Horticulture Australia

Economic, Social, Health and Environmental Benefits of Turf

TU17003

Final Report

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Executive Summary

Balmoral Group is pleased to present the Final Report into the Economic, Social, and Environmental Benefits of the Turfgrass and Lawncare Industries. In brief the report delivers:

- A statistical model estimating the extent of turfgrass in suburbs within Australian capital cities, broken down into home lawns, park turf, sports field turf, median strip / easement, and roadside.
- An Input-Output Analysis of the turfgrass growing, delivery, installation and maintenance sectors demonstrating the economic impact of the industry on the economy.
- The quantification of the economic, social, environmental and health impacts of turfgrass – following on and expanding on the Literature Review conducted in Milestone 1.
- An exploratory analysis of the relationship between estimated total turfgrass cover and the severity of urban heat island effects within Australian capital cities

The report comprehensively demonstrates that turfgrass provides a range of benefits to people living in Sydney and Melbourne totalling $6.02 and $5.32 billion dollars annually respectively. These benefits are generated from a number of different uses of turf in the urban environment including home lawns, and turf used in parks, sports fields, roadsides, and median strips/easements (see Figure I.)

Figure I: Total annual benefit ($) of turf to Greater Sydney and Melbourne by turf use and function.

Additionally, the total economic impact of the turfgrass and lawncare growing, delivery, installation and maintenance industries in the NSW/ACT and Vic./Tas. Growing regions was $5.098 billion in 2016/17.

In order to develop these estimates, values for a range of benefits for turfgrass were computed for each Greater Capital City area (described in Table I. with $/m^2/year values summarised in Table II.). The benefit values were chosen from the economic and environmental literature to overlap as little as possible in order to limit the possibility of double counting.

Table I: Summary description of the benefits that are measured in the report.

Benefit Stream	Description
Avoided Costs of Home Cooling	Irrigated turf in the local environment lowers temperatures, allowing people to spend less on cooling and therefore avoid the negative health and social effects Urban Heat Island.
Greenhouse Gas (GHG) Sequestration	Turf sequesters carbon dioxide, a greenhouse gas that contributes to climate change. Carbon dioxide removed from the atmosphere has a value, equal to approximately $3/Ha of turf annually.
Avoided Cost of Alternative Land Covers	Turf is a low-cost alternative to other land cover materials. The avoided costs of maintaining pavements and synthetic turf surfaces are a benefit to society.
Increase in House Rent Value	Homes with turfed lawns attract a market premium. The annual value of this premium is the extra rent a property does, or would, earn as a result of having turfed lawn. The extra amount that people are willing to pay to live in a house with turfed lawn account for the value of the private benefits it generates, including the benefits of exercise, space for children and pets, neighbourhood pride, and others.
Willingness to Pay (WTP) Value for Turfed Park and Sports Field Areas	Public turfed greenspaces serve as community focal points and improve physical and mental health for neighbourhood residents. These benefits are many and varied, but the Willingness to Pay (WTP) per household per year for turfed parks and sports fields encompasses the social environmental, and health benefits they provide to the local community.

Table II: Average benefit values in $ per m² per year of turfgrass for different uses of turf uses within capital city suburbs in Australia.

		Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	ACT.
ALL TURF	Avoided Costs of Cooling	0.033	0.017	0.027	0.018	0.017	0.003	0.029	0.009
	GHG Sequestration	0.0003							
	Avoided Cost of Alt. Land Covers	6.77							
Home Lawn	Increase House Rent Value	4.45	3.33	2.54	2.91	3.13	1.55	2.59	3.25
Park Turf	Willingness to Pay Value	31.47	25.79	18.73	22.77	18.20	13.60	15.36	17.93
Sports Field Turf	Willingness to Pay Value	31.51	26.10	18.84	22.90	18.31	13.68	15.45	18.04
	Avoided Cost of Synthetic Turf	6.80							

While the total value of market and non-market impacts per suburb have not been extended to the other Capital cities due to the absence of more detailed and representative data on the exact amount of turfgrass coverage across Australia, this report lays the groundwork to comprehensively analyse the total benefits across all suburbs in Australia outside Sydney and Melbourne.

Together these results suggest that the amount spent on turfgrass in the urban fabric is an investment well made. We also find that the relationship between turfgrass cover and UHI effects are mixed and may require a greater depth of study in order to discover the role turf cover has to play in reducing Urban Heat Island (UHI) effects.

Additional to what is presented and summarised in this report, an online database created in Power BI was developed in order to facilitate ease of access and applicability of the final product for Horticulture Innovation Australia and its members. This dashboard can be accessed through a secure portal, or by scanning the QR Code to the right:

https://www.balmoralgroup.us/turfau2019

The login details to access the dashboard can be obtained by contacting HIA.

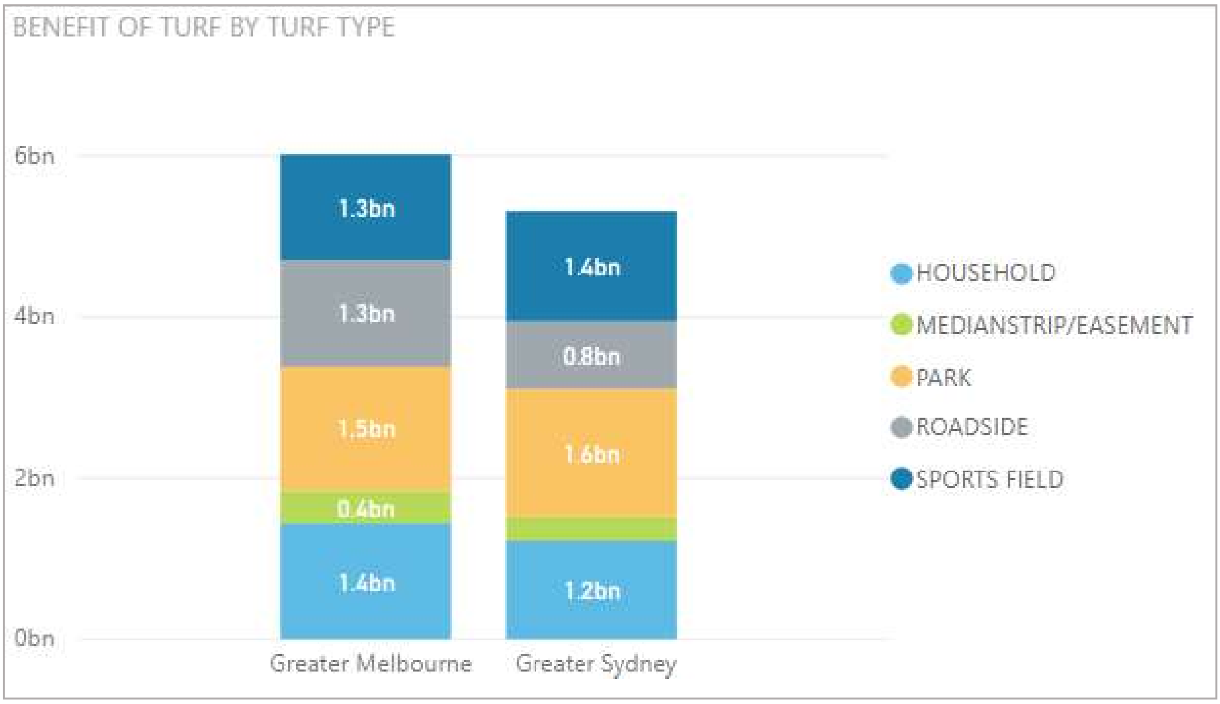
Table of Contents

1 Summary of Results

1.1 Total Economic, Environmental, Health, and Social Benefits of Turfgrass

The total non-market benefits of turfgrass in Sydney and Melbourne suburbs are approximately $6.02 and $5.32 billion dollars respectively, as illustrated in Figure 1 below.

Figure 1: Total annual benefit ($) of turf to Greater Sydney and Melbourne by turf use and function.



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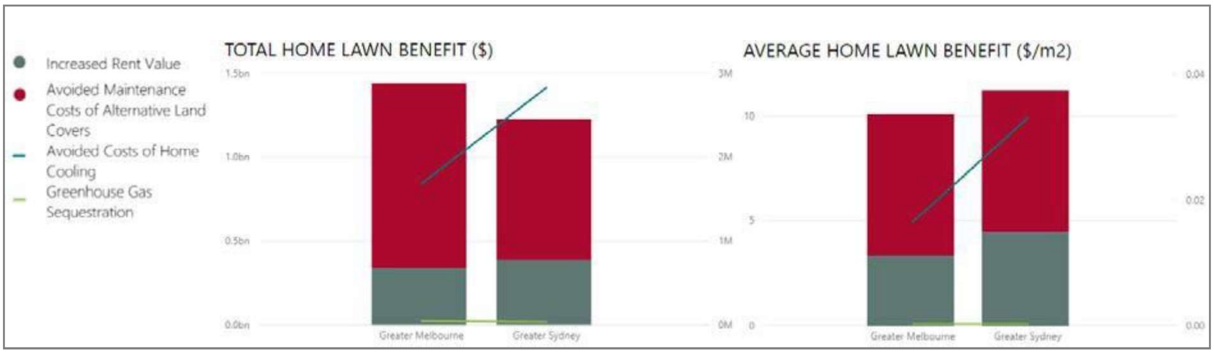
Different uses of turf provide benefits from different pathways. Figures 2-4 break down the total benefits generated in Sydney and Melbourne, as well as the average benefit generated within individual suburbs for home lawn, park, and sports field turf.

Figure 2: The total benefits of home lawn in Sydney and Melbourne, as well as the average benefits derived per m² of turf in individual suburbs. Increased rent value and Avoided Maintenance costs are scaled on the left axis, Avoided Costs of Home Cooling and Greenhouse Gas Sequestration are scaled on the right axis.



Home lawns generate approximately $1.4B and $1.2B worth of benefits in Melbourne and Sydney respectively. These benefits are primarily driven by the avoided costs of maintaining more expensive types of land covers such as synthetic turf or pavements, however the increased rental yield generated by properties that have home lawns is also a significant contributor to the total benefits. Sydney experiences a greater benefit from the cooling benefits of turf compared to Melbourne, due to the warmer climate.

Figure 3: The total benefits of home lawn in Sydney and Melbourne, as well as the average benefits derived per m² of turf in individual suburbs. Willingness to Pay value and Avoided Maintenance costs are scaled on the left axis, Avoided Costs of Home Cooling and Greenhouse Gas Sequestration are scaled on the right axis.

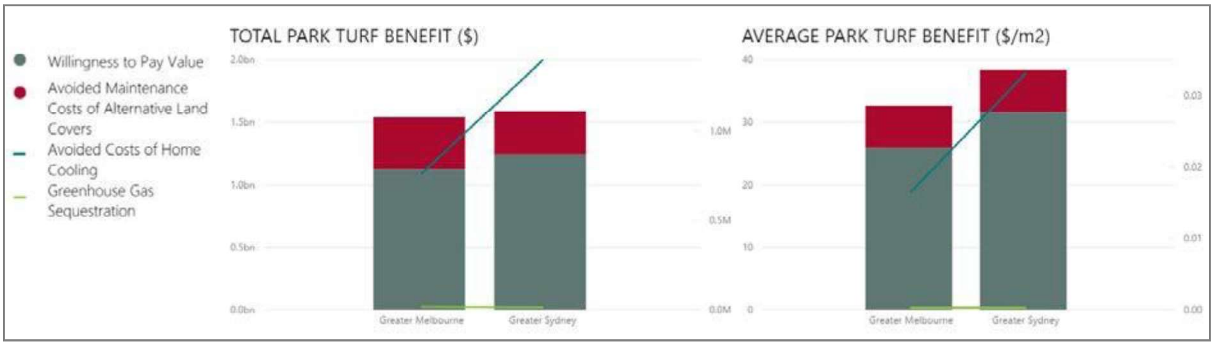
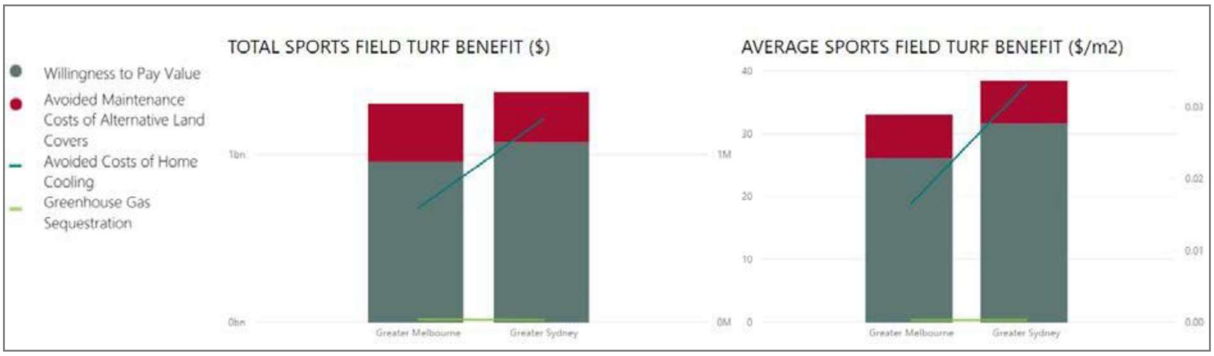


Figure 4: The total benefits of home lawn in Sydney and Melbourne, as well as the average benefits derived per m² of turf in individual suburbs. Willingness to Pay value and Avoided Maintenance costs are scaled on the left axis, Avoided Costs of Home Cooling and Greenhouse Gas Sequestration are scaled on the right axis.

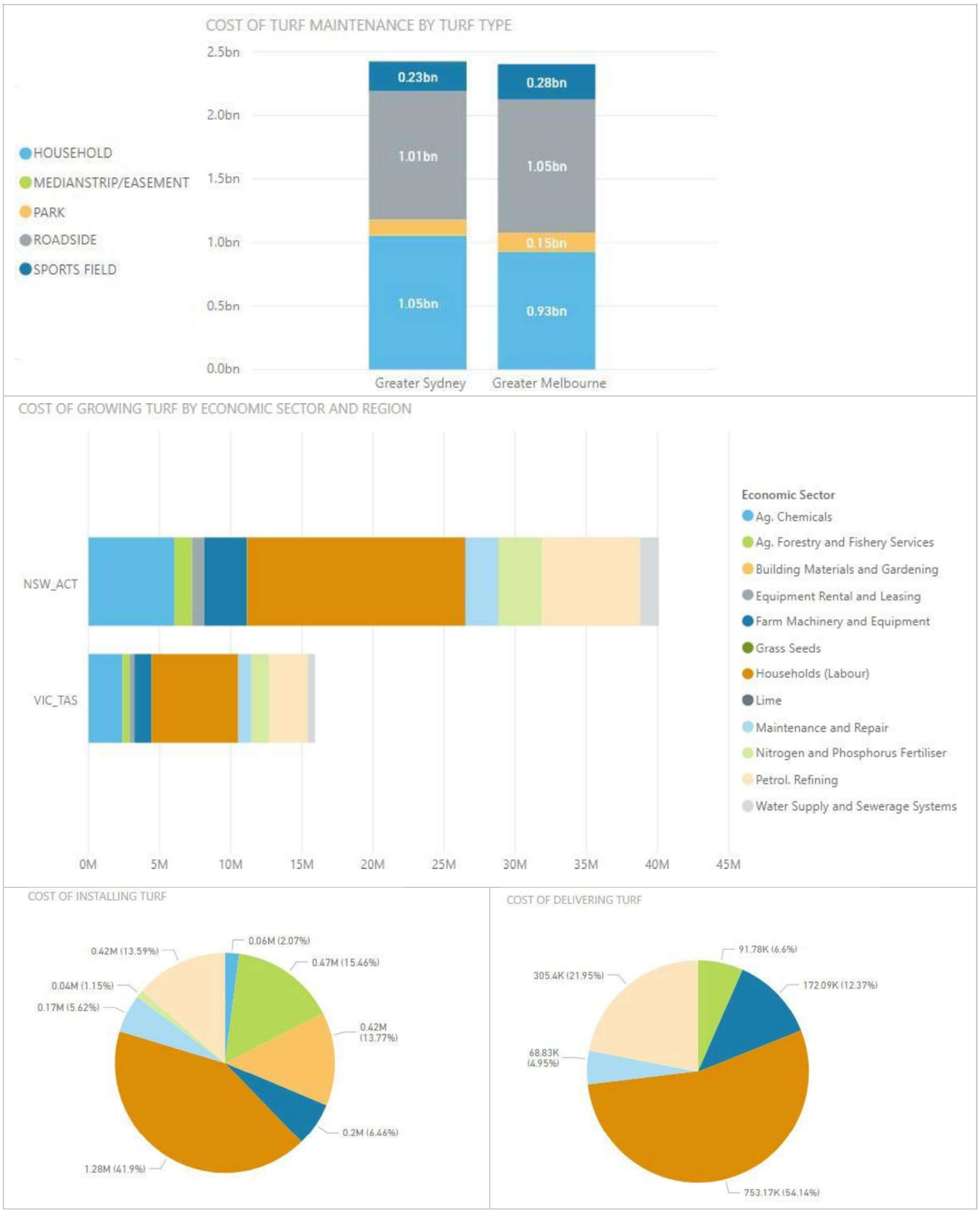


The Willingness to Pay (WTP) value for turfed public parks and sports fields is the main contributor to the benefits of turf in parks and sports fields. Suburbs with less greenspace, and a greater density of dwellings, experience the greatest WTP benefit per m² of turfed parks and sports fields due to the scarcity and number of people who benefit from those spaces.

1.2 Total Economic Impact of the Turfgrass and Lawncare Growing, Delivery, Installation and Maintenance Industry

The total economic impact of the turfgrass industry, taking into account production in 2016/17 in the NSW/ACT and Vic./Tas. Growing regions, and the lawncare and maintenance activity in Sydney and Melbourne is approximately $5.098 Billion dollars. The Figure 5 below illustrate how these costs are divided between turf uses and economic activities.

