Review of the Environmental Benefits of Turf

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HAL Project TU12017

Final Report

A review of the environmental benefits of turf

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30 September 2013

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This report provides background information and summarises the process and outcomes of a five-month project examining the environmental benefits of turf grass including the process and findings as well as recommendations for future research.

The project has been funded by HAL using the Australian turf grass production industry levy and matched funds from the Australian Government

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Disclaimer

MEDIA SUMMARY

Despite providing a number of environmental benefits, turf is sometimes viewed unfavorably by consumers, business and government in relation to its environmental credentials. This appears to be unjustified as turf undoubtedly possesses a number of qualities that improve the environment (particularly in urban areas) and turf also plays a critical role in a number of environmental and ecosystem processes.

The Australia turf industry commissioned a report to comprehensively review turf's environmental credentials. The study *A Review of the Environmental Benefits of Turf* (TU12017) was a levy funded project commissioned through Horticulture Australia Limited (HAL) and conducted by private research provider BioScience Australia Pty Ltd.

This project conducted a review of literature in Australia and internationally in order to distil a comprehensive list of the environmental benefits of turfgrass (see table below).

Summary list of the environmental benefits of turf grass

ATMOSPHERE QUALITY BENEFITS	**WATER QUALITY BENENFITS**	**LAND QUALITY BENFITS**	**OTHER BENEFITS**
Air pollution control/air quality improvement Oxygen generation Dust prevention & stabilisation Carbon sequestration and sinks	Water filtration and purification (phytoremediation) Water run-off reduction Rainwater harvesting & entrapment - groundwater recharge	Reduction in nutrient movement & loss Erosion control Soil improvement and restoration Biodegradation of synthetic organic compounds (phytoremediation) Alleviating heat island effects	Noise and glare reduction Fire prevention Biodiversity and ecosystem services

The review incorporated all available refereed (scientific/academic) and non-refereed (industry journal/magazine) articles to identify key environmental claims. These claims were then critically assessed in terms of whether there was sufficient supporting scientific information and, conversely, where further research is recommended. The final results will also be presented in a summary document that can be used as a practical guide for the industry in order to inform future levy investment decisions and will also be distributed electronically to all levy payers to assist them with their individual marketing and promotion activities.

In assessing the environmental functions of turf grass the reviewers identified key areas where turf is well supported and widely recognised as providing significant benefits; areas where there is solid evidence but less recognition for turf grass as an environmental solution; and areas where turf's capabilities are obvious but lack rigorous or consistent quantitative results and therefore warrant further attention.

The review was undertaken to assist the turf industry to better market its product into environmental markets and to assist in prioritising future research investment. For more information or to download copy of the report contact Turf Australia www.turfaustralia.com.au.

TECHNICAL SUMMARY

This report documents the process, findings and recommendations of a comprehensive literature review to determine the environmental benefits of natural turf grass and the extent for which the claims are supported by rigorous research in Australia and internationally. Gaps in the literature have been identified and form the basis of the list of recommendations for further research.

The methodology for this report involved conducting a desktop study over a six month period. This process involved the identification, collection, review and summary of a wide variety of sources of literature including national and international research as well as peer-reviewed and non peer-reviewed publications (i.e. scientific journal articles, industry publications and government reports). This information was critically selected and analysed to separate that based on robust scientific evidence from material based on opinion in order to determine the degree extent of, and rigour behind, claims of environmental benefit.

The environmental benefits of turf grass have been categorised into four groups: 1). Atmosphere Quality, 2). Land Quality, 3). Water Quality and 4) Other Environmental Benefits. Atmosphere quality benefits arising from turf grass include: carbon sequestration, oxygen generation and air quality improvement. Water quality benefits include: rainwater entrapment, filtration and purification, flood control and runoff reduction. Land benefits include reduced nutrient loss, heat island effect alleviation and erosion control. Other environmental benefits are reduced noise and glare pollution and increased biodiversity via habitat creation.

The literature reviewed presents a convincing case for further research to be conducted into the beneficial use of turf grass for environmental purposes. It encourages a more encompassing view of turf grass and outlines the reasons it should be viewed for the benefits it provides beyond the aesthetic. Overall, it is recommended that further research is conducted within Australia. Independent research should be conducted to minimise any potential bias (or perception of bias) that may arise, as the existing evidence on the environmental benefit of turf grass is at times ambiguous or inconclusive. Future research should be based upon the existing research methodologies, however further studies should

standardise turf grass plot size, measurement units, time scales and methods used for measurement wherever possible.

PROJECT OUTPUTS LIST:

1. A literature review of the benefits of turfgrass (this Report);
2. A summary document to inform the industry to make future research investment decision and for levy payers to use within their businesses (Appendix 1);
3. Media release x 1 (Media Summary to be sent out to media outlets upon approval of final report by HAL);
4. Turf industry newsletter article x 1 (Media Summary to be sent to Turf Australia);
5. A presentation at future industry forum/conference (To be presented at next Turf IAC Meeting, November 2013, Cleveland, QLD).

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TABLE OF CONTENTS

1 INTRODUCTION

The turf grass industry is significant in Australia with approximately 240 levy-paying turf grass primary production enterprises that grow, harvest, sell and in many cases install turf grass (HAL 2012). Although a definitive value for the industry remains elusive, all estimates provide a relatively high economic value to Australia. These range from Australian Bureau of Statistics (2001) estimate of $147.7 million per year to the Aldous et al figure that valued all turf grass related products, services, sales and maintenance at approximately $1 billion per annum (Aldous et al., 2007). The industry itself settled on a figure of $188.4 million based on leviable production area multiplied by an agreed average sale price of $6 per sq/m (HAL 2012).

What is undisputed is that turf grass[1,2] is an abundant part of the environmental landscape particularly within urban and suburban areas. In Australia turf grass commonly includes various cool and warm season grass species such as buffalo grass, zoysia grass, green couch, blue couch, kikuyu, tall fescue and carpetgrass. Turf grass is generally grown in turf or sod farms and is then cut, transported and laid on a new area which has ideally been prepared earlier (Beard, 2005). The turf grass sod is maintained through watering and sometimes fertilisation until it is established (formation of a root system). Once established, turf grass can be used for its desired purpose such as in residential, commercial and industrial areas, for use in schools, open space areas, roadsides, sporting fields or parks and gardens.

Grass is a naturally occurring plant, however, human manipulated turf grasses have enhanced the quality of our built and natural environments for more than 100 years (Beard and Green, 1994). In the past few decades, urban and suburban areas have developed at unprecedented rates (Golubiewski, 2006) which has led to the increased use of turf grass in residential, industrial, commercial and sporting areas (Qian and Follett, 2002; Milesi *et al.*, 2005). In recent years turf grass has gained a negative image, especially in the face of environmental

[1] Turf grass is a 'species or cultivar of grass, usually of spreading habit, that is maintained as a mowed turf' (Beard, 2005) and is the 'surface layer of fields and pastures, consisting of earth containing a dense growth of grasses with their roots; sod' (William Collins Sons and Co Ltd., 1987). Grass plants are low-growing monocots which are comprised of leaves, stems and roots (Michigan State University, 2004).

[2] For the purposes of this report turf grass refers to the natural variety (not artificial) and environmental benefits which arise once the turf grass sod has been transplanted and established.

uncertainty as maintenance practices can have potentially adverse environmental impacts due to chemical pollution, water usage and greenhouse gas emissions (Higginson and McMaugh, 2008).

However, turf grass does provide many benefits which have been enhanced as a result of improvements in quality and variety development coupled with the utilisation of new management techniques and technologies (Higginson and McMaugh, 2008). These benefits can be grouped into three categories as outlined by Beard, (1994) and Beard and Green, (1994) which are; functional, recreational and aesthetic benefits. Recreational benefits refer to physical health, sporting, leisure and social benefits. Aesthetic benefits include quality of life, mental health, well-being, social harmony and improved productivity (Beard and Green, 1994). Functional benefits are comprised mostly of environmental benefits which provide a positive effect on the natural environment such as erosion control, flood control, dust stabilisation, oxygen generation and fire prevention. It is acknowledged that there are many economic, social and health benefits that arise from the use of turf grass. However, this report will focus solely on the functional or environmental benefits (Beard, 1994; Beard and Green, 1994).

These environmental benefits of turf grass are widely lauded by academics, scientists and industry professionals alike. This report will seek to identify all of the environmental benefits arising from the use of turf grass and critically examine the extent to which these claims are supported by scientific evidence. It will focus on the environmental benefits relating to atmospheric, water and land quality, including benefits such as: oxygen generation, pollution absorption, noise reduction, soil erosion mitigation, carbon sequestration, greenhouse gas reduction and increased biodiversity. This report will also outline potential research recommendations and will provide a framework for the Australian turf grass industry to prioritise future research investment by highlighting areas that require further attention or more rigorous scientific examination.

This review was undertaken over a seven month period on a part-time basis and directly addressed the priority activity listed within the *Australian Turf Industry R&D Strategic Investment Plan (SIP) 2012-2017 'A plan to drive the growth and sustainability of the Australian turf industry'* (HAL 2012) under the extension section for completion in 2012/13:

Strategy 3.1 Environmental Data and Information
Collect and maintain a resource of information which details the relationship between Turf and the environment (e.g. in areas such as carbon sequestration; water use; microclimate impact; erosion control).

This activity was also listed as two of the seven recommendations for action from the SIP process; to commission a comprehensive desk audit of relevant studies in Australia and overseas. This report forms part of the deliverable requirements for project TU12017 produced as one of the following project outputs:

1. A literature review of the benefits of turfgrass (this report);
2. A summary document to inform the industry to make future research investment decision and for levy payers to use practically within their businesses;
3. Media release x 1;
4. Turf industry newsletter article x 1;
5. A presentation at future industry forum/conference (if required).

2 ENVIRONMENTAL BENEFITS OF TURF GRASS

The environmental benefits in this report have been categorised into four areas of 1) Atmosphere Quality, 2) Land Quality, 3) Water Quality and 4) Other Benefits. Atmosphere Quality Benefits arising from turf grass include: carbon sequestration, oxygen generation and air quality improvement. Water Quality Benefits include: rainwater entrapment, filtration, purification, flood control and reduced runoff, groundwater recharge and sediment catchment. Land Benefits consist of a reduction in nutrient loss, heat island effect alleviation and erosion control. Other Benefits reduce noise pollution and glare and increased biodiversity.

