DELTA BLUEGRASS COMPANY

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Producers of peat-grown sod in the San Joaquin Delta

Contractor's License No. C-27 752734

June 26, 2015

<u>Via Email:</u> <u>julie.saare-edmonds@water.ca.gov</u>
Julie Saare-Edmonds
Senior Environmental Scientist
California Department of Water Resources
1416 9th Street
Sacramento, CA 95814

Re: **Comments of Delta Bluegrass Company on the Proposed Update of the State Model Water Efficient Landscape Ordinance ("MWELO") by the California Department of Water Resources, Revising Title 23 ("Waters"), Division 2, Chapter 2.7 of the California Code of Regulations**

Dear Ms. Saare-Edmonds:

This comment letter, submitted on behalf of Delta Bluegrass Company ("Delta Bluegrass"), addresses the California Department of Water Resources' proposed revisions to the State Model Water Efficient Landscape Ordinance ("MWELO"), which, if adopted, would revise Title 23, Division 2, Chapter 2.7 of the California Code of Regulations ("CCR").

We fully support the broadly stated objectives of the ordinance as set forth in Section 490(a)-(c). Water efficiency and erosion control have been, and continue to be, key components of modern turf-based landscaping alternatives. As an industry leader, Delta Bluegrass has invested substantial time and money in developing a number of turf blends, including California native grass blends, that are water-efficient and drought-tolerant.

However, Delta Bluegrass received no notice of the proposed MWELO revisions and only learned about them quite by accident on June 16. Subsequent discussions with others in

California's turf industry have confirmed that this stakeholder group (California's turf industry) was left out of the process even though it is directly and adversely affected by the proposed revisions. Because we did not receive adequate notice of the proposed revisions, we have not yet had sufficient time to thoroughly investigate and analyze the proposed revisions and their consequences, nor have we yet had an opportunity to fully discuss them with counsel and other consultants.

The specific proposed revisions that most concern Delta Bluegrass are contained in sections 490.1(a), 491(q) (new "ET adjustment factor") and 492.6(a)(1)(D)-(F), which, if adopted, would prohibit the use of turf in street medians, most parkways less than 10 feet wide, and elsewhere. Section 491(q)'s change in the ET adjustment factor, from .70 to .50, is based on an *average* plant factor of .425 ET. The ET adjustment factor for all-season turf is well above .50, which means that the revised definition will necessarily relegate turf to a very minor role in landscaping.

Section 490.1(a)'s reduction of the applicable square footage requirement to 500 sf for new construction projects and 2,500 sf for rehabilitated landscape projects also creates a serious problem. The MWELO was originally intended for large landscape projects. Only when applied to such projects could the increased cost of compliance be justified. MWELO compliance makes no cost-benefit sense as applied to small projects. Further, with or without the revised Section 490.1(a), individual homeowners are not likely to use expensive experts, soil analyses, and the like in a residential project. As a result, the proposed revised regulations will become effectively unenforceable or enforceable only at great and unreasonable expense.

For Delta Bluegrass, the economic effect of these proposed MWELO revisions would be devastating.

In their current form, the proposed prohibitions and restrictions on the use of turf in landscaping do not reflect a sound understanding of the role of turf in modern water-efficient landscaping, do not advance the objectives of the authorizing statute, and are legally defective for a number of reasons, some of which are noted below.

The proposed MWELO revisions treat all types of turf the same.[1] In fact, there are

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[1] California Code of Regulations ("CCR"), Title 23 ("Waters"), Division 2 ("Department of Water Resources"), Chapter 2.7 ("Model Water Efficient Landscape Ordinance"), section 491, subsection (nnn) defines "turf" as follows:

> "turf" means a ground cover surface of mowed grass. Annual bluegrass, Kentucky bluegrass, Perennial ryegrass, Red fescue, and Tall fescue are cool-

many different types of turf, including water-efficient and drought-tolerant varieties. For a good overview of the water efficiency of various turfs, see "*Managing Turfgrasses during Drought,*" University of California, Division of Agriculture and Natural Resources, Publication 8395 (August, 2009) (UC Peer Reviewed), a copy of which is attached hereto. Used properly, turf can be a water-efficient component of landscapes that also helps cool the immediate environment, reduces soil erosion, dust and fire danger, and, of course, provides an aesthetically pleasing and functional landscape. The benefits of turf as part of drought-tolerant and water-efficient landscaping have been ignored in the drafting of the proposed MWELO revisions, a problem that we think could have been avoided had representatives of the turf industry been consulted.

Another key point – also ignored in the proposed revisions – is the fact that, as stated in the article cited above, "the turfgrass industry has a significant direct economic impact on our economy and indirect impact on our tourist economy."

The proposed regulation prohibiting and/or restricting the use of turf in landscaping will do little to address drought-related water shortages in California. The "benefit," if any, will be negligible. On the "cost" side, however, the adverse impacts will be substantial indeed. As written, the regulation is complicated, confusing, and not likely to be consistently interpreted and applied. If the regulation can be enforced at all, enforcement will require the diversion of considerable public and private resources. The prohibition of turf in landscaping will decimate an important and well-established California industry, resulting in job losses and related adverse economic impacts. Ironically, prohibiting the use of water-efficient and drought-resistant turf will also hamper efforts to create climate-appropriate landscapes that are water-efficient and combat soil erosion. And, of course, the loss of turf as a component of landscaping will have negative aesthetic consequences as well, i.e., it will lower the quality of life for many Californians, without a corresponding benefit. For a more detailed explanation of the many benefits of turf, see J. Beard and R. Green, "*The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans,*" Journal of Environmental Quality, Vol. 23, no. 3 (May-June, 1994), a copy of which is attached hereto.

We were alarmed to discover that the proposed regulation does not include a sunset provision that applies to the prohibition of turf in California landscaping. The proposed MWELO revisions respond to the Governor's April 1, 2015 Executive Order B-29-15, which is in the nature of an emergency order. One would therefore expect a sunset date clearly stated in the regulation. As currently written, however, the turf prohibitions and restrictions would be permanent, extending well beyond the drought. A permanent regulation should not be

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season grasses. Bermudagrass, Kikuyugrass, Seashore Paspalum, St. Augustinegrass, Zoysiagrass, and Buffalo grass are warm-season grasses.

enacted under the guise of emergency regulation in order to avoid public input, CEQA review, the rigors of the Administrative Procedures Act (Gov. Code, §11340 et seq.), and other legal requirements ordinarily applicable to agency rule-making.

As drafted, the proposed MWELO revisions go far beyond the water conservation concerns reflected in the legislative findings set forth in Section 490(a). In its current form, Section 490(b)(1) provides that a purpose of the ordinance is to "promote the values and benefits of landscapes while recognizing the need to invest water and other resources as efficiently as possible." As revised, that statement of purpose would be "[to] promote the values and benefits of landscaping practices that integrate and transcend the conservation and efficient use of water."

Integrating water-efficient practices into landscaping is a legitimate objective, consistent with the legislative findings and common sense. But "transcending" the conservation and efficient use of water implies a much broader reshaping of the landscaping industry. Such regulatory overreaching – reflected again in the substantive provisions prohibiting the use of turf – goes beyond the legislative findings and the purpose of the authorizing statute. In effect, the proposed regulation seizes upon the current drought as an opportunity to reconfigure an entire industry along lines that are neither necessary to achieve the legitimate purpose of the regulation nor consistent with the landscaping tastes and preferences of Californians generally.

Rather than "transcending" the water conservation goals of the existing MWELO, the object of the exercise should be to enforce the existing ordinance.[2]

In addition to the fact that the proposed provisions prohibiting the use of turf will be complicated in their implementation, difficult and expensive to enforce, will not advance sound public policy, and will impose negative economic consequences, they are also legally defective.

For example, the proposed regulation exceeds and conflicts with the agency's statutory authority. The authority for Section 492.6(a)(1)(D)-(F)'s proposed prohibitions and restrictions on the use of turf in landscaping is Gov. Code § 65595. The regulation also cites to Gov. Code § 65596. However, the prohibitions conflict directly with the "Model Ordinance Criteria" set forth in Gov. Code § 65596, which provides, in pertinent part:

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[2] We note, also, that the least water-efficient landscape projects are the existing projects, which generally employ inefficient irrigation technologies and concepts that are now outdated. In contrast, newer landscaping projects in California virtually always take advantage of water-efficient and drought-tolerant plants and water-saving technologies.

> The updated model ordinance adopted pursuant to Section 65595 shall do all the following in order to reduce water use:
>
> (a) Include provisions for water conservation and the appropriate use and groupings of plants that are well-adapted to particular sites and to particular climatic, soil, or topographic conditions. <u>The model ordinance shall not prohibit or require specific plant species</u>, but it may include conditions for the use of plant species or encourage water conserving plants. However, <u>the model ordinance shall not include conditions that have the effect of prohibiting or requiring specific plant species</u>.

(Emphasis added.)

The proposed revised regulation would conflict with and exceed its statutory authorization and, for that reason, the agency's scope of authority. An administrative agency cannot, under the guise of rule-making, abridge or enlarge its authority or exceed its powers given to it by statute - the source of its power.

The regulation, if adopted, would also run afoul of the Fifth Amendment of the U.S. Constitution. While the proposed MWELO revisions are expressly intended to benefit Californians generally, the economic burden of the proposed regulation falls disproportionately on the California turf industry. The protection afforded by the Fifth Amendment's "takings clause" extends to business revenue and other "personal" property to the same degree that it protects individuals' interests in real property, a fundamental legal tenet reaffirmed by the U.S. Supreme Court earlier this week in *Horne v. Department of Agriculture*, 2015 U.S. LEXIS 4064.

