GCSAA

Photo courtesy of USGA

Golf Course Environmental Profile

Phase II, Volume II

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

EIFG GCSAA USGA

Funded by the USGA through the Environmental Institute for Golf, the philanthropic organization of the GCSAA.

Golf Course Superintendents Association of America

Golf Course Environmental Profile

Phase II, Volume II

2015 Nutrient Use and Management Practices on U.S. Golf Courses

The second phase of the Golf Course Environmental Profile was conducted by the Golf Course Superintendents Association of America through the Environmental Institute for Golf and funded by the United States Golf Association.

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Foreword

Nutrient study illustrates golf's commitment to sustainable practices

Results from our latest survey, Nutrient Use and Management Practices on U.S. Golf Courses — part of the groundbreaking, multiphase Golf Course Environmental Profile Project — show significant reductions in nutrient use and increases in key conservation practices at golf facilities across the country.

Funded by the USGA through the Environmental Institute for Golf, the Golf Course Environmental Profile Project provides critical information for the golf course management profession and assists efforts to advocate for superintendents and the entire industry. By comparing data from this latest study with results from the first nutrient use survey in 2006, GCSAA is able to measure our industry's progress and communicate superintendents' ongoing efforts toward resource conservation and environmental protection.

GCSAA members are stewards of every golf facility's greatest asset, the course itself. Study after study has demonstrated our dedication to the continual advancement of sustainable practices. The results from this latest nutrient use survey are no different. Since 2006, facilities have significantly decreased nutrient application rates; voluntarily reduced the number of acres fertilized; and increasingly adopted conservation practices such as overseeding, the recycling of mower clippings, and test-based, precision fertilizer applications.

We have been entrusted with a small piece of this Earth, and it is our responsibility to educate others about the many benefits of golf's professionally managed land and the game itself. Just as you continue to communicate these points to your golfers and in your communities, GCSAA will use the data collected through the Profile Project surveys to advocate for our profession and the golf industry as a whole.

On behalf of your board of directors, I thank all the superintendents who took the time to take part in this study.

Peter J. Grass, CGCS
2016 GCSAA President

Executive Summary

Objectives

Nutrient use and management practices on U.S. golf courses were documented for the first time in a 2006 survey conducted by the Golf Course Superintendents Association of America.

The objectives of the second Nutrient Use and Management Practices Survey were to compare results from 2014 to those from 2006, in an attempt to document, characterize and/or quantify the use of nitrogen, phosphate and potash on golf course turf in terms of:

- trends in nutrient use on a national and regional scale
- the role of climate and weather on nutrient use patterns
- the role of management and agronomic practices on nutrient use patterns
- the role of external factors such as regulations, economics and research advances on nutrient use patterns
- trends in the use of different nutrient sources and amendments
- trends in storage and calibration of fertilizer equipment

Key results

National nutrient use

U.S. golf courses have significantly decreased their overall nutrient use since 2006.

- Nitrogen use was reduced by 34%, or the equivalent of 30,970 tons annually.
- Phosphate use was reduced by 53%, or the equivalent of 17,867 tons annually.
- Potash use was reduced by 42%, or the equivalent of 37,419 tons annually.

Factors responsible for these decreases include:

- Conservation practices (that resulted in reduced nutrient use rates and fertilized acres)
- Facility closures

Conservation practices

Adoption of almost all conservation practices has increased since 2006 and has resulted in decreased nutrient use rates and reductions in fertilized acres. These conservation practices were responsible for approximately 90% of all decreases in nutrient use.

The most common conservation practices include:

- avoidance of overseeding
- fertilizing based on soil test results
- returning clippings
- precision fertilizer application

Avoidance of overseeding is one of the conservation practices that contributed to 90% of the nutrient use savings that occurred nationwide from 2006 to 2014. **Photo courtesy of Tim Powers**

Reduced nutrient use rates

Reductions in nutrient use rates made since 2006 have resulted in:

- 49% of all nitrogen savings since 2006, for an estimated annual savings of 15,226 tons nitrogen
- 27% of all phosphate savings since 2006, for an estimated annual savings of 4,901 tons of phosphate
- 53% of all potash savings since 2006, or an estimated annual savings of 19,740 tons of potash

Reductions in fertilized acreage

Reductions in the number of acres treated with fertilizers have resulted in:

- 40% of all nitrogen savings since 2006, for an estimated annual savings of 12,224 tons of nitrogen
- 66% of all phosphate savings since 2006, for an estimated annual savings of 11,851 tons of phosphate
- 39% of all potash savings since 2006, for an estimated annual savings of 14,489 tons of potash

Modern soil analytical laboratories utilize robotic sample handling systems and the latest chemical analysis methods to provide accurate test results to golf course managers. **Photo courtesy of Brookside Laboratories**

Greens were the most likely feature to be fertilized, and roughs the least likely.

Facility closures

A net decrease of 618 golf facilities nationally between 2006 and 2014 led to approximately 9% of the observed nutrient use reductions.

- All regions except the Upper West/Mountain had decreases in the number of facilities.
- Estimated annual nutrient savings as a result of decreased facility numbers were 3,519 tons of nitrogen, 1,115 tons of phosphate and 3,190 tons of potash.

Regional nutrient use

- Nutrient use differs dramatically among the nation's seven agronomic regions, both in total amount used, and in rates used.
- The impact of climate on the length of the growing season is the most important contributor to regional differences in nutrient use. The lowest nutrient rates occur in the cool climates of the Northeast and North Central regions, while the highest rates occur in the Southeast and Southwest regions, which have the highest average temperatures.
- The number of facilities per region also contributes to regional differences in total nutrient use. Regions with many facilities (such as the North Central region) have higher total nutrient use, regardless of how low their nutrient use rates may be, while regions with fewer facilities (Pacific, Southwest) have lower total nutrient use, even if nutrient use rates are relatively high.
- Variation in nutrient use was also significant *within* each agronomic region, particularly in the Pacific and Southwest regions, which have the most diverse climates.

Introduction: Why do we need a golf course environmental profile?

The Environmental Institute for Golf (EIFG) is sponsoring a long-range initiative to address the golf industry's lack of comprehensive national data on management practices, property features and environmental stewardship on the nation's golf courses. In the past, it has been difficult to document current practices or to track changes in the industry — information that would be valuable to golf course superintendents, golf industry leaders, turfgrass scientists and environmental regulators in their joint efforts to enhance environmental stewardship on the nation's golf courses.

To respond to this need, the Golf Course Superintendents Association of America (GCSAA) and the EIFG in 2006 initiated a project to conduct a series of surveys to document water use, fertilizer use, pest management practices, energy use, environmental stewardship and property profiles. Known as the Golf Course Environmental Profile, the results were released from 2007 to 2012 and provided a baseline of information for use in the management of golf facilities as well as offering an opportunity to communicate golf's environmental efforts to the public.

Results were published in the peer-reviewed scientific journal *Applied Turfgrass Science* (recently renamed *Crop, Forage and Turfgrass Management*), as well as in *Golf Course Management* and online documents. All reports from the first phase of the Environmental Profile project are available online (www.gcsaa.org/Environment/Environmental-Profile/Golf-Course-Environmental-Profile-Overview). A listing of the published articles appears in the "Further Reading" section of this report.

In fall 2014, the second phase of the Golf Course Environmental Profile began, with a follow-up set of surveys that mirrors the previous series. The surveys are being conducted by the GCSAA through the EIFG and funded by the United States Golf Association (USGA). The second survey to be released in the second phase focuses on nutrient use and management practices, and explores trends, changes and progress that have been made since the initial nutrient use survey was conducted eight years ago.

The objectives of the current Nutrient Use and Management Practices Survey were to compare results from 2014 to those from the initial 2006 survey, in an attempt to document, characterize and/or quantify:

- trends in nutrient use on a national and regional scale
- the role of climate and weather on nutrient use patterns

N, P and K: How they are reported

The results of this survey report nutrients used in the same units used on fertilizer labels:

For nitrogen, data is shown in terms of elemental N (nitrogen)
For phosphorous, data is shown in terms of phosphate (P_2O_5)
For potassium, data is shown in terms of potash (K_2O).

Nitrogen is reported as the raw element without the need for a conversion factor. To convert the values for phosphate to elemental phosphorus and potash to elemental potassium, use the following equations:

(Pounds phosphate (P_2O_5))/2.29= Pounds phosphorous (P)
(Pounds potash (K_2O))/1.21= Pounds potassium (K)

Interpreting the data: Means, medians and totals

The data in this report is presented in three different forms: the mean, the median or the total.

When estimating how much of a given nutrient is used by an entire region of the country, the values shown are totals. That is, the estimated nutrient for each golf course in the region is summed together. Total nutrient use data for a region is based on the nutrient use for each golf course in the region, multiplied by the number of golf courses in the region.

To understand how the typical, or average golf course behaves, however, two different statistics are used. With the exception of nutrient rate data, all of the "average" data presented in this report is reported in the form of a statistic known as the mean. However, the nutrient rate data is reported in the form of a different statistic, known as the median. The median is the value at the midpoint of a data set: half of the population is higher than the median, and half is lower. The median is used to represent the most "average" number in a data set, and is probably most familiar to those of you who track real estate prices (as in the "median price of new homes") or household income.

Although the mean and the median are frequently very close in value to one another, there are important differences. First, they are calculated differently. The median is the value at which half of the population is above it, and half is below it. The mean is the sum of all of the numbers in a data set, divided by the number of values in the data set. Second, they perform differently when unusually high or low values are compared to the rest of the data set. When these are present, the data set is said to be "skewed."

The mean has the disadvantage of being heavily influenced by very high or low values, so that it provides a distorted measurement of the "average" when the data is skewed. The median is less influenced and is therefore considered the best estimate of the "average" of a data set when the data distribution is skewed.

Because the nutrient rate data from this survey tended to be skewed, with the bulk of the data bunched together on the low end of the scale, and fewer values at the high end, the median is the most accurate estimate of average behavior for the nutrient rate values presented in this report.

% of facilities applying fertilizer to each feature

Golf course feature	Nitrogen		Phosphate		Potash	
	2006	2014	2006	2014	2006	2014
Greens	98 a	98 a	93 b	80 a	96 b	95 a
Tees	97 a	96 a	90 b	66 a	95 b	90 a
Fairways	97 b	95 a	85 b	54 a	94 b	86 a
Roughs	80 b	74 a	68 b	37 a	76 b	64 a

Table 1. Percent of 18-hole facilities that apply fertilizer to each feature. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

Changes in total nutrient use: 2006-2014

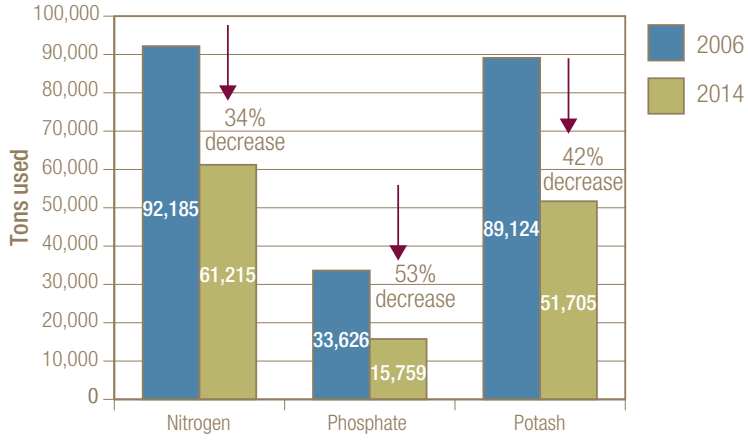

Figure 1. Changes in total nutrient use for nitrogen, phosphate and potash: 2006 vs. 2014.

Factors in nutrient use reduction: 2006-2014

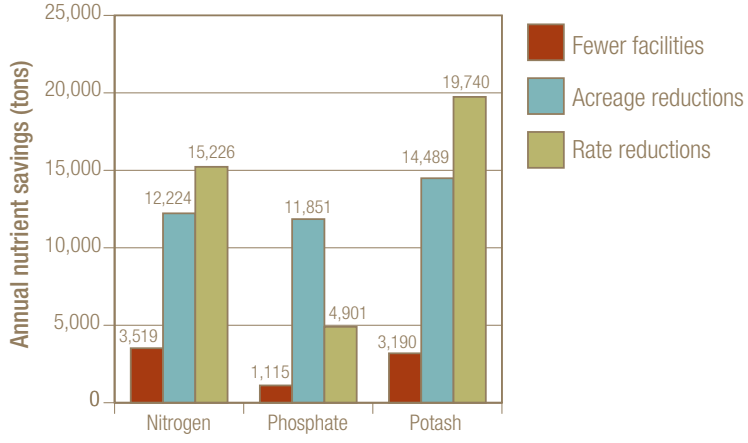

Figure 2. Factors contributing to decreased nutrient use, 2006-2014. Reductions in nutrient rates and acreages were responsible for over 90% of the decreases in total nutrient use since 2006.

- the role of conservation and agronomic practices on nutrient use patterns
- the role of external factors such as regulations, economics and research advances on nutrient use patterns
- trends in the use of different nutrient sources and amendments
- trends in storage and calibration of fertilizer equipment

RESULTS

National Nutrient Use

- U.S. golf courses have decreased their nutrient use since 2006 (Figure 1), with annual reductions of 34% (30,970 tons) for nitrogen, 53% (17,867 tons) for phosphate and 42% (37, 419 tons) for potash (Figure 1, Table A1).
- All seven agronomic regions have recorded decreases in total nitrogen, phosphate and potash use since 2006.

Factors Influencing National Nutrient Use Trends

Nutrient use decreases occurred as a result of three major factors (Table A2, Figure 2). Voluntary reductions in nutrient use rates (Table 2) and in the number of fertilized acres (Figure 3, Table A3) were responsible for over 90% of the observed decline in total nutrient use. A decrease in the number of facilities was responsible for approximately 9% of the observed decrease in total nutrient use (Table A4).

Reduced nutrient use rates

Nitrogen use rates were reduced by 13% to 30%, depending on the region (Table 2), resulting in savings of an estimated 15,226 tons of nitrogen per year (Table A2).

- The greatest reductions in nitrogen use rates occurred in the Southeast, Southwest and Upper West/Mountain regions (Table 2).
- Nitrogen use rates were highest on greens, and consecutively lower on tees, practice areas, fairways, grounds and roughs (Figure 4, Table A5).
- Nitrogen use rates were correlated with the length of the growing season, with the highest rates occurring in regions having the longest growing seasons (Table 2).

Phosphate use rates were reduced by 39% to 75%, depending on the region (Table 2), resulting in savings of an estimated 4,901 tons of phosphate per year (Table A2).

- Increases in government restrictions on the use of phosphate (Table 3) are an important factor in this large decrease.
- The greatest reductions in phosphate use rates occurred in the Northeast, Transition, North

Nutrient use rates and climatic factors

Region	Nitrogen			Phosphate			Potash			Climate	
	2006	2014	% change	2006	2014	% change	2006	2014	% change	Active turf growth (months)	Average temp (F)
	Pounds/1,000 square feet			Pounds/1,000 square feet			Pounds/1,000 square feet				
North Central	**2.22 a**	**1.70 a***	23	**0.53 a**	**0.16 a***	70	**1.78 a**	**1.02 ab***	44	5-7	48
Northeast	**2.33 ab**	**1.93 ab***	17	**0.72 b**	**0.18 a***	75	**1.93 a**	**1.31 bc***	33	6-7	50
Pacific	2.55 bc	2.23 b	13	**0.80 bc**	**0.46 bcd***	43	**2.08 ab**	**1.34 bcd***	38	7-11	55
Southeast	**4.22 d**	**2.95 c***	30	**1.18 d**	**0.50 cd***	58	**4.36 d**	**2.63 e***	40	12	68
Southwest	**4.22 d**	**3.14 c***	26	**1.43 d**	**0.88 d***	39	**3.44 c**	**2.15 de***	36	12	66
Transition	**2.51 bc**	**2.13 b***	15	**0.93 c**	**0.28 abc***	70	**2.32 b**	**1.47 cd***	35	9	57
Upper West/ Mountain	**2.73 c**	**2.03 ab***	26	**0.76 bc**	**0.25 ab***	67	**2.07 ab**	**0.87 a***	57	5-9	49
U.S.	**2.75**	**2.17***	21	**0.82**	**0.30***	63	**2.38**	**1.47***	39		

Table 2. Nutrient use rates in 2006 vs. 2014 for 18-hole golf courses, and the climatic factors that affect them. For each 2006 vs. 2014 comparison, values in bold type with the lower value followed by an asterisk indicate that there was a significant difference between the 2006 and 2014 values ($P \leq 0.10$). Reading down each column, values followed by the same letter are not significantly different at the 90% confidence level. All values shown are medians.