2.1 Atmosphere Quality Benefits

It is critical that atmospheric quality is maintained to reduce the potential environmental and human health impacts associated with decreased air quality and air pollution. The anthropogenic and natural sources which contribute to the degradation of atmospheric quality are many and varied and have been well documented. Turf grass has the potential to provide atmospheric quality improvements such as air pollution control, oxygen generation, dust stabilisation and carbon sequestration.

2.1.1 Air pollution control/air quality improvement

Air pollution is the 'introduction of chemicals, particulate matter or other biological materials that cause harm or discomfort to humans or other living organisms… into the atmosphere' (Creamer, 2012). Natural sources of air pollution include some vegetation, volcanic eruptions, bushfires and dust storms. In contrast, fossil fuel combustion, aerosols, aircraft and motor vehicle emissions and industrial/commercial processes are anthropogenic or human-caused sources of air pollution (Colls, 2002; Creamer, 2012). These sources and processes can emit harmful substances into the atmosphere including carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs) and particulate matter (Colls, 2002; Creamer, 2012).

Air pollution has serious human health implications and can lead to incidences of respiratory, heart and lung diseases which are estimated to contribute to two million deaths, per year, worldwide (Gunjar *et al*., 2010; Creamer, 2012). Air pollution can also have serious environmental impacts including ozone depletion, increased concentrations of greenhouse gases, ocean acidification, plant injury and tissue changes (Creamer, 2012; Gunjar *et al.*, 2010).

Turf grass and vegetation can control air pollution and act to improve air quality by absorbing pollutants, smoke, dust and dirt particles from the atmosphere (they can also prevent air pollution through dust stabilization) as turf grasses trap particulate matter in the grass blades. Turf grass absorbs CO_2 as an input along with light energy for photosynthesis which reduces the carbon abundance in the atmosphere (Shoulders, 1989) and releases oxygen as a byproduct (Shoulders, 1989). Turf grass can also reduce smog pollution through the process of evapotranspiration[3] (Rosenfeld *et al.,* 1998).

The environmental benefit of controlling and reducing air pollution is not however isolated to turf grasses and occurs with other types and species of vegetation. To date there is little quantified information about these processes and the extent of the role that turf grasses play.

It is recommended that the amount of air pollution reduction capabilities of turfgrass be more comprehensively measured and compared to the role of other vegetation types.

2.1.2 Oxygen generation

Turf grass like all other vegetation species is a classified as a photoautotroph, meaning that it ulitises a carbon and energy (light) source to undergo the process of oxygenic photosynthesis (known simply as photosynthesis). Photosynthesis is a process in which turf grass plants absorb and breakdown atmospheric CO_2 and water to an energy source. Energy is generated from this process and organic products and oxygen are produced as byproducts (Spikes and Mayne, 1960). These organic products are used by the turf grass plant for growth while the plant is releasing oxygen into the environment (Watschke, 1990). Oxygen is consumed by humans and animals for breathing, who in turn breathe out CO_2 and start the cycle again. [4]

The oxygen generation from turf grass is claimed to play a significant role in fulfilling human oxygen requirements. For example, a US based turf grass research group has claimed that a

[3] Evapotranspiration is a process which trees and plants undergo; they absorb water through their root system and emit it as vapour through their leaves, which provides a cooling effect (Gartland, 2008).

[4] Where the turf grass plant uses CO_2 (carbon dioxide), $2H_2O$ (water), and light to produce CH_2O (organic products) plus H_2O (water) and O_2 (oxygen) (Spikes and Mayne, 1960).

2500 square foot (~232m^2) area of turf grass is able to absorb and release enough CO_2 and oxygen for a family of four (The National Turf grass Research Initiative, 2003). Another study estimated that the oxygen needs of one person for one day are provided for by a 25 square foot (~2.3m^2) area of turf grass (Watschke, 1990). An area of 150 acres (~60ha) of turf grass provides enough oxygen for 7,000 people (American Society of Golf Course Architects, 1990).

That turf grass produces oxygen through photosynthesis is indisputable. What is less certain is the parameters around turfgrass and its role within this process. The literature does not provide information on how many of these results were obtained, what methods were used, how they were measured or modeled, what grasses were tested, under what conditions (e.g season, maintenance regime) and what assumptions were made in regards to relatively baseline information such as the assumption of how oxygen much oxygen one human requires per day. Often the statistics available do not source the information correctly or at all in some instances. Additionally, the claims from the above studies are produced by the turf grass industry and are only present in industry sponsored publications or those published directly by the industry body such as the American Society of Golf Course Architects and The National Turf Grass Research Initiative. As the turf grass industry has produced these documents there *may* be the potential for bias regarding the role of turf grass and if not, there is certainly the chance of the *perception* of bias.

Greater evidence is needed to quantify the amount of oxygen generated by turf grass and the relative importance of that function generally and more specifically in areas such as cities and suburbs.

2.1.3 Dust prevention & stabilisation

Dust refers to 'particles of earth or other matter small enough to be raised and carried by the wind' (Jackson, 2009). Dust particles exist in varying sizes and are generated from natural or anthropogenic sources including bacteria, sea salt, vegetation, soil and fungi (Western Australian Department of Health, 2010) or from vehicle exhaust, mining, farming activities and un-surfaced roads (Inyang and Bae, 2006). Dust can have a harmful impact on human health and the amenity of residents (Western Australian Department of Health, 2010) as it poses health risks such as aggravating asthma and eczema conditions and through spreading

infectious (Jackson, 2009). It can also contain disease causing microorganisms such as aspergillus which attacks the human sinus and central nervous systems (Inyang and Bae, 2006). Dust can also cause or contribute to environmental problems such as water pollution and sedimentation (Aird, 2011). The threat of dust impacts is increasing in many areas due to the population expansion and infrastructure development (Inyang and Bae, 2006).

The prevention and stabilisation of dust is necessary to mitigate or minimise the negative human and environmental health impacts associated with its movement. Turf grass releases relatively small amounts of dust compared to the amount of dust released from bare areas devoid of vegetation (Shoulders, 1989). The control of dust can be achieved through capture and suppression by using vegetation and soil coverings such as turf grass which slows the wind velocity and prevents dust particles from becoming detached and airborne (Aird, 2011). Particulate matter falls from the atmosphere (Watschke, 1990) and turf grass has been cited as trapping around 12 million tons of dust and dirt per year (Watschke, 1990; Tuton, n.d.) in between its leaves (Shoulders, 1989). These entrapped particles are then moved via rainfall to enter and become incorporated (secured) as part of the living soil system (Watschke, 1990). This figure does not provide the full information on the amount of dust trapped from turf grass and excludes information on whether dust is trapped at a worldwide or national/local level.

The benefit of dust stabilisation and prevention is not limited to turf grass, and other vegetation species also have the ability to control dust. The benefit of turf grass to stabilise and control dust, although undoubtedly real, is currently more assumed than based on a substantial amount of quantitative scientific evidence.

Further research into the ability of turf grass to stabilise dust should be conducted especially in regards to the amount of dust per year and over the lifespan of turf grass compared with other vegetation types and/or bare soil. Research could also determine how the rates of dust stabilisation occur throughout the life time of turf grass and if rates are reduced as the turf grass ages or indeed differ under different maintenance regimes.

2.1.4 Carbon sequestration[5] & sinks

CO_2 is a greenhouse gas and is part of the greenhouse effect. The greenhouse effect is a naturally occurring phenomenon which is essential for maintaining life on Earth however, anthropogenic sources and processes such as the burning of fossil fuels, land use change and deforestation (Lal, 2007; AAS, 2010) have contributed to the 'enhanced greenhouse effect'. The enhanced greenhouse effect increases the concentration of greenhouse gases in the atmosphere which increases the affects of thermal radiation from the sun, which has been attributed to accelerating climate change and is 'widely believed to be responsible for the observed increase in global mean temperatures through the 20th century' (IPCC, 2007; BOM, n.d.). Scientific evidence supports the advent of climate change as climate change impacts such as increased temperature, sea level rise, decreased water availability, snow and ice cover are increasing in frequency (IPCC, 2007; AAS, 2010; CSIRO and BOM, 2010). These impacts have been rigorously examined at length and pose a serious threat to human health, quality of life, economy, society and the environment (IPCC, 2007; Lal, 2007; AAS, 2010; BOM, n.d.; CSIRO and BOM, 2010).

Firstly, turf grass has been claimed to have a negative impact on atmospheric quality as managed turf grass systems (as would be found in golf courses, public parks, sport fields or even domestic gardens) require irrigation and fertilisation to enhance plant productivity (and therefore impact carbon storage). Additionally, in undertaking the maintenance of these areas, it is claimed that soil and greenhouse gas emissions can sometimes be increased for example with the use of fuel for machinery (Townsend-Small and Czimczik, 2010; Selhorst & Lal 2011). There is evidence to suggest that the capacity of turf grass to sequester carbon can be greatly reduced if it is not being maintained at an optimum level (Higginson and McMaugh, 2008). CO_2 and other greenhouse gas emissions associated with turf grass maintenance can be reduced through improved machinery maintenance (Cushnahan, 2009), reduced maintenance requirements and reduced fuel use and mowing frequency (Cathey, 2003; Power and Aldous, 2007; Hood, 2008). In addition, reducing fertiliser use, increasing aeration (Power and

[5] Sequestration 'noun' is the 'act of sequestering of state of being sequestered which is to (verb) remove or separate to retire into seclusion' (William Collins Sons and Co Ltd., 1987).

Aldous, 2007), landscape design, growth regulators (Cushnahan, 2009) soil preparation and irrigation types (Cathey, 2003) can also reduce greenhouse gas emissions.

Carbon sequestration is one of the strategies for mitigating climate change (Lal, 2007) and is considered a critical activity for decreasing atmospheric CO_2 levels (Smith *et al.,* 2009). Carbon sequestration is the long term storage of CO_2 (Harrison, 2011) and has been defined by the IPCC (2001) as being the 'addition of a substance of concern (carbon) to a reservoir'. It occurs when 'a positive dis-equlibrium is sustained over some period of time, with the system eventually achieving a new, higher steady-state (Jastrow *et al.,* 2007). Turf grass can be used as a method to mitigate climate change as it has the potential to act as a carbon sink for carbon sequestration through the process of photosynthesis (Sustainable Gardening Australia, n.d.), nutrient cycling and soil organic carbon accumulation (Qian and Follett, 2002; Milesi *et al.,* 2005; Bartlett and James, 2011). In short, turf grass can be used as a carbon sink as it absorbs more CO_2 than it releases (Huh *et al.,* 2008).