The proposed revisions would impose a devastating economic burden on Delta Bluegrass. The result would be a "taking" within the meaning of the Fifth Amendment, as well as under California law, for which the State of California would be required to pay just compensation. We are not aware of any effort by DWR to quantify the adverse economic effects of the proposed revisions or to offer just compensation to those who would be asked to bear the brunt of the economic sacrifice to benefit the public generally. We see nothing in the proposed regulation that suggests DWR has factored the Fifth Amendment issues into its decision-making.

Further, the proposed regulation, if adopted, would deprive Delta Bluegrass of equal protection. The landscaping industry in California encompasses many types of products, services, and technologies, including turf. However, the proposed MWELO revisions single out, prohibit and otherwise restrict the use of turf in landscaping. This is an invidious classification that not only runs afoul of the requirements of Gov. Code § 65596, as noted above, it also deprives Delta Bluegrass of equal protection of the laws. This is so because the classification is not rational, not based on sound science, and not reasonably calculated to advance the legitimate objectives of the authorizing statute.

Adoption of the proposed regulation would also constitute an improper exercise of the police power. An improper exercise of the police power occurs when a regulation does not further its stated purposes and/or those of the authorizing statute, or where the regulation does not relate in a reasonable fashion to those purposes.

Adoption of the proposed MWELO revisions, in their current form, would be arbitrary and capricious and a violation of due process. Rule-making is a quasi-legislative action and, as such, is subject to review as to whether the agency's decision was arbitrary, capricious, entirely lacking in evidentiary support or procedurally unfair. Discriminatory classifications may also violate due process. Here, the procedural unfairness – failure to notify major stakeholders who will be adversely impacted by the regulations – is patent. The classification of turf as a prohibited or restricted plant is, in our opinion, without a rational basis. Had representatives of the turf industry been afforded a meaningful opportunity to present evidence and argument on this point, we think it likely that the turf-related provisions of the proposed MWELO revisions would read very differently from the current draft.

The proposed prohibitions and restrictions on the use of turf in landscaping will, if adopted, have significant impacts on communities and natural environments throughout California. However, there was no environmental review of the proposed regulations under the California Environmental Quality Act ("CEQA"). Waiving CEQA review in response to an emergency situation is one thing. However, here the proposed prohibitions and restrictions at issue purport to be permanent or long-term, which is not the type of emergency measure that might warrant a CEQA waiver. The permanent or long-term environmental consequences of the proposed regulations are as yet unidentified, unquantified and unaddressed. Under these circumstances, CEQA review cannot be waived; rather, disclosure and analysis of those impacts by way of CEQA review is essential for responsible decision-making.

Request for Hearing. Delta Bluegrass respectfully requests that DWR properly notice and conduct public hearings on the proposed new regulations in order to give decision-makers an opportunity to hear from representatives of the turf industry, an important stakeholder, about the use of water-efficient turfs in times of drought. Such information is essential to responsible decision-making in this case.

Request for Extension of Comment Period. The Department's hurried approach to the drafting of the new regulations, as well as its failure to notify and engage representative of the California turf industry, is perplexing in light of the fact that California is now in its fourth year of the drought. Surely, there was sufficient time during this long drought to involve a

California industry that will be significantly adversely impacted by implementation of the proposed MWELO update.

In light of the fact that the California turf industry was apparently not represented in the stakeholder discussions and was not timely notified of the proposed revisions, Delta Bluegrass asks that the comment period be extended for another 60 to 90 days in order to allow more thoroughly considered and detailed comments.

Request for Review of Revised Proposals and Proposed Amendments. Delta Bluegrass requests that the proposed regulations be revised in response to the comments above. Delta Bluegrass also requests a fair and sufficient opportunity to review and respond to the revised proposed regulations.

Please do not hesitate to contact us with any questions. Thank you.

Very truly yours,

Edward Zuckerman
President, Delta Bluegrass Company

Attachments:
"*Managing Turfgrasses during Drought,*" University of California, Division of Agriculture and Natural Resources, Publication 8395 (August, 2009) (UC Peer Reviewed)

J. Beard and R. Green, "*The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans,*" Journal of Environmental Quality, Vol. 23, no. 3 (May-June, 1994)

cc: Thomas H. Keeling, Esq. (*Via U.S. Mail*)
Governor Edmund G. Brown, Jr. (*Via U.S. Mail*)
Assembly Member Susan Talamantes Eggman (*Via U.S. Mail*)
Senator Cathleen Galgiani (*Via U.S. Mail*)

ATTACHMENT 1

University of California
Division of Agriculture and Natural Resources
http://anrcatalog.ucdavis.edu

UC PEER REVIEWED

PUBLICATION 8395 / AUGUST 2009

Managing Turfgrasses during Drought

M. ALI HARIVANDI, University of California Cooperative Extension Advisor, San Francisco Bay Area; **JAMES BAIRD**, Turfgrass Specialist, University of California, Riverside; **JANET HARTIN**, University of California Cooperative Extension Advisor, San Bernardino County; **MICHAEL HENRY**, University of California Cooperative Extension Advisor, Riverside County; **DAVID SHAW**, University of California Cooperative Extension Advisor, San Diego County

INTRODUCTION

Most of California has a Mediterranean climate characterized by long, hot, dry summers, and turfgrasses must be watered to survive under these conditions. Californians must learn how to use water more efficiently as demand and cost rise and drought conditions continue.

Warm-season and cool-season grasses are used as turfgrass in California, based on their climatic adaptability. The warm-season species include common and hybrid bermudagrasses, St. Augustinegrass, seashore paspalum, zoysiagrass, buffalograss, and kikuyugrass. These grasses are used in the San Joaquin Valley, southern California, and parts of the greater San Francisco Bay Area. The cool-season grasses include tall fescue, perennial ryegrass, Kentucky bluegrass, fineleaf fescues in mixes, and specialty grasses such as creeping bentgrass and rough bluegrass. Turfgrasses can be irrigated at different levels. The Optimum irrigation is the amount of water needed for the most efficient growth, maximum quality, and best appearance of the respective turfgrasses. Deficit irrigation provides sufficient water to maintain adequate turfgrass appearance with less growth. In contrast, survival irrigation provides only enough water to allow survival and potential recovery of the desired species when adequate water is again available. Under survival irrigation, growth and quality are drastically reduced.

Figure 1 presents the percentage of reference evapotranspiration (ETo) obtained from the California Irrigation Management Information System, relative to the three irrigation levels for warm- and cool-season turfgrasses. Figure 1 also

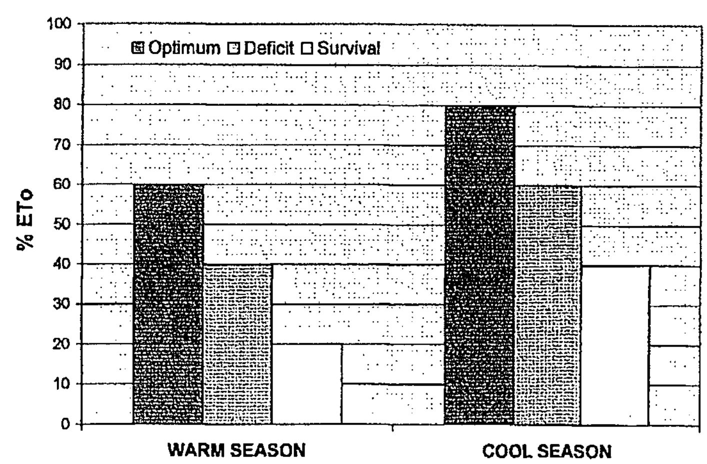

Figure 1. Turfgrass water requirements (as % of ETo) at optimum, deficit, and survival levels of irrigation.

indicates that both cool-season and warm-season turfgrasses, when irrigated at deficit levels, can save at least 25 percent of irrigation water needed for optimum growth. Irrigation at a survival rate would be at 30 percent of optimum for warm-season turfgrasses and about 50 percent of optimum for cool-season turfgrasses.

If water rationing is needed, both cool-season and warm-season turfgrasses can be irrigated at less than optimum levels. Where possible, using warm-season turfgrasses can result in considerable water savings compared with cool-season turfgrasses.

Background

Turfgrass directly affects the way most Californians live. It provides the play medium on many recreational facilities, cools the immediate environment, reduces reradiated heat, and provides an aesthetically pleasing and functional home landscape. In addition, the turfgrass industry has a significant direct economic impact on our economy and indirect impact on our tourist economy.

Many recreational facilities depend on uniform, vigorously growing, well-maintained turf that is able to recuperate from heavy use. These include soccer, baseball, and football fields, as well as golf courses, bowling greens, lacrosse and polo fields, general use and specialty parks, and school playgrounds. Turfgrasses provide a safety cushion that is especially beneficial in contact and physically intensive sports. Additionally, sites such as homes, industrial parks, cemeteries, greenbelts, roadsides, and dog parks can benefit from low-growing and traffic-tolerant green vegetation like turfgrasses.

Most Californians now live in urban and suburban centers where glass, steel, concrete, asphalt, buildings, and cars prevail; turfgrasses directly influence these immediate environments in positive ways. Actively growing turfgrasses reduce high summer ground surface temperatures due to transpirational cooling. Turfgrasses and other landscape plants reduce discomforting glare and noise. Soil erosion, dust, and fire danger are reduced or eliminated on turfed surfaces. Turfgrasses also increase infiltration of water into the soil profile and also enhance the quality of the water moving through or below the turfgrass system.

