



# Golf Course Environmental Profile

**Phase III, Volume II**  
Nutrient Use and Management Practices  
on U.S. Golf Courses

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Golf Course Superintendents Association of America

# Golf Course Environmental Profile

## Phase III, Volume II

# 2022 Nutrient Use and Management Practices on U.S. Golf Courses

The third phase of the Golf Course Environmental Profile was conducted  
by the Golf Course Superintendents Association of America.



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## Nutrient study shows significant reductions in nutrient application rates

As with the second phase of the Golf Course Environmental Profile, the third phase results show us that superintendents continue to show considerable reductions in nutrients used since 2006. The superintendents' knowledge and skills pertaining to sustainable nutrient use continues to be important to every golf facility.

Nutrients are a vital tool that superintendents use to produce healthy turf, but responsible, sustainable use of nutrients means that the managed turf -- and the environment surrounding it -- will be healthy for years to come.

The survey measured the use of nitrogen, phosphorus and potassium. Since 2006, the total amount of the applied nitrogen declined by 41%, applied phosphorus declined by 59% and applied potassium declined by 54%.

The number of fertilized acres also declined across the board, with acres fertilized by nitrogen decreasing by 24%, acres fertilized by phosphorus declining by 53% and acres fertilized by potassium declining by 32%. The average national application rates for all three nutrients also decreased.

On behalf of the GCSAA Board of Directors, I thank all of those who took the time to be a part of the study. This vital data, which help illustrates golf's commitment to sustainability would not be possible without the participation from golf course superintendents around the country.



A handwritten signature in black ink, appearing to read 'Kevin P. Breen'.

Kevin P. Breen, CGCS  
2022 GCSAA President

## Executive Summary Objectives

Nutrient use and management practices on U.S. golf facilities were previously documented in 2006 and 2014. These reports have proven to be valuable in directing practitioners and educators towards more efficient turfgrass management.

The objective of the third survey was to compare current nutrient use and practices to prior years to determine if change has occurred and to what extent. Specific areas of interest were quantifying the use of nitrogen (N), phosphorus ( $P_2O_5$ ), and potassium ( $K_2O$ ) in the following areas:

- National and regional nutrient use
- The influence of management practices on nutrient use
- Use of nutrient sources
- Presence and/or use of storage and equipment calibration

## Results National

The following changes have occurred since 2006:

### Applied Nutrients

- Projected applied N decreased by 41% to 54,376 tons.
- Projected applied  $P_2O_5$  decreased by 59% to 13,761 tons.
- Projected applied  $K_2O$  decreased 54% to 41,386 tons.

### Fertilized Acres

- Projected acres fertilized with N decreased by 25% to 889,378 acres.
- Projected acres fertilized with  $P_2O_5$  decreased by 53% to 472,923 acres.
- Projected acres fertilized with  $K_2O$  decreased by 32% to 767,883 acres.
- The national median of fertilized acres per facility decreased by 14% to 104.1 acres.

### Operational Facilities

- Operational golf facilities declined by 12% to 14,033.

### Application Rates

- Nitrogen application rates decreased by 31% to 1.6 lbs. per 1,000  $ft^2$ .
- $P_2O_5$  application rates decreased by 64% to 0.3 lbs. per 1,000  $ft^2$ .
- $K_2O$  application rates decreased by 46% to 1.1 lbs. per 1,000  $ft^2$ .

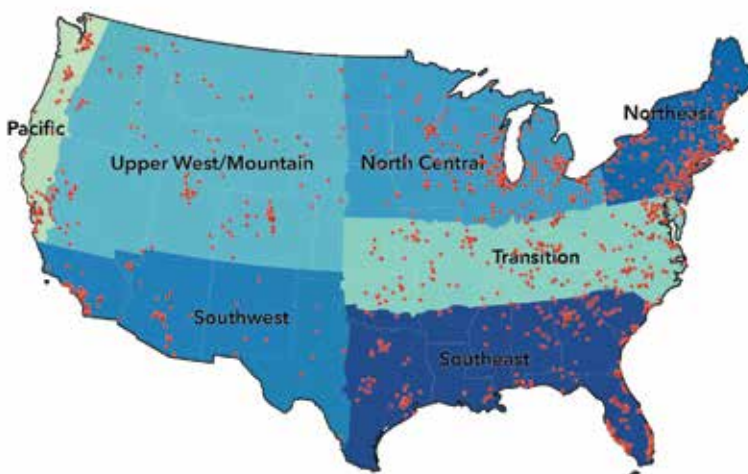


Figure 15. Distribution of 2022 survey and the seven agronomic regions.

## Management Practices

- Fertilizing based upon soil test results decreased to 43% of facilities.
- Reducing turfgrass acres decreased to 30% of facilities.
- Using plant growth models increased to 25% of facilities.

## Introduction

The Golf Course Superintendents Association of America's (GCSAA's) Golf Course Environmental Profile (GCEP) Survey Series was first launched in 2006 to develop a comprehensive environmental profile of golf courses in the United States. The objective was to establish baseline data on issues ranging from land use to regulations and practices governing water use, nutrients, and pest control.

A follow-up set of surveys was conducted starting in 2014 and provided scientifically valid measurements of industry change as it related to: 1) Energy Use and Environmental Practices on U.S. Golf Courses, 2) Land Use Characteristics and Environmental Stewardship Programs on U.S. Golf Courses, 3) Pest Management Practices on U.S. Golf Courses, 4) Nutrient Use and Management on U.S. Golf Courses, and 5) Water Use and Conservation Practices on U.S. Golf Courses.

The survey series, now in its third iteration, serves as the golf course management industry's benchmark by providing comprehensive data on the management practices, property features, and environmental stewardship of US golf courses.

The GCEP survey results are frequently used by those interested in the golf course management industry to:

- Document changes in environmental practices over time,
- Assist in determining the future direction of GCSAA environmental efforts and education,
- Identify key issues for potential research projects,
- Respond to governmental and public inquiries,
- Promote the efforts superintendents are making on their golf courses, and
- Provide a solid basis for comments on proposed regulatory issues

Results from the surveys are available in online documents (<https://www.gcsaa.org/Environment/golf-course-environmental-profile>) and are published in *Golf Course Management*. Survey results are also published in peer-reviewed scientific journals including *Crop, Forage and Turfgrass Management* (previously *Applied Turfgrass Science*) and *HortTechnology* benefiting scientists who routinely use the survey data to inform their research direction and regulators who must make evidence-based decisions.

Nutrient use on U.S. golf courses is an important management practice that increases management cost and has the potential to influence ecosystems. Therefore, assessing nutrient use and management practices are critical to the development and teaching of best management practices (BMPs). The objective of this survey study was to measure nutrient



use and management practices on U.S. golf courses in 2021 and to determine if changes occurred since 2006.

## Methodology

In order to compare changes from prior surveys, questions were identical to those used in 2006 and 2014. Nutrient data were reported as the guaranteed analysis on the fertilizer label such that nitrogen, phosphorus, and potassium were reported as N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O. A survey link was emailed to golf facilities using the mailing lists of the National Golf Foundation and the Golf Course Superintendents Association of America, which resulted in the link being sent to 14,033 unique golf facilities. A golf facility was defined as a business where golf could be played on one or more golf courses. The survey and the link were also

promoted on social media by GCSAA staff. The survey was available for completion for seven consecutive weeks beginning on 1 Apr. 2022. Respondents remained anonymous within the data file by omitting their names and assigning a unique identification number. Data were merged with data from the same survey conducted in 2006 and 2014 to allow for a measurement of change over time. Responses were received from 1,444 facilities, which represented 10.3% of the known total of U.S. golf facilities.

Respondents were grouped by agromorphic region (Figure 15). To provide a valid representation of U.S. golf courses, data were weighted. Responses were categorized into one of 35 categories depending upon the facility type (public or private), number of holes (9, 18, or 27+), and public green fee (<\$55 or ≥ \$55 per

round) (Table 34). The weights were calculated by determining the proportion of each group within the total survey response.

Statistical analysis identified the data as non-normally distributed. As a result, data were fit to a log-logistic model and median separations were performed using the Tukey-Kramer test ( $\alpha = 0.1$ ). Projected applied nutrients were determined by multiplying the number of golf facilities by the percentage that applied nutrients on a given course feature, and then multiplying that value by the average amount of nutrient applied. Projected fertilized acres were determined by dividing the total pounds of nutrients applied by the average pounds per 1,000 ft<sup>2</sup> and then converted to acres. Statistical separations were not conducted on projected values. Golf facility frequencies were calculated using statistical software. Differences among years were determined using the  $\chi^2$  test at the 10% significance level.



## Mean vs. Median

Mean = sum of all values divided by the number of values.

Median = midpoint of a frequency distribution.

The mean is more influenced by extremely high or low outliers than the median and is regularly used in agricultural sciences where these high or low outliers are rare. The median is less influenced by extremely high or low outliers and is regularly used in survey sciences where these high and low outliers are common. Therefore, the use of the median in this survey provides a greater probability of reporting the true value than using the mean.

## Significant Differences

Throughout this report, some tables and graphs contain letters such as a, b, or c next to numeric values. These letters indicate whether the values being compared are different. Values followed by a common letter are not different at the 90% confidence level. This means that when we state that two values are different, we are 90% confident that the true values differ.

## National

Across the United States key indicators like total nutrients, fertilized acres and application rates are on the decline. This is in part due to course closures and management practices/operations. Some related management practices like fertilizing based upon soil testing, reducing overseeding, and reducing turgrass acres are also on the decline as well.

## Nutrient Use

- Total projected applied N,  $P_2O_5$ , and  $K_2O$  declined by 41%, 59%, and 54% since 2006, respectively (Figure 1).

## Fertilized Acres

- Acres fertilized with N,  $P_2O_5$ , and  $K_2O$  declined by 25%, 53%, and 32% since 2006, respectively (Figure 2).
- Acres fertilized with N,  $P_2O_5$ , and  $K_2O$  declined within each agronomic region (Table 12).
- Greater than 96% of facilities reported N was applied to greens and tees (Table 1).
- The least common features to receive N were grounds, practice areas, and natural areas (Table 1).
- The proportion of facilities that

reported  $P_2O_5$  was applied has declined since 2006 on each course feature (Table 1 and Figure 6).

- The proportion of facilities that reported  $K_2O$  was applied has declined since 2006 on each course feature except practice areas (Table 1 and Figure 6).
- Median fertilized acres declined since 2006 by 14% (Table 13).

## Number of Facilities

- Operational golf facilities declined by 12% since 2006 (Table 14).

## Application Rates

- Nitrogen application rates have declined 31% from 2.30 lbs. per 1,000  $ft^2$  in 2006 to 1.58 lbs. per 1,000  $ft^2$  in 2021 (Table 2).
- $P_2O_5$  application rates declined by

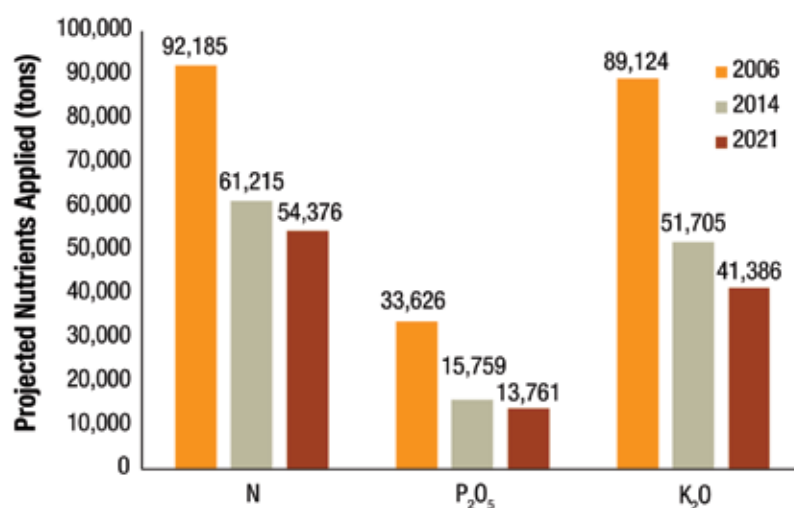


Figure 1. Projected N,  $P_2O_5$ , and  $K_2O$  applied on U.S. facilities in 2006, 2014, and 2021.

Table 1. Frequency of U.S. golf facilities that reported applications of nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) to each golf facility feature in 2006, 2014, and 2021.

Year	Greens	Tees	Fairways	Roughs	Practice Areas	Natural Areas	Grounds
Golf facilities (%)							
N							
2006	99.9 a <sup>1</sup>	98.1 a	96.2 a	73.2 a	59.6 a	8.0 a	56.5 a
2014	99.3 b	96.8 ab	91.7 b	65.2 b	59.6 a	3.9 b	58.0 a
2021	99.5 b	96.5 b	92.7 b	64.8 b	60.4 a	3.8 b	54.1 a
$P_2O_5$							
2006	92.4 a	88.7 a	82.1 a	61.1 a	51.8 a	6.1 a	48.6 a
2014	80.5 b	65.2 b	51.4 b	32.2 b	35.7 b	1.7 b	30.1 b
2021	74.9 c	59.4 c	49.5 b	31.1 b	35.7 b	1.8 b	26.1 c
$K_2O$							
2006	96.8 a	94.8 a	92.3 a	69.3 a	57.2 a	8.3 a	54.5 a
2014	95.0 ab	89.0 b	83.0 b	56.4 b	53.3 b	3.3 b	52.0 a
2021	92.8 b	86.3 b	80.1 b	54.9 b	53.4 a	3.2 b	46.0 b

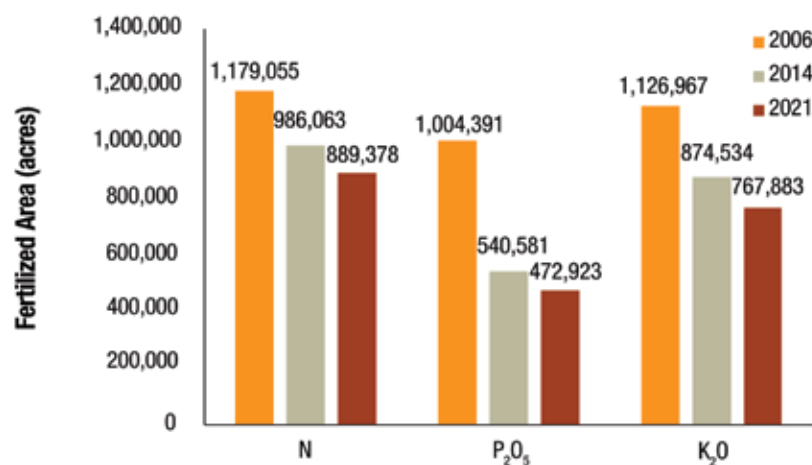
<sup>1</sup>Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.

**Table 2.** Nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) use rates on U.S. golf facilities in 2006, 2014, and 2021.

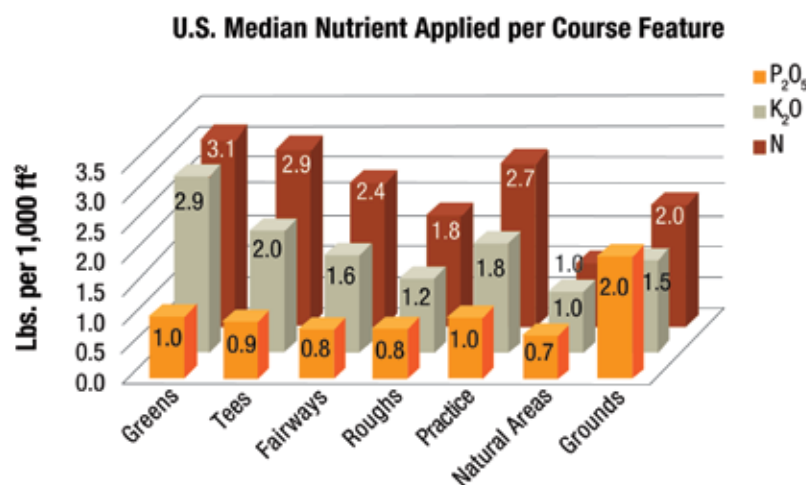
Year	U.S.	NC <sup>1</sup>	NE	Pac.	SE	SW	Trans.	UWM
<b>N (lbs. per 1,000 ft<sup>2</sup>)</b>								
2006	2.30 a <sup>ii</sup>	1.77 a	1.89 a	2.26 a	3.56 a	3.79 a	2.05 a	2.28 a
2014	1.68 b	1.29 b	1.58 a	1.67 a	2.71 b	2.48 ab	1.57 b	1.73 ab
2021	1.58 b	1.36 b	1.54 a	2.35 a	2.24 b	1.10 b	1.35 b	1.32 b
<b>P<sub>2</sub>O<sub>5</sub> (lbs. per 1,000 ft<sup>2</sup>)</b>								
2006	0.76 a	0.57 a	0.69 a	0.98 a	0.91 a	2.13 a	0.87 a	0.93 a
2014	0.25 b	0.13 b	0.20 b	0.38 a	0.83 ab	0.55 b	0.26 b	0.40 b
2021	0.27 b	0.09 b	0.38 b	0.58 a	0.46 b	0.90 b	0.25 b	0.27 b
<b>K<sub>2</sub>O (lbs. per 1,000 ft<sup>2</sup>)</b>								
2006	1.95 a	1.42 a	1.58 a	1.93 a	3.29 a	3.19 a	1.86 a	1.76 a
2014	1.16 b	0.70 b	1.07 b	1.21 a	2.73 ab	1.17 b	1.16 b	1.10 ab
2021	1.06 b	0.64 b	1.08 b	1.26 a	1.91 b	1.52 b	0.77 c	0.64 b

<sup>1</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.



