Water Issues Facing the Turfgrass Industry

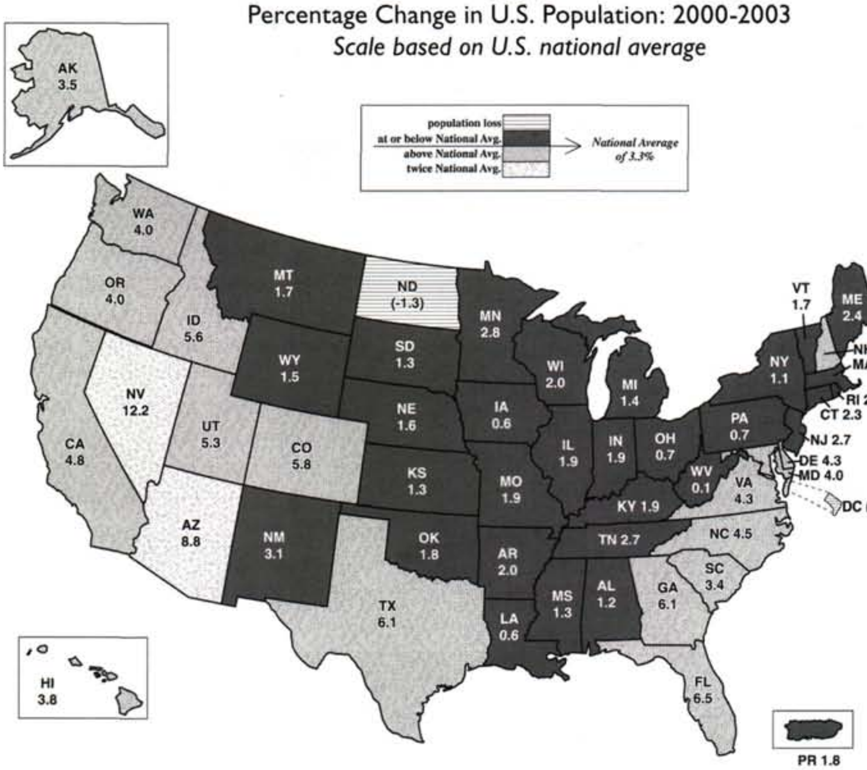
Leading turfgrass scientists meet to exchange ideas regarding issues facing turfgrass water use.

BY JAMES B. BEARD AND MICHAEL P. KENNA

Turfgrasses used in urban areas impact Americans daily in many ways. There are an estimated 50 million acres of maintained turfgrass in the United States on home lawns, golf courses, sports fields, parks, playgrounds, cemeteries, and highway rights-of-way. The annual economic value of this turfgrass is estimated to be $40 billion.[2]

Scientists have documented an array of benefits to the environment and humans resulting from turfgrasses, but critics point out the excessive water requirements and pesticide use for turfgrass versus other landscape materials. It is important, however, to point out that plants do not conserve water; people do. Turfgrasses belong to the grass family, which evolved over millions of years without pesticides and irrigation systems. There are grasses adapted to the wettest and driest climates in the world. Academic and industry research on turfgrass can and will continue to provide quality turfgrass while reducing pesticide use and conserving water.

Figure 1
Percentage Change in U.S. Population: 2000-2003
Scale based on U.S. national average



WATER CRISIS

There is no longer a significant relationship between population distribution and water availability. The desert Southwest of the United States (Arizona, Nevada, and California) is among the fastest-growing areas,[7] yet this is an area with undeniable water supply and distribution problems (Figure 1). According to the U.S. Geological Survey (USGS), total fresh water withdrawals during the last 45 years have declined as population has grown. The USGS concluded that more efficient industrial and agricultural water use accounted for the decrease in water withdrawals while population increased.

Urban water use can be divided into indoor and outdoor uses. Indoor water use remains fairly constant throughout the year; the peak demand for water during the summer, however, is the result of outdoor water use. Even in areas where water supplies are ample, an economic or investment concern exists whenever the peak demand becomes a driving force for water agencies' decision-making process. Flattening the peak demand is an objective of water agencies. Because the demand curve typically is highest during times of increased outdoor water use, conservation efforts target landscapes generally and turfgrasses specifically.