How Turfgrasses Use Water

Water enters a turfgrass plant through its root hairs, which are located near root tips. Water then moves upward through the plant to the leaves. A very small amount of the water taken up is used for plant growth, and the rest of the water transpires out of the plant through the stomatal pores. Water can also be lost from the turfgrass site by evaporation from leaf or soil surfaces. The water use rate is the total amount of water lost by a plant through evaporation and transpiration and used for growth, per unit of time. Because the amount of water used by turfgrasses for growth is so small, the water use rate is usually calculated as the evapotranspiration (ET) rate, which is the total rate of water loss by evaporation plus the rate of water loss by transpiration.

ET is expressed in units of depth and time such as inches (in) or millimeters (mm) per day, per week, or per month. Turfgrass ET depends on temperature, solar radiation, day length, wind, relative humidity, and other environmental factors. However, the ET rate also varies by species and the cultural practices used in maintaining the turf.

Water use rates have been established for the most commonly used warm- and cool-season turfgrass species. Research at Texas A&M in the late 1980s evaluated comparative water use rates among turfgrasses commonly grown in the United States. The comparative water use rates for those grasses used in California are presented in table 1. In the northern part of California and in the mountain regions of the state, turfgrasses are exclusively cool-

Table 1. Evapotranspiration rates of turfgrasses commonly grown in California

Relative ranking	ET rate (in/day)	Cool-season turfgrasses	Warm-season turfgrasses
very low	<0.24		buffalograss
low	0.24–0.28		bermudagrass zoysiagrass
medium	0.28–0.33	hard fescue Chewing's fescue red fescue seashore paspalum St. Augustine grass	
high	0.33–0.39	perennial ryegrass kikuyugrass	
very high	>0.39	tall fescue creeping bentgrass annual bluegrass Kentucky bluegrass rough bluegrass annual ryegrass	

Note: 1 inch = 2.54 cm.
Source: Adapted from Beard and Beard 2004.

Table 2. Suggested Kc values (% of ETo) for irrigation strategies resulting in optimum, deficit, and survival performance levels for selected turfgrasses grown in California.

Turfgrass performance level	Cool-season turfgrasses	Warm-season turfgrasses
	Kc*	Kc
optimum	0.80	0.60
deficit	0.60	0.40
survival	0.40	0.20

Note: * Kc (crop coefficient) is a dimensionless number that is multiplied by the ETo value to arrive at an estimate of crop ET, or water requirement.

season species. In other areas of the state, warm-season turfgrasses are grown extensively, and they perform well particularly in warm inland climates and desert areas. Both cool-season and warm-season species are grown in major populated areas of the state. Differences in water use rates have been noted between cultivars within all turfgrass species. Currently, research is underway throughout the United States to develop species and cultivars that have low water use rates. The lower-water-use turfgrasses have a low leaf-blade area and include species with narrow leaves with slow vertical extension rates and grasses with high shoot densities and high leaf numbers.

Warm-season turfgrass species use significantly less water than cool-season species. This is because warm-season grasses are more efficient at photosynthesis and are able to continue high-level carbohydrate production even under mild water stress when their stomates are partially closed. By contrast, cool-season grasses use a less efficient photosynthetic process and cannot produce enough carbohydrate to maintain growth unless their stomates are nearly wide open. Thus, when water is limited, transpiration rates of cool-season turfgrasses are generally higher than those of warm-season turfgrasses.

The effects of irrigating several species of turfgrasses below their optimal levels were investigated at Irvine, California. Cool-season grasses tested were Kentucky bluegrass, perennial ryegrass, and tall fescue; warm-season turfgrasses were hybrid bermudagrass, zoysiagrass, and seashore paspalum. Irrigation regimes supplied 100, 80, or 60 percent of calculated ET for each species. For acceptable turfgrass quality, 36 percent less water was required by the warm-season species than by the cool-season species.

Similar irrigation regimes can be created for any area of the state using ETo information and the crop coefficient (Kc) values (expressed as a percentage of ETo needed to satisfy water needs of a specific plant species) in table 2.

Water Use Versus Drought Resistance

The ET of a turfgrass is not synonymous with its ability to resist drought. Drought resistance includes mechanisms of drought avoidance (i.e., of retaining moisture within the plant) and of drought tolerance (i.e., of minimizing the damage to tissues caused by water deprivation).

Plant characteristics that contribute to drought avoidance include deep root systems with high root hair length and density, rolled leaf blades, thick cuticle (or ability to quickly form a thick cuticle following water stress initiation), reduced leaf area, slow leaf extension rates, and leaf orientation and density. Examples of turfgrasses with good drought avoidance mechanisms are common bermudagrass and seashore paspalum (both warm-season species) and tall fescue (a cool-season species).

Turfgrasses can also tolerate drought by escape (e.g., buffalograss, which tolerates drought with a dormancy mechanism) or by high tolerance to tissue dehydration (e.g., St. Augustinegrass). Through these mechanisms, turfgrass species have different levels of drought resistance (table 3). Comparison of the water use rates (table 1) and drought resistance (table 3) gives insight into the performance turfgrass species. Several turfgrasses, such as bermudagrass, seashore paspalum, and buffalograss, have both low water use rates and high drought resistance mechanisms. Other turfgrasses, such as tall fescue, have high water use rates and medium drought resistance. Still others, such as the ryegrasses and bluegrasses, have high water use rates and fair or poor drought resistance.

Some turfgrasses and ground covers can survive with very little applied water, as evidenced by a research study conducted at the South Coast

Table 3. Drought resistance comparisons of turfgrasses commonly grown in California.

Relative ranking	Cool-season turfgrasses	Warm-season turfgrasses
superior	—	bermudagrass (common) bermudagrass (hybrid) buffalograss
excellent	—	seashore paspalum zoysiagrass
good	—	St. Augustinegrass kikuyugrass
medium	tall fescue	—
fair	perennial ryegrass Kentucky bluegrass creeping bentgrass hard fescue Chewing's fescue red fescue	—
poor	colonial bentgrass annual bluegrass	—
very poor	rough bluegrass	—

Field Station, Irvine, California, in which plants were irrigated at 60, 40, and 20 percent of calculated ET. Of the 27 plant species tested, common and hybrid bermudagrasses and seashore paspalum performed best under very low irrigation regimes. Buffalograss also produced comparatively good cover and quality.

Irrigation and Other Cultural Practices for Turfgrass

Irrigation

The goal of irrigation management is to apply the correct amount of water at the correct time to optimize water uptake by the root system. It is also important to reduce the amount of water lost to runoff from the soil surface and deep percolation below the root zone. Regular water audits, ensuring that equipment is operating correctly, and using soil probes or soil moisture measuring devices help fine-tune irrigation schedules, promote healthy turfgrass, and decrease water waste.

Effective irrigation involves filling the root zone soil profile with each irrigation. This requires calculating the amount and frequency of water application based on weather data (used to estimate the ET of the turfgrass), the plant's rooting depth, and the water-holding capacity of the soil. These factors may also be used to plan deficit irrigation strategies.

Evapotranspiration and CIMIS

The California Irrigation Management System (CIMIS) provides irrigation managers, scientists, and water agencies with an accurate, site-specific means of estimating plant water demand based on the climatic parameters that drive evapotranspiration in plants. Reference evapotranspiration (ETo) approximates the water use of an irrigated grass pasture. Water use (ET) by turfgrasses is estimated by means of a correlation factor, the crop coefficient (Kc), according to the formula

$$ET = ETo \times Kc$$

Turfgrass Kc values fluctuate slightly during the season based on the percentage of plant cover, growth rate, root growth, stage of plant development, and turf management practices. For practical purposes, the Kc of cool-season turfgrasses is 0.8, and the Kc for warm-season turfgrasses is 0.6. Numerous CIMIS stations are located in varying climatic zones throughout California; daily water use information (i.e., ETo) is accessible online for most areas of California at the CIMIS website, http://www.cimis.water.ca.gov/cimis/welcome.jsp.

Soil water availability

The amount of water available for use by turfgrasses varies by soil texture and pore size and by the rooting depth of the turfgrass. After soil is irrigated and free drainage has taken place, the soil is full of water, or at field capacity. As plants extract the water from the soil, eventually the soil will become so dry that plants cannot be sustained. At this point (often called the permanent wilting point or percentage) there is still water in the soil but it is tightly held by mineral and organic particles and is unavailable for plant use. The total amount of water a soil can hold and the amount of available water a plant can absorb and use differ with different soil textures (table 4). These data, in conjunction with root depth, give the approximate amount of water that is available to a turfgrass plant.

Root system

Turfgrass species differ in their rooting depth and density Rooting depths vary from a few inches to many feet; they are also influenced by water patterns, soil characteristics, management practices such as mowing and fertilization, and by on-site compaction. The best method to determine root depth in a particular location is by digging into the

Table 4. Unavailable and available water for selected soil textures.

Soil texture	Total water (in/ft)	Available water (in/ft)	Unavailable water (in/ft)
sand	0.6–1.8	0.4–1.0	0.2–0.8
sandy loam	1.8–2.7	0.9–1.3	0.9–1.4
loam	2.7–4.0	1.3–2.0	1.4–2.0
silt loam	4.0–4.5	2.0–2.1	2.0–2.4
clay loam	4.2–4.8	1.8–2.1	2.4–2.7
clay	4.5–4.8	1.8–1.9	2.7–2.9

Note: 1 in/ft = 8.3 cm/m

soil and looking at the roots. Table 5 is a general guide to root depths. The available soil water is determined by multiplying the available water by the effective depth of the root system. Table 6 shows the amount of water available to turfgrasses growing in various soils at selected root system depths. Since proper irrigation should supply water to the root system, root depths and soil texture play an important role in both the amount of water applied and irrigation frequency.