**Figure 2.** Projected fertilized acres of U.S. golf facilities in 2006, 2014, and 2021.



**Figure 3.** Application rates of N,  $P_2O_5$ , and  $K_2O$  on U.S. golf facilities by course feature in 2021.

64% since 2006 (Table 2).

- $K_2O$  application rates declined by 46% since 2006 (Table 2).
- The greatest N and  $P_2O_5$  application rates were used on greens followed by tees and practice areas (Figure 3).
- Approximately 1 lb. of  $K_2O$  was applied to each course feature except grounds where 2 lbs. were applied (Figure 3).
- Median tons of N,  $P_2O_5$ , and  $K_2O$  declined since 2006 to 3.5, 0.5, and 2.3 tons per facility, respectively (Table 15).
- Overseeding was associated with greater application rates of N,  $P_2O_5$ , and  $K_2O$  on each course feature except  $K_2O$  on greens (Figure 4).
- 18- and 27+-hole facilities applied greater than 50% more N per 1,000 ft<sup>2</sup> than 9-hole facilities (Table 26). Application rates of  $P_2O_5$  were similar among facilities regardless of facility size. 27+-hole facilities applied similar amounts of  $K_2O$  as 9- and 18-hole facilities.

## Nutrient Sources

- The percentage of facilities that used natural organic N sources declined since 2006 from 64% to 54% (Table 27).
- Within facilities that used natural organic N sources, the most common sources were animal waste (68%) followed by biosolids (39%), crop products (14%), and food waste (13%) (Table 28).
- Among facilities that used natural organic N, the use of biosolids and food waste declined, animal waste increased, and crop products remained unchanged from 2006 to 2021.
- The percentage of slow-release N applied reduced from 66% in 2006 to 62% in 2021 (Table 29).
- Inversely, the percentage of quick-release N increased from 31% in 2006 to 35% in 2021 (Table 29).
- The frequency of facilities that applied soil amendments increased for each soil amendment except limestone (Table 30).
- 84% of facilities applied at least one soil amendment with the most common amendments being humic materials (58%) followed by amino acids/proteins (52%) (Table 30).



## Nutrient Ratios

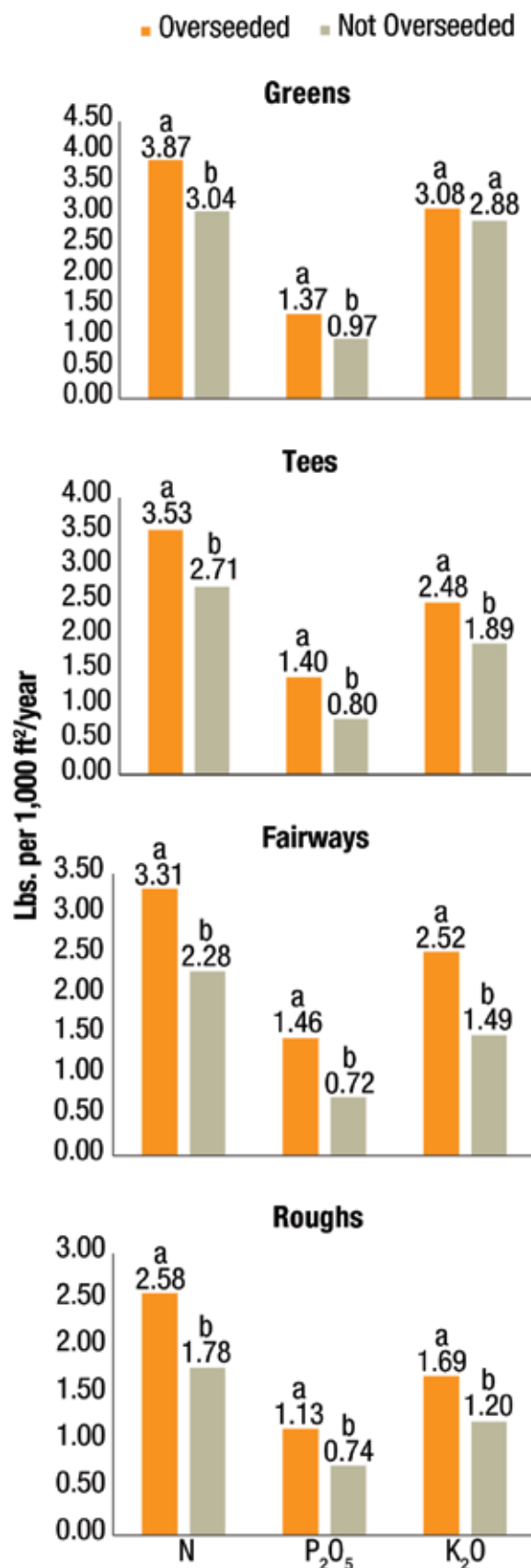
- The ratio of N to  $P_2O_5$  to  $K_2O$  increased to a 4.8 to 1 to 3.1 pooled across course features since 2006. The ratio was an increase since 2006 for total nutrients and nutrients applied to greens and tees (Table 19). The increase was likely a result of reduced amounts of applied  $P_2O_5$ .

## Nutrient Restrictions and Management Plans

- Facilities experiencing a nutrient restriction of any type increased to 18% since 2006 but declined since 2014 (Table 3).
- Yearly amount and/or amount of  $P_2O_5$  per application was the most common restriction (15%) (Table 3).
- Federal, state, tribal, or local nutrient restrictions were not associated with reduced application rates of N or  $K_2O$ , whereas restrictions were associated with a 72% reduction in  $P_2O_5$  applications, which were less than 0.1 lbs. per 1,000 ft<sup>2</sup> pooled across all course features (Figure 5).
- The percentage of facilities that used a written nutrient management plan in 2021 was 43%, equivalent to 2006 (Table 25).

## Soil Testing

- The percentage of facilities that soil tested greens declined since 2006 from 92% to 85% (Table 21).
- Fairways (61%) were the second most common feature soil tested followed by tees (57%) and practice areas (23%).
- Facilities that soil tested were associated with greater quantities of N applied to each course feature except natural areas (Figure 17). Facilities that soil tested applied approximately 25% more N than facilities that did not soil test when pooled across all course features.
- Facilities that soil tested were associated with greater quantities of  $P_2O_5$  applied to practices areas and roughs and were equivalent to facilities that did not soil test on all remaining course features (Figure 17).
- Facilities that soil tested were associated with greater quantities of  $K_2O$  applied to each course feature except natural areas (Figure 17). Facilities that soil tested applied approximately 34% more  $K_2O$  than facilities that

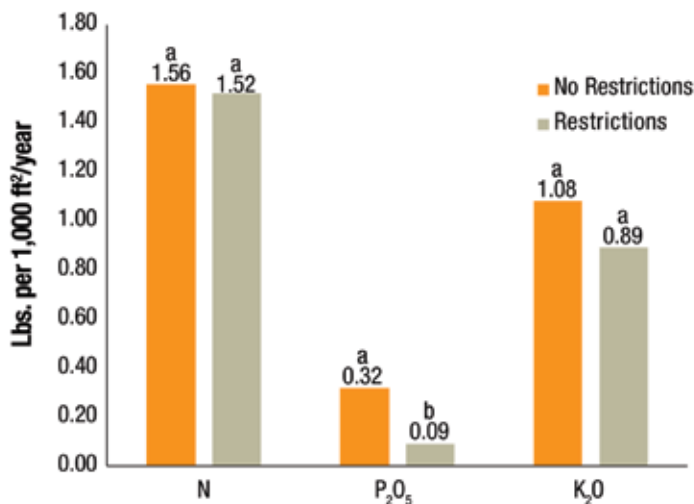


**Figure 4.** Application rates of N,  $P_2O_5$ , and  $K_2O$  on U.S. golf facilities by course feature associated with over-seeding in 2021. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

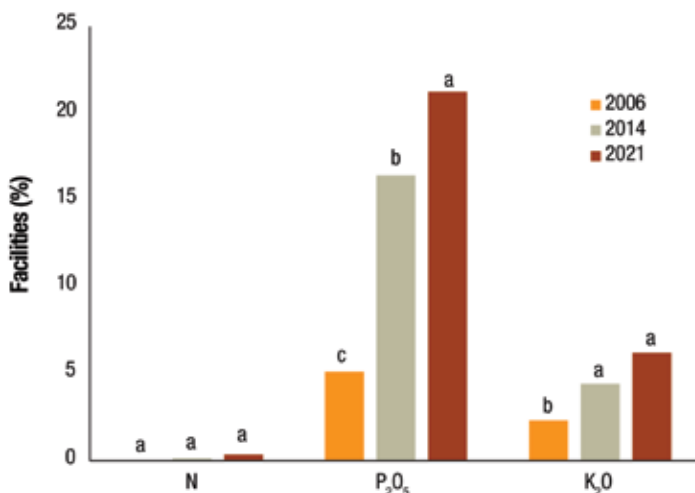
**Table 3.** Frequency of federal, state, local government, or tribal authority restrictions on nutrient applications on U.S. golf facilities in 2006, 2014, and 2021.

Restriction Type	2006	2014	2021
Nutrient Restriction of Any Type	7 c	23 a	18 b
Phosphate (total yearly amount or amount per application)	5 c	20 a	15 b
Date restrictions for applications	<1 b	7 a	7 a
Required buffer strips	2 b	8 a	7 a
Nitrogen (total yearly amount or amount per application)	2 b	5 a	4 a
Regional / state stormwater management plan	1 b	4 a	4 a
No-apply zones	1 c	6 a	3 b
Potash (total yearly amount or amount per application)	<1 ab	<1 b	2 a

<sup>i</sup>Within rows, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.



**Figure 5.** Application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on U.S. golf facilities associated with federal, state, tribal, or local nutrient restrictions in 2021. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.



**Figure 6.** Frequency of U.S. golf facilities that reported no applications of nitrogen (N), available phosphorus (P<sub>2</sub>O<sub>5</sub>), or soluble potash (K<sub>2</sub>O) in 2006, 2014, and 2021. Bars with a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.

did not soil test when pooled across all course features.

- The most common soil test extractant used for phosphorus and non-phosphorus nutrient analysis was saturated paste, which was generally more than twice as common as other extractants. (Table 22).
- The importance of using soil analysis for nutrient application decisions declined since 2006 and 2014 but remains one of the top seven most important factors (Table 23).
- The percentage of facilities that used soil test results with the intent of reducing reliance upon fertilizers declined since 2014 from 55% to 43% (Figure 16).
- Using soil test results to reduce reliance upon fertilizers was the only management practice that was associated with increased amounts of applied N (60%), P<sub>2</sub>O<sub>5</sub> (75%), and K<sub>2</sub>O (82%) (Table 24).

## Fertilizer Application and Storage

- The percentage of nutrient applications made with calibrated equipment declined on each course feature, yet remained at approximately of 50% of applications (Table 31).
- The median number of nutrient applications per year increased on each course feature except roughs (Table 32). Greens continue to account for 2-3 times as many applications as other course features (tees and fairways) and outnumber applications on roughs by more than 4-fold.
- The percentage of facilities that used a storage facility designed for nutrients increased from 51% in 2006 to 64% in 2021 (Table 33).

## COVID-19 Pandemic

- 76% of facilities reported that nutrient-use did not change as a result of the COVID-19 pandemic (Figure 18).
- Within the 15% and 9% of facilities that reported an increase and decrease, respectively, in applied nutrients resulting from the COVID-19 pandemic, 53% reported the cause was due to more rounds followed by 29% reporting the cause was related to budget (Figure 19).

## Regional Summary

Similar to the national trend, fewer nutrients were applied across the regions in conjunction with reduced fertilized acres. The median fertilized acres either remained unchanged or declined. Nutrient Use

- Total projected N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O declined within each agronomic region (Table 11). Nitrogen on the order of 30-40%, P<sub>2</sub>O<sub>5</sub> roughly 50-60% (SW being the exception) and K<sub>2</sub>O between 50-60%.
- The Southeast region used the greatest quantity and percentage of the total N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O applied in the U.S (Figure 7).

## Fertilized Acres

- Acres fertilized with N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O declined within each agronomic region (Table 12).
- Facilities that reported P<sub>2</sub>O<sub>5</sub> was applied has declined since 2006 on each course feature (Table 1 and Figure 6).
- Since 2006, median fertilized acres remained unchanged in the North Central, Northeast, and Upper West/Mountain regions (Table 13). Median fertilized acres declined in the Pacific, Southeast, Southwest, and Transition regions.

## Number of Facilities

- Operational golf facilities declined between 5% and 15% depending upon the region (Table 14).

## Application Rates

- Median N application rate declined in the North Central, Southeast, Southwest, Transition, and Upper West/Mountain regions since 2006 (Table 2). The median N application rate remained unchanged in the Northeast and Pacific regions since 2006 (Table 2).
- P<sub>2</sub>O<sub>5</sub> application rates declined within each region with the greatest reduction reported in the North Central (84%) (Table 2).
- K<sub>2</sub>O application rates declined within each agronomic region except the Pacific (Table 2).
- The greatest N and P<sub>2</sub>O<sub>5</sub> application rates were used on greens followed by tees and practice areas (Figure 3).

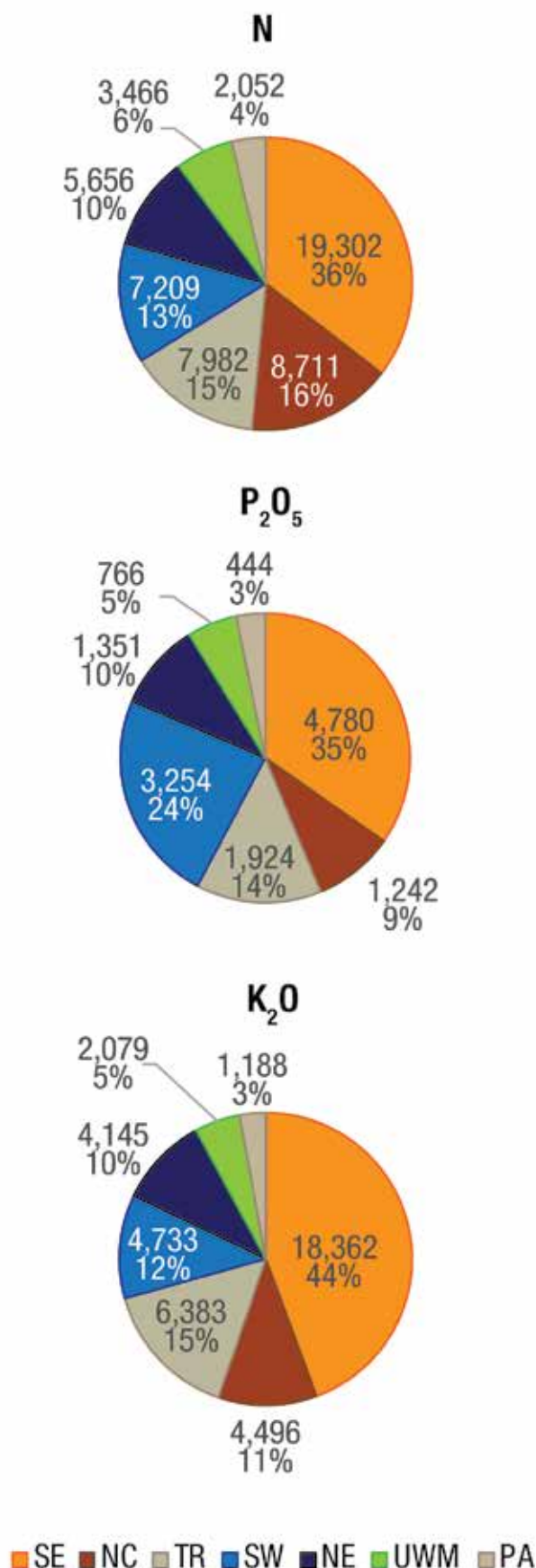


Figure 7. Projected tons and proportion of nutrient use on U.S. golf facilities by agronomic region in 2021.

