Literature Review on The Environmental, Social, and Health Benefits of Turfgrass*

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*Progress Report as at 26th March, 2008

1(a) Background and Objectives:

It is common knowledge that the general public is becoming very much more aware of environmental issues. With recent severe water shortages and the fear of climate change, the general public within Australia and the USA is developing a negative "greenhouse footprint" for turfgrass. This is because it is perceived that turfgrass requires to be maintained regularly, involving mowing, fertilising and watering. These three practices utilise water, a limited resource, create greenhouse emissions (from petrol mowers), and expose the environment to possible chemical pollution from fertiliser and pesticide usage.

This view is well illustrated by Kevin Walsh in "Waterwise Gardening" (Walsh, 2005) where he states, 'the first principle of waterwise gardening is to reduce the amount of lawn. Lawns soak up enormous amounts of water. Lawns use more water per square metre than any other part of the garden. In some parts of Australia, up to 90% of the water used in gardens is applied to lawns.' He goes on further in stating, ' Let's look at the front lawn… A majority of homes have most of the front of the property given over to grass. This serves very little function except perhaps to show off the house, some specimen trees and a fringe of garden beds. In some circumstances, it is really used as a car park. It is never used for entertaining or for children's play. Basically, such a lawn does not justify its existence. It would be best removed…' (Walsh sic.). He says a lot more negative things about side lawns and backyard lawns.

A recent "Action Earth Anti-Lawn Campaign", involving a high profile ex-Olympian swimmer, has been aired on Foxtel and Austar programs as well as on various websites (July, 2007). This campaign claimed that, 'all lawn types require huge amounts of water, chemicals and fertilisers to make them look half decent.' The argument presented mirrors that of Walsh (2005) above, although no claims are substantiated with any evidence whatsoever.

The Sydney Morning Herald (November 15, 2007, page 1) in an article about Australia's contribution to global warming states that, 'the State Government targets petrol lawn mowers in its fight to improve air quality in Sydney…The Assistant Environment Minister, Verity Firth, said… a typical four-stroke lawn mower produces as much pollution in one hour as four cars.'

The ABC's Gardening Australia magazine (October, 2007 issue), termed "the green issue", is not quite as damning in its statement about lawns. It states, 'Lawns have had bad press for years, but they don't have to be the resource

drain they are often made out to be. A lawn is a place for children and pets to play, and can also have environmental benefits including reducing the heat sink effect of your yard. Select slow-growing, drought-hardy lawn varieties to reduce the need for mowing, fertilising and added water.'

Unsubstantiated statements similar to examples above are very common in gardening books, magazines, newspapers and television programs, and they can only have a negative impact on both the image and consequently on the sale of turfgrass. However, how much scientific truth is there in these statements? There needs to be a thorough review of the scientific literature so that the turfgrass industry can be fully informed on just where it stands from an environmental and ecological point of view.

Such a review is the objective of this research project. If it is scientifically determined that turfgrass does have a negative "environmental impact", then recommendations will be made, based on sound scientific principles, to overcome such negative effects and to provide information to the industry so that turfgrass can be marketed and advertised in a more positive manner that will attract sales.

Many of the solutions to turf's perceived "negative environmental impact" exist already, but they aren't being publicised effectively by the Industry. For example, as stated by the ABC above, simply by selecting slow-growing, drought-hardy lawn varieties can lead to a significant reduction in the need for mowing, fertilising and watering. Furthermore, as backyards in Australian city homes continue to become very much smaller or non-existent, the demand for petrol lawn mowers should decline. Hand-pushed mowers should be sufficient for most modern situations but are not being marketed in a positive manner, or even being marketed at all.

1(b) Methodology:

The methodology being employed is a detailed literature review using internet and library searches, as well as the TGIF data file (Michigan State University – Turfgrass Information File, 2007) which contains over 100,000 records of turf references. The following areas are being examined:

1. The benefits of turfgrass, including environmental, aesthetic, socio-economic, and health aspects of its use as part of the total landscape in an urban green space;

2. Research in relation to turf's use on sporting fields, with special reference to surface quality and heat stress;

3. Water usage and efficiency studies, including the need to emphasise the selection of varieties for particular uses;

4. Heat sink effects of turf use with reference to the energy balance between turf and its replacement competitors;

5. Carbon sequestration capacity of turfgrass; and

6. Greenhouse gas emissions related to turfgrass use and maintenance.

2 The Literature Review and Discussion:

2.1. The Environmental Benefits of Turfgrass:

The seminal environmental study of turfgrasses was conducted by J.B. Beard in the early 1990's (Beard, J.B. & R.L. Green 1994). This study seeks to evaluate Beard's results in the context of the Australian environment, and to build on that base.

