Natural grass vs Synthetic Surfaces for recreation and Sports: An evidence review

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Executive Summary:

Appropriate surface provision is fundamental to inspiring individuals to participate in outdoor sports and recreation activities. Although outdoor sports traditionally have been played on natural grass fields, the synthetic turf option has gained popularity over the past few decades around the world and in different states of Australia, including South Australia. The use of synthetic surfaces in sports and recreation activities, however, has long been debated, particularly due to their negative environmental and health impacts, although we have limited understanding about the impacts per se. This study, therefore, aims to provide a knowledge base for this debate by exploring the benefits and disadvantages of synthetic turf compared with natural grass. Findings suggest that natural grass turf has multiple environmental benefits compared with synthetic turf sports surfaces. Natural grass fields also have certain health benefits related to heat dissipation and psychological comfort, while synthetic turf offers health and social benefits in terms of the capacity to sustain heavy use and accessibility. This review suggests that choosing the right surface option for outdoor sports needs an adequate consideration of both short- and long-term environmental, health and wellbeing factors.

1. Introduction

Traditionally outdoor sports and recreation activities have been performed on natural grass surfaces. Maintenance of grass turf surfaces involves different activities including mowing, irrigation and control of weeds, pests and disease. Despite

significant maintenance, natural turf has a low carrying capacity[1]. Due to the changes in the profile of sports, particularly at the elite level, expectations for high-quality sports grounds have increased worldwide. Given this context, replacing the natural grass with synthetic turf (also referred to as artificial turf) received traction around the world from the mid-1970s onwards. Several traditional sports such as hockey, soccer and rugby started to use synthetic turf pitches. Australia has increasingly embraced artificial turf technology around the same time. In particular, it started to replace natural grass with artificial surfaces in first-class and international sports venues, complying with the decision of international sporting governing bodies to allow artificial turf.

Such popularity impacted the expectation of local sporting clubs and associations across Australia. In order to provide high-quality sports surfaces, ground management authorities have increasingly adopted plans to replace natural grass surfaces with synthetic ones. However, the use of synthetic surfaces in sports and recreation activities has long been debated, particularly based on their negative environmental and health impacts, which are not well documented. This study, therefore, aims to provide a knowledge base by examining the benefits and disadvantages of synthetic turf compared with natural grass.

2. Scope and objective of the Study

The City of Adelaide is encircled by parklands, which provide residents a myriad of sporting and recreational opportunities. These activities, together with the events organised in the park lands, contribute to the physical and mental wellbeing of the residents, making it one of the world's most liveable cities. Therefore, the sustainable management of parklands is crucial to maintain its status as one of the best liveable cities.

The sustainable management of parklands, however, has always been a challenging task for authorities concerned. It is challenging in the context of the different functions that they are required to perform, from accommodating national sporting

[1] James, I. (2015) Surface classification, function, construction and maintenance, in Dixon, S. Fleming, P., James, I. and Carre, M. (eds.) *The science and engineering of sport surfaces*, Routledge, Oxon.

stadiums to preserving significant remnants of vegetation. This challenge is magnified by the fact that the metropolitan Adelaide region is poorly serviced by space. As a result, the parklands service a population that extends well beyond the residents of the City of Adelaide. Furthermore, inner-city and surrounding urban density is increasing, and population growth is projected to steadily climb, whilst no new significant parcels of open space have been identified.

Park-based sports and other physical activities are crucial means for maintaining health and wellbeing[2]. Considering this, the Adelaide Park Lands Authority adopted a plan to encourage its residents to engage in sports and recreation activities by providing improved playing surfaces[3]. As such, the provision of quality surfaces is considered an important underlying factor because it motivates the community to engage in sports and exercise activities. City planners, therefore, seeks to deliver 'fit for purpose' facilities for the community so that the participants can perform to the best of their ability.

A way of providing more opportunities within the existing footprint of formal and informal sporting areas in the parklands is to increase the carrying capacity of spaces through the use of alternative surfaces. Synthetic sports surfaces have now been determined as a viable alternative to natural grass surfaces. However, in order to make the decision about the appropriate surface provision for sports, it is essential to shed light on various aspects of synthetic and natural grass turf.

Objective of the study

The objective of this study is to provide strategic direction for the future provision and management of sports and recreation surfaces in the City of Adelaide. The study specifically seeks to achieve the following objectives:

- Identify international and national trends in relation to sustainable recreation and sports landscape provision and management;

[2] Government of South Australia (2016) Healthy parks and health people South Australia 2016-2021, South Australia.
[3] Adelaide Park Lands Authority (2017) Adelaide Park Land Management Strategy 2015-2025, Government of South Australia.

- Assess the short- and long-term environmental impacts of natural and artificial surfaces for recreation and sports activities; and
- Understand the impacts of natural and artificial turf on health and well-being of the residents in the context of carrying capacity and usability.

3. Methodology

The methodology for this report involved conducting desktop research. This process involved the identification, collection, review and summary of a wide variety of sources of literature including peer-reviewed (i.e. scientific journal articles, books) and grey literature (i.e. technical reports published by governmental agencies, academic institutions and industry publications). This information was critically selected and analysed to understand different aspects of natural grass and synthetic turf, as well as to compare the benefits and disadvantages between natural and synthetic turf systems. Although some cited reports came directly or indirectly from industries with a financial interest in promoting natural or artificial turf, data were cross-checked with other sources to ensure the validity of the conclusions as much as possible.

4. International and National Trends of sports and recreation surfaces

There is an ongoing debate about the provision of sports and recreation surfaces. Such debate has been triggered by the increasing popularity of synthetic surfaces over the natural grass surface. The synthetic surfaces gained popularity as an alternative to natural turf largely because it permits relatively higher usage and 'all-weather' durability. This means artificial turf offers the benefits of high-intensity use – often are used for 50 hours per week for team sports.

