the ratio of impervious surface area to lawn area was remarkably consistent in urban areas across the United States. (Image courtesy Chris Elvidge.)

Milesi and her team refined the initial satellite-based estimates of impervious surfaces by carefully comparing them to aerial photos collected over 13 different metro areas. “Using the aerial photos, we identified a predictive ratio between impervious surface area and lawn area that was remarkably consistent across all the urban areas we analyzed,” she explains.



According to Milesi’s estimates, more surface area in the United States is devoted to lawns than to individual irrigated crops such as corn or wheat. This map uses shades of green to indicate the fraction of the U.S. land surface area covered by lawns, including residential, industrial, and recreational. (Map courtesy Cristina Milesi.)

In essence, they analyzed satellite and aerial imagery and came up with a formula that said, “If the impervious surface area is *this much,* then the lawn surface area is probably *that much*.” Then they applied their mathematical formula to the total impervious surface area in the United States.

“Even conservatively,” Milesi says, “I estimate there are three times more acres of lawns in the U.S. than irrigated corn.” This means lawns—including residential and commercial lawns, golf courses, etc—could be considered the single largest irrigated crop in America in terms of surface area, covering about 128,000 square kilometers in all. Her next task was to figure out some of the ecological impacts of this crop of lawns Americans are cultivating.

Ecological Impact of Lawns
Looking for Lawns

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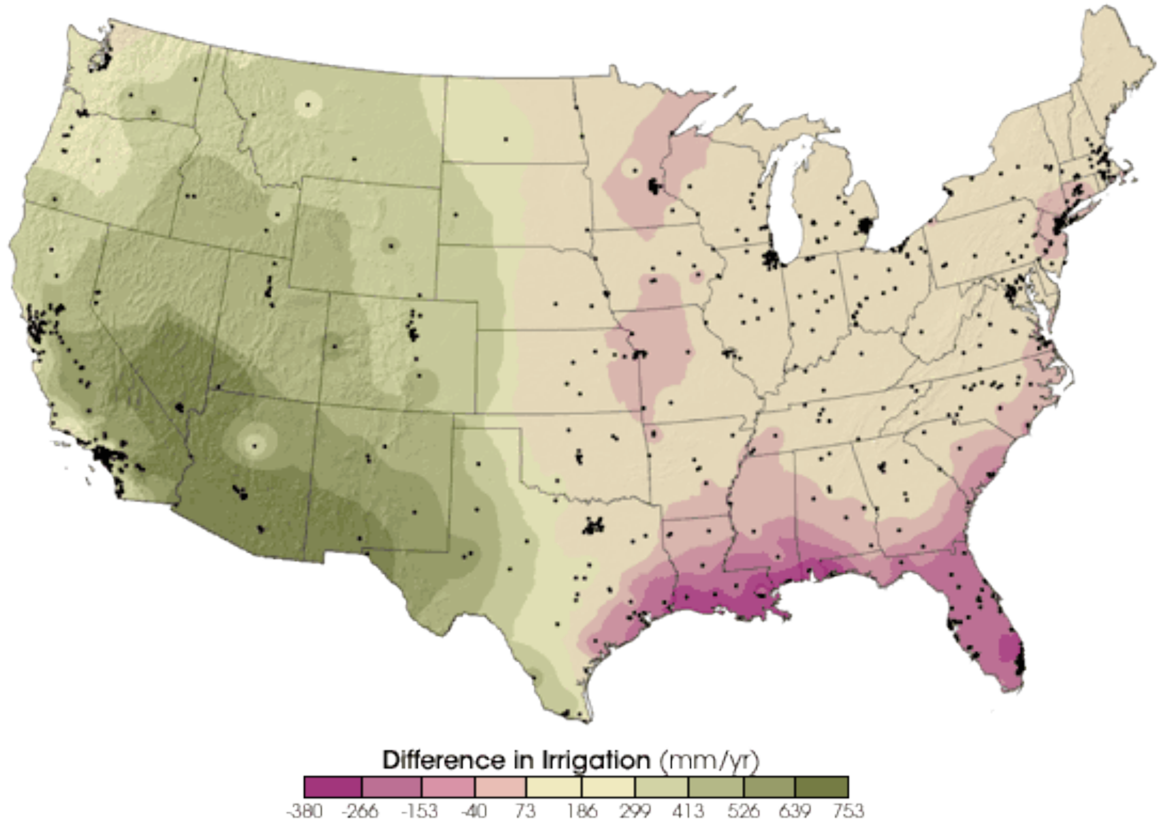
Recognizing that different people and businesses treat their lawns differently, she had a computer simulate the effect on the water cycle and carbon cycle of different lawn management techniques. The variables the models tested included watering a fixed amount (including rainfall) versus watering according to weather and evaporation rates, adding different amounts of fertilizer, and leaving the clippings on the lawn after mowing or bagging them up.