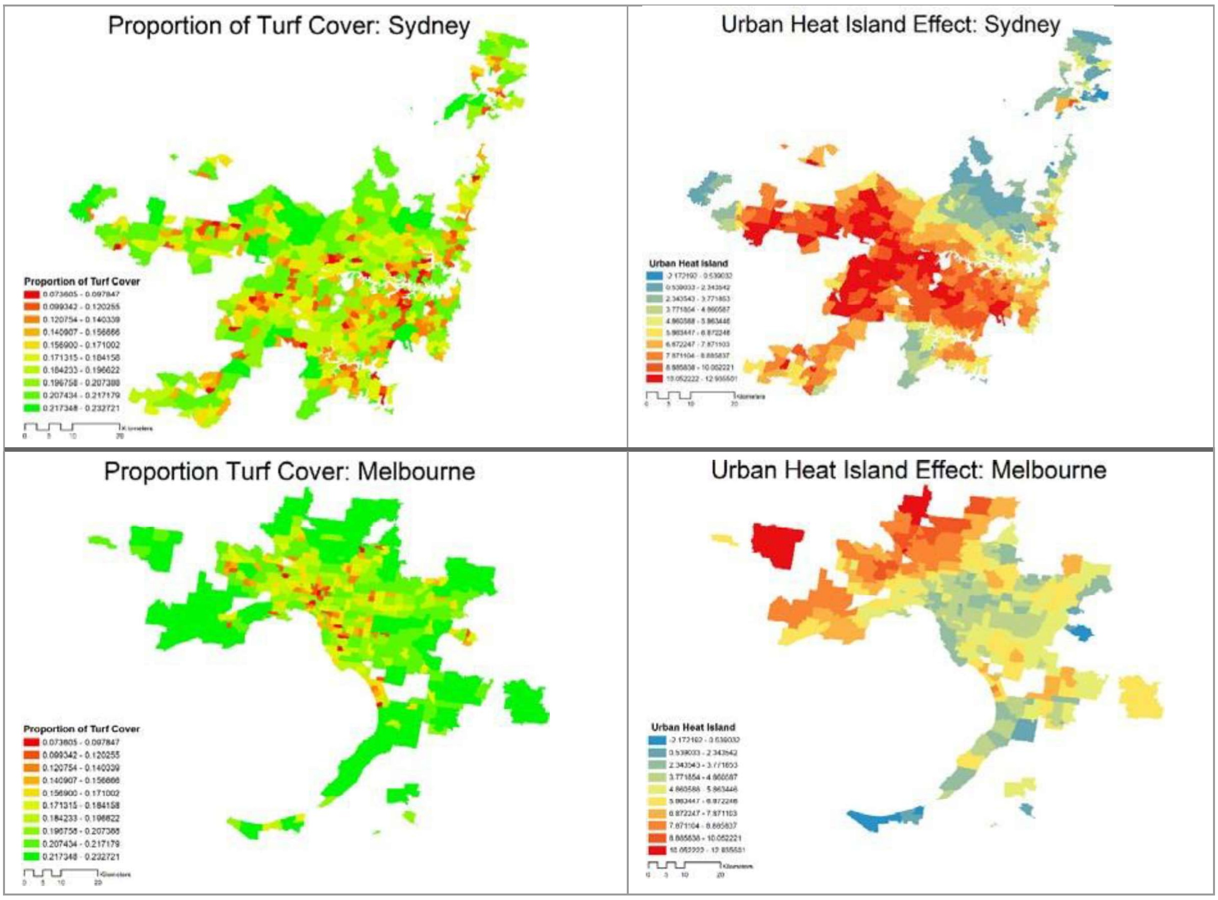
Figure 5: Breakdown of the maintenance costs of turf in Sydney and Melbourne (Top) as well as the costs of growing, installing, and delivering turf in the NSW/ACT and Vic./Tas. Regions (Middle and Bottom).



1.3 Relationship between Turfgrass and Urban Heat Island Effects

Estimates of total turf cover were compared with measurements of Urban Heat Island effects in order to determine if turf land uses had a measurable impact on urban temperatures. The results show that results are generally mixed, and that a more detailed and representative analysis of turfgrass coverage across a range of Australian cities would contribute to a better understanding of how it relates to cooling effects, especially during the hot summer months.

Figure 6: Maps of the estimated proportion turf cover in each suburb (Left), compared to the Urban Heat Island effect (Right) in Sydney and Melbourne.



2 Quantifying the Economic, Social, Health and Environmental Benefits of Turf

2.1 Literature of Turf Benefit Values

The benefits of turf grass are wide-ranging, touching on many aspects of people's lives. One approach could be to construct an exhaustive list of every possible impact that grass has on the economy and people's experiences. However, an economic analysis of total benefits should ensure that the measured benefit categories do not overlap in order to avoid double counting. Therefore, we have identified a number of key benefit streams that capture the value of turf grass to society. These are:

- Cost savings from reduced cooling needs
- Increased residential rents
- Avoided alternative social infrastructure costs
- Value of carbon sequestered
- Willingness to pay for turfed public spaces

We provide a literature review that both identifies the key benefit streams relevant for the study and provides a breadth of supporting academic rigour. This approach ensures that our assumptions and calculations are sound in nature and can be communicated effectively. The following sections summarise the key benefits that detailed in the full academic literature review, in Appendix 3.

2.1.1 Economic Benefits

Economic benefits are those that, broadly speaking, generate measurable monetary value for people even if they do not directly purchase or pay for them on the market.

2.1.1.1 Cost savings from the reduction in cooling needs

Turf, through the process of evapotranspiration, reduces the average temperature of the surrounding neighbourhood, reducing the need for people to resort to air conditioning.

We adopt a formula used by Pomerantz (2017) to calculate the avoided cost of energy usage for Australians as a result of a change in temperatures, assuming that energy demand increases 0.678KWh

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surface coverage, and CD20C is the number of cooling days in a year (the number of days in the year

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According to economic theory, people will only pay up to the point where their marginal costs equal their marginal benefits. Therefore, we can say that the increase in demand for air conditioning is a reasonable estimate of how much people are willing to pay to avoid at least a portion the negative impacts of the Urban Heat Island Effects.

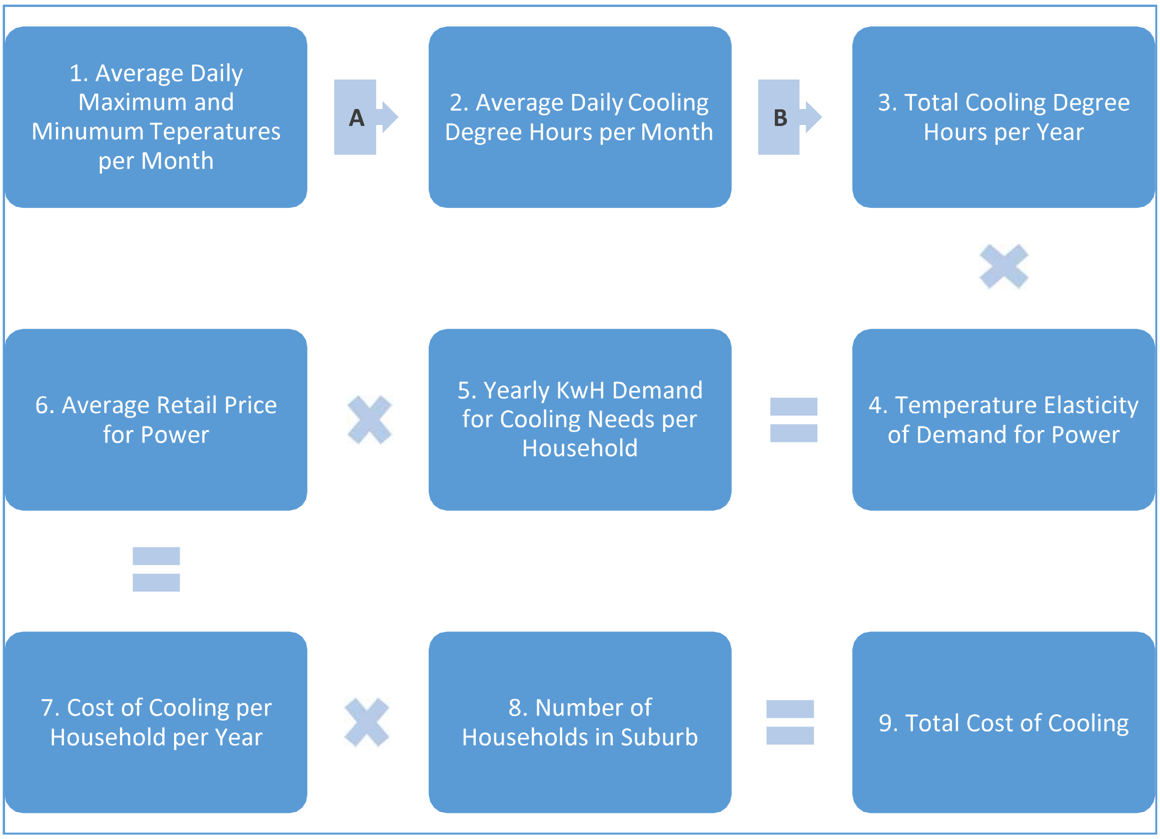
Cost savings from the reduction in cooling needs per m^2 of turf

Broadbent et al (2017) investigated the effect of land use on microclimates in Adelaide and found that v P] v •] v]] P temperature in a neighbourhood. We also take their measured estimate of 6.3% of total turf as]] P U • o o •night-timev respe]ctivvely for a • percentage increase in built-up area.

We therefore calculate the reduction in cooling needs provided by turf to households by estimating their demand for power in each month using monthly temperature averages, compared to what temperatures would be were all turfed areas replaced by built-up areas.

Figure 1 outlines the steps taken to calculate the value of the demand for power in each suburb and month. The value of turf is the difference in the total cost of cooling (Box 9) when the average daily maximum and minimum temperatures (Box 1) increase as a result of replacing irrigated turf area with impervious land such a pavement and synthetic turf, as described by Broadbent et al.

Figure 7: Calculation of the Total Cost of Cooling per year in each suburb



A	Average Daily Cooling Hours per Month were calculated by constructing daily temperature curves fitted to the daily average maximum and minimum temperatures in each month and summing the number of degree hours over 20. To calculate the impact of removing turf and replacing it with built-up surfaces. The average daily maximum and minimum temperatures were modified by proportion outlined by Broadbent et al.
B	The Total Cooling Degree Hours per year were calculated by multiplying the Average Daily Cooling Degree Hours per Month by the number of days in each month and summing them over the year.

The difference in the total cost of cooling in the current scenario, versus the scenario where turfed area is replaced by built-up areas, divided by the metres squared of turf gives the value per m^2 of turf for reduced cooling needs in each suburb.

2.1.1.2 Increased residential rents

The presence of outdoor vegetation has been shown to have a positive impact on properties in a number of contexts. People value turf in their back gardens for a number of reasons, such as the ability to raise children (and pets) with an outdoor environment, the local cooling effect, or just the colour green.

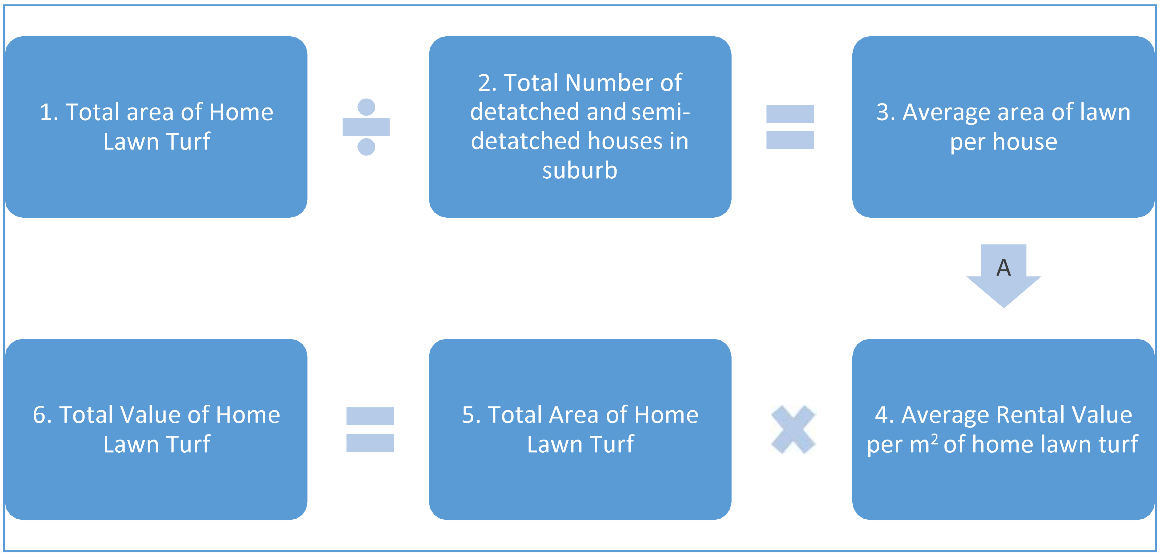
Macdonald et al (2010) investigate the ratio of lawn and garden (L&G) to total property area for a number of homes in Adelaide and find that for the median house price and L&G:area ratio, the value of outdoor L&G accounted for 3% of the property value. We abstract this result to the annual rent value of a home, relying on the linkage between house price and rents, the rental yield, approximately 4.2% over the medium-term (Fox and Tulip, RBA, 2014).

Value of increased housing rents per m^2 of turf

The precise proportion of the lawn and garden which is lawn, and furthermore the extent to which this 3% can be divided up between different types of vegetation is unknown. However, evidence from Strigall and Elam (2009) suggest that it is not the composition of vegetation that is significant in determining property prices, but the area of property. That is, the area of a property covered in trees, bushes or other garden vegetation does not have a significantly different value to turfed lawn. Therefore, we assume that 50% of the value attributed to lawn and garden in terms of rental values can be attributed specifically to lawn.

Figure 2 outlines the steps taken to calculate the total value to housing values – and therefore rents, due to the presence of turfed lawn.

Figure 8: Calculation of the Increased Residential Rents per year in each suburb



A	The average rental value per m^2 of turf is given by the median house rent divided by the average area of lawn per house. The median rent per house is sourced from the ABS 2016 Census.

2.1.1.3 Avoided urban infrastructure requirements for alternative surfaces

It is best practice to compare gross benefits to those of the alternative, creating a comparison of the relative trade-offs. We consider that, in most cases, the most immediate alternative land cover type are a mix of impervious surfaces such as pavements, concrete, or synthetic turf. For example, parks may be converted partially or wholly into paved boulevards or plazas, sports fields may choose to utilise synthetic turf over natural turf, or widening roads may infringe on roadside vegetation.

The avoided costs associated with using these surfaces are in most cases already incorporated into the design of the benefits described in the sections above. For example, the added heating effect attributable to turf relative to impervious surfaces are described in 2.1.1.1, and the relative costs to stormwater infrastructure are described in 2.1.1.3. However, the maintenance costs of these surfaces have so far been excluded, which are avoided as a result of choosing to use natural turf instead.

Value of alternative land cover maintenance per m^2 of turf

Without knowing the precise make-up of the alternative impervious surfaces, we assume that 50% of the alternatives would transition to paved or concreted surfaces, and 50% would transition to synthetic turf surfaces in a 'next best' land use scenario. The exception to this is for sports field turf, which we assume would be wholly replaced by synthetic turf in the alternative land use case. The annual maintenance costs for these surfaces are standard values, and are described in Table 1 using information sourced from Sport and Recreation Victoria (2010)^, and Veerman et al (2016)*.

Table 3: Maintenance costs of alternative land use materials, avoided due to the use of natural turf.

Surface Area	Maintenance cost per m^2 per year	Average cost per m^2 per year
*Sidewalk/Pavement**	$6.73	$6.77
*Synthetic Turf^*	$6.80	

2.1.2 Environmental Benefits

Environmental benefits capture the values that a healthy environment provides through ecosystem services. These benefits include improved air and water quality, and better habitats for other animals. Humans place value on these ecosystem services, both for the benefits they provide directly to humans, but because people generally value the concept of a healthy ecosystem in its own right.

2.1.2.1 Value of carbon sequestered

Carbon dioxide emissions are a global issue, affecting almost every facet of the natural and human environment. Estrada, Botzen and Richard (2017) estimated the effect of climate change on the GDP of cities throughout the world under different warming scenarios and find that the median city would suffer a reduction in GDP between 1.2% and 3.9%, excluding urban heat island effects, by 2100.

Qian and Follett (2012) examine the ability of turf grass to sequester carbon dioxide in urban ecosystems, and find that during the first 25-30 years, turf can be expected to sequester 0.34-1.4 Mg/ha/yr.

In the absence of a market for carbon dioxide emissions, we adopt Garnaut's (2011) value of $30/tonne, as the amount that would have to be assigned in order to meet Australia's commitments. However, we note that the actual price of carbon is likely to have increased since then due to more ambitious targets and the signing of the Paris Agreement.

Value of carbon dioxide sequestered per m^2 of turf

We adopt a mid-point of 0.87 Mg/ha/yr of carbon dioxide sequestered by turf per year from Qian and Follett's range as an appropriate estimate.

2.1.3 Social and Health Benefits

The range of social and health benefits that turf brings to people include the provision and use of community spaces that allow people to socialise outdoors, engage in physical activity, garner mental health benefits, as well as the abated negative health impacts of the Urban Heat Island.

These benefits tend to cross-over and interact in a way that makes separating out their individual components impossible. For example, the interaction between physical and mental health are well known, and people may play group sports activities as much for the opportunity to socialise as to reduce their chances of a heart attack later in life.

For the purposes of calculating the overall social and health benefits, we use the Willingness to Pay (WTP) value of turfed public greenspaces. Willingness to Pay values encompasses a wide range of aggregate benefits, including some that may never have been studied. However, without context, WTP value is not easily understood, and so we provide a description of how the WTP value of turf is described in the literature, as well as some examples of the social, and physical and mental benefits that constitute some of the reasons why people value turfed public greenspaces, that therefore are willing to pay for their maintenance.

2.1.3.1 Willingness to Pay for Turfed Public Spaces

Ambrey and Flemming (2014) conducted a study investigating the link between public greenspace (which includes parks, community gardens, cemeteries, sports fields, national parks, and wilderness) and life satisfaction in urban Australia, and found that the implicit WTP per household per year for a 1% increase in public greenspace (143m^2 on average) in the local area was 2012AUD$1,172.

We apply Ambrey and Flemming's WTP value to find the marginal value for 1m2 of any greenspace in a suburb and use that value to calculate the total value of turfed greenspace in that suburb.

However, the principal issue with taking the Ambrey and Flemming's values is that they relate to all kinds of greenspace, not just turf areas. Dwyer et al (1989) found that there were differences between the values that people placed on public parks depending on the types of vegetation available. Table 2 illustrates these differences between a heavily wooded park, a predominantly turfed park, and an athletics field. The results suggest that without the amenity provided by trees, parks and sports fields would have a value approximately 93% and 62% of what we would consider to be the 'typical' park, and furthermore the component of that value which relates to well-maintained turf (aside from other amenities such as playground equipment, cycleways, and picnic facilities) is 6.2% and 9.3% respectively.

Therefore, we adjust Ambrey and Flemming's values accordingly to reflect only the proportion of the WTP for parks and sports fields that are driven by the presence of turf.

Table 4: Results from Dwyer et al (1989) illustrating the proportional differences in willingness-to-pay values for different types of parks for their amenity benefits.