Table 5. Approximate root depths of common California turfgrasses under normal use conditions.

Cool-season grasses	Root depth (ft)
Kentucky bluegrass	0.5–1.5
perennial ryegrass	0.5–1.5
tall fescue	1.5–3.0
creeping bentgrass	0.3–1.5
annual bluegrass	0.1–0.3

Warm-season grasses	Root depth (ft)
bermudagrass	1.5–6.0
buffalograss	1.5–3.0
St. Augustinegrass	1.5–5.0
seashore paspalum	1.5–5.0
zoysiagrass	1.5–2.5

Note: 1 ft = 0.348 m.

Irrigation frequency

For scheduling turfgrass irrigation, the suggested depletion of available soil water is 50 percent before applying irrigation. In other words, irrigation is needed when one-half the available water that is present in a root profile is depleted. This practice allows for adequate water to be available at all times. If more than 50 percent of the available water is depleted (i.e., irrigations are not frequent enough), the turf suffers water stress.

Fifty percent of the available water divided by the ET equals the number of days of sufficient supply, or the number of days between irrigations. For example, for a cool-season turfgrass (Kc = 0.8) with a 12-inch rooting depth in a loam soil, the available water is 1.5 inches (from table 6). Fifty percent of 1.5 is 0.75 inches. If the ETo is 0.2 inches per day, the turfgrass ET equals 0.20×0.8, or 0.16 inches per day (ETo × Kc). It will take about 5 days ($0.75 \div 0.16 = 4.7$) to deplete 50 percent of the available water. It is normally desirable to water turf as infrequently as possible, so in this case the site would be irrigated by applying 0.80 inches (0.16×5) of water after 5 days.

Water application

The duration of sprinkler operation to resupply the water used by ET must be determined on-site and depends on how fast and how efficiently the water

Table 6. Water available to turfgrass under three soil textures and with three root system depths.

Soil texture	Available water (in/ft)	Water available (in/ft) to turfgrass at root depth		
		6 in.	12 in.	36 in.
sand	1.0	0.5	1.0	3.0
loam	1.5	0.75	1.5	4.5
clay loam	2.0	1.0	2.0	6.0

Note: 1 in/ft = 8.3 cm/m

is applied. The efficiency of irrigation is a function of system performance and management. Irrigation systems that are well designed, in good condition, and apply water uniformly will be much easier for managers to schedule.

The fieldwork to determine system performance can be either a brief, simple procedure or a complete, full inspection of all the irrigation system stations and hardware. Often referred to as an irrigation audit, the process is used to accurately determine the system precipitation rate (PR) and distribution uniformity (DU).

The precipitation rate is the rate at which water is delivered to the turfgrass area; it is measured in inches per hour. The distribution uniformity is a calculated statistic that indicates the amount of variation in the precipitation rate of the system. The precipitation rate and the distribution uniformity are the two most important irrigation system performance characteristics in calculating station run times and determining how evenly water is applied to the area.

Irrigation uniformity is important in turfgrass areas, since turfgrass consists of many small plants, each requiring access to soil and water. An irrigation system with poor uniformity yields areas that are too wet or too dry and nonuniform turfgrass performance. If there are dry areas, irrigation managers usually increase runtime to adequately irrigate them. In this case, water loss to deep percolation or runoff can be significant and may increase with poorer distribution uniformity. The distribution uniformity is only one measure of system performance; information on other statistical measures, such as the Christiansen's coefficient of uniformity and the scheduling coefficient, as well as procedures for determining precipitation rates can be found in *Evaluating Turfgrass Sprinkler Irrigation Systems* (ANR Publication 21503).

The actual run time is determined by dividing the crop coefficient (0.80 inches of water used, in the above example) by the precipitation rate of the sprinkler system. The run time is increased if the irrigation efficiency is considered. The distribution uniformity is a good estimate of the irrigation efficiency as long as the scheduling (management) is good and runoff is limited.

Using the efficiency in the above example, the run time (in hours) would be calculated by dividing 0.80 inches by the precipitation rate times the distribution uniformity; multiply by 60 to convert to minutes. More detailed information on irrigation scheduling can be found in *Turfgrass Irrigation Scheduling* (ANR Publication 21499).

Every effort should be made to prevent runoff. Application of water in short cycles, until the entire amount of water has been applied, is an effective way to reduce water waste due to runoff.

To prevent puddling or runoff on clay or compacted soils, and to prevent excessive drainage in sandy soils, plan on irrigating turfgrasses no less frequently than every third day. The total amount of water to be applied stays the same, but it should be adjusted for more frequent applications. In the example shown above, instead of applying 0.8 inches of water every 5 days, apply 0.5 inches every third day. If too much water is applied at once, water is lost to runoff or percolation below the root zone.

Deficit irrigation strategies

In drought conditions, it may be advisable to reduce turfgrass irrigation to the deficit level or even to the survival level (see fig. 1). If that is the case, in the example given above, instead of using a crop coefficient of 0.8, use the other reduced values given in table 2. This strategy applies less water than the turfgrass has used, which results in mild water stress. The available water will gradually become depleted below 50 percent. As mentioned previously, turfgrass species with drought resistance (especially warm-season grasses) reduce their water use rate as available soil water is used up. To maintain adequate turf quality, careful irrigation management is necessary and cultural practices may need to be adjusted.

Mowing

In addition to irrigation practices, mowing affects turfgrass growth, including root system development and water use. Higher cutting heights promote deeper root systems and higher water use rates. The higher water use rate with taller turf results from the more open canopy and reduced shoot density. Conversely, closely mowed turf has higher shoot density and a tight canopy, characteristics which reduce evapotranspiration.

The frequency of mowing also affects evapotranspiration. The long grass leaves of infrequently mowed turfgrass use more water. Infrequently mowed turf is also aesthetically and functionally inferior to turfgrass maintained consistently at an appropriate height.

The desired balance is achieved by mowing practices that enhance root system depth and density (and thus drought resistance) while efficiently using water.

Combining all factors involved, the turfgrass should be maintained at the tallest allowable height, within the recommended mowing height range, for the species being grown. Turf mowed at the tallest allowable height for the individual species and at a frequency that allows no more than one-third of the leaf blade to be removed best achieves that balance. Table 7 recommends mowing height ranges for selected turfgrasses.

Mowing turfgrasses when it is hot or when the soil is dry can injure the plants. When grasses are stressed by heat and drought, such as during a drought-declared summer, it is best to mow infrequently at a taller height.

Fertilization

Sufficient amounts of most nutrients required for turfgrass growth are normally available in native soils. However, all turfgrasses require nitrogen fertilizer, and in some soils they need phosphorus, potassium /or iron and other essential elements.

Table 7. Mowing height ranges for commonly grown turfgrasses.

Turfgrass species	Cutting height range (in.)
Cool-season turfgrasses	
creeping bentgrass	0.2–0.5
colonial bentgrass	0.5–1.0
red fescue	1.0–2.0
Kentucky bluegrass	1.5–2.5
perennial ryegrass	1.5–2.5
tall fescue	1.5–3.0
Warm-season turfgrasses	
bermudagrass	0.5–1.0
zoysiagrass	0.5–1.0
seashore paspalum	0.5–1.0
St. Augustinegrass	0.5–1.5
kikuyugrass	0.5–1.0

Note: 1 in = 2.54 cm.

Turfgrass fertilization practices directly influence water use: fertilization, especially nitrogen fertilization, increases turfgrass growth, and the greater the growth rate, the greater the water use. Root and shoot growth increase as nitrogen nutrition is raised from a deficiency level. The resulting deeper roots and more vigorous topgrowth benefit the turfgrass. Excessive nitrogen fertilization is not beneficial and can result in excessive topgrowth, poor root growth, and water pollution. To avoid excessive water use, nitrogen fertilizer programs must be monitored to produce the least amount of topgrowth and the greatest rooting possible within the use parameters of the turf. During drought, it is advisable that the lowest amount of nitrogen be applied within the recommended range. Most cool-season grasses grown as general purpose turf require about 2 pounds of actual nitrogen per 1,000 square feet (about 1 kilogram per 100 square meters), applied during March through April and again during late September through mid-October. During this period, due to temperature and water availability, grasses can use nitrogen efficiently to develop deep and extensive root systems. Fertilizing based on these recommendations allows the grass to survive deficit irrigation, heat, and drought stresses much better. Avoid nitrogen fertilization of cool-season grasses from May through September. During this period, if nitrogen must be applied because of play or other special use it should be applied lightly and infrequently. During drought, nitrogen application to warm-season grasses should not exceed 0.25 pounds of nitrogen per1,000 square feet per month (125 grams per 1,00 square meters), between April and September.

Adequate potassium may increase the drought tolerance of turfgrass. In general, an application of 1 to 2 pounds of potassium (as K_2O) per 1,000 square feet (0.5 to 1 kilogram per 100 square meter) in spring (March through April) may provide increased drought tolerance during the summer months.

Soil Compaction and Thatch

Soil compaction reduces the root and shoot growth of turfgrasses and also lowers the water infiltration rates. Turfgrass quality decreases in compacted soils; water use decreases with the slower growing, poorer quality turfgrass cover. Soil aerification is recommended to improve aeration, which increases shoot and root growth, water infiltration rate, and water use efficiency.

Thatch is an intermingled layer of dead and living organic matter that develops between the soil surface and the green turfgrass tissue. It consists of roots, stems, stolons, and rhizomes. A deep thatch layer, if hydrophobic (water repellent), reduces or eliminates water infiltration into the turfgrass soil profile. Water use efficiency increases when thatch is maintained at acceptable depths (around one-half inch, or 13 mm) and is not allowed to dry out.

