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Environmental Assessment of Intensive Lawn Care

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Environmental Assessment of Intensive Lawn Care

Executive Summary

While green lawns are as American as apple pie, they contribute to a host of adverse environmental impacts if not managed with restraint. Fertilization, in particular, deserves special attention as its production is energy-intensive with its use linked to pollution of surface and ground water, emissions of potent greenhouse gases, reduction of dissolved oxygen in rivers and lakes, and promotion of algal growth in water bodies. Pesticides and herbicides used on lawns and gardens also pose risks to surface and groundwater, aquatic ecosystems, birds and beneficial insects, and soil microorganisms.

Healthy growing lawns sequester carbon, and store significant quantities in soil. Carbon sequestration is an important benefit of urban lawns. Healthy lawns maintained with modest fertilization, watering, and clippings retention have relatively low impact. But moderation, as in many things, is essential in lawn management in order to minimize adverse impacts. More does not mean better. While fertilization can increase the rate of carbon capture, its use can also trigger emissions that negate that benefit. Fertilizer use should be guided by periodic soil samples, and excess avoided. Timing of fertilizer application is also important. Paying attention to a number of other simple guidelines, which vary by region, can reduce the impacts of lawn care.

Balancing Benefits and Risks of Intensive Lawn Management

Striking a balance between a lawn that is attractive and healthy, and one that triggers an inordinate range of adverse environmental impacts can be tricky. The key is to avoid excess.

Sticking to a few basics will go a long way toward minimizing the impact of lawn care:

- Take steps to reduce lawn size by converting to areas of natural plantings or xeriscaping[i1] so as to sharply reduce or eliminate need for fertilizing, irrigating, pesticide use, and mowing.
- Use soil test results as a guide to fertilizer use.[2] Apply no more than what may be needed for maintaining a healthy lawn, and in general seek to minimize fertilizer use.

[1] A landscaping method developed especially for arid and semiarid climates that utilizes water-conserving techniques (such as the use of drought-tolerant plants, mulch, and efficient irrigation) Merriam Webster Dictionary (2019)

[2] Soil testing is available in most states through University Extension services for a nominal fee ($15-20). Instructions for taking samples (a simple process) are provided on-line, and soil to be tested can be submitted via the mail.

- Consult recommendations of state and local universities regarding best management practices for lawn care. Such recommendations are available on-line for most states.
- Delay fertilization and herbicide/pesticide applications when significant rain is in the immediate forecast. Similarly, avoid or minimize watering for at least a week following fertilizer application.
- Don't over-water.
- Avoid cutting grass too short. Recommendations for most grass species specify cutting to not less than 2 inches, and preferably 2.5-3.5 inches. Longer grass is more stress tolerant, needs less watering, and is more resistant to weed development.
- Purchase a mulching mower and recycle lawn clippings by retaining them on the lawn.

Pristine Lawns and the Environment

Green lawns are part of what makes summer – summer. They beautify our neighborhoods, our parks, and our parkways, and they improve soil, capture carbon, and reduce erosion. But when managed intensively and heavily fertilized, lawns can also contribute to surface and groundwater pollution, be a direct source of potent greenhouse gas emissions, and result in substantial energy consumption.

Various estimates place the area of lawns in the U.S. at between 40 and 50 million acres. A satellite-based 2015 NASA report[3] indicated a turf grass[4] area, an area which includes residential lawns, parks, and golf courses, of over 49 million acres. This is an area larger than the state of Washington and roughly three times larger than that of irrigated corn. In 2018, Penn State University's Extension Division reported that 800 million gallons of gasoline, 100 million tons of fertilizer, and 70 million pounds of pesticides are consumed each year in maintaining turf grass in the United States.[5] Herbicides are also widely used.

Water consumption for lawn maintenance is also significant. According to the calculations of one research team, were the entire area of turf grass to be kept well-watered, it would use about 60 million acre-feet of water annually[6] (one acre foot is the quantity of water needed to cover one acre to a depth of one foot, equivalent to 43,560 ft^2 or 1,233 m^3). The EPA reports that outdoor water use

[3] NASA (2015)
[4] Turfgrasses are narrow-leaved grass species that form a uniform, long-lived ground cover that can tolerate traffic and low mowing heights.
[5] Cotrone (2018)
[6] Crane and Hornberger (2012)

accounts for more than 30 percent of total household water use, on average, but can be as much as 60 percent of total household water use in arid regions.[7] A 2016 survey of homeowners in six major US cities (Baltimore, Boston, Los Angeles, Miami, Minneapolis-St. Paul, and Phoenix)[8] focused on lawn care practices, and water and fertilizer use in particular. An interesting finding was that there is little difference in the percentage of people using irrigation at least once in a year in the various cities, with only slight variance between the wettest city (Miami, 85%) and the driest (Phoenix, 89%).