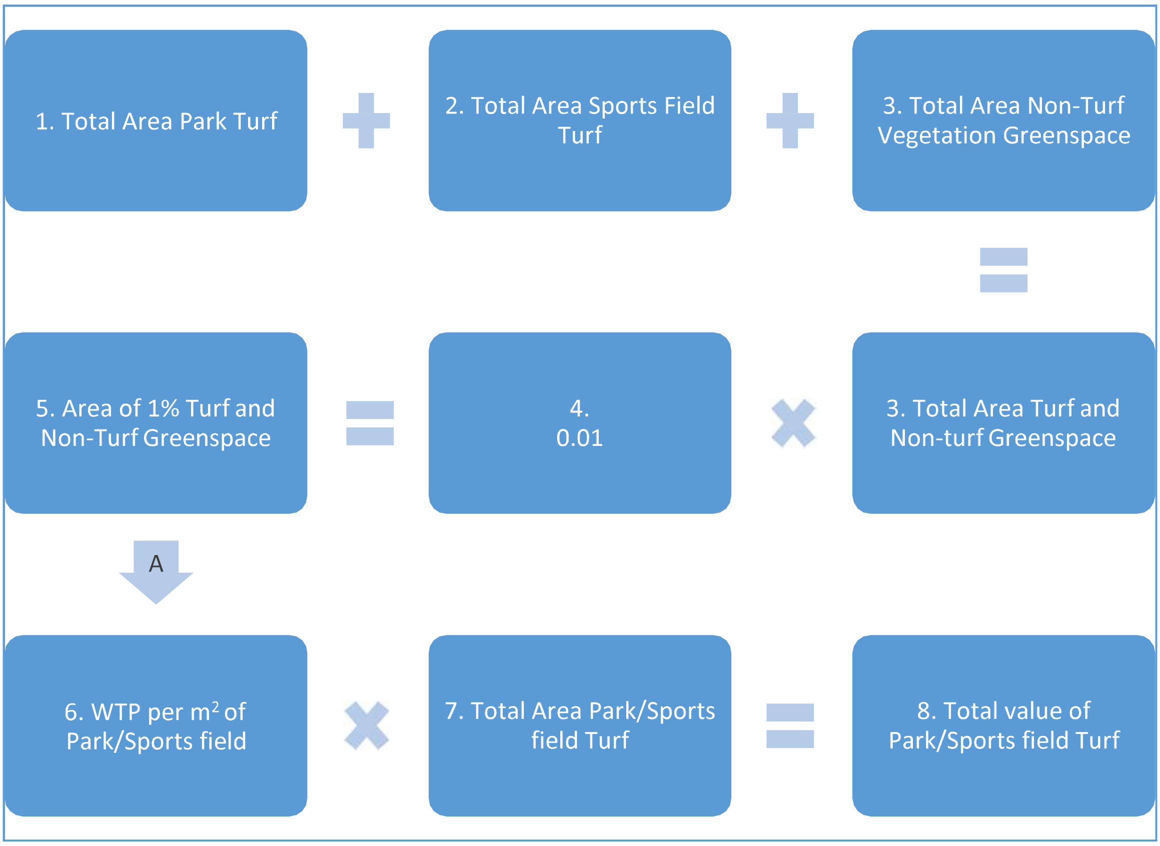
Park Type	*Description*	*Willingness to Pay*	*Proportional Value Compared to the Typical Park*
Typical Park	*Mowed grass with some scattered trees, some dense wood. Contains a picnic area and facilities as well as children's play equipment and biking trails.*	*$14.14*	*100%*
Predominantly Turf Park	*Mowed grass with very few trees anywhere. Contains a picnic area and facilities as well as children's play equipment and biking trails.*	*$13.15*	*93.0%*
Predominantly Turf Sports Field	*Mowed grass with very few trees anywhere. Contains athletics fields.*	*$8.73*	*61.7%*

Value of the Willingness to Pay for Turfed Public Greenspaces per m^2

The area of turf equivalent to 1% of total greenspace (both turfed and other vegetated spaces) in a suburb, and therefore the Willingness to Pay per household for that space varies greatly. For example, in densely populated suburbs where greenspace is scarce the WTP for a single m^2 of turf can be expected to be much higher than a suburb where there are already large urban parks, sports fields, or forests or a lower population. For the purposes of this study, non-turf vegetation greenspace includes public spaces such as parks and nature reserves covered by trees, bushes and grasses.

Figure 3 outlines the steps taken to calculate the area of 1% of turfed and non-turf greenspace, and therefore the marginal WTP value per m^2 of park or sports field turf.

Figure 9: Calculation of the Willingness to Pay for turfed public spaces per year in each suburb



A	The WTP per m^2 of Park or Sports field turf is the WTP for 1% of the turfed component of park or sports field as described by Ambrey and Flemming and Dwyer et al, divided by the area that describes 1% of all turfed and non-turf greenspace in the suburb.

2.1.3.1.1 The creation of community spaces

Frances et al (1998) conducted a study of inner-city neighbourhood common spaces and found that greenness in and around apartments was correlated with assessments residents made of their neighbourhood's social ties. Sugiyama et al (2008) found a statistically significant association between local social interaction (the number of days engaged in social interaction) and neighbourhood greenness. Sugiyama et al also extrapolated relationships between neighbourhood greenness, social interaction, physical activity, and mental health, finding all of them to be highly interdependent, confirming that urban green space, including turfed areas, is a nexus for multiple public goods.

2.1.3.1.2 Physical activity, mental health and well-being

By providing places to take part in physical exercise and recreation, turfed green spaces in the urban areas encourage people to lead healthier lives. This has a benefit not only for those people, but for society as a whole, as illness has a social as well as a private cost.

Mekala et al (2015) in their study of business cases for public investments in urban green infrastructure draw upon a number of non-market benefits for greenspaces and suggest that the average cost of physical inactivity in Australia is approximately 2015AUD$757 per physically inactive person[1] per year.

[1] Defined in the Social Health Atlas of Australia 2011

Coombes et al (2010) investigate the relationship between physical activity and accessibility of greenspace. Using their results, we can infer that the difference in likelihoods of people meeting the physical activity guidelines in the 1st quartile (people close to greenspace) and those in the 4th quartile (people far away from greenspace) was approximately 5%.

Combining Mekala et al and Coombe's et al's research, we can infer that if the number of people who are physically inactive throughout Australia increased by 5% in the absence of all turfed public areas, from 66% to 71%, the associated social costs would amount to 2015AUD$944,704,168 per year – almost one billion dollars.

The link between greenspace and better mental health outcomes is generally viewed as being positive by researchers. Lee et al (2017) estimated that the annual cost of mental illness in Australia was $12,800,000,000 each year, including depression, anxiety, and substance use. Nutsford, Pearson and Kingham (2013) investigate the association between access to urban green space in New Zealand (parks and sports fields, not natural areas or private land), and find that every 1% increase in the proportion of green space within 3km was associated with a 4% lower anxiety/mood disorder treatment.

However, while it may be possible to attempt to value each 1% proportion of urban land occupied by turfed greenspace in relation to a reduction in metal health disorder treatments, of approximately 4% of $1.535B ($61.4 million dollars a year), the change in the number of people seeking treatment does not necessarily lead to a proportional change in the costs of treating mental health disorders as a whole *per se*.

2.1.3.1.3 Health impacts due to reduced Urban Heat Island effects

The urban heat island (UHI) effect describes the elevated temperatures that occur around heavily urbanised areas due to their capacity to absorb heat and reduced capacity to release it. Urban green space is recognised as a way to reduce UHI effects through the provision of shade, and ability to lose heat through transpiration. The consequences for elevated temperatures can be dire, Nicholls et al (2008) examined the effects of elevated temperatures in Melbourne and found that when the mean daily temperature exceed Z • Z o (c U Z over is between 15- A9 Z] P Z Z v • o U v Z mortality for that same cohort is between 19-21% greater.

Estrada, Botzen and Richard (2017) take into account the effect of climate change on the GDP of cities throughout the world under different climate change scenarios[2], taking into account the UHI effect. Table 3 summarises the reduction in GDP for the median city in 2050 and 2100 under two different climate change scenarios, illustrating that UHI effects may double the GDP costs of climate change under different scenarios.

[2] Representative Concentration Pathways (RPCs) are a range of future scenarios for CO_2 concentration in the atmosphere. RCP4.5 describes a scenario where emissions peak around 2040, limiting the amount of energy absorbed by the Earth to 4.5W/m^2 by 2100. RCP8.5 describes a future with little emissions reduction with no foreseeable reduction in energy absorbed by the Earth.

Table 5: Results from Estrada, Botzen and Richard (2017) summarising the effects on city GDP due to climate change when the UHI effect is and is not taken into consideration.

		Climate Change Scenarios			
		RCP4.5		RCP8.5	
		No UHI Effect	UHI Effect Included	No UHI Effect	UHI Effect Included
Reduction in GDP of the median city in Year:	2050	0.7%	1.4%	0.9%	1.7%
	2100	1.2%	2.3%	3.9%	5.6%

The productivity costs of climate change for Australian cities are likely to reach billions of dollars by 2050, up to 50% of which will be attributable to the UHI effect, if we apply Estrada's assessment. Turf has a significant and highly valuable role to play in mitigating these costs, as demonstrated in Section 2.1.1.1.

2.2 Assigning Benefits to Turf Cover Uses

The benefits of turf described in section 2.1 must be allocated to the various uses of turf cover, based on who uses and benefits from them. Where some benefits such as the cost savings from reduced cooling needs may overlap with other benefit streams, we exclude them from our general results, but provide the calculations in an Appendix 1 for completeness sake. Table 4 summarises the approach taken, justified in the following sub-sections.

Table 6: Table summarising the measured benefits that accrue to the different uses of turf relevant for the study of non-market benefits. G indicates values that are used in the analysis□,□ 6□ □L□□G□L□F□D□W□H□V□ □□D□O□□H□ principal analysis to avoid double counting benefits, but are included in a sensitivity analysis to provide an indication of 'upper bound' values.

	Home Lawn	Park	Sports Field	Roadside	Median Strip / Easement
Cost saving from reduced cooling needs	A	A	A		
Increased rental value					
Avoided Alternative Land Use Costs					
Carbon sequestration					
WTP Value					

2.2.1 Benefits flowing from total turf

Reduced urban run-off and carbon sequestration benefits apply to turf generally and require no further disaggregation for different uses. This is because the use of the turf does not affect the ability for the turf to carry out these functions.

2.2.2 Benefits flowing from home lawns

Home lawns provide their owners with a number of benefits, including a space for physical recreation for humans and even pets, cooler local climate, and generally as a source of neighbourhood pride.

The principal benefit that accrues to home owners from the presence of a home lawn is captured in the value of the property that they are willing to pay to possess it. Despite the fact that different people may value home lawns for a variety of different reasons, on the whole, the average aggregates of these benefits will be captured in the increased value of property.

Since the benefits of home lawn are captured in the property value, we do not additionally account for the cost savings from reduced cooling needs, despite the fact that an irrigated lawn may provide cooling benefits for the property it belongs as well as the broader neighbourhood. The positive suburb-wide cooling benefits of irrigated home lawns will therefore be excluded from the principal analysis, it will be included in a sensitivity analysis to provide an 'upper bound' estimate of the total benefits of home lawns.

2.2.3 Benefits flowing from parks and sports field turf

Parks and sports fields provide a number of benefits to society as places of recreation, socialisation, and are at least partially valued simply for their existence. Additional benefits may also be received from people watching events at the facility or from people who value the opportunity to give others the benefit of the park, such as the relationship of sports fans or parents and children. Regardless of the particular uses of a park or sports field, the benefits that these facilities bring are, on average, captured in their Willingness to Pay value.

WTP value benefits may also to some degree reflect the benefits that people receive by having reduced cooling needs as a result of urban heat island abatement in their neighbourhood. Therefore, as with the home lawn benefits, we do not count the reduction in cooling needs as well as the WTP benefits in order to avoid double counting. These benefits are included in a sensitivity analysis in order to highlight the specific benefits of having cool oases in urban areas.

2.2.4 Benefits flowing from roadside, median strip and easement turf

Roadside, median strip and easement turf generally do not have use values to the extent that parks and sports fields do, and so we do not count WTP benefits towards the contribution they make to society. However, it must be recognised that the visual amenity of roadside and median strip turf does exist, which will not be reflected in this analysis.

The principal benefits that roadside, median strips and easements generate apply to their ability to provide local cooling and reduced runoff into urban stormwater systems.

2.3 The benefits relative to the costs

While we have extensively covered the overall gross benefits of turf in Australia, an understanding of net benefits (which will provide us with an understanding of the true benefits of turf) requires an understanding of the costs.

Broadly speaking, the costs to society of any activity are captured in three main categories:

- Direct costs – the amount spent on inputs, machinery, labour and equipment.
- Opportunity costs – the 'next best' use of the land
- Negative externalities – the disamenity, poor environmental outcomes, or social costs.

2.3.2 Direct Costs: cost of production, delivery, installation, and maintenance

The direct costs to society of the production, delivery and installation, and maintenance of turf are covered in Section 0, which will be used to inform the analysis. Although it is undoubtedly a 'good' thing that people are employed producing a product that provides numerous private and public benefits, they do not do so for free, nor is the equipment, water, and fertiliser required for them to do so available in unlimited quantities. Therefore, while we might interpret the total market impact of turf production as a benefit to society, in the context of examining the total economic benefits, they are costs we pay to enjoy them.

2.3.3 Negative externalities: the costs of increased nutrient flows in runoff

Runoff from urban areas creates a number of poor environmental outcomes including sedimentation and elevated levels of nitrogen in riverine and marine ecosystems. In order to reduce the amount of harmful stormwater runoff that enters the environment, local and metropolitan authorities are obliged to construct adequate storm water management assets. It is the cost of building and maintaining these additional assets due to the runoff from turfed areas that we value in order to deliver a full picture of the costs and benefits of turf to society. We assume that the negative effects of nutrient pollution, sedimentation and flooding are captured in the costs society pays for these stormwater assets.

Foraste et al (2011) define the total costs of runoff in terms of dollars per mg of Total Nitrogen (TN) per year, taking into account life cycle and asset replacement costs, best management practice, operations and maintenance, as well as the avoided costs of alternative strategies, equivalent to 2018AUD$0.034/mg/year.

While the scope of the project directly goes to the *benefits* of turf, we have decided to retain the costs of urban stormwater infrastructure as a result of runoff from turf for two reasons:

1. Any discussion of benefits in the absence of all the costs are vulnerable to being dismissed as one sided.
2. By self-reporting the social costs of turf, the turf industry can defend itself from claims that the negative externalities of turf outweigh the benefits.

However, while we measure and cost the impact of nutrient runoff from turfed compared to impervious surfaces, it is important to note that the impervious surfaces we are comparing to are a combination of paved and synthetic turf. Synthetic turf is a significant source of other types of pollution, such as microplastics. A single sports field loses between 1.5-2.5 tonnes of rubber into the environment each year, the full economic, environmental, and social impacts of which is still under-studied (Kole et at).

Significantly, while stormwater systems are typically designed to allow nutrients such as nitrogen to break down, microplastics are persistent in the environment for much longer. Therefore, the results produced in this report are likely to understate the negative impacts of replacing natural turf with synthetic alternatives, and they should therefore be taken with care.

Value of urban runoff infrastructure requirements per m^2 of turf

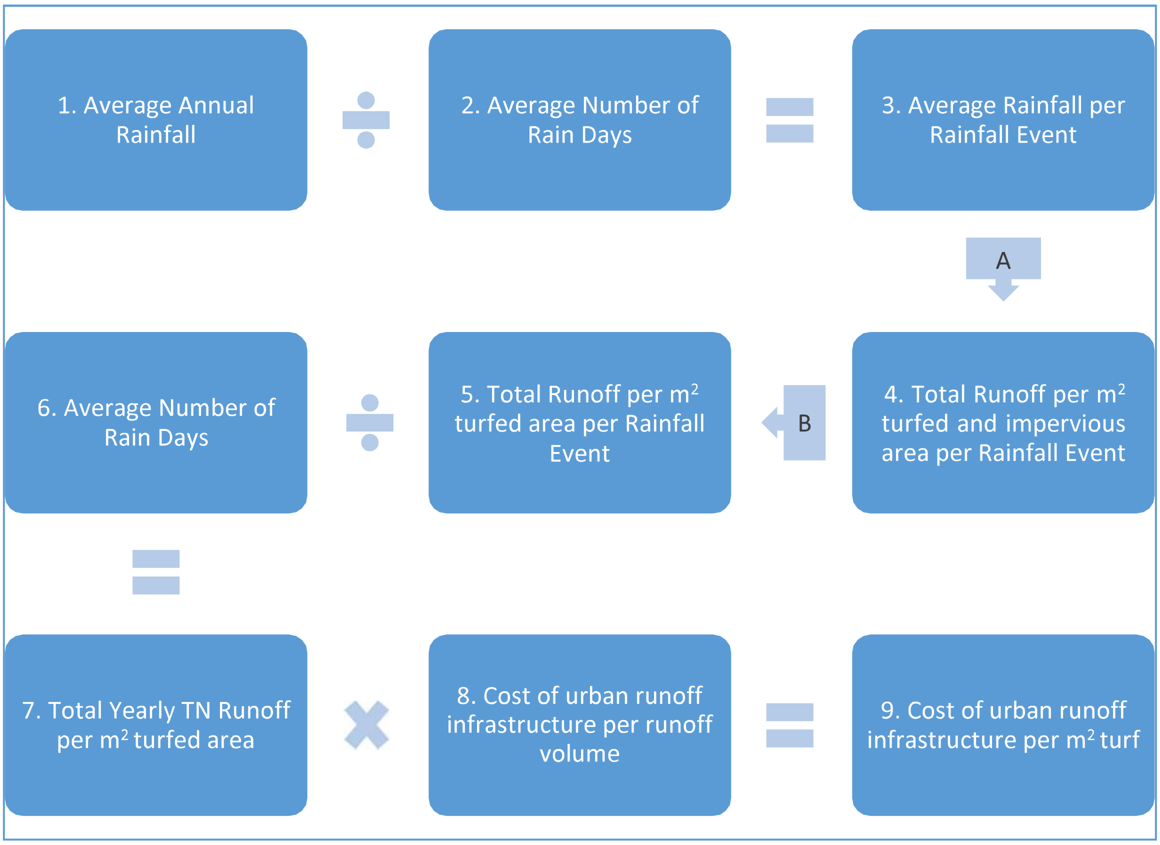
The amount of rainfall captured by turf is highly dependent on the magnitude of individual rainfall events, as well as the capacity for the soil to absorb moisture. The runoff curve number has been developed by the USDA Natural Resources Conservation Service (NRCS) (1986), given by:

$$3 = \frac{(\;\;2\;\;\;0.1755)^{\;6}}{2\;\;\;3.56}$$

Where Q is the runoff (mm) associated with a precipitation event, P (mm). The constants are calculated based on a standard initial abstraction coefficient (I) of 0.05, and a standard Curve Number (CN) coefficient, 74, associated with soils that are slow to infiltrate when thoroughly wet in fully developed urban areas covered by turf (>75% ground cover) in good condition. For example, under these conditions turfed surface area will capture between 45% of rainfall during a 5mm rainfall event, and 13% of rainfall in a 25mm rainfall event. This is used in conjunction with parameters for the volume of TN in runoff from turfed and impervious surfaces (Baron and Donn, CSIRO, 2010), approximately 3.76mg/L and 0.45mg/L respectively, in order to arrive at the final impact values.