Central and Upper West/Mountain regions.

- Phosphate use rates were highest on greens, and consecutively lower on tees and practice areas, fairways and grounds and roughs (Figure 4, Table A6).

Potash use rates were reduced by 33% to 57%, depending on the region (Table 2), resulting in savings of an estimated 19,740 tons of potash per year (Table A2).

- The greatest reductions in potash use rates occurred in the Upper West/Mountain region (Table 2).
- Potash use rates were highest on greens, and consecutively lower on tees, practice areas, fairways, grounds and roughs (Table A7).

Nutrient ratios

In the period between 2006 and 2014, there was also a change in the relative ratios of nitrogen, phosphate and potash, such that there were lower percentages of phosphate and potash used in 2014. This change is, presumably, a reflection of regulatory pressures that have caused both fertilizer manufacturers and golf course superintendents to shift toward lower use rates, particularly of phosphate (Table A8). See the sidebar, "Interpreting fertilizer application ratios" for further discussion on this topic.

Reductions in number of fertilized acres

- An estimated 4,166 or 27% of U.S. golf courses reduced their fertilized acreages between 2009 and 2014, which resulted in a 16% reduction in acres fertilized with nitrogen, a 46% reduction in acres fertilized with phosphate, and a 22% reduction in acres fer-

Reductions in fertilized acres: 2009-2014

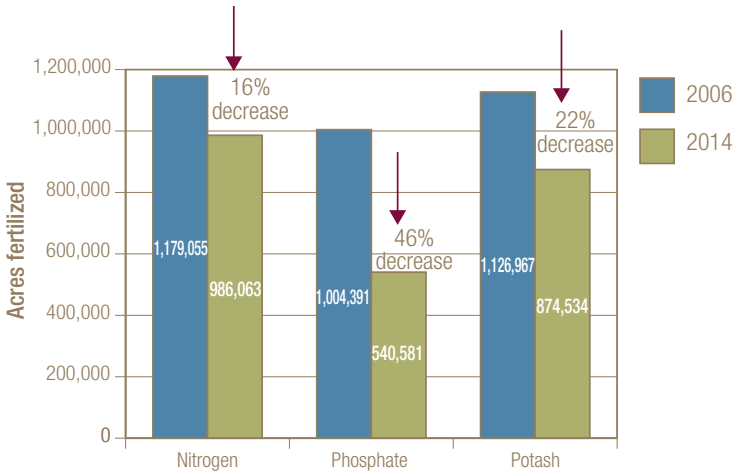

Figure 3. Voluntary reductions in the number of acres fertilized on golf courses, made from 2009 to 2014.

Interpreting fertilizer application ratios

The ratio of nitrogen to phosphate to potassium is a key factor in fertilizer formulation and turfgrass fertilizer management.

In general, turfgrass tissues contain approximately eight parts nitrogen, one part phosphate and four parts potassium (expressed as 8:1:4). This can be used as rough guideline for optimizing fertilizer ratios. For example, ratios with nitrogen to phosphate values that are lower than 8:1:4 (for example, 4:1:4) indicate excessive phosphorus may have been applied, whereas ratios with nitrogen to phosphate values that are higher than 8:1:4 (for example, 10:1:3), have a reduced likelihood of causing phosphate runoff problems.

Median U.S. nutrient use rates per golf course feature

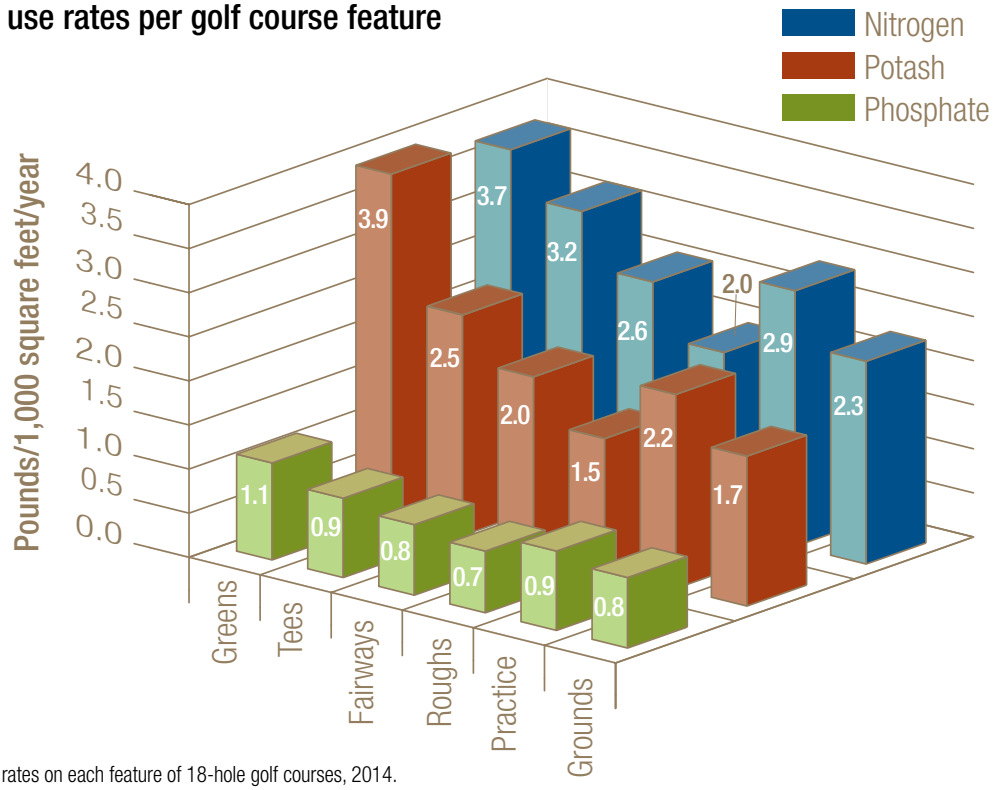

Figure 4. Median U.S. nutrient use rates on each feature of 18-hole golf courses, 2014.

tilized with potash (Figure 3, Table A3).
- Greens were the most likely feature to be fertilized, and roughs the least likely (Table 1).
- The amount of nitrogen, phosphate and potash saved as a result of acreage reductions was estimated to be 12,224, 11,851 and 14,489 tons per year, respectively (Table A3).

Conservation

- The reductions in nutrient rates and fertilized acres described above were responsible for approximately 90% of the observed nutrient savings, and came about through increased implementation of nutrient conservation practices.
- The most common conservation practices (Figure A1) included:
  - o avoiding overseeding
  - o fertilizing based on soil test results
  - o returning clippings
  - o precision fertilizer application

Trends in overseeding

- Winter overseeding of warm-season turf with cool-season turf results in the use of significantly more nitrogen, phosphate and potash (Figure 5).
- Winter overseeding was most common in the Southwest and Southeast regions, and the features most likely to be overseeded were tees, while the least likely were roughs (Table A9).
- In 2014, over 40% of respondents in the Southwest and Southeast regions either stopped or reduced overseeding (Table A9).

Surprising results on the impact of soil tests

- When asked what practices were used to reduce reliance on fertilizers, the most common response was the use of soil tests to determine fertilization rates (Figure A1).
- In 2014, greens were the most frequently tested feature, followed in descending order by fairways, tees and roughs (Table A10).
- Since 2006, there has been a small decrease in the number of golf courses conducting soil testing on all features and in all regions (Table A10).
- Surprisingly, the survey shows that golf courses conducting soil tests tend to use higher rates of nutrients than those that do not soil test (Table A11).
- These higher rates may stem from the fact that some turf soil guidelines currently in use target higher nutrient levels than are required for acceptable turf growth. This issue will be discussed further in the "New soil guidelines" section below.

Facility closures

Fertilized turf acreages were further reduced because there was a net decrease of 618 golf facili-

ties nationally between 2006 and 2014 (Table A4).

- All regions except the Upper West/Mountain had decreases in the number of facilities.
- The North Central, Southeast and Transition regions had the greatest decreases in the number of facilities.
- Estimated annual nutrient savings as a result of decreased facility numbers were 3,519 tons of nitrogen, 1,115 tons of phosphate and 3,190 tons of potash (Figure 2, Table A2).

FACTORS IN NUTRIENT USE DECISIONS

Development of new soil guidelines

- Superintendents use university manufacturer and consultant recommendations to develop nutrient management programs (Table A12). However, soil nutrient guidelines developed in the past tended to target higher levels of nutrients than may be required (2). In some cases, this may have resulted in the use of higher nutrient use rates than were absolutely necessary.
- Recent research has identified soil nutrient guidelines (such as the Minimum Levels for Sustainable Nutrition [MLSN]) that, although targeting lower use patterns than those previously identified, do not appear to sacrifice turf health or playability (2).
- Adoption of these newer guidelines should help to reverse the unexpected trend described above, where those who conduct soil tests apply more, rather than less nutrients per year.

Regulatory restrictions

- Respondents reported the increased importance, since 2006, of regulatory requirements in making nutrient applications decisions (Table A12).
- Restrictions on the use of phosphate far outstripped any others (Table 3) because of increasing concerns about the role of phosphorus in eutrophication and decreased quality of water sources.
- Of those who reported some type of nutrient restriction, phosphate restrictions were most frequently reported from the Pacific region (94%), followed by the North Central (93%), Northeast (89%), Transition (74%), Southeast (53%), Upper West/Mountain (36%) and Southwest (0%) regions.
- These restrictions had a significant impact in both 2006 and 2014 on lowering nutrient use rates (Figure 6).
- The frequency with which nutrient management plans and programs were developed has not increased since 2006. In 2014, these plans and programs were much more likely to be

Effects of overseeding

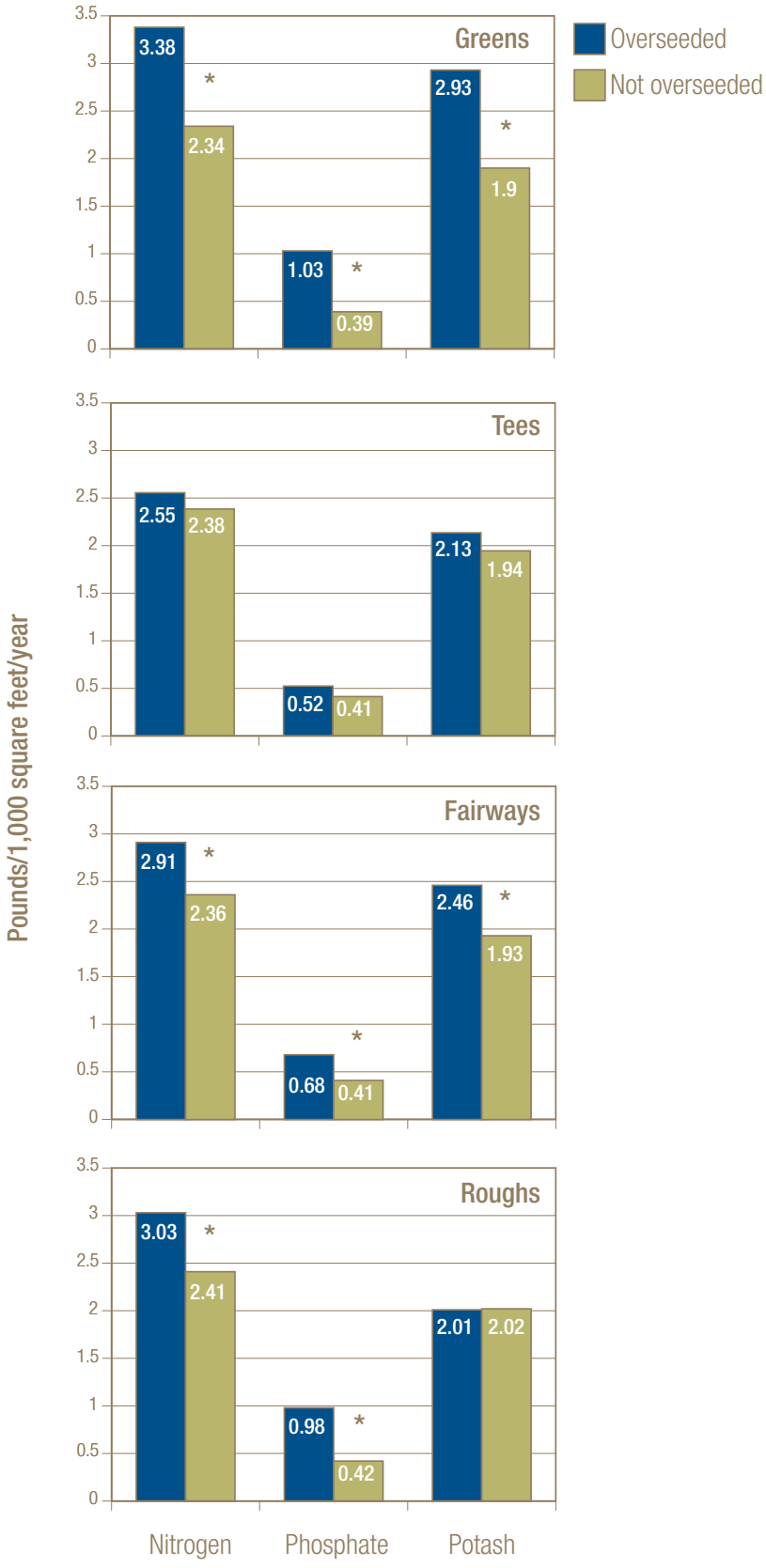

Figure 5. Increased nutrient use rates caused by overseeding in the Southwest, Southeast and Transition regions. All values shown are medians. An asterisk indicates a significant difference between overseeded and non-overseeded rates.

Restrictions on fertilizer applications

Restriction type	% of 18 hole facilities with restriction	
	2006	2014
Nutrient restrictions of any type	8 a	24 b
Phosphorus (total yearly amount or amount/ application)	5 a	19 b
Required buffer strips	3 a	8 b
Date restrictions for applications	<1 a	8 b
No-apply zones	2 a	7 b
Nitrogen (total yearly amount or amount/application)	2 a	6 b
Regional/state stormwater management plan	2 a	5 b
Potassium (total yearly amount or amount/application)	<1 a	<1 a

Table 3. Types of federal, state, local government or tribal authority restrictions on fertilizer applications reported by 18-hole facilities. Values within each two-column row that are followed by the same letter are not significantly different at the 90% confidence level.

Effects of legal restrictions

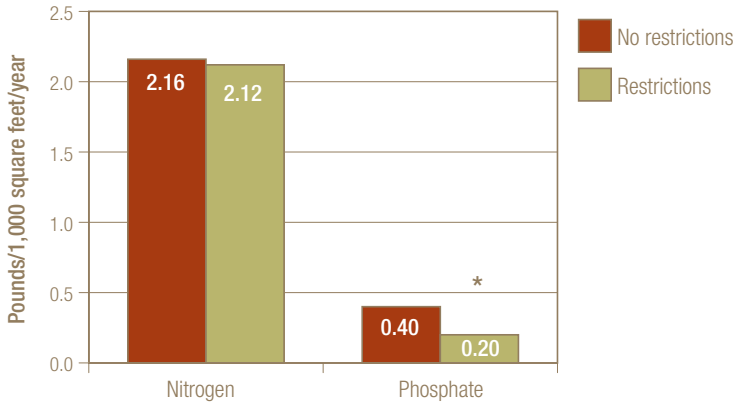

Figure 6. Effect of federal, state, tribal and/or local restrictions on nutrient use on 18-hole golf courses in 2014. An asterisk indicates a significant difference between nutrient use rates on golf courses with restrictions and those without restrictions.

developed than written regional guidelines for BMPs (best management practices Table A13).

