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RESEARCH LETTER

Estimating economic minimums of mowing, fertilizing, and irrigating turfgrass

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Abstract

The public health crisis and economic recession caused by the COVID-19 pandemic have forced turfgrass industry professionals to re-evaluate standard practices. Minimum costs required to fertilize, irrigate, and mow turfgrasses can be roughly estimated using climate data, turfgrass physiology information, and resource costs. Although the actual minimum costs vary situationally and regionally, mowing golf putting greens optimally requires about US$34 per acre per month, whereas other turfgrass areas cost less than US$11 per acre per growing month. Fertilizer applications to turfgrass cost US$22 or less per acre per growing month. Irrigation costs (water and electricity for pumping) vary widely, with the least expensive regions requiring ~US$300 per acre per year compared with 12 times more than that total in other parts of the United States.

1 | INTRODUCTION

The COVID-19 public health crisis beginning in late 2019 has created economic challenges for turfgrass managers. Whereas agricultural producers grow crops to make a profit by maximizing yields using minimum input costs, turfgrass managers cultivate surfaces to meet an aesthetic or functional ideal that is difficult, if not impossible, to quantify. In contrast to agricultural producers, turfgrass managers often do not share in profits and therefore have little incentive to maximize the economic return of resources. Many owners of turfgrass operations do not fully understand the agronomics of turfgrass management and therefore are unable to effectively evaluate the economic efficiency of the resources used. In our previous letter (Brosnan et al., 2020), we argued for the essentiality of turfgrass management to maintain a set of important societal and ecological benefits during a public health crisis. Here, we estimate economic minimums required for mowing, fertilizing, and irrigating turfgrasses across the United States to ensure those benefits.

Core ideas

- Turfgrass professionals have been forced to re-evaluate standard practices due to COVID-19.
- Mowing costs less than US$11 per acre per growing month for most situations.
- Fertilizing can be done effectively for US$22 or less per acre per month in many cases.
- Irrigation costs vary substantially, ranging from US$276 to US$3,672 per acre annually.

2 | ESTIMATING MOWING COSTS

Regular mowing during periods of active growth is a defining feature of natural turfgrass systems (Emmons & Rossi, 2015). Functional aspects of turfgrass systems (e.g., putting greens, sports fields, and lawns), turfgrass species, cultural practices (e.g., irrigation and fertilization), climate, and soil type determine mowing requirements (Cook & Ervin, 2010). Climate and soils being fixed, proper species selection and minimal cultural practices are the most effective means of reducing mowing requirements.

Turfgrass growth is determined by species/variety and height of cut, which therefore have the greatest influence on mowing requirements (Law, Bigelow, & Patton, 2016). When maintained at increased heights of cut, slow-growing species can require up to 70% less mowing than a rapidly growing low-cut turfgrass (Kopp & Guillard, 2002). Clipping removal rates maintained at approximately 30% have been shown to moderate turfgrass growth rate over calendar-based mowing (DeBels, Griffith, Kreuser, Melby, & Soldat, 2012).

Mowing more frequently results in a higher energy requirement, greater emissions, increased labor, and increased financial cost (Kowalewski, Schwartz, Grimshaw, McCrimmon, & Layton, 2014). Therefore, it behooves the turfgrass manager to establish standards (height of cut, frequency, performance, etc.) that balance functional needs with optimized growth rate (Table 1). Mowing cost per acre calculations used in Table 1 are based on manufacturer specifications and maximum mowing speed and do not include loss in productivity associated with turning and maneuvering or travel time to and from mowing locations.

3 | ESTIMATING FERTILIZER COSTS

Crop yields are critical for understanding agricultural economics; however, yield maximization has never been a goal of turfgrass management. In fact, excessive yield results in increased management costs and suboptimal aesthetics as well as function. However, quantifying yield of turfgrass is important for estimating input costs. For example, nutrient needs can be estimated by multiplying the turfgrass dry matter yield by the tissue nutrient content, mowing requirements can be estimated by the rate of turfgrass growth, and irrigation needs are often correlated with turfgrass yield.

Turfgrass requires 16 essential elements to complete its life cycle, of which all but one are routinely found to be non–growth limiting. Although phosphorus (P) and potassium (K) are often routinely applied by turfgrass managers (Gelernter, Stowell, Johnson, & Brown, 2016), these nutrients are typically found in levels well above growth-limiting thresholds (Gelernter et al., 2016; Johnson, Koenig, & Kopp, 2003; Kreuser, Pagliari, & Soldat, 2012; Schmid, Murphy, Clarke, DaCosta, & Ebdon, 2016). During an economic crisis, maintenance applications of P and K can be withheld for a short period of time (i.e., one season) without negative consequences in a large majority of cases. However, most turfgrass is constantly in a state of nitrogen (N) deficiency (Kussow, Soldat, Kreuser, & Houlihan, 2012), and, if neglected, many problems can occur. Therefore, here we consider the minimum N input costs to managing turfgrass in an economic crisis or to otherwise maximize profitability without sacrificing aesthetic or performance goals.