- Approximately 1 lb. of  $P_2O_5$  per 1,000  $ft^2$  was applied to each course feature except grounds where 2 lbs. per 1,000  $ft^2$  were applied (Figure 3).
- Median tons of N applied per facility per year declined since 2006 in each region except the Northeast and Pacific regions where median tons were equivalent to that applied in 2006 (Table 15). The greatest magnitude reduction was reported in the Southwest where the 12.8 tons applied in 2006 was reduced to 2.1 tons in 2021.
- Median tons of  $P_2O_5$  declined in each region since 2006 with six regions applying 0.8 tons of  $P_2O_5$  or less in 2021 (Table 15).
- Median  $K_2O$  declined since 2006 within each region (Table 15). The greatest reduction in applied  $K_2O$  occurred in the Southwest region where facilities reported they applied 7.5 fewer tons of  $K_2O$  in 2021 than in 2006.

### Nutrient Management Plans

- The percentage of facilities within each region that used a written nutrient management plan remained unchanged since 2006 and ranged between 35% in the Northeast to 52% in the North Central (Table 25).

### Soil Testing

- The percentage of facilities that soil tested greens declined in the North Central, Northeast, and Transition regions, and remained unchanged in the remaining regions since 2006 (Table 21).
- Within regions, the percentage of facilities that soil tested greens ranged from 74% in the North Central to 98% in the Southeast (Table 21).
- Within each region, fairways were the second most common feature soil tested followed by tees and practice areas (Table 21).
- In general, within each region the most common soil test extractant used for phosphorus and non-phosphorus nutrient analysis was saturated paste followed by Mehlich-3 and Bray (Table 22).

### North Central Nutrient Use

- N,  $P_2O_5$ , and  $K_2O$  use in the North Central region declined by 42%, 73%, and 62%, respectively, since 2006 (Table 4, Table 11).
- The application rates (per 1,000  $ft^2$ ) of N,  $P_2O_5$ , and  $K_2O$  were 23%, 84%, and 55% less than that of 2006 (Table 4, Figure 8).
- Since 2006, N rates were reduced on each course feature (Table 16).
- Since 2006,  $P_2O_5$  rate reductions were reported on greens, tees, fairways, and grounds but did not change on roughs, practice areas, or natural areas (Table 17).
- Since 2006,  $K_2O$  rate reductions were reported on each course feature except natural areas (Table 18).
- Median tons of N,  $P_2O_5$ , and  $K_2O$  applied per facility in the North Central region declined by 31%, 85%, and 59% since 2006 (Table 15).
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 52% (Table 25).
- The percentage of facilities that used natural organic N sources declined since 2006 from 56% to 47% (Table 27).
- The percentage of facilities that used slow-release N sources declined since 2006 from 70% to 66% (Table 29).

### Nutrient Storage and Application

- The percentage of nutrient applications made with calibrated equipment declined on each course feature since 2006 (Table 31).
- The number of nutrient applications made per year increased on each course feature except roughs (Table 32).
- The percentage of facilities that used storage suitable for fertilizer increased since 2006 from 43 to 58% (Table 33).

### Fertilized Acres

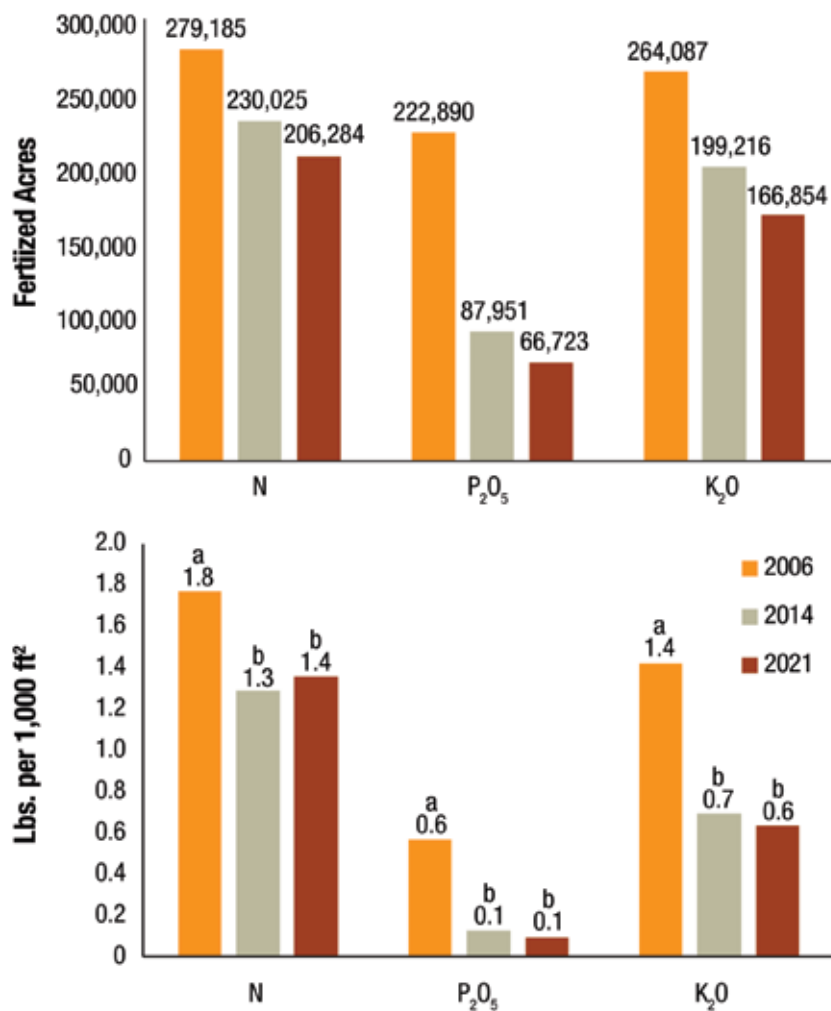
- The number of acres fertilized with N,  $P_2O_5$ , or  $K_2O$  were 26%, 70%, and 37% less than those reported in 2006 (Table 4, Figure 8).
- Median fertilized acres in the North Central were equivalent to those reported in 2006 (Table 13). Median fertilized acres of roughs, greens, and tees were also equivalent to 2006. However, median fertilized acres of fairways, practice areas, and grounds declined since 2006. Median fertilized acres of natural areas increased 2-fold since 2006.

### Overseed

- The percentage of facilities that overseeded greens, tees, and fairways increased since 2014 (Table 20). Concomitantly, the percentage of facilities that did not overseed any course feature declined from 89% to 79%.

**Table 4.** Projected nutrient use, fertilized area, and nutrient application rate in the North Central region and U.S. in 2006, 2014, and 2021.

Year	U.S.	NC	U.S.	NC	U.S.	NC
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft²)	
	N					
2006	92,185	15,047	1,179,055	279,185	2.30	1.77
2014	61,215	10,612	986,063	230,025	1.68	1.29
2021	54,376	8,711	889,378	206,284	1.58	1.36
Δ '06 to '21 (%)	-41	-42	-25	-26	-31	-23
	P <sub>2</sub> O <sub>5</sub>					
2006	33,626	4,657	1,004,391	222,890	0.76	0.57
2014	15,759	1,421	540,581	87,951	0.25	0.13
2021	13,761	1,242	472,923	66,723	0.27	0.09
Δ'06 to '21 (%)	-59	-73	-53	-70	-64	-83
	K <sub>2</sub> O					
2006	89,124	11,960	1,126,967	264,087	1.95	1.42
2014	51,705	7,142	874,534	199,216	1.16	0.70
2021	41,386	4,496	767,883	166,854	1.06	0.64
Δ'06 to '21 (%)	-54	-62	-32	-37	-46	-55



**Figure 8.** Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the North Central region in 2006, 2014, and 2021.

### Soil Testing

- The percentage of facilities that soil tested putting greens declined since 2006 to 74% (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (45%) followed by Bray (23%) and Mehlich-3 (18%) (Table 22).

### Operational Facilities

- The number of operational facilities in the North Central region declined by 568 facilities or 14% since 2006 (Table 14).
- Changes in operational facilities resulted in reduced use of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O (Table 14).

### Northeast Nutrient Use

- N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O use in the Northeast region declined by 38%, 61%, and 49%, respectively, since 2006 (Table 5, Table 11).
- The application rates of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O were 44% and 32% less than that of 2006, but the application rate of N did not change since 2006 (Table 5, Figure 9).
- Since 2006, the total N rate did not change, but N rates were reduced on each course feature except nature areas (Table 16).
- Since 2006, P<sub>2</sub>O<sub>5</sub> rate reductions were reported on greens, tees, fairways, and grounds; did not change on roughs and practice areas; and increased on natural areas (Table 17).
- Since 2006, K<sub>2</sub>O rate reductions were reported on each course feature except natural areas (Table 18).
- Median tons of N applied per facility in the Northeast region was equivalent to those applied in 2006 (Table 15). Median tons of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O applied per facility declined by 45% and 31% since 2006.
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 35% (Table 25).
- The percentage of facilities that used natural organic N sources declined since 2006 from 75% to 56% (Table 27).
- The percentage of facilities that used slow-release N sources declined since 2006 from 69% to 63% (Table 29).

### Nutrient Storage and Application

- The percentage of nutrient applications made with calibrated equipment declined on greens and fairways and remained unchanged on tees and roughs since 2006 (Table 31).
- The number of nutrient applications made per year increased on each course feature except roughs (Table 32).
- The percentage of facilities that used storage suitable for fertilizer increased since 2006 from 49% to 65% (Table 33).

### Fertilized Acres

- The number of acres fertilized with N,



**Table 5.** Projected nutrient use, fertilized area, and nutrient application rate in the Northeast region and U.S. in 2006, 2014, and 2021.

Year	U.S.	NE	U.S.	NE	U.S.	NE
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft²)	
	N					
2006	92,185	9,139	1,179,055	161,846	2.30	1.89
2014	61,215	6,560	986,063	134,774	1.68	1.58
2021	54,376	5,656	889,378	125,551	1.58	1.54
Δ '06 to '21 (%)	-41	-38	-25	-22	-31	-19
	P <sub>2</sub> O <sub>5</sub>					
2006	33,626	3,483	1,004,391	143,916	0.76	0.69
2014	15,759	1,152	540,581	57,360	0.25	0.20
2021	13,761	1,351	472,923	50,298	0.27	0.38
Δ'06 to '21 (%)	-59	-61	-53	-65	-64	-44
	K <sub>2</sub> O					
2006	89,124	8,090	1,126,967	157,981	1.95	1.58
2014	51,705	4,719	874,534	121,645	1.16	1.07
2021	41,386	4,145	767,883	110,601	1.06	1.08
Δ'06 to '21 (%)	-54	-49	-32	-30	-46	-32

P<sub>2</sub>O<sub>5</sub>, or K<sub>2</sub>O were 22%, 65%, and 30% less than those reported in 2006 (Table 5, Figure 9).

- Median fertilized acres in the Northeast were equivalent to those reported in 2006 and were the third lowest of all regions at 90.1 acres (Table 13). Median fertilized acres of roughs, fairways, and natural areas were also equivalent to 2006. However, median fertilized acres of practice areas and grounds declined since 2006. Median fertilized acres of greens and tees increased since 2006.

### Overseed

- The percentage of facilities that stopped overseeding increased to 2% (Table 20). The percentage of facilities that overseeded each course feature was equivalent to those reported in 2014. The percentage of facilities that did not overseed any course feature increased from 71% to 79%.

### Soil Testing

- The percentage of facilities that soil tested declined since 2006 for each course feature except for roughs, grounds, and natural areas (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (51%) followed by Mehlich-3 (27%) and Bray (13%) (Table 22).

### Operational Facilities

- The number of operational facilities in the Northeast region declined by 269 facilities or 10% since 2006 (Table 14).
- Changes in operational facilities resulted in reduced use of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O (Table 14).

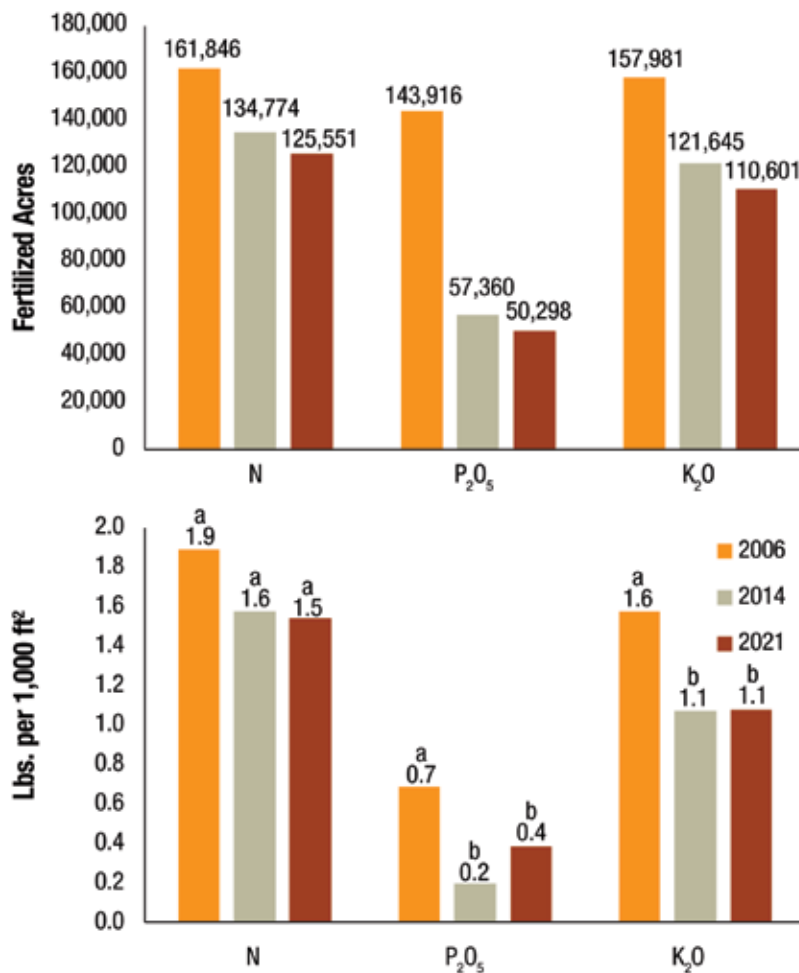


Figure 9. Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the Northeast region in 2006, 2014, and 2021.

## Pacific Nutrient Use

- N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O use in the Pacific region declined by 34%, 61%, and 56%, respectively, since 2006 (Table 6, Table 11).
- The application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O did not change since 2006 (Table 6, Figure 10).
- Although the overall N rate did not change since 2006, N rates were reduced on greens, fairways, and roughs (Table 16).
- Although the overall P<sub>2</sub>O<sub>5</sub> rate did not change since 2006, P<sub>2</sub>O<sub>5</sub> rates were reduced on greens and natural areas (Table 17).
- Although the overall K<sub>2</sub>O rate did not change since 2006, K<sub>2</sub>O rates were reduced on greens, tees, fairways, roughs, practice areas, and grounds (Table 18).
- Median tons of N applied per facility did not change since 2006, but median tons of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O applied per facility declined by 67% and 63% since 2006 (Table 15).
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 38% (Table 25).
- The percentage of facilities that used natural organic N sources remained unchanged since 2006 at 56% (Table 27).
- The percentage of facilities that used slow-release N sources remained unchanged since 2006 at 54% (Table 29).

## Nutrient Storage and Application

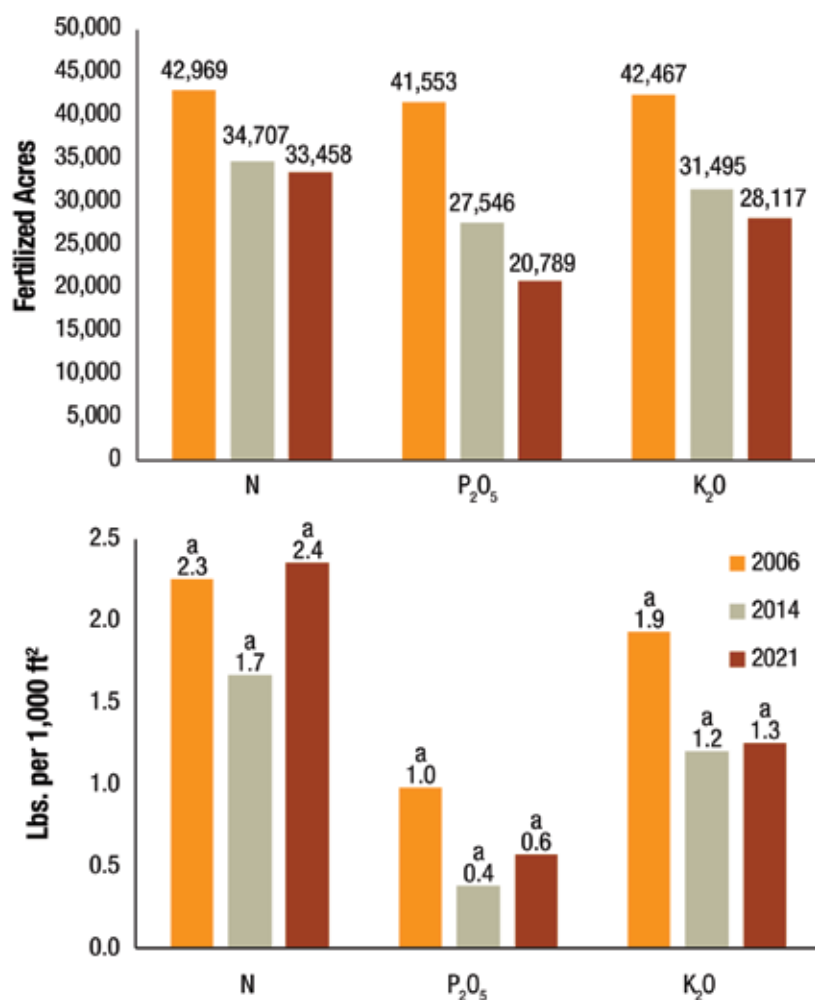
- The percentage of nutrient applications made with calibrated equipment remained unchanged on each course feature since 2006 (Table 31).
- The number of nutrient applications made per year increased from 16.1 to 22.2 since 2006 on greens but remained unchanged on other course features (Table 32).
- The percentage of facilities that used storage suitable for fertilizer increased since 2006 from 62% to 81% (Table 33).