Aerification and dethatching should be undertaken in fall (October) or spring (March or April) for optimum results. Avoid aerifying and dethatching in midsummer when high temperatures may negatively affect the grass.

Other Considerations

- Conduct an irrigation system uniformity test (audit) in spring to identify and correct the irrigation system's inefficiency and non-uniformity (see *Evaluating Turfgrass Sprinkler Irrigation Systems*, UCCE Publication 21503).
- Irrigate late at night or early in the morning. At these times water loss by evaporation is minimal and distribution uniformity is usually good because of good water pressure and limited wind.
- Avoid runoff by ensuring that water application rates are not greater than soil infiltration rates (the rate water enters the soil). To avoid runoff, cycle water applications by applying the required amount of water over a series of consecutive shorter irrigations. Cycling should not be confused with watering every day, which is not recommended.
- Apply less water in shaded areas than in areas of open sun. Soil moisture measuring devices can be used to determine water needs of turfgrasses growing in various microclimates. In general, during the hot summer months, grasses planted in shade require about half as much water as same grass grown nearby in full sun.
- Repair and maintain irrigation systems. Observe system operation and make necessary repairs to increase uniformity and climate runoff.
- Act now if your facility is considering installing a new, more effective and more efficient irrigation system.
- Regrade mounds and redesign topographic features that create irrigation challenges. Turfgrass grown on slopes and mounds is prone to water loss due to runoff. Landscape design features that deflect irrigation water intended for turfgrass to elsewhere, such as sidewalks, driveways, and other hard surfaces should be modified.
- Investigate irrigating with recycled water. Drought will happen again!

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ATTACHMENT 2

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The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans

By Drs. James B. Beard* and Robert L. Green

ABSTRACT

Turfgrasses have been utilized by humans to enhance their environment for more than 10 centuries. The complexity and comprehensiveness of these environmental benefits that improve our quality-of-life are just now being quantitatively documented through research. Turfgrass benefits may be divided into (i) functional, (ii) recreational, and (iii) aesthetic components. Specific functional benefits include: excellent soil erosion control and dust stabilization thereby protecting a vital soil resource; improved recharge and quality protection of groundwater, plus flood control; enhanced entrapment and biodegradation of synthetic organic compounds; soil improvement that includes CO_2 conversion; accelerated restoration of disturbed soils; substantial urban beat dissipation-temperature moderation; reduced noise, glare, and visual pollution problems; decreased noxious pests and allergy-related pollens; safety in vehicle operation on roadsides and engine longevity on airfields; lowered fire hazard via open, green turfed firebreaks; and improved security of sensitive installations provided by high visibility zones. The recreational benefits include a low-cost surface for outdoor sport and leisure activities enhanced physical health of participants, and a unique low-cost cushion against personal impact injuries. The aesthetic benefits include enhanced beauty and attractiveness; a complimentary relationship to the total landscape ecosystem of flowers, shrubs and trees; improved mental health with a positive therapeutic impact, social harmony and stability; improved work productivity; and an overall better quality-of-life, especially in densely populated urban areas.

The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans

James B. Beard and Robert L. Green

For many centuries people have been willing to devote time and resources to enhance their quality-of-life and recreational opportunities through the use of turfgrasses (Beard, 1989a). Also, for many centuries turfgrasses have played a vital role in protecting our environment, long before it became an issue of major national and international importance to modem societies.

The Poaceae is the most ubiquitous of the higher plant groups found on this earth *(Gould,* 1968). With an estimated 600 genera and 7,500 species, the *Poaceae* ranks third in number of genera among families of flowering plants. In respect to completeness of representation in all regions of the world and to percentage of the total world's vegetation, it surpasses all other genera. Grasses are one of the first permanent vegetations to reappear after disasters, such as volcanic activity, extended droughts, floods, fires, explosions, abandoned urban ghettos, and battlefields. Without the forgiveness of the *Poaceae,* many ill-advised construction excavations and certain agricultural activities would have had far more disastrous effects on one of our most vital natural resources, the earth's surface soil mantle, on which terrestrial plants and animals live.

To the botanist, grass is a member of the family *Poaceae.* To humans, grasses are the most important of all plants. The cereal grains and corn *(Zea mays* L.), all members of the grass family, serve as food for humans and animals. A host of grazing ruminant animals use grasses as their major food source as forage, pasture, and prepared feeds. Bamboo *(Bambusa* spp., *Dendrocalamus* spp., and *Phyllostachys* spp.) is a major building material. Also, grasses of all types represent a large source of biomass for production of methanol, an alternate energy source.

The turfgrass species now in use evolved during the past 50 million years and they have been cultured by humans to provide an enhanced environment and quality-of-life for >10 centuries (Beard, 1973). The modem turfgrass industry has grown rapidly in the past three decades. It contributes substantially to the national economy, with numerous employment opportunities. The annual expenditure for maintaining turfgrass in the USA, including labor but excluding capital expenses, was conservatively estimated to be $25 billion (Cockerham and Gibeault, 1985). This economic impact has increased substantially during the past 10 yr. to $45 billion. This 1993 value was based on the 1985 data with adjustments for population growth and inflation. Also, the fixed assets of turf installations are valued at many times that of the annual maintenance expenditures.

The functional, recreational, and aesthetic contributions of turfgrasses than enhance the quality-of-life for humans often are overlooked and seldom addressed in the scientific literature. Our purpose is to document the beneficial contributions of turfgrasses as summarized in (Fig. 1).

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TURFGRASS FUNCTIONAL BENEFITS

Soil Erosion Control and Dust Stabilization

Turfgrasses are relatively inexpensive, durable groundcovers that protect our valuable, nonrenewable soil resource from water and wind erosion. Agricultural operations and similar activities such as construction involve extensive land disruption, in contrast to turfed land areas, which are maintained in a long-term stable state.

Runoff water from agriculture and urban areas currently account for 64 and 5%, respectively, of the nonpoint surface-water pollution affecting the 265,485 km of rivers in the USA; and 57 and 12%, respectively, of the non-point surface-water pollution affecting the 3.3 million hectares of lakes in the USA. Sediment and nutrients account for 47 and 13%, respectively, of the nonpoint surface-water pollution in rivers and 22 and 59%, respectively, of the nonpoint surface-water pollution in lakes. In the 1987 USDA National Resources Inventory it was estimated that the annual sheet and rill erosion on the 153 million hectares of cultivated cropland in the USA was 9184 kg ha^{-1} (U.S. Department of Agriculture, 1989).

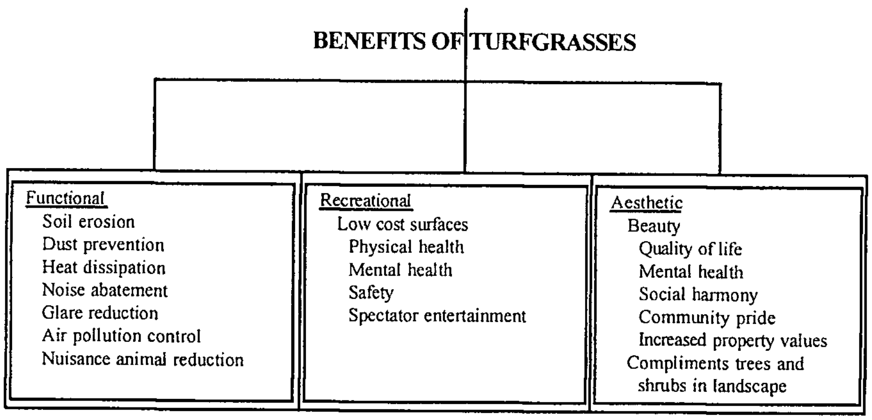

Fig. 1. Diagrammatic summary of benefits derived from turfs.

Gross et al. (1991) reported sediment bsses of ~ 10 to 60 kg ha^{-1} from turfgrass plots during a 30 min storm that produced 76 mm h^{-1} of rainfall; soil loss for bare soil plots averaged 223 kg ha^{-1}. They concluded that well maintained residential turfgrass stands should not be a significant source of sediment entering bodies of water. It generally is recognized that a few large storms each year are responsible for most soil erosion losses (Menzel, 1991). Other studies and reviews (Gross et al., 1990; Morton et al., 1988; Petrovic, 1990; Watschke and Mumma, 1989; Watson, 1985) have demonstrated or concluded that quality turfgrass stands modify the overland flow process so that runoff is insignificant in all but the most intense rainfall events. The ability of grasses to function as vegetative filter strips that greatly reduce the quantity of sediment transported into surface streams and rivers is well documented, especially when positioned downslope of cropland, mines, and animal production facilities (Barfield and Albrecht, 1982; Dillaha et al, 1988; U.S. Environmental Protection Agency, 1976; Young, 1980). A key characteristic of mowed turfgrasses that contributes to this very effective erosion control is a dense ground cover with a high shoot density ranging from 75 million to >20 billion shoots per hectare (Beard, 1973; Lush, 1990). Regular mowing, as practiced in turf culture, increases the shoot density substantially because of enhanced tillering when compared with ungrazed grasslands (Beard, 1973). Putting and bowling greens mowed at a 4-mm height possess up to 66 billion shoots ha^{-1}.

The erosion control effectiveness of turfgrass is the combined result of a high shoot density and root mass for surface soil stabilization, plus a high biomass matrix that provides resistance to lateral surface water flow, thus slowing otherwise potentially erosive water velocities. Therefore, perennial turfgrasses offer one of the most cost-efficient methods to control water and wind erosion of soil. Such control is very important in eliminating dust and mud problems around homes, factories, schools, and businesses. When this major erosion control benefit is combined with the groundwater recharge, organic chemical decomposition, and soil improvement benefits discussed in the next three sections, the resultant relatively stable turfgrass ecosystem is quite effective in soil and water preservation.