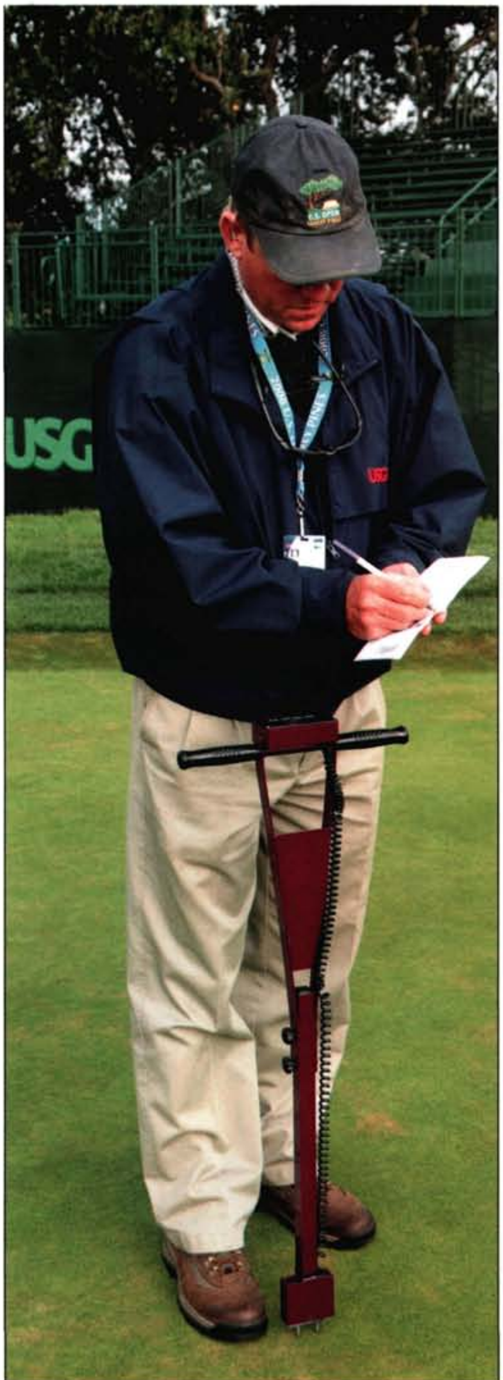
Clearly, water conservation can have positive benefits, such as extending the availability of water to more people or other uses and reducing the costs associated with developing new water resources. Outdoor water use estimations are complicated, however, and have many shortcomings. There is a need for more research and analysis to refine outdoor water use. There also is a need to clarify how much water is consumed by various landscape materials and how much is returned either through evaporation, runoff, or groundwater recharge.

LOW-PRECIPITATION LANDSCAPES

Several problems can result from the loss of a turfgrass cover by not allowing appropriate irrigation in low-precipitation regions. The seven categories of problems include diseases and airborne dust, heat stress islands, wildfires, soil erosion and flooding, urban pollutants, criminal activity, and human disharmony. There is a tendency to use a simplistic approach for eliminating certain water uses by enacting public laws. A single-issue approach of not permitting irrigation on all or a portion of the land area, such as grassed lawns, can lead to other potentially serious problems.

Officials need to take these consequences into consideration when proposing legislation to exclude irrigation from all or part of the urban landscape. There are many other functional benefits attributed to the use of the turfgrass/soil ecosystem in urban landscapes that are summarized briefly. Certainly, the social and economic values of these benefits are substantial, but studies quantifying the economic aspects are needed.

Rather than eliminating certain water uses in low-precipitation landscapes, there are other substantial savings to be accomplished in furthering water conservation. These actions range from sustainable best management practices (BMPs) for irrigating turfgrass to repairing leaks in municipal water distribution systems. Incongruities in laws and "money-for-grass" approaches, which eliminate grassy areas but allow the use of ornamental shrubs and trees with higher water use rates, are not sound approaches. An integrated, holistic approach to water use in populated areas is essential. The elimination of turfgrasses from open areas in urban landscapes should be implemented only as a last resort in arid climates. Turfgrasses not only use water, but also collect, hold, and clean it while enhancing subsequent groundwater recharge and contributing to transpiration cooling.



Accurately managing moisture levels in the rootzone is essential to provide top playing conditions, especially on putting greens. USGA Green Section agronomist Pat Gross checks putting green moisture levels at this year's U.S. Open at Torrey Pines.