## Fertilized Acres

- The number of acres fertilized with N,

**Table 6.** Projected nutrient use, fertilized area, and nutrient application rate in the Pacific region and U.S. in 2006, 2014, and 2021.

Year	U.S.	Pacific	U.S.	Pacific	U.S.	Pacific
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft²)	
	N					
2006	92,185	3,110	1,179,055	42,969	2.30	2.26
2014	61,215	2,124	986,063	34,707	1.68	1.67
2021	54,376	2,052	889,378	33,458	1.58	2.35
Δ '06 to '21 (%)	-41	-34	-25	-22	-31	4
	P <sub>2</sub> O <sub>5</sub>					
2006	33,626	1,123	1,004,391	41,553	0.76	0.98
2014	15,759	966	540,581	27,546	0.25	0.38
2021	13,761	444	472,923	20,789	0.27	0.58
Δ'06 to '21 (%)	-59	-61	-53	-50	-64	-41
	K <sub>2</sub> O					
2006	89,124	2,697	1,126,967	42,467	1.95	1.93
2014	51,705	1,949	874,534	31,495	1.16	1.21
2021	41,386	1,188	767,883	28,117	1.06	1.26
Δ '06 to '21 (%)	-54	-56	-32	-34	-46	-35



**Figure 10.** Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the Pacific region in 2006, 2014, and 2021.

$P_2O_5$ , or  $K_2O$  were 22%, 50%, and 34% less than those reported in 2006 (Table 6, Figure 10).

- Median fertilized acres in the Pacific declined since 2006 from 123.7 to 79.2, which was the lowest among all regions (Table 13). However, median fertilized acres of the individual course features did not change since 2006 (Table 13).

### Overseed

- The percentage of facilities that stopped overseeding was 8% and equivalent to 2014 (Table 20). The percentage of facilities that overseeded greens declined from 16% to 4%, whereas the percentage of facilities that overseeded roughs increased from 4% to 11% since 2014. The percentage of facilities that did not overseed any course feature remained equivalent to 2014 at 62%.

### Soil Testing

- The percentage of facilities that soil tested remained unchanged since 2006 for each course feature except roughs and grounds, both of which declined (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (44%) followed by Bray (21%) and Mehlich-3 (19%) (Table 22).

### Operational Facilities

- The number of operational facilities in the Pacific region declined by 64 facilities or 10% since 2006 (Table 14).
- Changes in operational facilities resulted in reduced use of N,  $P_2O_5$ , and  $K_2O$  (Table 14).

## Southeast Nutrient Use

- N,  $P_2O_5$ , and  $K_2O$  use in the Southeast region declined by 41%, 57%, and 51%, respectively, since 2006 (Table 7, Table 11).
- The application rates of N,  $P_2O_5$ , and  $K_2O$  were 37%, 50%, and 42% less than that of 2006 (Table 7, Figure 11).
- Since 2006, N rates were reduced on each course feature except natural areas (Table 16).
- Since 2006,  $P_2O_5$  rate reductions were reported on each course feature except practice areas and natural areas (Table 17).
- Since 2006,  $K_2O$  rate reductions were reported on each course feature except natural areas (Table 18).
- Median tons of N,  $P_2O_5$ , and  $K_2O$  applied per facility in the Southeast region declined by 46%, 64%, and 52% since 2006 (Table 15).
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 41% (Table 25).
- The percentage of facilities that used natural organic N sources remained unchanged since 2006 at 62% (Table 27).
- The percentage of facilities that used slow-release N sources declined since 2006 from 65% to 60% (Table 29).

## Nutrient Storage and Application

- The percentage of nutrient applications made with calibrated equipment declined from 72% to 55% on fairways since 2006 but remained unchanged on remaining course features (Table 31).
- The number of nutrient applications made per year increased on each course feature except roughs (Table 32).
- The percentage of facilities that used storage suitable for fertilizer increased since 2006 from 59% to 72% (Table 33).

### Fertilized Acres

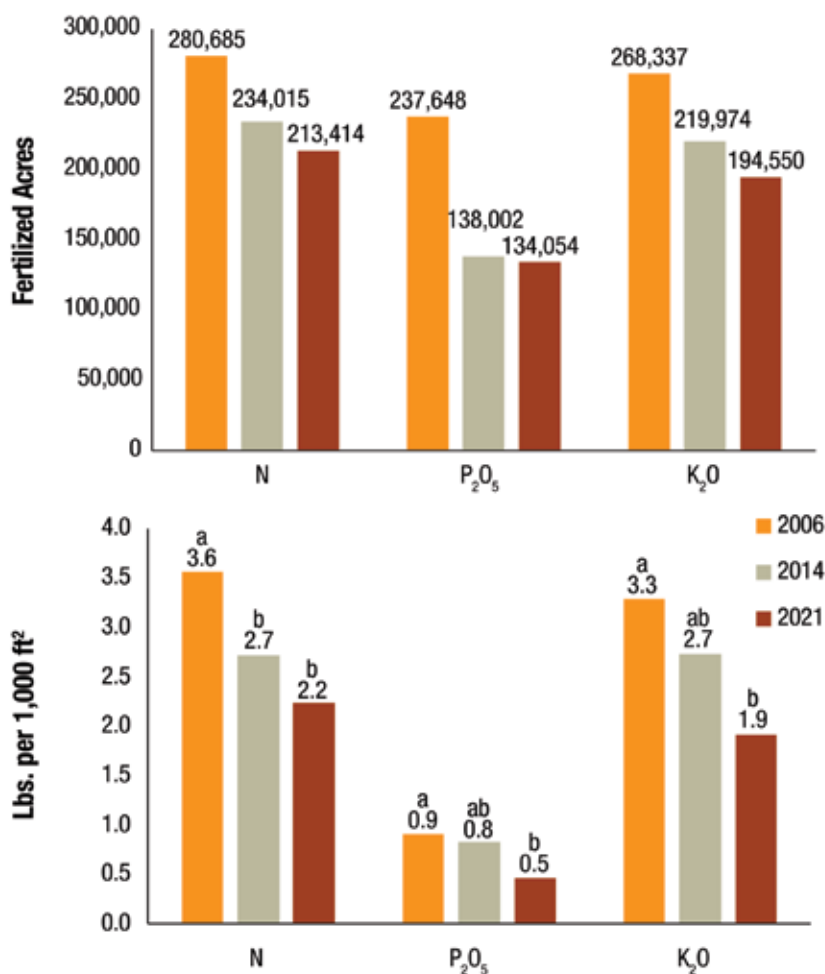
- The number of acres fertilized with N,  $P_2O_5$ , or  $K_2O$  were 24%, 44%, and 27% less than those reported in 2006 (Table 7, Figure 11).
- Median fertilized acres in the Southeast declined since 2006 from 130.8 to 107.7 acres (Table 13). Median fertilized acres of fairways and grounds also declined since 2006, but all remaining course features did not change.

### Overseed

- The percentage of facilities that stopped overseeding increased since 2014 from 20% to 30% (Table 20). The percentage of facilities that overseeded greens, tees, and fairways

**Table 7.** Projected nutrient use, fertilized area, and nutrient application rate in the Southeast region and U.S. in 2006, 2014, and 2021.

Year	U.S.	SE	U.S.	SE	U.S.	SE
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft²)	
	N					
2006	92,185	32,532	1,179,055	280,685	2.30	3.56
2014	61,215	18,894	986,063	234,015	1.68	2.71
2021	54,376	19,302	889,378	213,414	1.58	2.24
Δ '06 to '21 (%)	-41	-41	-25	-24	-31	-37
	P <sub>2</sub> O <sub>5</sub>					
2006	33,626	11,114	1,004,391	237,648	0.76	0.91
2014	15,759	5,144	540,581	138,002	0.25	0.83
2021	13,761	4,780	472,923	134,054	0.27	0.46
Δ'06 to '21 (%)	-59	-57	-53	-44	-64	-50
	K <sub>2</sub> O					
2006	89,124	37,246	1,126,967	268,337	1.95	3.29
2014	51,705	20,478	874,534	219,974	1.16	2.73
2021	41,386	18,362	767,883	194,550	1.06	1.91
Δ'06 to '21 (%)	-54	-51	-32	-27	-46	-42



**Figure 11.** Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the Southeast region in 2006, 2014, and 2021.

declined since 2014, and the percentage of facilities that did not overseed any course feature increased from 37% to 63%.

### Soil Testing

- The percentage of facilities that soil tested putting greens, tees, and fairways remained unchanged since 2006 but declined for practice areas, roughs, and natural areas (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (41%) followed by Mehlich-3 (25%) and Mehlich-1 (22%) (Table 22).

### Operational Facilities

- The number of operational facilities in the Southeast region declined by 479 facilities or 15% since 2006 (Table 14).
- Changes in operational facilities resulted in reduced use of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O (Table 14).

## Southwest Nutrient Use

- N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O use in the Southwest region declined by 46%, 40%, and 61%, respectively, since 2006 (Table 8, Table 11).
- The application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O were 71%, 58%, and 52% less than that of 2006 (Table 8, Figure 12).
- Since 2006, N rates were reduced on greens, tees, and practice areas and remained unchanged on other course features (Table 16).
- Although the total rate of P<sub>2</sub>O<sub>5</sub> declined since 2006, rate reductions were not reported on any individual course feature (Table 17).
- Since 2006, K<sub>2</sub>O rate reductions were reported on greens, tees, and practice areas and remained unchanged on other course features (Table 18).
- Median tons of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O applied per facility in the Southwest region declined by 84%, 71%, and 71% since 2006 (Table 15). The reduction in tons of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O were the greatest among all regions.
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 46% (Table 25).
- The percentage of facilities that used natural organic N sources declined since 2006 from 56% to 36% (Table 27).
- The percentage of facilities that used slow-release N sources declined since 2006 from 57% to 48% (Table 29).

## Nutrient Storage and Application

- The percentage of nutrient applications made with calibrated equipment declined since 2006 on tees and fairways and remained unchanged on greens and roughs (Table 31).
- The number of nutrient applications made per year increased on each course feature except roughs (Table 32).
- The percentage of facilities that used storage suitable for fertilizer declined since 2006 to 48% (Table 33).

## Fertilized Acres

- The number of acres fertilized with N, P<sub>2</sub>O<sub>5</sub>, or K<sub>2</sub>O were 32%, 36%, and 40% less than those reported in 2006 (Table 8, Figure 12).

**Table 8.** Projected nutrient use, fertilized area, and nutrient application rate in the Southwest region and U.S. in 2006, 2014, and 2021.

Year	U.S.	SW	U.S.	SW	U.S.	SW
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft²)	
	N					
2006	92,185	13,247	1,179,055	118,683	2.30	3.79
2014	61,215	8,986	986,063	93,383	1.68	2.48
2021	54,376	7,209	889,378	80,850	1.58	1.10
Δ '06 to '21 (%)	-41	-46	-25	-32	-31	-71
	P <sub>2</sub> O <sub>5</sub>					
2006	33,626	5,408	1,004,391	99,658	0.76	2.13
2014	15,759	3,053	540,581	75,983	0.25	0.55
2021	13,761	3,254	472,923	63,323	0.27	0.90
Δ '06 to '21 (%)	-59	-40	-53	-36	-64	-58
	K <sub>2</sub> O					
2006	89,124	12,127	1,126,967	113,167	1.95	3.19
2014	51,705	6,397	874,534	81,642	1.16	1.17
2021	41,386	4,733	767,883	67,637	1.06	1.52
Δ '06 to '21 (%)	-54	-61	-32	-40	-46	-52

- Median fertilized acres in the Southwest declined since 2006 from 148.4 to 89.6 acres (Table 13). Median fertilized acres of roughs, fairways, natural areas, and practice areas were equivalent to 2006. Median fertilized acres of grounds declined since 2006, and median fertilized acres of greens and tees increased since 2006.

## Overseed

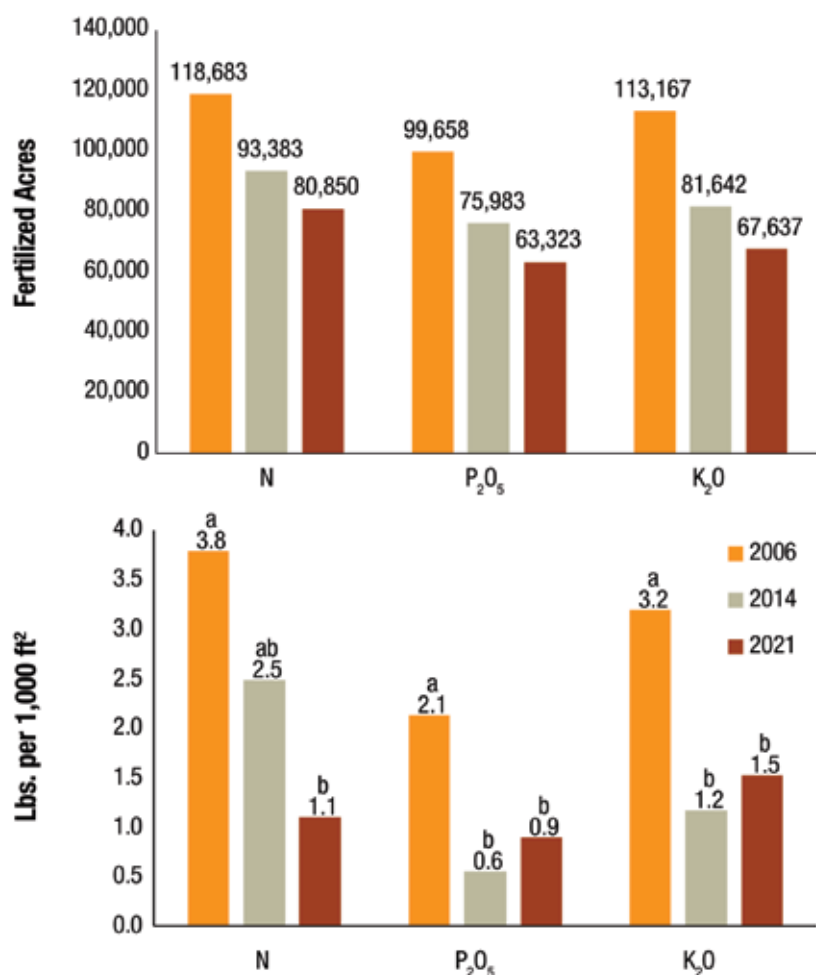
- The percentage of facilities that stopped overseeding was equivalent to those in 2014 (Table 20). The percentage of facilities that overseeded each course feature remained unchanged since 2014 except on roughs where the percentage declined from 30% to 17%. The percentage of facilities that did not overseed any course feature has remained unchanged 2014 at 40%.

## Soil Testing

- The percentage of facilities that soil tested remained unchanged since 2006 for each course feature except roughs, which decreased from 31% to 14% (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (60%), mentioned more so in the Southwest than any other region, followed by Bray (18%) and Mehlich-3 (12%) (Table 22).

## Operational Facilities

- The number of operational facilities in the Southwest region declined by 83 facilities or 7% since 2006 (Table 14).
- Changes in operational facilities resulted in reduced use of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O (Table 14).



**Figure 12.** Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the Southwest region in 2006, 2014, and 2021.



## Transition Nutrient Use

- N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O use in the Transition region declined by 41%, 67%, and 50%, respectively, since 2006 (Table 9, Table 11).
- The application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O were 34%, 71%, and 59% less than that of 2006 (Table 9, Figure 13).
- Since 2006, N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O rates were reduced on each course feature except natural areas (Table 16, Table 17, Table 18).
- Median tons of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O applied per facility in the Transition region declined by 43%, 72%, and 66% since 2006 (Table 15).
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 43% (Table 25).
- The percentage of facilities that used natural organic N sources declined since 2006 from 65% to 55% (Table 27).
- The percentage of facilities that used slow-release N sources remained unchanged since 2006 at 61% (Table 29).