Beard (Beard, J.B. 1992b) provides a useful summary of the major functional, recreational and aesthetic benefits to the environment derived from utilising turfgrasses. These are:

Functional
Soil erosion control
- Dust prevention
- Rain water entrapment and ground water recharge
- Solar heat dissipation
- Glare reduction
- Noise abatement
- Organic chemical / pollutant entrapment and degradation
- Air pollution control
- Nuisance animal / pest reduction
- Fire prevention
- Security / visibility
- Environmental protection

Recreational
- Low cost surfaces
- Physical health
- Mental health
- Safety cushion
- Spectator entertainment

Aesthetic
- Beauty
- Quality of life
- Mental health
- Social harmony
- Community pride
- Increased property values
- Compliments trees and shrubs in the landscape.

Beard & Green (1994) expand on these environmental benefits in considerably more detail. In recent correspondence with Professor James Beard (Email of 15th February 2008), he states that this paper remains the only comprehensive, peer-reviewed paper on the topic of turfgrass benefits to the environment. It is the authors' view that we need not repeat this exercise but to expand on its base, and to attempt to relate the findings within the Australian context.

The management of turfgrass systems in urban areas generally require:

- Exposure of bare soil surfaces;
- Exposure of areas with disturbed soil structure;
- Vegetation planting, upkeep and maintenance;
- Irrigation;
- Pest management, and
- Fertilization.

These practices can intensify potentially adverse environmental effects, such as soil erosion, sediment and run-off water movement, losses of applied chemicals and nutrients, contamination of groundwater, leaching of pesticides and fertilizers, disturbance of adjacent ecosystems, and impacts on non-target plants and animals (Balogh, J.C. & Walker, J.W., 1992).

The golf course industry has responded to the above issue in a very positive way. Environmental management programs for golf courses have become common practice in recent years (eg: Stubbs, D., 1995 & 1996; Australian Golf Union, 1998).

Although there can be potential environmental risks associated with turfgrass management, the overall benefits of turfgrass should not be underestimated. Healthy turfgrass provides considerable benefit to land surfaces in urban environments by providing resistance to insect and weed infestation (Beard, J.B., 1982). Its dense root system also enables an efficient use of applied nutrients and water, which in turn limits the need for unnecessary irrigation, fertilizer and pesticide applications (Beard, J.B., 1989b). Furthermore, it has a major influence in minimising diffuse pollution by sediments and nutrients in surface waters. Research on various land use types compared with turfgrass indicates that sediment and nutrient losses from urban and turfgrass systems is considerably less than losses from agricultural and forest systems (see Table 1, adapted from Koehler et al., 1982).

Table 1: Estimated Contributions to Surface Waters from Selected Non-point or Diffuse Sources (after Koehler et al., 1982) – Average load in million tons per year.

Source	Sediment	Nitrogen	Phosphorus
Cropland	1870	4.3	1.56
Pasture and Rangeland	1220	2.5	1.08
Forest	256	0.4	0.09
Urban, including Turfgrass	20	0.2	0.02

An Australian study measured soil and nutrient movement from four turf farms in the Wyong region of NSW (Martin & Aragao, 1996). As expected, soil movement was greatest in the period shortly after turf harvest and on land of steeper slope. Measured soil movement averaged 0.61 tonnes/ha/year, with a range from 0.04 to 2.13 tonnes/ha/year. Overall, the soil movement figures were greater than those reported for well managed permanent pastures but were small when compared with irrigated crops grown under conventional tillage. The results are similar to those measured in overseas studies.

This above study (Martin & Aragao, 1996) also reported nutrient loads in runoff from turf farms. Results were as follows (in kg/ha/year): total phosphorus 1.1; nitrate nitrogen 1.4; sulfate 10.1; calcium 6.7; magnesium 2.6; sodium 7.6; potassium 5.9. These results are intermediate between values recorded in the literature for intensive cropping systems and perennial pasture.

Surface run-off is important in transporting both dissolved chemicals and suspended sediment from turfgrass systems to surface waters. Although the volume of surface run–off and sediment loss from turfgrass systems is relatively low compared to other management systems (see Table 2 adapted from Gross C.M. et al., 1990), the volume of run-off from bare soil on turfgrass construction sites is considerably higher (19.2 vs. <1 tonnes/ha per year of sediment) (Daniel T.C. et al., 1979).

Table 2: Average Annual Sediment Losses from Selected soils and slopes under Different Management Conditions (after Gross, C.M. et al., 1990) – Annual Sediment Loss in tons per acre.

Soil Texture/ % Slope	Fallow	Cropping	Rotation	Turfgrass
Loam/4	41.6	19.7	2.7	0.3
Silt Loam/8	112.8	85.5	11.4	0.3
Silt Loam/16	151.9	84.1	25.3	<0.1
Fine Sandy Loam/8	20.3	28.1	5.5	<0.1
Sandy Clay Loam/10	64.7	25.8	10.8	<0.1

These results clearly demonstrate the effectiveness of turfgrass in minimising sediment movement from catchments to adjacent waterways. As nutrients such as nitrogen and phosphorus, and other contaminants such as pesticides, are transported primarily in association with eroded sediment (see Higginson & McMaugh, 2007), then turfgrass is highly effective in minimising their movement as well.