Figure 4 outlines the steps taken to calculate the total value of the infrastructure required in each suburb per year to deal with the nutrient runoff from turf.

Figure 10: Calculation of the costs of stormwater infrastructure each year in each suburb.



A	The Total Runoff per m^2 of turfed and impervious area per Rainfall event were calculated using the Runoff Curve Number equation (NRCS, 1986), as well as standard parameters for the mass of TN from turfed and impervious surfaces. Data from the Bureau of Meteorology.
B	The Total Avoided Runoff per m^2 of turfed area is the difference between the Total Runoff per m^2 of turfed area and the Total Runoff per m^2 of impervious area.

3 Quantifying the Economic Impact of the Production, Distribution, Installation, and Maintenance of Turf

3.1 Economic Impact Modelling

The Total Economic Impact of the production, distribution and installation, and maintenance of turf can be defined separately and with respect to two fundamental factors, capital inputs and labour inputs. Capital inputs are comprised of machinery, chemicals, land, seeds and other physical factors, whereas labour is a measure of the time and value of human effort required.

A 'demand pull' input-output separates out the different functions of turf, as defined in Section 2.2, and allocates the total annual demand for goods and services relating to different sectors of the economy associated with turf production, distribution and installation, and maintenance. This approach was used by Beddow et al (2001) to estimate the total economic impact of turf in Virginia. Input-Output Modelling of the Turf Industry, which we replicate in the following sections for the Australian context using a variety of corroborated input data sources.

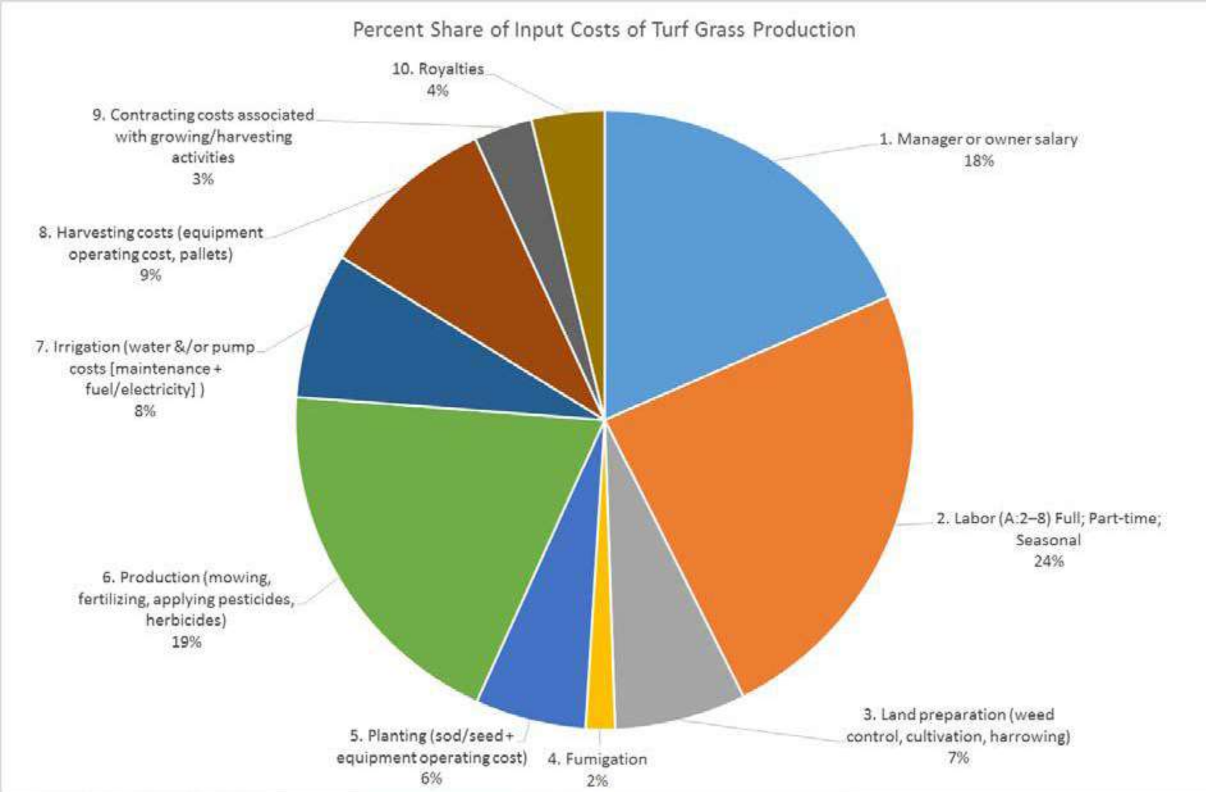
As with Section 2, the aim of this Section is to define the economic costs of turf per m^2 and therefore compute a comparable matrix of the costs and benefits of turf provided to the Australia on a local, regional, and nationwide level. In many cases, the data collected for the analysis is only generalised data which we apply to all turf. Therefore, it is important to note that there is significant variation in local practices and conditions that will cause costs to vary.

The Turf Industry Research and Statistics 2016/17 (TU16001) report is the primary source of data for the area of turf in m^2 terms which is produced, delivered and installed, as well as the total value of that farm-gate production, $228,640,318. This value concords with the Australian Bureau of Statistics - *Value of Agricultural Commodities Produced, Australia, 2016-17,* which reports that the Gross Value of cultivated turf production was $230,436,159. Therefore, we use the area of turf reported in TU16001 along with the costs per m^2 identified in the following sub-sections to arrive at total costs for those activities at the state level. The total costs for the Turf Maintenance and Care industries are defined using the total areas as described in Section 4. Quantifying the Extent of Turf Cover in Urban Australian Suburbs.

3.1.1 Inputs into Turf Production

The inputs required to produce turf are well understood. A number of data points and studies exist that will allow us to calculate the total economic impact of turf grass production at the farm-gate. Haydu, Aldous and Satterthwaite (2008) undertook an Economic Analysis of the Australian turf grass industry in 2006 which break down costs into various section and inputs. Figure 5 illustrates the relative costs breakdown of various growing activities Haydu et al find.

Figure 11: Breakdown of the Input costs of Turf grass growing in Australia in 2006, from Haydu et al (2008)



However, turf grass production has probably advanced since 2006, and the relative weight of inputs may be different now as to what they were then. Data from Turf Australia, in the form of a Turf Cost of Production Calculator, illustrates a case study of a 60ha farm in Queensland. While individual farms will have variation in costs, it appears that at least for this example, owner salary is about the same (23%), whereas labour costs are far higher (41.72%). Furthermore, planting, irrigation, and harvesting costs take up a smaller proportion of farming activities, whereas production activities have taken up a greater share of costs. This is indicative of industry trends towards making more efficient use of capital inputs for routine activities, with a greater emphasis on labour costs as well as efforts to produce greater quality turf.

We use the data from the Turf Australia Cost of Production Calculator to assign the items described in those case studies to different sectors of the economy. Due to the limited sample set, the researchers collaborated with members of Turf Australia and Horticulture Innovation in order to ensure that the results were generally applicable and within reasonable bounds. We also adjust the data from Turf Australia, dated from 2012, for inflation, 12% in current dollars. Table 5 outlines the costs per m^2 mapped across the various relevant sectors of the economy.

Table 7: Costs of Turfgrass production per m^2 in 2018 AUD

Economic Sector	Cost per m2	Share of Total
Grass Seeds	0.002	0.05%
Ag. Forestry and Fishery Services	0.099	3.11%
Maintenance and Repair	0.185	5.80%
Nitrogen and Phosphorus Fertiliser	0.243	7.63%
Ag. Chemicals	0.480	15.07%
Petrol. Refining	0.547	17.18%
Lime	0.002	0.06%
Farm Machinery and Equipment	0.239	7.50%
Equipment Rental and Leasing	0.068	2.14%
Water and Electricity Utilities	0.105	3.28%
Households (Labour)	1.217	38.19%
TOTAL	3.186	100%

3.1.2 Inputs into Turf Delivery and Installation

Turf Delivery is its own type of economic activity, and the Turf Australia Costs of Production Calculator breaks down the individual costs for a typical square metre of turf, which we classify into the various economic sectors for Input-Output analysis, outlined in Table 6. While the person delivering turf may differ, sometimes the farm itself, a wholesaler or retailer, or the customer themselves, all turf used in the economy will have to be delivered one way or another. Therefore, the costs of delivery apply to all turf produced in Australia.

Table 8: Costs of Turfgrass delivery per m^2 in 2018 AUD

Economic Sector	Cost per m2	Share of Total
Ag. Forestry and Fishery Services	0.073	6.60%
Maintenance and Repair	0.055	4.95%
Petrol. Refining	0.243	21.95%
Farm Machinery and Equipment	0.137	12.37%
Households (Labour)	0.600	54.14%
TOTAL	1.107	100%

Like delivery, all turf must be installed, either by a professional landscaper or otherwise. However, we assume that only 10% of all turf that is installed will require site preparation. Therefore, the costs per m^2 reflected in Table 7 take into account the fact that only a certain proportion of turf will require some extra inputs such as soil and water retention products. However, the overall averages are applied to all turf in order to generate a whole of market picture of the overall costs of installation on average.

Table 9: Costs of Turfgrass installation per m² in 2018 AUD

Economic Sector	Cost per m2	Share of Total
Ag. Forestry and Fishery Services	0.377	15.46%
Maintenance and Repair	0.137	5.62%
Nitrogen and Phosphorus Fertiliser	0.028	1.15%
Ag. Chemicals	0.050	2.07%
Petrol. Refining	0.332	13.59%
Farm Machinery and Equipment	0.158	6.46%
Building Materials and Gardening	0.336	13.77%
Households (Labour)	1.022	41.90%
TOTAL	2.440	100%

Like the costs of production, the total costs of turfgrass delivery and installation are calculated using the totals volumes identified in the Turf Industry Research and Statistics 2016/17 (TU16001) on the regions identified in that report. Although it is theoretically possible to increase the granularity of the analysis to see how much turf is delivered to and installed in individual suburbs, the market analysis which would support that extrapolation has not yet been conducted. Therefore, as part of the general conclusions of this report, we include that detailed suburb-level market demand analysis for turf be investigated in order to support continued improvements in this research.

3.1.3 Inputs into the Turf Maintenance and Care Industry

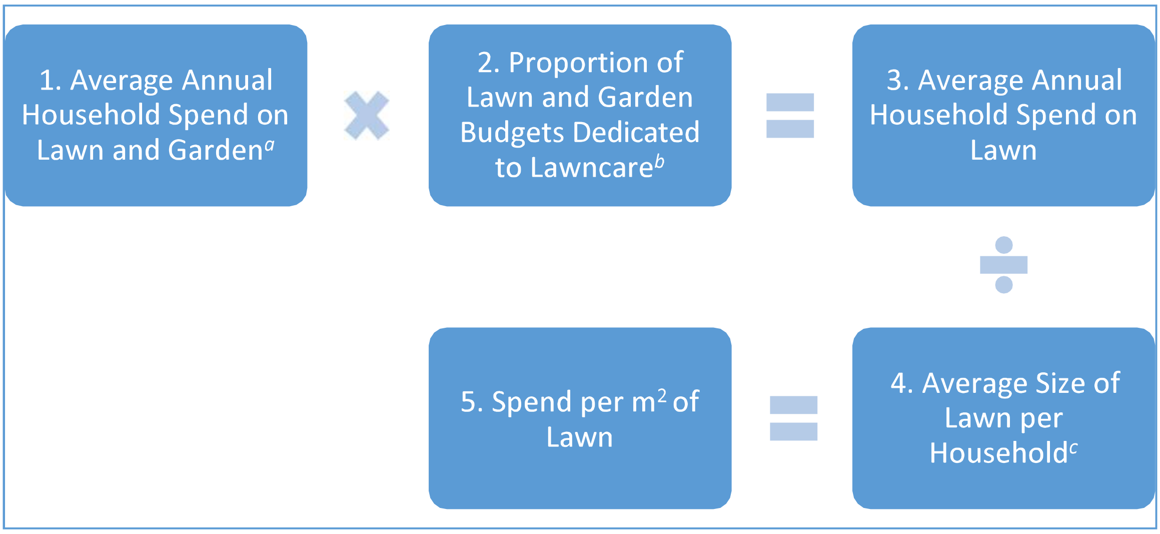
The maintenance and care of turf is highly dependent on types of activities for which it is used, as well as the willingness of the grass managers to pay for varying levels of upkeep. However, as discussed in Section 2.2, the broad categories of turf that have been identified in this report only cover home lawn, park, sports fields, roadside, median strip, and easement turf cover. Therefore, while different sub-categories of turf will demand greater or less upkeep, the values used in this report are broad averages and should be interpreted as such.

Because turf cover is estimated on a suburb-by-suburb level, the total costs of maintenance and care are reported on a suburb-scale level of granularity. This allows turfgrass owners and managers to compare the maintenance costs of turf to their benefits as described in Section 2 and detailed in Section 5. However, it should be clearly noted that the maintenance costs of turf do not include the costs of replacing turf, as these costs are completely captured in the costs of production, delivery and installation costs of turf and including them again as part of maintenance would be double counting. The costs of turfgrass replacement will also vary with the level of use and care provided, ie overused and poorly maintained turfgrass may have an expected useful life anywhere between 1-20 years, however properly managed turfgrass has a theoretically indefinite useful life. Therefore, when evaluating the costs and benefits of individual turfgrass installations, the costs of replacement (which this analysis does not provide) will have to be fully taken into account.

3.1.3.1 Home lawn maintenance and care costs

The amount that home owners, or tenants, in Australia spend on lawn maintenance and case is unique amongst the turf categories that are investigated in this report, in that it is highly dependent on two factors: the value of the home, and the amount of lawn each house has. We use a number of different sources of data to identify the amount that home owns can be expected to pay annually for the upkeep of lawn, which is outlined in Figure 6.

Figure 12: Calculation of home lawn maintenance costs per household in each suburb.



a	Fox and Tulip (RBA, 2014) examined the costs of home ownership and find that gardening and lawn care expenses account for 0.5% of rental income, which for the median weekly household would account for 1.2% of income. We use 0.5% of the median household rent in each suburb as the amount spent on maintaining lawn and garden.
b	The amount spend specifically on lawn was imputed through a survey of household maintenance websites which indicate that lawn accounts for approximately 39% of the entire garden maintenance budget. This would equate to 0.19% of median rental income or 0.47% of median income, from *a*, above. This is somewhat less than Zhou et al's (2008) findings from Baltimore that households spend between 0.83% and 1.44% of their weekly income on lawn care but fits with expectations that Australians may spend less on their lawns than their counterparts in the USA.
c	The average lawn size per household was calculated by dividing the total estimated area of home lawn and roadside turf per household by the number of detached and semi-detached households. Section 3.1.3.4 details the method for estimating the average total area of roadside turf each household is responsible for maintaining out of their entire lawncare budget.

The breakdown of goods and services that households purchase in order to maintain their lawns is not well understood in the Australian context. Therefore, we adopt the proportions of goods and services identified by Beddow et al (2001) in their study of the turfgrass and lawncare industries in Virginia. While extrapolating from Beddow's results assumes that the proportion of goods and services consumed in the lawncare industries is generalizable both between the USA and Australia, and through time, in the absence of more recent and local data, the analysis makes use of this breakdown as it is the most complete and detailed survey of consumer behaviours in this context to date. Efforts were made by researchers to confirm the broad pattern of consumption with a number of industry representatives who assisted with the project, and it was determined that the estimates fall within reasonable bounds to be considered useful for the purposes of this analysis. The breakdown of Beddow et al's estimates of the percent of expenditure spent per lawn, extrapolated to the median Sydney Household is presented in Table 8.

Table 10: Annual costs of Home Lawn maintenance for the median Sydney household.

Economic Sector	Cost per HH	Share of Total
Grass Seeds	0.142	0.03%
Greenhouse and Nursery Products	0.052	0.01%
Wood Products	21.517	4.89%
Ag. Forestry and Fishery Services	0.158	0.04%
Maintenance and Repair	25.190	5.72%
Nitrogen and Phosphorus Fertiliser	26.833	6.10%
Ag. Chemicals	32.873	7.47%
Petrol. Refining	17.921	4.07%
Lime	4.832	1.10%
Hand and Edge Tools	14.711	3.34%
Farm Machinery and Equipment	222.929	50.64%
Equipment Rental and Leasing	5.063	1.15%
Water Supply and Sewerage Systems	39.899	9.06%
Building Materials and Gardening	0.806	0.18%
Households (Labour)	27.267	6.19%
TOTAL	440.196	100%

However, homeowners are responsible for maintaining not only their own lawns, but the lawn on the roadside verge bordering their properties. This means that a proportion of the amount described in Table 8 will have to be diverted from the value of inputs into home lawns, into those that are dedicated to maintaining roadside turf. The process for doing so are described in section 3.1.3.4.

3.1.3.2 Park turf maintenance and care costs

Determining the value of inputs into goods and services used in the maintenance of park turf followed a two-step procedure: first, calculating the general cost per square metre to maintain turf in a typical suburban park from a number of park budgets sourced from local governments, and second, independently calculating the expected costs of the various turf-care activities and inputs described in those budgets using data on individual activities sourced from the Turf Australia Costs of Production Calculator. The two points of data were then compared to determine the validity of the results, so that the costs as broken down into individual economic sectors could be applied with confidence.

The typical cost per m^2 for the maintenance of park turf by local governments is generally between $1.00 and $3.05, averaging about $2.30. Table 9 outlines the estimated cost per m^2 calculated by applying costs to a list of annual activities typical of maintaining park turf (City of Greater Geralton, 2019). The total estimated cost per m^2 of maintaining park turf is $2.41, indicating that this is a highly accurate method of breaking down turf maintenance activities into individual economic sectors.

Table 11: Costs of Park Turfgrass maintenance per m^2 in 2018 AUD

Economic Sector	Cost per m2	Share of Total
Maintenance and Repair	0.092	3.81%
Nitrogen and Phosphorus Fertiliser	0.424	17.59%
Ag. Chemicals	0.738	30.59%
Petrol. Refining	0.248	10.27%
Farm Machinery and Equipment	0.067	2.76%
Building Materials and Gardening	0.336	13.93%
Households (Labour)	0.508	21.05%
TOTAL	2.412	100%

3.1.3.3 Sports field turf maintenance and care costs

Like park turf, the value of inputs into the maintenance of sports field turf was compared to estimates derived from the valuation of individual maintenance activities and how often a typical sports field is treated by each one. Comparing them therefore provides a point of confirmation allowing us to extrapolate our estimates to all the sports field area.