Synthetic turf was first used in Major League Baseball in the Houston Astrodome stadium in the USA in 1966. Since then, synthetic turf is increasingly used for different sports including hockey, soccer and tennis around the word. These sports are replacing natural grass grounds with synthetic surfaces for a variety of reasons. The following discussion briefly highlights the historical evolution and recent trends in surface provision in relation to different sports.

Hockey

Hockey was one of the early adapters of synthetic grass pitches. The synthetic grass pitch was introduced in hockey in the 1970s, because the synthetic turf pitches are flatter than natural grass surfaces. This resulted in the use of artificial turf for the international hockey tournament at the 1976 Olympic Games in Montreal. The introduction of artificial turf led hockey to become much faster and more exciting, and thereby a more popular sport. At present, synthetic turf pitches are used widely at many levels of hockey supported by the International Hockey Federation (FIH). Although Hockey is played on a variety of surfaces, the preferred surface is synthetic turf. There are three types of synthetic surfaces: sand-filled turf, water-based turf and hybrid turf. International hockey matches are usually played on a water-based pitch because it prevents the ball from bouncing up and hitting the players, resulting in much better quality and speed of play. At present, all FIH tournaments are hosted on water-based artificial surfaces. Yet, FIH has recently announced that they are going to allow international tournaments to be played on grass surfaces. In addition, FIH announced that the 2024 Paris Olympics will not be played on water-based pitches, in order to save water.

In Australia, hockey was the first sport to start using synthetic grass at the elite level. Considering a strong and accelerating demand, artificial turf has made rapid progress in Australian hockey. All international and Elite Premier League games in Australia are now played on water-based synthetic surfaces, while natural grass pitches are still used for a significant proportion of games at both junior and senior levels[4]. In recent years, there has been a move toward using hybrid synthetic turf at the regional and community level in Australia because hockey can be played wet or dry on the new generation of hybrid surfaces[4]. In addition to this, hybrid synthetic surfaces are being promoted as they can provide a multi-use facility. For instance, soccer can be played on the same surface.

[4] Western Australian Department of Sports and Recreation (2011) Natural grass vs synthetic turf study, Tredwell Management Services, SA.

Hockey is traditionally a winter sport. Yet, with the increase in the provision of synthetic turf pitches, hockey has become a year-round sport in Australia, particularly at club level[5]. Synthetic hockey pitches are more durable than natural turf pitches. While synthetic turf pitches can be programmed to be used intensively, the natural grass pitches cannot sustain such a high level of use.

Soccer

Synthetic grass was first used by American football and baseball stadiums in the 1970s. Given the all-weather capability, synthetic grass fields became increasingly common in the United States and Canada. However, due to concerns about the safety of players, many North American Football grounds had converted back to natural grass by the early 1990s[6]. Later, a significant advancement occurred in synthetic sports surface technology that reduced the previous concerns in relation to artificial turf. As such, the production companies began to make synthetic turf more and more similar to natural grass fields. This improvement induced the building of synthetic turf fields for international and national sport events including soccer.

Like American football, the experiment of playing soccer on synthetic turf was unsuccessful in the 1980s, but later, due to the advent of third-generation turf, soccer on synthetic turf had gained popularity. Consequently, Fédération Internationale de Football Association (FIFA) and Union for European Football Associations (UEFA) recognised the potential of playing football on the artificial turf fields. In 2001, both FIFA and UEFA developed a guideline to ensure a specific standard to build synthetic grass fields around the world. The first international game programmed on artificial turf was in 2003 at the FIFA U-17 World Championship. Following this successful experiment, FIFA decided to arrange artificial turf for the entire 2007 U-17 World Championship in Peru. At the senior level, 2015 the FIFA Women's World Cup was the first international tournament to be entirely played on artificial turf. Yet, artificial turf became a contentious issue in this tournament as many players raised concern over injury and different behaviour of balls. In order to avoid such concern,

[5]https://www.humanrights.gov.au/sites/default/files/content/racial_discrimination/whats_the_score/pdf/hockey.pdf

[6] Claudio, L. (2008) Synthetic turf: Health debate takes root, *Environmental Health Perspective*, 116(3).

all matches of this year's Women's World cup tournament in France are programmed to be played on artificial grass pitches, and FIFA decided to allow only natural grass fields for the 2023 Women's World Cup.

UEFA matches are played on either natural turf or synthetic turf with the exception of the final, which must be played on natural turf. For UEFA matches, artificial turf fields are prepared in accordance with FIFA Quality Programme standards and UEFA Stadium Infrastructure Regulations.

Soccer is the most popular club-based team sport in Australia with more than 1.1 million participants, as per the Australian Sports Commission Survey[7]. In order to meet the growing demand, the local football associations, clubs and local government associations are now under pressure to convert natural grass fields to synthetic ones so that they can train more players and hold more matches. Synthetic football fields have gained popularity across different states in Australia. In 2017, there were around 150 synthetic football fields in Australia, with many others under construction or in the planning stage[8]. The growth of synthetic football turf was triggered by increased playing capacity from 20-25 hours per week on natural grass to over 60 hours per week[8].

Tennis

Tennis is played globally on a variety of surfaces. There are three major types of surfaces used for elite-level tennis: natural grass, porous/clay and hard court. For instance, Wimbledon Championship tournaments are played on natural grass courts, while Australian Open tournaments are played on hard courts. The International Tennis Federation has recognised the use of synthetic grass surfaces in international elite level sport since the 1970s.