Economics

- As described above, the net decrease of 618 golf facilities since 2006, which was largely triggered by the Great Recession, has driven about 9% of the nutrient use reductions reported here (Figure 2, Table A2).
- In addition, survey respondents reported that fertilizer cost has grown in importance as a factor in nutrient use decisions (Table A12).
- This observation is further supported by the U.S. Department of Agriculture's Economic Research Service, which reported that the average cost of phosphate- and potassium-based fertilizers increased by more than 100% between 2006 and 2013 (the last year that data was collected), and the cost of nitrogen-based fertilizers has increased by over 60% (1).
- Golf course size also has an impact, with nine- and 18-hole golf courses using significantly less nitrogen and potash per unit area than golf courses with 27+ holes. Public golf courses used significantly less nitrogen and potash per unit area than private golf courses (Table A14).

NUTRIENT MANAGEMENT DECISION MAKING

- The most common factors involved in making nutrient application decisions (Table A12) were:
  - o weather
  - o visual observation/scouting
  - o previous product performance
  - o soil analysis
  - o disease problems
- There was little change in the importance of these factors from 2006. to 2014.
- The greatest changes since 2006 have occurred in the increased importance of fertilizer cost, regulatory requirements, university recommendations and property owners' maintenance standards (Table A12).

NITROGEN SOURCES, AMENDMENTS AND SUPPLEMENTS

Organic fertilizers

- Organic fertilizers (materials derived from either plant or animal products containing one or more elements, other than carbon, hydrogen or oxygen, which are essential for plant growth) were used on 64% of all golf courses in 2014, which is consistent with use in 2006 (Table A15).

- Organic products based on animal waste were used by 65% of those who apply organic fertilizers, making this the most common source, followed by local sewage sludge (39%), crop products such as soybean or corn meal (14%), or food waste, including composted products (13%).
- Relatively high percentages of phosphate in some organic fertilizer sources may limit their further adoption, because of increasing restrictions on the use of phosphate.

Slow-release vs. quick-release nitrogen

- Nitrogen fertilizers are available in quick-release (water-soluble) formulations, as well as slow-release (water-insoluble) formulations.
- In 2014, two-thirds of all nitrogen was applied as slow-release, and one-third as a quick-release formulation, representing little change in use patterns since 2006 (Table A16).
- It is notable that in both 2006 and 2014, the Southwest region reported the highest percentage use of quick-release nitrogen. It is likely that this region's low annual rainfall is responsible for this trend, since quick-release nitrogen is less likely to move to surface or ground water in low-rainfall areas and quick-release nitrogen products are typically less expensive per unit of fertilizer.
- The popularity of slow-release (water-insoluble) products is based on convenience (since fewer applications are required), decreased risk of foliage burn, and decreased likelihood of leaching into groundwater when used properly. Their cost is higher, however, which may explain their flat adoption rate during the years of the Great Recession.

Amendments and supplements

- A wide variety of amendments and supplements are applied to improve physical and chemical properties of the soil.
- In 2014, the most commonly applied products included humic materials, amino acids/proteins, gypsum and biostimulants (Table A17).
- The greatest increase in adoption since 2006 has occurred for sulfur, compost teas, calcium chloride, microbial inoculants and gypsum (Table A17).

FERTILIZER APPLICATION AND STORAGE

Calibration

- Calibration of fertilizer equipment helps ensure that fertilizer is not being applied at either too high or too low a rate.
- The frequency with which equipment was calibrated prior to use has changed little since 2006 (Table A18).
- Fairway and rough applications were more frequently calibrated than applications for greens and tees (Table A18). This may be due to the much larger fertilized acreages associated with those features, and therefore greater economic and environmental incentives for accuracy.

Application frequency

- In 2014, the number of annual fertilizer applications increased for all features except roughs (Table A19). This trend, when combined with data illustrating large decreases in nutrient rates (Table 2), indicates that superintendents are applying smaller amounts of fertilizer at higher frequencies than in the past. This has multiple benefits, including:
  - minimized potential nutrient runoff
  - more precise calibration of fertilizer rates to turf growth
  - better management of clippings
- As might be expected, regions with the longest growing season and highest rainfall, such as the Southeast, had the highest number of fertilizer applications per year, especially on greens, while cooler regions with fewer months of active turfgrass growth had the lowest number of applications.
- Greens received by far more fertilizer applications than any other golf course feature. This is to be expected, partly because greens receive the most traffic and are treated with higher rates of fertilizer (Tables A6-A8). More applications also allow fertilizer to be dispensed in smaller doses as a means of preventing growth surges.

Storage

- Improved fertilizer storage facilities help limit the risk of accidental environmental contamination.
- Since 2006, there has been an increase — from 46% to 65% — in the number of golf courses storing fertilizer in a facility designed for fertilizer storage (Table A20) that, at a minimum, has an impervious floor, a cover, ventilation, security (locked with access restricted), and containment features to prevent loss to the environment and/or contamination from runoff.

REGIONAL NUTRIENT USE SUMMARY

The sections that follow provide detailed accounts of the nutrient use patterns for each of the survey's seven agronomic regions. Some of the key regional results are listed below.

Current status

- Nutrient use patterns varied dramatically among the nation's seven agronomic regions (Table 2, Table A1, Figure 7).
- Climate was by far the most important factor influencing these diverse nutrient use patterns.
  - o For example, the lowest nutrient rates for 2014 were observed in the North Central and Northeast regions, which have the coolest average temperatures, and the shortest periods of active turf growth.
  - o The highest nutrient rates occurred in the Southeast and Southwest regions, which have the longest active growth periods and highest average temperatures (Table 2).
- Frequent use of overseeding in the Southwest and Southeast, as well as widespread use of high nitrogen-requiring bermudagrass, also contributes to higher nutrient rates in those two regions.

2006 vs. 2014

- Total nutrient use
  - o All regions reported large decreases in total nitrogen, phosphate and potash use (Table A1).
  - o The greatest percentage decreases for total nitrogen use occurred in the Southeast region, for phosphate use in the North Central and Northeast regions, and for potash use in the Southwest and Southeast regions (Table A1).
- Nutrient rates
  - o All regions reported significant decreases in the rates of nitrogen, phosphate or potash used (Table 2).
  - o The greatest percentage decreases for nitrogen rate occurred in the Southeast region, for phosphate rate in the North Central and Transition regions, and for potash in the Upper West/Mountain region (Table 2).
- Number of fertilized acres
  - o All regions reported significant reductions in the number of acres fertilized with nitrogen, phosphate and/or potash (Table A3).
  - o The greatest decreases in the percentage of acres fertilized with nitrogen and potash occurred in the Southwest region, and the greatest decreases in the percentage of acres fertilized with phosphate occurred in the North Central and Northeast regions (Table A3).

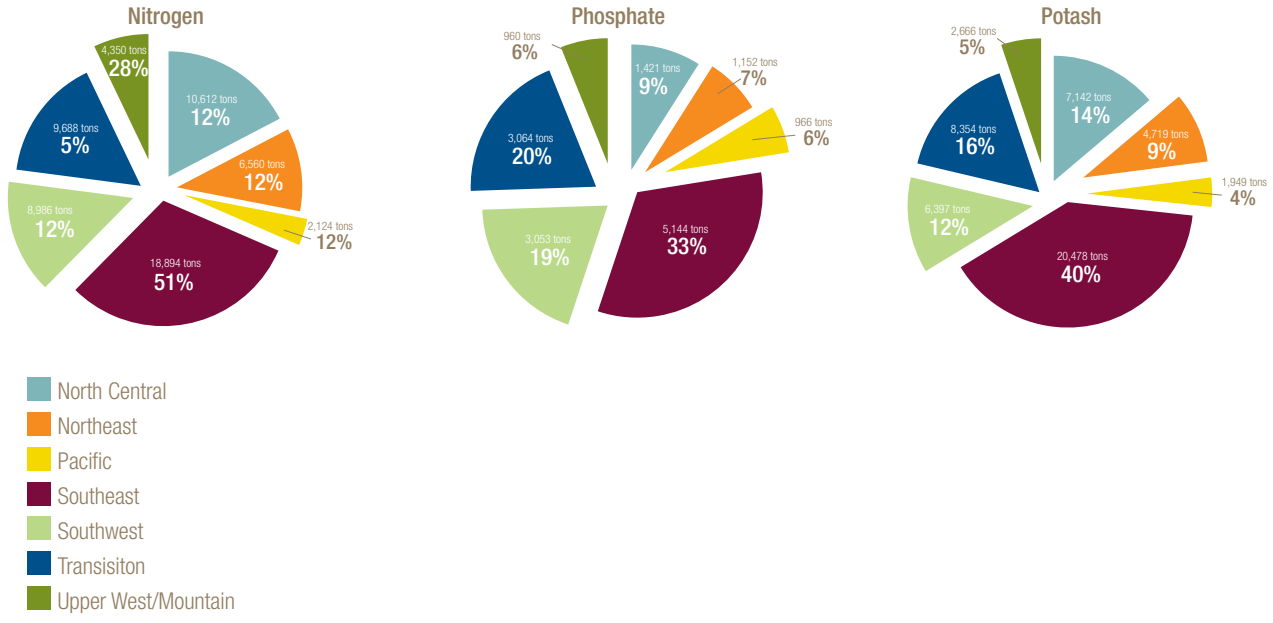

Figure 7. Total nutrient use, and percent nutrient use by region, 2014.

Nutrient use patterns for the North Central region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds 1,000 square feet)	North Central	2.22	1.70	-23	0.53	0.16	-70	1.78	1.00	-44
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	North Central	15,047	10,612	-30	4,657	1,421	-70	11,960	7,142	-40
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	North Central	279,185	230,025	-18	222,890	87,951	-61	264,087	199,216	-25
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 4. Nutrient use patterns in 2006 vs. 2014 for the North Central region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

NORTH CENTRAL REGION

Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the North Central region decreased by 30%, while phosphate decreased by 70% and potash use by 40% (Table A1, Table 4).
  - o The North Central region had the largest decrease in total phosphate use in the nation from 2006 to 2014 (Table A1).
  - o Total nutrient use is influenced by the large number of golf courses in the region (Table A4), which pushes total tons used upward, but the total is also influenced by the low nutrient rates (Figure 8, Table 2) that are used.
- Rates of nitrogen, phosphate and potash all decreased significantly between 2006 and 2014 (Figure 8, Table 4).
  - o The North Central region tied with the Transition region for the largest decrease in phosphate rates (Table 2).
  - o The North Central region had the lowest nutrient use rates in the nation in both 2006 and 2014. This is largely due to the cool climate and short growing season (Table 5) in this region.
- The number of acres treated with fertilizer dropped dramatically, especially for phosphate (Figure 8). The North Central and Northeast regions were tied for the greatest percentage reduction in total number of acres fertilized with phosphate (Figure 8, Table A3)
- These nutrient use patterns are due to a combination of factors.
  - o Restrictions on the use of phosphate were reported by 93% of respondents who reported some type of nutrient restrictions.
  - o Conservation efforts, such as reducing nutrient rates and reducing numbers of fertilized acres, were the major contributors to the large drop in total nutrient use from 2006 to 2014.

Factors in nutrient use reduction: North Central region

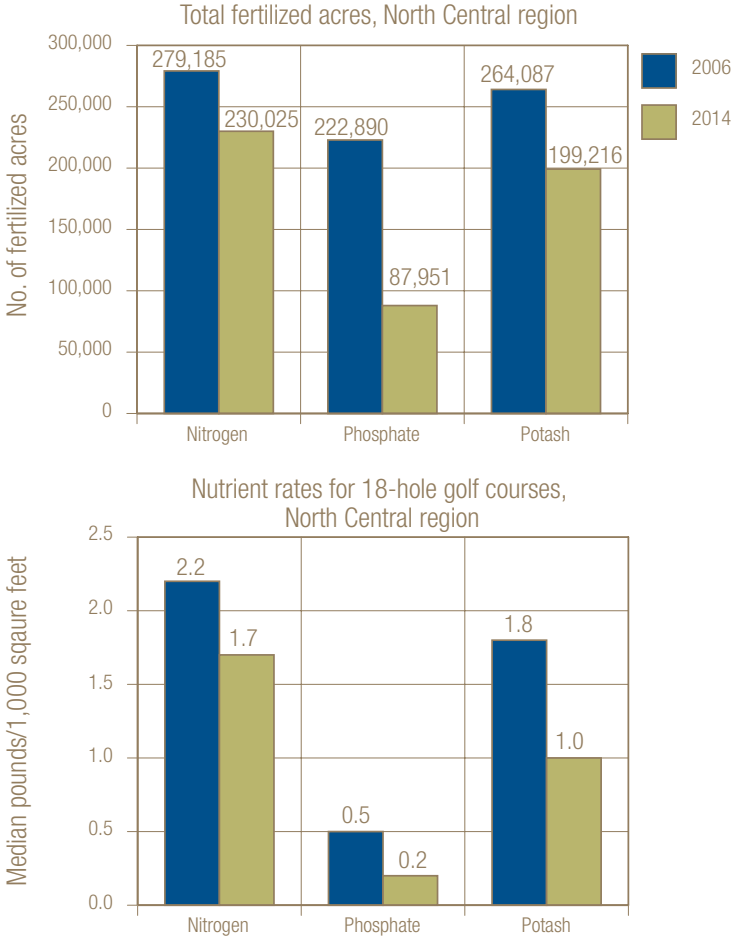

Figure 8. Major factors in nutrient use reductions for the North Central region. Since 2006, reductions in the number of fertilized acres and in nutrient rates had the greatest influence on reductions in total nutrient use.

Variation in growing season: North Central region

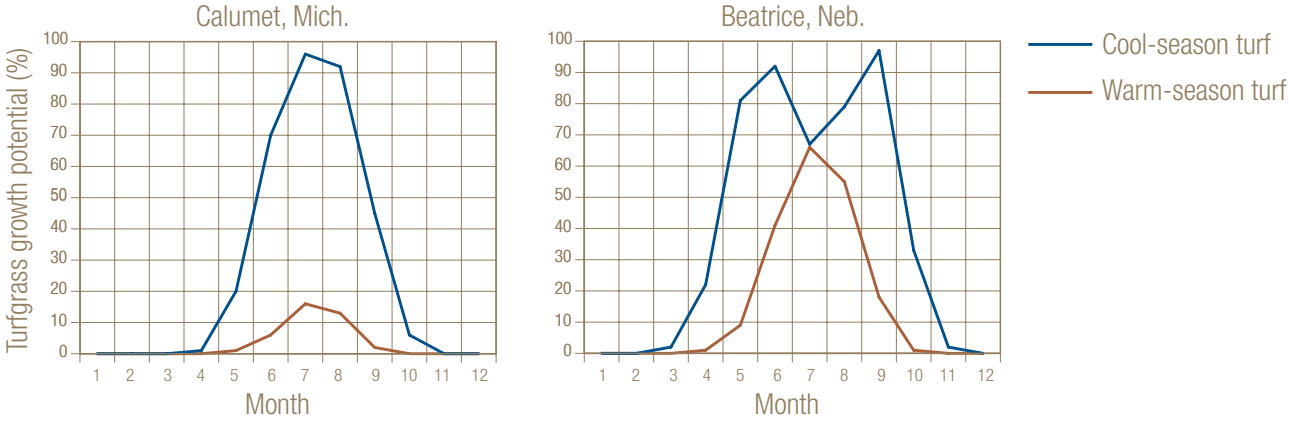

Figure 9. Variation in growing season in the North Central region. The turf growing season ranges from approximately five to seven months. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in North Central region climate

	Lowest	Highest
Average temperature (F)	37.6	53.7
Rainfall (feet)	1.5	3.9
Active turf growth (months)	5	7

Table 5. Variation in North Central region climate. Temperature and rainfall values are based on 30-year normal annual average temperatures.

