SACRED
BOVINES

HOW "GREEN" ARE LAWNS?

DOUGLAS ALLCHIN

The front lawn, where children play. The city park. Baseball fields, football fields, soccer fields. Golf courses. Cemeteries, too. They are familiar environments that seem to epitomize the value of enjoying nature. Celebrated fondly in song as the "green, green grass of home." The aesthetic of lawns is deeply embedded in the American psyche (Jenkins, 1994). And for some municipalities and individuals, maintaining their quality seems sacrosanct (Pollan, 1989; Steinberg, 2006, pp. 179–200).

However, approaching grass from a biological perspective might inform our values in different ways. A lawn is an ecosystem. And turf is intensively managed—perhaps not always in ways that express other widely shared environmental values. Here, I address the popular belief about lawns—this month's Sacred Bovine—that they are environmentally friendly, even "green."

Backyard Science

Grassy areas are so common as to nearly escape notice. One may easily forget that grass is living. And that plant science is relevant. But where better to begin appreciating biology than in your own backyard? Indeed, in recent issues of this journal one can find activities based on grass—one using germination to measure toxicity of household substances (Morris & Winter, 2021); and another using green foxtail millet to illustrate morphology, growth cycles, and genetics (Kaggwam et al., 2021). Photosynthesis, C4 pathways, leaf structure, transpiration, roots, geotropism, seeds, genetics, and so on could all be made more familiar through the example of lawns.

Grass may also be viewed as a *crop*. And, given parks and sports fields, not an insignificant one. A 2005 study using satellite imagery concluded that turf covers 163,812 square kilometers (about 40 million acres)—or an area roughly the size of the state of Wisconsin—about 2% of the continental United States. That makes it "the single largest irrigated crop in the country" (Milesi et al., 2005). Golf courses alone account for 2 million acres (larger than the state of Delaware).

Managing all that turf is big business. It employs over a million people and generates $77 billion in revenue annually—more than the U.S. government provides in foreign aid, and equivalent to about 2% of the federal budget (LawnStarter, 2016; see also Banks & McConnell, 2015; Steinberg, 2006, pp. 63–82).

Turf is also big science. In 1947 the U.S. Department of Agriculture teamed up with the U.S. Golf Association (and several golf courses) to establish an experimental turf research center in Georgia. Now there are academic programs at dozens of universities and (by my count) over 100 faculty positions. The premier textbook, Emmons and Rossi's *Turfgrass Science and Management*, along with its 15-week laboratory manual, is in its fifth edition, but now faces competition from Gregory Bell's *Turfgrass: Physiology and Ecology*. One can follow the research journals, such as the *Journal of Turfgrass Science*, *Weed and Turfgrass Science* or *Applied Turfgrass Science*. Every four years, the International Turfgrass Society holds a conference, with hundreds of research presentations.

The Ecology of Lawns

Here, I focus on the *ecology* of lawns. To some, that framing may seem puzzling: lawns are not "natural." They are cultivated and mindfully managed. Hence, they may seem outside ecological science—more akin to agronomy. But this may be yet another prejudice (one more Sacred Bovine?): that ecology is only about "nature," wholly untouched by human culture. But most of the standard textbook ecological concepts can be illustrated by just stepping outside your back door.

First, consider the **oxygen and carbon cycles**. Photosynthesizing plants, of course, absorb carbon dioxide and release oxygen. That would seem to be favorable for improving the local air quality for humans. Indeed, the Lawn Institute (2023) conspicuously reminds the public that "one 5,000 square feet grass lawn can produce enough oxygen each day to support 14 to 34 people." That sounds impressive, surely. But let students think critically and walk fully through the science. Grass grows, yes. But lawns are regularly mowed, as if grazed by animals. The cut grass gradually decays. That microbial decomposition *uses* oxygen. It uses just as much oxygen as was produced in fixing the same amount of carbon originally. The net gain is zero. Focusing on the production of oxygen alone, disregarding coincident respiration, is misleading. Just biased industry promotion. A complete balance sheet indicates no net environmental benefit.

Similar problems haunt the **carbon cycle**. At first, one might imagine that by absorbing carbon dioxide, grass lawns function as an important greenhouse gas reservoir (or sink), helping to limit global warming and climate change. That is certainly the message of the turf industry. One can certainly measure the *rate* of carbon capture by lawns. Primary productivity, of course, is a standard statistic for any ecosystem. Lawns certainly exhibit positive net productivity: at 2.8–5.6 Mg C/ha (for both aboveground and root biomass) (Wang et al., 2022).