Table 2 also gives a clear indication of the effect of slope on sediment loss, particularly in the case of bare fallow systems and rotational farming. The effect of slope on sediment loss from turfgrass systems was minimal in this study, probably reflecting the dense sward of protective vegetation that turfgrass is generally able to provide when managed correctly.

In 1990, the United States Golf Association (USGA, 1994) funded a three-year environmental research program to quantify and document the impact of turfgrass management on the environment. One objective was to understand and quantify the degradation and fate of turfgrass pesticides and fertilisers so as to be able to accurately predict or simulate their environmental impacts. Research programs were established at 10 Universities within the USA. Results reported for fertilisers suggest a very strong trend exists between the rate of nitrogen application and leaching losses of nitrogen as nitrate (see Figure 1). The relationship between soil type and subsurface loss of nitrogen agrees

closely with previous research conducted on both turf and agricultural systems (see Figure 2). Regardless of the turf cover used, runoff concentrations of applied nitrogen did not appear to be different for different species of turfgrass. Results reported are consistent with those of other researchers, namely that runoff decreases with an increasing amount of soil cover. Turfgrass, due to its dense surface cover, not only attenuates surface losses of water but reduces the potential for surface and subsurface losses of nitrogen as well. Phosphate concentrations in leachate never exceeded the irrigation water content of 1 to 2.5 mg/L. This is not surprising given the high affinity of phosphate for soil particle surfaces, which effectively decreases leaching potential (USGA, 1994). Loss of phosphate in both agricultural and turfgrass systems usually occurs through sediment loss and transport during construction or turf establishment (Higginson & McMaugh, 2007; USGA, 2001).

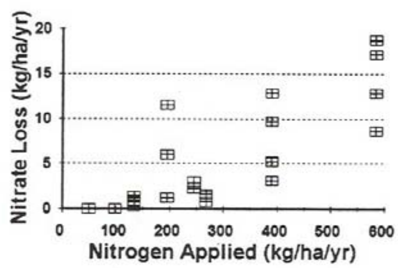


Figure 1. Effect of nitrogen application rate on subsurface nitrogen loss (1 lbs./A = 1.12 kg ha⁻¹).

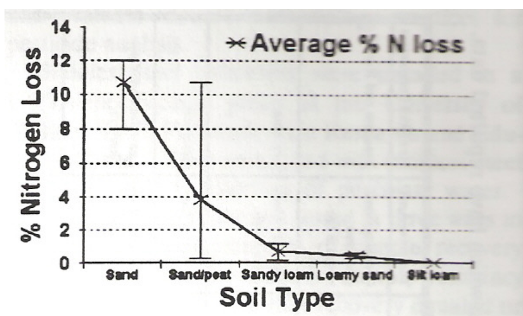
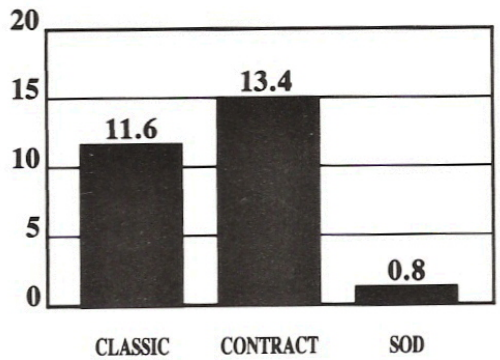


Figure 2. Effect of soil type on subsurface nitrogen loss. Percent nitrogen loss is averaged over studies reporting results for the various soil types. The range of values reported is represented with the 'I' bar.

A study by Pennsylvania State University (Watschke, T.L. 1990) examined the potential effects of turf on the amount of runoff and on the quality of the runoff water. The study compared three treatments; a sodded turf (sod), a seeded turf (classic) and a contractor-applied turf (contract). All plots were maintained equally and uniformally irrigated with a controlled system. The amount of runoff from each plot was measured and samples were chemically analysed for nutrients and pesticides. The results clearly indicate that the sodded turf proved to be 15 times more effective than either of the seeded plots at controlling runoff (see Chart I from Watschke, 1990). When the runoff water

was analysed, researchers found almost no detectable amounts of the eight pesticides and nutrients that had been applied to the turf (Watschke, 1990).