- o Facility closures played a smaller, but significant role, contributing approximately 16% to total nitrogen use reductions, 6% to total phosphate reductions and 10% to total potash reductions.
- o The region's moderate temperatures and five- to seven-month growing season allow facilities to fertilize less than warmer regions that have longer growing seasons.

Climate

- Average temperatures in the North Central region are some of the coolest in the U.S., and have a relatively small range, from a low of 37.6 F to a high of 53.7 F, depending on the location (Table 5).
- Rainfall is moderate, with average levels ranging from 1.5 feet to 3.9 feet per year, depending on location (Table 5).
- The homogeneity in climatic conditions across this region results in a smaller range of nutrient usage within the region than most other regions of the country.
- In cooler areas of the North Central region such as Calumet, Mich., turf is actively growing for an average of five months per year, while warmer locations such as Beatrice, Neb., show active turf growth for approximately seven months (Figure 9).

Nutrient use patterns for the Northeast region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds/1,000 square feet) for 18-hole facilities	Northeast	2.33	1.93	-17	0.72	0.18	-75	1.93	1.30	-33
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	Northeast	9,139	6,560	-28	3,483	1,152	-67	8.090	4,719	-42
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	Northeast	161,846	134,774	-17	143,916	57,360	-60	157,981	121,645	-23
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 6. Nutrient use patterns in 2006 vs. 2014 for the Northeast region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

NORTHEAST REGION

Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the Northeast region decreased by 28%, while phosphate decreased by 67% and potash use by 42% (Table A1, Table 6).
- Rates of nitrogen, phosphate and potash all decreased significantly between 2006 and 2014 (Figure 10, Table 6).
- The number of acres treated with fertilizer dropped dramatically, especially for phosphate (Figure 10, Table A3). The Northeast region and the North Central region had the greatest percentage reduction in number of acres fertilized with phosphate.
- These nutrient use patterns are due to a combination of factors.
  - o Conservation efforts, such as reduced nutrient rates and reduced numbers of fertilized acres, were the major contributors to the large drop in total nutrient use from 2006 to 2014.
  - o Facility closures played a smaller, but significant role, contributing approximately 6% to total nitrogen use reductions, 2% to total phosphate reductions and 4% to total potash reductions.
  - o Restrictions on the use of phosphate were reported by 89% of those respondents who reported some type of nutrient restrictions.
  - o The region's moderate temperatures and six- to seven-month growing season allow facilities to fertilize less than warmer regions that have longer growing seasons.

Climate

- Average temperatures in the Northeast region are cool and have a relatively small range, from a low of 38.4 F to a high of 56.2 F, depending on the location (Table 7).

Factors in nutrient use reduction: Northeast region

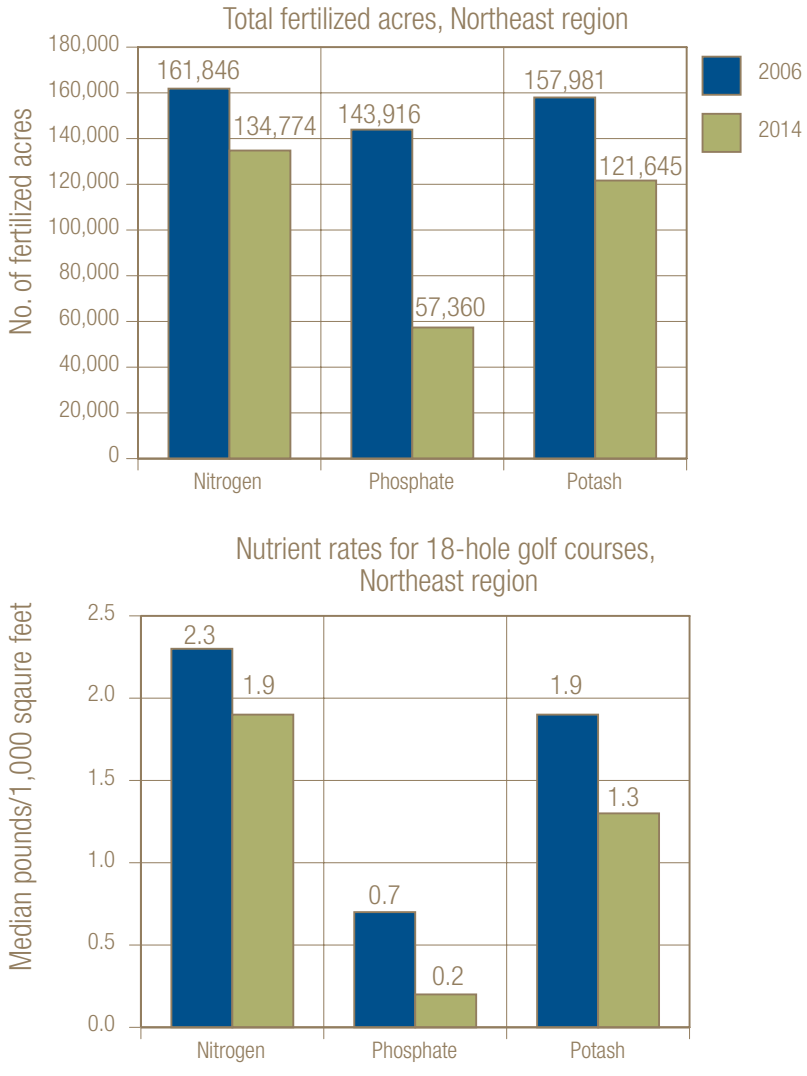

Figure 10. Major factors in nutrient use reductions for the Northeast region, 2006 vs. 2014. Since 2006, conservation practices such as reductions in the number of fertilized acres and in nutrient rates were the major contributors to reductions in total nutrient use.

Variation in growing season: Northeast region

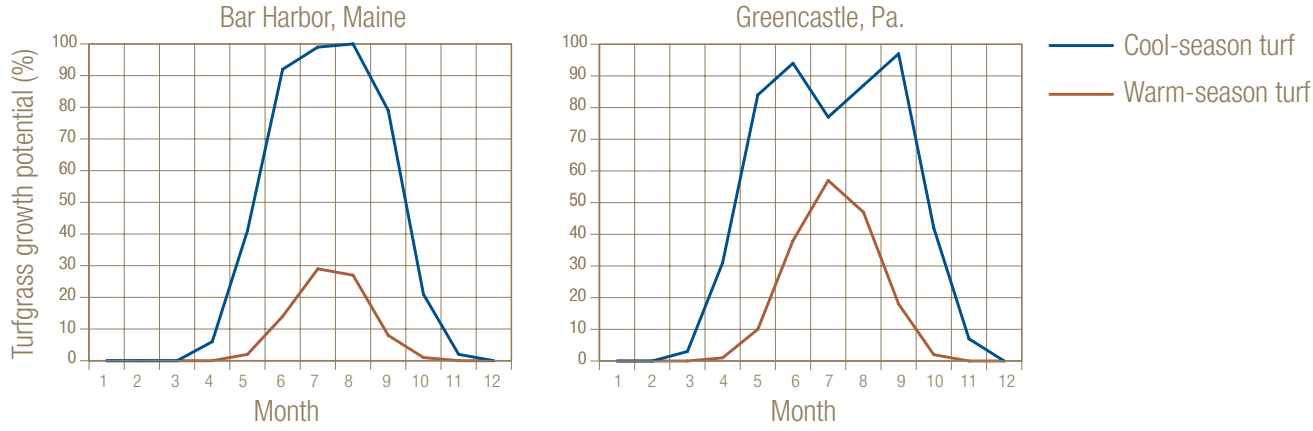

Figure 11. Variation in growing season in the Northeast region. The turf growing season ranges from approximately six to seven months. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in Northeast region climate

	Lowest	Highest
Average temperature (F)	38.4	56.2
Rainfall (feet)	2.7	4.6
Active turf growth (months)	6	7

Table 7. Variation in climate in the Northeast region. Temperature and rainfall values are based on 30-year normal annual average temperatures.

- Rainfall is moderate to substantial, with average levels ranging from 2.7 feet to 4.6 feet per year, depending on location (Table 7).
- In cooler areas of the Northeast region such as Bar Harbor, Maine, turf is actively growing for an average of six months per year, while warmer locations such as Greencastle, Pa., show active turf growth for approximately seven months per year (Figure 11).

Nutrient use patterns for the Pacific region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds/1,000 square feet for 18-hole facilities	Pacific	2.55	2.23	-13	0.80	0.46	-43	2.08	1.30	-38
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	Pacific	3,110	2,124	-32	1,123	966	-14	2,697	1,949	-28
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	Pacific	42,969	34,707	-19	41,553	27,546	-34	42,467	31,495	-26
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 8. Nutrient use patterns in 2006 vs. 2014 for the Pacific region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

PACIFIC REGION

Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the Pacific region decreased by 32%, while phosphate decreased by 14% and potash use by 28% (Table A1, Table 8). The Pacific region had the lowest total usage of all three nutrients in both 2006 and 2014 (Table A1). This is primarily due to the small number of facilities in this region (Table A4).
- The rates of all three nutrients used decreased between 2006 and 2014 (Figure 12, Table 8), but only phosphate and potash decreased significantly.
- The number of acres treated with fertilizer also decreased, especially for phosphate (Figure 12).
- These nutrient use patterns are due to a combination of factors.
  - o Conservation efforts, such as reduced nutrient rates and reduced numbers of fertilized acres, were the major contributors to the large drop in total nutrient use from 2006 to 2014.
  - o Facility closures played a smaller, but significant role, contributing approximately 7% to total nitrogen use reductions, 15% to total phosphate reductions and 7% to total potash reductions.
  - o Restrictions on the use of phosphate were common, cited by 94% of respondents who reported some type of nutrient restrictions. This was the highest incidence of phosphate regulations in the country.
  - o The region's heterogeneous climate produced a wide range of nutrient use patterns.

Factors in nutrient use reductions: Pacific region

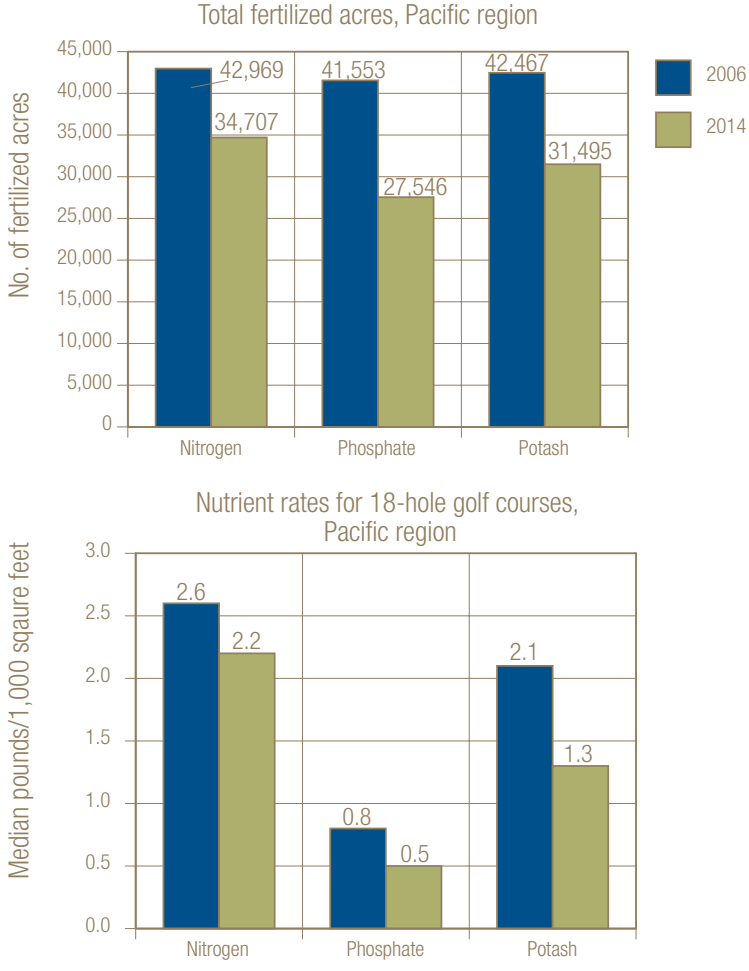

Figure 12. Major factors in nutrient use reductions for the Pacific region, 2006 vs. 2014. Since 2006, conservation practices such as reductions in the number of fertilized acres and in nutrient rates were the major contributors to reductions in total nutrient use.

Variation in growing season: Pacific region

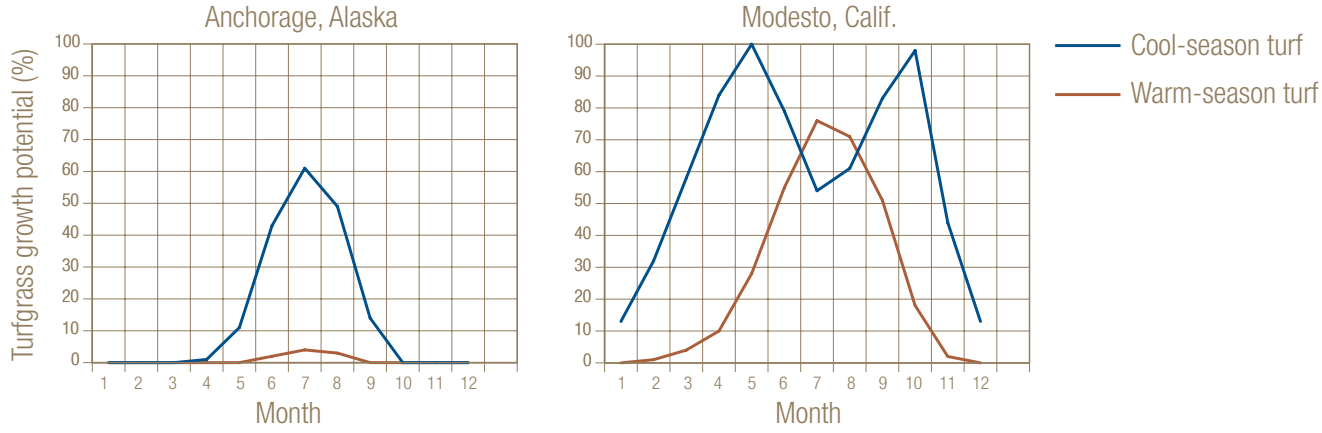

Figure 13. Variation in growing season in the Pacific region. The turf growing season ranges from approximately four to 11 months in length. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in Pacific region climate

	Lowest	Highest
Average temperature (F)	34.0	62.1
Precipitation (feet)	0.8	14.2
Active turf growth (months)	4	11

Table 9. Variation in Pacific region climate. Temperature and rainfall values are based on 30-year normal annual average temperatures.

Climate

- The Pacific region covers a diverse area of the U.S. that ranges from the hot Central Valley of California, to the long winters of Alaska, to the cool redwood forests of Oregon.
- Average temperatures have a large range, from a low of 34.0 F to a high of 62.1 F, depending on the location (Table 9).
- Precipitation varies significantly, depending on the location, from some of the driest areas, which receive an average of only 0.8 foot per year, to areas with some of the highest precipitation in the country, which have a high of 14.2 feet per year (Table 9).
- Due to the variability in climatic conditions across this region, nutrient use patterns also vary considerably.
- In cooler areas of the Pacific region such as Anchorage, Alaska, turf is actively growing for an average of four months per year, while in warmer locations such as Modesto, Calif., turf growth is active for approximately 11 months (Figure 13). This is the broadest range of growing conditions among the seven agronomic regions.