## Nutrient Storage and Application

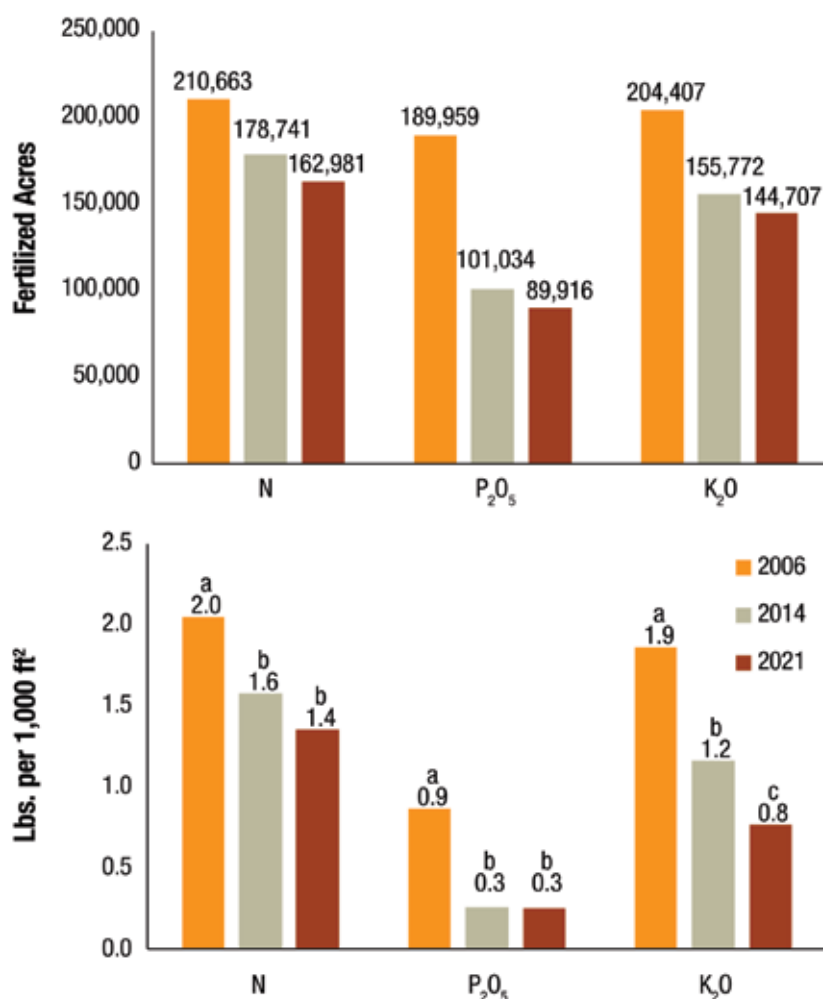
- The percentage of nutrient applications made with calibrated equipment remained unchanged on each course feature since 2006 (Table 31).
- The number of nutrient applications made per year increased since 2006 on greens and remained unchanged on other course features (Table 32).
- The percentage of facilities that used storage suitable for fertilizer increased since 2006 from 49% to 64% (Table 33).

## Fertilized Acres

- The number of acres fertilized with N, P<sub>2</sub>O<sub>5</sub>, or K<sub>2</sub>O were 23%, 53%, and 29% less than those reported in 2006 (Table 9, Figure 13).
- Median fertilized acres in the Transition region declined since 2006 from 119.9 to 103.5 acres (Table 13). Median fertilized acres of roughs, fairways, and greens were also equivalent to 2006. However, median fertilized acres of practice areas and grounds declined since 2006. Median

**Table 9.** Projected nutrient use, fertilized area, and nutrient application rate in the Transition region and U.S. in 2006, 2014, and 2021.

Year	U.S.	Trans	U.S.	Trans	U.S.	Trans
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft <sup>2</sup> )	
<b>N</b>						
2006	92,185	13,600	1,179,055	210,663	2.30	2.05
2014	61,215	9,688	986,063	178,741	1.68	1.57
2021	54,376	7,982	889,378	162,981	1.58	1.35
Δ '06 to '21 (%)	-41	-41	-25	-23	-31	-34
<b>P<sub>2</sub>O<sub>5</sub></b>						
2006	33,626	5,876	1,004,391	189,959	0.76	0.87
2014	15,759	3,064	540,581	101,034	0.25	0.26
2021	13,761	1,924	472,923	89,916	0.27	0.25
Δ '06 to '21 (%)	-59	-67	-53	-53	-64	-71
<b>K<sub>2</sub>O</b>						
2006	89,124	12,670	1,126,967	204,407	1.95	1.86
2014	51,705	8,354	874,534	155,772	1.16	1.16
2021	41,386	6,383	767,883	144,707	1.06	0.77
Δ '06 to '21 (%)	-54	-50	-32	-29	-46	-59



**Figure 13.** Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the Transition region in 2006, 2014, and 2021.

fertilized acres of natural areas and tees increased since 2006.

### Overseed

- The percentage of facilities that overseeded fairways increased since 2014 from 8% to 18% (Table 20). The percentage of facilities that stopped overseeding or did not overseed any course feature remained unchanged since 2014 at 10% and 64%, respectively.

### Soil Testing

- The percentage of facilities that soil tested declined since 2006 for each course feature except for roughs and grounds (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (48%) followed by Mehlich-3 (33%), mentioned more in the Transition region than any other region, and Mehlich-1 (11%) (Table 22).

### Operational Facilities

- The number of operational facilities in the Transition region declined by 442 facilities or 15% since 2006 (Table 14).
- Changes in operational facilities resulted in reduced use of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O (Table 14).

## Upper West/Mountain Nutrient Use

- N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O use in the Upper West/Mountain region declined by 37%, 61%, and 52%, respectively, since 2006 (Table 10, Table 11).
- The application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O were 42%, 71%, and 64% less than that of 2006 (Table 10, Figure 14).
- Since 2006, N rates were reduced on each course feature except roughs, natural areas, and grounds (Table 16).
- Since 2006, P<sub>2</sub>O<sub>5</sub> rate reductions were reported on each course feature except natural areas and grounds (Table 17).
- Since 2006, K<sub>2</sub>O rate reductions were reported on each course feature except natural areas (Table 18).
- Median tons of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O applied per facility in the Upper West/Mountain region declined by 39%, 67%, and 62% since 2006 (Table 15).
- The percentage of facilities that used a written nutrient management plan remained unchanged since 2006 at 36% (Table 25).
- The percentage of facilities that used natural organic N sources remained unchanged since 2006 at 62% (Table 27).
- The percentage of facilities that used slow-release N sources remained unchanged since 2006 at 68% (Table 29).

## Nutrient Storage and Application

- The percentage of nutrient applications made with calibrated equipment declined on each course feature since 2006 except roughs (Table 31).
- The number of nutrient applications made per year increased on each course feature except roughs (Table 32).
- The percentage of facilities that used storage suitable for fertilizer increased since 2006 from 41% to 66% (Table 33).

### Fertilized Acres

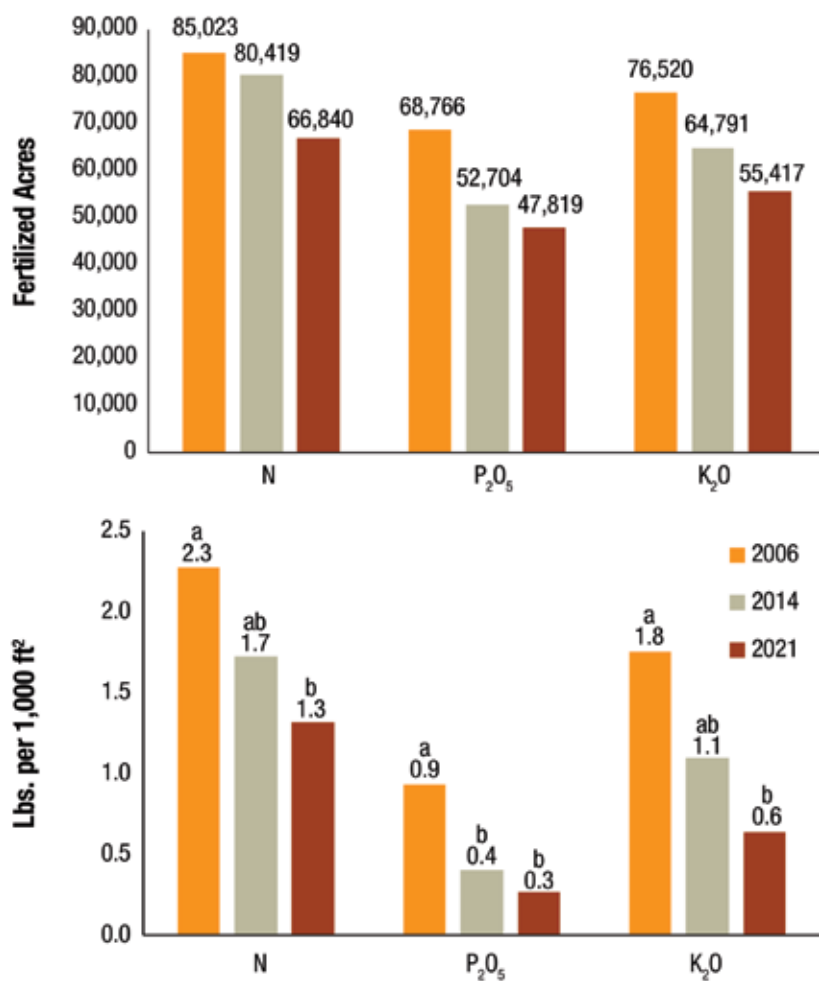
- The number of acres fertilized with N, P<sub>2</sub>O<sub>5</sub>, or K<sub>2</sub>O were 21%, 30%, and 28% less than those reported in 2006 (Table 10, Figure 14).
- Median fertilized acres in the Upper West/Mountain were equivalent to those reported in 2006 at 115.1 (Table 13). Median fertilized acres of roughs, fairways, natural areas, and tees were also equivalent to 2006. However, median fertilized acres of practice areas and grounds declined since 2006. Median fertilized acres of greens increased since 2006.

### Overseed

- The percentage of facilities that overseeded greens and tees decreased since 2014 (Table 20). The percentage of facilities that did not overseed any

**Table 10.** Projected nutrient use, fertilized area, and nutrient application rate in the Upper West/Mountain region and U.S. in 2006, 2014, and 2021.

Year	U.S.	UWM	U.S.	UWM	U.S.	UWM
	Projected Use (tons)		Projected Area (acres)		Nutrient Applied (lbs. per 1,000 ft²)	
	N					
2006	92,185	5,510	1,179,055	85,023	2.30	2.28
2014	61,215	4,350	986,063	80,419	1.68	1.73
2021	54,376	3,466	889,378	66,840	1.58	1.32
Δ '06 to '21 (%)	-41	-37	-25	-21	-31	-42
	P <sub>2</sub> O <sub>5</sub>					
2006	33,626	1,965	1,004,391	68,766	0.76	0.93
2014	15,759	960	540,581	52,704	0.25	0.40
2021	13,761	766	472,923	47,819	0.27	0.27
Δ '06 to '21 (%)	-59	-61	-53	-30	-64	-71
	K <sub>2</sub> O					
2006	89,124	4,334	1,126,967	76,520	1.95	1.76
2014	51,705	2,666	874,534	64,791	1.16	1.10
2021	41,386	2,079	767,883	55,417	1.06	0.64
Δ '06 to '21 (%)	-54	-52	-32	-28	-46	-64



**Figure 14.** Fertilized acres and application rates of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O on golf facilities in the Upper West/Mountain region in 2006, 2014, and 2021.

course feature increased from 80% to 88%.

### Soil Testing

- The percentage of facilities that soil tested remained unchanged since 2006 on each course feature except for practice areas and roughs, both of which increased (Table 21).
- The most common soil test extractant used for phosphorus analysis was saturated paste (51%) followed by Bray (21%) and Mehlich-3 (15%) (Table 22).

2006 (Table 14).

- Changes in operational facilities resulted in reduced use of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O (Table 14).

### Operational Facilities

- The number of operational facilities in the Upper West/Mountain region declined by 52 facilities or 5% since

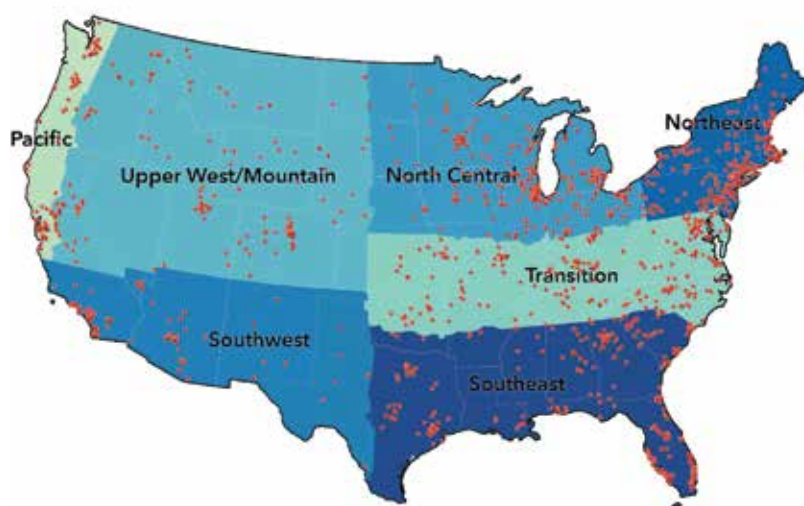


Figure 15. Distribution of 2022 survey and the seven agronomic regions.

## Conclusions and Recommendations

The reduction of applied N,  $P_2O_5$ , and  $K_2O$  since 2006 is likely a result of reduced application rates and fertilized acres. It appears the reduction in fertilized acres occurred as a result of both facility closures and acre reductions at operational facilities.

Perhaps the most significant nutrient reduction occurred with applied  $P_2O_5$ . This reduction appears to be at least partially a result of mandated phosphorous restrictions, which was the most common restriction reported by facilities (15%) (Table 3). Because phosphorus is an element of potential environmental impairment, superintendents are encouraged to opt out of  $P_2O_5$  application and reintroduce  $P_2O_5$  only after a soil test or turfgrass response validates it is needed. Whether voluntary or mandated, this recommendation appears to be followed by more facilities year-over-year evidenced by the finding that more facilities did not apply any  $P_2O_5$  in 2021 than in both 2014 and 2006 (Table 3).

A beneficial turfgrass response to applied potassium is rare when soil potassium is sufficient and a turfgrass response to applied potassium is far less common than responses to applied N. Thus, the use of potassium should be much lower than that of N if maximizing efficient nutrient management is a goal. However, the quantity and appli-

cation rate of  $K_2O$  was only slightly less than that of N nationally and the application rate of  $K_2O$  actually exceeded that of N in the Southwest region (Table 2). This is of little environmental concern because potassium is not known to be an element of impairment. However, excessive  $K_2O$  applications have been shown to increase the risk of certain diseases, especially on cool-season grasses, and is a source of economic loss if no return is expected. Thus, it is recommended that facilities re-evaluate the benefit of applied  $K_2O$  at their location by either contacting their local land-grant university turfgrass specialist and/or conducting their own onsite  $K_2O$  evaluation.