REGULATORY CONSIDERATIONS

The Environmental Protection Agency (EPA) is responsible for implementing the Clean Water Act and Safe Drinking Water Act, portions of the Coastal Zone Act, and several international agreements protecting our oceans and shores. The EPA's activities are targeted to prevent pollution wherever possible and to reduce risk for people and ecosystems in cost-effective ways. In recent years, water security also has become a more critical part of the EPA's mission. Hall discusses the legislative history and context of the Safe Drinking Water Act and Clean Water Act, along with how the goals of these two acts are integrated through federal, state, and local implementation.[9]

MUNICIPAL POLICIES

There are two fundamentally different legal systems that govern the allocation of water throughout the United States. Under the riparian system, which applies to 29 eastern states that were historically considered wet states, ownership of land along a waterway determines the right to use of the water. In times of shortage, all owners along a stream must reduce the use of water. Because of water scarcity in the West, it was impractical for water rights to depend on ownership of land along streams. This resulted in the prior appropriation system of water rights, which was originally developed by miners in California and adopted by nine arid western states.

Under prior appropriation, a water right is obtained by diverting water and putting it to beneficial use. An entity whose appropriation is "first in time" has a right "senior" to one who later obtains a water right. In times of water shortages, senior rights must be fully satisfied before junior rights are met, sometimes resulting in juniors receiving no water at all. Richardson further explains these systems and various other existing water policies.[16]

In the United States, most water policy is at the state and local (municipal) level; the drinking water system is extremely decentralized and is structured in four basic ways: (1) owned by local governments, (2) independent government authorities, (3) privately owned companies, and (4) public-private partnerships. There are 53,000 community water systems in the United States, and they provide 90% of Americans with their tap water. Only 424 community water systems serve more than 100,000 people. In total, 80% of community water systems serve 82% of the U.S. population. Local governments or an independent government authority own 86% of the community water systems.

Historically, pricing qualifies the costs of capture, treatment, and conveyance. Consequently, this method often obscures the larger, but less quantifiable, societal interest in preserving our water resources. In regard to water rates, there are well-established policies, primarily due to the efforts of the American Water Works Association (AWWA), whose members provide approximately 85% of the drinking water across the United States.

TURFGRASS AND THE ENVIRONMENT

The first step toward water conservation is selecting the correct turfgrass for the climate in which it will be grown. Kenna presents a breakdown of climate zones in the United States and the differences between cool-season and warm-season turfgrasses (Figure 2).[13] During the last 30 years, turfgrass scientists have determined the water use rates for major turfgrass species. Turfgrasses can survive on much lower amounts of water than most people realize; several turfgrass species have good drought resistance. A great deal of this information is available on the Internet through sources such as the Turfgrass Information File at Michigan State University (http://tic.msu.edu).

Agricultural chemicals registered with the EPA are applied to turfgrass, and through several processes, these chemicals break down into biologically inactive byproducts. Two concerns are whether pesticides and nutrients leach or run off from turfgrass areas. The downward movement of pesticides or nutrients through the soil system by water is called leaching. Runoff is the portion of precipitation or rainfall that leaves the area over the soil surface. There are several interacting processes that influence the fate of pesticides and fertilizers applied to turfgrass. Seven processes that influence the fate of pesticides and nutrients include volatilization, water solubility, disruption, plant uptake, degradation, runoff, and leaching.[13] Branham[3] and King

Figure 2: Major Turfgrass Climatic Zones and Geographic Distribution of Species in the U.S.