Nutrient use patterns in 2006 vs. 2014 for the Southeast region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds/1,000 square feet) for 18-hole facilities	Southeast	4.22	2.95	-30	1.18	0.50	-58	4.36	2.60	-40
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	Southeast	32,532	18,894	-42	11,114	5,144	-54	37,246	20,478	-45
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	Southeast	280,685	234,015	-17	237,648	138,002	-42	268,337	219,974	-18
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 10. Nutrient use patterns in 2006 vs. 2014 for the Southeast region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

SOUTHEAST REGION

Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the Southeast region decreased by 42%, while phosphate use decreased by 54% and potash by 45% (Tables A1,10). The Southeast had the largest decrease in total nitrogen use of any other agronomic region, as well as the largest decrease in nitrogen rates (Tables A1,2).
- There were significant decreases in the rates of all three nutrients used between 2006 and 2014 (Figure 14, Table 10).
- The total number of acres treated with fertilizer also decreased, especially for phosphate (Figure 14). However, a high percentage of acres are still fertilized with nitrogen.
- These nutrient use patterns are due to a combination of factors.
  - o Conservation efforts, such as reduced nutrient rates and reduced numbers of fertilized acres, were the major contributors to the large drop in total nutrient use from 2006 to 2014.
  - o Facility closures played a smaller, but significant role, contributing approximately 13% to total nitrogen use reductions, 9% to total phosphate reductions and 11% to total potash reductions.
  - o Restrictions on the use of phosphate were reported by 53% of those respondents who reported some type of nutrient restrictions.
  - o The region's heterogeneous climate produced a wide range of nutrient use patterns.

Factors in nutrient use reductions: Southeast region

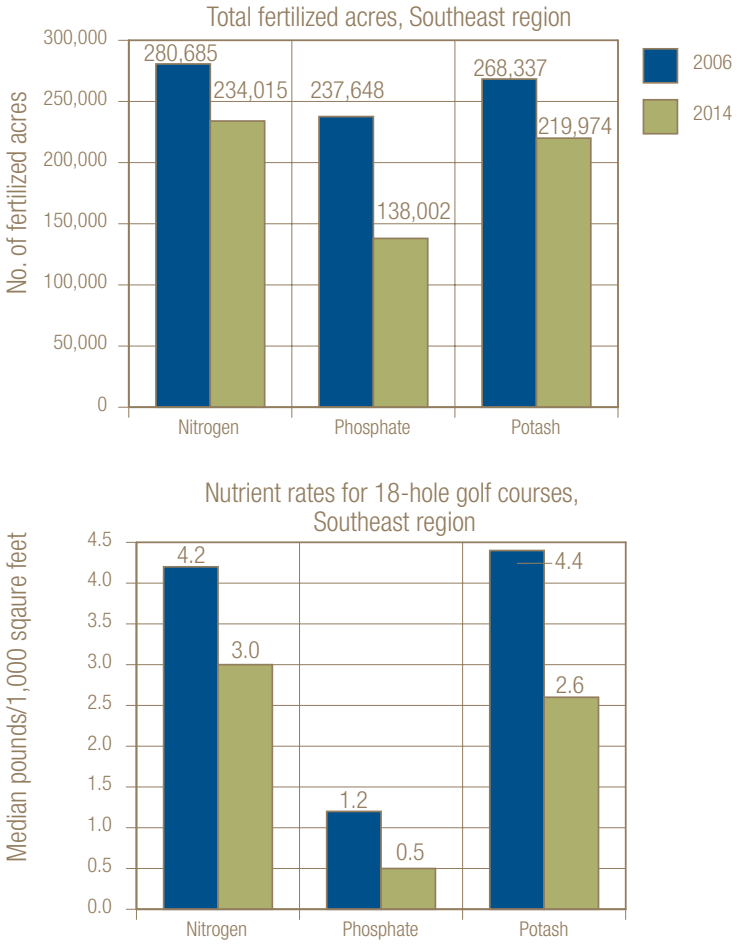

Figure 14. Major factors in nutrient use reductions for the Southeast region, 2006 vs. 2014. Since 2006, conservation practices such as reductions in the number of fertilized acres and in nutrient rates were the major contributors to reductions in total nutrient use.

Variation in growing season: Southeast region

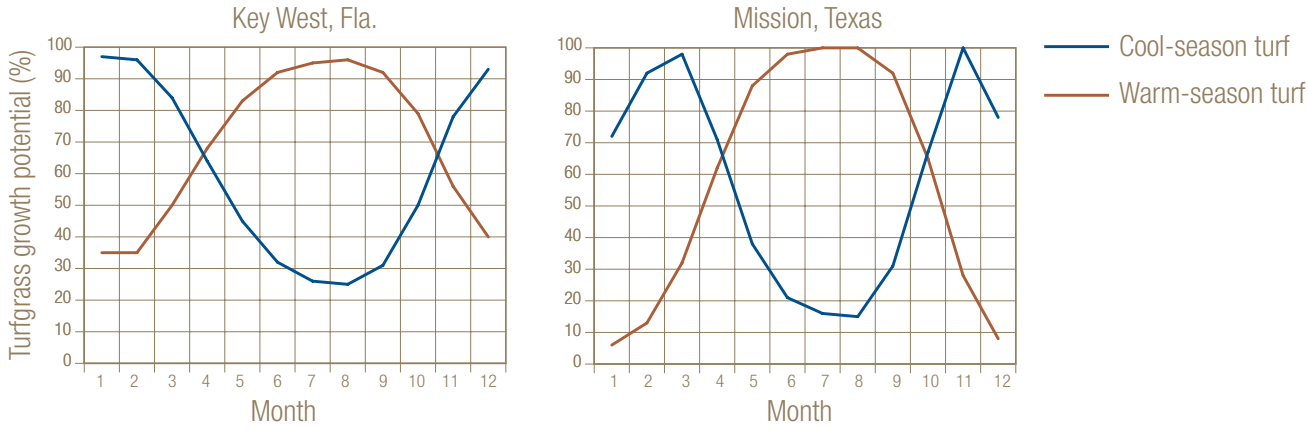

Figure 15. Variation in growing season in the Southeast region. The turf growing season is 12 months long in most locations. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in Southeast region climate

	Lowest	Highest
Average temperature (F)	45.8	77.8
Rainfall (feet)	1.7	5.7
Active turf growth (months)	12	12

Table 11. Variation in Southeast region climate. Temperature and rainfall values are based on 30-year normal annual average temperatures.

Climate

- Average temperatures in the Southeast region are the warmest in the country, and range very widely from 45.8 F all the way to 77.8 F, depending on location (Table 11).
- Rainfall varies from moderate to heavy, depending on location (Table 11).
- The climatic variability across this region led to a wide range of nutrient use patterns.
- Turf is actively growing 12 months of the year in most locations in this region (Figure 15).

Nutrient use patterns for the Southwest region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds/1,000 square feet) for 18-hole facilities	Southwest	4.22	3.14	-26	1.43	0.88	-39	3.44	2.20	-36
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	Southwest	13,247	8,986	-32	5,408	3,053	-44	12,127	6,397	-47
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	Southwest	118,683	93,383	-21	99,658	75,983	-24	113,167	81,642	-28
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 12. Nutrient use patterns in 2006 vs. 2014 for the Southwest region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

SOUTHWEST REGION
Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the Southwest region decreased by 32%, while phosphate use decreased by 44% and potash by 47% (Table A1, Table 12). The Southwest had the largest percentage decrease in total use of potash of any agronomic region (Table A1).
- The rates of all three nutrients used decreased significantly between 2006 and 2014 (Figure 16, Table 12).
- The number of acres treated with all three nutrients also decreased (Figure 16). The Southwest had the largest percentage decrease in number of acres treated with both nitrogen and potash (Table A3).
- These nutrient use patterns are due to a combination of factors.
  - o Conservation efforts, such as reduced nutrient rates and reduced numbers of fertilized acres, were the major contributor to the large drop in total nutrient use from 2006 to 2014.
  - o Facility closures played a smaller, but significant role, contributing approximately 3% to total nitrogen use reductions, 2% to total phosphate reductions and 2% to total potash reductions.
  - o Unlike survey respondents in other regions of the country, those from the Southwest reported no restrictions on the use of phosphate. This correlates with the observation that the Southwest also had the lowest percentage drop in phosphate rates and acres fertilized with phosphate (Tables 2,A3).
  - o The region's heterogeneous climate produced a wide range of nutrient use patterns.

Factors in nutrient use reductions: Southwest region

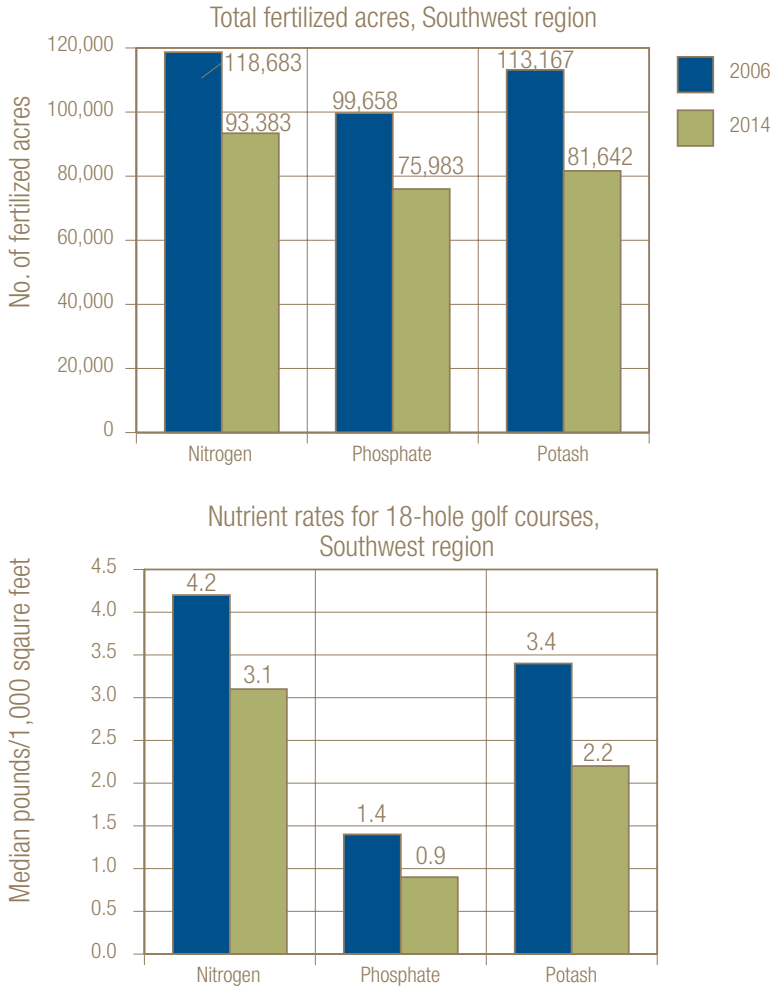

Figure 16. Major factors in nutrient use reductions for the Southwest region, 2006 vs. 2014. Since 2006, conservation practices such as reductions in the number of fertilized acres and in nutrient rates have been the major contributors to reductions in total nutrient use.

Variation in growing season: Southwest

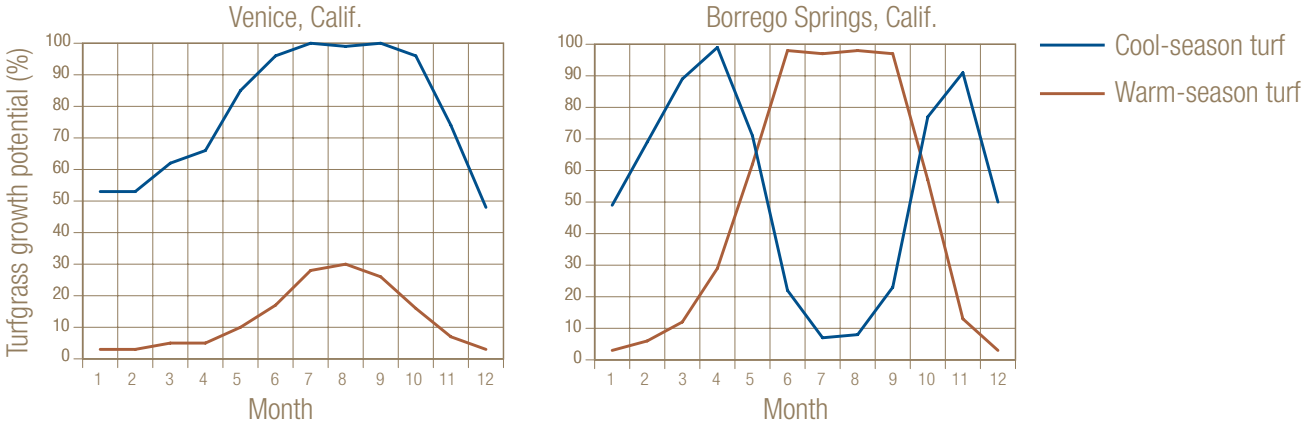

Figure 17. Variation in growing season in the Southwest region. The turf growing season is 12 months long in most locations. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in Southwest region climate

	Lowest	Highest
Average temperature (F)	40.5	75.2
Rainfall (feet)	0.3	10.2
Active turf growth (months)	12	12

Table 13. Variation in Southwest region climate. Temperature and rainfall values are based on 30-year normal annual average temperatures.

Climate

- Average temperatures in the Southwest region are the warmest in the country, and range widely from 45.8 F all the way to 77.8 F, depending on location (Table 13).
- Rainfall varies from moderate to heavy, depending on location (Table 13).
- The climatic variability across this region led to a wide range of nutrient use patterns.
- Turf is actively growing 12 months of the year in most locations in this region (Figure 17).

Nutrient use patterns for the Transition region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds/1,000 square feet) for 18-hole facilities	Transition	2.51	2.13	-15	0.93	0.28	-70	2.32	1.50	-35
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	Transition	13,600	9,688	-29	5,876	3,064	-48	12,670	8,354	-34
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	Transition	210,663	178,741	-15	189,959	101,034	-47	204,407	155,772	-24
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 14. Nutrient use patterns in 2006 vs. 2014 for the Transition region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

TRANSITION REGION
Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the Transition region decreased by 29%, while phosphate use decreased by 48% and potash use by 34% (Table A1, Table 14).
- There were significant decreases in the rates of all three nutrients used between 2006 and 2014 (Figure 18, Table 14) The Transition region tied with the North Central region for the greatest percentage decrease in phosphate rates.
- The number of acres treated with fertilizer has also decreased significantly for all three nutrients, most notably for phosphate (Table A3).
- These nutrient use patterns are due to a combination of factors.
  - o Conservation efforts, such as reducing nutrient rates and reducing numbers of fertilized acres, were the major contributors to the large drop in total nutrient use from 2006 to 2014.
  - o Facility closures played a smaller role, contributing approximately 6% to total nitrogen use reductions, 2% to total phosphate reductions and 3% to total potash reductions.
  - o Of Transition region respondents who reported some type of nutrient restriction, 74% indicated that phosphate restrictions have been imposed. This is reflected in the large decreases in phosphate use, phosphate rate and number of acres fertilized with phosphate (Tables A1,2,A3).