To estimate the minimum cost of replacing N used by turfgrass, a temperature-based turfgrass growth model (Pace Turf, 2014; Equation 1) was used to estimate monthly growth. The model calculates growth potential using

TABLE 1 Monthly mowing cost per acre as affected by land use, species, mowing height, and mowing frequency

Surface	Turfgrass species	Mowing height[a]	Mowing frequency during peak growth[b]	Monthly cost per acre[c]
		in		US$
Putting greens	creeping bentgrass, annual bluegrass, and hybrid bermudagrass	0.15	three times a week	33.51[d]
Fairways, tees, approaches, and surrounds	perennial ryegrass, creeping bentgrass, annual bluegrass, and hybrid bermudagrass	0.5	twice a week	9.73[e]
	Kentucky bluegrass, common bermudagrass, and zoysiagrass	0.75	twice a week	9.73
Sports fields	hybrid bermudagrass, and common bermudagrass	1.0	twice a week	9.73
	Kentucky bluegrass and perennial ryegrass	2.0	once a week	10.24[f]
Roughs, lawns, parks, and cemeteries	hybrid bermudagrass, common bermudagrass, zoysiagrass, centipedegrass, and St. Augustinegrass	1.5	once a week	10.24
	Kentucky bluegrass, perennial ryegrass, tall fescue, and fine fescue	4.0	once a week	10.24

[a]The mowing height for these turfgrasses has been raised to facilitate a reduce mowing frequency during periods of low or no use.
[b]Clipping removal rates maintained at ∼30% have been shown to moderate turfgrass growth rate over calendar mowing.
[c]Mowing cost per acre calculations are based on manufacturer specifications and maximum mowing speed and do not include loss in productivity from turning and maneuvering or travel time to and from the mowing location.
[d]Mowing cost based on Jacobsen Eclipse 322 hybrid gasoline reel mower specification (0.32 h per acre, 0.16 gallons gasoline per acre), federal minimum wage US$7.25, US$1.81 per gallon of gasoline, and the minimum mowing frequency of three times a week.
[e]Mowing cost based on John Deere 7500A fairway mower specification (0.13 h per acre, 0.09 gallons diesel per acre), federal minimum wage US$7.25, US$2.43 per gallon of diesel, and the minimum mowing frequency of twice a week.
[f]Mowing cost based on Toro Groundsmaster 4300D mower specification (0.22 h per acre, 0.33 gallons diesel per acre), federal minimum wage US$7.25, US$2.43 per gallon of diesel, and the minimum mowing frequency of once a week.

optimum temperature of cool-season (20 °C) and warm-season turfgrass (31.1 °C) in eight U.S. cities compared with average monthly air temperature (http://www.weatherbase.com/). In addition to average air temperature and optimum growth temperature, the model uses a variance constant (set to 10 for cool-season grasses and 12 for warm-season grasses).

$$\text{Relative growth potential} = e^{-0.5\left(\frac{\text{avg. monthly temp.} - \text{optimum growth temp.}}{\text{variance}}\right)^2} \quad (1)$$

Next, the relative growth potential for each month within each city was multiplied by an estimate of the maximum turfgrass N use, where N use is the N removed via mowing each month. One pound per 1,000 ft^2 was chosen for this value based on an assumption of maximum turfgrass biomass production at 0.82 lb per 1,000 ft^2 d^{-1} (Hull, 1992) and average tissue content of 4.0% N.

Nitrogen fertilizer in the form of urea (urea ammonium nitrate) or ammonium sulfate can be found from suppliers at a cost of approximately US$0.5 per pound of N (Quinn, 2020). The average size of managed turfgrass on a golf course in the United States is 82 acres, and the areas that are routinely fertilized (greens, tees, and fairways) comprise 34 acres on average (Gelernter, Stowell, Johnson, & Brown, 2017). Therefore, to replace the annually estimated N used (i.e., that removed via mowing) on these areas for a typical golf course in the United States would cost less than US$5,000 on average, ranging from US$3,228 in a cool climate (Ithaca, NY) to US$7,606 in Dallas, TX, at a property where cool-season and warm-season grasses might be managed year-round (Table 2). Although golf courses were used in this example, the calculations can be applied to

TABLE 2 Estimated annual turfgrass N use for eight U.S. cities

Estimates	Corvalis, OR	Dallas, TX	Fort Laud-erdale, FL	Ithaca, NY	Knoxville, TN	Las Cruces, NM	Lincoln, NE	Madison, WI
Cool-season N use, lbs 1,000 ft^{-2}	4.7	5.8	0.0	4.4	5.8	5.9	4.8	4.5
Warm-season N use, lbs 1,000 ft^{-2}	0.0	4.5	7.3	0.0	2.7	3.3	0.0	0.0
N use, lbs 1,000 ft^{-2}	4.7	10.3	7.3	4.4	8.5	9.2	4.8	4.5
Annual cost of total N, US$ acre^{-1}	102	224	159	95	185	199	104	99

Note. Estimates were derived by calculating relative turf growth potential (0–100%) using the PACE Turf model and then multiplying the relative growth potential by a conservative estimate of maximum monthly N use for cool- and warm-season grasses (1 lb 1,000 ft^{-2}) based on a 0.82 lbs dry matter per 1,000 ft^{2} daily growth rate and a tissue content of 4% N. The estimated N use was then used to calculate a per acre cost based on a N source at US$0.50 per pound of N.