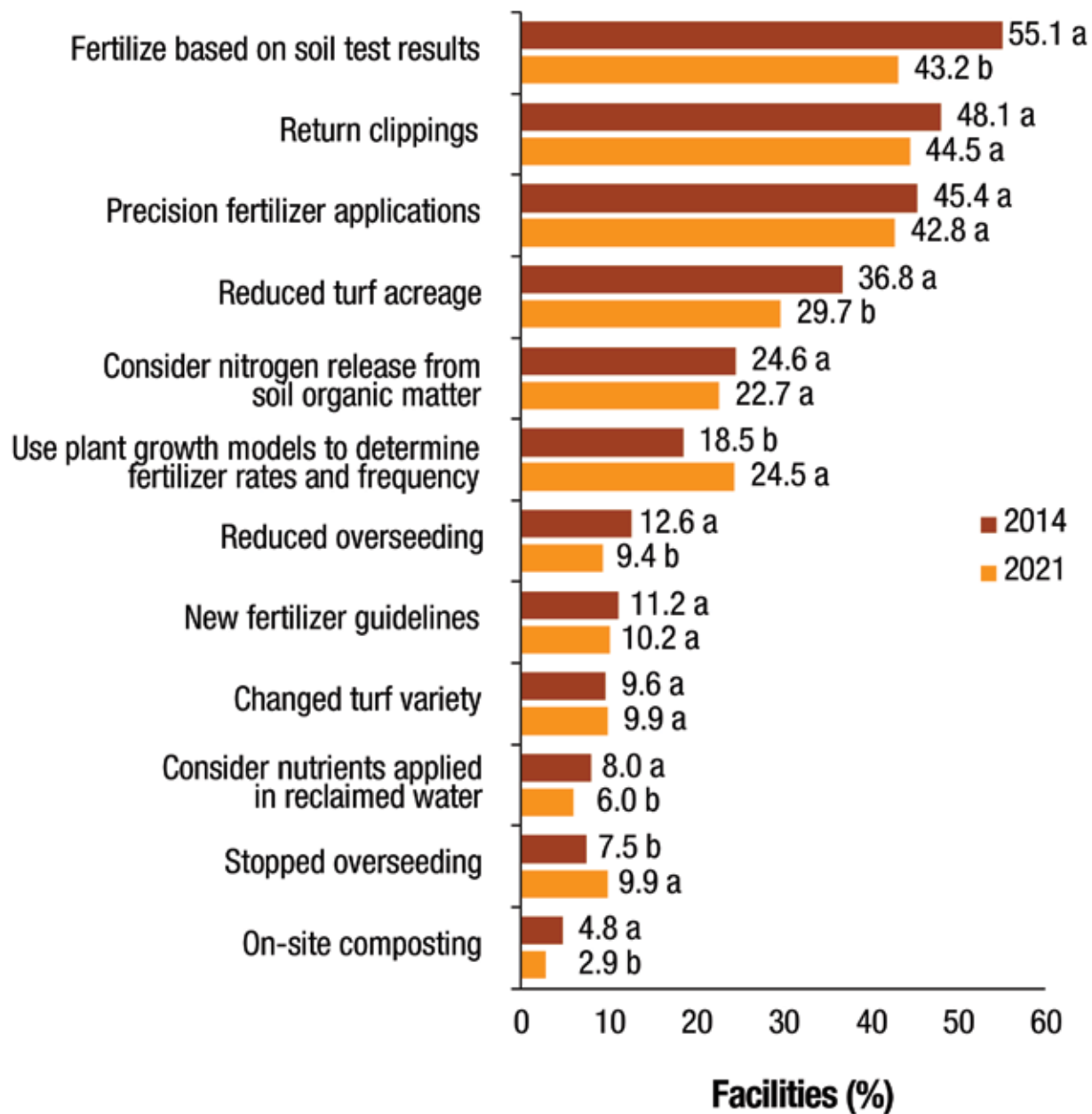
Soil testing should result in a more efficient use of applied nutrients and remains a common nutrient management tool. It is an important factor when making nutrient application decisions. However, soil testing was the only management practice associated with increases in applied N,  $P_2O_5$ , and  $K_2O$  (Table 24, Figure 17). This association does not denote causality but should be investigated further to more confidently determine the cause and potentially refine the soil testing and application process. It is recommended that superintendents contact their local land-grant university for accurate soil testing information specific to turfgrass in their location.

Spreader calibration is an essential component of efficient nutrient manage-

ment. Nationally and in most regions, the percentage of nutrient applications made with calibrated equipment decreased on each course feature, and no region reported an increase since 2006 or 2014 (Table 31). Nationally, approximately one-half of nutrient applications made on golf facilities are made with calibrated equipment which, in turn, indicates the remaining half is not. It is recommended that facilities take the time to calibrate equipment prior to applications. Although this process may require additional time, the potential money savings and increased risk justifies the process.

Improperly stored fertilizer represents potential point-source pollution as any mishap can be traced back to that specific location. It appears U.S. golf facilities recognize this concern as the percentage of facilities that have storage appropriate for fertilizer has increased in every region except the Southwest since 2006 (Table 33). It is recommended that facilities continue to add proper fertilizer storage at their locations.

## Appendix



**Figure 16.** Frequency of management practices used on U.S. golf facilities with the intent of reducing reliance on applied nutrients in 2014 and 2021. Bars with a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.



**Table 11.** Projected nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) applied to U.S. golf courses in 2006, 2014, and 2021.

Region	2006	2014	2021	2006-2021
	Tons			$\Delta\%$
	N			
U.S.	92,185	61,215	54,376	-41.0
North Central	15,047	10,612	8,711	-42.1
Northeast	9,139	6,560	5,656	-38.1
Pacific	3,110	2,124	2,052	-34.0
Southeast	32,532	18,894	19,302	-40.7
Southwest	13,247	8,986	7,209	-45.6
Transition	13,600	9,688	7,982	-41.3
Upper West/Mountain	5,510	4,350	3,466	-37.1
	$P_2O_5$			
U.S.	33,626	15,759	13,761	-59.1
North Central	4,657	1,421	1,242	-73.3
Northeast	3,483	1,152	1,351	-61.2
Pacific	1,123	966	444	-60.5
Southeast	11,114	5,144	4,780	-57.0
Southwest	5,408	3,053	3,254	-39.8
Transition	5,876	3,064	1,924	-67.3
Upper West/Mountain	1,965	960	766	-61.0
	$K_2O$			
U.S.	89,124	51,705	41,386	-53.6
North Central	11,960	7,142	4,496	-62.4
Northeast	8,090	4,719	4,145	-48.8
Pacific	2,697	1,949	1,188	-55.9
Southeast	37,246	20,478	18,362	-50.7
Southwest	12,127	6,397	4,733	-61.0
Transition	12,670	8,354	6,383	-49.6
Upper West/Mountain	4,334	2,666	2,079	-52.0

**Table 12.** Projected acres fertilized with nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) on U.S. golf facilities in 2006, 2014, and 2021.

Region	2006	2014	2021	2006-2021
	Area (acres)			Δ%
	N			
U.S.	1,179,055	986,063	889,378	-24.6
North Central	279,185	230,025	206,284	-26.1
Northeast	161,846	134,774	125,551	-22.4
Pacific	42,969	34,707	33,458	-22.1
Southeast	280,685	234,015	213,414	-24.0
Southwest	118,683	93,383	80,850	-31.9
Transition	210,663	178,741	162,981	-22.6
Upper West/Mountain	85,023	80,419	66,840	-21.4
	P <sub>2</sub> O <sub>5</sub>			
U.S.	1,004,391	540,581	472,923	-52.9
North Central	222,890	87,951	66,723	-70.1
Northeast	143,916	57,360	50,298	-65.1
Pacific	41,553	27,546	20,789	-50.0
Southeast	237,648	138,002	134,054	-43.6
Southwest	99,658	75,983	63,323	-36.5
Transition	189,959	101,034	89,916	-52.7
Upper West/Mountain	68,766	52,704	47,819	-30.5
	K <sub>2</sub> O			
U.S.	1,126,967	874,534	767,883	-31.9
North Central	264,087	199,216	166,854	-36.8
Northeast	157,981	121,645	110,601	-30.0
Pacific	42,467	31,495	28,117	-33.8
Southeast	268,337	219,974	194,550	-27.5
Southwest	113,167	81,642	67,637	-40.2
Transition	204,407	155,772	144,707	-29.2
Upper West/Mountain	76,520	64,791	55,417	-27.6

**Table 13.** Median fertilized acres on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Area (acres)							
	Total							
2006	120.4 a <sup>ii</sup>	125.2 a	88.6 a	123.7 a	130.8 a	148.4 a	119.9 a	124.2 a
2014	114.3 a	107.0 b	106.4 a	125.3 ab	107.3 b	171.1 a	124.2 a	137.5 a
2021	104.1 b	117.8 ab	90.1 a	79.2 b	107.7 b	89.6 b	103.5 b	115.1 a
	Roughs							
2006	40.8 a	45.4 a	33.0 a	31.0 ab	42.3 a	41.1 a	45.4 ab	35.9 a
2014	38.8 a	38.8 b	28.9 a	45.2 a	41.6 a	47.8 a	41.6 b	35.4 a
2021	40.6 a	42.7 ab	29.5 a	26.7 b	47.1 a	40.6 a	47.7 a	32.0 a
	Fairways							
2006	25.6 a	23.6 a	21.3 a	27.8 a	31.2 a	31.1 a	24.8 a	26.5 a
2014	23.8 b	21.9 ab	21.3 a	26.1 a	27.1 b	31.5 a	21.8 b	27.0 a
2021	23.4 b	20.9 b	21.3 a	26.6 a	27.5 b	28.4 a	22.9 ab	22.9 a
	Natural Areas							
2006	13.9 b	13.4 b	9.6 a	17.8 a	15.0 a	29.2 a	12.4 b	18.6 a
2014	12.2 b	13.6 b	9.8 a	11.7 a	10.9 a	31.3 a	9.2 b	25.2 a
2021	17.3 a	26.9 a	14.2 a	8.9 a	16.0 a	16.7 a	17.5 a	17.5 a
	Practice Areas							
2006	4.9 a	4.0 a	3.6 a	4.0 a	6.1 a	5.1 ab	5.6 a	5.5 a
2014	4.6 a	4.0 a	3.1 ab	4.0 a	5.0 b	6.4 a	5.8 a	4.8 ab
2021	3.6 b	2.1 b	2.7 b	3.1 a	5.3 ab	4.5 b	3.8 b	4.0 b
	Greens							
2006	2.4 b	2.4 b	2.5 b	2.2 a	2.7 a	2.3 b	2.5 ab	1.9 b
2014	2.5 b	2.6 a	2.6 ab	2.5 a	2.6 a	2.8 a	2.4 b	2.2 ab
2021	2.7 a	2.6 ab	2.8 a	2.4 a	2.8 a	2.7 a	2.7 a	2.3 a
	Tees							
2006	2.2 b	2.0 a	1.9 b	1.8 a	3.0 a	2.3 b	2.3 b	1.7 a
2014	2.3 ab	2.2 a	2.0 ab	2.2 a	2.7 b	3.1 a	2.3 b	1.9 a
2021	2.4 a	2.1 a	2.1 a	2.0 a	3.0 a	2.7 a	2.6 a	2.0 a
	Grounds							
2006	1.7 a	1.6 a	1.7 a	1.0 a	2.0 a	1.6 a	1.7 a	1.5 a
2014	1.4 b	1.4 a	1.4 ab	1.5 a	1.4 b	1.2 ab	1.4 ab	1.2 ab
2021	1.1 c	0.9 b	1.2 b	0.8 a	1.5 b	0.9 b	1.1 b	0.9 b

<sup>i</sup> NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup> Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 14.** Number of U.S. golf facilities in 2006, 2014, and 2021 and the projected change in nutrient use.

Region	Golf facilities			Projected nutrient applied <sup>i</sup>		
	2006	2014	2021	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
	No.			Δ 2006-2021 (tons)		
U.S.	15,990	15,372	14,033	-5,027	-1,536	-3,952
North Central	4,123	3,920	3,555	-1,005	-130	-549
Northeast	2,739	2,690	2,470	-387	-117	-324
Pacific	629	615	565	-181	-51	-126
Southeast	3,216	3,020	2,737	-2,056	-694	-1,953
Southwest	1,221	1,208	1,138	-352	-216	-221
Transition	2,951	2,793	2,509	-975	-315	-735
Upper West/Mountain	1,111	1,125	1,059	-70	-13	-43

<sup>i</sup> Determined by multiplying the change in golf facilities from 2006 to 2021 by the average amount of N, P<sub>2</sub>O<sub>5</sub>, or K<sub>2</sub>O applied.

**Table 15.** Median nitrogen (N), available phosphorus (P<sub>2</sub>O<sub>5</sub>), and soluble potash (K<sub>2</sub>O) use per U.S. golf facility in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Nutrients applied (tons yr <sup>-1</sup> )							
	N							
2006	5.8 a	4.8 a	3.4 a	5.8 a	10.0 a	12.8 a	5.1 a	6.2 a
2014	4.0 b	2.6 c	3.4 a	4.5 a	6.0 b	8.9 a	4.1 a	5.2 ab
2021	3.5 b	3.3 b	2.8 a	3.7 a	5.4 b	2.1 b	2.9 b	3.8 b
Year	P <sub>2</sub> O <sub>5</sub>							
	P <sub>2</sub> O <sub>5</sub>							
	K <sub>2</sub> O							
2006	1.6 a	1.3 a	1.1 a	2.1 a	2.2 a	4.8 a	1.8 a	1.8 a
2014	0.5 b	0.2 b	0.4 b	0.9 ab	1.7 a	1.3 b	0.6 b	0.9 ab
2021	0.5 b	0.2 b	0.6 b	0.7 b	0.8 b	1.4 b	0.5 b	0.6 b
Year	K <sub>2</sub> O							
	K <sub>2</sub> O							
	K <sub>2</sub> O							
2006	5.0 a	3.9 a	2.9 a	4.9 a	9.7 a	10.5 a	4.7 a	4.7 a
2014	2.9 b	1.5 b	2.3 ab	3.4 ab	6.2 b	4.1 ab	3.1 b	3.3 ab
2021	2.3 c	1.6 b	2.0 b	1.8 b	4.7 b	3.0 b	1.6 c	1.8 b

<sup>i</sup> NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup> Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 16.** Nitrogen (N) use rates on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	N (lbs. 1,000 ft <sup>-2</sup> yr <sup>-1</sup> )							
	Total							
2006	2.3 a <sup>ii</sup>	1.8 a	1.9 a	2.3 a	3.6 a	3.8 a	2.0 a	2.3 a
2014	1.7 b	1.3 b	1.6 a	1.7 a	2.7 b	2.5 ab	1.6 b	1.7 ab
2021	1.6 b	1.4 b	1.5 a	2.4 a	2.2 b	1.1 b	1.4 b	1.3 b
	Greens							
2006	4.3 a	3.4 a	3.6 a	5.1 a	7.7 a	5.1 a	4.2 a	3.9 a
2014	3.8 b	2.8 b	3.2 b	4.0 b	5.9 b	5.1 a	4.0 a	3.5 b
2021	3.1 c	2.4 c	2.5 c	3.8 b	5.5 b	3.8 b	3.2 b	2.8 c
	Tees							
2006	3.9 a	3.4 a	3.6 a	4.6 a	5.8 a	4.9 a	3.4 a	3.4 a
2014	3.1 b	2.7 b	3.0 b	3.5 b	4.1 b	4.8 a	2.7 b	2.9 b
2021	2.9 c	2.6 b	2.5 c	3.9 ab	4.0 b	4.0 b	2.5 c	2.9 b
	Fairways							
2006	3.1 a	2.7 a	2.8 a	3.4 a	4.5 a	4.1 a	2.9 a	2.8 a
2014	2.6 b	2.1 b	2.3 b	2.8 ab	3.5 b	4.2 a	2.6 b	2.4 b
2021	2.4 c	2.0 b	1.9 c	2.7 b	3.5 b	3.7 a	2.3 c	2.4 b
	Roughs							
2006	2.4 a	1.7 a	1.9 a	2.6 a	4.0 a	3.2 a	2.1 a	2.3 a
2014	1.9 b	1.4 b	1.5 b	1.9 b	2.7 b	3.3 a	1.7 b	1.9 b
2021	1.8 b	1.3 b	1.4 b	2.0 b	2.6 b	2.8 a	1.7 b	2.1 ab
	Practice Areas							
2006	3.3 a	2.7 a	2.6 a	3.2 a	5.1 a	4.4 a	3.0 a	2.9 a
2014	2.8 b	2.5 ab	2.2 b	2.8 a	3.6 b	4.6 a	2.5 b	2.6 ab
2021	2.7 b	2.3 b	2.1 b	2.8 a	3.8 b	3.1 b	2.5 b	2.4 b
	Natural Areas							
2006	1.3 a	1.2 a	1.0 a	1.1 a	1.4 a	2.2 a	1.3 a	1.2 a
2014	1.1 b	0.8 ab	0.7 a	1.0 a	1.3 a	1.6 a	0.9 b	1.4 a
2021	1.0 ab	0.7 b	1.2 a	1.1 a	1.4 a	1.4 a	0.9 ab	0.8 a
	Grounds							
2006	2.6 a	2.3 a	2.2 a	3.4 a	3.8 a	3.1 ab	2.4 a	2.5 a
2014	2.2 b	2.0 b	1.9 b	2.9 a	2.8 b	3.8 a	1.8 b	2.4 a
2021	2.0 c	1.8 c	1.8 b	2.8 a	2.5 b	2.7 b	1.9 b	2.1 a

<sup>i</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.