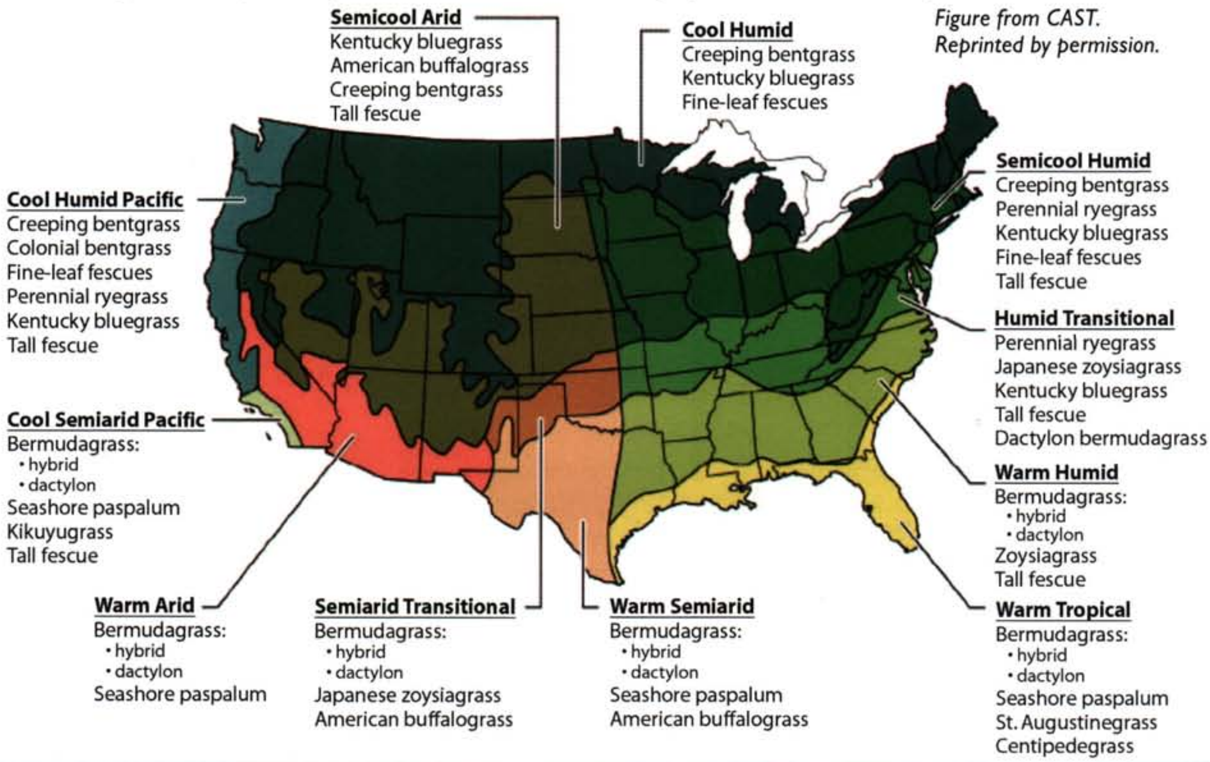


Figure from CAST. Reprinted by permission.

and Balogh[14] further examine these processes and the likelihood that the pesticides will reach ground or surface water.

SOIL WATER

Water flow through soil is influenced partly by local weather conditions. Rainfall places water at the soil surface, and its intensity and duration dictate which portion will infiltrate or run off. Solar radiation, relative humidity, and wind control the rate of water evapotranspiration. Water flow through soil also is influenced by the characteristics and current growth stage of the turfgrass plant. The atmosphere's evaporative demand is tempered by the plant that draws water for transpiration from the soil. Consequently, intra- and inter-species differences in canopy resistance and variations in turfgrass cultural practices affect soil water uptake.

Water flow through soil is controlled by retention and transmission capabilities of the soil pore space.[15] Coarser-textured soils show greater transmission capabilities, and finer-textured soils show greater retention capabilities. Antecedent soil water content also affects the rate of water infiltration and flow through soil.

GROUNDWATER

Turfgrasses and associated management practices reduce the potential for leaching of pesticides and nutrients to groundwater. Branham reviews the manner in which a healthy turfgrass protects groundwater.[3] Turfgrass can provide considerable protection against leaching because of the high levels of organic matter and associated microbial activity that serve to immobilize and degrade applied pesticides and nitrates. Excessive irrigation or large rain events, which lead to preferential or macropore flow, can mitigate these advantages and push solutes below this zone of microbial activity.

It is unwise to generalize when discussing pesticides because each pesticide has different characteristics that affect its distribution and fate; most pesticides currently used in turfgrass, however, present fairly low risks of producing significant groundwater contamination. Healthy turfgrass has a great capacity to use applied nutrients. Nitrate leaching may present problems, however, in some segments of the turfgrass industry where nitrogen fertilization rates have not been reduced to account for turfgrass age and clippings return.

An important issue for the golf course industry is how golf course management affects water quality of the surrounding water resources. The USGA has funded several studies to analyze the movement of nutrients and pesticides from turfgrass in both plot- and watershed-scale study areas.