CHART I: RUNOFF, % total applied



Another major study (Snyder,G.H. & Cisar, G.L. 1997) looked at the mobility and persistence of turfgrass pesticides applied to a United States Golf Association (USGA) -type green. Because water percolation can be much more appreciable in a coarse-textured man-made rooting media, leaching of pesticides from a USGA green is an obvious area for investigation. In the above study, two commonly used herbicides were investigated, namely Dicamba and 2,4-D. The results indicate that, although only 10% as much Dicamba as 2,4-D was applied, nearly 65% as much Dicamba was recovered in the percolate water over a 2-month period following application. Clearly, Dicamba was much more mobile than 2,4-D in the USGA green. Nevertheless, the average concentrations of both herbicides in the percolate was well below Maximum Contaminant Levels set by USA authorities (2.6 and 1.2 micrograms per litre compared to 70 micrograms per litre). Clearly, herbicide leaching from turfgrass grown on an ideal drainage media (such as that of a standard USGA green) indicates that herbicide leaching under normal turfgrass circumstances is not a major environmental problem.

Under Australian conditions, there has been limited research undertaken of the fate and behaviour of pesticides applied to turfgrass. One study by Baskaran, S. et al. (1997) indicated that some pesticides do have a leaching potential from turfgrass under average rainfall conditions of Sydney and Brisbane, although the amount of leaching measured was relatively small and well below contaminant levels set by Australian authorities (ANZECC, 1992). The above study by Baskaran et al. also showed that absorption of commonly used pesticides under Australian turf was greater in the thatch than in the rooting medium, and column leaching studies showed that Dicamba had the greatest potential for leaching and Chlopyriphos had the lowest. These results are consistent with those reported in the USA (USGA, 1994).

2.2 Aesthetic and Social Benefits of Turfgrass:

There are many keen gardeners and garden-lovers in Australia that gain great pleasure and enjoyment from a beautiful lawn as a back-drop and framework to a garden. The social and health benefits of this pleasure, particularly to older generations, are immense. As well, lawns are places where children and pets can play, and these beneficial social aspects of turfgrass use are of considerable importance to the average Australian lawn owner.

A recent consumer survey (Turf Producers Australia, 2007) has shown that 50% of the average backyard in Australian cities that used to be turfed is now being landscaped, with the emphasis being on entertainment and outdoor living space, such as barbeques, courtyards and pools. This reduction in the percentage of turfed area also reflects an expansion of landscaped garden space where the lawn is more commonly being used as just part of the overall garden design, and not the prominent feature that it once used to be. The survey also showed that 77% of all backyards surveyed, and 72% of all frontyards, had a lawn of some description.

The same survey revealed that 74% of consumers considered it important to have a lawn/grassed area in community areas, such as local parks and gardens, and only 8% did not consider it to be important. The benefits of local parks and gardens for passive recreation are immense, commonly being used to walk the dog, have family picnics, kick a ball with one's mates, or simply just to relax, go for a walk and enjoy the scenery.

In terms of health, parks have been viewed almost exclusively as venues for leisure and sport. Yet recent research shows that "green nature" ,such as parks, can reduce crime, foster psychological wellbeing, reduce stress, boost immunity, enhance productivity and promote healing (Maller, C. et al., 2002). According to Maller et al. (2002), parks are a fundamental health resource, particularly in terms of disease prevention. The initial evidence documenting the positive effects of "green nature' on blood pressure, cholesterol, outlook on life and stress-reduction is sufficient to warrant its incorporation into strategies for the Australian National Health Priority Areas of 'Mental Health' and 'Cardiovascular Disease'. The extent to which parks, and particularly turfgrass in parks, can contribute to these areas awaits specific investigation.

Beard & Green (1994) report on research which 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 mind and the mental health of citizens in an urban environment.

Some recent Australian research (Maller et al., 2002) demonstrates that contact with companion animals (eg: walking the dog) has multiple positive physiological and psychological effects on human health including: decreasing blood pressure, heart rate and cholesterol; reducing anxiety and stress and providing protection against stress-related diseases; provision of companionship and kinship; and the opportunity to nurture. All of these factors improve quality of life and enhance health and wellbeing. Parks are important in providing a setting for pet-owners to interact both with their pet and with other pet-owners and park users, which can positively influence the social aspects of health. In addition, parks are essential in the preservation of habitat for native wildlife, as well as providing people with the opportunity to observe or encounter animals in their natural environment (Maller et al., 2002).

Maller and her fellow researchers at Deakin University (Maller et al., 2002) conclude that, 'There is a clear message for park managers to join public health fora, as not only do parks protect the essential systems of life and biodiversity,

but they also are a fundamental setting for health promotion and the creation of wellbeing that to date has not been recognised.' Turfgrass, as an essential component of the park landscape, must play a major role in these health benefits.

Another recent study from Deakin University (Henderson-Wilson, C., 2008) surveyed 221 residents in public and private housing in inner Sydney and Melbourne, and suburban Parramatta in Sydney's west. She found that among those things that influenced health and wellbeing, access to green open spaces and a body of water were paramount. She reports that high-rise residents feel a much better quality of life if they can get involved in community gardens or simply just take a stroll in the park. Exposure to nature has been found to enhance psychological wellbeing, to increase immunity to disease and to improve productivity, while isolation from nature has been linked with depression. She reports that, since 1996, medium to high-density housing has spread strongly in Australia's big cities. People are moving away from the traditional house with a backyard, and that's limiting the opportunity for people to be close to nature. The onus now is on urban planners and developers to have green spaces, including community gardens, in their developments and to ensure that parks and lakes are nearby. Having nature within a five-minute walk, or under 500m away, positively helped people's health and wellbeing.