Factors in nutrient use reductions: Transition region

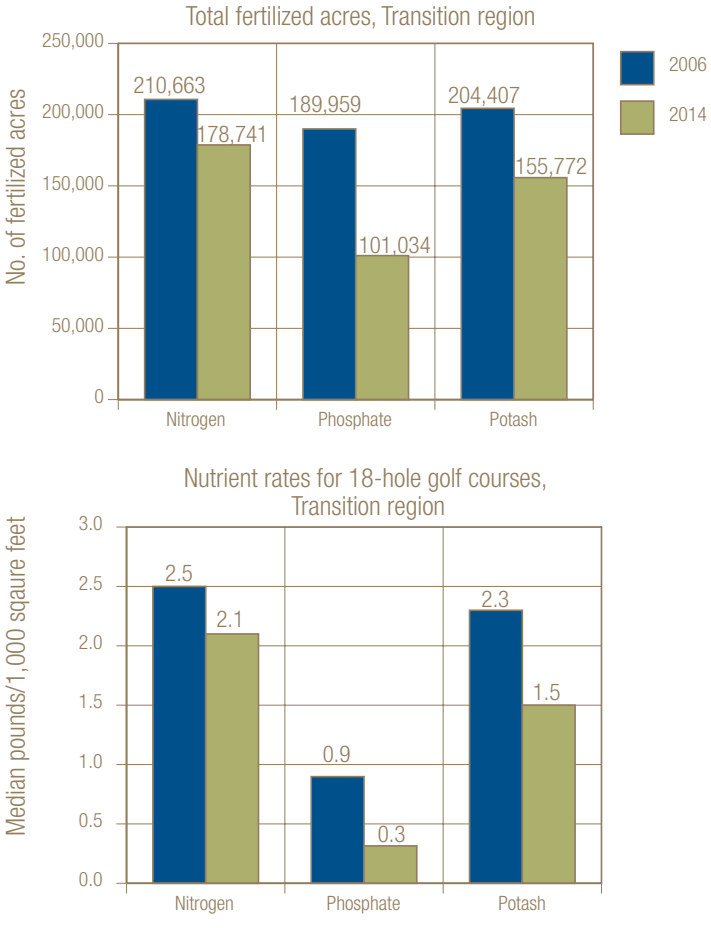

Figure 18. Major factors in nutrient use reductions for the Transition region, 2006 vs. 2014. Since 2006, conservation practices such as reductions in the number of fertilized acres and in nutrient rates have been the major contributors to reductions in total nutrient use.

Variation in growing season: Transition region

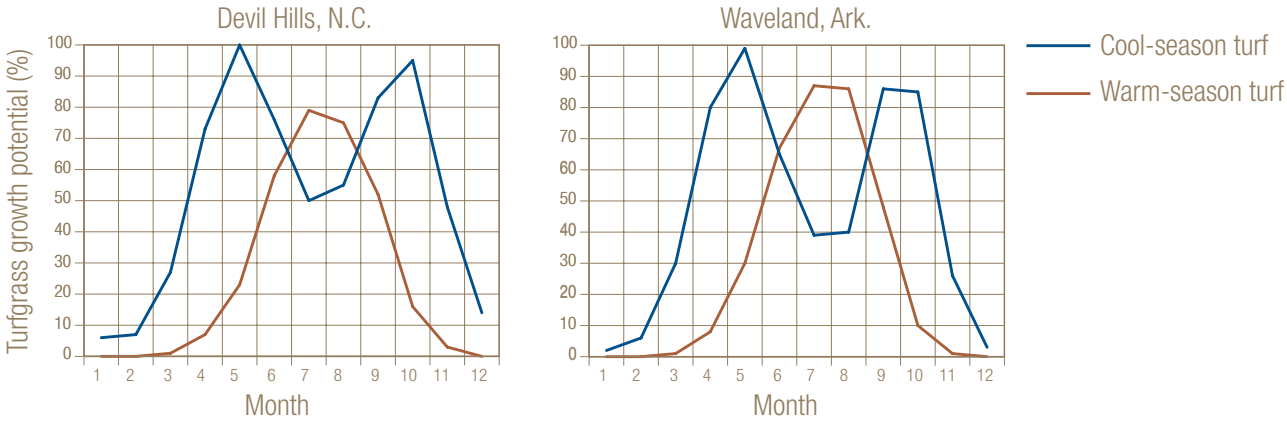

Figure 19. Variation in growing season in the Transition region. The turf growing season is nine months long in most locations. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in Transition region climate

	Lowest	Highest
Average temperature (F)	47.2	68.6
Rainfall (feet)	2.0	7.1
Active turf growth (months)	9	9

Table 15. Variation in Transition region climate. Temperature and rainfall values are based on 30-year normal annual average temperatures.

Climate

- Average temperatures in the Transition region are moderate, and vary only slightly across the region, from 47.2 F to 68.6 F (Table 15).
- This region has highly variable average precipitation rates, ranging from only 2.0 feet to as high as 7.1 feet per year (Table 15).
- Turf is actively growing nine months of the year in most locations in this region. There is little variation in the length of the growing season across the region (Figure 19).

Nutrient use patterns for the Upper West/Mountain region

		Nitrogen			Phosphate			Potash		
	Region	2006	2014	% change	2006	2014	% change	2006	2014	% change
Rate (pounds/1,000 square feet) for 18-hole facilities	Upper West/ Mountain	2.73	2.03	-26	0.76	0.25	-67	2.07	0.90	-57
	U.S.	2.75	2.17	-21	0.82	0.30	-63	2.38	1.47	-38
Total use (tons)	Upper West/ Mountain	5,510	4,350	-21	1,965	960	-51	4,334	2,666	-39
	U.S.	92,185	61,215	-34	33,626	15,759	-53	89,124	51,705	-42
Total no. fertilized acres	Upper West/ Mountain	85,023	80,419	-5	68,766	52,704	-23	76,520	64,791	-15
	U.S.	1,179,055	986,063	-16	1,004,391	540,581	-46	1,126,967	874,534	-22

Table 16. Nutrient use patterns in 2006 vs. 2014 for the Upper West/Mountain region vs. the U.S. as a whole. Median nutrient use rates are for 18-hole golf courses. Total nutrient use and total number of fertilized acres includes all golf courses in the region.

UPPER WEST/MOUNTAIN REGION

Nutrient use patterns

- From 2006 to 2014, total nitrogen use in the Upper West/Mountain region decreased by 21%, while phosphate use decreased by 51% and potash use by 39% (Table A1, Table 16).
- The rates of all three nutrients used decreased significantly between 2006 and 2014 (Figure 20, Table 16). The Upper West/Mountain region had the greatest percentage decrease in potash rates (Table 2).
- The number of acres treated with fertilizer decreased for all three nutrients, though at lower levels than in other agronomic regions (Table A3).
- These nutrient use patterns are due to a combination of factors.
  - o Conservation efforts, such as reduced nutrient rates and reduced numbers of fertilized acres, were the major contributors to the large drop in total nutrient use from 2006 to 2014.
  - o Facility closures did not play a role in decreased nutrient use, as the Upper West/Mountain region was the only region in which the number of facilities increased between 2006 and 2014 (from 1,111 to 1,125) (Table A4).
  - o Of Upper West/Mountain region respondents who reported some type of nutrient restriction, 36% indicated that phosphate restrictions had been imposed. Other than the Southwest region, the Upper West/Mountain has the lowest incidence of phosphate restrictions reported among the agronomic regions.

Factors in nutrient use reductions: Upper West/Mountain region

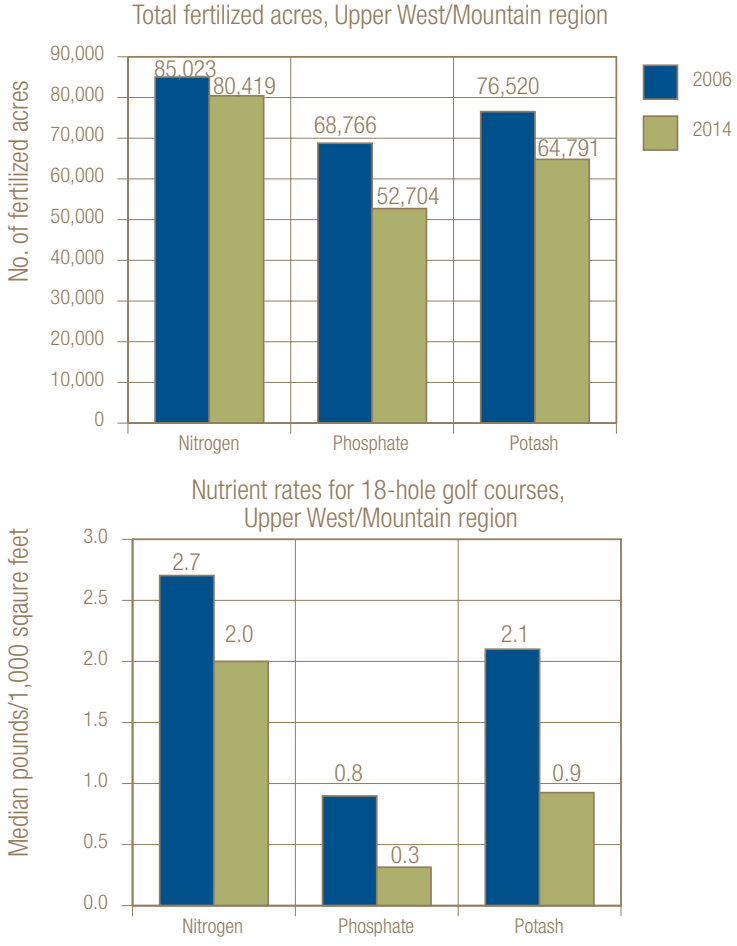

Figure 20. Major factors in nutrient use reductions for the Upper West/Mountain region, 2006 vs. 2014. Since 2006, conservation practices such as reductions in the number of fertilized acres and in nutrient rates were the major contributors to reductions in total nutrient use.

Variation in growing season: Upper West/Mountain region

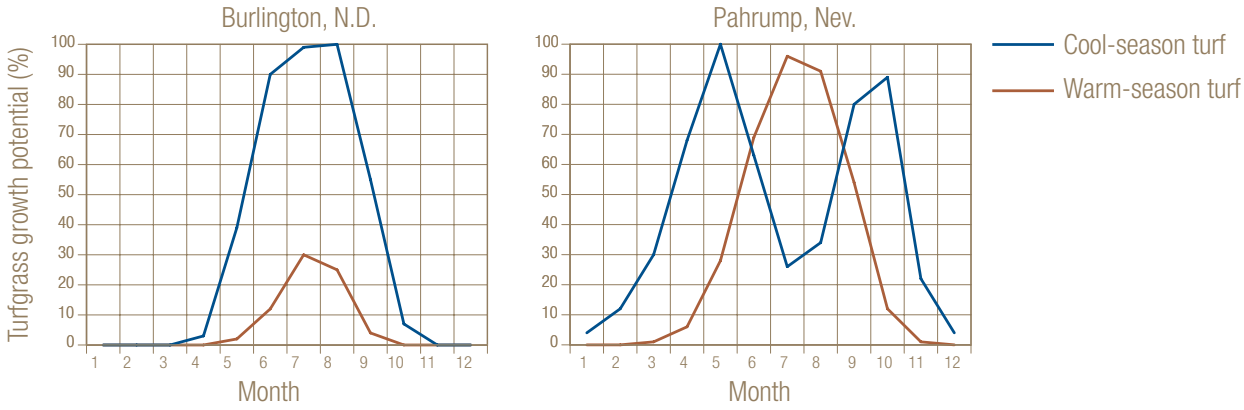

Figure 21. Variation in growing season in the Upper West/Mountain region. The turf growing season ranges from five to nine months. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Variation in Upper West/Mountain region climate

	Lowest	Highest
Average temperature (F)	34.4	64.6
Rainfall (feet)	0.4	4.9
Active turf growth (months)	5	9

Table 17. Variation in Upper West/Mountain region climate. Temperature and rainfall values are based on 30-year normal annual average temperatures.

Climate

- The Upper West/Mountain region encompasses the largest of the agronomic regions in terms of area. Climates vary greatly, from the deserts of Nevada to the mountains of Colorado, to the cold winters of North Dakota.
- Average temperatures in the Upper West/Mountain region are comparatively cool from 34.4 F to 64.6 F (Table 17).
- Rainfall varies from quite low to moderate (Table 17).
- This climatic variability resulted in a broad range of nutrient use patterns across the region.
- In cooler areas of the Upper West/Mountain region such as Burlington, N.D., turf is actively growing for an average of five months per year, while warmer locations such as Pahrump, Nev., show active turf growth for approximately nine months of the year (Figure 21).

Distribution of 2015 survey responses

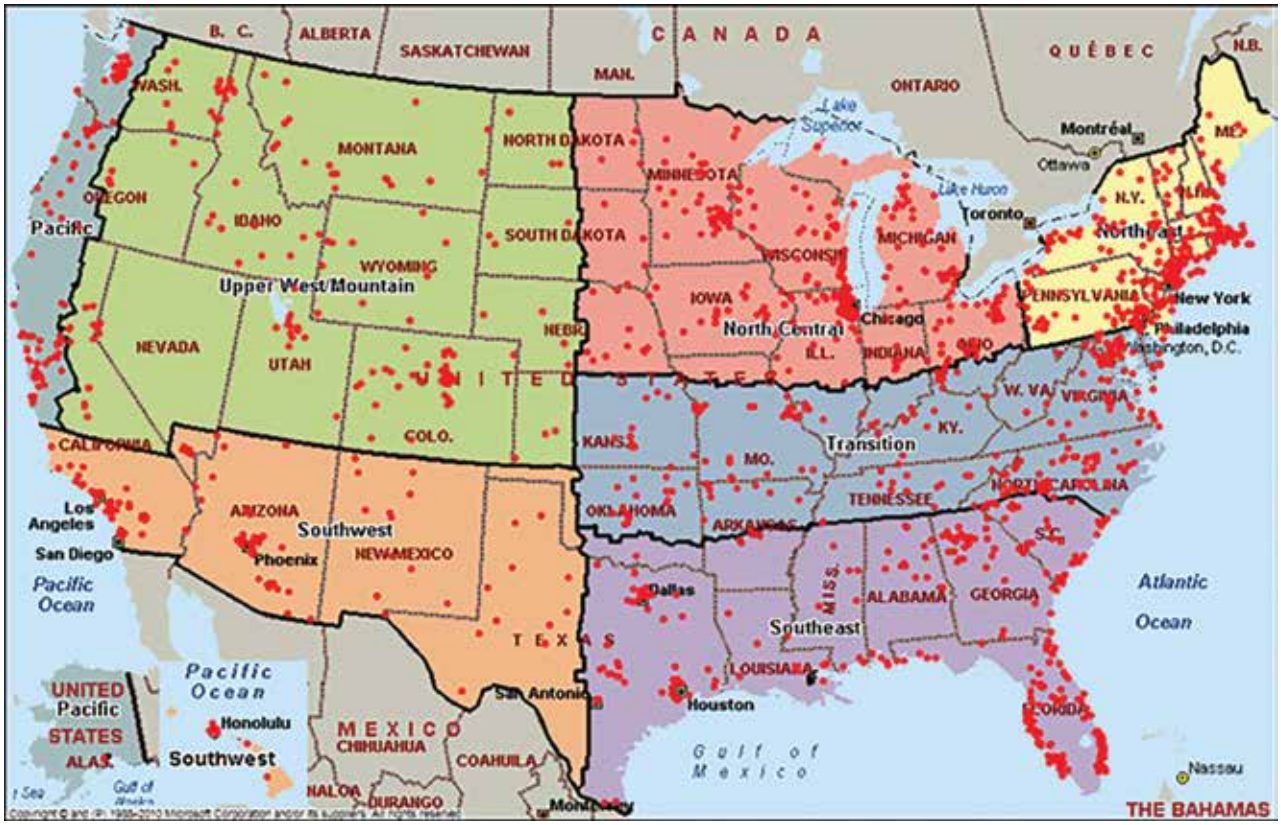

Figure 22. Distribution of 2015 survey responses across the survey's seven agronomic regions.

CONCLUSIONS AND RECOMMENDATIONS

- Significant reductions in nutrient use have occurred over the past eight years as a result of a combination of voluntary conservation practices, regulatory restrictions, golf facility closures and economically driven decisions.
- The dramatic downward shifts in nutrient use rates that occurred between 2006 and 2014 were made without apparent declines in turf quality and playability. This could be due to storage of excess nutrients in the soil, and as a result, it is expected that, as the soil's nutrient reservoirs are depleted by turf growth, fertilizer use will not continue to decline at the same rate as documented above and may even increase slightly to meet plant requirements.
- Annual use ratios of nitrogen to phosphate to potash that are appropriate to the grass species and root-zone soil type should be used in order to provide expected levels of turf quality with minimum fertilizer inputs.
- Management practices such as reductions in overall and/or fertilized turf acreage, decreased winter overseeding and precision fertilizer applications will lead to further nutrient conservation, and will have the added benefit of supporting water conservation efforts as well.