Turf grasses have been argued as being an effective carbon store (Gillette *et al.,* 2011) if they are managed efficiently (Baird, 2011). The ability of turf grass to sequester carbon could be attributed to its lack of soil disturbance and high productivity (Qian & Follett, 2002). Many studies (Jo and McPherson, 1995; Qian and Follett, 2002; Huh *et al.,* 2008; Griffith, 2010; Zirkle, 2010; Zirkle *et al.,* 2011) have enquired into how turf grass can be used for carbon sequestration and conclusions drawn from these studies have supported that turf grass is a successful medium for carbon sequestration. Studies conducted by Qian and Follett (2002) and Sahu (2008) concluded that carbon sequestration in turf grass soils occurred at a significant rate (Qian and Follett, 2002) 'that is comparable or exceeds those reported for native grasses' (Sahu, 2008). Zirkle (2010) found that turf grass is a positive net sink for carbon which has been claimed to hold up to 3 tonnes of carbon per year for 30 years in one hectare of turf grass (Layt, 2009; Layt n.d.(a)). Moreover, carbon sequestration occurs for up to 45 years after installation of turf grass and occurs at an average rate of 804 pounds per acre or (~900kg per ha) (Sahu, 2008) with the most rapid increase of carbon sequestration occurring in the first 25-30 years (Sahu, 2008).

Studies have produced positive outcomes in regard to the amount of CO_2 turf grass can sequester. Amounts of carbon sequestration potential differ based on studies, site and size selected (refer to Table One). The average sized home lawn is claimed to sequester 'four to

seven times the amount of carbon compared to the output from burning fossil fuels using a typical modern lawn mower' (Sahu, 2008). Sahu also claimed that turf has the potential to sequester carbon at a rate of one ton per hectare per year (1 t ha^{-1} yr^{-1}) or at 1.0 to 0.9 megagrams of carbon per hectare per year for 25-30 years (Qian and Follett, 2002). Carbon sequestration in home lawns is at a rate of 0.18Mg/ha/yr for 40 years (Pouyat *et al.,* 2009) and can sequester between 20.3kg and 163.4kg of carbon per lawn per year (Zirkle *et al.*, 2011) or 10 tons of carbon per acre for a 12 year period (Griffith, 2010). A study conducted on a golf course in New Zealand concluded that the golf course sequestered 28t/ha over 40years (Huh *et al.,* 2008). Soccer fields of more than one acre in size can remove a carbon equivalent of driving a car over 3000 miles (~4828 km) (Harrison, 2011). Turf grass in urban landscapes, in the USA, has the potential to sequester 12 to 15 million tons of carbon per year during a 25-30 year time period (Qian and Follett, 2002).

Along with carbon sequestration, turf grass also has the ability to absorb other atmospheric greenhouse gases and gaseous pollutants from the air including carbon monoxide (CO), methane (CH_4), sulfur dioxide (SO_2), ozone (O_3), hydrogen fluoride (HF) and peroxylacteyl nitrate ($C_2H_3NO_5$) (Watschke, 1990). A study conducted by Gladon, Brahm and Christians (1993) used several varieties of turf grass to show the absorption and release rates of CO. Results showed that in particular Tall Fescue had the greatest ability for CO absorption and could be used the absorb CO from 'environments with a greater than normal CO concentration e.g. those often found in urban environments such as roadsides (Gladon *et al*, 1993). Bacteria found in soils are the largest biological sink for traces of CH_4 (Groffman, 2009). A study conducted by Taha *et al.* (1997) demonstrated that 'the simulations also indicate that the net effect of increased urban vegetation is a decrease in ozone concentrations' this study was mostly conducted on the use of trees as urban vegetation, however turf grass undergoes the same ecological processes as trees, such as photosynthesis, so the net outcome would be similar albeit at different magnitude.

In many instances the carbon generated from management practices such as mowing is not fully considered in the literature although there are exceptions (e.g. Cushnahan 2009; Singh 2007). It appears likely that the maintenance regime will change the net carbon sequestration equation and will influence the scale of benefits achievable. Singh 2007 listed some key management strategies that, when implemented can have a significant positive impact on sequestration capabilities. These were to limit pesticide applications; reduce nitrogen

application rates especially when the area has been established for over 10 years; and to use organic fertilizers.

Carbon sequestration and greenhouse gas reduction rates can be optimised if the soil is healthy and fertile. Healthy and fertile soils can be gained through improving ribosomes, leaves and root systems, managing grass correctly, reducing chemical inputs, using organic chemicals and having biologically active soils (Capeness, 2008; Griffith, 2010). The largest amounts of carbon storage have been claimed to occur in well managed turf grass which is regularly irrigated, maintained and mowed in a manner that does not disturb the root zone (Sahu, 2008; Layt, 2010). The return of grass clippings onto the turf grass surface (mulch mowing) can reduce soil erosion, increase water infiltration and soil enrichment (Roberts, 1991) and can produce higher intakes as the breakdown of grass clippings produces nitrogen (N) which is needed for nitrogen nutrient recycling (Layt, 2010).
Higginson and McMaugh claimed that if carbon sequestration is done efficiently and effectively it could potentially generate economic gain for turf grass growers through an emissions trading scheme (ETS) (Higginson and McMaugh, 2008). However, at this point in time it would be unlikely that turf grass could generate a net income from its role in carbon sequestration under any of the proposed federal schemes planned for Australia.

Turf grasses undoubtedly sequester carbon, however solid scientific evidence in this area is lacking especially in warmer climatic areas. The estimates available vary greatly and are often difficult to interpret, standardize or extrapolate more broadly. Current data available on turf grass carbon sequestration is inconsistent, uncertain and indefinite which is highlighted by the figures in Table 1, comparing the claimed carbon sequestration rates of turf from the studies identified in this report.

More research is required to gain an understanding of these figures and their effects on reducing CO_2 in the atmosphere. Additional effort is required to determine the actual rates and the quantity of carbon sequestered by turf grasses, by different turf types, different soils, being used for different purposes (e.g. golf courses versus a roadside planting), in different climate areas and most particularly for grasses under different maintenance regimes. A life cycle approach to determining the net carbon equation (including production and transportation) for turfgrass would also be welcomed.

Table 1: Table showing cited carbon sequestration rates for turf grass in different studies.

Figures cited in literature	Figures standardised into Australian metric units	Reference
Golf courses sequester 28t/ha/yr over a 40yr period	28,000kg/ha/yr for a 40yr period	Huh *et al*, 2008
Sequester carbon at a rate of 10t/ac/yr for a 12yr period	24,752kg/ ha/yr for a 12yr period	Griffith, 2010
Average net carbon sequestration in Kentucky Bluegrass over a 12 year period 10tons/acre	3,672 kg/ha/year over 12 years	Singh 2007
1ha of turf grass can sequester 3t of carbon per year for 30yrs	3,000kg/ha/yr for 30yrs	Layt, 2009 and Layt, n.d.(a)
Carbon sequestration occurs at a rate of 1t/ha/yr for 25-30yrs	1,000kg/ha/yr for 25-30yrs	Qian and Follett, 2002
Sequester 1.0 to 0.9 megagrams of carbon per hectare year during a 25-30 year time period	900 - 1000 kg/ha/year over 25-30 years	Qian and Follett, 2002
Sequester 80.6 – 183.0 g C/m^2/year	830kg/ha/yr – 1830kg/ha/yr	Zirkle *et al*, 2011
0.44 Mega grams per hectare per year on golf courses in Ohio	440 kg/ha/yr for 91.4 years	Selhorst & Lal 2011
Sequestration in turf grass occurs an average rate of 804lb/ac	900kg/ha	Sahu, 2008
Soccer fields in one acre removes the carbon equivalent to driving a car over 3,000 miles	Soccer field of 0.40ha removes the carbon equivalent to driving a car over 4,828km	Harrison, 2011
Average sized home lawn is claimed to sequester 4-7 times the amount of carbon compared to the output of a typical modern lawn mower	n/a	Sahu, 2008
Carbon sequestration occurs in home lawns is at a rate of 0.18Mg/ha/yr for 40 years	n/a	Pouyat *et al*, 2009

2.2 Water Quality Benefits

Water usage and turf grass maintenance practices have often been viewed as having a negative impact on the environment. As turf grass is a living plant, most varieties requires irrigation for survival especially during establishment of the turf grass sod (Roberts, 1991). If water is withdrawn from turf grass it can lead to decreased turf grass quality, increased weeds, pests, diseases, salinity, hardness, shear and uneven surfacing and ultimately death (Connellan 2013, Power and Aldous, 2007). Two key inputs required for turf grass survival include water for irrigation and periodically chemicals such as pesticides and fertilisers. Historically, these inputs are often associated with excess usage and are viewed as contributing to environmental problems in surrounding areas and waterways. Turf grass is seen to have excessive or 'luxury' water requirements particularly in areas where optimal performance is required such as sporting fields or golf courses where turf grass has a 'consumption far beyond need [beyond survival requirements]' (Kneebone and Pepper, 1984). Turf grass has been cited to lose as much as 10 litres of water per square metre per week (Drury, 2003).

Undoubtedly, water requirements of turf grass vary depending on user requirements and expectations. For example, a residential lawn requires far less watering and upkeep than turf grass used for a bowling green. There is some evidence to suggest that if the application rate of water increases, turf grass can adapt to this and increase the amount of water it uses or 'needs' (Kneebone and Pepper, 1984). Over-irrigation is largely attributed to human error, miscalculation, poor landscape design or improper irrigation practices through ignorance or poorly designed, maintained or scheduled irrigation systems (Beard and Green, 1994; Sports Turf Managers Association, n.d.). In many cases this perception and the practice of over-irrigating turf is based on a vague understanding of the plant's water requirements at any given point in space and time. Over-irrigation not only wastes water but it can have a negative impact on the turf grass plant itself as it can impact upon growth and nitrogen uptake (Poulter and Dahler, 2010).