SURFACE WATER

Available knowledge about surface runoff quantity and chemistry from urban landscapes has increased over the last two decades; more information is required, however, before any overarching, widespread conclusions can be made. King and Balogh discuss factors that affect surface runoff, such as climate, site and soil conditions, and management.[14] The most significant climate factors are precipitation, evapotranspiration, and temperature. Site and soil conditions also affect potential off-site movement of sediment, nutrients, and pesticides. The most significant site and soil conditions are soil texture and organic matter content, bulk density, hydraulic conductivity, thatch layer, landscape slope, and proximity to water resources.

The most critical factor affecting surface runoff is management, which includes irrigation, drainage, fertilizer and pesticide application, and cultural practices. A reasonable case could be made that runoff volume generally is small, and losses of pesticides and nutrients are less than those from agriculture.[14] More geographically diverse, long-term data sets on both cool- and warm-season grasses and on well-defined catchments under natural conditions would further document this aspect.

PESTICIDE AND NUTRIENT MODELING

Researchers who develop various approaches to turfgrass management, regulators and the regulated community concerned about off-site transport of pesticides and nutrients, and various scientists and engineers who designed

Aquatic plants are being established in this small lake to filter nutrients and provide habitat for aquatic species.

the best management practices (BMPs) for managed turfgrass rely on mathematical models to predict the fate of turfgrass chemicals. Most of these models have not been designed for turfgrass, and the unique aspects of turfgrass relative to row crops should be incorporated into model algorithms and input guides. In addition, there can be fundamental questions about the overall model application scenarios regarding their ability to offer reliable predictions. Although models are useful tools, their content and application must be continually scrutinized and improved.

Cohen et al. summarize the key practices and research regarding techniques and applications of mathematical models that predict the offsite transport of turfgrass chemicals to water resources.[5] These models are important tools for risk assessment and risk management of turfgrass chemicals, but they have potential to produce results that deviate significantly from reality. There are fundamental conceptual model and algorithm issues when evaluating chemical fate in turfgrass compared with row crop agricultural systems.

PLANT SELECTION

Water use declines as the leaf area/leaf elongation rate decreases and the turfgrass density increases. Also, turfgrasses with deep, extensive root systems, coupled with decreased water use, are more drought resistant and have greater water conservation potential. Water usage rates vary with species and cultivars, as documented by extensive research, and are affected by external factors, especially environmental conditions. Selecting low-water-use and/or drought-resistant turfgrass species and cultivars is a primary means of decreasing water needs. Also, selection of turfgrass species and cultivars that are adapted to local climatic conditions can result in significant water savings. For example, in arid and semiarid climatic conditions, warm-season turfgrasses use less water than cool-season turfgrasses. Devitt and Morris address these plant selection factors as they relate to water conservation.[6]

Currently, there is a lack of scientific data on the water use of trees, shrubs, and ground covers, as well as on how this water use is influenced by growing conditions and irrigation. Note that grassland-dominant plant communities occur in drier climates compared with forest lands. Emphasis should be placed on choosing functional landscapes and avoiding banning entire plant categories without justification. Turfgrasses that have lower water requirements should be used when possible.

TURFGRASS WATER USE

As water availability becomes increasingly limited and more costly, water conservation in turfgrass culture becomes extremely important. Without adequate water, turfgrass becomes brown and desiccated, and it may die in severe instances. Turfgrass growth characteristics that affect water use include differences in canopy configuration or leaf orientation, tiller or shoot density, growth habit, rooting depth, and root density. Water usage rates vary with species and cultivar and are affected by many external factors, especially environmental conditions. Huang discusses the water use characteristics of different turfgrasses and how environmental factors affect turfgrass water use.[11]

Water use of turfgrasses is evaluated based on the total amount of water required for growth and transpiration (water lost from leaves), plus the amount of water lost from the soil surface (evaporation). Transpiration water consumption accounts for more than 90% of the total amount of water transported into the plants, with 1% to 3% actually used for metabolic processes.

Dormant turfgrass plants have limited or no transpiration water loss, and thus have low water usage. The leaves of dormant turfgrass turn brown in response to a water deficit, but the growing points in the stem are not dead. In general, turfgrasses, especially those with rhizomes (underground stems), can survive without water for several weeks or months with limited damage, depending on the air temperature. Allowing certain turfgrasses to go dormant in low-maintenance areas can result in significant water savings without loss of turfgrass.