Groundwater Recharge and Surface Water Quality

One of the key mechanisms by which turfgrasses preserve water is their superior capability to trap and hold runoff, which results in more water infiltrating and filtering through the soil-turfgrass ecosystem. A mowed turfgrass possesses a leaf and stem biomass ranging from 1,000 to 30,000 kg ha^{-1}, depending on the grass species, season, and cultural regime (Lush, 1990). This biomass is composed of a matrix of relatively fine-textured stems and narrow leaves with numerous, random open spaces. The canopy matrix is porous in terms of the water infiltration capability.

Studies in Maryland conducted on the same research site have shown that surface-water runoff losses from a cultivated tobacco *(Nicotiana tabacum* L.) site averaged 6.7 mm ha^{-1} 4 wk^{-1} during the tobacco-growing season (May-September); whereas, the surface-water runoff loss from perennial turfgrass averaged only 0.6 mm ha^{-1} 4 wk^{-1} (Angle, 1985; Gross et al., 1990). Surface runoff losses of total N and P for tobacco were 2.34 and 0.48 kg ha^{-1} 4 wk^{-1}, respectively. Losses of N and P from the turf averaged only 0.012 and 0.002 kg ha^{-1} 4 wk^{-1}, respectively. Other studies have shown a similar ability of a turfgrass cover to reduce runoff, and therefore enhance soil water infiltration and groundwater recharge (Bennett, 1939; Gross et al., 1991; Jean and Juang, 1979; Morton et al., 1988; Watschke and Mumma, 1989). Finally, the reduced runoff volume from a turfgrass cover offers the potential to decrease the storm-water management requirements and costly structures used in urban development (Schuyler, 1987). Turfgrass ecosystems can support abundant populations of earthworms *(Lumbricidae)* of from 200 to 300 m^{-2} (Potter et al., 1985, 1990a). Earthworm activity increases the amount of macropore space within the soil, that results in higher soil water infiltration rates and water-retention capacity (Lee, 1985).

Organic Chemical Decomposition

The runoff water and sediment that occurs from impervious surfaces in urban areas carries many pollutants, (Schuyler, 1987) including metals such as Pb, Cd, Cu, and Zn; hydrocarbon compounds as from oil, grease and fuels; and household and industrial hazardous wastes such as waste oils, paint thinners, organic preservations, and solvents. Turfgrass areas can be designed for the catchment and filtration of these polluted runoff waters (Schuyler, 1987). It is significant that large populations of diverse soil microflora and microfauna are supported by this same soil-turfgrass ecosystem. Microflora constitute the largest proportion of the decomposer biomass of most soils. The bacterial biomass component ranges from 30 to 300 g m^{-2}, and fungi from 50 to 500 g m^{-2}, with actinomycetes probably in a similar range (Alexander, 1977). Soil invertebrate decomposer biomass ranges from 1 to 200 g m^{-2}, with the higher values occurring in soils dominated by earthworms (Curry, 1986). Though soil animals play an important part in the decomposition process, only 10% or less of the CO_2 produced during decomposition has been attributed to them (Peterson and Luxton, 1982).

The bacterial population in the moist litter, grass clippings, and thatch of a turf commonly is in the order of 10^9 organisms cm^{-2} of litter surface (Clark and Paul, 1970). These organisms offer one of the most active biological systems for the degradation of trapped organic chemicals and pesticides. The average microbial biomass pool is reported to be 700, 850, and 1090 kg C ha^{-1} for arable, forest, and grassland systems, respectively (Smith and Paul, 1990). A microbial biomass of 1200 kg C ha^{-1} has been reported for grasslands in the USA (Smith and Paul, 1988). Microbial biomass values of mowed turfgrasses are not yet available, but are probably even higher due to the high C biomass contained in the senescent leaves and grass clippings that accumulate near the soil surface and to a more favorable soil moisture regime due to irrigation (Smith and Paul, 1990).

The turfgrass ecosystem also supports a diverse community of nonpest invertebrates. For example, a Kentucky bluegrass *(Poa pratensis* L.)-red fescue *(Festuca rubra* L.) polystand in New Jersey supported 83 different taxa of invertebrates including insects, mites *(Acarina* spp.), nematodes *(Nematoda* spp.), annelids *(Annelida* spp.), gastropods *(Gastropoda* spp.), and other groups (Streu, 1973). Similarly, dozens of species of rove beetles, *(Staphylinidae*), ground beetles *(Carabidae), ants* (*Formicidae*), spiders *(Araneae),* and other groups of invertebrates have been recovered from turfgrass sites (Arnold and Potter, 1987; Cockfield and Potter; 1983, 1984, 1985). Earthworms, oribatid mites *(Cryptostigmata),* Collembola, and other invertebrates also are abundant in turfgrass soils (Arnold and Potter, 1987; Potter et al., 1985, 1990a,b; Vavrek and Niemczyk, 1990).

There also is the gaseous dimension of atmospheric pollution control. Carbon monoxide concentrations >50 μL often occur in urban environments, especially near roadsides (Jaffe, 1968). Gladon et al. (1993) reported that certain turfgrasses, such as tall rescue *(Festuca arundinacea* Schreber), may be useful as an absorber of CO from the urban environment.

Soil Improvement and Restoration

An extremely important function of turfgrasses is soil improvement through organic matter additions derived from the turnover of roots and other plant tissues that are synthesized in part from atmospheric CO_2 via photosynthesis. A high proportion of the world's most fertile soils has been developed under a vegetative cover of grass (Gould, 1968). The root depth potential ranges from 0.5 to 3 m, depending on the turfgrass species, extent of defoliation, and soil-environmental conditions. Generally, C_4 warm-season turfgrasses produce a deeper, more extensive root system than the C_3 cool-season species (Beard, 1989b). More work has been reported on the rooting characteristics of Kentucky bluegrass than any other species. The root system biomass of a Kentucky bluegrass lawn is in the range of 11,000 to 16,100 kg ha^{-1} (Boeker, 1974; Falk, 1976). In the upper 150 mm of the soil there are ~ 122,000 roots and 6.1X 10^7 root hairs per liter of soil, with a combined length of >74 km and a surface area of ~ 2.6 m^2 (Dittmer, 1938).

Falk (1976) estimated that the annual root system turnover rate was 42% for a lawn. Using Falk's estimate, 6761 kg of root biomass per hectare would be turned over into the soil each year. This estimate is low because it did not account for root secretions, death and decay of fine roots and root hairs, and consumption of roots by soil animals. The amount of root biomass annually produced and turned over into the soil, or root net productivity, for a defoliated grassland is higher than the amount reported for ungrazed prairie ecosystem (Dahlman and Kucera, 1965; Sims and Singh, 1971, 1978). Similarly, the net effect of regular mowing on prostrate growing turfgrasses would be to concentrate energies into increased vegetative growth, as opposed to reproductive processes, and to form a canopy of numerous dense, short, rapid growing plants with a fibrous root system. Also, many prairie lands in the USA generally show decreased productivity under regular defoliation, as by mowing, since most native grass species found in these ecosystems form meristematic crowns that are elevated higher above the soil and where removal is more likely when compared with turfgrass species. Dahlman and Kucera (1965) estimated the time required for a central Missouri prairie to reach 99% soil organic matter equilibrium to be 110, 420, and 590 yr for the A_1, A_2, and B_2 soil horizons, respectively.

Accelerated soil restoration of environmentally damaged areas by planting perennial grasses is employed effectively on highly eroded rural landscapes, burned-over lands, garbage dumps, mining operations, and steep timber harvest areas. These areas may then be developed as parks, golf courses, sports field complexes, and recreational areas.

Heat Dissipation-Temperature Moderation

The overall temperature of urban areas may be as much as 5 to 7°C warmer than that of nearby rural areas. Through the cooling process of transpiration, turfgrasses dissipate high levels of radiant heat in urban areas. Maximum daily canopy temperatures of a green, growing *Cynodon* turf was found to be 21°C cooler than a brown dormant turf and 39 'C cooler than a synthetic surface (Table 1; Beard and Johns, 1985). The transpirational cooling effect of green turfs and landscapes can save energy by reductions in the energy input required for interior mechanical cooling of adjacent homes and buildings (Johns and Beard, 1985).

An additional asset of a turfgrass ecosystem is the lower total energy input requirements for maintenance compared with other landscape types. A comparison of typical landscapes used in Florida revealed a lawn was the least energy intensive at 31.5 MJ m^{-2} yr^{-1}, followed by 5-yr-old trees at 87.5 MJ m^{-2} yr^{-1}, and then by shrubs at 114.8 MJ m^{-2} yr^{-1} (Parker, 1982). Similarly, Busey and Parker (1992) reported that the annual hours required for turf maintenance was 1.076 h 100 m^2, while 12.37 h 100 m^2 was required for shrub beds, which seem to be low values. Energy inputs for maintenance could be reduced by proper selection of resource efficient, sustainable species and cultivars of turfgrasses, trees, and shrubs.

Noise Abatement and Glare Reduction

The surface characteristics of turfgrasses function in noise abatement as well as in multi-directional light reflection that reduces glare. Studies have shown that turfgrass surfaces absorb harsh sounds significantly better than hard surfaces such as pavement, gravel, or bare ground (Cook and Van Haverbake, 1971; Robinette, 1972). These benefits are maximized by an integrated landscape of turfgrasses, trees, and shrubs. Unfortunately, the proper use of turfgrasses, trees, and shrubs in concert to maximize noise abatement has received little attention within the scientific community.