A study conducted in Australia during 2006-07 found that the turf grass industry used an average of 6.5 megalitres per hectare of turf grass with a total water consumption across Australia of approximately 34,668 megalitres (Aldous *et al.*, 2007). Although water usage is perceived as being excessive, actual water usage for landscape irrigation is 10% of total water usage (Beard and Green, 1994) compared with 47% for agricultural purposes (Beard and

Green, 1994). However, there is no published scientific data to support the claims that turf grasses are a higher water user than trees or shrubs (Beard and Green, 1994). In comparison to other vegetation types (trees and shrubs), turf grass has been found to use less water on a per-unit land-area basis (Beard and Green, 1994) as evapotranspiration rates increase as leaf area increases (Beard and Green, 1994). Turf grass uses less water than other landscaping plants using 109mm/year versus 254mm/year for landscaping plants as after establishment landscaping plants water requirements and water use continue to rise whereas turf grass water use stabilised after establishment (Carson, 2007).

Water conservation advocates for the utilisation of better management techniques (Cushnahan, 2009) and environmental management programs (Higginson and McMaugh, 2008) which must be based on sound science as, after a point, reduction in water inputs can result in a decline of 'turf grass performance and the associated benefits' (Carrow, 2006). Total water usage can be reduced by up to 50% (Shashua-Bar *et al.*, 2009) if best management practices are used, i.e. inputs are reduced and turf grass is partly shaded. Water use can also be minimised if reclaimed wastewater, greywater or recycled water is used for irrigation (Beard and Green, 1994; Hood, 2008). Wastewater often does not affect the growth of turf grasses and is priced at about half that of potable water, with cost savings cited as averaging about $8000/ha/yr for a typical sporting field in 2006 (Menzel and Broomhall, 2006). Other techniques for minimising water include the appropriate selection of turf grass species e.g. those which are resistant to drought, disease and shade and with lower evapotranspiration rates (Beard and Green, 1994; Cathey, 2003; Power and Aldous, 2007; Higginson and McMaugh, 2008; Cushnahan, 2009; Keepin, 2009) and by watering turf grass deeply and less frequently (Sports Turf Managers Association, n.d.). Recent research has found that some specific cultivars of turf grass can tolerate poorer quality water than many other vegetation types and can be used to dispose of these lower quality water sources (such as treated sewerage wastewater and landfill leachate) as turf grasses are able to absorb and accumulate harmful elements and heavy metals in their biomass (Gabka and Wolski, 2011). Controlled irrigation systems can be used to minimise water usage as they schedule and monitor water usage at a rate which does not exceed turf grass actual requirements (Higginson and McMaugh, 2008).

The second key input for maintaining turf grass is chemical use. The use of chemicals for pest management and fertilisation can intensify the potentially adverse environmental impacts

such as sediment runoff, soil erosion and chemical leaching (Higginson and McMaugh, 2008). Similarly, the use of fertilisers and pesticides could potentially be a significant source of pollution to local water supplies (Gross *et al.*, 1990) and drinking water sources when applied in excess (Zhu, 2003), at the wrong time or in the wrong way (Beard and Green, 1994). Nitrate leaching may also be a problem if nitrogen fertilisation does not account for turf grass age or the return of grass clippings (Higginson and McMaugh, 2008).

Turf grass has a dense root system which is able to efficiently use nutrients and water, limiting the amount of chemicals and irrigation required (Higginson and McMaugh, 2008). This root system also reduces runoff and allows for the infiltration of soil resources (Beard and Green, 1994) and aids in increasing pest resistance in turf grass (Roberts, 1991). This means that only an insignificant amount of nutrients would pass through the root zone and into water bodies from appropriately managed turf areas (Beard and Green, 1994). Best management practices, integrated pest management and education can be used to help overcome problems associated with chemical usage and if turf grass is managed appropriately and effectively, the amount of fertilisers required can be reduced as can the mowing frequency and energy requirements (Hood, 2008).

2.2.1 Water filtration and purification (phytoremediation)

The amount of water on Earth today is the exact same as it was before human civilization began (Postel, 2011). Water is an essential resource needed to maintain all life on earth. The benefits of water are extensive and range from drinking water to sustaining fisheries and generating hydropower (Postel, 2011). Turf grasses have a large above ground biomass which gives time for rainwater to be effectively infiltrated into the soil and into groundwater supplies and helps protect and improve water quality (Beard and Green, 1994). Turf grass can reduce factors degrading water quality such as eroded top soil (Smith, 2011) and can slow down runoff and trap pollutants, sediments (Minnesota Department of Agriculture, 2012) and heavy metals (Layt, 2010), preventing them from leaching into adjacent water bodies. Water purification occurs when water is leached through the turf grass root zone and into underground aquifers (The Lawn Institute, 2009) or when it is run over grassed areas as the leaves trap suspended solids and sediment material (Shoulders, 1989). Rainwater that has been filtered by turf grasses is up to 10 times less acidic than water runoff from a hard surface such as concrete or asphalt (The Lawn Institute, 2009).

Turf grass is used in food processing industry as a method of cleaning wastewater before it is discharged into natural water bodies (Shoulders, 1989). Similarly research conducted by Loch et al confirmed and quantified turfgrass cultivars' salinity tolerance for their use in saline situations (such as canal and coastal developments) and also in areas where lower quality, saline water was in use such as the use bore water and treated wastewater on golf courses (Loch et al 2006).

Turf grass appears to be successful in the purification and filtration of rainwater supplies via the process of phytoremediation. More research is warranted to quantify the amount of rainwater that can be filtered and purified in Australia especially in relation to site remediation work as well as Water Sensitive Urban Design (WSUD) principles being increasingly employed by urban local authorities. Research into other commercial and industrial uses of turf grass to dispose of variable quality wastewaters may also present potential new market opportunities for the turf grass industry.

2.2.2 Water runoff reduction

If runoff is not controlled, it can contain pollutants, chemicals and pesticides which lead to eutrophication and contamination of adjacent water bodies including lakes, rivers and streams which can then create toxic environments or uninhabitable conditions for flora and fauna species (Higgison and McMaugh, 2007). Turf grasses can produce runoff, however the runoff from turf grass only occurs in the worst storms while compared to other surfaces, runoff would have occurred much earlier (Pease, 2011). Stormwater runoff from a healthy, dense area of turf grass can be at or near zero, meaning that nearly 100 percent of stormwater runoff is reduced through the application of turf grass depending on the size of the area and the intensity of the rainfall event (Minnesota University, 2006). Generally speaking, the runoff produced by turf grass that could lead to contamination of water bodies is far less than the runoff contamination from hard surface coverings (Higginson and McMaugh, 2008). Additionally, the amount of contamination produced from turf is generally lower (Higginson and McMaugh, 2008).

Studies prove that turf grass can be an effective means for reducing water runoff. It has the ability to resist water runoff and a healthy turf system can withhold lateral water movement. It can retain vast quantities of water and has a high infiltration rate of 1 inch (~2.54cm) per

hour (Shoulders, 1989). A 10,000 square foot area (~0.0929ha) of turf grass can absorb over 6,000 gallons (~22,712 litres) of rainwater without producing any runoff (Wells, 2005) which also contributes to flood control. A study undertaken by Gutierrez and Hernandez (1996) to study runoff and erosion in Mexican grassland concluded that, in general, 'surface runoff decreases with an increase in grass cover'.

Areas of turf grass play a significant role in reducing water runoff and can retain vast quantities of water. Further research should be conducted into determining the actual infiltration rate and absorption of turf grass and could be compared between turf grass species and other ground cover options (such as mulch or hardscape materials). The use of turf grass for soil water infiltration and flood control purposes could also be investigated further.

2.2.3 Rainwater harvesting & entrapment - groundwater recharge

Rainwater harvesting or entrapment is an effective way of reducing water scarcity (Helmreich and Horn, 2009) and increasing water conservation (Mercer, 2007). Rainwater harvesting or entrapment refers to the methods or technologies used to collect rainwater and surface runoff from the roofs of buildings or other catchment surfaces, where it is stored for future use (Helmreich and Horn, 2009; Rattenbury, 2012). Once rainwater has been harvested, it can be used for various purposes including for household water supply (Helmreich and Horn, 2009), irrigation, cleaning and cooling towers (Mercer, 2007).

Turf grasses are capable of preserving and trapping runoff and rainwater due to its growth habitat, dense plant canopy, biomass matrix and earthworm activity (Beard, 1998) enabling rainwater to be captured by the turf grass system instead of becoming runoff (University of California, Riverside Turf grass Research Program, 2002). In turn, this reduces excess runoff and results in more water for infiltration into the soil (Beard and Green, 1994; Beard, 1998; Sports Turf Managers Association, n.d.). Unsurprisingly, a healthy lawn can absorb rainfall and reduce runoff 80 times more efficiently than other human-made, less permeable surfaces such as driveways and footpaths (The National Turf grass Research Initiative, 2003) and can absorb rainfall four times more effectively than a hay field and six times more than a wheat field, only a virgin forest can exceed the absorption rates of turf grass (Canaway, 1999).

Sodded lawns have also been claimed to be 10 to 12 times more effective at absorbing water than seeded lawns (GreenMaster, 1991).

The dense plant canopy of mowed turf can act as a 'sponge' by absorbing vast amounts of water which increases the rate of groundwater recharge and is a very effective system for the entrapment of water (Beard and Green, 1993). Many pollutants coming from other land surface types (e.g. asphalt or concrete) can be trapped in the blades of turf grass which thereby limits the potential of these pollutants from entering nearby water bodies (Beard and Green, 1993). The biomass of turf grass is composed of fine-textured stems, narrow leaves and open spaces. This creates a matrix ranging from 890 to 26,700 pounds per acre (403 to 12,110kg) which is porous and can accommodate water infiltration (Beard, 1998). Water retention and higher infiltration rates is said to be due to the earthworm population residing in the turf grass ecosystem. Earthworms increase the amount of space within the soil which results in higher soil water infiltration rates and water-retention capacity (Beard, 1998).