However, for the sake of assessing overall carbon balance, incremental increases in storage and cumulative storage are more important than annual productivity. Namely, not all the newly captured carbon remains fixed. Newly seeded lawns certainly exhibit an increase in overall biomass in the first few years. After that, the analysis becomes more complex. Roots and stubble die, and then rot. With relatively high turnover rates, biomass accumulation slows significantly or stops altogether. Little organic matter accumulates in the soil. What counts is the persisting standing crop.

The American Biology Teacher, Vol. 85, No. 4, pp. 237–239, ISSN 0002-7685, electronic ISSN 1938-4211. DOI: https://doi.org/10.1525/abt.2023.84.5.237

Here, comparison matters. Lawns certainly store more carbon than parking lots or bare soil. But when compared to other land uses—meadow, perennial garden, shrubs, trees, or unmanaged vegetation—the carbon storage is relatively low (Gillman et al., 2023; Wang et al., 2022, Table 2). Sadly, perhaps, the aesthetic and typical function of lawns or sports fields means that they are short. They just don't have much biomass. Thus, lawns are not effective carbon sinks. Their contribution to carbon sequestration is minimal. More boastful rhetoric of many lawn advocates.

Biogeochemical cycles also apply to lawns. Grasses take up nitrates and phosphates, just as other plants do. But lawns are mowed. And the "harvest" of clippings is often considered waste and removed. Soil minerals are thereby exported and slowly depleted. No wonder, then, that fertilizers are applied to maintain a dense turf. Inevitably, though, excess fertilizers are leached. That is especially true in residential areas, where adjacent paved areas and storm sewers easily collect the runoff. Streams, lakes, and downstream ocean outlets are affected, from algal blooms to dead zones. An avid environmentalist may point to irresponsible agricultural practices without realizing that homeowners, golf courses, and even schools (with their athletic fields) also farm grass.

Nitrogen fertilizers are especially insidious. First, they can enhance soil respiration, offsetting any observed carbon increase in turf biomass. More importantly, the nitrifying bacteria in the soil—described in any typical biology textbook—convert nitrate (NO_3) to gaseous nitrous oxide (N_2O), which is released into the atmosphere. Nitrous oxide contributes to depleting the ozone layer. It is also a greenhouse gas, 300 times more potent than carbon dioxide. A recent study of pasture converted to suburban lawns recorded a remarkable 37-fold increase in N_2O emissions (Van Delden et al., 2016). Fertilizing turf significantly increases N_2O—in one study, by 50% (Gu et al., 2015; Xun et al., 2022). In another, a sports field in Australia emitted 2.5 times more N_2O than an adjacent unmanaged field (Riches et al., 2020). As an indication of scale (although somewhat dated), in 1984 the United States applied more fertilizer to lawns than was applied to all agricultural crops in India (Jenkins, 1994, p. 142). In addition, the production of nitrogen fertilizers is enormously energy intensive, and places further pressures on energy production and fossil fuel use: even more greenhouse gases. In one study, the production of fertilizer was estimated (as a single factor) to reduce the net carbon capture potential of turf by 10% (Gu et al., 2015). *Interconnectedness*: a familiar ecological theme. The nitrogen cycle links to global warming and the carbon cycle.

Ecosystems also exhibit **species-species interactions**. However, lawns are atypical ecosystems. By design, they aim to be *monocultures*. Only one species (in concept, at least!). Such systems are inherently unstable. Suppressing **competing species**—namely, *weeds*—thus poses a major challenge to those envisioning a uniform green carpet. Hence, turf managers and homeowners apply herbicides. In 2012, 28 million pounds (~13 kilotons) were applied to lawns and gardens in the United States—5% of the national total (Atwood & Paisley-Jones, 2017, p. 12). Application rates vary, but indiscriminate overuse is common, and leaching can harm the local environment or, potentially, contaminate groundwater. *More interconnectedness*.

In addition, lawns exhibit **predator-prey and parasite-host interactions**. They are inherently susceptible to infections by pathogens, foraging by insects, and damage by nematodes and grubs. Hence, lawn management typically also includes pesticides (fungicides, insecticides, and others). In 2012, 14 million pounds (~6 kilotons) of insecticides were used in home and garden settings—nearly *one-quarter* of the U.S. total (Atwood & Paisley-Jones, 2017, p. 12). For the homeowner, Scotts Company's quick guide on lawn care provides 37 pages to help troubleshoot your pests, typically identifying the relevant pesticide for "immediate control" (Christians & Ritchie, 2006). But pesticides, too, are susceptible to overuse and runoff—with sequel harm to local fauna. Unintended and often *hidden consequences*.

