THE ENVIRONMENTAL PROTECTION AND BENEFICIAL CONTRIBUTIONS OF GOLF COURSE TURFS[1]

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ABSTRACT

During the past decade allegations concerning the adverse effects of golf courses on the quality of our environment have received headlines in nearly every country where golf is played. Unfortunately, these allegations tend to be based on pseudo-scientific arguments that are not germane, but rather are focused to draw on the popular press to promote such allegations by preying on the ignorance of the general populace. Research is ongoing to identify those allegations that are invalid as well as those environmental concerns that can be supported by sound scientific data in order that appropriate adjustments can be made to eliminate or minimize any potential problems. Equally important is the need to recognize and quantify the beneficial contributions of turfgrasses when properly maintained as part of a positive golf course environment. This paper presents our current state of knowledge concerning the benefits of golf course turfs as documented by sound scientific data.

INTRODUCTION

An 18-hole golf course facility in the United States typically is comprised of (a) 2.0 to 3.0 acres (0.8 to 1.2 ha) of putting green area, (b) 1.5 to 3.0 acres (0.6 to 1.2 ha) of teeing area, and (c) 25 to 50 acres (10 to 20 ha) of fairway area (Table 1). In other words, only 20 to 30% of the area on a golf course is used and maintained to specific criteria as part of the playing requirements of the game. Except for the varying types of physical structures that may be constructed on site, a majority of the golf course property is devoted to a low maintenance, natural landscape. A properly planned and maintained golf course facility offers a diversity of functional benefits to the overall community, in addition to the physical and mental health benefits provided from the game itself. These benefits are significant when compared to alternate uses such as industry, business, and residential housing, especially in the case of urban areas where a majority of the golf courses are located. In addition, greater benefits are devised from golf course facilities when compared to agricultural production operations in rural areas.

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Table 1. Comparative turf use by area for a representative 18-hole golf course in the United States.

Turf Use	Area-Acres (ha)	Percent of Area
Rough-water-woodland	130.0 (52.65)	72.2
Fairways	40.0 (16.2)	22.2
Building-parking lots	5.2 (2.11)	2.9
Putting greens	2.5 (1.01)	1.4
Tees	2.3 (0.93)	1.3
Total area	180.0 (72.9)	100.0

Turfgrasses have been used by humans to enhance their environment for over 10 centuries. The complexity and comprehensiveness of the environmental benefits that improve our quality-of-life are just now being quantitatively documented through research. Turfgrass benefits may be divided into (a) functional, (b) recreational, and (c) aesthetic components. The major benefits of a golf course derived from the extensive use of turfgrasses, plus the associated, trees, shrubs, and flowering plants, are summarized as follows.

Soil erosion control and dust stabilization - vital soil resource protection.

Turfgrasses serve as an inexpensive, durable ground cover that protects our valuable, non-renewable soil resources. Perennial turfgrasses offer one of the most cost efficient methods to control wind and water erosion of soil, and thus are very important in eliminating dust and mud problems.

Gross *et al.* (1991) reported sediment losses of approximately 8.9 to 53.4 lb. per acre (10 to 60 kg ha^{-1}) from turfgrass plots during a 30 minute storm that produced 3 inches per hour (76 mm h^{-1}) of rainfall; soil loss for bare soil plots averaged 198 lb. per acre (223 kg ha^{-1}). They concluded that well-maintained 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 concluded that quality turfgrass stands modify the overland flow process so that runoff is insignificant in all but the most intense rainfall events. 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 30 million to >8 billion shoots per acre (75 million to > 20 billion shoots ha^{-1}); putting greens mowed at a 0.15 inch (4-mm) height possess in the order of 26.7 billion shoots per acre (66 billion shoots ha^{-1}) (Beard, 1973; Lush, 1990). Regular mowing, as practiced in turf culture, increases the shoot density substantially because of enhanced tillering when compared to ungrazed grassland (Beard, 1973).

The erosion control effectiveness of turfgrass is the combined result of a high shoot density and root mass for soil surface 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 wind and water 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 ground water recharge, organic chemical decomposition, and carbon storage benefits discussed in the next three sections, the resultant relatively stable turfgrass ecosystem is quite effective in soil and water preservation, as well as in restoration. This restoration of environmentally damaged areas via perennial grasses encompasses highly eroded landscapes, burned-over land, garbage dumps, mining operations, and forestry harvesting.