Groundwater recharge is enhanced through the ability of turf grass to slow water, allow infiltration and thereby reduce runoff enhancing groundwater recharge ability (Beard, 1998; University of California, Riverside Turf grass Research Program, 2002). A study conducted in 1985 in Maryland in the USA compared surface water runoff rates between perennial turf grass and cultivated tobacco systems. Surface water runoff losses were 11 times greater in the tobacco systems than in the turf grass system (Gross *et al.*, 1990; University of California, Riverside Turf grass Research Program, 2002). Nutrient runoff losses were also greater in tobacco systems with 240 times more phosphorous (P) and 195 times more nitrogen (N) being lost. Conclusions from the report state that when compared with agronomic row crops, nutrient and sediment losses from turf via runoff, and leaching are relatively low (Gross *et al.*, 1990).

Extensive research has been conducted on turf grass's ability to trap rainwater and for use in rainwater harvesting. However further research could be done to find solid scientific evidence on the infiltration rates and in comparing turf grass types.

2.3 Land Quality Benefits

Land is comprised of soil, water, flora and fauna (Stroosnijder, 2007). Land of poor quality which has been degraded can be due to natural or anthropogenic processes. Natural processes

include soil erosion, desertification, pollution and soil degradation (Morgan, 1992; Stroosnijder, 2007). Land clearing is an human-induced process of land degradation and is 'one of the most significant pressures affecting the land environment' (State of the Environment Committee, 2011). Land clearing can have widespread and devastating effects on the natural environment as the removal of trees, plants and vegetation cover can lead to soil exposure to weathering and erosion, compaction, reduced fertility, salinity and acidification. It also exposes soil to the effects of weathering and erosion which can result in soil loss, nutrient depletion, reduced agricultural usability and productivity and can lead to soil acidification (State of the Environment 2011 Committee, 2011).

High quality land is needed for a variety of purposes including for growing horticulture crops, agriculture, housing and recreation. It offers many environmental benefits including providing habitat and shade for animal species, managing the micro-climate of an area, providing greenhouse sinks for greenhouse gases and providing nutrients for the soil and the retention of soil moisture for vegetation growth.

It is important that land quality is upheld to gain the environmental, social and economic benefits. Degradation of land can be counteracted through the application of turf grass which can mitigate and minimise the potential negative consequences. Turf grass can improve land quality through reducing nutrient loss, reducing and controlling wind and water erosion, through restoring and improving soil quality. It can also assist with the biodegradation of organic compounds and mitigate the heat island effect reducing pressure on energy consumption.

2.3.1 Reduction in nutrient movement & loss

Turf grass accounts for less nutrient and sediment loss when compared to other land types (Higginson and McMaugh, 2008). Sediment and nutrient runoff can occur from water running off vegetation. This can lead to serious environmental effects such as accelerated eutrophication of water bodies, habitat loss, dissolved oxygen loss leading to fish kills and reduction in water clarity (Nemitz *et al.,* 2007). It is therefore important to reduce sediment and nutrient loss from soils than if these effects are to be avoided.

A study was conducted to compare soil erosion control measures and sod (turf grass) was one of the most effective treatments for minimising sediment loss (Nemitz *et al.*, 2007). Turf grass Producers International (2006) stated that 'a U.S. Geologically Survey funded project documented that grassed areas established with turf grass sod are up to 15 times more effective in controlling runoff that seed established grasses'. They also refer to another study where turf grass was compared to other erosion control measures such as straw, which concluded that sod has a far better performance than straw for reducing runoff rates and total soil losses (Turf grass Producers International, 2006).

Healthy[6] turf grass systems have the ability to absorb the majority of nutrients applied to it as fertiliser and can minimise the amount which is leached or runoff (Hochmuth *et al.*, 2009). Turf grasses have a strong and expansive root system which can enhance the entrapment and uptake of essential nutrients such as nitrogen (N) and phosphorous (P) (Hochmuth *et al.*, 2009; Irrigation and Water Management, 2011) and therefore minimise the potential of Eutrophication. Eutrophication creates ecosystems which are over-enriched with nutrients from outside sources (usually N and P) and can lead increased bacteria and rates of photosynthesis and respiration which can create extra pressures on the ecosystem services and can change the structure and living conditions of the ecosystem (O'Sullivan, 1995).

Turf grass has the ability to reduce the movement of soil and nutrients as well as possessing a high capacity to absorb excess nutrients in marginal or 'polluted' water sources. This represents an opportunity to build on a currently underdeveloped market for the use of turf as a nutrient sink and should be further investigated.

2.3.2 Erosion control

Erosion can be defined as the 'wearing away of land surface by wind, water, ice or other geologic agents' (Lee, 2006). It is a naturally occurring process which is often enhanced by human activities and processes such as land clearing and land use methods and can be particularly exacerbated if areas are without vegetated ground cover (Carrow, 2004). Wind

[6] A healthy turf grass system refers to turf grass which maintains a 'complete and dense cover over the soil to reduce erosion and weed growth…it has an expansive root system that fills the soil and absorbs nutrients and water' (Hochmuth *et al*, 2009).

and water can erode and degrade soil resources (Carrow, 2004) leading to environmental degradation, sedimentation, runoff, inhibition of plant and fish habitat and chemical exposure (Lee, 2006; Kowalczyk *et al.,* 2011).

Erosion control is 'the process of restraining the initial movement of soil particles by wind and water' (Lancaster and Austin, 1994). Several methods and practices can be used to minimise and mitigate these effects such as using vegetation including turf grasses, contour grass strips and grassed swales (Beard and Green, 1994; Ligdi and Morgan, 1995; Deletic, 2001; Coughlan *et al.,* 2007). Turf grass is a very effective, cheap and durable form of erosion control (Beard and Green, 1994; Higgison and McMaugh, 2007) due to its dense root system which binds to the soil and between the soil easily. Turf grass provides ground cover to protect soil resources from erosion and sediment movement and pollution (Shoulders, 1989; Beard and Green, 1994; Coughlan *et al.,* 2007) as it minimises sediment movement from catchments to adjacent waterways (Gross *et al.,* 1990). Turf grass has been found to be more effective than other control treatments such as roadside barriers and drains (Coughlan *et al.,* 2007).

Many studies have been conducted to determine the effectiveness of turf grass in reducing soil erosion potential. These studies conclude that turf grass is a very successful method of controlling erosion due to its high shoot density (from 75 million to >20 billion shoots per hectare (Beard, 1994), root mass (Beard and Green, 1994; University of California, Riverside Turf grass Research Program, 2002) and high biomass matrix which provide soil stabilisation and resistance to lateral surface water flow (Beard and Green, 1994). Turf grass has the potential to reduce on-site and off-site erosion and sediment pollution runoff by providing two main functions to alleviate erosion potential, including acting as a buffer strip to trap sediment and runoff and through providing surface protection to reduce sediment detachment (Loch *et al.,* 2009). The reduction in sediment movement protects soil resources and reduces water pollution of nearby water bodies such as lakes, rivers and streams (University of California, Riverside Turf grass Research Program, 2002).

Another study by Ligdi and Morgan (1995) used metal rods to simulate the effects of using contour grass strips as a method of erosion control. The study demonstrated that 'contour grass strips reduced sediment concentrations to at least one-third of that recorded with bare soil control on slopes between 5 and 10%' (Ligdi and Morgan, 1995), however on slopes of

20% the use of grass strips are a method for erosion control actually increased the erosion twofold (Ligdi and Morgan, 1995). A study conducted on Mexican grassland by Gutuerrez and Hernandez (1996) concluded that an increase in grass cover reduces surface runoff and an increase of grass aerial cover reduces interrill erosion (1996).

A study (Gross *et al.,* 1991) was conducted to compare turf grass plots against bare soil in which a 30 minute storm period which produced 76mm per hour of rainfall, turf grass plots recorded sediment losses of 10-60kg ha^{-1} compared with 223kg ha-1 for bare soils these results show that low density turf grass can significantly reduce sediment losses (Gross *et al.,* 1991) and are not a significant source of sediment entering water bodies (Beard and Green, 1994). A study conducted to identify the potential use of turf grass in reducing sediment movement and erosion on construction sites (Loch *et al.,* 2009) showed that turf grass could be used as a buffer strip to trap runoff and as a surface covering which would help to reduce on-site and off-site erosion (Loch *et al.,* 2009). Results of the study showed that turf grass is an effective method for reducing erosion and sediment movement. Turf grass can be used for erosion control on a relatively high gradient and for trapping and controlling sediment (Loch *et al.,* 2009). This information has been communicated to, and well received by, the erosion and sediment control industry with qualitative data and anecdotal evidence that turf grass is being increasingly accepted for this purpose (Holborn & Pearce 2013).

The use of turf grass for erosion control has been well documented in the literature. However, the use of turf grass as a natural source of erosion control could be further researched when it is used in place of artificial or man-made erosion control methods. The available research results should also be well communicated as this represents a substantial and growing market opportunity for the industry.

2.3.3 Soil improvement & restoration

Turf grass has a vital function in the restoration of environmentally damaged lands and soils (Beard and Green, 1993). Turf grass can help restore damaged soils such as those affected by fire, erosion, mining, harvest and landfill areas (University of California, Riverside Turf grass Research Program, 2002). Turf grass like many other grass plants are constantly creating new topsoil from decomposing roots, stems and leaves (Wells, 2005). Soil improvement can occur using turf grasses through the addition of organic matter from composting (turnover) of organic materials such as roots and plant tissues through photosynthesis (Beard and Green,

1994; Beard, 1998; University of California, Riverside Turf grass Research Program, 2002). As the plant tissue dies, it is incorporated into the root system which is turned over at an estimated annual rate of 42%, meaning that approximately 6,017 pounds per acre (Beard, 1998) or 6761kg per hectare (Beard and Green, 1994) of root biomass is turned over into the soil per year. A high proportion of fertile soils are often developed under a vegetative grass cover such as that of turf grass (Beard and Green, 1994).

2.3.4 Biodegradation of synthetic organic compounds (including phytoremediation)

Turf grass is home to many species of microorganisms, microflora, microfauna and earthworms (Beard, 1998). These species are supported by, and cause the decomposition of, roots and shoots and play an important role in the ecological process of degradation of animal wastes, organic chemicals/materials, noxious chemicals and pesticides into harmless substances (Beard, 1998; Carson, 2011; Layt, n.d.(c); University of California, Riverside Turf grass Research Program, 2002). These species can break down a range from 0.1 – 50 pounds per square feet of chemicals and pesticides and turf grasses can catch and filter these polluted runoffs therefore protecting water bodies and groundwater sources from contamination (Beard and Green, 1994; Beard, 1998).