Another study looked at public aesthetic preferences in urban parks and the efficient use of water (Bitar, H., 2004). Two predominant sub-groups within the public were identified, namely those preferring densely forested, natural looking landscapes that are dominated by native/indigenous vegetation, and those preferring more formal, picturesque-style landscapes dominated by lush exotic types of vegetation. Turfgrass or lawn plays a prominent role in the second landscape type.

The results obtained by Bitar from this study infer that native/indigenous vegetated, self-sustained landscapes are more preferred than some more formal landscapes planted with exotic water-hungry vegetation. Nevertheless, the consensus on these environments is not absolute as these two groups accounted for only 45% of the total variance in the data set. Bitar argues that, when variations in preferences emerge from within a given population, the obvious reaction by designers, managers and planners of public parks, should be to provide a variety of types of environments to meet these preferences. Users can then select those that best appeal to their individual preferences.

The implications of this research to the Australian turfgrass industry are not as damning as might first be perceived. Even though there is an apparent drift towards "native lovers" as compared to "exotic lovers" in preferences for parks and gardens, the population tested was only small. "Native lovers" comprised 45% of the population and "exotic lovers" 33%. The message to the turfgrass industry is that there is still a large proportion of the population that prefers European-type gardens comprising rolling lawns and trees, but that this group appears to be declining within the Australian context, particularly when water conservation issues are considered. Furthermore, this study did not include sports fields and parks designed for "active" forms of recreation, an area where turfgrass is still very much the preferred option when compared to its competitors, such as artificial turf and hard-surface areas (eg: asphalt, etc.). A recent survey (Turf Producers Association, 2007) showed that 60% of the

population surveyed considered synthetic turf to be unAustralian, and only 14% disagreed with that view.

2.3. Water Usage by Turfgrass:

Water quantity and quality are now major global environmental issues. As a consequence, the demand for more water-efficient turfgrasses will continue to grow (Landry, G., 2000). Considerable political pressure has been developing in the USA to minimise water use in the urban environment. This concept, termed the "Xeriscape" concept, aimed to reduce water usage by as much as 30% by promoting water conservation. One guideline was to "limit lawn area" , stating that turfgrass is the number one consumer of water in the landscape, and that trees and shrubs be promoted as replacements for turfgrass. Similar statements and concepts have been published in Australia (see Walsh, 2005). Beard argues (Beard, 1993) that the xeriscape concept is not based on sound scientific principles, and that more science has been published on the water usage rates and drought tolerance or drought avoidance of turfgrasses than on any other group of garden trees and shrubs.

This "negative environmental footprint" of turfgrass being a major user of water, however, still persists. For example, a recent consumer survey (Turf Producers Australia Limited, 2007) indicates that misinformation and ignorance about the water requirements of turf is a major area of concern for landscapers. The general consumer perception is that turf uses huge volumes of water and ties up resources. This has led to a reduction in the use of turf for the residential market. Furthermore, Governments, via Regional Water Boards, are strongly promoting a "water wise" policy, and this has been misinterpreted by consumers because of publication in the media and in books of scientifically unsupported statements (eg: Walsh, K., 2005).

Another recent stocktake report on the turfgrass industry (Kiri-ganai Research Pty Ltd, 2007) reaches a similar conclusion. It states that there is a strong public misconception that turf and green space are high water users and "legitimately" the first target in water restrictions. The reality is, according to the report, that the industry has a positive story to communicate about the availability of new turf varieties that use less water, and about the industry's success in improving water use efficiency in turf production and maintenance.

Other professional views agree with the above approach. Bitar (Bitar, H., 2004) states that there is a consensus among irrigation experts that two things contribute to the increase in water consumption in urban parks and gardens. Firstly, the extensive use of turfgrasses and non-Australian exotic plant materials, and secondly, the lack of water zoning (ie. Grouping of plants of similar water needs together into irrigation zones). He also states that most of the water-use in urban parks is dictated by the presence of big stretches of mowed lawn.

For the turfgrass industry to be fully informed on its real level of water usage, it is necessary for a review of published scientific literature (such as this one) to be undertaken, and to promote positive attempts already made by the industry to address the "problem", such as selection of drought tolerant or drought avoiding varieties of turfgrass, and the use of controlled irrigation systems that apply water only when required by use of in-situ soil moisture monitoring systems or other irrigation scheduling techniques.