Decreased Noxious Pests, Allergy-Related Pollens, and Human Disease Exposure

Closely mowed residential lawns reduce the numbers of nuisance pests such as snakes *(Ophidia* spp.), rodents *(Rodentia), mosquitoes (Culicidae* spp.), ticks *(Ixodoidea* spp.; *Acari* order), and chiggers *(Trombiculidae* spp.; *Acari* order). As undesirable small animals seek haven in taller grasses, flowers, and shrubs at locations more distant from the house, they also are less likely to invade the house.

Allergy-related pollens can cause human discomfort and potentially serious health concerns to susceptible individuals. Dense lawns typically are void of the many weedy species that often produce allergy-related pollens. In addition, most turfgrasses that are mowed regularly at a low height tend to remain vegetative with minimal floral development, and thus have reduced pollen production; however, the best solution for those who enjoy outdoor gardening activities is to select turfgrass species and cultivars that do not form flowers nor the resultant allergy-related pollen. The turf cultural practices employed also influence flower and pollen production.

Exposure to a number of serious human diseases is facilitated by key insect vectors such as mosquitos and ticks. Of current concern is Lyme disease, which is spread by a tick commonly found in unmowed tall grass and woodland-shrub habitats. A closely mowed lawn around residences offers a less favorable habitat for unwanted nuisance insects and disease vectors (Clopton and Gold, 1993). Chigger mite *(T. irritens)* population densities were found to be highest at the ecotone or transition area of neighboring 600-

mm tall grass beyond the mowed turf. This is attributed to the distinct decrease in temperature and solar radiation at the ecotone.

Table 1. Temperature comparisons of four types of surfaces on August 20 in College Station, TX.

Type of surface	Maximum daytime surface temperature	Minimum nocturnal surface temperature
Green growing *Cyodon* turf	31°C	24°C
Dry bare soil	39°C	26°C
Brown summer-dormant *Cynodon* turf	52°C	27°C
Dry synthetic turf	70°C	29°C

Safety in Vehicle Operation-Equipment Longevity

Roadside turfgrasses aid in highway safety, as well as erosion control, by serving as a stabilized zone for emergency stoppage of vehicles (Beard, 1973). Mowed roadside turfs enhance line-of-sight visibility and views of signs and animal hazards, which are vital factors for operators of fast-moving vehicles. Turfgrasses are used for soil and dust stabilization around airport runways and taxiways to prolong the operating life of airplane engines (Beard, 1973). Furthermore, turfgrasses are used on small airstrips as a low-cost means to stabilize the runway surface.

Security For Vital Installations and Lower Fire Hazard

Expanses of green, low-growing turfs in the landscape provide a high visibility zone that discourages unwanted intruders and vandals. Such turfs offer a low-cost approach that is a viable security measure, especially around sensitive military, and police installations. Also, the low fuel value of green, prostrate-growing turfs serves a valuable function as a firebreak that significantly lowers the fire hazard if properly positioned (Youngner, 1970). This attribute is especially important for homes and buildings adjacent to extensive woodland or brush areas.

Wildlife Habitat

The ever-increasing human population of the world results in a continuous increase in land area devoted to urban development. The impact on the wildlife species normally found in such areas is of concern. Certainly, proper planning of appropriate landscapes around homes, businesses, industrial complexes, and public buildings can enhance the potential to support a representative wildlife community that residents may enjoy. A diverse wildlife population can be achieved by an integrated landscape composed of turfgrass, tree, shrub, and water features, such as that found on golf courses (Green and Marshall, 1987; Maffei, 1978). A study of golf courses and parks in Cincinnati, OH, has shown conclusively that passerine birds benefit from golf courses, even to the extent that golf courses may be described as bird sanctuaries (Andrew, 1987). Ponds, lakes, and wetlands are very desirable features as used in parks and golf courses because they create aquatic habitats, as well as diversity in visual landscape aesthetics. Considerable preconstruction planning of golf courses, parks, and recreational areas is needed to address their impact on natural habitats. Properly designed urban landscape green areas such as golf courses and parks can maintain and even promote plant and animal diversity, natural habitats, and wetlands when compared to intensive agriculture and urban residential usage. A naturalized style of golf course design is unquestionably conducive to both golf reaction and wildlife management. Typically, 1.7 times more area on a golf course is used for natural habitats such as roughs, woodlands, and water features than the combined area devoted to greens, tees, and fairways.

TURFGRASS RECREATIONAL BENEFITS

Turfs provide a low-cost, safe recreational surface. Many outdoor sports and recreational activities utilize turfgrasses, including archery, badminton, baseball, cricket, croquet, field hockey, football, golf, hiking, horse racing, horseshoes, lawn bowling, lawn tennis, lacrosse, polo, rugby, shooting, skiing, soccer, softball, track and field, and volleyball.

Both the enjoyment and the benefits of improved physical and mental health derived from recreation and leisure activities on turfs are vital to contemporary society, especially in densely populated urban areas. Community pride and interest can be derived from quality sports fields and parks. Also, spectators derive entertainment from sporting competitions played on turfs.

Turfgrasses provide a unique, low-cost cushioning effect that reduces injuries to the participants when compared with poorly or nonturfed soils, particularly in the more active contact sports like football, rugby, and soccer (Gramckow, 1968). In a study of 12 Pennsylvania high school football programs Harper et al. (1984) reported that 21% of injuries were classified as either definitely or possibly field related. Surface hardness measurements obtained with a Clegg impact soil tester (Lafayette Instrument Co., Lafayette, IN) illustrate the substantial benefit of a properly managed, quality turf in reducing the hardness of sports fields (Table 2; Beard and Sifers, 1993, p. 40; Rogers et al., 1988; Rogers and Waddington, 1990, 1992). Turfs are resilient and pleasant to walk on. This resiliency can help to protect the legs of participants, whether running or walking.

Table 2. Impact absorption values for high school athletic fields versus other surfaces (Rogers et al., 1988).

	Impact hammer weight	
Type of surface	0.5 kg	2.25 kg
	^{g}max†	
High school athletic fields	50-286‡	33-167
Artificial turf	109-172	60-91
Frozen practice athletic field	404	303
Tiled, concrete basement floor	1440	1280
Carpet and pad on tiled concrete floor	260	190
Carpet and pad on hardwood floor	86	134

† ^{g}max = maximum deceleration (harder surfaces have greater ^{g}max values).

‡ Good maintenance practices and field conditions generally were associated with lower impact values that indicated less hardness

Home lawn owners derive the benefits of both physical exercise and therapeutic relaxation from the stresses of the work place through activities involved in the care and grooming of lawns. Many people find lawn maintenance an excellent opportunity to enjoy reasonable exercise and a healthy mental diversion.

TURFGRASS AESTHETIC BENEFITS

Francis Bacon, during the Renaissance in England, wrote that next to the house there is to be a lawn, with an avenue of trees in the middle, and covered shady walks on either side. Respondents to a Harris-*Life* survey reported that one of the things 95% of the respondents wanted most around them was green grass and trees (Hooper, 1970). Turfgrasses provide beauty and attractiveness that enhance the quality-of-life for human activities. Their aesthetic benefits are magnified when combined within an integrated landscape of trees, shrubs, and flowers. A turf has numerous, important mental therapeutic benefits in addition to being attractive. These important dimensions that contribute to our quality of life are too often overlooked.

Improves Mental Health Via a Positive Therapeutic Impact

Most city dwellers attach considerable importance to urban parks and forests with views of grass, trees, and open space (Ulrich, 1986). Cities can be very dismal without green turfgrasses in parks, beside boulevards, and surrounding homes, schools, businesses, and the workplace. The result can be a loss of productivity, more susceptibility to anxieties, and mental disease. For example, an outdoor view contributed to more rapid recovery for hospital patients (Ulrich, 1984). Kaplan and Kaplan (1989) addressed the role of nature, including parks, woodland areas, and large landscape sites in contributing to a person's quality-of-life within urban areas. The role encompassed the opportunity to use nature facilities in recreational activities as well as aesthetics, i.e., the appreciation of natural beauty. They also reported an increased sense of residential neighborhood satisfaction and of general well being when there was a nearby nature landscape. Finally, personal satisfaction improved if individuals were actually involved in gardening activities such as care of the landscape.

Contributes to Social Harmony and Improved Productivity

How we use vegetations, such as turfgrasses, in our surroundings is basic to social stability and harmony. Ugliness is costly. A turfed landscape area surrounding a factory or business is an asset in conveying a favorable *we care* impression to employees and the general public. These employees have lower levels of perceived job stress (Kaplan and plan, 1989). Recent research demonstrates that visual encounters with outdoor landscapes and vegetation can be linked to health and in turn can be related to the economic benefits of visual quality (Ulrich, 1986). The clean, cool, natural green of turfgrasses provides a pleasant environment in which to live, work, and play. Such aesthetic values are of increasing importance to the human spirit and the mental health of citizens because of rapid paced lifestyles and increasing urbanization.

CONTEMPORARY ISSUES

In recent national headlines, there have been allegations that turfgrass culture has a major role adversely affecting the environment. It is important to address these allegations and to identify those that can be supported by sound scientific data in order to make the adjustments needed to eliminate or minimize any potential problem. At the same time it is necessary to nullify those unfounded allegations that are based on speculative pseudo-scientific information.