Tennis Australia recognises the use of all these types of surfaces; however, synthetic turf courts are not accredited surfaces by Tennis Australia, and therefore

[7] https://www.ffa.com.au/news/football-continues-dominate-australian-club-sport
[8] Northern NSW Football (2017) Synthetic fields: A guide to synthetic surfaces for football, New South Wales. Available at: https://footballfacilities.com.au/wp-content/uploads/sites/11/2018/10/SyntheticFields-v2-2017.pdf

Australian ranking points tournaments both at junior and senior level do not use synthetic turf. Nevertheless, synthetic turf surfaces are widely used and promoted for club and community level tennis across Australia. The primary benefit of installing artificial surfaces for clubs and community centers is that they can increase their memberships and generate more revenue. Despite an increasing trend in the use of artificial grass and clay court surfaces across Australia, natural grass courts have remained a prominent choice for regional and local tennis tournaments[9].

Given the fact that tennis requires a consistent, even turf coverage and density, local clubs prefer synthetic courts to lawn courts. The most common surface choices at the community club level are sand-filled artificial grass and synthetic clay. Synthetic turf courts provide more playability than lawn courts. Synthetic turf courts are often compatible with other sports (e.g. hockey), while natural grass and clay courts are normally not compatible with any other sport.

5. Life Cycle of Natural Grass and Synthetic Sports Surface

5.1 Natural Turf for sports

Natural grass surfaces are considered as appropriate surface provisions for many sports (e.g. soccer and golf) and other recreation activities. There are several positive aspects of choosing natural grass turf for sports and recreation activities. Studies suggest that well-maintained natural grass turf is proven to be environmentally-friendly, sustainable and carbon-friendly. Yet, natural turf poses some challenges. The following discussion highlights various aspects of the life cycle of natural grass surfaces.

5.1.1 Installation

Construction of natural grass turf depends on the level of sports. International and first-class sports venues are constructed by maintaining stringent standards, while local ground management authorities aim to install high-quality sports grounds to

[9] National Tennis Facility Planning and Development Guide. Available at: https://www.tennis.com.au/wp-content/uploads/2013/04/TA-National-Tennis-Facility-Planning-and-Development-Guide.pdf

accommodate an increasing number of players. Therefore, construction standards for elite and premier grounds are higher than those for local sports grounds. In order to construct a superior quality of sports surface, imported sand profile over the natural sub-based with sub-surface drainage is installed, which is used for international and national grade sports. Local sports grounds, on the other hand, are constructed using natural soils with the provision of surface drainage.

Natural grass turfs are usually prepared by laying sods, while seeding is an alternative option. Installing grass sods is considered a better choice because it provides diverse positive benefits. In recent years, grass breeders have developed new and innovative natural grass solutions for sports fields. As a result, turfgrass has now become more tolerant of environmental stresses (e.g. heat, excessive rainfall), diseases and pests. In addition, some varieties of grass are resistant to heavy wear, meaning that natural grass fields are capable of coping with heavy use.

5.1.2 Maintenance

Once installed, turfgrass establishes roots and develops a relationship with soil and its microorganism within a short period of time. It, therefore, self-replenishes and can be sustained for a longer period. However, maintaining playability on turfgrass involves a range of maintenance activities: irrigation, mowing, fertilisation, weeding, disinfestation, aeration, vertical cutting and sand dressing. All these activities involve a sustained effort throughout the year, which has an impact on the environment. The management of a natural grass turf field and its environmental consequences depends on diverse factors including the size of the surface, purpose and weather conditions.

Turfgrass management requires to maintain a certain level of soil nutrient and to protect grass from pests and diseases. The chemicals used for managing turfgrass are likely to harm the environment. For instance, runoff from the playing surfaces can pollute nearby lakes, streams and rivers. Besides, insecticides applied for the control of pests may also affect beneficial species. Therefore, there is a growing demand for reducing the use of fertilizer and pesticides. A responsible and judicious application

of pesticides, herbicides and fertilizer is necessary in order to reduce the harmful effects on the environment and public health.

5.1.3 End of Life Disposal

Natural grass turf is self-renewing and therefore does not produce any waste. In professional sport surfaces, surfaces are replaced every 10-20 years, but this waste is biodegradable. Therefore, natural grass surfaces have almost no end of life cost.

5.2 Synthetic turf for sports

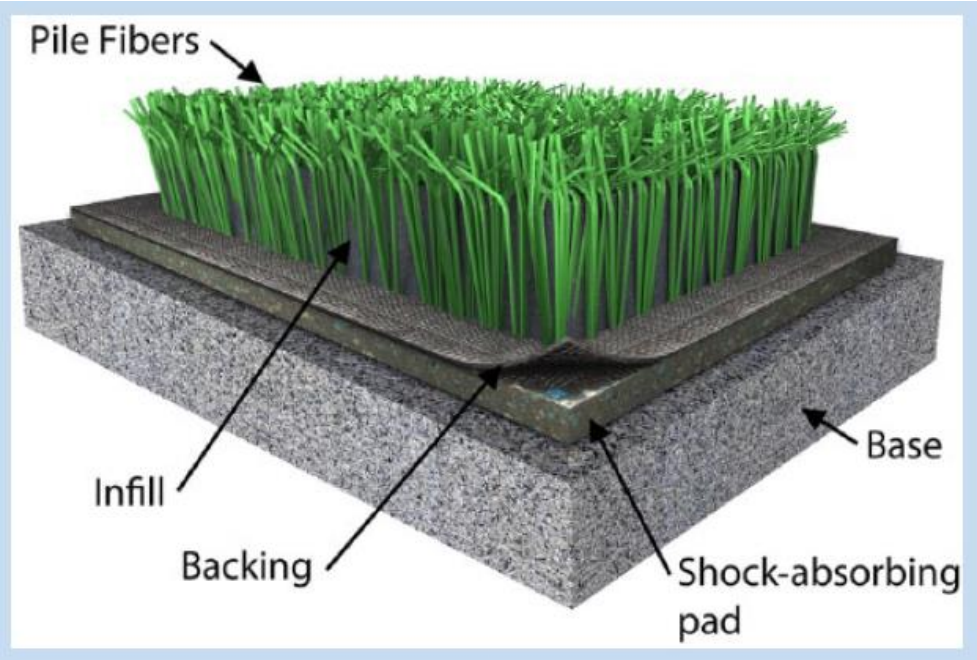
Synthetic surfaces are now used by many sports as an alternative to turfgrass. This popularity has increased primarily because it permits all-weather play and can withstand heavy use. The popularity continues to rise as synthetic turf has been refined from an abrasive surface to a surface that more closely resembles the features of natural grass turf[10].