However, maintenance levels of sports fields, more so than park turf, is highly variable and depends on the level of use and the type of use. Community sports fields, which constitute the majority of sports fields in the environment, typically require a lower level of care than elite sports fields for the equivalent activities, which in turn often demand less care than those for special uses such as animal racing, high-level golf, or Olympic-grade arenas. Therefore, we choose to apply the estimated costs for a community-level sports field, which are generally around 80% that of elite-level fields (WA Dept. of Local Government, Sport and Cultural Industries (DLGSCI), 2011). This contributes to the general conclusions of the project, that a more extensive and detailed survey of turf in Australia would contribute to an improved application of this research.

A schedule of maintenance activities for a typical sports field from Sport and Recreation Victoria (2011) were used to estimate and breakdown costs into relevant economic sectors, and then compared to schedules of typical costs per m^2 from the DLGSCI (2011) in order to cross-reference and validate the information. It was determined from these sources that a typical community-level sports field costs in the range of \$3.78-\$4.48/m^2 annually. Again, it is important to note that these do not take into account replacement costs, as these are accounted for in the costs of production, delivery, and installation. Table 10 outlines the computed breakdown and total costs of sports field maintenance.

Table 12: Costs of Sports Field Turfgrass maintenance per m² in 2018 AUD

Economic Sector	Cost per m2	Share of Total
Grass Seeds	0.265	5.83%
Maintenance and Repair	0.395	8.67%
Nitrogen and Phosphorus Fertiliser	1.131	24.87%
Ag. Chemicals	0.402	8.83%
Petrol. Refining	0.404	8.88%
Farm Machinery and Equipment	0.078	1.71%
Water Supply and Sewerage Systems	0.806	17.72%
Building Materials and Gardening	0.336	7.39%
Households (Labour)	0.732	16.10%
TOTAL	4.55	100%

The computed cost per m^2 for maintaining sports fields falls closely near the range of values indicated by the literature, if a little high, however given that the approach already applies a somewhat lower estimate due to the selection of only community-level sports fields, it is appropriate.

3.1.3.4 Roadside turf maintenance and care costs

Attempting to estimate the value of the inputs into roadside turf present a difficulty in that both home owners, other property owners and local government are responsible for maintaining roadside turf depending on property boundaries. This was solved by taking an average of the total area of roadside turf per metre of road in the suburb and multiplying that by twice the average length of the road-facing border of a detached or semi-detached house. This provided the average area of roadside turf that a homeowner is responsible for maintaining. The total costs of lawncare for each household, as described in section 3.1.3.1, Table 8 were then divided proportionally over the area of private lawn, and the area of roadside. It was then assumed that the average value per m^2 of goods and services that homeowners in a suburb provided for in maintaining roadside turf would be replicated for all the other roadside turf not accounted for in this way.

3.1.3.5 Median strip and easement turf maintenance and care costs

Median strip and easement turf is generally maintained by local governments, but do not require as high a standard of care as other pieces of turfed public infrastructure. These link or buffer areas are mown or slashed typically between 2 and 4 times per year. Herbicide application constitutes the other major cost component of maintaining these areas, the costs of which are approximately 3.04 times that of mowing (Berger, 2005). This allows us to interpolate the machinery, chemical and labour inputs for the activities which go into maintaining median strips and easements, outlined in Table 11.

Table 13: Costs of Median strip and Easement Turfgrass maintenance per m² in 2018 AUD

Economic Sector	Cost per m2	Share of Total
Maintenance and Repair	0.001	1.67%
Ag. Chemicals	0.059	74.48%
Petrol. Refining	0.008	9.58%
Households (Labour)	0.011	13.77%
TOTAL	4.55	100%

4 Quantifying the Extent of Turf Cover in Urban Australian Suburbs

4.1 Types of Turf Use Cover Modelled

Different uses of turf serve different functions in society, and as indicated in Section 2.2, the uses of turf that we classify in this study are based on the classifications described by Holborn (2014), TU13027 *Identifying and quantifying turfgrass groundcover in urban areas using on line satellite imagery*, who sampled 31 suburbs between Sydney and Melbourne and divided turf into the following categories:

- Home Lawn
- Park
- Sports field
- Roadside
- Median Strip / Easement

It should be recognised that there are many sub-categories of turf which may yield greater benefits than those described in Section 2.2. For example, school yard or field turf, a subsection of park or sports field turf, may have additional benefits specifically to school children for whom the opportunity to play between classes may increase long-term health, as well as educational outcomes. Turf on elite racing tracks or sports fields are probably far more valuable than those on local community grounds for the economic activity they play a part in supporting. Depending on the location, a chain of easements in a suburban locality may provide a critical habitat corridor between nature reserves.

However, without a detailed census of all the turf infrastructure and facilities, attempting to attribute values to these sub-uses of turf goes beyond the scope of this study. Therefore, we use those uses defined above, and note that the benefits we ascribe to them are likely to be conservative, which is the most defensible approach.

Statistical techniques, such as linear regression, can be used to extrapolate the information collated by Holborn to other urban suburbs, thereby allowing us to estimate the total amount of turf by turf use that currently exists. This technique is limited in its ability to estimate turf coverage in *all* Australian suburbs, as the factors that drive land use decisions by homeowners, local governments or private companies, are likely to be fundamentally different within the greater capital city areas compared to rural and regional Australia. Therefore, we limit our estimates to suburbs within Australia's Greater Capital City Areas, as defined by the Australian Bureau of Statistics. We consider this to be both conservative and appropriate, as the overwhelming majority of turf is likely to be consumed and used within the Greater Capital City Areas.

4.2 Literature of Urban Greenspace Including Turf

The starting point for attempting to model the extent of different turf use coverage and extrapolate the results to the many hundreds of suburbs not surveyed by Holborn is previous academic literature that has attempted to achieve similar goals.

Davies et al (2008) conducted a study of Sheffiled (UK) to predict greenspace using a number of variables and found that the mean normalised difference vegetation index (NDVI) and the total length of roads were the best predictors.

Pham et al (2013) conducted a study to predict the distribution of street and backyard vegetation in Canada and found that the presence of park is a strong predictor of home lawns, due to the fact that the two are at least somewhat interchangeable for users, or that those places without some lawns tend to demand access to public parks to a greater extent than those that do. Other significant variables include the distance to CBD, population density, building age, and the proportion of dwellings over 5 storeys.

Mennis (2006) examine the relationships between socioeconomic characteristics and vegetation in Denver, Colorado and find that almost all the variables they looked at were significant at the 5% level, and found that home age, commercial density, population density, residential density, percent minority, elevation, and distance to highways were able to explain 60% of vegetation intensity.

Cui (2011) research the relationships between socio-economic factors and the extent, composition and change of urban greenspace in Canberra over multiple years. They find that housing density, median household income, high income households, the percentage of those with bachelor's degrees, and the percent born outside of Australia are explanatory in determining the extent to vegetation intensity in a suburb.

Using these studies as a starting point, we collected a number of socio-economic and topographic variables to compare to the data collected to Holborn, and ultimately determine the extent of turf cover across urban Australian suburbs.

4.3 Modelling Turf Grass Coverage in Australian Urban Suburbs

Estimation of turf grass coverage progressed in two stages, these were:

- Estimation of total turf coverage
- Estimation of the proportion of different uses of turf that composed total turf

Estimating to the total extent of turf and then determining the breakdown of the individual categories, as opposed to the opposite (estimating the extent of individual uses of turf and the adding to produce a total turf area), was undertaken in order to ensure that the accumulated errors of multiple estimates do not produce spurious results.

4.3.1 Estimation of total turf coverage

Holborn's results of total turf coverage in 31 Sydney and Melbourne suburbs were analysed with respect to a number of topographic and demographic information, using an Ordinary Least Squares (OLS) linear regression. Due to the low sample size, the effect of multiple variables on the total area of turf present in a suburb could not be determined. Ultimately, the best predictor of the total turf area was the area of the suburb itself, explaining 90% of the variation in the sample. Table 12 outlines the results of the OLS regression.

Table 14: Model coefficients for estimation of total turf area by suburb.

Variable	Coefficient	Standard Error	t-ratio	P[|T|>t]
Constant	(0.22)	0.17	(1.29)	0.21
AREA	0.24	0.01	17.03	-
Adjusted R^2	0.9060			

As illustrated in Table 12, the extent of total turf is a fairly constant proportion of each suburb. This model is robust, with high explanatory power, as well as a highly significant variables with tight standard errors. We apply this model to all the suburbs in the sample to determine the total area of turf, that is:

$$6\,K \quad P = H = \quad 6 \quad (\qquad)^6 = 0.24 \times 5 \qquad (= \quad)^6 \quad 0.22$$

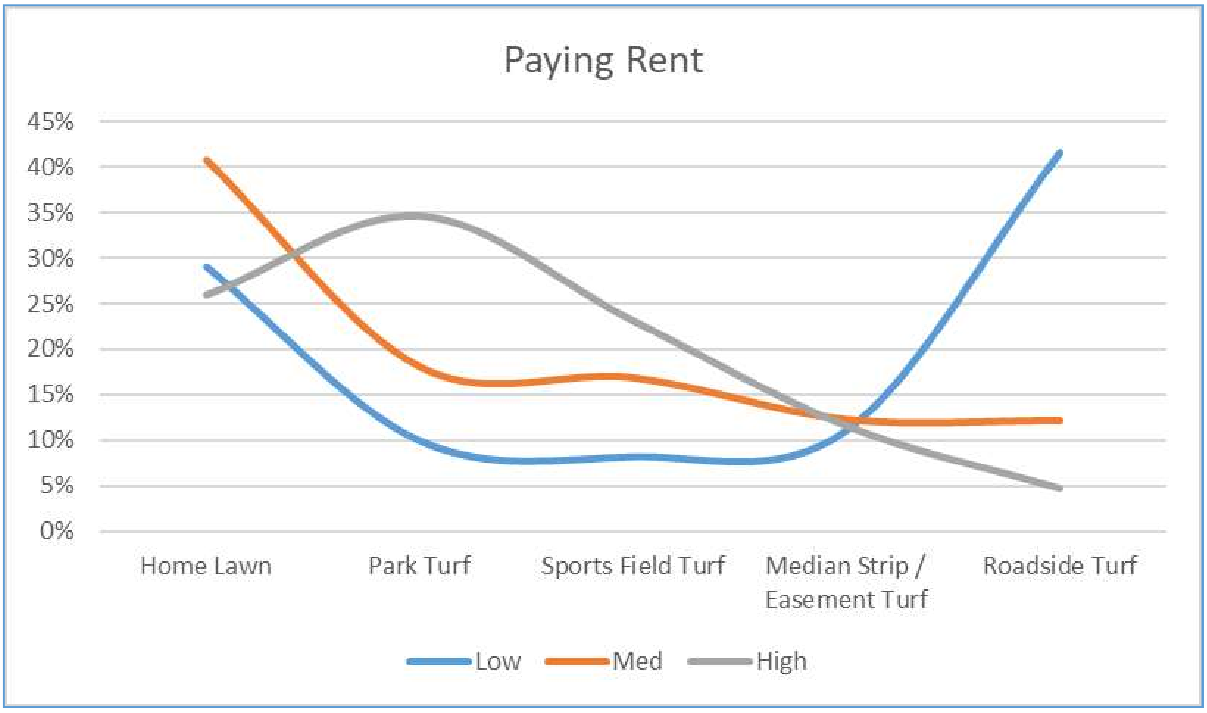
However, the model fails to produce well-behaved results in one respect, for those suburbs with an area of less than approximately 1.0km^2 the predicted coverage of turf becomes negative. Therefore, in order to address this limitation in the model, for those suburbs with an estimated total turf area of less than 0.1km^2, the minimum area observed by Holborn, we instead apply the mean turf area of the entire sample, approximately 21% of the total turf area.

4.3.2 Estimation of turf composition

Once estimated, breaking down the total turf area into multiple smaller components requires a modelling approach that considers all the uses of turf simultaneously. The aim is to avoid the statistically spurious approach of attempting to model several proportions simultaneously and summing the results. Therefore, we take an alternative approach from regression modelling, we use an index of topographic and socio-economic variables to differentiate between different types of suburbs which also have distinct turf cover characteristics.

A number of variables were considered, and ultimately an index based on the proportion of people in a suburb paying rent, as opposed to mortgaging or owning their own home outright, was identified as offering the most insight into how turf cover varies between suburbs. Figure 7 illustrates the split of turf cover use by low, medium and high values of the renting index. The strength of this approach is that for each index value, the proportion of all uses of turf, by definition, sum to 100%.

Figure 13: High, medium, and low values of the Renting Index verses the composition of turf. A number of other indices trialled by the researchers, are provided in technical Appendix 1 for comparison.



The theoretical justifications for a Renting Index being explanatory for the purposes of illustrating turf cover are also attractive. People who are renting are more likely to live in higher density suburbs, with more apartment blocks, and therefore desire and benefit most from the existence of turfed parks and sports fields. However, the amount of home lawn is greatest in suburbs where there is a mix of renters and owners. This may be explained in two ways: firstly, in suburbs where there are few renters, this could indicate that there is low demand to live in the area, otherwise home owners would be tempted to lease their home and live elsewhere, in these suburbs there may be low incentive to invest in home improvement such as home lawns; secondly, in suburbs where renters are the majority, this likely reflects suburbs with a high demand for dwellings and therefore an increasing housing density, which ultimately crowds out space in residential areas for home lawn. Finally, low renting is associated with high levels of roadside turf, indicating that suburbs with rich roadside vegetation are desirable places to purchase a home to live in, as they offer some value or amenity directly to the home, whereas a family may be more likely to rent in the short-to-medium term a dwelling without such extravagant trappings. Homeowners are also probably more likely than renters to demand that local councils protect roadside verges for the benefit of the neighbourhood than renters, who are more likely to see themselves as more temporary citizens of a suburb. These explanations mirror those put forward by various researchers in Section 4.2, lending weight to the results.

The only category of turf whose distribution is not easily explained by this index is median strip and easement turf, however the cover percentages for this use of turf vary uniformly between 11-12% across all suburbs. Therefore, it appears, at least within this relatively limited sample, that the presence of this use of turf is relatively insensitive to the type of suburb.

For the purposes of extending the Renting Index to the rest of the suburbs, each suburb was classified as either a low, medium or high renting suburb, and then assigned the turf cover variables of that model suburb. A 'Low' Renting suburb is defined as one where renters make up 33% or less of dwellings, a 'Medium' Renting suburb is one where renters make up between 33% and 57%, and a 'High' Renting suburb is one where renters make up greater than 57% of dwellings.

4.3.2.1 Exclusions from the study area

Because the estimates of turf cover are derived from 31 suburbs in Sydney and Melbourne, the external validity of the data is a potential source of error in the results. It may be for example that the number of people paying rent in different suburbs of different cities respond to fundamentally different levels of turf cover. This potential source of error is why we restrict the characteristics of suburbs that we produce results to those with a population density of 350 per km^2 or greater, which is roughly the threshold where all the land use in a suburb is principally urban or suburban, without the results being confounded by other land uses such as farming, national park, or heavy industrial. We also exclude from the main body of the report, results from capital cities excluding Sydney and Melbourne. This removes a number of suburbs, but still leaves approximately 1,000 suburbs for which we produce rigorous and defensible results. The results for capital cities outside of Sydney and Melbourne are discussed in Appendix 1.

As mentioned in the previous section of the report, should a more detailed survey or census of turfgrass cover in a greater variety of suburbs and cities be undertaken, then this would enable the results of this research to be applied to a greater, more representative, and ultimately more accurate study area.

5 Detailed Results: The Total Economic, Social, Health and Environmental Impact of Turf

The following subsections detail the aggregate benefits and costs of turf on a city or regional basis. However, because estimates of turf cover were computed on a suburb-by-suburb level, a significant database of approximately 1,000 suburbs and the computed values of the benefits and costs of turf now exists which could not be included in this report. During stakeholder meetings with representatives of Horticulture Innovation Australia and Turf Australia it was determined that this level of data would be of great benefit to users of this report, but that a need was identified to make the data available in a format which supported both ease of use and control of the product.

Therefore, Balmoral Group Australia has created an online application in the form of a Power BI dashboard, which can be accessed through a secure portal (or by scanning the QR Code to the right):

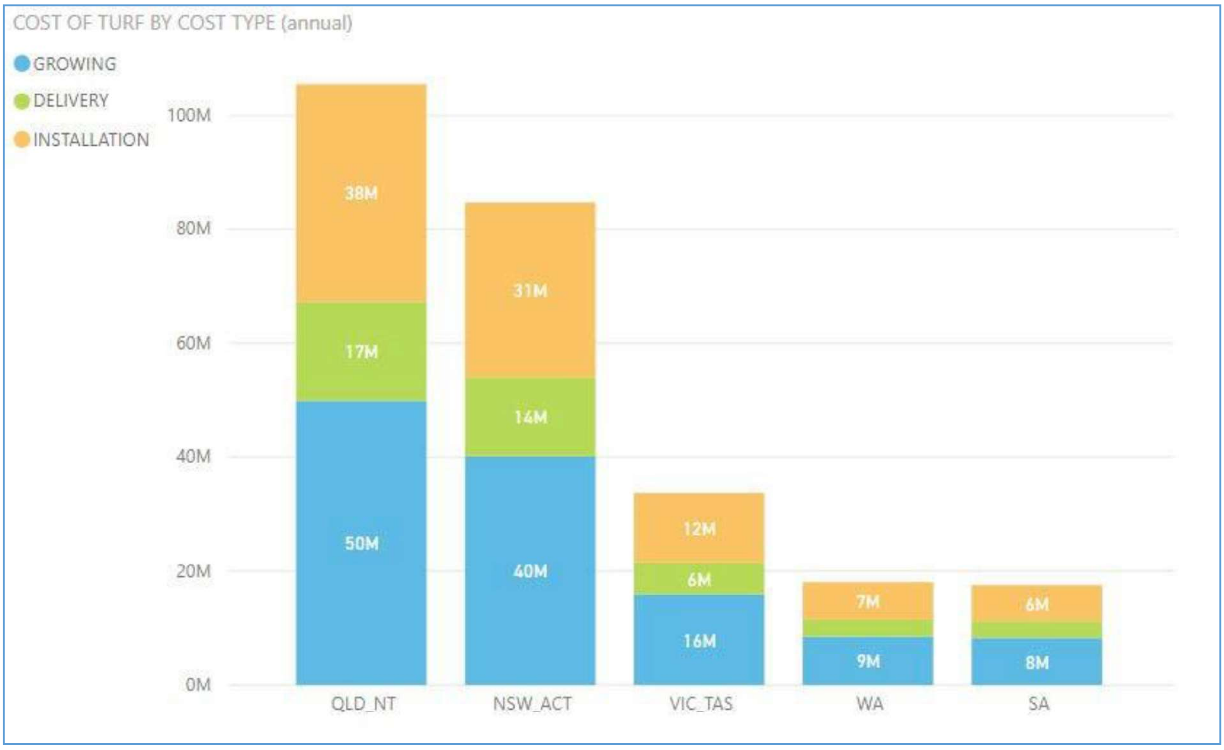
https://www.balmoralgroup.us/turfau2019

The login details to access the dashboard can be obtained by contacting HIA: Contact.Person@hortilculture.com.au

5.1 Total Production, Delivery and Installation Costs of Turf by State Regions

As described previously, the total volumes of turfgrass production from the Turf Industry Research and Statistics 2016/17 (TU16001) report for each of the growing regions were combined with breakdown of estimates of the values of inputs required to produce them. Figure 8 shows the relative values of the inputs into growing, delivering, and installing turfgrass.