Nitrogen (N) when applied to lawns can be a problem on at least two counts. One, nitrogen commonly finds its way into surface and ground water where, as nitrate (NO_3) it can pose a significant human health hazard. In ground water, nitrates can persist for decades and accumulate as more nitrogen is periodically applied to the land surface. Secondly, fertilizer application can result in emissions of nitrous oxide (N_2O) – a very potent greenhouse gas. Phosphates can also be problematic, as runoff can result in reduction of dissolved oxygen in rivers and lakes, and promotion of algal growth in water bodies.

A residential lawn care survey conducted in the Baltimore metropolitan area[9] examined nitrogen input to urban watersheds resulting from lawn care practices. The quantity of fertilizer N applied to residential lawns by homeowners and by professional lawn care companies varied greatly, with a mean fertilizer N application rate of 2.5 lb. per 1,000 square feet per year (97.6 kg /ha/yr.), and a standard deviation almost as large. The difference between the highest and lowest annual N application rates was more than 20-fold. The annual input of nitrogen from fertilizer was determined to account for over one-half of nitrogen flows to the urban watershed. This study also found that neighborhoods with more expensive homes tended to pay more attention to the appearance of lawns, and consequently to apply the greatest quantities of fertilizer.

A 2011 study of the Minneapolis-St. Paul urban area[10] also examined the relationship of fertilization practices to nitrogen emissions to the environment. In this case, nitrogen fluxes to the environment were found to be dominated by food consumption[11] and

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[7] USEPA (2018b)
[8] Groffman et al. (2016)
[9] Law et al. (2004)
[10] Fissore et al. (2011)
[11] Especially consumption of meat products, which require about six times more N per unit of calorific content than plant products (Liu et al. 2016).

lawn fertilizer applications, which together accounted for 65% of total household N inputs.

In addition to the problem of N intrusion into surface and ground waters, there are concerns about fertilizer-related emissions of greenhouse gases (GHG) and their contribution to climate change. On the one hand, a number of studies have found that not only do healthy lawns capture carbon dioxide from the air and release oxygen, but that they also progressively build stocks of soil carbon in the process. On the other hand, research, which has examined emissions of N_2O following fertilization, has found substantial net greenhouse gas emissions from well-tended lawns even when long-term soil carbon storage is taken into account. Soil microbes react with nitrogen, particularly in the first few weeks following application, and especially in the abundance of water, to form N_2O. N_2O has 300 times the heat trapping ability of carbon dioxide. EPA statistics show 8 thousand tons of N_2O emissions annually from urban turf grass fertilization, translating to 2.5 million tons of carbon dioxide equivalent (CO2e) emissions.[12]

GHG are also emitted in the manufacture of fertilizer. As reported by the Fertilizer Institute, natural gas is used in the production of nitrogen and in the manufacture of dry fertilizers such as potash and phosphate. Natural gas is a feedstock in nitrogen production as well as a source of energy in fertilizer production. Data from 2017 showed energy consumption of 9.5 million Btu (10.0 GJ), and CO_2e emissions of 1.1 metric ton, per 1.0 nutrient ton of fertilizer.

The University of Florida examined GHG emissions from land development and landscaping in that state[13], determining that fertilizer production, transportation, storage, and transfer, and subsequent release of N_2O following fertilizer application results in annual CO_2e emissions of approximately 29 pounds (13.2 kg) per 1,000 ft^2 (.0093 ha) of lawn. Considered in addition were emissions from lawn sprinkling, mowing, and periodic application of pesticides. Lawn sprinkling using ground water was found to result in greater emissions than fertilizer production and use; investigation of energy consumed in pumping, treating, and subsequent movement of water, and associated GHG emissions resulted in annual CO_2e emissions per 1,000 ft^2 of lawn of 34 pounds (15.4 kg). Total annual emissions from lawn care were calculated at 79.1 pounds (35.9 kg) per 1,000 ft^2.

Herbicides and pesticides, especially when not used in moderation, pose other problems. A comprehensive review of research of lawn care product impacts on water supplies[14] reported that 77% of households apply herbicide and that most of the commonly used lawn fertilizers contain pesticides. As with fertilizer use, research has found that excess watering often results in lawn care pesticides being carried into storm

[12] USEPA (2018a)
[13] Jones (2010)
[14] Schneemann (2015)

drains, and then into nearby water bodies. In severe rainfall events it has been found that runoff can result in loss of over 90% of pesticide via overland flow. Some of those pesticides leach into groundwater.