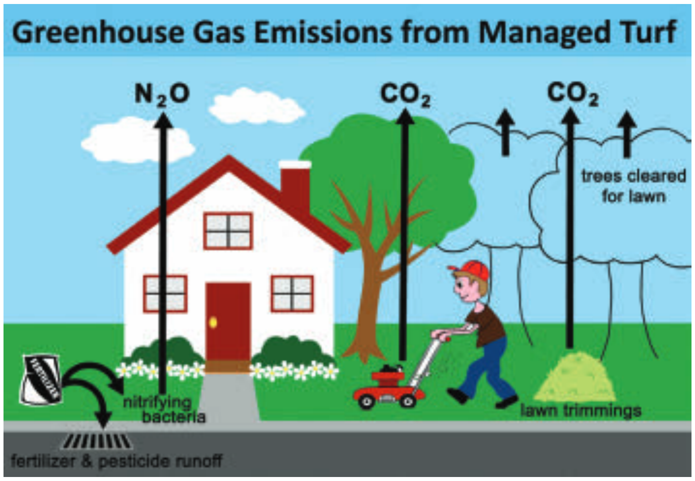

Figure 1. Greenhouse gas emissions and other pollutants from intensively managed turf.

Lawns and fields are also part of the **water cycle**. Trying to keep lawns green during the hottest summer months or in certain climates requires substantial supplemental water. This "irrigation" accounts for at least 30% (by some accounts, 50%–70%) of residential water use (e.g., EPA, 2022a; Milesi et al., 2005). In many regions of the country—where availability of water is an ongoing issue—concerns about lawns and their alternatives have already entered the public discourse. As periodic drought begins to afflict more and more regions, however, and as the population grows, the use of water for sustaining turf may become more widely problematic. Sports fields continue to be idealized as living green carpets. El Paso, Texas, situated within the Chihuahuan desert, with less than 25 cm of annual rainfall, still supports (to my personal amazement) 11 golf courses. Palm Springs, California, with roughly half that annual rainfall, has 100 courses within a 20-mile radius. Yet again, *interconnectedness*.

One may also take note of the **pollutants** generated by human efforts to maintain lawns to meet the popularly embraced ideals. Mowing requires energy, as does irrigation and fertilization of sports fields and golf courses. Add to that the energy of manufacturing the equipment and applied products, and transporting them. These "hidden" activities all add to greenhouse gases (GHGs). "Based on this land area [of 2% of the United States] and other CO_2-equivalent emissions from lawn management, the total CO_2 emission from lawns in the U.S. is about 25 million tons annually" (Appalachian State University, 2015). Lawns are overall sources of GHGs, not sinks (Figure 1).

Other pollutants come from lawn mowers, edgers, leaf blowers and such, powered by small gasoline engines: volatile organic compounds, fine particulates (soot), carbon monoxide and nitrogen oxides (NO_x). "In 2011, approximately 26.7 million tons of pollutants were emitted by gasoline-powered lawn and garden equipment (GLGE) (VOC = 461,800; CO = 5,793,200; NOx = 68,500, PM10 = 20,700; CO2 = 20,382,400), accounting for 24%–45% of all nonroad gasoline emissions" (Banks & McConnell, 2015, p. 1).

Yard waste also contributes to local **solid waste** disposal. Since the 1990s, practices have changed dramatically. Now, 70% is composted or burned. Still, "in 2018, landfills received about 10.5 million tons of yard trimmings, which comprised 7.2 percent of all municipal solid waste landfilled" (EPA, 2022b).

Finally, one may consider the **biodiversity** of lawns. As noted, the implicit intent (in the traditional image, at least) is to foster a monoculture. Compared with other landscaping options, lawns reduce habitat for wildlife. Even the varieties of lawn grass species are limited. Ironically, the most popular American lawn grass, "Kentucky" bluegrass, is not from Kentucky. *Poa pratensis* is native to northern Europe and Asia (Beard, 1998). In other contexts, grass lawns might well be viewed as non-native species displacing local ones, akin to the classic cases of kudzu, purple loosestrife, or golden bamboo.

The Verdict

From an ecological perspective (cycles, interactions, biodiversity), then, one may realize that green lawns are, ironically, not very "green." That conclusion might lead us to reconceptualize landscaping alternatives: vegetable or herb gardens, flowering perennials, butterfly gardens, mixed native grasses, shrubs and trees, and so on—all aligned with local habitats (e.g., Bormann et al., 1993; Daniels, 1995; Penick, 2013; Roach, 1993). The irony may also raise the question of why lawns seem so "natural" (considered in the next Sacred Bovine essay).

Regardless, grass lawns are familiar cases that can weave thematically through a whole ecology unit. It is remarkable (and ironic) how we can marvel at global diversity and fret about the threats to tropical rainforests and exotic coral reefs, while seemingly overlooking nearby household lawns, golf courses, and athletic fields. What better way to learn ecology and the lessons of interconnectedness, though, than by exploring our own backyards?