Figure 14: Value of the inputs into turf growing, delivery and installation in state regions.



As illustrated in Figure 8, the Queensland and NT region uses the greatest quantity of inputs in the growing, delivery and installation of turf, followed by NSW and ACT, driven by the volume of turf grass produced – approximately $105M and $85M in total respectively. The dominance of the Queensland/NT and NSW/ACT regions is probably linked to the favourable growing conditions due to warmer temperatures and water availability in the key growing areas. Interestingly, despite having a population and experiencing growth comparable to Sydney, turf growing activity in Victoria/Tasmania servicing Melbourne is relatively muted. We also know that most turf produced (90%) is used within 200kms of where it is grown (Haydu, Aldous and Satterthwaite, 2008), so there is relatively little inter-state transport of turf.

It can be noted that the relatively low average price per m^2 of turf faced by growers in Queensland/NT ($5.1/m^2) compared to Victoria/Tasmania ($8.1/m^2) is possibly driven at least partly by the mismatch between the volume of production and demand between those two regions. However, this research does not investigate potential differences in the costs of production, delivery, and installation which could also drive differences in prices, as it assumed that input costs are uniform across Australia. Figure 9 illustrates the breakdown of these input costs by individual economic sectors.

Figure 15: Breakdown of input costs for growing, delivery and installation by individual economic sector.

Input from the households (labour) sector of the economy is by far the greatest contributor to the value of inputs into turfgrass production, representing approximately 40%, 54% and 49% of inputs into growing, delivery and installation respectively. This is typical of horticultural industries, which can require a significant amount of manual labour and handling.

The turfgrass industry also makes heavy use of inputs such as petrol and oil for the operation of farm machinery equipment and trucks, and agricultural chemicals such as herbicides, pesticides and fertilisers. Since these are generally exposed to international markets, these inputs are susceptible to changing global conditions. For example, while the global fertiliser market has spent many years in a state of oversupply and lower prices, global production is concentrated in areas of geopolitical and production volatility, and local supply has not kept up with demand (ANZ, 2018). Therefore, the costs of these inputs are not guaranteed to remain as they are in this snapshot and may be vulnerable to changing economic conditions or shocks.

Table 13 outlines the total economic expenditure by growing, delivery, installation, as well as maintenance and lawncare in the NSW/ACT and Vic/Tas growing region, and for Sydney and Melbourne. The grand total for all the economic output spent in the production and care of turfgrass in this region exceeds $5 Billion dollars. It is important to note that the geographic reference areas do not perfectly align, as the economic effort spent maintaining turf in Canberra and Hobart, as well as areas outside the capital city areas are excluded. However, it does provide an indication of the importance of the turfgrass and lawncare industry to the economies of those markets.

Table 15: Total Economic Expenditure by Turf Growing, Delivery, Installation or Maintenance in the NSW/ACT and Vic./Tas. growing region, and turf in Greater Sydney and Melbourne. Values shown in $'000's.

	NSW/ACT and Vic./Tas.			**Maintenance and Lawn Care - Sydney and Melbourne**					
ECONOMIC SECTOR	Turf Growing	Turf Delivery	Turf Installation	Home Lawns	Park Turf	Sports Field Turf	Median Strip / Easement Turf	Roadside Turf	TOTAL
GRASS SEEDS	*64.75*	-	-	*639.87*	-	*29,826.63*	-	*668.19*	31,199.44
GREENHOUSE AND NURSERY PRODUCTS	-	-	-	*235.19*	-	-	-	*245.59*	480.78
WOOD PRODUCTS	-	-	-	*96,793.88*	-	-	-	*101,077.27*	197,871.15
AG. FORESTRY AND FISHERY SERVICES	*3,815.90*	*2,815.79*	*14,533.70*	*712.44*	-	-	-	*743.97*	22,621.80
MAINTENANCE AND REPAIR	*7,119.26*	*2,111.84*	*5,279.61*	*113,313.08*	*10,326.91*	*44,346.73*	*138.74*	*118,327.49*	300,963.66
NITROGEN AND PHOSPHORUS FERTILISER	*9,372.98*	-	*1,079.15*	*120,706.77*	*47,688.61*	*127,150.70*	-	*126,048.38*	432,046.59
AG. CHEMICALS	*18,499.94*	-	*1,942.47*	*147,877.34*	*82,954.78*	*45,146.89*	*6,186.03*	*154,421.32*	457,028.78
PETROL. REFINING	*21,093.70*	*9,369.54*	*12,776.65*	*80,615.42*	*27,859.50*	*45,411.16*	*796.02*	*84,182.87*	282,104.86
LIME	*73.38*	-	-	*21,737.98*	-	-	-	*22,699.94*	44,511.30
HAND AND EDGE TOOLS	-	-	-	*66,175.88*	-	-	-	*69,104.35*	135,280.23
FARM MACHINERY AND EQUIPMENT	*9,205.84*	*5,279.61*	*6,071.55*	*1,002,818.82*	*7,487.85*	*8,741.45*	*40.51*	*1,047,196.27*	2,086,841.90
EQUIPMENT RENTAL AND LEASING	*2,624.69*	-	-	*22,776.27*	-	-	-	*23,784.18*	49,185.14
WATER AND ELECTRICITY UTILITIES	*4,027.88*	-	-	*179,481.23*	-	*90,570.49*	-	*187,423.76*	461,503.36
BUILDING MATERIALS AND GARDENING	-	-	*12,949.82*	*3,627.56*	*37,769.38*	*37,763.76*	-	*3,788.09*	95,898.61
HOUSEHOLDS (LABOUR)	*46,900.02*	*23,107.08*	*39,392.73*	*122,657.90*	*57,080.24*	*82,297.35*	*1,143.83*	*128,085.85*	500,665.00
TOTAL	122,798.34	42,683.86	94,025.68	1,980,169.65	271,167.26	511,255.15	8,305.13	2,067,797.52	**5,098,202.60**

5.2 Benefits and Costs of Turf

The following subsections detail the average benefits of each of the separate uses of turf examined in the analysis for each of the suburbs in Sydney and Melbourne. While the total benefits of turf for the other capital cities can be computed based on the estimated areas of turf calculated in section 4, we have excluded them from the main body of the report for the reasons outlined in section 4.3.2.1 – a lack of confidence regarding the external validity of the turf cover estimates would reduce the defensibility of the entire report. Therefore, we include an analysis of the turf cover for the capital cities not included here in Appendix 1. However, Table 14 outlines the values per m^2 of turf for all of the capital cities investigated.

Table 16: Benefits and Costs of Turfgrass (\$ per m^2) per year in the Greater Capital City Areas of Australia.

<table>
<tr><th></th><th></th><th>Sydney</th><th>Melbourne</th><th>Brisbane</th><th>Adelaide</th><th>Perth</th><th>Hobart</th><th>Darwin</th><th>ACT.</th></tr>
<tr><td rowspan="4">ALL TURF</td><td>Avoided Costs of Cooling</td><td>0.033</td><td>0.017</td><td>0.027</td><td>0.018</td><td>0.017</td><td>0.003</td><td>0.029</td><td>0.009</td></tr>
<tr><td>GHG Sequestration</td><td colspan="8">0.0003</td></tr>
<tr><td>Avoided Cost of Alt. Land Covers</td><td colspan="8">6.77</td></tr>
<tr><td>Costs of Runoff Infrastructure</td><td>0.039</td><td>0.014</td><td>0.044</td><td>0.011</td><td>0.022</td><td>0.012</td><td>0.086</td><td>0.018</td></tr>
<tr><td rowspan="2">Home Lawn</td><td>Increase House Value</td><td>4.45</td><td>3.33</td><td>2.54</td><td>2.91</td><td>3.13</td><td>1.55</td><td>2.59</td><td>3.25</td></tr>
<tr><td>Maintenance Costs of Home Lawn Turf</td><td>15.64</td><td>12.08</td><td>7.24</td><td>7.96</td><td>8.67</td><td>4.37</td><td>8.08</td><td>9.53</td></tr>
<tr><td rowspan="2">Park Turf</td><td>Willingness to Pay Value</td><td>31.47</td><td>25.79</td><td>18.73</td><td>22.77</td><td>18.20</td><td>13.60</td><td>15.36</td><td>17.93</td></tr>
<tr><td>Maintenance Costs of Park Turf</td><td colspan="8">2.41</td></tr>
<tr><td rowspan="3">Sports Field Turf</td><td>Willingness to Pay Value</td><td>31.51</td><td>26.10</td><td>18.84</td><td>22.90</td><td>18.31</td><td>13.68</td><td>15.45</td><td>18.04</td></tr>
<tr><td>Avoided Cost of Synthetic Turf</td><td colspan="8">6.80</td></tr>
<tr><td>Maintenance Costs of Sports Field Turf</td><td colspan="8">4.55</td></tr>
</table>

A more detailed breakdown of the benefits and costs of turfgrass care and maintenance on an individual suburb level, and an aggregate regional level can be found in the Power BI database introduced at the beginning of this chapter.

5.2.1 Benefits and Costs of Home Lawn

The benefits that accrue to home lawns, as outlined in section 2.2 are the increased home rental values, the value of carbon dioxide sequestration, and the avoided costs of maintaining alternate land cover – pavement and synthetic turf.

Table 15 outlines the average value per m^2, per suburb, and totalled across the city for the benefits of home lawn turf compared to the maintenance costs and negative externalities associated with runoff.

The largest benefit for home lawn turf is attributed to the avoided maintenance costs of alternative land uses, however, compared to the value of inputs used in the maintenance of home lawns, it is actually a comparable amount if a little higher in Sydney and a little lower in Melbourne.

The negative externalities associated with runoff from home lawn turf are relatively minor compared to the overall costs and benefits. Similarly, the benefits associated with the value of carbon dioxide sequestration are almost trivially small in comparison to the other benefit streams.

Interestingly, the maintenance cost of home lawn turf is well in excess of what people pay for the opportunity to have a home lawn in the first place through increased home rental values. This indicates that people may value home lawn turf much more than what is imputed through the increased value that it brings to a property and is worth further investigation to uncover what the true value of home lawn turf is.

While the avoided cost of cooling is not included as a benefit in Table 15 for the purposes of avoiding double counting, it does have a total benefit equal to approximately $2.8M in Sydney and $1.6M in Melbourne.

Table 17: Benefits and Costs of home lawn turf in Sydney and Melbourne

	Sydney			Melbourne		
BENEFITS	**Average Per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**	**Average per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**
Increased House Values	4.45	604,096	389,038	3.33	1,020,092	339,691
Value of GHG Sequestration	0.0003	58	38	0.0003	146	49
Avoided Costs of Alternative Land Cover	6.77	1,322,779	851,870	6.77	3,313,012	1,103,233
COSTS						
Cost of Runoff Infrastructure	0.04	7,195	4,634	0.01	6,694	2,229
Maintenance Costs of Turf	15.64	1,638,454	1,055,165	12.08	2,777,793	925,005

5.2.2 Benefits and Costs of Park and Sports Field Turf

The benefits that are attributed to park and sports field turf are the local resident's willingness to pay to have turfed parks and sports fields, the value of carbon dioxide sequestration, and the avoided costs of maintaining alternate land cover – pavement and synthetic turf.

Table 16 and Table 17 outlines the average value per m^2, per suburb, and totalled across the city for the benefits of park turf compared to the maintenance costs and negative externalities associated with runoff. By far the greatest benefit value for park turf is captured in willingness to pay, more than $1B in both Sydney and Melbourne. This equates roughly to a WTP per household per m^2 of turfed park area of $0.019 in Sydney and $0.007 in Melbourne.

The maintenance costs per m^2 for turfed park areas are approximately 35% those of pavement and synthetic turf. Therefore, we can assert that for the benefits that turfed park areas provide, the costs of maintaining them are a good investment.

While the avoided cost of cooling is not included as a benefit in Table 16 or Table 17 for the purposes of avoiding double counting, it does have a total benefit equal to approximately $1.4M in Sydney and $0.8M in Melbourne, and $1.2M and $0.7M for sports field turf respectively.

Table 18: Benefits and Costs of park turf in Sydney and Melbourne

	Sydney			**Melbourne**		
BENEFITS	**Average Per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**	**Average per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**
Willingness to Pay Value	31.47	1,932,918	1,244,799	25.79	3,381,938	1,126,185
Value of GHG Sequestration	0.0003	24	15	0.0003	55	18
Avoided Costs of Alternative Land Cover	6.77	541,048	348,435	6.77	1,238,959	412,573
COSTS						
Cost of Runoff Infrastructure	0.04	3,096	1,994	0.01	2,564	854
Maintenance Costs of Turf	2.41	192,790	124,156	2.41	441,474	147,010

Table 20 outlines the average value per m^2, per suburb, and totalled across the city for the benefits of park turf compared to the maintenance costs and negative externalities associated with runoff. As for park turf, the household willingness to pay for turfed sports field areas represents the largest benefit stream, totalling approximately $1B in both Sydney and Melbourne.

Table 19: Benefits and Costs of sports field turf in Sydney and Melbourne

	Sydney			Melbourne		
BENEFITS	**Average Per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**	**Average per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**
Willingness to Pay Value	31.51	1,666,401	1,073,162	26.10	2,878,817	958,646
Value of GHG Sequestration	0.0003	21	13	0.0003	46	15
Avoided Costs of Alternative Land Cover	6.80	471,695	303,771	6.80	1,040,649	346,536
COSTS						
Cost of Runoff Infrastructure	0.04	2,718	1,750	0.01	2,189	729
Maintenance Costs of Turf	4.55	363,419	234,042	4.55	832,473	277,213

5.2.3 Benefits and Costs of Median Strip / Easement and Roadside Turf

Table 18 and Table 19 outline the average value per m^2, per suburb, and totalled across the city for the benefits of median strip/easement and roadside turf respectively compared to the maintenance costs and negative externalities associated with runoff.

The majority of the 'benefits' associated with median strip and easement turf are the avoided costs of maintaining pavement or synthetic turf, as opposed to the relatively low effort that goes into maintaining this type of turf use. Likewise, for roadside turf, the most impactful benefit are the avoided costs of alternate land cover types.

Table 20: Benefits and Costs of median strip / easement turf in Sydney and Melbourne

	Sydney			Melbourne		
BENEFITS	**Average Per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**	**Average per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**
Avoided Cooling Costs	0.03	1,492	961	0.02	1,802	600
Value of GHG Sequestration	0.0003	21	13	0.0003	54	18
Avoided Costs of Alternative Land Cover	6.77	469,406	302,298	6.77	1,220,475	406,418
COSTS						
Cost of Runoff Infrastructure	0.04	2,495	1,607	0.01	2,421	806
Maintenance Costs of Turf	0.08	5,501	3,542	0.08	14,302	4,763

The estimated maintenance costs for maintaining roadside turf are significant, which we attribute to the assumption that people will spend as much time, effort and money maintaining the turf in front of their house as they do on their private lawns. This assumption may be flawed due to the fact that people probably do not have the same incentive to maintain public greenspaces as they do for their private lawns - it directly increases the value of the house and implicitly the benefits they derive from it. However, in the absence of more accurate data on the effort that households put in to maintaining roadside turf compared to their private yards, we choose to use a conservative estimate which is likely to understate the total benefits, rather than overstate them.

A potential omission from the benefits of roadside turf are the amenity values or property values that are derived from having turfed streetscapes. A number of studies (Sander and Haight (2010), Saphores and Li (2012), and Li et al (2015)) have attempted to quantify the effect of lawn surrounding a house on property value and while the results are positive, the effects are inconsequentially small and in the case of non-irrigated grass, which we expect to be the majority of roadside turf, not statistically different from zero. Therefore, we do not include these as a source of benefits for roadside turf.

Table 21: Benefits and Costs of roadside turf in Sydney and Melbourne

	Sydney			Melbourne		
BENEFITS	**Average Per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**	**Average per m2 ($)**	**Average Total Per Suburb ($)**	**Total ($'000)**
Avoided Cooling Costs	0.03	3,087	1,988	0.02	4,823	1,606
Value of GHG Sequestration	0.0003	58	38	0.0003	176	59
Avoided Costs of Alternative Land Cover	6.77	1,326,096	854,006	6.77	3,995,066	1,330,357
COSTS						
Cost of Runoff Infrastructure	0.04	6,265	4,034	0.01	7,468	2,487
Maintenance Costs of Turf	15.64	1,579,201	1,017,005	12.08	3,155,532	1,050,792

5.3 Relationship between Total Turf Cover and the Urban Heat Island Effect

The estimated proportions of turf cover (see Section 4) were compared in a GIS application to the average urban heat island effects in each suburb to investigate the measurable impact, if any, of turf in ameliorating the negative effects of increased temperature. The Urban Heat Island maps used were sourced from a CSIRO study (CSIRO 2016) which measured the UHI effect over the 2015/16 summer for each of the state capital cities except for Hobart. The UHI effect was calculated by subtracting the measured land surface temperature from an estimate of the non-urban baseline temperature. Figure 10 illustrates the distribution of the results for each of the capital cities, by state or territory.

Figure 16: Proportion of Total Turfgrass in each suburb correlated with the average urban heat index (UHI), broken down by state/territory capital.

As Figure 10 shows, the results are mixed, with some cities demonstrating a negative, neutral, or in some cases a positive correlation between turf cover and UHI. As mentioned earlier, this may be because the estimates of turf cover produced lack applicability to other cities, which would create an error which may obfuscate the true relationship between UHI and turf cover. Secondly, there may be other land uses and topographic effects that are correlated with turf cover, which increase overall UHI but are not apparent in a simple two-way comparison. Thirdly, because the UHI estimates were generated over a single summer there may be greater climate patterns that are not apparent in the data. And lastly, it is known that unirrigated turf does not produce a cooling effect, and that it is possible that irrigation rates decline in summer in some cities and therefore turfed areas do contribute to increased summer temperatures.

It should also be noted that while we compare turf cover to UHI effects in summer, an analysis of UHI effects in other months would be a useful and important contribution to the study of the relationship between turfed areas and urban temperatures.