Construction of synthetic turf fields for sports has evolved over the last 50 years due to the advancement of turf technology. The first-generation synthetic turf was introduced in the late 1960s, known as ChemGrass, which was soon referred to as AstroTurf[11]. This turf was a short-pile nylon carpet without infill, installed over a compacted soil base. Many stadiums installed AstroTurf around this period, but some reverted back to natural grass due to players' complaints about burns and other injuries. The second-generation turf carpet was composed of much longer fiber filled with silica sand to keep the fibers upright. A shock-absorbing pad beneath the carpet was a new feature in second-generation synthetic turf fields. This turf system was widely adopted within the United States during the late 1980s and 1990s. In the third-generation turf, a number of new features were added to second-generation turf. The third-generation system uses a granular material to fill the space between the carpet pile fibers (see Figure 5.1). Infill materials in third-generation systems

[10] Serensits, T., McNitt, A. & Sorochan, J. (2013) Synthetic turf, Madison: American Society for Agronomy.
[11] Jastifer, J. McNitt, A., Mack, C., Kent, R. and McCullough (2019) Synthetic turf: History, design, maintenance, and athlete safety, *Sports Health: A Multidisciplinary Approach*, 11(1).

consist of crumb rubber, or a combination of crumb rubber and silica sand, as opposed to the pure sand used in second-generation surfaces. Third generation surfaces are now commonly used around the world and in Australia.

Figure 1: Components of a third-generation synthetic playing surface



Source: Jastifer et al. (2019)

The third-generation synthetic turf has evolved substantially over the last two decades as manufacturers are continuously addressing the concerns related to environment, safety and health[12]. In addition, an increase in variations of synthetic turf systems has taken place due to meeting the sports-specific requirements. It is therefore difficult to identify a standard for third-generation synthetic turf system.

5.2.1 Installation

Synthetic turf fields are essentially comprised of two main parts: base design and surface system design. The surface system design is dependent on the requirements of specific sports, while the base design is almost universal. A gravel base is typically installed beneath the carpet and shock-absorbing pad, which contains a drainage system. The base is typically installed at a depth of 15cm to

[12] Toronto Public Health (2015) Health impact assessment of the use of artificial turf in Toronto, City of Toronto.

30cm[13]. Shock-absorbing pads are often installed between the base and the carpet depending on the thickness of the carpet. They are generally installed at a thickness between 25 mm and 35 mm. Pads were used to increase shock absorption. The carpets are made of nylon, polyethylene or polypropylene. The backing and blades of the carpet are primarily manufactured with recycled plastics and rubbers. Synthetic turf fields are infilled with crumb rubber, which is often made from recycled tyres, or a mix of sand and crumb rubber to keep the plastic fibers upright and provide shock absorption, resembling that of natural grass turf. One estimation suggests that a large synthetic soccer pitch uses approximately 27,000 tyers[14].

The installation of synthetic turf is a complex and integrated process. Therefore, the construction of synthetic turf requires a budget that is significantly higher than that of natural turfgrass. The following table summarises the cost comparison between natural and synthetic turf installation in different sports at the community level, based on a study commissioned by the Department of Sports and Recreation in Western Australia.

Table 1: Cost comparison between Natural grass and synthetic Turf sports surfaces for selected sports

Sport	Construction Cost	
	Natural Grass	Synthetic Turf
Hockey	$186,750	$550,000
Soccer	$212,000	$705,000
Tennis	$27,500	$69,000

Source: DoSR, Western Australia, 2011

5.2.2 Maintenance

A common misconception of synthetic turf sports fields is that they are maintenance-free, but this is far from reality[15]. Regular maintenance is required to maintain

[13] Serensits, T., McNitt, A. and Sorochan, J. (2013) Synthetic turf, Madison: American Society for Agronomy.
[14] Huber, C. (2006). A new turf war - Synthetic turf in New York City Parks. New York, USA: Research Department at New Yorkers for Parks.
[15] Jastifer, J. McNitt, A., Mack, C., Kent, R. and McCullough (2019) Synthetic turf: History, design, maintenance, and athlete safety, *Sports Health*, 11(1).

playability and safety, and prolong the life span of turf. Standard maintenance practices include brooming, topdressing, removing surface debris and controlling weeds, moss and algae. Performing these activities depends on the intensity of use of a field. In addition to that, deep cleaning is required to remove inorganic (e.g. chewing gum, tobacco, oil) and organic (e.g. vomit, saliva and animal droppings) contaminants.

The maintenance activities are performed using equipment and cleaning products. The operational costs to maintain synthetic turf sports fields are higher than that of natural grass at a community level. Table 2 provides a comparison of annual operating costs between natural grass and synthetic turf for selected sports fields.