Enhanced ground water recharge and protection of surface water quality.

One of the key mechanisms by which turfgrasses preserve water is their superior capability to essentially trap and hold runoff, which results in more water infiltrating and filtering downward through the soil-turfgrass ecosystem. A mowed turfgrass possesses a leaf and stem biomass ranging from 890 to 26,700 lb. per acre (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 matrix is porous in terms of the water infiltration capability. Turfgrass ecosystems often support abundant populations of earthworms (*Lumbricidae*) of from 18.6 to 28 earthworms per square foot (200 to 300/m^2) (Potter *et* *al.*, 1985, 1990a). Earthworm activity increases the amount of macropore space within the soil, which results in higher soil water infiltration rates and water-retention capacity (Lee, 1985). Studies in Maryland conducted on the same research site have shown that surface-water runoff losses from conventionally cultivated tobacco (Nicotiana tabacum L.) averaged 0.11 inch per acre (6.7 mm ha^{-1}) $month^{-1}$ during the tobacco-growing season (May-September), whereas the surface-water runoff loss from perennial turfgrass plots averaged 0.0096 inch per acre (0.6 mm ha^{-1}) $month^{-1}$ (Angle, 1985; Gross *et al.*, 1990). Surface runoff losses of total N and total P for tobacco were 2.08 and 0.427 lb. per acre (2.34 and 0.48 kg ha^{-1}) $month^{-1}$, respectively, during the tobacco-growing season. Losses for the same parameters from turf averaged 0.0107 and 0.078 lb. per acre (0.012 and 0.002 kg ha^{-1}) $month^{-1}$, respectively. Other studies have shown a similar ability of a turf or grass cover to reduce runoff and therefore enhance soil water infiltration and ground water recharge (Bennett, 1939; Gross *et al.*, 1991; Jean and Juang, 1979; Morton *et al.*, 1988; Watschke and Mumma, 1989). Finally, the reduced runoff volume, due to a turfgrass cover, may decrease the storm-water management requirements for urban tract development (Schuyler, 1987).

Improved biodegradation of organic chemicals.

A diverse, large population of soil micro-flora and -fauna are supported by the decomposition of roots and rhizomes. These same organisms offer one of the most active biological systems for the degradation of organic chemicals and pesticides trapped by the turf. Thus, this turf-ecosystem is important in the protection of ground water quality.

The runoff water and sediment that occurs from impervious surfaces in urban areas carries many pollutants, (Schuyler, 1987) including metals such as lead, cadmium, copper, and zinc; hydrocarbon compounds as from oil, grease and fuels; and household and industrial hazardous wastes such as waste oils, paint thinners, organic preservatives, 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 ranging 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 623, 756, and 970 lb. C per acre (700, 850, and 1,090 kg C ha^{-1}) for arable, forest, and grassland systems, respectively (Smith and Paul, 1990). A microbial biomass of 1,068 lb. C per acre (1,200 kg C ha^{-1}) has been reported for grasslands in the United States (Smith and Paul, 1988). Microbial biomass values of mowed turfgrasses are not yet available, but are probably even higher due to the high carbon 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 non-pest invertebrates (Potter, 1992). For example, a Kentucky bluegrass-red fescue (*Poa pratensis - Festuca rubra*) polystand in New Jersey supported 83 different taxa of invertebrates including insects, mites, nematodes, annelids, gastropods, and other groups (Streu, 1973). Similarly, dozens of species of *Staphylinidae* (rove beetles), *Carabidae* (ground beetles), *Formicidae* (ants), *Araneae* (spiders), and other groups of invertebrates have been recovered from turfgrass sites (Arnold and Potter, 1987; Cockerfield and Potter; 1983; 1984; 1985). Earthworms (*Lumbricidae*), oribatid mites (*Cryptostigmata*), Collembola, and other invertebrates also are abundant in turfgrass soils (Arnold and Potter, 1987; Potter *et al.*, 1985; Potter *et al.*, 1990a,b; Vavrek and Niemczyk, 1990).