The University of Western Australia (Colmer, T. 2007), via their Turf Industries Research Steering Committee established in 1995, has initiated such a research program. During the period 1997-2004, they have commenced in consultation with industry groups a research program that includes:

- Collection of data on turf water use against which turf managers can benchmark their irrigation scheduling;
- Information on potential water savings from use of soil-water sensor controlled irrigation scheduling;
- Use of fly ash amendments to improve water and nutrient use in turf systems on sandy soils; and
- Data on nutrient budgets for several fertiliser types and rates against which industry can benchmark fertiliser management to optimise turf quality, and minimise environmental impacts.

A web-site providing additional details on past and present projects, and listing publications arising from the above work, has been established in order to keep industry and other groups informed (Colmer, T., 2007).

The ACTEW Corporation in Canberra has recently commenced a turf and irrigation research project at Rosary Primary School in Watson, ACT (ACTEW, 2008a). This project, termed “Grass Roots”, is a water conservation initiative that seeks to develop best practice watering regimes and to benchmark water use requirements for turf, in particular in large open spaces. Since 2006, the school oval has been a complex research site with five different varieties of turf, cross-laid with different sprinkler and drip irrigation systems. The project is attempting to determine the most efficient way to keep large grassed areas, such as schools and parks, alive and healthy through more sustainable water use. The challenge of “Grass Roots” was to learn how to spread less water even further whilst maintaining the grass in an acceptable condition. This research was driven by recent very severe water restrictions within the ACT.

Results for the first full year (2007) of operation have been very promising (ACTEW, 2008b). “Grass Roots” achieved during the year an approximate 40% saving in water use. This is in line with a Stage 3 water restrictions target of 35% reduction.

The term evapotranspiration (ET) combines the evaporation processes that occur from the soil with the transpiration rate occurring from the growing plants. ET rates are a means of assessing the relative efficiency of various turfgrass varieties in utilising the available water. A turfgrass cultivar possessing a low ET rate is not necessarily drought tolerant, however such a cultivar is better able to delay the onset of drought stress. The situation is complicated by the fact that ET rates for a cultivar can be altered substantially by any changes in cultural practices or environmental conditions that may alter the canopy density, leaf area, leaf orientation, or vertical leaf extension rate. As a consequence, it is important to conduct comparative ET rate studies at the interspecies level in a controlled, stress-free environment. Sufficient basic information is available from such studies to conclude that specific species and cultivars can be selected with lower ET rates, thus enabling the selection of turfgrasses that will contribute to water conservation strategies. This process can also assist in the breeding of water-conserving turfgrass varieties (Beard, 1985).

Beard (1989a) has published comprehensive reviews of research carried out on water use rates and water stress of turfgrasses. Kim and Beard (1988) studied the comparative ET rates and associated morphological characters of 11 warm-season turfgrasses representing 9 species. Significant differences in ET rates were found both among and between 10 warm-season turfgrass species (Taliaferro & McMaugh, 1993) encouraging selection and genetic development for drought tolerance and other physiological characteristics.

The interest in breeding and selecting turfgrasses with drought tolerance is still active within the USA. One such example is being undertaken in San Antonio by the Texas A&M University System (Chalmers, D.R. et al., 2006).

The selection of grasses with lower ET rates is only one tool available in conserving water use. Turfgrass management, including the manipulation of the primary cultural practices of mowing, fertilising and irrigating, very much contributes to the overall water use efficiency of the sward. Turfgrass managers interested in conserving water should mow high and frequently, fertilise to meet nutritional needs only, and irrigate infrequently based on the use of soil moisture sensing devices rather than on set time schedules (Shearman, R.C. 1985). Another study reported by Beard (1988) reviews the effects of plant growth and cultural practices on ET rate, and reports nitrogen levels and mowing heights that maximise water conservation.

The importance of the grass root system in dehydration avoidance and drought resistance is clearly demonstrated in a study by Beard & Sifers (1997). This study investigated the genetic diversity in drought resistance among genotypes of Cynodon and Zoysia species. Among the 26 Cynodon genotypes tested, substantial genetic diversity was detected and those with the shorter root systems tended to have poorer dehydration avoidance and poorer drought resistance. Among the 9 Zoysia grasses tested, the genetic diversity was much narrower and all had much poorer dehydration avoidance than the Cynodon species, attributed primarily to a very limited root system and a higher evapotranspiration rate. Obviously, the genetic potential for producing a much greater root depth, density and biomass is a trait well worth selecting for when seeking drought resistance or dehydration avoidance in turfgrasses.

2.4. Energy Saving and Heat Sink Effects of using Turfgrass:

The overall temperature of urban areas may be as much as 5 to 7 degrees C. warmer than nearby rural areas. Turfgrasses can serve in dissipating the high heat loads generated in urban areas through the cooling process of evaporation. Furthermore, the cooling effect of irrigated turf and landscapes can result in energy savings via reducing energy inputs required for mechanical cooling (Beard, 1993).