Regulations and nutrient management plans

- Golf courses should be prepared to deal with continued increases in regulatory restrictions on fertilizer use, particularly with regard to phosphorus.
- Fewer than 50% of golf courses report use of nutrient management plans and programs and/or written regional guidelines for best management practices (Table A13). Increased adoption of such plans is recommended in order to provide science-based guidance and organization in the implementation of nutrient management strategies.

Soil tests

- Soil tests are an important component of nutrient management programs that can help avoid both under- and overfertilization.
- Soil test results should be interpreted using the most current, region-appropriate soil nutrient and plant requirement guidelines, in order to minimize environmental impact and unnecessarily high fertilizer application rates.

Calibration and storage

- There is still room for greater adoption of calibration techniques in order to ensure fertilizer is not being applied at either too high or too low a rate.
- While the number of golf courses with specially designated fertilizer storage facilities has increased, there is still room for improvement in the use of these facilities.

Methodology

Survey questions adhered as closely as possible to those in the 2006 survey. However, input from golf, environmental, academic and regulatory sources was integrated into the 2014 survey in order to clarify questions or to integrate information on new technologies and issues in golf course management.

PACE Turf was contracted to provide technical oversight of the survey, analyze and summarize the data, and to prepare reports for publication in peer-reviewed scientific journals, as well as in GCSAA publications and websites.

The National Golf Foundation (NGF) was contracted to refine and format the survey instrument for online use, conduct the survey, manage the recruitment of participants, collate the data and complete the analysis in collaboration with GCSAA and PACE Turf.

Survey response

Of the 15,372 golf facilities in the U.S. at the time the survey was completed, 13,723 U.S. golf courses managed by superintendents with available email addresses were identified by integrating GCSAA and NGF databases. An initial email invitation, which included a link to the online survey, was sent to prospective participants in March, 2015, followed by three follow-up email reminders. A total of 1,529 completed surveys were received, which represents a 9.9% response coverage (Table A21). This is somewhat lower than the 16.1% response coverage from the earlier survey, which also included a mail survey campaign. While both surveys targeted the same population, respondents in 2014 were not identical to those in 2006.

To gain insights into survey data, respondents were stratified by agronomic region (Figure 22, Table A21), as well as by golf course type, number of holes and green fees.

To ensure that the data was representative of the broad spectrum of golf facilities in the nation, responses were weighted so that the diversity in golf course size, type and geographic location were accurately reflected in the survey data. When data was restricted to specific regions or specific golf course sizes, weighted data was not used.

Climate and weather data

This report incorporates, for the first time, specific information on each survey respondent's climate and weather, thus providing greater insights on nutrient use patterns. Each respondent's ZIP code was matched to 30-year average air temperature and precipitation data from the PRISM Climate Group at Oregon State University (www.prism.oregonstate.edu).

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1. USDA Economic Research Service, 2013. Average U.S. farm prices of selected fertilizers, 1960-2013. (www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx#26727) Accessed May 17, 2016.
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Further Reading

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Appendix

Conservation practices

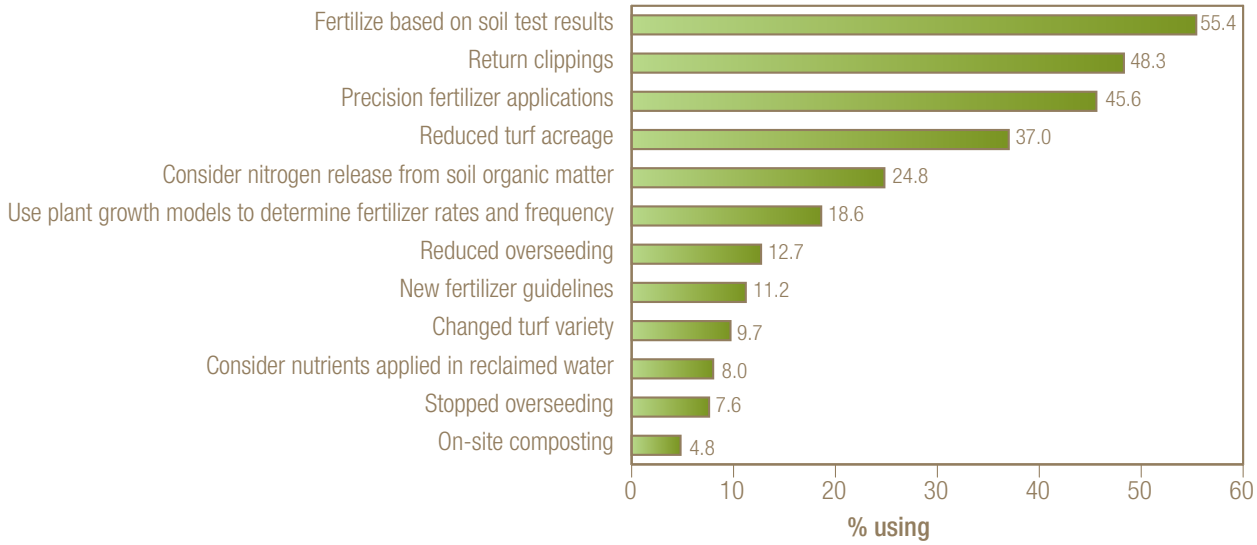

Figure A1. Nutrient conservation practices that resulted in nutrient savings from 2006 to 2014.

Projected regional and national nutrient use

	Nitrogen (tons)				Phosphate (tons)				Potash (tons)			
Region	2006	2014	change	% change	2006	2014	change	% change	2006	2014	change	% change
North Central	15,047	10,612	-4,435	-30	4,657	1,421	-3,236	-70	11,960	7,142	-4,818	-40
Northeast	9,139	6,560	-2,579	-28	3,483	1,152	-2,331	-67	8,090	4,719	-3,371	-42
Pacific	3,110	2,124	-986	-32	1,123	966	-157	-14	2,697	1,949	-748	-28
Southeast	32,532	18,894	-13,638	-42	11,114	5,144	-5,970	-54	37,246	20,478	-16,768	-45
Southwest	13,247	8,986	-4,261	-32	5,408	3,053	-2,355	-44	12,127	6,397	-5,730	-47
Transition	13,600	9,688	-3,912	-29	5,876	3,064	-2,812	-48	12,670	8,354	-4,316	-34
Upper West/ Mountain	5,510	4,350	-1,160	-21	1,965	960	-1,005	-51	4,334	2,666	-1,668	-39
U.S.	92,185	61,215	-30,970	-34	33,626	15,759	-17,867	-53	89,124	51,705	-37,419	-42

Table A1. Projected regional and national nutrient use (tons), 2006 vs. 2014.

Summary of factors contributing to reduced nutrient use

	Total nutrient reduction 2006-2014	Conservation				Fewer facilities	
		Reduced nutrient rates		Acreage reductions			
Nutrient	Tons	Tons	% of total reduction	Tons	% of total reduction	Tons	% of total reduction
Nitrogen	-30,969	15,226	49	12,224	40	3,519	11
Phosphate	-17,867	4,901	27	11,851	66	1,115	6
Potash	-37,419	19,740	53	14,489	39	3,190	9

Table A2. Summary of factors contributing to reduced nutrient use, 2006-2014.

Reductions in fertilized acreage

	Nitrogen				Phosphate				Potash			
	2006	2014	% change	N savings	2006	2014	% change	P_2O_5 savings	2006	2014	% change	K_2O savings
Region	acres			tons	acres			tons	acres			tons
North Central	279,185	230,025	-18	2,248	222,890	87,951	-61	2,057	264,087	199,216	-25	2,261
Northeast	161,846	134,774	-17	1,297	143,916	57,360	-60	1,697	157,981	121,645	-23	1,425
Pacific	42,969	34,707	-19	504	41,553	27,546	-34	488	42,467	31,495	-26	669
Southeast	280,685	234,015	-17	3,761	237,648	138,002	-42	3,689	268,337	219,974	-18	4,529
Southwest	118,683	93,383	-21	2,425	99,658	75,983	-24	928	113,167	81,642	-28	2,472
Transition	210,663	178,741	-15	1,738	189,959	101,034	-47	2,712	204,407	155,772	-24	2,648
Upper West/ Mountain	85,023	80,419	-5	251	68,766	52,704	-23	280	76,520	64,791	-15	485
U.S.	1,179,055	986,063	-16	12,224	1,004,391	540,581	-46	11,851	1,126,967	874,534	-22	14,489

Table A3. Reductions in fertilized acreages from 2006 to 2014, and the estimated nutrient savings that resulted.

Changes in nutrient use due to reductions in the number of golf facilities

	No. of U.S. golf facilities				Projected change (tons), 2006-2014		
Region	2006	2014	Change 2006-2014	% change	Nitrogen	Phosphate	Potash
North Central	4,123	3,920	-203	-5	-708	-184	-496
Northeast	2,739	2,690	-49	-2	-156	-49	-119
Pacific	629	615	-14	-2	-70	-24	-51
Southeast	3,216	3,020	-196	-6	-1,815	-555	-1,868
Southwest	1,221	1,208	-13	-1	-136	-51	-109
Transition	2,951	2,793	-158	-5	-705	-274	-594
Upper West/ Mountain	1,111	1,125	+14	1	70	21	47
U.S.	15,990	15,372	-618	-4	-3,519	-1,115	-3,190

Table A4. Changes in nutrient use resulting from reductions in the number of golf facilities, 2006-2014.

Median nitrogen use rates for 18-hole golf courses

	Median nitrogen use (pounds/1,000 square feet/year)													
	Greens		Tees		Fairways		Roughs		Practice		Grounds		Total Course	
Region	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014
North Central	3.3 b	2.7 a	3.5b	2.7 a	2.8 b	2.1 a	1.7 b	1.4 a	2.9 b	2.4 a	2.4 b	1.9 a	2.2 b	1.7 a
Northeast	3.5 b	3.1 a	3.7 b	3.1 a	2.8 b	2.3 a	1.8 b	1.6 a	2.7 b	2.4 a	2.4 b	2.1 a	2.3 b	1.9 a
Pacific	4.8 b	3.7 a	4.3 b	3.3 a	3.3 b	2.8 a	2.5 b	2.0 a	3.3 a	2.8 a	3.3 b	2.6 a	2.6 a	2.2 a
Southeast	7.4 b	5.6 a	5.6 b	4.1 a	4.5 b	3.5 a	3.9 b	2.7 a	4.9 b	3.5 a	3.6 b	2.9 a	4.2 b	3.0 a
Southwest	5.5 b	4.7 a	5.8 b	4.3 a	5.1 b	4.0 a	1.2 b	3.0 a	5.0 b	4.3 a	4.2 b	3.7 a	4.2 b	3.1 a
Transition	4.3 b	3.9 a	3.4 b	2.7 a	2.9 b	2.5 a	2.2 b	1.9 a	2.9 b	2.6 a	2.5 b	2.1 a	2.5 b	2.1 a
Upper West/ Mountain	3.7 b	3.4 a	3.7 b	3.1 a	3.1 b	2.5 a	2.5 b	2.0 a	3.1 b	2.8 a	2.8 b	2.4 a	2.7 b	2.0 a
U.S.	4.3 b	3.7 a	4.0 b	3.2 a	3.2 b	2.6 a	2.4 b	2.0 a	3.4 b	2.9 a	2.8 b	2.3 a	2.8 b	2.2 a

Table A5. Median nitrogen use in pounds/1,000 square feet for 18-hole golf courses. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level. No-mow acreage fertilization rates were omitted because there were too few responses to generate a valid analysis. Course-wide nitrogen use rates are lower than those for most features because significant portions of many golf courses are not fertilized at all (Table 1).

Median phosphate use rates for 18-hole golf courses

	Median phosphate use (pounds/1,000 square feet/year)													
	Greens		Tees		Fairways		Roughs		Practice		Grounds		Total Course	
Region	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014
North Central	1.1 b	0.7 a	1.1 b	0.6 a	0.8 b	0.5 a	0.5 a	0.5 a	0.9 a	0.9 a	0.7 a	0.6 a	0.5 b	0.2 a
Northeast	1.2 b	0.8 a	1.3 b	0.8 a	0.9 b	0.6 a	0.6 a	0.5 a	1.0 b	0.7 a	0.8 a	0.7 a	0.7 b	0.2 a
Pacific	1.5 b	0.9 a	1.3 b	0.9 a	1.0 a	0.8 a	0.8 b	0.5 a	1.0 a	0.8 a	1.2 b	0.7 a	0.8 b	0.5 a
Southeast	2.2 b	1.6 a	1.7 b	1.2 a	1.5 b	1.1 a	1.3 b	1.0 a	1.5 b	1.0 a	1.3 b	0.9 a	1.2 b	0.5 a
Southwest	2.4 b	1.7 a	2.3 b	1.4 a	2.1 b	1.4 a	1.9 b	1.2 a	2.2 b	1.5 a	1.8 a	1.5 a	1.4 b	0.9 a
Transition	1.6 b	1.2 a	1.3 b	0.9 a	1.1 b	0.8 a	1.0 b	7.4 a	1.2 b	0.9 a	1.1 b	0.8 a	0.9 b	0.3 a
Upper West/ Mountain	1.3 b	0.8 a	1.2 b	0.8 a	1.1 b	0.6 a	0.9 b	0.5 a	1.1 b	0.8 a	1.1 b	0.7 a	0.8 b	0.3 a
U.S.	1.5 b	1.1 a	1.4 b	0.9 a	1.1 b	0.8 a	0.9 b	0.7 a	1.2 b	0.9 a	1.0 b	0.8 a	0.8 b	0.3 a

Table A6. Median phosphate use in pounds/1,000 square feet for 18-hole golf courses. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level. No-mow acreage fertilization rates were omitted because there were too few responses to generate a valid analysis. Course-wide phosphate use rates are lower than those for most features because significant portions of many golf courses are not fertilized at all (Table 1).

Median potash use rates for 18-hole golf courses

	Median potash use (pounds/1,000 square feet/year)													
	Greens		Tees		Fairways		Roughs		Practice		Grounds		Total Course	
Region	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014
North Central	3.7 b	2.5 a	3.1 b	2.1 a	2.3 b	1.5 a	1.2 b	0.8 a	2.5 b	1.7 a	1.9 b	1.2 a	1.8 b	1.0 a
Northeast	3.5 b	2.9 a	3.3 b	2.4 a	2.4 b	1.7 a	1.4 b	1.1 a	2.4 b	1.8 a	2.0 b	1.4 a	1.9 b	0.3 a
Pacific	4.4 b	2.9 a	3.5 b	2.3 a	2.6 b	1.9 a	2.1 b	1.2 a	2.7 b	1.8 a	2.5 b	1.6 a	2.1 b	1.3 a
Southeast	10.2 b	8.3 a	5.6 b	3.9 a	4.5 b	3.3 a	4.0 b	2.6 a	4.8 b	3.2 a	3.4 b	2.5 a	4.4 b	2.6 a
Southwest	7.4 b	5.2 a	4.9 b	3.4 a	4.2 b	2.7 a	3.6 b	2.0 a	4.3 b	2.8 a	3.6 b	2.4 a	3.4 b	2.2 a
Transition	4.8 a	4.4 a	3.1 b	2.2 a	2.6 b	1.9 a	2.0 b	1.5 a	2.6 b	2.1 a	2.2 b	1.6 a	2.3 b	1.5 a
Upper West/ Mountain	4.1 b	3.0 a	3.2 b	1.8 b	2.5 b	1.4 a	2.1 b	1.2 a	3.0 b	1.6 a	2.6 b	1.4 a	2.1 b	0.9 a
U.S.	4.9 b	3.9 a	3.6 b	2.5 a	2.8 b	2.0 a	2.1 b	1.5 a	3.0 b	2.2 a	2.4 b	1.7 a	2.4 b	1.5 a

Table A7. Median potash use in pounds/1,000 square feet for 18-hole golf courses. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level. No-mow acreage fertilization rates were omitted because there were too few responses to generate a valid analysis. Course-wide potash use rates are lower than those for most features because significant portions of many golf courses are not fertilized at all (Table 1).