Water

Some of the results weren't surprising, explains Milesi. The model confirmed that if people watered according to a fixed amount, about 2.5 centimeters (1 inch) per week minus rainfall, then lawns in rainier places, such as Lincoln Park, Michigan, wouldn't need any irrigation at all, while Yuma, Arizona, would need the full 2.5 centimeters of irrigation each week.

"If people watered according to what the meteorology indicated, factoring in temperature and humidity, for example, then it would improve irrigation efficiency —use less water—in the Southeast, where humidity is high. But in the West, there is so much sun and humidity is so low that plants can evaporate a lot more than 1 inch of water a week." In the West, if people watered according to evaporation rates, the model predicts they would need to water nearly 200 centimeters per year.



Milesi modeled the effect of watering a fixed amount of 1-inch per week or watering based on environmental conditions that affect the rate of evaporation of water from plants and soil, such as temperature and relative humidity. This map shows where watering according to environmental conditions would decrease water use (pink areas) or increase it (green). Not surprisingly, the amount of water required to keep pace with evaporation in the South, where humidity is high, is much less than the amount required in the West, where humidity is low. (Image courtesy Cristina Milesi.)

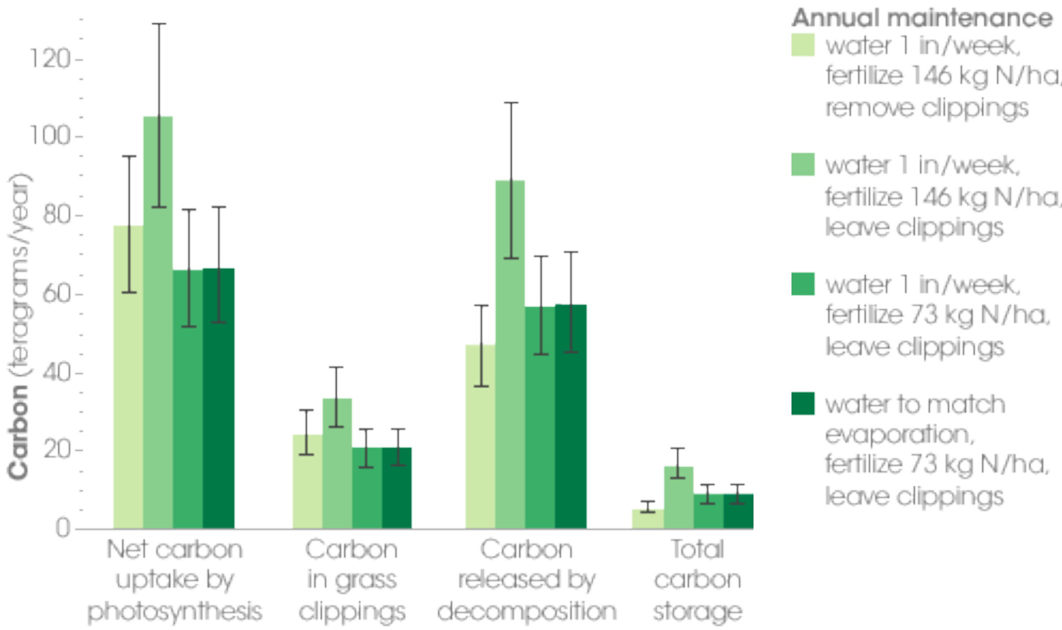
Why is important to know how much water we use to irrigate our lawns? Across the United States, water supplies are increasingly under pressure as populations grow. The water table has dropped hundreds of feet in many locations, and rivers and streams go dry for long stretches in various seasons as water is siphoned off for agriculture, industry, and individual residences. All along the Atlantic seaboard from Florida to New York, saltwater is flowing into formerly freshwater aquifers and wells because we are pumping freshwater out faster than nature can put it back.

Given these pressures, says Milesi, it's important to think about how society uses the available water. "Depending on the irrigation schemes I portrayed with the computer simulations, whether you choose a fixed amount or choose an amount tied to weather and evaporation, domestic and commercial water use for lawns would be 695 to 900 liters (184 to 238 gallons) per person per day if all lawns [in the Lower 48] were well-watered." That means about 200 gallons of fresh, usually drinking-quality water per person per day would be required to keep up our nation's lawn surface area.