Table 2: Comparison of annual operating costs to maintain natural grass versus synthetic turf

Sport	Operating Cost (Annual)	
	Natural Grass (Community level)	Synthetic Turf
Hockey	$22,350	$10,000 (Sand filled)
Soccer	$27,250	$25,000
Tennis	$9,500	$4,000

Source: DoSR, Western Australia, 2011

In addition to that, there are replacement costs for replacing synthetic turf at the end of its life. Unlike natural grass surfaces, synthetic turf has a definite lifespan. The lifespan of a synthetic surface is dependent on the level of usage, maintenance and expected performance from the surface. The life of synthetic turf also varies from sport to sport. For instance, the surface used for club-based hockey could last 8-10 years[16].

[16] Western Australian Department of Sports and Recreation (2011) Natural grass vs synthetic turf study, Tredwell Management Services, SA.

5.2.3 End of Life Disposal

As noted above, synthetic sports surfaces have a specific lifespan. End of life disposal of synthetic turf involves considerable cost and environmental consequences. Disposal costs are associated with removal, transportation and landfill. According to the Synthetic Turf Council, a typical sport field is about 80,000 square feet, which comprises of 400,000 pounds of infill and 40,000 pounds of turf[17]. The infill within the pile of the carpet becomes waste as it becomes contaminated over time. At present, turf ends up in landfill, but different initiatives have recently been taken to recycle synthetic turf. Recycling synthetic turf is challenging as it contains a variety of polymers, which need specialised technologies. Therefore, very limited recycling facilities are available, resulting in high transportation costs.

6. Environmental Considerations

Making a decision on preferred sport surfaces needs to consider several environmental factors. These environmental considerations need to be evaluated with due care in order to make environmentally sustainable choices. This section highlights some major environmental aspects in relation to natural grass turf surfaces.

6.1 Greenhouse Gas Emissions

The turfgrass industry produces greenhouse gasses (GHG). Emissions of GHG occur through the production of carbon dioxide in fuel combustion, and the volatilization of nitrous oxide from fertilizers. Growing, installation and management of turfgrass emit GHG. More specifically, the activities involved in the management of natural grass turf produce GHG throughout the year. The following table breaks down the activities that consume energy and cause GHG emissions.

[17] Synthtic Turf Council (2015) Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components, Atlanta, GA.

Table 3: Energy use and GHG emissions in the production and maintenance of natural grass sports surfaces

Direct GHG producers	Indirect GHG producers
Irrigation	Manufacture of Machinery
Mowing	Manufacture of fertiliser/insecticide
Fertilisation/Pest and disease control	Transport of Sand
Topdressing	Production and distribution of fuel and electricity
Verticutting	-
Aeration	-

Although the maintenance of natural grass turf emits GHG, it can offset emissions by sequestering carbon dioxide. This means natural turf produces oxygen and reduces GHG by sinking carbon dioxide carbon in the soil through the process of photosynthesis. One estimation suggests that turfgrass can sink four times the amount of carbon produced by maintaining it[18]. The rate of carbon sequestration is expected to be higher as turf equipment industries are developing products with greater fuel-use efficiency and lower emissions.

The carbon footprint of synthetic turf is much higher compared to natural grass turf when the whole life cycle is considered[19]. Yet, research is scant about the total emission of GHG during the life cycle of a synthetic turf system as opposed to a natural grass surface. One study has estimated that CO^2 emissions from manufacturing, transporting, installing, maintaining and disposing of a 9000 m^2 synthetic turf field in Toronto over a 10-year period is 55.6 tons, while emission from construction and maintenance of a natural grass field of the same size is 16.9 tons[20]. The carbon footprint of synthetic turf tends to come primarily from production, transportation and disposal. The production of artificial turf requires a substantial amount of fossil fuels as it is a petroleum-based product. Like natural grass,

[18] Sahu, R. 2008. Technical Assessment of the Carbon Sequestration Potential of Managed Turfgrass in the United States, Alexandria, VA, USA. Available at: http://multivu.prnewswire.com/broadcast/33322/33322cr.pdf

[19] Simon, R. (2010) Review of the Impacts of Crumb Rubber in Artificial Turf Applications, University of California, Berkeley, USA.

[20] Meil, J. and Bushi, L. (2007) Estimating the Required Global Warming Offsets to Achieve a Carbon Neutral Synthetic Field Turf System Installation, Athena Institute, Ontario, Canada.

synthetic turf requires regular maintenance that uses fuel-powered machinery. In addition, unlike natural turf, synthetic turf does not absorb carbon dioxides. As the installation of synthetic turf requires the removal of a significant amount of soil that reduces its porosity, it reduces the soil's capacity to sink carbon. The disposal of synthetic turf also leaves a significant carbon footprint. Table 4 presents the activities related to energy use and GHG emission for construction, maintenance and disposal of synthetic turf.

Table 4: Energy use and greenhouse gas emissions in a life cycle of synthetic turf

Direct GHG producers	**Indirect GHG producers**
Brushing	Manufacture of Machinery
Harrowing	Transportation of Materials
Grooming	Manufacture of cleaning chemicals
Watering	Production and distribution of fuel and electricity
Disposal	-

6.2 Water Use

Maintenance of turfgrasses requires a substantial amount of water for irrigation. The water requirements of natural grass depend on the species of grass being grown, the function of the grass, and the climate in which it is grown. Among these factors, environmental conditions have larger effects on the amount of water usage. In dry climates, for instance, heavy irrigation is needed in maintaining the quality of natural grass as rainfall cannot meet the water demand of plants (see Table 5). Studies suggest that water use is significantly higher than that needed to maintain synthetic grass turfs[21].

[21] Cheng, H., Hu, Y. and Reinhard, M. (2014) Environmental and Health Impacts of Artificial turf: A review, *Environmental Science and Technology*, 48.