Studies have begun to examine different turf and grass types and their ability to assist in phytoremediation of contaminated land areas including oil polluted desert areas a remnant of the 1991 Gulf War in the Middle East (Mahmoud et al 2011) to heavy metal contaminated mining lands in Africa (Ansah 2012). This area represents a significant new market potential for turf grass given the already promising results from the preliminary research in this area.

Turf grasses support a large, diverse population of soil micro flora and micro fauna. Compared to grassland, the average microbial biomass is 42% less for cropland and 29% less for forests. These measurements were made on non-irrigated grasslands; thus, many irrigated turf grass areas would have even larger microbial populations. The turf grass soil ecosystems with its large microorganism population offers one of the most active biological systems for degradation of trapped organic chemicals and pesticides, thereby functioning in the protection of groundwater quality (Beard and Green, 1993).

This function is related to the previously listed function *2.2.1 Water filtration and purification* and requires further research to identify and quantify the parameters surround the use of turf grass for phytoremediation purposes.

2.3.5 Alleviating heat island effects

The urban heat island phenomenon/effect[7] can be described as one of the most prominent characteristics of urban climate. The heat island effect is often measured by the temperature difference recorded between the city centre and rural surroundings or suburban areas, with surface and air temperatures being recorded to be much higher than in rural areas (Chang *et al.*, 2007; Gartland, 2008). Excessive warmth in urban areas can be attributed to the use of dark surface materials such as asphalt and roofing (Henry and Dicks, 1987; Akbari *et al.*, 2001), reduced vegetation (Akbari *et al.*, 2001) and by the high solar radiation absorbance by urban surfaces or 'hardscape' elements of the urban landscape (Rosenfeld *et al.*, 1995; Akbari *et al.*, 2001). These three factors contribute to the warming of the air in urban areas, thereby producing a heat island effect (Akbari *et al.*, 2001). Hard surfaces such as concrete, gravel, pavers and bitumen are the hottest feature in an outdoor setting (Layt, n.d. (b). Various anthropogenic factors contribute to this effect such as traffic congestion, intense human activity and tall buildings (Chang *et al.*, 2007). The outcomes of this effect such as intense solar radiation and high air temperatures (Shashua-Bar *et al.*, 2009) can lead to many negative scenarios including mortality, disease, air pollution and increased energy usage (Chang *et al.*, 2007; Gartland, 2008).

However, there are several strategies identified in the literature to mitigate and alleviate the effects of the urban heat island (Chang *et al.*, 2007; Keepin, 2009) such as the use of vegetated surfaces (Beard and Green, 1994). Turf grasses has been described as "nature's air conditioner" and a type of vegetated surface that can help minimise the harmful human health, economic and environmental impacts associated with the heat-island effect. Vegetation and plants of all types play an important role in climate and micro-climate regulation (Watschke, 1990) as they can reduce heat dissipation and temperatures. Turf grasses reduce temperature in two ways; the first is by providing shade of heat-absorbing surfaces and the second through

[7] The urban heat island phenomenon/effect will be referred to as the 'heat island effect' for the purposes of this report

the process of evapotranspiration which dissipates high levels of radiant energy in urban areas and provides a cooling effect (Beard and Green, 1994; Beard, 1998; Bonan, 2000; University of California, Riverside Turf grass Research Program, 2002; Chang *et al.*, 2007; The Turf grass Resource Centre, 2007; Gartland, 2008; Shashua-Bar *et al.*, 2009).

Vegetated surfaces are on average cooler than non-vegetated surfaces (Bonan, 2000) and shaded vegetated surfaces provide for even greater cooling (Shashua-Bar *et al.*, 2009) and can be up to 30^{o}C cooler than asphalt on 'a hot summer's day' (The Lawn Institute, n.d.). If vegetation is planted close to buildings, it can reduce surface wall temperatures by up to 17^{o}C (Chang *et al.*, 2007). Studies have claimed that the average front lawn can produce a cooling effect which is equal to the use of two air conditioners (Carson, 2007) or that eight average front lawns have the same cooling effect of approximately 70 tons of air conditioning (The National Turf grass Research Initiative, 2003).

In a pilot study conducted in Queensland, Australia by Poulter, Holborn and Dahler (2008) the researchers tested the temperature differences between green and hard landscape surface coverings namely turf grass, mulch, gravel, artificial turf, paving and concrete. Turf grass was shown to have one of the lowest daily average temperatures compared to all other types with artificial turf reaching a temperature of over 60^{o}C in winter (Poulter *et al.*, 2008). In another Australian study conducted by Layt (2010) on a day in the middle of summertime with an air temperature recording of 40^{o}C, the temperature of turf grass recorded at 45.65^{o}C compared to dark concrete which recorded at 78.27^{o}C. Turf grass had the lowest temperature, with the second lowest recorded temperatures belonging to wet cast quartz pavers recorded at 59.10^{o}C (Layt, 2010).

Well managed areas of turf grass can promote sustainability as they positively contribute to the three pillars of sustainability affecting ecological (environmental), social and economic realms. Turf grass can have other benefits stemming from the reduction of heat on warm days as it can reduce the need for use of indoor air conditioners and can therefore potentially reduce the amount of energy used. Turf grass can also be used for green roofs which are specially engineered roofing systems which are designed with the use of vegetation which undergo evapotranspiration and therefore offer additional cooling effects. Turf grass is obviously successful at reducing urban temperatures which are heightened by man-made

materials such as buildings and concrete. However, once again the ability of turf grass to lower temperatures can also be achieved by other vegetation species.

The temperature reduction for various vegetation types should be compared to determine which has the highest reduction of temperature and to see which combination of vegetation is most effective for example, the use turf grass *and* trees. Additionally, claims about reductions in temperatures resulting in reduced energy use should be quantified fir Australia in summer.

2.4 Other Benefits

2.4.1 Noise & glare reduction

Turf grass can successfully reduce noise and glare in urban environments (Beard and Green, 1994). Turf grasses have been shown to control sound levels as its rough surface characteristics absorb, deflect, reflect and refract various unwanted noises (Sports Turf Managers Association, n.d.) and turf grass has a far greater success rate of abating harsh sounds than most other surface such as bare ground or pavement (Beard and Green, 1994; Beard, 1998). An area of 70 feet of turf grass near a roadside can abate vehicle noise by up to 40% (Beard and Green 1993). The surface of turf grass can reduce glare as it reflects light in different directions which lowers the harshness and stress of light in bright conditions on the human eye (Beard and Green, 1993; Canaway, 1999).

2.4.2 Fire prevention

Turf grass can act as a buffer zone of grass around buildings helps to retard the spread of fires and acts as a vital firebreak which decreases the likelihood of fire significantly (Watschke, 1990; Beard and Green, 1993). It also serves as a high visibility zone which can make the advent of fire more obvious (Beard and Green, 1993; Beard and Green, 1994). Extended drought periods during the 1980s and 1990s in the United States led landowners to remove turf grass from their property and replace it with other vegetation species. However when wildfires swept through the area, consuming homes and recently planted vegetation species the landowners who retained significant amounts of turf grass suffered minimal fire damage compared to those who replaced turf grass (Cathey, 2003).

2.4.3 Biodiversity & ecosystem services

The turf grass ecosystem is home to abundant populations of earthworms which can help to retain water and achieve higher water infiltration rates (Beard and Green, 1994). Turf grass provides an essential habitat and breeding ground for certain fauna species which are critical for maintaining a balanced ecosystem (Layt, 2009; Layt, n.d.(a)) and have potential value as an area of conservation for native wildlife and threatened species of bird, frog, mammal and reptile (Hodgkison *et al.*, 2007). Studies conducted in the US have found that golf courses (large areas of turf grass) have the potential to support threatened bird species (Hodgkison *et al.*, 2007). Golf courses located on the Gold Coast of Queensland, Australia are home to small areas of flora species of lowland eucalypt and melaleuca vegetation (Hodgkison *et al.*, 2007). In a study conducted by Hodgkison, Hero and Warnken (2007) concluded that golf courses provide habitat for threatened species and urban-adapted species and the presence of species not commonly observed in suburban areas (e.g. koalas, skinks, gliders and lace monitors) suggests that golf courses are a superior habitat for these species over urban areas. Also in some of the golf courses studied, the number of bird species present was greater than the number of bird species present in eucalypt forest areas suggesting that golf courses can lead to an increase in numbers of these populations (Hodgkison *et al.*, 2007), however if eucalypt forests were to be replaced by large areas of turf grass such as golf courses could lead to the local decline of many regional species (Hodgkison *et al.*, 2007). The study also found that golf courses were a better refuge for birds and mammals instead of reptiles and amphibians.

Properly designed urban landscapes which incorporate turf grass can provide wildlife habitat and promote animal and plant diversity (Beard and Green, 1994). The majority of research has been focused on identifying the habitat provision of golf courses which although containing large tracts of managed turf areas also usually contain large and small trees, areas of 'rough' and water bodies.

What has been less studied is the habitat provision of turf grass areas alone and although some claims are heartening, for example (Beard, 1998) that turf grass ecosystems can be home to more than 100 taxa including insects, beetles, earthworms, nematodes and other invertebrates, this requires substantially more research.

3 CONCLUSION

This report has critically analysed a vast amount of literature surrounding the perceived and actual environmental benefits of natural turf grass. Environmental benefits of turf grass positively affect areas of water, land, and atmosphere quality and can also increase biodiversity and reduce the likelihood of fire, noise and glare. It is obvious that natural turf grasses play a significant role in the environment through their various environmental, monetary, societal and health benefits and can positively contribute to the environment, society and the economy. As Beard (2004) said - turf grasses contribute a diverse array of benefits that make them one of the best friends of the urban environmentalists and they greatly enhance our quality of life, especially in densely populated urban areas (see Table 2).