Similar issues exist with herbicide use. In addition to impacts to surface and groundwater, research has also linked use of lawn care pesticides to toxic impacts on aquatic ecosystems[15], birds and beneficial insects[16], and soil microorganisms.[17]

The average size of lawn in the U.S. for new homes was reported in 2016 at about 0.17 acre, or 7,405 ft^2 (0.069 ha).[18] Homes existing prior to that time had larger lawns on average. Using the 2016 reported average lawn size in conjunction with University of Florida calculations of average fertilizer use, sprinkling requirements, and associated emissions translates to 209,983 Btu (222 MJ) of annual energy consumption, and 586 pounds (266 kg) of CO_2e emissions for a typical lawn. While Florida lawn care requirements may not be typical of those in other regions of the country, the numbers provide an indication of the magnitude of emissions linked to lawn care. A website showing average lawn and home size in each state is available via HomeAdvisor: (https://www.homeadvisor.com/r/average-yard-size-by-state/).

Weighing Carbon Capture vs Nitrous Oxide Emissions

Carbon Capture by Turf Grass

Several studies have examined carbon sequestration by urban lawns[19], with all of these documenting capture of atmospheric carbon by turf grass and accumulation of soil carbon over time. These studies also indicate that lawn turf grasses are especially well suited for carbon sequestration because the soil on which they grow is seldom disturbed, and that fertilized lawns capture carbon more rapidly that those which are not. For example, a study conducted by Ohio State University in cooperation with Scotts Miracle Grow – a fertilizer manufacturing and distributing company – concluded that the average carbon sequestration rate is lower in lawns that receive low-level care (such as mowing only) than in intensively managed lawns where fertilizer is applied four times annually, irrigation is employed, and pesticides are used.[20] Although emissions of N_2O linked to fertilizer applications were discussed in the body of the final report, these were not mentioned in the findings summary, an omission that could have dramatically altered study conclusions. The summary results, which suggested that heavy fertilization practices are environmentally beneficial, were widely reported in the popular

15 Helfrich et al. (2009)
16 Thompson (2014)
17 Kalia and Gosal (2011)
18 McGill (2016)
19 Pouyat et al. (2006), Qian et al. (2010), Zirkle et al. (2011), Sahu (2014), Hamido et al. (2016), Ziter (2018)
20 Zirkle et al. (2011)

media.[21] Other, more recent, studies that have reported carbon sequestration in urban lawns also did not consider fertilizer-related N_2O emissions; these also received considerable media attention.[22] But, as discussed on the following page, ignoring N_2O emissions can lead to erroneous conclusions.

It is an important determination that turf grass, and urban lawns in particular, can capture and store significant quantities of carbon, and that they do this most effectively with careful management. In this regard, a consistent finding of research is that thorough mulching and retention of grass clippings, and mowing to a proper height (not too short), are extremely important in achieving soil carbon retention. In fact, whereas retention of grass clippings can foster carbon accumulation, systematic removal of clippings can shift the turf balance from carbon sink to carbon source. Removal of clippings for disposal is also often a burden for composting sites and garbage collection systems.

Nitrous Oxide (N_2O) Emissions

The 500 pound gorilla in lawn management is the potential for N_2O emissions from fertilizer use. Virtually every study of the climate impacts of lawn care has found benefit from maintaining a healthy lawn. Healthy lawns and thick grass promote carbon accumulation, minimize erosion and runoff, and inhibit weed growth and the need for herbicides. But research has also consistently demonstrated that there is a fine line between maintaining a healthy lawn and going overboard.

One recent study[23] examined N_2O emissions in an urban turf grass system in Nashville, Tennessee. Observations were used as a basis for further study of the long-term (i.e. 75 year) impacts of lawn management practices on the sequestration rate of soil organic carbon, emissions of soil N_2O, and net global warming potential (GWP). Three management intensity levels were examined in which annual nitrogen fertilizer applications ranged from 0.7 to 3.2 lbs per acre (0.8 to 3.6 kg N ha), with resulting CO_2e sequestration rates of 622 to 2180 lbs/ac. (697 to 2443 kg/ha) respectively. Although higher fertilization rates were found to substantially increase soil carbon (CO_2e) sequestration, they also led to higher N_2O emissions. Overall, turf grasses were found to be a carbon *source*. Results indicated that reduction of fertilization is the most effective strategy for mitigating the GWP of turf grasses, and that recycling lawn clippings, reducing irrigation, and mowing less frequently are also effective in lowering net GWP. A minimum lawn maintenance program without irrigation and fertilization was found to reduce annual N_2O emissions and net GWP by approximately 53% and 70%, respectively, with the price of gradual depletion of soil organic carbon, when compared to intensive management.