Table 5: Typical water use per year in maintaining natural grass

Sport	Area (ha)	Water Use (ML/yr)
Hockey	0.70	4.2
Soccer	0.80	4.8
Tennis	0.06	0.4

Source: GoWA

Given the fact that water resources are under pressure due to population growth and change of climate patterns across different states in Australia, the heavy irrigation needed for maintaining natural grass turf sports grounds has been questioned. In particular, an increased drought condition and water shortages over the past decade added pressure to use water in a sustainable manner[22]. Accordingly, the City of Adelaide adopted a plan to reduce the usage of mains water and to increase the use of recycled water and stormwater[23]. Given this context, water needs to be used efficiently by selecting the right grass species that suits South Australian climate conditions. Turfgrasses are classified into two groups based on their climatic adaptation: cool-season and warm-season. Cool-season grasses need a higher amount of water than that of warm-season grasses. Besides, drought-tolerance of warm-season turfgrasses (e.g. Kikuyu or Couch) is significantly higher than cool-season grasses[24]. Therefore, there is a tendency to use warm-season turfgrass species across different states in Australia, including South Australia.

One positive aspect of natural grass turf is that it absorbs stormwater. Therefore, there is no need to irrigate throughout the year. Besides, recycled water can be used for irrigating turfgrass. Another positive aspect of choosing natural grass turf is that it contributes to increasing the water quality by filtering runoff. Such a process also reduces erosion of soil quality.

Water requirements in a synthetic sports surface are considerably low compared to a natural grass field. However, synthetic turf fields require a substantial amount of water primarily to reduce the surface temperature during sunny summer days.

[22] CSIRO and BoM (2014) State of the climate 2014, CSIRO and Bureau of Meteorology, Melbourne
[23] See City of Adelaide 2016-2020 Strategic Plan
[24] Western Australian Department of Sports and Recreation (2011) Natural grass vs synthetic turf study, Tredwell Management Services, SA.

Irrigation is the most common method used to reduce the temperature of turf, but that cooling effect is short-lived. A substantial amount of water is also needed to clean and improve field sanitation. As synthetic turf does not absorb stormwater, it drains after a heavy rain without the filtration that natural grass usually provides. The run-off tends to contain a wide range of harmful materials that can contaminate watersheds. One study found that 25 different chemical species and 4 metals (e.g. lead, zinc, cadmium) are likely to release into the water from rubber infill of synthetic turf[25]. Thus, synthetic turf could contribute to water pollution.

6.3 Heat Risks

The effects of various field surfaces on human thermal stress have received attention due to changes in climate. A study conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) notes that the surface temperature is going to increase 3.8°C in Australia by 2090[26]. Such large-scale warming will enhance heat risks, especially for urban people because of shortages of vegetation cover and increases of hard surfaces that lead to artificial temperature rise, commonly known as urban heat island effects. Choosing a surface provision for sports, therefore, needs to consider changes in climate, particularly the potential heat risks.

The provision of natural grass fields is advocated because turfgrass is cooler than synthetic turf. As a living organism, natural grass absorbs water through roots and transpires water to keep surfaces cooler. The surface temperature of natural grass turf is usually close to the air temperature because of evaporative cooling. Besides, turfgrass fields can serve as a source of cooling for the surrounding air, and thereby reduce the likelihood of heat stress in nearby residents.

The surface temperatures of synthetic turf playing surfaces, on the other hand, are significantly higher than those of natural grass turf when exposed to sunlight[27].

[25] Claudio, L. (2008) Synthetic turf: Health debate takes root, *Focus*, 116(3).
[26] CSIRO (2009) Climate Change in Australia: Technical report, Aspendale VIC: CSIRO and Australian Bureau of Meteorology.
[27] Thoms, A., Brosman, J., Zidek, J. and Sorochan, J. (2014) Models for predicting surface temperatures on synthetic turf playing surfaces, *Procedia Engineering*, 72.

Synthetic turf absorbs, retains and emanates heat when exposed to sunlight. Although the performance and safety of players has been improved due to continuous improvement of the properties and characteristics of natural turf, these developments are still to prevent the turf from reaching a higher temperature than natural grass[28]. For instance, studies on first-generation synthetic turf at Pennsylvania State University found that synthetic surface temperatures were 25°C–30°C higher than natural grass[29]. Studies that compared the third generation synthetic turf and natural grass also recorded a significant difference in surface temperatures. Petrass et al. (2015) found that the surface temperature of the synthetic turf was more than 20°C warmer than the adjacent natural grass in Victoria, Australia[30]. Another study by Brigham Young University researcher in the United States, which compared the air temperature of natural turf and synthetic grass at the surface of a football field, found that the surface temperature of synthetic turf was approximately 30°C hotter than natural grass turf[31]. A recent study conducted in one eastern suburb of Adelaide found that the artificial turf field was approximately 20°C warmer than a nearby irrigated turf field[32]. This study also noted that air temperatures over artificial turf were higher than those of bitumen. These elevated temperatures heat up surrounding plants, buildings and communities, often killing the plants. In other words, through absorbing and radiating heat from the sun, synthetic turf contributes to the urban 'heat island' effect.