There also is the gaseous dimension of atmospheric pollution control. Carbon monoxide (CO) concentrations greater than 50 μl often occur in urban environments, especially near roadsides (Jaffe, 1968). Gladon, et.al. (1993) reported that certain turfgrasses, such as tall fescue (*Festuca arundinacea*), 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 carbon dioxide (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 of turfgrasses ranges from 1.6 to 9.8 feet (0.5 to 3 m), depending on the 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, (*Poa pratensis*), than any other species. The root system biomass of a *P. pratensis* turf is in the range of 9,790 to 14,240 lb. per acre (11,000 to 16,100 kg ha^{-1}) (Boeker, 1974; Falk, 1976). In the upper 6 inches (150 mm) of the soil there are approximately 122,000 roots and 6.1 x 10^7 root hairs per liter (2.2 pints) of soil, with a combined length of over 46 miles (74 km) and a surface area of about 28 square feet or 2.6 m^2 (Dittmer, 1938).

Falk (1976) estimated that the annual root system turnover rate was 42% for a turf. Using Falk's estimate, 6,035 pounds of root biomass per acre (6,761 kg 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 and 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 United States 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 to turfgrass species.

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 golf courses, and recreational areas.

Enhanced heat dissipation - temperature moderation.

Through the cooling process of transpiration, turfgrasses dissipate high levels of radiant heat in urban areas. The overall temperature of urban areas may be as much as 9 to 12°F (5 to 7°C) warmer than that of nearby rural areas. Maximum daily canopy temperatures of a green bermudagrass (*Cynodon* spp.) turf was found to be 38°F (21°C) cooler than a brown dormant turf and 70°F (39°C) cooler than a synthetic turf surface (Table 2) (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 mechanically cooling of adjacent homes and buildings (Johns and Beard, 1985).

Noise abatement, glare reduction, and visual pollution control.

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.

Table 2. Comparative temperatures of four surfaces assessed in August in College Station, Texas (from Johns and Beard, 1985).

Type of surface	Maximum temperature in °F (°C)	Percent temperature increase over green turf
Green growing turf	88 (31.1)	--
Dry, bare soil	102 (38.9)	16
Brown, dormant turf	126 (52.2)	43
Synthetic turf	158(70.0)	80

Decreased noxious pests, allergy-related pollens, and human disease exposure.

Closely mowed turfs reduce the numbers of nuisance pests such as snakes, rodents (*Rodentia*), mosquitoes, ticks (*Acari*[2] rder), and chiggers (*Acari*[2]order).

Allergy-related pollens can cause human discomfort and potentially serious health concerns to susceptible individuals. Dense turfs 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.

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 turf offers a less favorable habitat for unwanted nuisance insects and disease vectors (Clopton and Gold, 1993). Chigger mite (*Trombicula irritens*) population densities were found to be highest at the ecotone or transition area of neighboring 24 inch (600 mm) tall grass beyond the mowed turf. This is attributed to the distinct decrease in temperature and solar radiation at the ecotone.

Contributes substantially to the national economy.

From a monetary standpoint, the golf industry contributes in excess of US $18 billion annually to the United States economy.

Provides a favorable wildlife habitat.

The 70+% of a golf course that is allocated to rough and non-play area encompasses turfgrasses, trees, and water in the primary rough and turfgrasses, flowers, shrubs, trees, and water in the secondary rough and perimeter areas. 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, Ohio 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 golf courses because they create aquatic habitats, as well as diversity in visual landscape aesthetics. 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. Thus, golf courses are important naturalized open spaces, especially in areas of urban development and intensive agriculture.

Enhanced physical health of golf participants.

The enjoyment and benefits of improved physical/mental health derived from golfing activities on turfgrasses are vital to a contemporary industrialized society, especially in densely populated urban areas. There are 15,000 golf courses in the United States offering 24 million golfers more than 2.4 billion hours of healthy, outdoor recreation.

Improves Mental Health Via a Positive Therapeutic Impact.

Most city dwellers attach considerable importance to urban green areas, with views of grass, trees, and open space (Ulrich, 1986). Cities can be very dismal without green turfgrasses, with the result being 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 reported an increased sense of residential neighborhood satisfaction and of general well-being when there was a nearby nature landscape.

Enhanced beauty and aesthetics.

Turfgrasses provide beauty and attractiveness that enhance the quality-of-life for human activities. 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.

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