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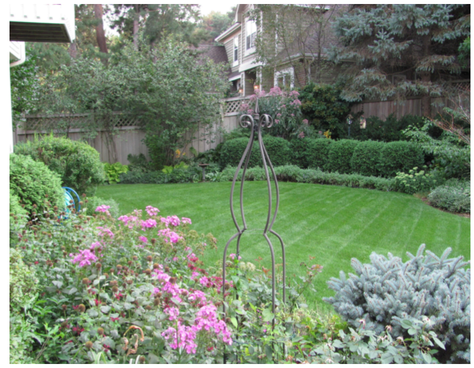
[21] Montalvo (2015, Mooney (2015)
[22] Hickman (2018), Montalvo (2015), Mooney (2015), Pierre-Louis (2018)
[23] Gu et al. (2015)

A similar investigation focused on southern California.[24] Soil organic carbon sequestration rates, N_2O emissions, and CO_2e emissions generated by fuel combustion, fertilizer production, and irrigation were studied. Findings showed that soil carbon sequestration rates in ornamental lawns more than compensated for emissions of N_2O. However, when indirect emissions linked to fertilizer manufacture, irrigation, and fuel combustion in mowing were taken into account, CO2e emissions were found to greatly exceed soil sequestration. The study report indicated that the City of Irvine recommends 2 to 15 fertilizer applications per year, at a per-application rate of 1.0 lb/1,000 ft2 (50 kg/ha), and that both the high and low application rates led to net emissions. Yet, when it was assumed that lawns would be mowed regardless of whether fertilizer and irrigation were applied, with fuel use in mowing therefore removed from calculations, the results of this study showed a small net carbon benefit from fertilization and irrigation when 2 fertilizer applications were applied annually. Above 4 applications, the lawns became a carbon source even without mowing, with the magnitude of net emissions increasing with each subsequent fertilizer application. A recent Swedish study25 yielded very similar results.



Several studies have reported that emissions of N_2O are highest in the days and weeks following application of nitrogen fertilizer.[26] Emissions were generally found to peak within one to two weeks. One study found that emissions increased by as much as 15 times within 3 days of application, with the greatest increases recorded when significant precipitation occurred within the first 2-3 days following N fertilization.[27] Consequently, scientists recommend delaying fertilization if significant rains are forecast in the near term; heavy sprinkling immediately following fertilizer application should also be avoided.[28] Another general finding is that application of excess N fertilizer increases the likelihood of N emissions to air or water.[29] In view of a 2014 finding that only 26% of homeowners have soil tested prior to fertilizer application,[30] the likelihood of nutrients being applied in excess of soil needs is high.

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[24] Townsend-Small and Czimczik (2010)
[25] Wesström (2015)
[26] Bremer (2006), Jones (2010), Townsend-Small and Czimczik (2010). Sanders (2012), Gu et al. (2015)
[27] Bremer (2006)
[28] When granular fertilizer is used a light sprinkling is recommended within a week to ten days following application to activate the fertilizer and break down granules.
[29] Millar (2015)
[30] Khachatryan et al. (2014)

Related to the observation that heavy rainfall following N application promotes N_2O emissions, is the finding that climate has a large effect on both N_2O emissions and N leaching in lawn soils. For instance, in a 2014 study, the humid subtropical climate of Miami was found to be associated with very high rates of N leaching and of N_2O emissions under intensive lawn management. Mobile, Alabama, in contrast, showed the highest rates of N_2O emissions under minimal or moderate lawn maintenance, with this attributed to the high average annual rate of precipitation and associated high atmospheric deposition of N in the Mobile area. Savannah, Georgia was found to have the lowest rates of N leaching of four metropolitan areas studied because of relatively low average precipitation compared to the other sites.[31]

Consideration of the N dynamics of lawns in early stages of establishment, and changing characteristics with age, led one research team to recommend age-dependent lawn management practices in order to minimize N2O emissions. Recommendations include a high dose fertilizer application at the initial stage of lawn establishment to enhance carbon sequestration, followed by decreasing fertilization rates as a lawn ages. It was recommended that over the long term, minimum lawn maintenance be practiced, with recycling of lawn clippings coupled with minimum irrigation and mowing, to mitigate climate change effects.[32]

Summary

Green lawns are esthetically beautiful, and bring joy as the drabness of winter gives way to spring. They also capture and store carbon, with carbon stocks increasing steadily as turf grass ages. Carbon stocks also increase more rapidly with fertilization and irrigation. But heavy and frequent fertilization can also lead to runoff of nutrients, as well as herbicides and pesticides into rivers and streams and ground water intrusion, and emissions of greenhouse gases. Responsible management requires moderation, with actions based on results from periodic soil testing, and guided by recommendations from trusted sources. Taking steps to reduce the area of turf grass requiring intensive management will invariably reduce the overall environmental impact of lawns.

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