Table 22: Average UHI effect for suburbs in each of the major cities

City	Mean Suburb UHI (C)
Adelaide	7.79
Sydney	7.24
Canberra	5.77
Melbourne	5.69
Brisbane	5.44
Darwin	5.25
Perth	2.03

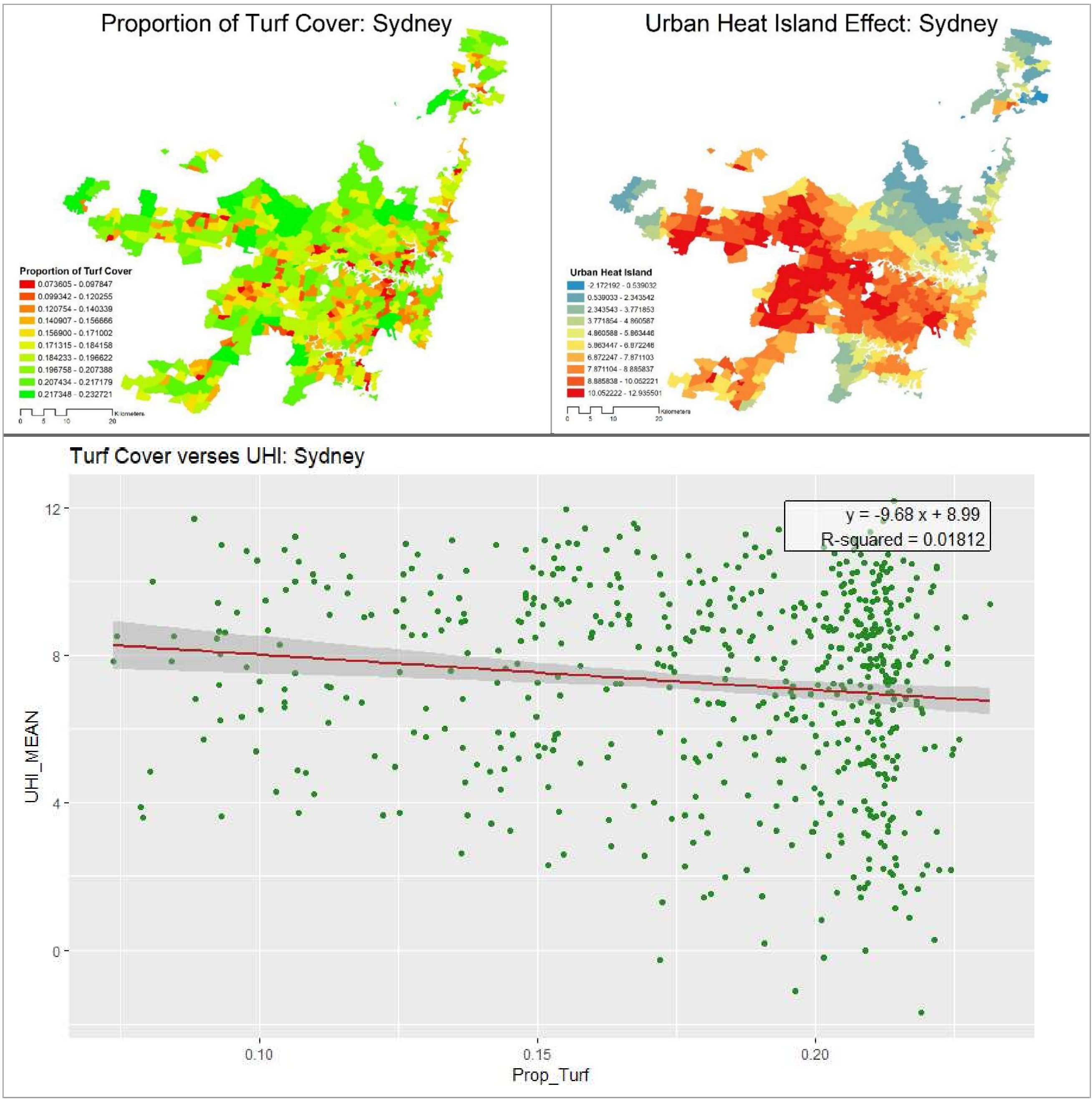
Table 20 outlines the average UHI effect in each of the major cities (bar Hobart), illustrating that Adelaide and Sydney currently face the greatest impacts. However, care must be taken when attempting to draw conclusions from this data because, as mentioned previously, these results are only true for a single summer period between 2015/16 and therefore lack the temporal scope to take into account wider climate patterns.

The following sub-sections make a detailed analysis of each Sydney and Melbourne, comparing turf cover to the average UHI in each suburb. A detailed analysis of other relationship between the estimated turf cover and UHI effects for the other capital cities is presented in Appendix 2. As outlined earlier, this is because potential issues around the external validity of the estimates mean that the results that could over- or under- estimate of the impact turf cover has on urban temperatures in other cities.

5.3.1 Turf Cover and UHI - Sydney

Figure 11 compares the measured average UHI and estimated total turf cover in Sydney by suburb.

Figure 17: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Sydney.



The results of the OLS linear regression predicting UHI on turf cover are summarised in Table 21. In addition, a model with population density as a proxy for land use intensity was estimated in order to try to account for the presence of buildings and roads that may be positively correlated with turf but increase the UHI far more.

Table 23: Results of OLS regressions predicting mean UHI on turf cover and population density in Sydney.

Variable (t-value)	Model 1	Model 2
Constant	8.99	8.23
Prop_Turf	-9.68 (-3.32) ***	-10.77 (-3.86) ***
Pop_Den		0.0003 (7.61) ***
R-Squared	.018	.105
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

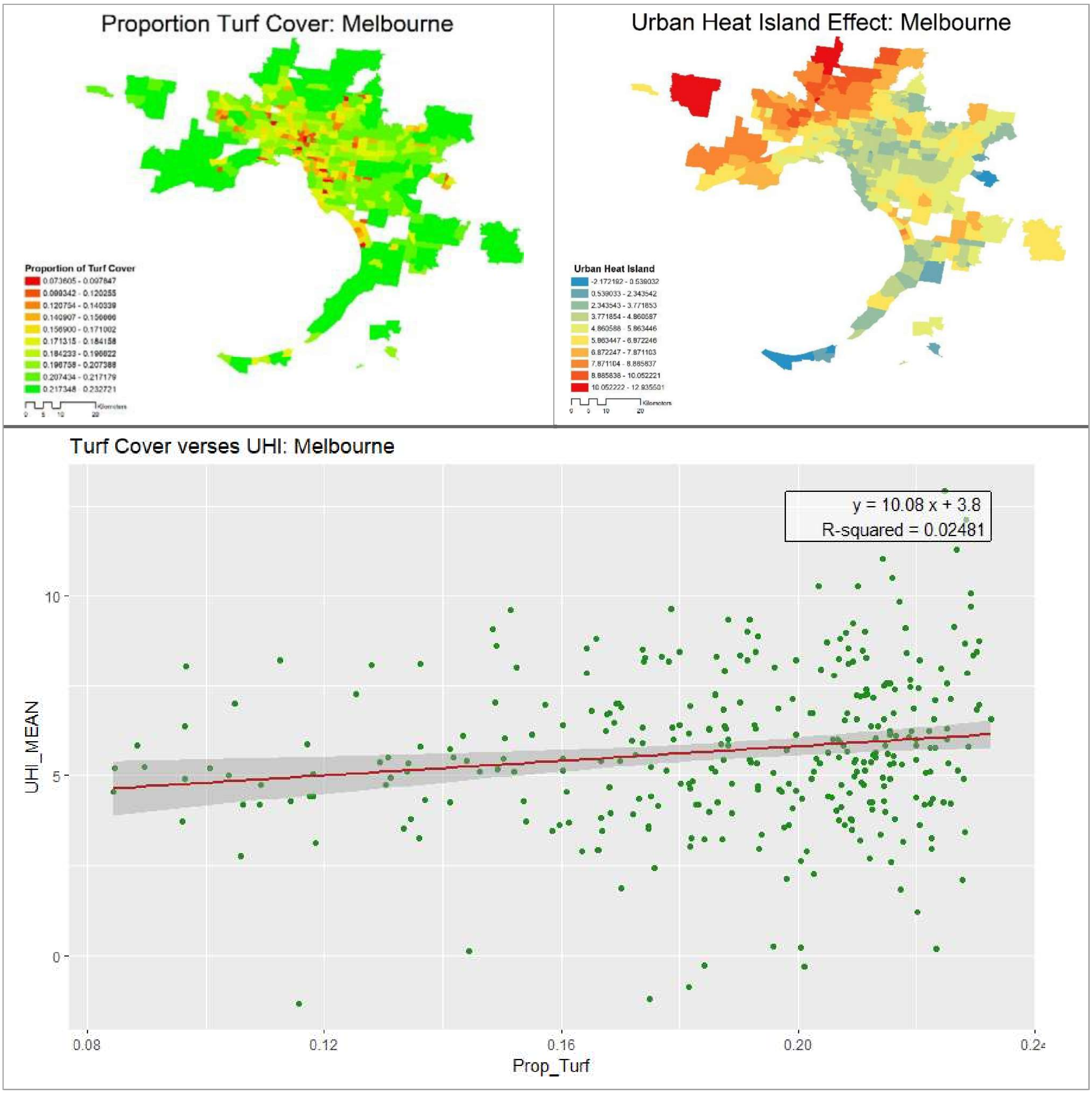
The OLS regressions for UHI on turf cover and population density suggest that turf cover is a significant predictor of UHI, and that holding population density constant, a 1% increase in turf cover is associated with a 0.108 C decrease in the UHI. This is a significant result and suggests that in Sydney, preserving and maintaining turf cover is a useful strategy for ameliorating the negative effects of the UHI. As demonstrated in Figure 10, Sydney experiences the greatest UHI impacts of any of the major capital cities,

In Figure 11 we can also see that the UHI effect is not evenly distributed. The warming effect of the UHI is comparatively lower in the northern suburbs, and higher in the western and south western suburbs. We can relate higher temperatures in these suburbs to places of relatively new urban growth, where cooling vegetation may not have had time to be established. As well, in newer suburbs houses tend to take up a larger proportion of lots, reducing overall lawn sizes.

5.3.2 Turf Cover and UHI - Melbourne

Figure 12 compares the measured average UHI and estimated total turf cover in Melbourne by suburb.

Figure 18: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Melbourne.



In comparison to Sydney, the OLS regression for Melbourne suggests that turf cover is actually positively correlated with UHI. The UHI map suggests that large suburbs, particularly to the north-west such as those around Melton, are under the most pressure from elevated temperatures. Figure 13, a satellite image of a section of Melton, shows that in the Summer of 2015/16 large areas that we would typically expect to be covered in living, green grass is instead dead grass or bare earth. Even the turf on the golf course is in the process of drying out and dying off. During the period of 2015/16 Melton's water supply switched to Melbourne Water because local reservoirs had failed.

While strong conclusions cannot be drawn based on a single snapshot of temperature and turf cover, the results of the analysis suggest that while turf cover may be beneficial to reducing UHI effects when well irrigated and maintained, if turf is allowed to die off then the effect on the local suburb can be the opposite.

Figure 19: A satellite image of Melton during the summer of 2015/16, showing dead grass or bare earth where usually green turfgrass would be expected to be the dominant land cover use (Source: Google Earth. 2019).

Table 22 outlines the results of the OLS regressions, showing that turf cover is a significant explanatory variable for predicting UHI, whereas population density is not.

Table 24: Results of OLS regressions predicting mean UHI on turf cover and population density in Melbourne.

Variable (t-value)	Model 1	Model 2
Constant	3.80	4.14
Prop_Turf	10.08 (5.72) ***	8.99 (2.37) **
Pop_Den		-0.59E-04 (-0.72) N.S.
R-Squared	.025	.026
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

6 APPENDIX 1: Turf Cover Estimation

This appendix reports the results of the turf cover estimation for both the total turf area and the breakdown of that area into different uses and functions. As described in earlier chapters, these estimates were based on a sample of 31 Sydney and Melbourne suburbs taken by Holborn (2014), TU13027 *Identifying and quantifying turfgrass groundcover in urban areas using on line satellite imagery.* Therefore, concerns regarding the external validity of the results regarding their applicability to other cities naturally arise: other cities or state may have any number of differing planning laws, patterns of development or cultural relationships with urban lawn that introduce uncertainty when applying general results derived from such a limited sample of data. The results of the turf cover estimates are provided here in good faith but should be used with caution when attempting to use them to calculate the unit or total benefits or costs of turf where it is not clear that the results are robust. The purpose of supplying this appendix is to demonstrate that the estimation of the total economic, health, social, and environmental benefits and other impacts of turf would be improved with a more accurate and representative estimation of total turf cover across Australia.

Figure 14 shows the output of the OLS linear regression model, illustrating that 90% of the variation in total turf cover area can be explained through the total area of the suburb. This was by far the most explanatory variable out of all those investigated and was used to generate the estimates of total turf cover. While other variables, such as population density, road length, NDVI, and others may also be explanatory, without a larger dataset, deriving statistically significant results for smaller effects becomes impossible.

Figure 20: LIMDEP output of the OLS linear regression predicting total turf cover

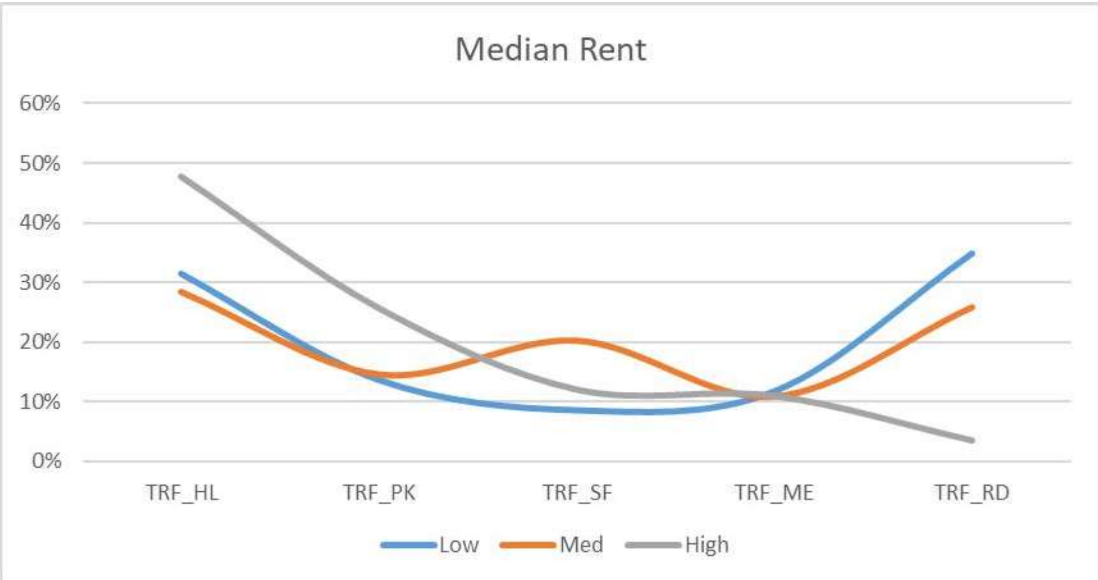
```
REGRESS;Lhs=TOTTUAR;Rhs=ONE,AREA$

+----------------------------------------------------------------------+
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = TOTTUAR  Mean=   1.659458719    , S.D.=   2.283171717     |
| Model size: Observations =       31, Parameters =   2, Deg.Fr.=    29 |
| Residuals:  Sum of squares= 14.21066633    , Std.Dev.=        .70002 |
| Fit:        R-squared=  .909131, Adjusted R-squared =         .90600 |
| Model test: F[  1,     29] =  290.14,     Prob value =        .00000 |
| Diagnostic: Log-L =    -31.8972, Restricted(b=0) Log-L =    -69.0714 |
|             LogAmemiyaPrCrt.=    -.651, Akaike Info. Crt.=     2.187 |
| Autocorrel: Durbin-Watson Statistic =   2.05596,    Rho =     -.02798 |
+----------------------------------------------------------------------+
+---------+-------------+--------------+-------+---------+----------+
|Variable  Coefficient Standard Error t-ratio P[|T|>t] Mean of X  Product
+---------+-------------+--------------+-------+---------+----------+
Constant         (0.22)           0.17    (1.29)    0.21            (0.22)
AREA              0.24            0.01    17.03       -        7.97____1.87
                                                                    1.66
```

The following graphs (Figure 15 to Figure 19) outline the various demographic indices used to break down total turf into the different functional uses of turf, i.e. home lawn, park and sports field, median strip / easement, and roadside turf. All of the demographic data used in the analysis is sourced from the 2016 Census (ABS).