Water Conservation

Conservation of water has become an issue, not only in the arid regions of the USA, but also in many densely populated eastern urban areas that do not have adequate reservoir supplies as a contingency when extended droughts occur. Considering all our uses for water in the USA, the average person directly or indirectly uses between 6,813 and 7,570 L d^{1} (Rossillon, 1985). To put in perspective, this is more than applying 25 mm of water across a 929 m^2 lawn each day for a year. Industry accounts for 43% of our water use, agricultural irrigation for 47%, and domestic use for cooking, bathing, sanitation, drinking, and landscape irrigation for the remaining 10%. Decisions concerning the most effective programs to reduce water use should consider these data. A primary concern that is seldom mentioned is the actual water leakage loss rate of municipal water distribution systems.

The original xeriscape group and others have actively promoted the reduction of turfgrass areas and their replacement with trees and shrubs as an urban water conservation measure (Beard, 1993). Statements have been made in widely distributed nonscientific publications such as all turfgrasses are higher water users than trees and shrubs. There are no published scientific data available to support this allegation. In fact, the limited experimental data available suggest the opposite position.

Very few of the many hundreds of tree and shrub species-cultivars have actually been quantitatively assessed for their evapotranspiration rates. In contrast, a major portion of the turfgrass species-cultivars have been assessed for their evapotranspiration rates. There are *Cynodon* cultivars with evapotranspiration rates of < 3 mm d^{1}, whose evapotranspiration rates are 50% lower during dry-down periods between irrigation or rain (Beard, 1990). If one compares the evapotranspiration studies that are available, typically trees and shrubs are found to be higher water users than turfgrasses on a per unit land area basis (D. Devitt, 1993, personal communication). This is based on the sound premise that the evapotranspiration rate increases with leaf area when under a positive water balance (Johns et al., 1983; Kim and Beard, 1987). Note that the major grasslands of the world are located in the semiarid regions, whereas the major forests of the world are located in the higher rainfall areas.

Much confusion has arisen from the low water use landscape plant lists from the xeriscape groups that have been widely distributed. The lists are based on the incorrect assumption that those plants capable of surviving in arid regions are low water users, when these plants typically are only drought resistant. When these species are placed in an urban landscape with drip or other forms of irrigation, many can become high water users. This occurs because the physiological mechanisms controlling evapotranspiration and drought resistance are distinctly different and can not be directly correlated within a plant species or cultivar (Beard, 1989b).

For unirrigated landscape sites, detailed assessments have been conducted of drought resistance and dehydration avoidance for many turfgrass species and cultivars (Sifers et al., 1990). The results have shown that a number of turfgrass genotypes possess superior dehydration avoidance and can remain green for 158 d in a high sand root zone without irrigation under the hot summer conditions in College Station, TX. Comparable detailed studies of dehydration avoidance and drought resistance among tree and shrub species are lacking.

When turfed areas are irrigated, the adjacent trees and shrubs also are being irrigated as a result of the multitude of shallow tree and shrub roots that concentrate under the irrigated turf area (Whitcomb and Roberts, 1973). Thus, when a homeowner is irrigating the lawn, most of the adjacent trees and shrubs also are being irrigated.

Numerous turfgrass species are capable of ceasing growth, entering dormancy, and turning brown during summer drought stress, but they readily recover once rainfall occurs (Sifers et al., 1990). Some people incorrectly assume that turfgrasses must be kept green throughout the summer period to survive, and thus will irrigate. Many trees drop their leaves during summer drought stress or during the winter period when only brown bark remains. What then is wrong with a tan to golden-brown turf during summer droughts, if one chooses not to irrigate? If water conservation is the goal, then a dormant turf uses little water whereas certain trees and shrubs may continue to remove water from lower soil depths.

Some advocates propose the replacement of turfgrasses with a mulch cover and then planting landscape shrubs within the mulched area as a water conservation measure. Some mulches do reduce evaporation of moisture from the soil however, the presence of a mulch increases the radiant energy load on the under side of deciduous shrubs and trees, which have a majority of their stomata on the undersides of the leaves. This in turn substantially increases the evapotranspiration rate. For example, detailed studies revealed that crape myrtle *(Lagerstroemia indica* L.) grown on a mulched surface used 0.63 to 1.25 kg m^{-2} d^{-1} more water than those located in a bare soil, and 0.83 to 1.09 kg m^{-2} d^{-1} more water than crape myrtle located in a bermudagrass *(Cynodon* spp.) turf (Zajicek and Heilman, 1991). Further, crape myrtle located on bare soil used 0.2 kg m^{-2} d^{-1} more water than when growing in a bermudagrass turf. Sensible heat and long wave radiation from the mulched area increased plant temperatures and thus the leaf air vapor pressure deficit and associated transpiration rate.

In summary, there is no valid scientific basis for water conservation strategies or legislation requiring extensive use of trees and shrubs in lieu of turfgrasses. Rather the proper strategy based on good science is the use of appropriate low-water-use turfgrasses, trees, and shrubs for moderate-to-low irrigated landscapes and similarly to select appropriate dehydration-avoidant and drought-resistant turfgrasses, trees, and shrubs for nonirrigated landscape areas. The main cause for excessive landscape water use in most situations is the human factor. The waste of water results from improper irrigation practices and poor landscape designs, rather than any one major group of landscape plant materials.

What is the future? Great natural genetic diversity exists among turfgrass genotypes in terms of both low evapotranspiration rates and superior dehydration avoidance/drought resistance (Beard, 1989b). Applying appropriate breeding techniques should achieve even lower water use rates among the currently used turfgrass species and other cultivars.

There is one caution as we strive for low evapotranspiration rates. One must avoid a narrow, single-issue emphasis that ignores the potential effects of a lowered evapotranspiration rate on the total urban ecosystem. Urban areas already suffer substantially higher temperatures than adjacent rural areas. Lowering the evapotranspiration rate through plant material selection and judicious irrigation will reduce transpirational cooling and increase heat loads on residences and buildings, thereby increasing energy requirements for interior mechanical cooling. Depending on the relative costs and availability of water vs. energy, it may be wise in certain urban areas not to strive for the lowest possible water-using landscapes. Here again, detailed scientific investigations will be required to develop appropriate definitive strategies that take into consideration the total effects on all components within the urban ecosystem. Furthermore, turfgrass areas can be irrigated with reclaimed wastewater. This practice has been successfully evaluated for turfs (Anderson et al., 1981a,b; Dudeck et al., 1979; Hayes et al., 1990a,b). In this age of conservation and recycling, irrigating turf and landscape sites with recycled water has considerable merit.

Groundwater and Surface Water Quality Preservation

Ten percent of the turfgrass areas in the USA receive a higher intensity of culture that involves fertilization. Appropriate questions must be addressed concerning the potential for these chemicals to enter groundwater by downward leaching or surface water via runoff following intense precipitation.

First it has been noted previously that the perennial turfgrasses have an extensive, fibrous root system that tends to dominate the upper 200 to 300 mm of the soil profile. This root system has an abundance of root hairs distributed along the full length of the roots (Green et al., 1991). Second, the turfgrass ecosystem forms a very dense aboveground biomass that reduces runoff and thus allows time for soil infiltration of water. Consequently, fertilization of turfgrasses, according to established cultural strategies, presents a negligible potential for nutrient elements to pass through the root zone into the groundwater or be transported by runoff water into surface waters. This has been confirmed by a number of studies or reviews (Cohen et al., 1990; Gold et al, 1990; Gross et al., 1990; Morton et al., 1988; Petrovic, 1990; Watschke and Mumma, 1989). Turfgrass root systems are highly efficient in the uptake of applied nutrients. Comparatively less $N0_3$ leaching occurs from turfgrasses than from row crop agriculture (Gold et al., 1990). In terms of the net effect of N fertilizer use and other factors contributing to water pollution from N, the USEPA estimated that only 1.2% of community water system wells and 2.4% of rural domestic wells nationwide contain NO_3 exceeding 10 mg L^{-1}, which is the Maximum Contaminant Level (U.S. Environmental Protection Agency, 1990, 1992).

Fertilizer application during a time of the year when the turfgrass is dormant or nongrowing is a potentially negative situation. This is because the normally efficient nutrient uptake system of the roots is less operative (Petrovic, 1990). Another potentially negative situation may occur during the process of applying fertilizer. For example, if material gets on sidewalks, driveways, and streets, it may be washed into the sewer system and eventually out into rivers and lakes. Obviously, the individual applying the fertilizer must be informed as to the need to apply all fertilizer to the target turf area only. In addition, fertilizer spreaders can be obtained with appropriate protective edging devices to avoid throwing or dropping fertilizer onto nontarget areas. When fertilizer is applied, it is best followed by a light irrigation to move the particles into the soil, thereby minimizing the potential of nutrients entering lateral surface water flow. On the other hand, excessive irrigation may cause problems on course sandy soils. Excessive application rates of water-soluble N fertilizers on turfgrasses followed by over-watering on sandy soils can cause NO_3 contamination of groundwater (Brown et al., 1982; Snyder et al., 1984).

Trends in turfgrass fertilization have been toward lower N application rates. The highest rates were used during the 1960s. The rates now used on professional turf areas have been reduced to one-third of those formerly used. In addition, the use of slow-release N carriers has increased. In fact, the turfgrass industry has been a leader in the development of slow-release nutrient carriers that offer increased environmental protection.

For the future, the breeding of turfgrasses with improved tolerance to N stress should be emphasized. It also is critical to educate the general public that the darkest green turf, which many people strive for, is in fact not the healthiest turf. A medium green turf with a moderate growth rate will have the deepest root system with less thatching, reduced disease and insect problems, and increased tolerance to environmental stresses such as heat, drought, cold, and wear (Beard, 1973).

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