Water use of turfgrasses is influenced by environmental factors such as temperature, wind, solar radiation, relative humidity, soil texture, and soil moisture. These factors affect both plant transpiration and soil evaporation. Understanding the environmental factors influencing water use is important for developing efficient cultural strategies for turfgrass, especially in areas with limited water supply. Knowledge of critical plant physiological status and soil moisture content of different soil types is important for scheduling when to irrigate, how much water to apply by irrigation to replenish water loss through evapotranspiration, and how deep to irrigate the soil.

CULTURAL PRACTICES

There is adequate research to substantiate specific cultural practices, or systems approaches, to decrease turfgrass water use, conserve water, and enhance drought resistance. Mowing height and frequency, nutrition, and irrigation are primary cultural practices that directly impact vertical elongation rate, leaf surface area, canopy resistance, rooting characteristics, and resultant water use. These practices, as explained by Shearman, can be used immediately to conserve water and maintain turfgrass quality and functional benefits.[17] Secondary cultural practices, such as turfgrass cultivation, topdressing, wetting agents, plant growth regulators, and pest management, also influence turfgrass top and root growth and subsequently influence potential water conservation.

ACHIEVING EFFICIENT IRRIGATION

Huck and Zoldoske discuss many elements of high water use efficiency in irrigation, beginning with proper system design and including installation, management, and maintenance of the irrigation system.[12] One critical element

The USGA has funded several research projects to understand the hydrology, surface flow, runoff, and leaching of water from golf course turf. This project at Oklahoma State University is designed to understand how to minimize runoff by the use of vegetative filter strips along the edges of fairways.

is to apply the proper amount of water when the landscape needs the water to avoid both deep percolation and runoff. This practice may include cycling of control valves to minimize the surface movement of applied water.

A second important element to high water use efficiency is to apply water as uniformly as possible. Innovative sprinkler designs for turfgrass and drip/micro irrigation for landscape plants have improved irrigation uniformity significantly in recent years, when properly designed and installed. Tools now exist for designers to model sprinkler application uniformity before the system is purchased and installed. Thus, it is reasonable to specify the irrigation application uniformity in a contract before purchasing an irrigation system.

Auditing can be used to verify system performance after installation. Improved controllers for residential irrigation systems, combined with highly uniform sprinkler and/or drip irrigation systems, will produce high water use efficiency, leading to significant water savings over conventional practices. This approach has been validated on extensive turfgrass areas and needs to be emphasized for home landscapes.

RECYCLED WATER

In dry regions of the country, and in highly populated metropolitan areas where water is a limited natural resource, irrigation of landscapes with municipal recycled water, untreated household gray water, or other low-quality (saline) water is a viable means of coping with potable water shortages. Harivandi et al. explain these methods and the associated benefits and concerns of their use.[10] Many years of practice and field observation on extensive turfgrass areas confirm that recycled or brackish water can be used successfully to irrigate turfgrasses. Water conservation resulting from this practice far outweighs the potential negative impacts. Nonetheless, recycled or brackish water quality must be evaluated thoroughly before developing appropriate plant cultural strategies for its use.

Irrigation water quality, which is a function of the volume and type of dissolved salts present in the water, affects the chemical and physical properties of soil, and therefore plant-soil-water relations. The interrelationships can be monitored by regular chemical analysis, and in many situations can be managed. Currently, the use of household gray water for irrigating home landscapes is not widely practiced. More research is needed to determine the most effective, least expensive, and safest (vis-à-vis human health) methods for using such water.

PUBLIC POLICY APPROACH

A water conservation program can be very effective. It can be based on science, and it can be embraced by the citizens of a community. The water conservation program in San Antonio, Texas, fits that description. San Antonio is a community in a semiarid climate that has decreased per-capita water use by more than 40% since the early 1980s and has avoided conflict over landscape watering. Success has been achieved because the San Antonio Water System recognized the value of lawns to its citizens and worked with them to develop a comprehensive water conservation program that addressed infrastructure improvements, inefficient plumbing, industrial technology, and other water-saving opportunities, along with savings in landscape watering. The landscape watering savings were based on opportunities identified in outside research and local studies, resulting in changes in turfgrass management, variety or cultivar selection, and irrigation technology, without attempting to eliminate lawns.