Table 2: Summary list of the environmental benefits of turf grass

ATMOSPHERE QUALITY BENEFITS	**WATER QUALITY BENENFITS**	**LAND QUALITY BENFITS**	**OTHER BENFITS**
Air pollution control/air quality improvement Oxygen generation Dust prevention & stabilisation Carbon sequestration and sinks	Water filtration and purification (phtyoremediation) Water run-off reduction Rainwater harvesting & entrapment - groundwater recharge	Reduction in nutrient movement & loss Erosion control Soil improvement and restoration Biodegradation of synthetic organic compounds (phytoremediation) Alleviating heat island effects	Noise and glare reduction Fire prevention Biodiversity and ecosystem services

At present the data available and evidence of environmental benefits is not always supported by rigorous scientific analysis and results can be ambiguous. The industry literature often does not provide information on how results were obtained, what methods were used, how they were measured or modeled and what assumptions were made within their calculations. This leads to research recommendations which focuses on these areas and ensures appropriate data is available for Australian conditions. This research should ideally be conducted in Australia to ensure it is locally accurate and relevant.

While it is evident from the extensive literature reviewed that well-managed, natural turf grass has numerous environmental benefits, uncertainty about the extent of these benefits still exists. Further research must be taken to determine the scientific evidence to support these claims and ensure the full environmental benefits of turf grass are identified and the extent of these benefits are known.

4 RECOMMENDATIONS FOR FURTHER STUDY

The literature reviewed in this project presents a convincing case for further research, in most areas relating to the environmental benefits of turf grass including atmosphere, water, land and other environmental benefits. Although there are vast amounts of literature regarding the environmental benefits of turf grass, there are several 'gaps' in the literature which have been identified. These gaps form the basis of the recommendations for further study which are suggested.

Overall, further studies into the environmental benefits of turf grass should be conducted on a national or local scale in Australia as many of the studies and publications examined for literature review have been conducted overseas. It was difficult to find independent scientific results on the environmental benefits of turf grass for many of the claims and a high proportion of the studies or articles have been commissioned, supported or funded either in part or in full by the turf grass industry. This could potentially create a situation for bias to occur where results may be embellished or framed in a certain light. Often the literature published in industry publications particularly those in the industry magazines lacked solid scientific evidence, so it is recommended that independent research is undertaken to establish the environmental benefit and the extent of these benefits in Australia. In light of this, it is

recommended that independent, rigorous, scientific research is conducted to mitigate any potential bias or the perception of bias.

Although there are many environmental benefits that arise from turf grass, the majority of these can be achieved by vegetation and plant species in general, such as alleviating the heat island effect, oxygen generation and carbon sequestration. It is recommended that turf grass be tested in comparison to other types of plant and vegetation types to better quantify and compare benefits. Many of the environmental benefits associated with turf grass could be maximised by use of an integrated landscape where turf grass is used in conjunction with other vegetation or plant species such as the use of trees to increase the evapotranspiration effect which reduces temperatures and the heat island effect (Beard and Green, 1994), area for biodiversity and noise reduction (Beard and Green, 1994).

Major recommendations regarding the environmental benefits of turf grass include: standardising the size of turf grass plot, unit of measurement including timecales and methods used for measurement. The current benefits of turf grass vary in these areas which is well illustrated by the results listed in Table 1. Because these variables are inconsistent, ambiguous statistics are often produced which can be difficult to interpret and even more difficult to support.

4.1 Recommendations for Atmosphere Quality Benefits

There is a wide variety of information available regarding the environmental benefits of carbon sequestration from turf grass. However some of the results produced from these studies can be misleading and are often hard to interpret as most are from international sources with the majority conducted in the USA and therefore most of the statistics are recorded in American units. It is recommended that Australian studies are undertaken which would compare the results between those which already exist. Of the literature reviewed on the environmental benefit of carbon sequestration and carbon sinks from turf grass, most studies and research has been commissioned or funded in part or in full, by the turf grass industry (Higginson and McMaugh, 2008; Huh *et al.*, 2008) or are by authors who may have a vested interested in the turf grass industry (Layt 2009, 2010, n.d(a) (b) (c)). Other studies have been conducted or funded by government departments such as Jo and McPherson (1995) and Pouyat *et al.* (2009). Only Shau, (2008) explicitly states his study was conducted independently and only two studies found may have been independent but they do not

communicate this in their work (Qian and Follett, 2002; Sahu, 2008; Zirkle, 2010, 2011). It is recommended that all commissioned research be conducted as independently as possible to minimise any potential bias and the potential *perception of bias* which could arise during the studies and experiments.

However, of the studies reviewed in this project, many are rigorous and have sound methodologies. Most studies were comparing carbon sequestration rates of: turf grass species, residential landscapes, managed or non-managed grasses and have methodologies which either use available data or primary data collected from undisturbed soil core samples which are then compared using statistical analysis such as regression (Qian and Follett 2002; Huh *et al.,* 2008; Pouyat *et al.,* 2009). Other studies model sequestration rates using equations and available data (Zirkle, 2010) or estimate values based on available data (Sahu, 2008). Another study determines CO_2 exchange through the measurement of ecosystem respiration and the net ecosystem exchange (Baird, 2011). The variability within the results suggests that further research is required which takes into account the turfgrass type, cultivar, climate, soil and management input regime all of which are liable to impact the sequestration capacity of the tested grasses.

Further research on carbon sequestration should be undertaken in Australia as a priority. This research should investigate the effectiveness of turf grass to sequester carbon on both a national and local scale. The effectiveness could also be assessed on turf grass used for different purposes (current literature is generally based on golf courses) e.g. agriculture, commercial, residential, industrial and sporting and compare variations of carbon sequestration rates between different maintenance practices.

Rates of carbon sequestration vary depending on irrigation, fertiliser, and grass types and if turf grass is not being maintained in balance, the potential for carbon sequestration is greatly reduced. More research could be conducted on turf types to determine which has the highest potential for carbon sequestration and what the optimum rate of carbon sequestration is and to determine at what point this rate decreases in turf grass in Australia. This could also identify how carbon sequestration levels can be maintained and what maintenance regimes, best management practices, technologies and techniques. Additional research is required into improving soil quality for long periods of time, which increase carbon sequestration rates

(Qian and Follett, 2002). Research could also be conducted into the reduction of other greenhouse gases from turf grass such as carbon monoxide, methane and sulfur dioxide.

Further research could be conducted into how turf grass could be used in the application of any future versions of the carbon tax and/or emissions trading scheme in Australia and aim to determine what/if there are any monetary benefits or offsets potentially available.

Research methods employed to examine the environmental benefits of turf grass will allow scientists to fill the gaps in knowledge in key scientific fields. Much of the literature reviewed in this report was based upon a combination of primary and secondary data. Primary data used in the literature reviewed used modeling, laboratory experimentation, laboratory analysis and field observation as methods of data collation. Whereas secondary data used in the literature was used to make inference and conclusions. It is recommended that if future research is conducted, it should use the methodologies found in previously conducted studies to form the basis of the research and achieve some reliability and repeatability as well as some preliminary comparison of results.

4.2 Recommendations for Water Quality Benefits

There is currently a lot of information available about erosion control at an international level (mostly golf courses and in the USA). Studies are often inconclusive and do not give the full amounts of erosion controlled. More information is required on Australian soil erosion control and the actual erosion and sediment control potential of turf grass. Further research could also compare turf grass to other types of erosion control methods used in Australia in order to assist those requiring erosions control to better select the optimum measures to install. The ability of turfgrass to filter or clean pollutants and the use of that to improve waterway health and potential dispose of polluted or variable quality wastewaters should be further researched and the market potential for the of turf for this purpose should be investigated. This presents substantial opportunities in areas such as wastewater treatment and the mining industry but especially in the rapidly expanding coal seam gas industry whose water quality issues are significant.

4.3 Recommendations for Land Quality Benefits

Additional studies should be conducted on the alleviation of the urban heat island effect a national and local level. The potential of turf grass to alleviate this effect may differ based

upon geographical location and at present, most studies into this have been conducted in the USA. The associated monetary values could also investigated as there is associated economic benefits as a result of the alleviation of the heat island effect as it can help to reduce energy costs (e.g. electricity) and air pollution (e.g. respiratory diseases). Using turf grass in conjunction with other vegetation should also be investigated as the maximum cooling effect is 'obtained in the daytime hours by the strategy with trees over grass' (Shashua-Bar *et al.,* 2009). This may also extend to include an examination of the use of turfgrass sod in green roof installations.

4.4 Recommendations for Other Benefits

As suggested by Hodgkison *et al.* (2007) the use of turf grass for biodiversity and conservation needs to be further investigated on a more localised scale that targets grassed areas only and includes a range of target species. This will help to determine the ecological function of turf grass in providing a place of foraging and refuge for urban-adapted species.

Noise abatement is likely to be a minor consideration in terms of utlising turf specifically for this purpose but further research into this area should be conducted as a greater reduction in noise has been proven when turf grass and other vegetation types (e.g. trees and shrubs) are used in combination. It is suggested that studies are to be conducted which will determine how much extra noise can be abated using these vegetation types in conjunction rather than turf grass as a medium alone.

4.5 General Recommendations

The industry has invested substantially in developing new cultivars based on aesthetic appearance and maintenance requirements but also for specific purposes such as shade, salinity and wear tolerance. These cultivars also tend to require fewer inputs and therefore reduce the potential impact on the environment of maintaining these turf grasses in acceptable condition. There is now an opportunity for the industry (either collectively or more likely as individual businesses) to select and breed cultivars for specific purposes such as phytoremediation, cooling capabilities or carbon sequestration. This process should also focus on selecting and if possible developing, native grasses into turf grass varieties as the use of turf grass for environmental purposes will inevitably be limited if there is a limited native varieties available for use in what are often environmentally sensitive areas.

The industry should also invest some time and resources to draft policy positions on key environmental issues in all aspects of the turf grass life cycle including production and maintenance and then communicate that widely to target audiences including government. An example of this might be an industry water-use policy. These policies should then be built into a future turf accreditation scheme as a basis from which to differentiate those producers and their product from 'the rest'.

Finally, the political and community focus on the environment both now and potentially more so in the future provides an opportunity for the industry to become the provider of environmental solutions as opposed to an environmental problem which it was perceived as during the national water crisis of the 2000s. In conjunction with building the evidence to support turf grass's role in the environment, the industry should invest in quantifying its own parameters and communicating them. The industry currently lacks basic statistics such as the size of areas under turf grass in the community, the true value of those areas, the value of turf in the environment (for example costing the value of turf as an erosion control measure) and its comparative cost and efficacy to alternatives (like artificial turf) over the lifetime of the product.