**Table 17.** Available phosphorus ( $P_2O_5$ ) use rates on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	$P_2O_5$ (lbs. 1,000 ft <sup>-2</sup> yr <sup>-1</sup> )							
	Total							
2006	0.8 a <sup>ii</sup>	0.6 a	0.7 a	1.0 a	0.9 a	2.1 a	0.9 a	0.9 a
2014	0.2 b	0.1 b	0.2 b	0.4 a	0.8 ab	0.6 b	0.3 b	0.4 b
2021	0.3 b	0.1 b	0.4 b	0.6 a	0.5 b	0.9 b	0.3 b	0.3 b
	Greens							
2006	1.5 a	1.0 a	1.2 a	1.7 a	2.2 a	2.1 a	1.6 a	1.3 a
2014	1.1 b	0.7 b	0.8 b	1.1 b	1.7 b	1.8 a	1.4 b	0.9 b
2021	1.0 c	0.6 b	0.8 b	1.0 b	1.8 b	1.7 a	1.0 c	0.7 c
	Tees							
2006	1.3 a	1.0 a	1.3 a	1.4 a	1.7 a	1.8 a	1.3 a	1.0 a
2014	1.0 b	0.7 b	0.9 b	1.1 a	1.3 b	1.5 a	1.0 b	0.8 b
2021	0.9 b	0.6 b	0.8 b	1.2 a	1.4 b	1.7 a	0.9 b	0.6 c
	Fairways							
2006	1.1 a	0.8 a	0.9 a	1.0 a	1.5 a	1.6 a	1.1 a	0.9 a
2014	0.9 b	0.5 b	0.6 b	0.9 a	1.2 b	1.4 a	1.0 a	0.7 ab
2021	0.8 b	0.5 b	0.7 b	0.9 a	1.2 b	1.6 a	0.7 b	0.5 b
	Roughs							
2006	0.9 a	0.5 a	0.7 a	0.8 a	1.4 a	1.5 a	0.9 a	0.8 a
2014	0.8 b	0.4 b	0.5 b	0.6 a	1.2 ab	1.3 a	0.8 ab	0.7 ab
2021	0.8 b	0.4 ab	0.7 ab	0.6 a	1.1 b	1.3 a	0.6 b	0.5 b
	Practice Areas							
2006	1.2 a	0.8 a	1.0 a	1.0 a	1.6 a	1.8 a	1.2 a	1.0 a
2014	1.0 b	0.8 a	0.6 b	0.9 a	1.1 b	1.6 a	1.0 b	0.8 ab
2021	1.0 b	0.9 a	1.0 a	0.9 a	1.3 ab	1.4 a	0.9 b	0.6 b
	Natural Areas							
2006	0.8 a	0.7 a	0.6 b	1.1 a	1.1 a	1.3 a	0.7 a	0.4 a
2014	0.7 a	0.0 <sup>iii</sup>	0.5 ab	0.8 ab	0.6 a	1.1 a	0.6 a	0.6 a
2021	0.7 a	0.3 a	1.8 a	0.4 b	0.7 a	1.5 a	0.8 a	0.3 a
	Grounds							
2006	2.6 a	2.3 a	2.2 a	3.4 a	3.8 a	3.1 ab	2.4 a	2.5 a
2014	2.2 b	2.0 b	1.9 b	2.9 a	2.8 b	3.8 a	1.8 b	2.4 a
2021	2.0 c	1.8 c	1.8 b	2.8 a	2.5 b	2.7 b	1.9 b	2.1 a

<sup>i</sup> NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup> Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

<sup>iii</sup> Values without variability were not analyzed.

**Table 18.** Soluble potash ( $K_2O$ ) use rates on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	<b><math>K_2O</math> (lbs. 1,000 ft<sup>-2</sup> yr<sup>-1</sup>)</b>							
	Total							
2006	1.9 a <sup>ii</sup>	1.4 a	1.6 a	1.9 a	3.3 a	3.2 a	1.9 a	1.8 a
2014	1.2 b	0.7 b	1.1 b	1.2 a	2.7 ab	1.2 b	1.2 b	1.1 ab
2021	1.1 b	0.6 b	1.1 b	1.3 a	1.9 b	1.5 b	0.8 c	0.6 b
	Greens							
2006	4.5 a	3.4 a	3.4 a	4.6 a	9.9 a	6.6 a	4.3 a	3.2 a
2014	3.6 b	2.4 b	2.7 b	3.2 b	7.8 b	5.0 b	4.2 a	3.0 a
2021	2.9 c	1.9 c	2.1 c	3.1 b	6.8 c	3.5 c	3.1 b	2.2 b
	Tees							
2006	3.3 a	2.8 a	3.1 a	3.6 a	5.8 a	4.0 a	2.9 a	2.2 a
2014	2.4 b	2.0 b	2.2 b	2.6 b	3.8 b	3.4 ab	2.3 b	2.0 ab
2021	2.0 c	1.6 c	1.6 c	2.3 b	3.8 b	2.9 b	1.8 c	1.7 b
	Fairways							
2006	2.6 a	2.1 a	2.3 a	2.6 a	4.6 a	3.0 a	2.5 a	1.9 a
2014	1.9 b	1.4 b	1.5 b	2.0 ab	3.3 b	2.8 a	2.0 b	1.6 ab
2021	1.6 c	1.1 c	1.3 c	1.7 b	3.1 b	2.4 a	1.6 c	1.4 b
	Roughs							
2006	1.9 a	1.2 a	1.5 a	2.0 a	4.1 a	2.3 a	1.8 a	1.7 a
2014	1.5 b	0.8 b	1.1 b	1.3 b	2.7 b	2.2 a	1.5 b	1.3 b
2021	1.2 c	0.6 c	0.9 b	1.1 b	2.6 b	1.8 a	1.2 c	1.2 b
	Practice Areas							
2006	2.9 a	2.1 a	2.3 a	2.4 a	5.2 a	3.6 a	2.6 a	2.3 a
2014	2.2 b	1.8 b	1.6 b	1.9 ab	3.4 b	2.9 ab	2.1 b	1.7 b
2021	1.8 c	1.2 c	1.6 b	1.7 b	3.2 b	2.2 b	1.6 c	1.3 b
	Natural Areas							
2006	1.1 a	1.0 a	0.9 a	1.2 a	1.7 a	1.2 a	1.1 a	0.8 a
2014	1.1 a	0.9 a	0.7 a	1.1 a	1.5 a	1.6 a	0.9 a	1.2 a
2021	1.0 a	0.6 a	0.8 a	1.1 a	1.7 a	1.4 a	0.9 a	0.6 a
	Grounds							
2006	2.2 a	1.8 a	1.8 a	2.5 a	3.5 a	2.3 a	2.0 a	1.9 a
2014	1.6 b	1.3 b	1.3 b	2.2 ab	2.5 b	2.5 a	1.5 b	1.6 ab
2021	1.5 c	0.9 c	1.2 b	1.7 b	2.6 b	2.3 a	1.5 b	1.3 b

<sup>i</sup> NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup> Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 19.** Ratios of applied nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) on U.S. golf facilities in 2006, 2014, and 2021.

Year	N	$P_2O_5$	$K_2O$
	Total		
2006	2.6 b <sup>i</sup>	1	2.2 c
2014	5.7 a	1	3.9 a
2021	4.8 a	1	3.1 b
	Greens		
2006	3.0 c	1	3.0 b
2014	3.6 a	1	3.4 a
2021	3.3 b	1	2.9 b
	Tees		
2006	3.0 b	1	2.5 a
2014	3.4 a	1	2.5 a
2021	3.4 a	1	2.3 b
	Fairways		
2006	3.1 b	1	2.5 a
2014	3.3 a	1	2.5 a
2021	3.3 a	1	2.3 b
	Roughs		
2006	2.8 a	1	2.3 a
2014	2.9 a	1	2.3 a
2021	3.0 a	1	2.2 a
	Practice		
2006	2.9 b	1	2.4 a
2014	3.3 a	1	2.4 a
2021	3.0 ab	1	2.1 b
	Natural Areas		
2006	2.0 a	1	1.6 a
2014	1.7 a	1	1.9 a
2021	1.4 a	1	1.5 a
	Grounds		
2006	2.8 b	1	2.2 a
2014	3.1 a	1	2.3 a
2021	2.9 ab	1	2.1 a

<sup>i</sup> Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 20.** Frequency of overseeding practices on U.S. golf facilities in 2014 and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	%							
	Stopped Overseeding							
2014	8 b <sup>ii</sup>	1 a	<1 b	6 a	20 b	10 a	11 a	2 a
2021	10 a	1 a	2 a	8 a	30 a	13 a	10 a	1 a
	Reduced Overseeding							
2014	13 a	1 a	5 a	7 a	24 a	33 a	20 a	5 a
2021	9 b	<1 a	5 a	11 a	19 a	33 a	8 b	4 a
	Overseeded Greens							
2014	17 a	7 b	20 a	16 a	28 a	41 a	6 a	14 a
2021	13 b	13 a	17 a	4 b	9 b	35 a	7 a	6 b
	Overseeded Tees							
2014	31 a	7 b	24 a	30 a	58 a	69 a	33 a	17 a
2021	24 b	13 a	17 a	35 a	36 b	58 a	23 a	9 b
	Overseeded Fairways							
2014	14 a	4 b	15 a	11 a	20 a	43 a	8 b	11 a
2021	13 a	9 a	10 a	15 a	12 b	34 a	18 a	7 a
	Overseeded Roughs							
2014	6 a	2 a	7 a	4 b	3 a	30 a	6 a	3 a
2021	6 a	4 a	5 a	11 a	4 a	17 b	9 a	3 a
	Did Not Overseed Any Feature							
2014	65 b	89 a	71 b	68 a	37 b	30 a	62 a	80 b
2021	70 a	79 b	79 a	62 a	63 a	40 a	64 a	88 a

<sup>i</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.

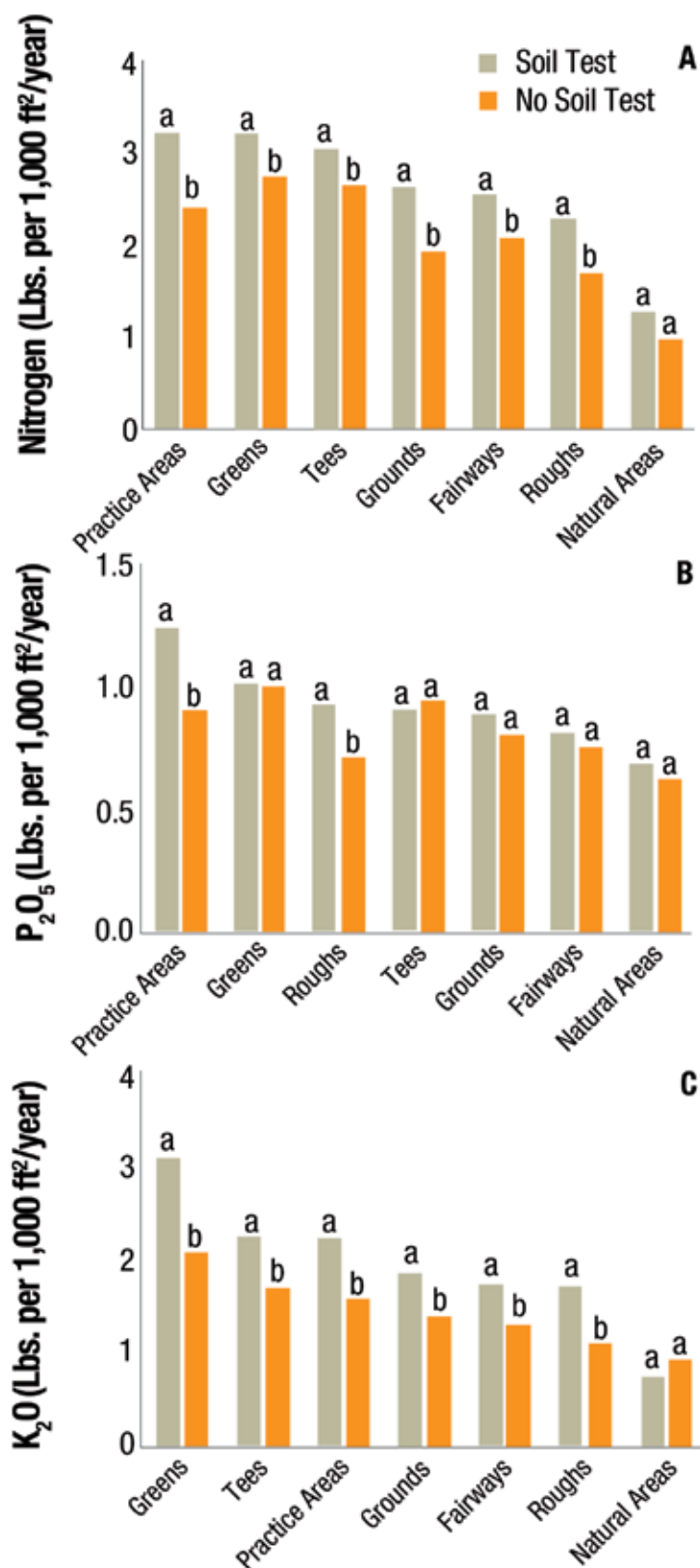
**Table 21.** Frequency of U.S. golf facilities that soil tested course features in 2006, 2014, and 2021.

Year	U.S.	NC <sup>1</sup>	NE	Pac.	SE	SW	Trans.	UWM
<b>Golf facilities (%)</b>								
<b>Greens</b>								
2006	92 a <sup>ii</sup>	86 a	95 a	94 a	96 a	91 a	95 a	92 a
2014	91 a	85 a	91 b	92 a	98 a	93 a	88 b	91 a
2021	85 b	74 b	87 b	97 a	98 a	87 a	79 b	85 a
<b>Tees</b>								
2006	70 a	62 a	77 a	74 a	80 a	64 a	69 a	62 a
2014	63 b	56 a	73 a	58 a	71 b	63 a	63 ab	53 a
2021	57 c	45 b	58 b	66 a	77 ab	60 a	53 b	50 a
<b>Fairways</b>								
2006	75 a	66 a	78 a	77 a	83 a	83 a	71 a	75 a
2014	67 b	58 b	69 b	70 a	74 a	70 a	66 ab	68 a
2021	61 c	48 c	61 b	69 a	79 a	67 a	56 b	62 a
<b>Practice Areas</b>								
2006	31 a	18 a	27 a	26 a	51 a	31 a	32 a	32 a
2014	27 b	17 a	27 ab	15 a	41 b	31 a	29 ab	20 b
2021	23 c	10 b	21 b	19 a	38 b	28 a	26 b	17 b
<b>Roughs</b>								
2006	22 a	10 a	21 a	16 a	34 a	31 a	27 a	21 a
2014	19 b	10 a	18 a	13 a	25 b	25 ab	23 a	21 a
2021	14 c	3 b	15 a	5 b	23 b	14 b	23 a	9 b
<b>Grounds</b>								
2006	13 a	8 a	13 a	8 a	19 a	11 a	16 a	12 a
2014	12 a	8 a	13 a	6 ab	19 a	7 a	14 a	6 a
2021	7 b	2 b	9 a	3 b	11 b	5 a	11 a	6 a
<b>Natural Areas</b>								
2006	4 a	2 a	3 a	2 a	5 a	4 a	5 a	5 a
2014	3 a	1 a	4 a	2 a	2 b	4 a	3 ab	1 b
2021	1 b	<1 a	3 a	2 a	1 c	1 a	2 b	2 ab

<sup>1</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.





**Figure 17.** Use rates of A.) Nitrogen, B.) available phosphorus (P<sub>2</sub>O<sub>5</sub>), C.) and soluble potash (K<sub>2</sub>O) on U.S. golf facilities that soil tested or did not soil test in 2021. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 22.** Frequency of soil extractant used for analysis of phosphorus and non-phosphorus nutrients on U.S. golf facilities in 2021.

Extractant	U.S.	NC <sup>1</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Golf facilities (%)							
	Phosphorus analysis							
Saturated Paste	47	45	51	44	41	60	48	51
Mehlich-3	23	18	27	19	25	12	33	15
Bray	14	23	13	21	10	18	5	21
Mehlich-1	11	7	5	14	22	-	11	3
Olsen	3	5	1	2	1	10	2	11
Modified Morgan	1	2	4	-	1	-	1	-
Extractant	Non-phosphorus nutrient analysis							
Saturated Paste	57	56	61	59	49	79	54	67
Mehlich-3	22	18	20	22	22	10	33	14
Mehlich-1	12	10	7	14	22	-	10	3
Bray	5	5	7	5	5	5	3	9
Olsen	2	6	2	-	0	4	-	7
Modified Morgan	2	4	4	-	1	2	1	-

<sup>1</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

**Table 23.** Importance of factors when making nutrient application decisions on U.S. golf facilities in 2006, 2014, and 2021.

Decision factor	2006	2014	2021
	Importance (1 to 5) <sup>i</sup>		
Visual observation / scouting	4.10 a <sup>ii</sup>	4.09 a	4.00 b
Precipitation / temperature / weather	4.12 a	4.14 a	3.99 b
Previous product performance on your established turf	4.08 a	4.09 a	3.98 b
Disease problems / pressure	4.06 a	3.98 b	3.90 c
Traffic / wear	3.77 b	3.88 a	3.89 a
Turf species	3.99 a	3.88 b	3.86 b
Soils / soil analysis	4.11 a	4.02 b	3.85 c
Golfers' expectations for turf performance	3.79 a	3.80 a	3.74 a
Cost of fertilizer	3.57 c	3.79 a	3.66 b
Length of growing season	3.77 a	3.74 a	3.63 b
Reduction of environmental impact	- <sup>iii</sup>	3.61 a	3.44 b
Clipping production	3.35 a	3.39 a	3.40 a
Golf events calendar	3.50 a	3.54 a	3.33 b
Regulatory requirements	2.65 c	3.04 a	2.90 b
Turf growth prediction models	2.75 b	2.83 ab	2.89 a
Manufacturer recommendations	2.80 ab	2.86 a	2.77 b
University recommendations	2.71 b	2.87 a	2.67 b
Consultant / service provider recommendations	2.62 a	2.54 ab	2.47 b
Tissue analysis	2.49 a	2.42 ab	2.35 b
Nutrient content of effluent water source	1.97 ab	1.89 b	2.01 a
Adjacent property owner's maintenance standards	1.77 c	1.96 a	1.85 b
Overseeding warm season grasses with cool-season grasses	-	1.31 a	1.29 a

<sup>i</sup> Respondents rated factors on a 1–5 scale, where 1 = not important at all, and 5 = extremely important.