A study by Beard (see Beard, J.B. 1990) gives an example of the unique cooling effect of turfgrass in dissipating heat energy and therefore enhancing the comfort of people in highly populated urban areas. The study consistently demonstrates that actively growing turfgrass can reduce surface temperatures

by 30-40 degrees F (1-4 degrees C) in comparison to bare soil and by 50-70 degrees F (10-20 degrees C) in comparison to synthetic turf surfaces (see Table below from Beard, 1990). Hardscapes (such as cement, asphalt and stone surfaces) also act as heat sinks with surfaces much hotter than turf.

Temperature Comparisons on a Selected Day in August			
Type of Surface	Maximum Daily Temp. (°F) Surface Temperature	3'' Above Surface	Nocturnal Min. Temp. Surface Temperature
Green, Irrigated Turf	88°	89°	76°
Synthetic Turf, Dry	158°	96°	84°
Brown, Dormant Turf	126°	95°	79°
Bare Soil, Dry	102°	91°	78°
			J.B. Beard

While hardscapes (concrete, specialty rock or paving) and semi-hardscapes (crushed stone, scattered boulders) can also be aesthetically pleasing, they can be environmentally damaging. Such designs can seal sections of the earth surface and can become heat sinks, absorbing large amounts of energy and then radiating that heat energy back into the surrounding area. Furthermore, such hard-surfaced areas can create storm water overflows when it rains which can lead to local flooding problems. While these forms of landscaping require minimal inputs for maintenance, such as water or fuel, their inert state fails to provide as many positive environmental benefits as turfgrass (Rogers, W. 1991).

Another example of the cooling effect of turfgrass in densely populated urban areas is occurring in Europe where cities are expanding and transit lines are proliferating. In France and Spain, new tram lines have been installed that are beautifying cities by creating greenbelts rather than taking them away. By installing turfgrass between and surrounding the actual tram lines, these cities are not only solving traffic congestion but are also solving noise pollution and creating an environment that looks a lot nicer, but also has a considerable cooling effect on ambient temperatures (Hunter Headlines, 2007).

2.5. The Carbon Sequestration Capacity of Turfgrass:

Australian soils are generally, on World standards, very low in carbon. The usual range for organic carbon content in Australian soils is between 1 an 5% (CSIRO, 1983). Some unusual and rare soils, such as Alpine Humus soils, can accumulate up to 12% but most Australian soils are exposed to high temperatures and dry conditions which prevent carbon accumulation. The effects of living organisms on soil organic matter and carbon are substantial. Of these, vegetation is the primary source of soil organic matter and thus the major influencing factor on the amount present.

Grasses in general, and particularly turfgrasses, develop a dense root mass and an organic thatch layer that is ideal for storage of carbon in soils. The extensive fibrous root system of turfgrasses contributes substantially to soil restoration and improvement through organic matter and carbon additions (Beard, 1993).

A study of historic soil testing records in the USA at Fort Collins, Colorado, (Y. Qian & R.F. Follett, 2002) estimates that golf course greens and fairways alone can sequester carbon (C) at average rates approaching 0.9 and 1 tonne per hectare per year, respectively. They concluded that C sequestration in turf soils occurs at a significant rate that is comparable to that reported for USA land that has been placed in the United States Department of Agriculture (USDA) Conservation Reserve Program (Follett, R et al., 2001).

The above researchers at Fort Collins report on historic data that indicates a strong pattern of soil organic matter response to decades of turfgrass culture. Total C sequestration continued for up to about 31 years in fairways and 45 years in putting greens. The most rapid increase occurred during the first 25 to 30 years after turfgrass establishment. A further paper by the same research team (Bandaranayake et al., 2003) using CENTURY model simulations near Denver and Fort Collins indicate that turfgass systems can serve as a C sink following establishment. Model estimates are that 23 to 32 Mg/ha (tonnes/ha) soil organic carbon were sequestered in the 0 to 20cm below the soil surface after about 30 years. These results compare very favourably with those estimated above from soil testing records (Qian & Follett, 2002).

By extrapolating from published data on root dry matter under turfgrass swards, it is possible to obtain another estimate of the role that turf plays in carbon storage within soils (Boeker, 1974; Boeker & Von Boberfeld, 1974). These authors report root dry matter from 0 to 20cms under various turfgrass swards grown in the Rhine Valley, Germany. The results indicate that up to 11% of a cubic metre of topsoil can be comprised of organic matter derived from root material. This represents a very substantial addition of carbon to the soil, approximately 4.5% by weight in the top 20cm.

Results (From Boeker & Von Boberfeld, 1974) are summarised in Table 3* below:

Soil depth	Root Dry Matter	Organic Matter	Organic Matter	Organic Carbon
Cm.	gm/1000 sq.cm.	% by volume	% by weight	% by weight
0-5	110	11	7.81	4.45
5-10	3.5	0.35	0.25	0.14
10-15	2.0	0.2	0.14	0.08
15-20	1.0	0.1	0.07	0.04

*Assumes a soil bulk density of 1.4 gm/cubic cm, and an average C content in organic matter of 57% (Hazelton & Murphy, 1992).