Every community's situation is different, and the formulas for decreasing water use may be different. The example provided by San Antonio shows that water use can be decreased in a manner that takes advantage of turfgrass benefits and is consistent with local positive attitudes toward turfgrass use.[8]

COMPREHENSIVE ASSESSMENT

Carrow and Duncan review various approaches for comprehensive water quality and environmental management.[4] The BMP approach developed over the past 35 years by the EPA for protection of surface and subsurface waters from sediment, nutrients, and pesticides has a long track record for being successfully implemented because of certain critical characteristics. It is science-based; incorporates all strategies in the ecosystem (holistic); embodies all stakeholders and their social, economic, and environmental concerns; values education and communication outreach; allows integration of new

Providing great playing conditions while conserving water is a top priority of all superintendents. This requires careful hand-watering of putting greens so that firm, but fair conditions are maintained and the stress on the putting green turf is minimized.

technologies; has been applied at the regulatory, watershed, community, and site-specific levels, as well as in educational realms; and maintains flexibility to adjust to new situations. Thus, this BMP model is the template for dealing with other complex environmental issues, such as water conservation.

An Environmental Management System (EMS) approach brings under one umbrella all environmental issues and consequences at a site. When a single issue (e.g., water conservation) is targeted by a group toward the turfgrass industry or a single facility, it is not uncommon for the only determination of success to be the decrease in water use, without any consideration for economic/job or unintended environmental consequences. Within an EMS, all environmental issues are addressed, including potential adverse effects.

SUMMARY

There is a pending water crisis due to population growth in areas with inadequate water supplies. Even in areas where water supplies are ample, an economic or investment concern exists whenever peak demand becomes a driving force in decisions about providing water to the public. There is a tendency to use a simplistic approach for eliminating certain water uses by enacting public laws. A single-issue approach of not permitting irrigation on all or a portion of the land area, such as grassed lawns, can lead to other potentially serious problems. Officials need to take these consequences into consideration when proposing legislation to exclude irrigation from all or part of the urban landscape.

In the United States, there is currently no national water policy, partly because of the history of the country and partly because most water issues have been treated as local issues, resulting in an extremely decentralized water delivery system. The nation's water issues need to be addressed in an integrated manner, focusing on programs at the watershed and basin levels. There is a need to reconcile the myriad laws, executive orders, and congressional guidance that have created a disjointed, ad hoc national water policy. The fiscal realities facing the nation need to be recognized to effectively coordinate the actions of federal, state, tribal, and local governments dealing with water.

For grassed landscapes, the first step toward water conservation is selecting the correct turfgrass for the climate in which it will be grown. There is adequate research to substantiate the use of specific cultural practices, or systems approaches, to decrease turfgrass water use, conserve water, and enhance drought resistance. These practices could be used immediately to conserve water and maintain turfgrass quality and functional benefits.

Recycled or brackish water can be used successfully to irrigate turfgrasses. Water conservation resulting from this practice far outweighs the potential negative impacts. Nonetheless, recycled or brackish water quality must be evaluated thoroughly before developing appropriate plant cultural strategies for its use. If irrigation systems are employed, proper design, installation, management, and maintenance are very important. One critical element is to apply the proper amount of water when the landscape needs the water to avoid both deep percolation and runoff.

Other concerns include potential pesticide and nutrient leaching and runoff from turfgrass areas. The legislative history and context of the Safe Drinking Water Act and the Clean Water Act demonstrate that federal, state, and local governments provide a clean and safe drinking water supply. It is important to understand that healthy turfgrass has a great capacity to use applied nutrients, break down pesticides, help recharge groundwater, and reduce surface runoff. The critical aspect is management, which includes irrigation, drainage, fertilizer and pesticide application, and cultural practices. Based on turfgrass landscape research, runoff volume generally is small and losses of pesticides and nutrients are less than those from agriculture. This information is being used to develop models for risk assessment and risk management of turfgrass chemicals.

The BMP approach developed by the EPA has a long track record of being implemented successfully. A water conservation program using a similar approach could be very effective. It can be based on science, and it can be embraced by the citizens of a community. The ultimate goal is to provide quality urban areas for daily activities and recreation while conserving and protecting the water supply.