The Australian turf industry has some important and well supported environmental stories to tell and should dedicate a proportion (probably a large proportion) of the marketing levy funds to undertake activities that effectively convey that information to consumers – both domestic and commercial. Opportunities for turf in emerging market such as Water Sensitive Urban Design (WSUD) and phytoremediation are prime opportunities for the industry to position itself well and claim a share of these markets but that will require a sound basis of evidence on which to stake their claims.

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6 APPENDIX 1 – SUMMARY DOCUMENT

TEXT ONLY – TO BE LAID OUT AND PRINTED IN
CONSULTATION WITH TURF AUSTRALIA AS AGREED

ATMOSPHERE QUALITY BENEFITS

Air pollution control/air quality improvement

Turf grass can control air pollution and improve air quality by absorbing pollutants, smoke, dust and dirt particles from the atmosphere (it can also prevent air pollution through dust stabilization) as turf grasses trap particulate matter in the grass blades. Turf grass also absorbs CO_2 as an input along with light energy for photosynthesis which reduces the carbon abundance in the atmosphere and releases oxygen as a byproduct.

Oxygen generation

Turf grass like all other plants uses carbon and energy (light) source to undergo the process of photosynthesis. Photosynthesis is where plants absorb and breakdown CO_2 and water to an energy source. Energy is generated from this process and organic products and oxygen are produced as byproducts. These organic products are used by the turf grass plant for growth while the plant is releasing oxygen into the environment. Because turf grass is so abundant it plays an important role in generating oxygen, especially in urban environments.

Dust prevention & stabilisation

Dust refers to particles of soil or other matter small enough to be moved and carried by the wind. Dust can have a harmful impact on human health by aggravating asthma and eczema conditions and dust can also contribute to environmental problems such as water pollution and sedimentation. Turf grass captures and suppresses dust by slowing the wind velocity allowing dust to settle as well as preventing dust particles from becoming detached and airborne in the first place. Dust particles that are caught by turfgrass are moved via rainfall to enter and become incorporated (secured) as part of the living soil system.

Carbon Sequestration and sinks

Carbon sequestration is the long term storage of carbon dioxide ($CO_{2)}$. CO_2 is a greenhouse gas and is contributing to climate change. The impacts of climate change pose a serious threat to human health, quality of life, economy, society and the environment. Turf grass can be

used as a method to mitigate climate change as it has the potential to act as a carbon sink for carbon sequestration through the process of photosynthesis, nutrient cycling and soil organic carbon accumulation. Appropriately maintained turf grass can sequester carbon at a rate that makes it a net carbon sink meaning that turf grass can capture, convert and store more carbon in the soil than is produced to maintain (mow) it. Along with carbon sequestration, turf grass can also absorb other atmospheric greenhouse gases and gaseous pollutants carbon monoxide (CO), methane (CH_4), sulfur dioxide (SO_2), ozone (O_3), hydrogen fluoride (HF) and peroxylacteyl nitrate ($C_2H_3NO_5$).

WATER QUALITY BENENFITS

Water filtration and purification (phtyoremediation)

Water is an essential resource needed to maintain all life on earth. Turf grass can reduce factors degrading water quality such as eroded top soil and can slow down runoff and trap pollutants, sediments and heavy metals, preventing them from leaching into adjacent water bodies. Water purification occurs when water is leached through the turf grass root zone and into underground aquifers or when it is run over grassed areas as the leaves trap suspended solids and sediment material. Turf grass is also used in industries such as food processing as a method of cleaning wastewater before it is discharged into natural water bodies (a type of phytoremediation). Some turf grass types have very high tolerance of salts and nutrients and are suitable to use to dispose of lower quality wastewaters such treated sewerage and mining wastewaters.

Water run-off reduction

If runoff is not controlled, it can contain pollutants, chemicals and pesticides which lead to eutrophication and contamination of adjacent water bodies including lakes, rivers and streams which can damage or kill aquatic plants and animals. Areas of turf grass play a significant role in reducing water runoff and can retain vast quantities of water. Stormwater runoff from a healthy, dense area of turf grass can be at or near zero, meaning that virtually all runoff is eliminated. Generally speaking, the runoff produced by turf grass that could lead to contamination of water bodies is far less than the runoff contamination from hard surface coverings and the amount of contamination produced from turf is generally much lower.

Rainwater harvesting and entrapment – ground water recharge

Rainwater harvesting or entrapment refers to the methods or technologies used to collect rainwater and surface runoff from the roofs of buildings or other catchment surfaces, where it is stored for future use. Turf grasses are capable of preserving and trapping runoff and rainwater in the soil due to its growth habitat, dense plant canopy, biomass matrix and earthworm activity enabling rainwater to be captured by the turf grass system instead of becoming runoff. In turn, this reduces excess runoff and results in more water for infiltration into the soil. The dense plant canopy of mowed turf can act as a 'sponge' by absorbing vast amounts of water which increases the rate of groundwater recharge and is a very effective system for the entrapment of water. Many pollutants coming from other land surface types (e.g. asphalt or concrete) can be trapped in the blades of turf grass which thereby limits the potential of these pollutants from entering nearby water bodies and assists with groundwater recharge.

LAND QUALITY BENFITS

Reduction in nutrient movement & loss

Sediment and nutrient runoff can occur from water running off bare areas of earth, cultivated areas and some types of vegetation. This can lead to serious environmental effects such as accelerated eutrophication of water bodies, habitat loss, dissolved oxygen loss leading to fish kills and reduction in water clarity. Healthy turf grass systems have the ability to absorb the majority of nutrients applied to it as fertiliser and can minimise the amount which is leached or runoff. Turf grasses have a strong and expansive root system which can enhance the entrapment and uptake of essential nutrients such as nitrogen (N) and phosphorous (P) and therefore minimise the potential of Eutrophication.

Erosion control

Turf grass is a very effective, cheap and durable form of erosion control due to its dense root system which binds to the soil quickly and readily. Turf grass provides ground cover to protect soil resources from erosion and sediment movement and pollution as it minimises sediment movement from catchments to adjacent waterways. Turf grass has been found to be more effective than other control treatments such as roadside barriers and drains. Turf grass controls erosion due to its high shoot density, root mass and high biomass matrix which provide soil stabilisation and resistance to lateral surface water flow. Turf grass has the potential to reduce on-site and off-site erosion and sediment pollution runoff by providing two main functions to alleviate erosion potential, including acting as a buffer strip to trap sediment

and runoff and through providing surface protection to reduce sediment detachment. Turf grass can be used for erosion control on a relatively high gradient and for trapping and controlling sediment.

Soil improvement and restoration

Turf grass has a vital function in the restoration of environmentally damaged lands and soils. Turf grass can help restore damaged soils such as those affected by fire, erosion, mining, harvest and landfill areas. Turf grass like other plants is constantly creating new topsoil from decomposing roots, stems and leaves. Soil improvement can occur using turf grasses through the addition of organic matter from composting (turnover) of organic materials such as roots and plant tissues through photosynthesis. As the plant tissue dies, it is incorporated into the root system is turned over into the soil. A high proportion of fertile soils are often developed under a vegetative grass cover such as that of turf grass.

Biodegradation of synthetic organic compounds (phytoremediation)

Turf grass is home to many species of microorganisms, microflora, microfauna and earthworms. These species are supported by, and cause the decomposition of, roots and shoots and play an important role in the ecological process of degradation of animal wastes, organic chemicals/materials, noxious chemicals and pesticides into harmless substances. The turf grass soil ecosystems with its large microorganism population offers one of the most active biological systems for degradation of trapped organic chemicals and pesticides, thereby functioning in the protection of soils and groundwater quality. Turf grasses can catch, filter and process polluted runoffs therefore protecting water bodies and groundwater sources from contamination. Turf has the ability to assist in phytoremediation of contaminated land areas including oil and heavy metal contaminated land.

Alleviating heat island effects

The urban heat island phenomenon is often measured by the temperature difference recorded between the city centre and rural surroundings or suburban areas, with surface and air temperatures being recorded to be much higher in built-up city areas than in rural areas. Excessive warmth in urban areas can be attributed to the use of dark surface materials such as asphalt and roofing, reduced vegetation and by the high solar radiation absorbance by urban surfaces or ‘hardscape’ elements of the urban landscape. These three factors contribute to the warming of the air in urban areas, thereby producing a heat island effect.

Turf grasses has been described as “nature’s air conditioner” and a type of vegetated surface that can help minimise the harmful human health, economic and environmental impacts associated with the heat-island effect. Turf grasses reduce temperature in two ways; the first is by providing shade of heat-absorbing surfaces and the second through the process of evapotranspiration which dissipates high levels of radiant energy in urban areas and provides a cooling effect. Vegetated surfaces (including green roofs) are on average cooler than non-vegetated surfaces and shaded vegetated surfaces provide for even greater cooling and can then reduce the reliance on artificial cooling from air conditioning.

OTHER BENEFITS

Noise and glare reduction

Turf grass can successfully reduce noise and glare in urban environments and have been shown to control sound levels as its rough surface characteristics absorb, deflect, reflect and refract various unwanted noises and turf grass has a far greater success rate of abating harsh sounds than surfaces such as bare ground or pavement. The surface of turf grass can reduce glare as it reflects light in different directions which lowers the harshness and stress of light in bright conditions on the human eye.

Fire prevention

Turf grass can act as a buffer zone of grass around buildings helps to retard the spread of fires and acts as a vital firebreak which decreases the likelihood of fire significantly. It also serves as a high visibility zone which can make the advent of fire more obvious.

Biodiversity and ecosystem services

Properly designed urban landscapes which incorporate turf grass can provide wildlife habitat and promote animal and plant diversity. The turf grass ecosystem is home to abundant populations of earthworms which can help to retain water and achieve higher water infiltration rates. Turf grass provides an essential habitat and breeding ground for certain fauna species which are critical for maintaining a balanced ecosystem and have potential value as an area of conservation for native wildlife and threatened species of bird, frog, mammal and reptile. Studies on urban golf courses golf courses were a better refuge for birds and mammals instead of reptiles and amphibians.