As these results were collected at two or three sampling dates, it is possible to estimate the rate of carbon sequestration. Averaging all of the Rhine Valley data in Table 4 provides a carbon sequestration rate of about 2.2 tonnes/ha/year. This is about twice the rate reported by Qian & Follett (2002) in Denver and Fort Collins, Colorado. There is considerable variation in the Rhine Valley data which appears to be very much species related. Results are compared in Table 4 below:

Authors	Results reported	Organic Matter	Carbon
		Tonnes/ha/yr	Tonnes/ha/yr
Qian & Follett Bandaranayake et al.	Soil test results Century Model	1.6 – 2.1	0.9 – 1.2
Boeker & Von Boberfeld	Poa/Festuca	3.2	1.8
Boeker, 1974	Agrostis/Table 1	0.7	0.4
Boeker, 1974	Festuca/ Table 3	4.6	2.6
Boeker, 1974	Lolium/Phleum/ Poa/ Table 5	3.8	2.2
Boeker, 1974	Festuca/Table 7	5.4	3.1
Boeker, 1974	Festuca/ Table 8	6.5	3.7
Boeker, 1974	Lolium/ Table 9	2.4	1.4

Turf can and should be playing a more positive role in the global warming debate. Most climate-change scientists now believe that global warming caused by human activities has already begun; and 90% believe that countries should take immediate steps to reduce carbon dioxide emissions. Turfgrass requires carbon dioxide to survive, and as it removes it from the atmosphere, it replaces it with oxygen as a result of the photosynthetic process. Grass is such an efficient carbon dioxide/oxygen converter that an area of just 15 square metres can generate enough oxygen to meet the needs of a family of four (Journal of Environmental Turfgrass 4:1, 1992).

2.6. Turfgrass Utilisation in Sports and Sporting Fields:

Many social and sporting events take place on lawns or turfgrass, such as Bowls, Golf, Cricket, Horse Racing, Football, Rugby, Croquet and Tennis. The role that a good quality turfgrass plays in the success and safety of these sports is of great importance, and is a very positive aspect of turfgrass that is often neglected.

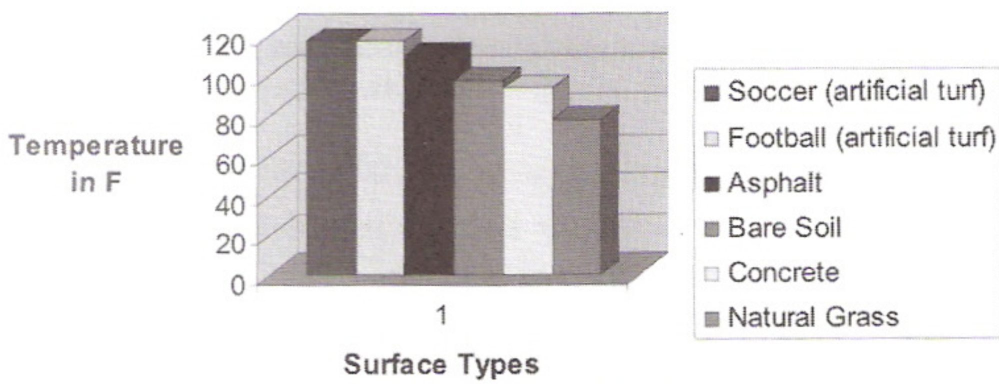
Tennis is a sport that has mostly neglected turf as a surface, and now utilises almost entirely (except for Wimbledon) artificial surfaces. There is considerable evidence that this has led to greater heat stress for the players and an increase in sporting injuries, particularly involving ankles and feet.

For example, a study by Brigham Young University (BYU, 2002) in the USA compared surface temperatures of a range of sports field surfaces commonly used in the USA (see Table below). This study was implemented by BYU after observing exceedingly hot temperatures from synthetic turf surfaces, including a case where one coach received blisters on his feet through his tennis shoes. BYU has set 120 degrees F (49 degrees C) as the maximum safe temperature that a playing surface can reach, since temperatures in excess of this can cause skin injury in less than 10 minutes.

Further to this, observations by a turfgrass specialist at the University of Missouri (Fresenburg, 2005) explain that many ankle and foot injuries are due to greater levels of torque, velocity and traction found in association with artificial turf surfaces. His observations show that the potential pressure on joints and bones is increased from the inability of a fully-planted, cleat-wearing foot to divot or twist out, an action that releases force. He noted that while

some might see divots or ripped-out grass from a natural grass surface as "damage", it is actually a healthy sign indicating that the surface is doing its job of yielding to the athlete's impact, therefore being less likely to cause an injury.

Table 1[14] **Surface Temperature Comparisions**



4. Acknowledgements:

We gratefully acknowledge assistance provided by Horticulture Australia Limited (HAL) and their support for this project.

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