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The workshop, hosted by the Council for Agricultural Science and Technology (CAST), provided an opportunity for researchers, scientists, environmentalists, and water specialists to join together to discuss the issues facing the turfgrass and water industries. This resulted in CAST Special Publication 27 entitled *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes*, which is available from the Council for Agricultural Science and Technology (CAST), Ames, Iowa. Access http://www.cast-science.org/ for information on ordering this important publication.

LITERATURE CITED

1. Beard, J. B. 2008. Integrated multiple factor considerations in low-precipitation landscape approaches. Pages 33-40. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

2. Beard, J. B., and M. P. Kenna (eds.). 2008. Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

3. Branham, B. 2008. Leaching of pesticides and nitrate in turfgrasses. Pages 107-120. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

4. Carrow, R. N., and R. R. Duncan. 2008. Best management practices for turfgrass water resources: holistic-systems approach. Pages 273-294. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

5. Cohen, S. Z., Q. Ma, N. L. Barnes, and S. Jackson. 2008. Pesticide and nutrient modeling. Pages 153-170. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

6. Devitt, D. A., and R. L. Morris. 2008. Urban landscape water conservation and the species effect. Pages 171-192. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

7. Fender, D. H. 2008. Urban turfgrasses in times of a water crisis: benefits and concerns. Pages 11-31. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

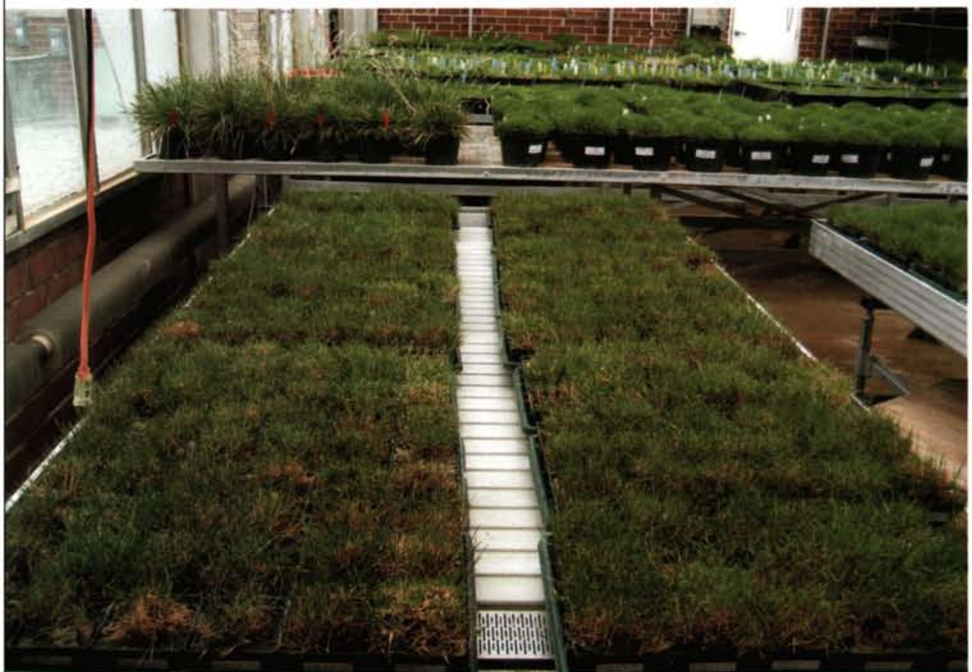
8. Finch, C. 2008. San Antonio water conservation program addresses lawngrass/landscapes. Pages 259-272. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

9. Hall, B. 2008. Regulatory considerations for water quality protection. Pages 41-52. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

10. Harivandi, M. A., K. B. Marcum, and Y. Qian. 2008. Recycled, gray, and saline water irrigation for turfgrass. Pages 243-257. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.

11. Huang, B. 2008. Turfgrass water requirements and factors affecting water usage. Pages 193-203. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa. (TGIF Record 133443).

12. Huck, M. T., and D. F. Zoldoske. 2008. Achieving high efficiency in water application via overhead sprinkler irrigation. Pages 223-242. *In* J. B. Beard and M. P. Kenna (eds.). Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Special Publication 27. Council for Agricultural Science and Technology. Ames, Iowa.



During the last 30 years, turfgrass scientists have determined the water use rates for major turfgrass species. Turfgrasses can survive on much lower amounts of water than most people realize; several turfgrass species have good drought resistance.

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