Another important issue with synthetic turf in relation to heat is that the natural cooling process is slower than that of natural grass. Therefore, irrigation is the main method of cooling the synthetic sports surfaces. One study has documented that surface temperature of turf rebound 20 minutes after irrigation stops is only slightly

28 Villacanas, V., Sanchez-Sanchez, J., Garcıa-Unanue, J., Lopez, J and Gallardo, L. (2016) The influence of various types of artificial turfs on football fields and their effects on the thermal profile of surfaces, *Journal of Sports Engineering and Technology*, 23(1).
29 Buskirk E.R., McLaughlin E.R., and Loomis J.L. (1971) Microclimate over artificial turf. *Journal of Health Physical Education Recreation*, 42.
30 Petrass, L., Twomey, D., Harvey, J., Otago, L. and LeRossigno, P. (2015) Comparison of surface temperatures of different synthetic turf systems and natural grass: Have advances in synthetic turf technology made a difference, *Journal of Sports Engineering and Technology*. 229(1).
31 Williams, C,F., and Pulley, G.E. (2002) Synthetic surface heat studies. Available at: https://aces.nmsu.edu/programs/turf/documents/brigham-young-study.pdf
32 Seed Consulting Services, EnDev Geographic and Monash University (2018). Collaborative Heat Mapping for Eastern and Northern Adelaide Report. Prepared for the City of Unley on behalf of the Eastern Region Alliance of Councils and the City of Salisbury.

cooler (less than 10 degree) than a non-irrigated surface three hours after watering[33]. Another study found that irrigation of the synthetic turf had reduced the surface temperature from 79ºC to 29ºC, but the temperature rebounded to 73ºC after 20 minutes[34]. Therefore, weather conditions are required to be considered duly before choosing a surface option for outdoor sports.

6.4 Public Health and Safety

Sports surface options have numerous impacts on human health. Environmental and social determinants of health such as air quality, water quality, physical activity, social inclusion and disability are often considered as crucial indicators for assessing health impacts. In line with this framework, this section reviews how different surface options impact on human health and wellbeing.

Given the numerous health benefits, grass surfaces are considered as a benchmark standard for safety. As noted earlier, manufacturers are continuously developing the quality of synthetic turf to reduce the negative impacts on health and environment. However, some concerns have remained unaddressed. One major health-related concern is that synthetic turf contains several contaminants and, therefore, the users are likely to be exposed to toxicological risks. The major concerns stem from the infill material that is typically derived from recycled crumb rubber that contains a range of organic contaminants and heavy metals that are suspected to pose a risk to human health. Available evidence, however, does not support such a claim. For instance, a Dutch study found that no elevated health risks from playing sports on synthetic turf pitches with recycled rubber granulate[35]. Likewise, Cheng et al. (2014) report that the users of synthetic turf fields are not exposed to elevated health risks[36]. Another study also reports that health risks caused by chemicals released from synthetic turf are

33 Serensits, T. (2011) Is there any way to cool synthetic Turf?, Sports Turf. Available at: http://sturf.lib.msu.edu/article/2011jun20.pdf
34 Williams, C,F., and Pulley, G.E. (2002) Synthetic surface heat studies. Available at: https://aces.nmsu.edu/programs/turf/documents/brigham-young-study.pdf
35 Pronk, M.E., Woutersen, M. and Herremans, J. (2018) Synthetic turf pitches with rubber granulate infill: are there health risks for people playing sports on such pitches?, *Journal of Exposure Science & Environmental Epidemiology*.
36 Cheng, H., Hu, Y. and Reinhard, M. (2014) Environmental and Health impacts of artificial turf: A review*, Environmental Science and Technology*, 48(4).

minimal for users, including vulnerable populations such as children[37]. Yet, information is limited to reach any certain conclusion about the potential health risks associated with synthetic turf. In particular, research is lacking on long-term health effects on users of synthetic turf surfaces.

Synthetic turf fields can also increase the risk of health-related illnesses among users in summer as they are made of heat-retaining materials. This is particularly relevant to the case of South Australian, where summer is dry and hot (28.3°C average). The users of synthetic turf fields are, therefore, susceptible to heat-related illnesses such as dehydration, heat exhaustion and heatstroke while playing in hot conditions.

Another debated health issue associated with health is injuries. It is often claimed that the incidence of injuries on synthetic turf is higher than on natural grass turf. The current evidence, however, is inconclusive to support such a claim. Research is scant on sports other than soccer and football, making it difficult to compare sport-specific injury incidences. In soccer-related studies, findings are inconsistent. A study compared the risk of acute injuries between third-generation synthetic turf and natural grass in male professional soccer players and found no significant differences in injury rate and pattern between turf types[38]. Another study found that the incidence of injury using a third generation synthetic turf and natural grass was the same among a group of young female soccer players[39]. By contrast, Steffen et al. (2007) reported that injury incidence, particularly ankle sprain, among young female soccer players was higher during matches played on synthetic turf than natural grass[40].

When compared with natural grass, synthetic turf serves different health and wellbeing benefits. Sports and recreational spaces are needed to ensure

[37] Norwegian Institute of Public Health (2006) Artificial turf pitches – an assessment of the health risks for football players. Available at: https://www.isss-sportsurfacescience.org/downloads/documents/74wa3x7e22_fhiengelsk.pdf
[38] Bjørneboe, J., Bahr, R. and Andersen, T.E. (2010) Risk of injury on third-generation artificial turf in Norwegian professional football, *British Journal of Sports Medicine*, 44(11).
[39] Ekstrand, J., Timpka, T. and Hagglund, M. (2006) Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study, *British Journal of Sports Medicine*, 4o.
[40] Steffen, K. Andersen, T.E. and Bahr, R. (2007) Risk of injury on artificial turf and natural grass in young female football players. *British Journal of Sports Medicine*, 41.

opportunities for all members of a community, particularly for people with disabilities. Inclusive playgrounds provide social benefits for people with and without disabilities. One advantage of synthetic turf systems is that they are more accessible compared to natural grass turf, meaning that synthetic turf surfaces tend to provide more opportunities for diverse community members such as the elderly, people with disabilities and people with injuries. Given that synthetic playing surfaces are more uniform compared with natural grass, it becomes easier to access for people using mobility aids. Another advantage is that synthetic turf has a significantly higher capacity to endure use than natural grass. A high-quality natural grass surface can be used for up to 20 hours per week, while synthetic surfaces can sustain approximately 60 hours per week[41]. As such, synthetic turf provision is likely to increase the participation of people in sports, and thereby enhance the physical, mental and social wellbeing of the participants[42]. A body of literature confirms that sports participation has positive effects upon the physical, psychological and social wellbeing of individuals[43]. In this sense, synthetic turf may contribute to improving community health and wellbeing by engaging more people in sports.