References

Appalachian State University. (2015, January 22). *Perfect lawns aren't perfect for the environment, research shows*. Appalachian Today. https://today.appstate.edu/2015/01/22/chuanhui-gu

Atwood, D., & Paisley-Jones, C. (2017). *Pesticides industry sales and usage, 2008–2012 market estimates*. Environmental Protection Agency. https://www.epa.gov/pesticides/pesticides-industry-sales-and-usage-2008-2012-market-estimates

Banks, J., & McConnell, R. (2015). *National lawn and garden equipment emissions*. 2015 International Emissions Inventory Conference, San Diego, CA. https://www.epa.gov/sites/default/files/2015-09/documents/banks.pdf

Beard, J. B. (1998, March). Origins of turfgrass species. *Golf Course Management,* 49–55.

Bormann, F. H., Balmori, D., & Geballe, G. T. (1993). *Redesigning the American Lawn*. Yale University Press.

Christians, N., & Ritchie, A. (2006). *Scotts Lawns: Your Quick Guide to a Beautiful Yard*. Meredith Books.

Daniels, S. (1995). *The Wild Lawn Handbook*. Macmillan.

EPA. (2022a). *How we use water*. WaterSense. https://www.epa.gov/watersense/how-we-use-water

EPA. (2022b). *Yard trimming: Material-specific data*. Facts and Figures about Materials, Waste and Recycling. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/yard-trimmings-material-specific-data

Gillman, L., Bollard, B., & Leuzinger, S. (2023). Calling time on the imperial lawn and the imperative for greenhouse gas mitigation. *Global Sustainability, 6*, E3. https://doi.org/10.1017/sus.2023.1

Gu, C., Hornberger, G., Crane, J., & Carrico, A. (2015). The effects of household management practices on the global warming potential of urban lawns. *Journal of Environmental Management, 151*, 232–245.

Jenkins, V. S. (1994). *The Lawn: A History of an American Obsession*. Smithsonian Institution Press.

Kaggwam, R. J., Jiang, H., Ryan, R. A., Zahller, J. P., Kellogg, E., Woodford-Thomas, T., & Callis-Duehl, K. L. (2021). Exploring grass morphology & mutant phenotypes using *Staria viridis*. *American Biology Teacher*, *83*, 311–319.

Lawn Institute. (2023). *Environmental benefits*. https://www.thelawninstitute.org/environmental-benefits

LawnStarter. (2016). *U.S. lawn care industry statistics*. https://www.lawnstarter.com/lawn-care/lawn-care-industry-statistics

Milesi, C., Elvidge, C. D., Dietz, J. B., Tuttle, B. T., Nemani, R. R., & Running, S. W. (2005). Mapping and modeling the geochemical cycling of turf grasses in the United States. *Environmental Management*, *36*(3), 426–438. https://doi.org/10.1007/s00267-004-0316-2

Morris, J., & Winter, M. (2021). Using grass germination to measure the toxicity of household substances & teach statistical methods. *American Biology Teacher*, *83*, 42–47.

Penick, P. (2013). *Lawn Gone! Low Maintenance, Sustainable, Attractive Alternatives for Your Yard*. Ten Speed Press.

Pollan, M. (1989, May 28). Why mow? The case against lawns. *New York Times Magazine*.

Riches, D., Porter, I., Dingle, G., Gendall, A. & Grover, S. (2020). Soil greenhouse gas emissions from Australian sports fields. *Science of the Total Environment*, *707*, 134420.

Roach, M. (Ed.) (1993). *The Natural Lawn and Alternatives*. Brooklyn Botanic Garden.

Steinberg, T. (2006). *American Green: The Obsessive Quest for the Perfect Lawn*. W.W. Norton.

Van Delden, L., Larsen, E., Rowling's, D., Scheer, D., & Grace, P. (2016). Establishing turf grass increases soil greenhouse gas emissions in peri-urban environments. *Urban Ecosystems*, *19*, 749–762.

Wang, R., Mattox, C. M., Phillips, C. L., & Kowalewski, A. R. (2022). Carbon sequestration in turfgrass–soil systems. *Plants, 11*, 2478. https://doi.org/10.3390/plants11192478

Xun, Z., Xu, T., Ren, B., Zhao, X., Quan, Z., Bai, L., & Fang, Y. (2022). Nitrogen fertilization of lawns enhanced soil nitrous oxide emissions by increasing autotrophic nitrification. *Frontiers in Environmental Science*, *10*, 943920. https://doi.org/10.3389/fenvs.2022.943920