TABLE 3 Comparison of cost/acre to irrigate golf courses located across the United States

Location	Growing season	Irrigated acres	ET[a]	Precipitation[a]	Irrigation requirement[b]	Water use[a]	Total cost/acre[c]
			in	in	in	acre-ft	US$
Albuquerque, NM	Feb.–Nov.	168	47.0	6.6	43.7	616	3,671.63
Bend, OR	May–Oct.	91	33.8	3.8	31.9	307	879.12
Vancouver, WA	June–Sept.	88	25.6	5.4	22.9	88	295.45
Dallas, TX[d]	Apr.–Nov.	100	39.7	34.4	22.5	113	1,744.13
Portland, OR	June–Sept.	94	24.0	4.6	21.7	53	276.60
Naples, FL	Jan.–Dec.	82	46.2	54.0	19.2	287	742.30
Lincoln, NE	May–Oct.	86	26.8	18.6	17.5	151	1,795.82
Ithaca, NY	Apr.–Oct.	50	23.3	23.3	11.6	17	1,054.90
Knoxville, TN[d,e]	May–Oct.	108	21.0	20.9	10.6	95	50.22

Note. ET, evapotranspiration.
[a] Numbers listed for growing season.
[b] Irrigation requirement calculated as ET minus 50% of precipitation.
[c] Column lists cost per irrigated acre and includes cost for water and pumping.
[d] Pumping costs were not reported for these locations.
[e] Irrigated acres and water use from English, Menard, Jensen, Brosnan, and Boyer (2015).

any turfgrass area in the United States. The cost of application (e.g., from labor, equipment, and maintenance) was not factored into these calculations. If replacement levels of P and K are added, these costs will no more than double because P and K are used in smaller quantities than N and per unit costs of the P and K fertilizers are similar to that of N. These cost figures were conservatively estimated based on plant N use and do not represent actual N recommendations. In many cases, N fertilization rates (and costs) could be far less than those listed in Table 2.

4 | IRRIGATION COSTS

Sufficient water, either through rainfall or irrigation, is essential for the growth and survival of turfgrasses. Inadequate water allocations can have significant negative impacts on the aesthetics and health of turf areas and under extreme conditions can result in complete loss of stands. In arid and semi-arid regions of the United States, the rate of evapotranspiration generally exceeds precipitation, and golf courses require supplemental irrigation (Table 3) to ensure functionality. However, climate change, recurrent drought, and rapid urbanization have increased public demands for potable water, leaving fewer freshwater resources available for landscape irrigation. In fact, governing bodies have increasingly established restrictive irrigation guidelines and provided incentives to reduce turfgrass acreage (California Water Boards, 2020; San Antonio Water Systems, 2020; State of Georgia, 2020; USEPA, 2013; Water Authority. 2020). The escalating cost of potable water limits its use, even when water is available for irrigation. Table 3 lists irrigation costs of golf courses surveyed by the respective authors of this report. The golf courses span the entire country, represent climate zones from arid to temperate, and include inland and coastal regions. In some locations (Vancouver, WA, and Portland, OR), golf courses do not pay for irrigation water because they have access to surface water or groundwater. All golf courses have electricity costs associated with pumping water for irrigation. As expected, the golf course located in the arid Southwest (Albuquerque, NM) uses more water and pays considerably more for water than golf couses in other regions. Limiting irrigation water to reduce costs during the pandemic would not be possible without seriously damaging or destroying the turf cover, as evidenced by the low annual precipitation and high evapotranspiration rates (Table 3).

It is incumbent upon owners, administrators, and managers of facilities to work together to understand turfgrass water requirements in their particular climatic region. Knowledge about the duration of the growing season, efficiency of their irrigation system, type of turfgrass used, and consumer expectation or perception of healthy turfgrass are imperative to making informed decisions about water use. Investment of time and resources in such long-term planning and crisis preparedness will allow facilities to respond effectively in economically difficult times, such as the current COVID-19 pandemic or during a major drought. Major federal and corporate funding agencies have invested in advancing turfgrass research related to water use, and several strategies to reduce or eliminate potable water for irrigation are considered (Leinauer, Sevostianova, Serena, Schiavon, & Macolino, 2010). This includes reducing the irrigated area, developing drought-tolerant varieties, using recycled water for landscape irrigation, improving irrigation efficiency by adopting new technologies, and implementing general water-conserving management practices by combining more than one approach. Working with the state's extension specialists and turfgrass associations, owners and managers of turfgrass facilities can learn and implement practices best suited for their use, budget, and consumer expectations.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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