6.5 Ecosystem services and biodiversity

Natural turf is a living organism, and while installed, it develops a relationship with microorganisms as the roots establish themselves. Turfgrass serves as a habitat for insects, animals and other organisms. Other benefits to the ecosystem provided by natural grass surfaces include rainwater entrapment, climate regulation, absorbing pollutants from air and oxygen generation.[44] As such, natural grass not only provides ecosystem services but also conserves biodiversity. Synthetic turf, on the other hand, does not have such ecological benefits and cannot uphold organic biodiversity. As the base of synthetic turf systems is compacted, the living organisms die, and so are unable to provide services to clean and absorb water or carbon. Replacement of

[41] Sheppard, M. (2019) The smart guide to synthetic sports surfaces; Volume 1: Surfaces and standards, Smart Connection Consultancy, Melbourne, Australia.
[42] Downward, P. and Rasciute, S. (2011) Does sport make you happy? An analysis of the well-being derived from sports participation, *International Review of Applied Economics*, 25(3).
[43] Eime, R.M., Young, J.A., Harvey, J. Charity, M.J. and Payne, W.R. (2013) A systematic review of the psychological and social benefits of participation in sport for adults: informing development of a conceptual model of health through sport, *International Journal of Behavioural Nutrition and Physical Activity*, 10(135).
[44] Thompson, G.L. and Kao-Kniffin, J. (2017) Applying biodiversity and ecosystem function theory to turfgrass management, *Crop Science*, 57.

natural grass with synthetic turf may also inhibit the growth of trees and other vegetation. Planting trees is discouraged around artificial turf as they may harm the turf system by penetrating their roots. As the climate is warming, this compounds the issues of health effects of hot fields due to reduced ability to shade them. Thus, the synthetic turf may negatively affect the health of the ecosystem.

7. Summary of Findings

This review aimed to understand environmental, health and welfare impacts of natural grass compared to synthetic turf in the context of sports fields. The assessment was conducted to expand our understanding of the existing debates in relation to grass and synthetic turf, which may help the city planners, local councils and ground managers to make an informed decision regarding sports surface options. This review, however, does not provide a complete summary of the current literature, rather it critically examines selected resources to provide insights into the key environmental and health concerns related to natural and synthetic turf. It is important to note that given the large variation in design of installations and the characteristics of natural fields and of artificial turf systems, it is difficult to accurately compare the environmental and health impacts between natural and artificial systems. Information is also limited to draw any specific comparison.

Synthetic turf surfaces have become popular in major outdoor sports at the elite, regional and local levels around the world. Such a trend at elite level sports, however, has shifted towards natural turf options in recent years in response to safety and other health-related concerns. This shift is likely to influence the sports ground authorities' decisions regarding choosing sports surface options. In Australia, natural grass fields are increasingly replaced by the synthetic turf, particularly at the regional and community level. The City of Adelaide is no exception. In this context, the selection of appropriate turf option for outdoor sports is needed to consider the following factors:

- Carbon footprint of natural turf is much lower than synthetic turf. Natural grass fields are important carbon sequesterers – removing carbon from the atmosphere, while synthetic turf fields release carbon into the atmosphere

during different stages such as manufacturing, transportation, installation, maintenance and end-of-life disposal.

- Natural grass fields need more water compared to synthetic turf fields for their maintenance. The requirement of water depends on local climatic conditions.
- Hazardous substances from synthetic turf system are likely to contaminate surface and groundwater, while fertilisers and pesticides used for maintaining natural grass turf are likely to contaminate water.
- Synthetic turf retains heat that contributes to increasing the field surface temperature and air temperature near fields. It thus may contribute to urban heat island effect in nearby neighbourhoods. Natural grass turf, by contrast, reduces urban heat island effects.
- Synthetic surfaces release different hazardous substances which may impact the health of the users. The available evidence, however, shows no elevated health risks from exposure to synthetic turf. More research is needed to explore the potential long-term impacts of synthetic turf on human health.
- Natural grass fields provide diverse ecological benefits such as upholding biodiversity and clean air and water, while synthetic turf has negative impacts on the health of the ecosystem.

The following table presents the key benefits and disadvantages of playing on natural grass and artificial turf:

Table 6: Comparative features of natural grass and synthetic turf

Natural Turf	**Synthetic Turf**
Stays cooler on hot days	Can heat up to over 3 times the local air temperature
Needs more water	Needs less water
Produce oxygen & reduce pollution	Does not produce oxygen & usually ends up as landfill
Self-replenishing	Eventually requires replacement
Cheaper to install/ high maintenance cost	Expensive to install/ low maintenance cost

Self-sanitising	Require sanitising
Safer sporting surface	Increased risk of sporting injury
Needs to give rest	Endures extensive use

In conclusion, based on the information and analysis of this study, it can be said that choosing an option for playing surfaces needs to consider environmental, health and social factors that this study illustrated. In addition, local environmental contexts and location of the sports surfaces must be considered duly in order to select the best surface option for sports. More specifically, the selection of a surface option in Adelaide Parklands for engaging more people in outdoor sports needs to consider the long-term vision for parkland management and sustainability.