<sup>ii</sup> Within rows, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

<sup>iii</sup> Not asked in 2006.

**Table 24.** Association between management practice used with the intent of reducing reliance upon applied nutrients and median nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) applied on U.S. golf facilities in 2021.

Management practice	Was management practice used?					
	Yes	No	Yes	No	Yes	No
	N (tons yr <sup>-1</sup> )		P <sub>2</sub> O <sub>5</sub> (tons yr <sup>-1</sup> )		K <sub>2</sub> O (tons yr <sup>-1</sup> )	
Fertilize based on soil test results	4.40 a <sup>i</sup>	2.75 b	0.63 a	0.36 b	3.08 a	1.69 b
Return clippings	3.44 a	3.55 a	0.37 b	0.64 a	2.16 a	2.48 a
Use precision fertilizer applications	3.75 a	3.26 a	0.40 b	0.56 a	2.38 a	2.22 a
Reduce turf acreage	3.27 a	3.62 a	0.38 b	0.54 a	1.93 b	2.52 a
Consider nitrogen release from soil organic matter	3.55 a	3.47 a	0.36 b	0.53 a	2.11 a	2.36 a
Use plant growth models to determine fertilizer rates and frequency	3.96 a	3.32 a	0.57 a	0.44 a	2.34 a	2.28 a
Reduce overseeding	3.88 a	3.45 a	0.71 a	0.45 a	2.95 a	2.22 a
Use new fertilizer guidelines	4.40 a	3.40 a	0.60 a	0.46 a	2.57 a	2.27 a
Change turf variety	5.00 a	3.37 b	0.41 a	0.48 a	3.57 a	2.19 b
Consider nutrients applied in reclaimed water	3.19 a	3.51 a	0.35 a	0.49 a	2.27 a	2.30 a
Stop overseeding	4.31 a	3.38 a	1.21 a	0.42 b	3.56 a	2.14 b
Compost on-site	3.61 a	3.48 a	0.33 a	0.48 a	1.48 a	2.34 a

<sup>i</sup>Within rows and nutrient, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 25.** Frequency of U.S. golf facilities with a written nutrient management plan.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Facilities (%)							
2006	47 a <sup>ii</sup>	52 a	41 a	47 a	48 a	50 a	42 a	44 a
2014	44 a	52 a	41 a	31 a	43 a	45 a	41 a	46 a
2021	43 a	52 a	35 a	38 a	41 a	46 a	43 a	36 a

<sup>i</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.

**Table 26.** Nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potash ( $K_2O$ ) use rates on U.S. golf facilities by golf holes and facility type in 2021.

	N	$P_2O_5$	$K_2O$
Golf Holes	lbs. 1,000 ft <sup>-2</sup> yr <sup>-1</sup>		
9	1.11 b <sup>i</sup>	0.24 a	0.74 b
18	1.67 a	0.29 a	1.14 a
27+	1.95 a	0.17 a	1.20 ab
Facility Type			
Public	1.44 b	0.25 a	0.93 b
Private	1.81 a	0.29 a	1.28 a

<sup>i</sup>Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 27.** Frequency of natural organic nitrogen use on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
Golf facilities (%)								
2006	64 a <sup>ii</sup>	56 a	75 a	66 a	67 a	56 a	65 a	57 a
2014	61 a	51 ab	74 a	61 a	64 a	67 a	64 ab	53 a
2021	54 b	47 b	56 b	56 a	62 a	36 b	55 b	62 a

<sup>i</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.

	Biosolid	Animal Waste	Crop products	Food waste
Facilities (%)				
2006	47.3 a <sup>i</sup>	63.6 b	14.6 a	24.5 a
2014	38.5 b	64.7 ab	14.3 a	13.4 b
2021	38.6 b	68.4 a	13.6 a	13.1 b

**Table 28.** Frequency (percentage) of natural organic sources used by U.S. golf facilities that used natural organic products in 2006, 2014, and 2021.

<sup>i</sup>Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.



**Table 29.** Percentage of slow and quick-release nitrogen applied on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Slow-Release Nitrogen (%)							
2006	66 a <sup>ii</sup>	70 a	69 a	60 a	65 a	57 a	62 a	65 a
2014	65 a	69 ab	71 a	59 a	62 ab	49 b	61 a	68 a
2021	62 b	66 b	63 b	54 a	60 b	48 b	61 a	68 a
Year	Quick-Release Nitrogen (%)							
2006	31 b	28 b	29 b	35 a	31 b	42 b	34 a	33 a
2014	32 b	29 b	28 b	38 a	33 ab	49 a	36 a	29 a
2021	35 a	32 a	35 a	42 a	36 a	49 ab	35 a	30 a

<sup>i</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 30.** Frequency of soil amendment and supplement use on U.S. golf courses in 2006, 2014, and 2021.

Soil Amendment	2006	2014	2021
	Golf facilities (%)		
Used at least one amendment	76 b <sup>i</sup>	83 a	84 a
Humic materials	41 c	53 b	58 a
Amino acids/proteins	38 b	49 a	52 a
Biostimulants	43 b	48 a	50 a
Gypsum	34 c	49 a	44 b
Sulfur	8 b	27 a	25 a
Limestone	22 b	26 a	22 b
Sugars (sucrose, molasses, etc.)	14 b	18 a	18 a
Microbial inoculants	14 b	20 a	18 a
Compost	13 b	14 ab	16 a
Biocontrol agents	6 b	8 a	10 a
Calcium chloride	5 b	9 a	8 a
Compost teas	3 c	8 a	6 b

<sup>i</sup>Within rows, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.

**Table 31.** Percentage of nutrient applications made using calibrated equipment on U.S. golf facilities in 2007, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Nutrient Applications (%)							
	Greens							
2006	57 a <sup>ii</sup>	52 a	60 a	51 a	59 a	55 a	63 a	50 a
2014	54 a	50 a	56 ab	28 b	56 a	60 a	61 a	50 a
2021	46 b	40 b	50 b	37 ab	53 a	47 a	56 a	29 b
	Tees							
2006	58 a	50 a	61 a	51 a	60 a	59 a	64 a	59 a
2014	55 a	48 ab	57 a	28 b	58 a	54 ab	62 a	64 a
2021	50 b	41 b	55 a	47 ab	56 a	45 b	58 a	39 b
	Fairways							
2006	67 a	62 a	70 a	58 a	72 a	59 a	71 a	73 a
2014	61 b	55 a	68 a	37 a	64 ab	55 ab	64 a	70 a
2021	51 c	43 b	55 b	49 a	55 b	44 b	63 a	45 b
	Roughs							
2006	71 a	70 a	77 a	55 a	73 a	54 a	77 a	74 a
2014	67 a	67 a	76 a	49 a	69 a	58 a	64 b	66 a
2021	60 b	54 b	68 a	72 a	62 a	50 a	65 ab	56 a

<sup>i</sup>NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup>Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 32.** Number of nutrient applications made annually on U.S. golf facilities in 2006, 2014, and 2021.

Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Nutrient applications yr <sup>-1</sup>							
	Greens							
2006	11.9 c <sup>ii</sup>	8.9 b	9.3 c	16.1 b	20.0 b	17.2 b	12.1 b	9.5 b
2014	14.4 b	9.7 b	10.6 b	20.7 a	30.3 a	22.2 a	14.2 a	13.7 a
2021	16.3 a	11.0 a	13.7 a	22.2 a	31.8 a	23.5 a	15.7 a	16.3 a
	Tees							
2006	5.4 b	5.2 b	5.7 b	6.7 a	6.5 b	5.9 b	4.7 a	3.8 b
2014	5.5 b	5.1 b	5.4 b	7.2 a	7.7 a	8.8 a	4.3 a	4.3 ab
2021	6.2 a	5.8 a	7.1 a	7.5 a	7.7 a	7.7 a	4.6 a	4.6 a
	Fairways							
2006	3.5 c	3.2 b	3.1 b	4.0 a	4.4 b	5.0 b	3.4 b	2.6 b
2014	4.0 b	3.5 ab	3.5 b	5.3 a	5.7 a	6.3 ab	3.9 a	3.0 b
2021	4.6 a	3.9 a	4.6 a	4.5 a	6.5 a	7.9 a	3.6 ab	4.1 a
	Roughs							
2006	2.6 a	1.8 a	2.0 a	3.0 a	3.9 a	4.4 a	2.4 a	2.1 a
2014	2.5 a	1.9 a	2.1 a	2.4 a	3.7 a	4.8 a	2.3 a	2.1 a
2021	2.6 a	2.0 a	2.1 a	2.8 a	3.9 a	4.4 a	2.2 a	2.5 a

<sup>i</sup> NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

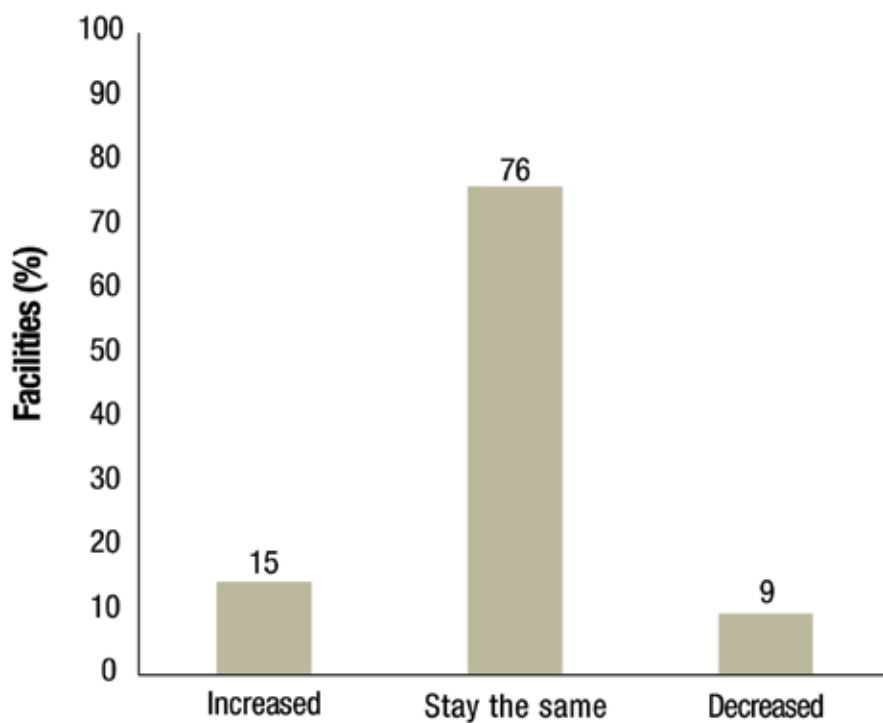
<sup>ii</sup> Within columns, values followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

**Table 33.** Frequency of U.S. golf facilities that used fertilizer storage that, at a minimum, had an impervious floor and roof, ventilation, security (locked with access restricted), and containment features to prevent loss to the environment and/or contamination from run off in 2006, 2014, and 2021.

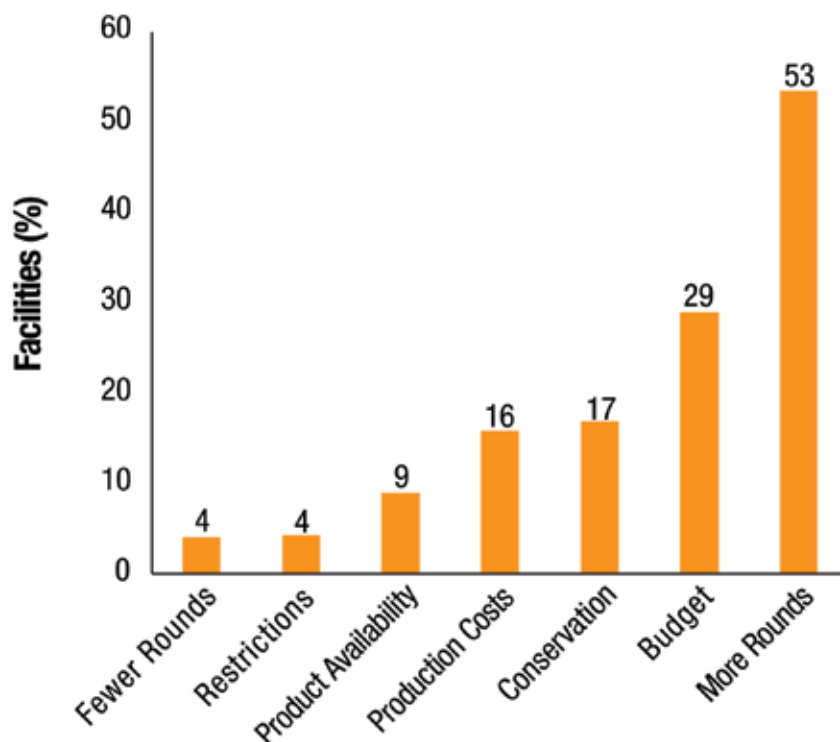
Year	U.S.	NC <sup>i</sup>	NE	Pac.	SE	SW	Trans.	UWM
	Golf facilities (%)							
2006	51 b <sup>ii</sup>	43 b	49 b	62 b	59 b	65 a	49 b	41 b
2014	63 a	59 a	64 a	72 ab	66 ab	72 a	58 ab	66 a
2021	64 a	58 a	65 a	81 a	72 a	48 b	64 a	66 a

<sup>i</sup> NC, North Central; NE, Northeast; Pac., Pacific; SE, Southeast; SW, Southwest; Trans., Transition; UWM, Upper West/Mountain.

<sup>ii</sup> Within columns, values followed by a common letter are not significantly different according to the  $\chi^2$  test at the 10% significance level.



**Figure 18.** Frequency (percentage) of facilities that reported applied nutrients increased, stayed the same, or decreased in 2021 as a result of the COVID pandemic.



**Figure 19.** Frequency (percentage) of factors that contributed to nutrient changes on U.S. golf facilities as a result of the COVID-19 pandemic. Values only include facilities where nutrient changes were reported (24% of total U.S. facilities).

**Table 34.** 2021 nutrient survey responses and weighting factors categorized by region, facility type, number of holes, and green fee.

Region	Facility type	Holes	Green fee	Golf facilities		Survey responses		Weight
		(No.)	( $\text{\$}$ )	(No.)	(%)	(No.)	(%)	
Northeast	All	9	All	647	4.6	28	1.9	2.378
Northeast	Public	18	< 55	508	3.6	26	1.8	2.011
Northeast	Public	18	$\geq 55$	557	4.0	65	4.5	0.882
Northeast	Private	18	All	579	4.1	99	6.9	0.602
Northeast	All	27+	All	179	1.3	27	1.9	0.682
North Central	All	9	All	1144	8.2	22	1.5	5.351
North Central	Public	18	< 55	1183	8.4	64	4.4	1.902
North Central	Public	18	$\geq 55$	472	3.4	73	5.1	0.665
North Central	Private	18	All	451	3.2	83	5.7	0.559
North Central	All	27+	All	305	2.2	33	2.3	0.951
Transition	All	9	All	640	4.6	17	1.2	3.874
Transition	Public	18	< 55	818	5.8	61	4.2	1.380
Transition	Public	18	$\geq 55$	355	2.5	52	3.6	0.702
Transition	Private	18	All	520	3.7	90	6.2	0.595
Transition	All	27+	All	176	1.3	27	1.9	0.671
Southeast	All	9	All	458	3.3	6	0.4	7.855
Southeast	Public	18	< 55	744	5.3	59	4.1	1.298
Southeast	Public	18	$\geq 55$	503	3.6	66	4.6	0.784
Southeast	Private	18	All	684	4.9	136	9.4	0.518
Southeast	All	27+	All	348	2.5	62	4.3	0.578
Southwest	All	9	All	241	1.7	4	0.3	6.200
Southwest	Public	18	< 55	169	1.2	13	0.9	1.338
Southwest	Public	18	$\geq 55$	335	2.4	44	3.0	0.783
Southwest	Private	18	All	225	1.6	40	2.8	0.579
Southwest	All	27+	All	168	1.2	15	1.0	1.152
Upper West/Mountain	All	9	All	384	2.7	12	0.8	3.293
Upper West/Mountain	Public	18	< 55	179	1.3	27	1.9	0.682
Upper West/Mountain	Public	18	$\geq 55$	272	1.9	59	4.1	0.474
Upper West/Mountain	Private	18	All	149	1.1	35	2.4	0.438
Upper West/Mountain	All	27+	All	75	0.5	13	0.9	0.594
Pacific	All	9	All	162	1.2	6	0.4	2.778
Pacific	Public	18	< 55	52	0.4	3	0.2	1.784
Pacific	Public	18	$\geq 55$	184	1.3	42	2.9	0.451
Pacific	Private	18	All	112	0.8	26	1.8	0.443
Pacific	All	27+	All	55	0.4	9	0.6	0.629





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