Carbon

After running a series of model simulations using different amounts of fertilizer, watering schedules, and leaving or removing the cut grass after mowing, Milesi says that a well-watered and fertilized lawn is a carbon sink. If people recycle the grass clippings, leaving them to decompose on the lawn, the U.S. lawn area could store up to 16.7 teragrams of carbon each year. That's equivalent to about 37 billion pounds—the weight of about 147,000 blue whales. Even if people bag their grass clippings and compost them off site, (many cities now collect and compost yard waste as part of the waste management program), lawn surfaces still appear to be a carbon sink, although at a much smaller rate of about 5.9 teragrams of carbon per year. (If the clippings decompose in a landfill, however, all bets are off, as the oxygen-poor environment increases production of carbon-containing methane, a potent greenhouse gas.)

The fact that recycling the clippings on the lawn would be so productive is a little surprising, according to Milesi. After all, decomposing grass is a source of carbon, with bacterial activity releasing carbon dioxide back into the atmosphere. But apparently, grass is more efficient than Milesi expected. The growth boost provided by the recycling of nitrogen from the decomposing grass clippings more than makes up for the carbon being released.



Different lawn maintenance scenarios (green bars) resulted in different amounts of total carbon storage in lawns. The graph above shows (left to right) the major parts of the carbon cycle in lawns: carbon taken in during photosynthesis, carbon contained in grass clippings, and carbon lost as carbon dioxide during decomposition processes in the soil. Lawns that received at least one inch of water per week, 146 kilograms of nitrogen fertilizer per hectare, and had the grass clippings left on the ground to naturally decompose stored the most carbon, about 17 teragrams per year. Black lines show the range of variability in the estimates. (Image adapted from Milesi et al.)

"In fact, the model suggests that if we recycle the clippings on the grass, we can almost halve the amount of synthetic nitrogen fertilizer, and the carbon storage is still greater than it would be if we used the higher amounts of fertilizer but removed the clippings from the lawn." That could be good news for estuaries and other coastal areas where runoff of excess nitrogen from land surfaces is major source of water pollution, leading to algae overgrowth and dead zones, where aquatic life can't survive.

Having real numbers to describe the impact of human-designed landscapes is important to scientists. But just as interesting to Milesi was one of her more descriptive findings: in most of the United States, lawns just aren't natural. When she had the ecosystem computer models generate a "control" scenario in which lawns were not irrigated or fertilized, she says, "The only places I could grow grass in the conterminous U.S. were a few areas in the Northeast and the Great Plains." Everywhere else, lawns have to be coddled to keep them going and to keep weeds and other plants from taking over.

In parts of the West, many cities are already trying to encourage people to stop coddling their lawns through incentives for xeriscaping (landscaping with an eye toward water conservation, using native or drought-tolerant plants, well designed irrigation systems, and stone) as well as through fines and other penalties for violating city-mandated watering schedules.

Future Plans
More Lawns than Irrigated Corn

Future Plans

Her Ph.D. is finished, and her work has been reviewed by fellow scientists and published in the scientific journal *Environmental Management*. You might suppose that after four or more years of thinking about the nation's grass, Milesi might be a little sick of the topic. But she says she's still interested in lawns.

In future projects, Milesi wants to extend her research to other types of urban vegetation, for example comparing urban tree cover to lawn area. She is also interested in studying the potential benefits of different types of urban vegetation on urban living, for example, how vegetation helps to cool urban areas and to reduce pollution. (Image courtesy Photos.com)

Among her next projects, she says, "I am planning on extending the research to other components of urban vegetation, such as the urban tree cover and seeing how it compares to lawns. And I want to look at how water use and carbon cycling are impacted by changes in climate, such as during droughts or with longer growing seasons due to increases in temperature. I am also interested in quantifying other benefits of urban vegetation to urban living, such as its contribution to the mitigation of the urban heat island effect and to pollution removal."

So, she'll still be thinking about lawns, she says, just not her own. "Obviously, I don't fit completely into my model's control group of 'no water and no fertilizer,' because if so, I wouldn't be able to grow a lawn in northern California." But you won't find streams of water running from sprinklers in her yard. Instead, she gives her lawn just barely enough water to hang on through the hot, dry summers. Laughing, she admits that her family's small lawn "is easily the worst-looking lawn on the block," and unless northern California undergoes a radical climate revolution, it's likely to stay that way.

References:

Milesi, C., S.W. Running, C.D. Elvidge, J.B. Dietz, B.T. Tuttle, R.R. Nemani. (2005) Mapping and modeling the biogeochemical cycling of turf grasses in the United States. *Environmental Management* 36(3), 426-438.

Ecological Impact of Lawns