Fertilizer application ratios for nitrogen, phosphate and potash

	2006			2014		
Region	Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash
North Central	4.0	1	3.2	10.0*	1	6.2**
Northeast	3.2	1	2.6	9.8*	1	6.2**
Pacific	3.3	1	2.6	4.7*	1	2.9
Southeast	3.5	1	3.6	5.9*	1	4.8**
Southwest	3.0	1	2.4	3.3	1	2.3
Transition	2.6	1	2.4	6.8*	1	4.4**
Upper West/ Mountain	3.5	1	2.7	8.0*	1	3.4**
U.S.	3.3	1	2.9	6.9*	1	4.4**

*Significant change in the proportion of nitrogen to other nutrients in 2006 vs. 2014 at a 90% confidence level.
**Significant change in the proportion of potassium to other nutrients in 2006 vs. 2014 at a 90% confidence level.

Table A8. Fertilizer application ratios for nitrogen, phosphate and potash in 2006 and 2014. Data is based on median nutrient use rates for 18-hole golf courses. Median values shown were computed based on nutrient ratios determined for each respondent. Ratios computed from the data in Tables A5-A7 will differ somewhat from those shown below because the data from Tables A6-A8 data is a composite of nutrient rates for each region.

Overseeding practices in 2014

	Conservation-driven changes in overseeding		% who overseed by feature				
Region	% who stopped overseeding	% who reduced overseeding	Greens	Tees	Fairways	Roughs	% who do not overseed any feature
Southeast	20	24	28	59	20	3	37
Southwest	10	33	41	69	43	30	30
Transition	11	20	6	33	8	6	62

Table A9. Overseeding practices in 2014 in the Southeast, Southwest and Transition regions, where overseeding is most common.

Mean % of 18-hole facilities conducting soil tests

	Greens		Tees		Fairways		Roughs	
Region	2006	2014	2006	2014	2006	2014	2006	2014
North Central	92 a	89 a	71 a	68 a	75 b	69 a	13 a	14 a
Northeast	95 a	93 a	78 a	79 a	81 a	78 a	21 a	28 b
Pacific	99 b	90 a	78 b	59 a	80 a	75 a	17 a	13 a
Southeast	98 a	98 a	84 b	78 a	87 b	79 a	34 a	31 a
Southwest	98 a	96 a	65 a	69 a	85 a	79 a	38 b	22a
Transition	96 a	93 a	77 a	71 a	81 a	74 a	34 a	36 a
Upper West/ Mountain	998 b	92 a	77 b	54 a	88 b	76 a	28 a	20 a
U.S.	96 b	93 a	76 b	71 a	82 b	76 a	26 a	25 a

Table A10. Mean percent of 18-hole facilities conducting soil tests. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

Influence of soil testing on nutrient use, 2014

	Nitrogen (pounds/ 1,000 square feet)		Phosphate (pounds/ 1,000 square feet)		Potash (pounds/ 1,000 square feet)	
	Soil tests		Soil tests		Soil tests	
Feature	Yes	No	Yes	No	Yes	No
Greens	3.71 b	3.22 a	1.07 b	0.73 a	4.04 b	2.44a
Tees	3.35 b	2.79 a	0.96 b	0.77 a	2.80 b	1.87 a
Fairways	2.78 b	2.17 a	0.83 a	0.74 a	2.15 b	1.44 a
Roughs	2.16 b	1.87 a	0.74 a	0.72 a	1.71 b	1.35 a

Table A11. Influence of soil testing on nutrient use for a typical 18-hole golf course in 2014. For each comparison, values in the same row that are followed by the same letter indicate that they were not significantly different at the 90% confidence level.

Factors involved in nutrient use decisions

Factors	2006	2014
Precipitation/temperature/weather	4.16 a	4.17 a
Visual observation/scouting	4.12 a	4.14 a
Previous product performance	4.12 a	4.12 a
Soils/soil analysis	4.23 b	4.10 a
Disease problems/pressure	4.06 b	3.97 a
Turf species	4.08 b	4.00 a
Traffic/wear	3.86 a	3.95 b
Cost of fertilizer	3.60 a	3.82 b
Golfer expectations	3.88 a	4.00 b
Length of growing season	3.80 a	3.80 a
Reduced environmental impact	*	3.71
Golf events calendar	3.62 a	3.67 a
Clipping production	3.50 a	3.60 b
Regulatory requirements	2.80 a	3.16 b
University recommendations	2.83 a	2.94 b
Turf growth prediction models	2.92 a	3.01 b
Manufacturer recommendations	2.80 a	2.87 b
Consultant/service provide recommendations	2.72 b	2.62 a
Tissue analysis	2.75 b	2.65 a
Nutrient content of reuse (effluent, reclaimed, recycled) water source	2.29 a	2.23 a
Adjacent property owners' maintenance standards	2.05 a	2.22 b

*Not asked in 2006.

Table A12. Factors involved in nutrient use decisions. Respondents rated factors on a 1-5 scale, where 1 = not important at all, and 5 = extremely important. Values shown represent the mean score for all respondents. Values within each two-column row that are followed by the same letter are not significantly different at the 90% confidence level.

Mean % of facilities with written nutrient plans

	% with plan or program		% with written regional guidelines for BMPs†
Region	2006	2014	2014‡
North Central	55 a	51 a	22
Northeast	45 a	42 a	51
Pacific	55 b	36 a	19
Southeast	47 a	48 a	41
Southwest	44 a	38 a	8
Transition	45 a	45 a	34
Upper West/ Mountain	47 a	45 a	8
U.S.	48 a	45 a	31

†BMPs = Best Management Practices.
‡Question not asked in 2006.

Table A13. Mean percent of all 18-hole facilities with written nutrient management plans or fertilizer programs. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

2014 trends in nutrient use rates

	Nitrogen	Phosphate	Potash
No. of holes	median pounds/1,000 square feet/year		
9	1.93 a	0.44 a	1.46 a
18	2.02 a	0.30 a	1.46 a
27+	2.46 b	0.39 a	1.96 b
Facility type			
Public	1.98 a	0.33 a	1.39 a
Private	2.22 b	0.32 a	1.74 b

Table A14. Trends in nutrient use rates in 2014 for different sizes and types of golf courses. For each comparison (number of holes or golf course type), values followed by the same letter indicate that they were not significantly different at the 90% confidence level.

18-hole facilities using organic nitrogen sources

	% using organic fertilizers	
Region	2006	2014
North Central	59 a	57 a
Northeast	74 a	74 a
Pacific	62 a	55 a
Southeast	67 a	66 a
Southwest	56 a	63 a
Transition	63 a	64 a
Upper West/Mountain	67 a	63 a
U.S.	64 a	64 a

Table A15. Mean percent of 18-hole facilities using organic nitrogen sources. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

% of slow-release vs. quick-release nitrogen applied

Region	Mean 30-year normal precipitation (inches)	% of slow-release nitrogen applied		% of quick-release nitrogen applied	
		2006	2014	2006	2014
North Central	34.6	70 a	70 a	32 a	32 a
Northeast	45.6	67 a	69 a	34 a	33 a
Pacific	36.5	62 b	55 a	39 a	48 b
Southeast	50.9	65 a	65 a	36 a	36 a
Southwest	14.5	51 a	53 a	54 a	53 a
Transition	45.1	64 a	62 a	38 a	41 a
Upper West/Mountain	17.9	64 a	66 a	38 a	36 a
U.S.		65 a	65 a	37 a	38 a

Table A16. Average percent of slow-release vs. quick-release nitrogen applied at 18-hole facilities. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

% of 18-hole facilities using soil amendments and supplements

Amendments & supplements	2006	2014
Humic materials	48 a	61 b
Amino acids/proteins	47 a	58 b
Gypsum	40 a	56 b
Biostimulants	51 a	57 b
Sulfur	9 a	28 b
Limestone	24 a	27 b
Microbial inoculants	16 a	23 b
Sugars (sucrose, molasses, etc.)	17 a	23 b
Compost	14 a	15 a
Calcium chloride	5 a	9 b
Compost teas	3 a	8 b
Biocontrol agents	7 a	9 b

Table A17. Percent of all 18-hole facilities using different soil amendments and supplements. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

% of applications made with calibrated equipment

	Greens		Tees		Fairways		Roughs	
Region	2006	2014	2006	2014	2006	2014	2006	2014
North Central	64 a	64 a	63 a	63 a	71 a	67 a	77 a	76 a
Northeast	71 a	71 a	70 a	71 a	78 a	75 a	84 a	81 a
Pacific	61 b	47 a	58 a	50 a	67 b	55 a	64 a	67 a
Southeast	66 a	68 a	70 a	71 a	77 a	75 a	79 a	77 a
Southwest	65 a	64 a	64 a	59 a	65 a	62 a	66 a	69 a
Transition	70 a	72 a	69 a	73 a	76 a	75 a	80 a	80 a
Upper West/ Mountain	67 a	64 a	67 a	71 a	77 a	75 a	80 a	75 a
U.S.	67 a	67 a	67 a	68 a	74 b	71 a	78 a	77 a

Table A18. Percent of applications at 18-hole facilities in which equipment was calibrated prior to application for all golf courses. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

Number of fertilizer applications per year at 18-hole facilities

	Greens		Tees		Fairways		Roughs	
Region	2006	2014	2006	2014	2006	2014	2006	2014
North Central	11 a	14 b	7 a	8 a	5 a	6 a	2 a	4 a
Northeast	12 a	19 b	7 a	12 a	5 a	10 b	3 a	8 b
Pacific	18 a	32 b	8 a	13 a	5 a	19 b	3 a	12 a
Southeast	29 a	40 b	9 a	13 b	6 a	10 b	5 a	7 a
Southwest	26 a	27 a	9 a	10 a	9 a	11 a	7 a	7 a
Transition	15 a	23 b	6 a	10 a	5 a	9 b	3 a	9 a
Upper West/ Mountain	14 a	21 b	6 a	10 a	4 a	8 a	4 a	8 a
U.S.	17 a	25 b	7 a	11 b	5 a	10 b	4 a	7 a

Table A19. Number of fertilizer applications per year at 18-hole facilities. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

% 18-hole facilities with secure fertilizer storage

	% meeting storage conditions	
Region	2006	2014
North Central	43 a	60 b
Northeast	41 a	64 b
Pacific	55 a	71 b
Southeast	54 a	69 b
Southwest	42 a	71 b
Transition	47 a	62 b
Upper West/Mountain	43 a	59 b
U.S.	46 a	65 b

Table A20. Percent of 18-hole facilities having fertilizer storage that, at a minimum, has an impervious floor and roof, ventilation, security (locked with access restricted), and containment features to prevent loss to the environment and/or contamination from runoff. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level.

2014 nutrient survey responses

Facility description				2014 U.S. golf facilities		2014 survey response	
Region	No. of holes	Type	Green fees	No.	% total	No. of responses	% response
Northeast	9	all	all	737	4.8	38	2.5
Northeast	18	public	<$55	642	4.2	30	2
Northeast	18	public	>$55	507	3.3	50	3.3
Northeast	18	private	all	606	3.9	133	8.7
Northeast	27+	all	all	198	1.3	27	1.8
North Central	9	all	all	1,292	8.4	36	2.4
North Central	18	public	<$55	1,461	9.5	84	5.5
North Central	18	public	>$55	343	2.2	55	3.6
North Central	18	private	all	490	3.2	70	4.6
North Central	27+	all	all	334	2.2	46	3
Transition	9	all	all	716	4.7	8	0.5
Transition	18	public	<$55	1,020	6.6	67	4.4
Transition	18	public	>$55	309	2.0	47	3.1
Transition	18	private	all	553	3.6	82	5.4
Transition	27+	all	all	195	1.3	37	2.4
Southeast	9	all	all	532	3.5	6	0.4
Southeast	18	public	<$55	976	6.3	54	3.5
Southeast	18	public	>$55	426	2.8	63	4.1
Southeast	18	private	all	699	4.5	126	8.2
Southeast	27+	all	all	387	2.5	87	5.7
Southwest	9	all	all	261	1.7	6	0.4
Southwest	18	public	<$55	238	1.6	26	1.7
Southwest	18	public	>$55	304	2.0	38	2.5
Southwest	18	private	all	230	1.5	32	2.1
Southwest	27+	all	all	174	1.1	32	2.1
Upper West/Mtn	9	all	all	430	2.8	19	1.2
Upper West/Mtn	18	public	<$55	254	1.7	43	2.8
Upper West/Mtn	18	public	>$55	219	1.4	42	2.7
Upper West/Mtn	18	private	all	146	0.9	30	2
Upper West/Mtn	27+	all	all	75	0.5	27	1.8
Pacific	9	all	all	184	1.2	9	0.6
Pacific	18	public	<$55	101	0.7	17	1.1
Pacific	18	public	>$55	154	1.0	30	2
Pacific	18	private	all	117	0.8	22	1.4
Pacific	27+	all	all	60	0.4	10	0.7
Total				15,372	100	1,529	100

Table A21a. Nutrient survey responses in 2014 characterized by agronomic region, golf facility type, number of holes and green fees. To compensate for under- or over-representation when compared to the U.S. golf course proportions, data was weighted. Facilities refer to a business location where golf can be played on one or more golf courses.

2006 nutrient survey responses

Facility description				2006 U.S. golf facilities		2006 survey response	
Region	No. of holes	Type	Green fees	No.	% total	No. of responses	% response
Northeast	9	all	all	772	4.8	49	1.9
Northeast	18	public	<$55	770	4.8	95	3.7
Northeast	18	public	>$55	347	2.2	85	3.3
Northeast	18	private	all	646	4.0	154	6
Northeast	27+	all	all	204	1.3	30	1.2
North Central	9	all	all	1,405	8.8	97	3.8
North Central	18	public	<$55	1,543	9.6	230	9
North Central	18	public	>$55	275	1.7	99	3.9
North Central	18	private	all	551	3.4	176	6.9
North Central	27+	all	all	349	2.2	49	1.9
Transition	9	all	all	810	5.1	36	1.4
Transition	18	public	<$55	1,057	6.6	147	5.7
Transition	18	public	>$55	257	1.6	80	3.1
Transition	18	private	all	621	3.9	183	7.1
Transition	27+	all	all	206	1.3	26	1
Southeast	9	all	all	629	3.9	18	0.7
Southeast	18	public	<$55	1,011	6.3	107	4.2
Southeast	18	public	>$55	387	2.4	140	5.5
Southeast	18	private	all	766	4.8	218	8.5
Southeast	27+	all	all	423	2.6	51	2
Southwest	9	all	all	274	1.7	3	0.1
Southwest	18	public	<$55	266	1.7	34	1.3
Southwest	18	public	>$55	251	1.6	62	2.4
Southwest	18	private	all	253	1.6	76	3
Southwest	27+	all	all	177	1.1	23	0.9
Upper West/Mtn	9	all	all	450	2.8	19	0.7
Upper West/Mtn	18	public	<$55	310	1.9	58	2.3
Upper West/Mtn	18	public	>$55	136	0.9	52	2
Upper West/Mtn	18	private	all	146	0.9	46	1.8
Upper West/Mtn	27+	all	all	69	0.4	19	0.7
Pacific	9	all	all	200	1.3	16	0.6
Pacific	18	public	<$55	133	0.8	24	0.9
Pacific	18	public	>$55	106	0.7	21	0.8
Pacific	18	private	all	126	0.8	39	1.5
Pacific	27+	all	all	64	0.4	6	0.2
Total				15,990	100	2,568	100

Table A21b. Nutrient survey responses in 2006 characterized by agronomic region, golf facility type, number of holes and green fees. To compensate for under- or over-representation when compared to the U.S. golf course proportions, data was weighted. Facilities refer to a business location where golf can be played on one or more golf courses.

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