Figure 21: Turf uses differentiated by the proportion of people in a suburb paying rent

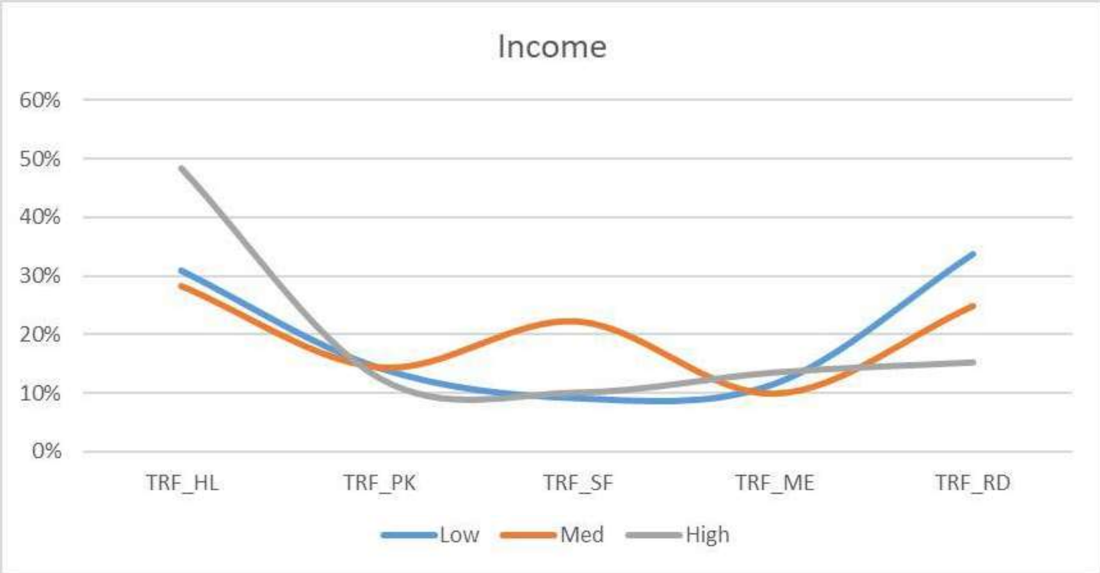
Split by Paying Rent	TRF_HL	TRF_PK	TRF_SF	TRF_ME	TRF_RD	TRF_TOT
Low	29%	10%	8%	11%	42%	100%
Med	41%	18%	17%	12%	12%	100%
High	26%	35%	23%	12%	5%	100%

Figure 22: Turf uses differentiated by the median rent paid in a suburb



Split by Median Rent	TRF_HL	TRF_PK	TRF_SF	TRF_ME	TRF_RD	TRF_TOT
Low	31%	14%	8%	12%	35%	100%
Med	28%	15%	20%	11%	26%	100%
High	48%	26%	12%	11%	3%	100%

Figure 23 Turf uses differentiated by the median weekly household income in a suburb

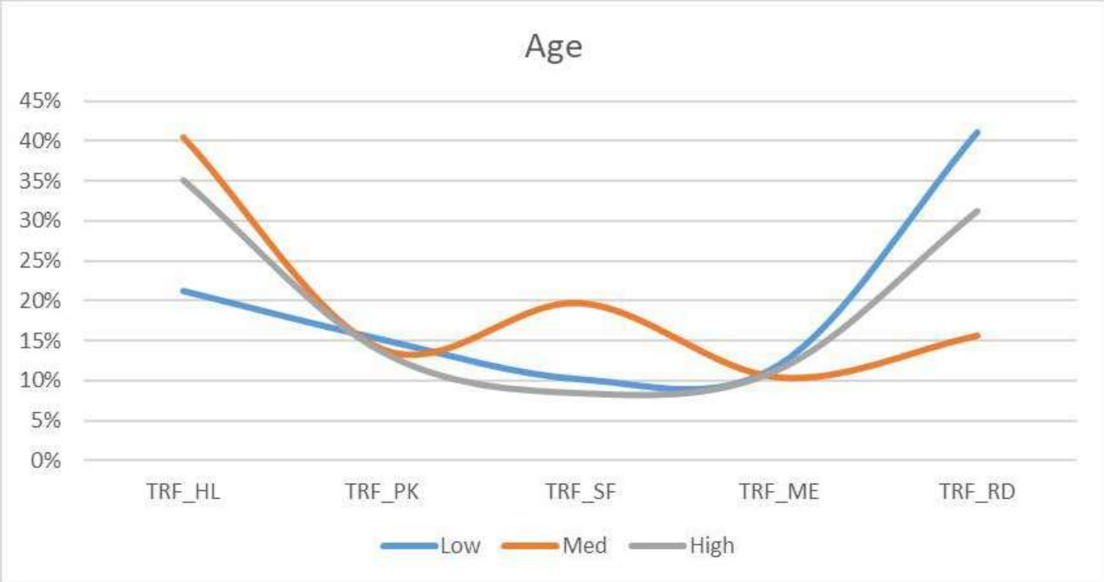


Split by Income	TRF_HL	TRF_PK	TRF_SF	TRF_ME	TRF_RD	TRF_TOT
Low	31%	14%	9%	12%	34%	100%
Med	28%	14%	22%	10%	25%	100%
High	48%	13%	10%	14%	15%	100%

Figure 24 Turf uses differentiated by the proportion of people in a suburb who own their home outright

Split by Wholly Owned	TRF_HL	TRF_PK	TRF_SF	TRF_ME	TRF_RD	TRF_TOT
Low	28%	13%	12%	13%	34%	100%
Med	31%	15%	9%	7%	38%	100%
High	40%	16%	14%	15%	15%	100%

Figure 25 Turf uses differentiated by the median age in a suburb



Split by Median Age	TRF_HL	TRF_PK	TRF_SF	TRF_ME	TRF_RD	TRF_TOT
Low	21%	15%	10%	12%	41%	100%
Med	40%	14%	20%	10%	16%	100%
High	35%	14%	8%	11%	31%	100%

As discussed in section 4.3.2, the index based on the proportion of people paying rent was the most descriptive and was used to model the different types of turf use composition based on different types of suburbs: those with a high, medium, or low proportion of renters.

The detailed breakdown, by suburb, for each of the capital cities of turf area can be found in the Power BI database provided as part of this report on the *SUBURB SELECTION AND TURF AREA* page. However, as there is considerable uncertainty as to the validity of the results beyond Sydney and Melbourne, only turf in the suburbs in those two cities have been valued for the full range of benefits and maintenance costs. As stated above, while the methodology described in this report provides enough detail to measure the benefits and other impacts of turf in cities outside of Sydney and Melbourne, caution should be used when doing so.

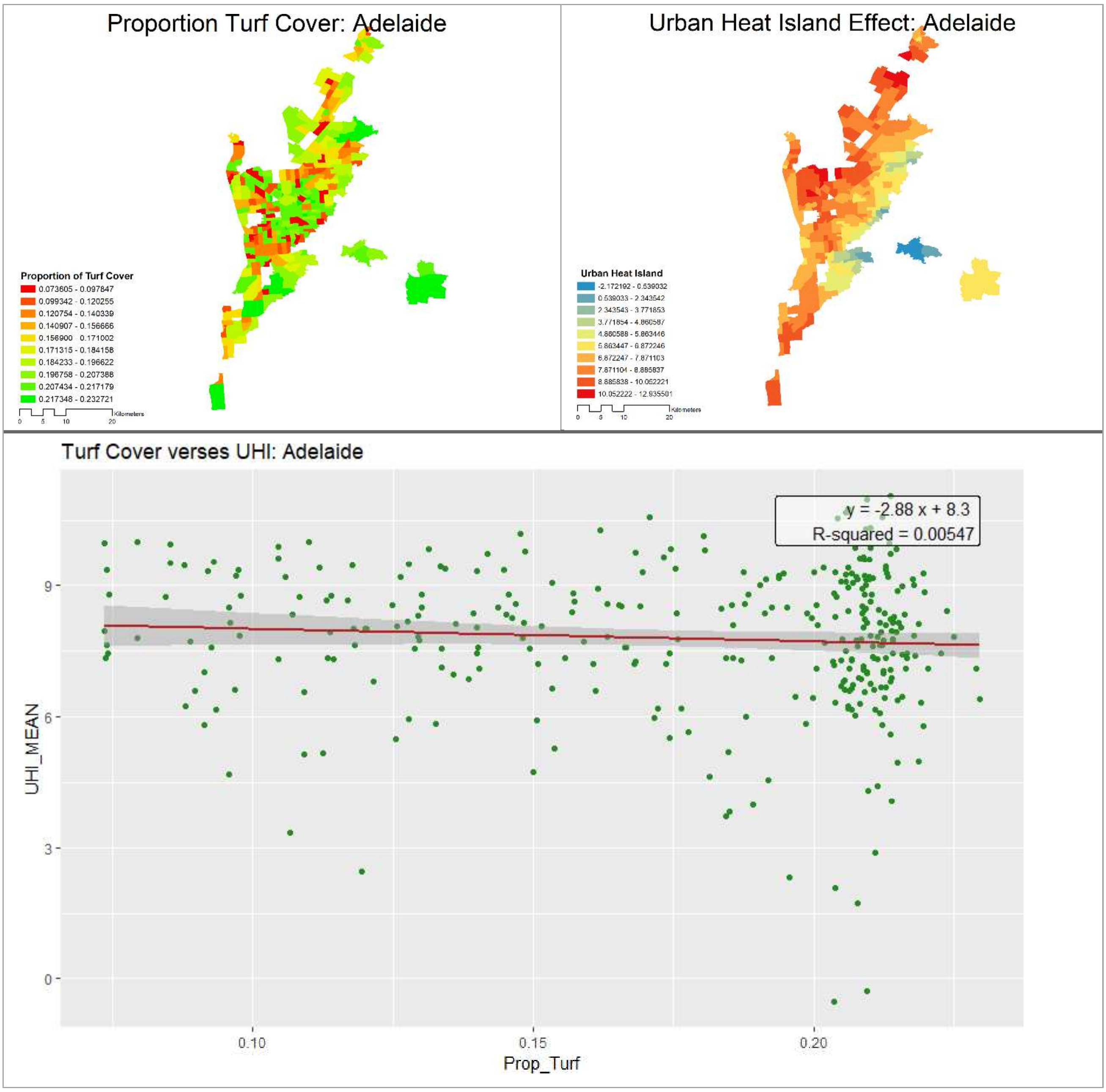
7 APPENDIX 2: Turf Cover and UHI effects for other Capital Cities.

This appendix details the results of the comparison between the estimated turf cover and measured UHI effects. While these estimates are reported in good faith, care should be taken when attempting to apply the results or claim benefits for turf cover in mitigating UHI where it is not clear that such an association exists. The purpose of this appendix, in combination with the results reported in Section 5.3, is to demonstrate that relationship between turf cover and UHI deserves to be investigated in more detail as a serious strategy for dealing with the negative effects of high temperatures on society.

7.1.1 Turf Cover and UHI - Adelaide

Figure 20 compares the measured average UHI and estimated total turf cover in Adelaide by suburb.

Figure 26: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Adelaide.



The OLS regression for Adelaide correlating UHI on predicted turf cover and population density are reported in Table 23. The results suggest that turf cover is not as significant a variable as population density, but there is still a negative correlation whereby a 1% increase in turf cover is associated with a 0.038 C decrease in the UHI. The low significance of the predictors compared to the models describing the same relationship in Sydney and Melbourne suggest that errors in the external validity of the model predicting total turf cover may be an issue for subsequently predicting UHI effects.

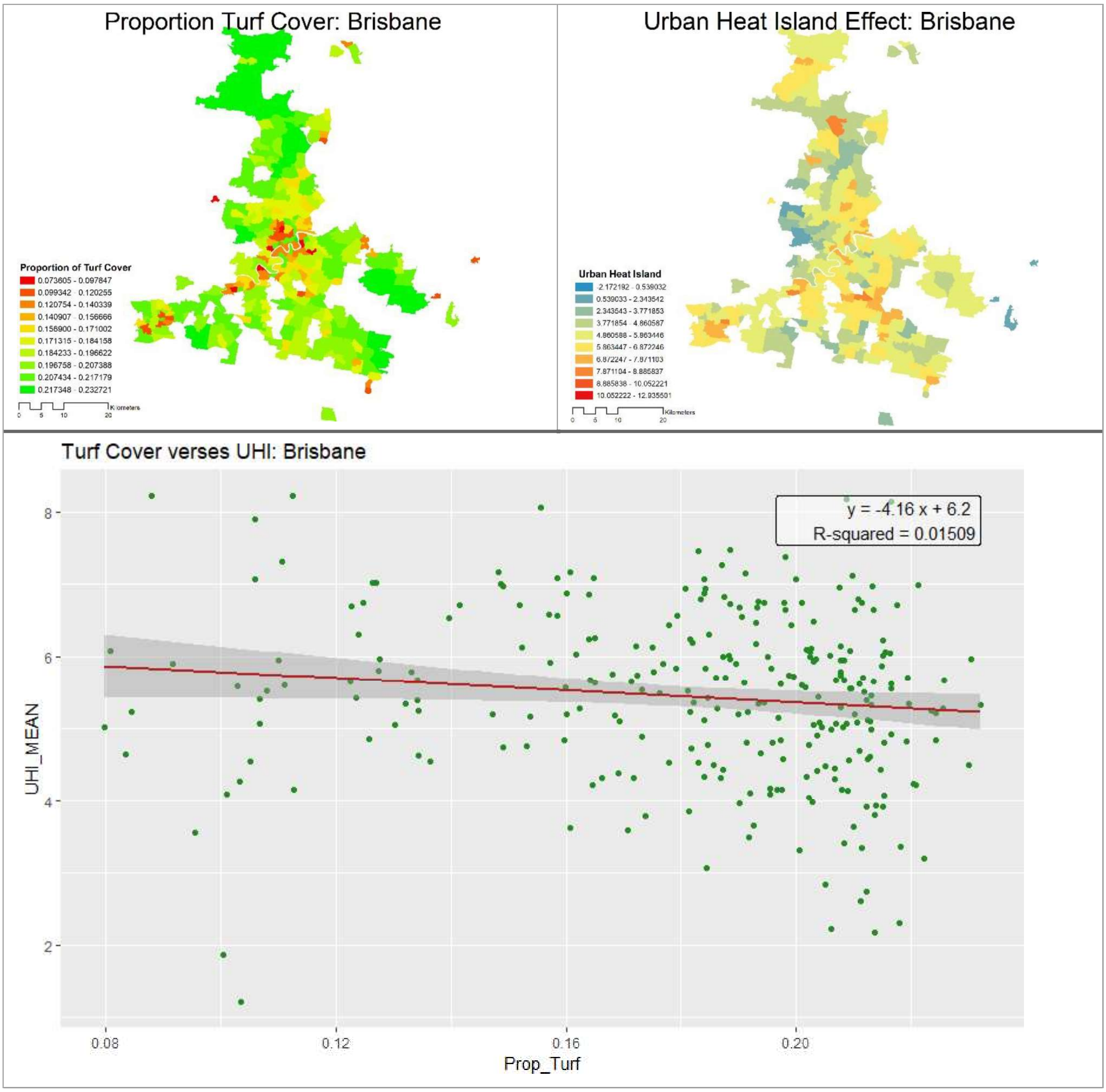
Table 25: Results of OLS regressions predicting mean UHI on turf cover and population density in Adelaide.

Variable (t-value)	Model 1	Model 2
Constant	8.30	7.08
Prop_Turf	-2.90 (-1.35) N.S.	-3.85 (-1.88) *
Pop_Den		0.0007 (5.68) ***
R-Squared	.005	.09
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

7.1.2 Turf Cover and UHI - Brisbane

Figure 21 compares the measured average UHI and estimated total turf cover in Brisbane by suburb.

Figure 27: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Perth.



The OLS regression for Brisbane correlating UHI on predicted turf cover and population density are reported in Table 24. The results suggest that turf cover is not as significant a variable as population density, but there is still a negative correlation whereby a 1% increase in turf cover is associated with a 0.041 C decrease in the UHI when considered independently of population density. However, when considered alongside population density, turf cover become insignificant, indicating that other land use characteristics may be more predictive of UHI effects than turf cover. A more detailed study extracting the competing land use effects, alongside a more detailed understanding of turf cover in Brisbane would add a greater level of understanding of the role turf plays in Brisbane's urban fabric.

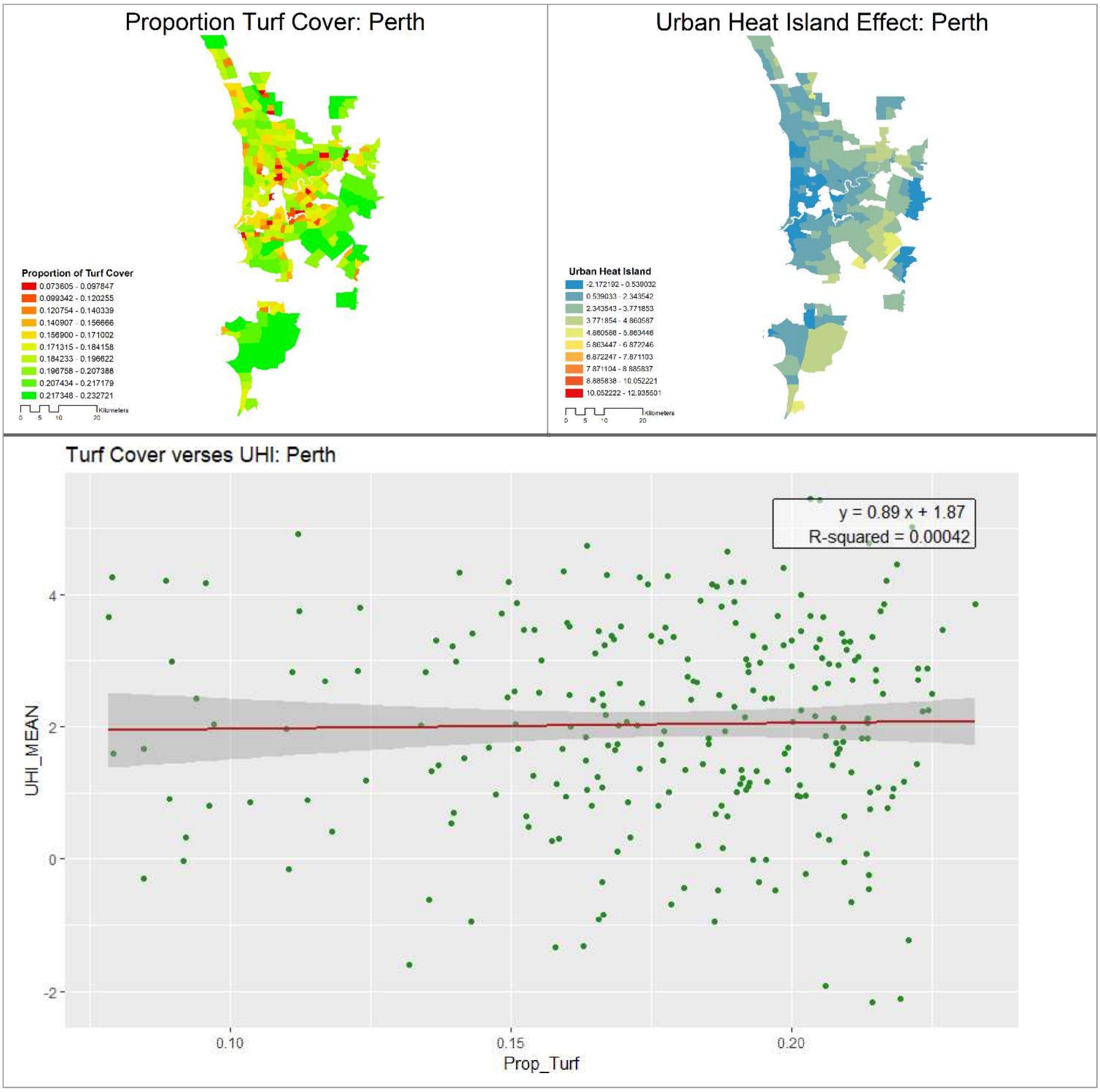
Table 26: Results of OLS regressions predicting mean UHI on turf cover and population density in Brisbane.

Variable (t-value)	Model 1	Model 2
Constant	6.20	5.05
Prop_Turf	-4.16 (-2.04) **	-1.24 (-0.62) N.S.
Pop_Den		0.0004 (5.56) ***
R-Squared	.015	.116
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

7.1.3 Turf Cover and UHI - Perth

Figure 22 compares the measured average UHI and estimated total turf cover in Perth by suburb.

Figure 28: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Perth.



The OLS regression for Perth correlating UHI on predicted turf cover and population density are reported in Table 24. The results suggest that neither turf cover or population density are significant predictors of UHI effects, and therefore, no determination can be made as to whether or not turf cover is beneficial for reducing temperature in Perth. It is likely that Perth is influenced by planning, topographic, and climatological factors that differentiate it from Sydney and Melbourne enough to warrant a closer examination of the interplay between land cover such as turf and the UHI effect.

Furthermore, Peth experienced the lowest average UHI effect of any of the major cities during the 2015/16 summer, which could indicate that there was not enough variation in temperatures for turf to make a measurable impact in that year.

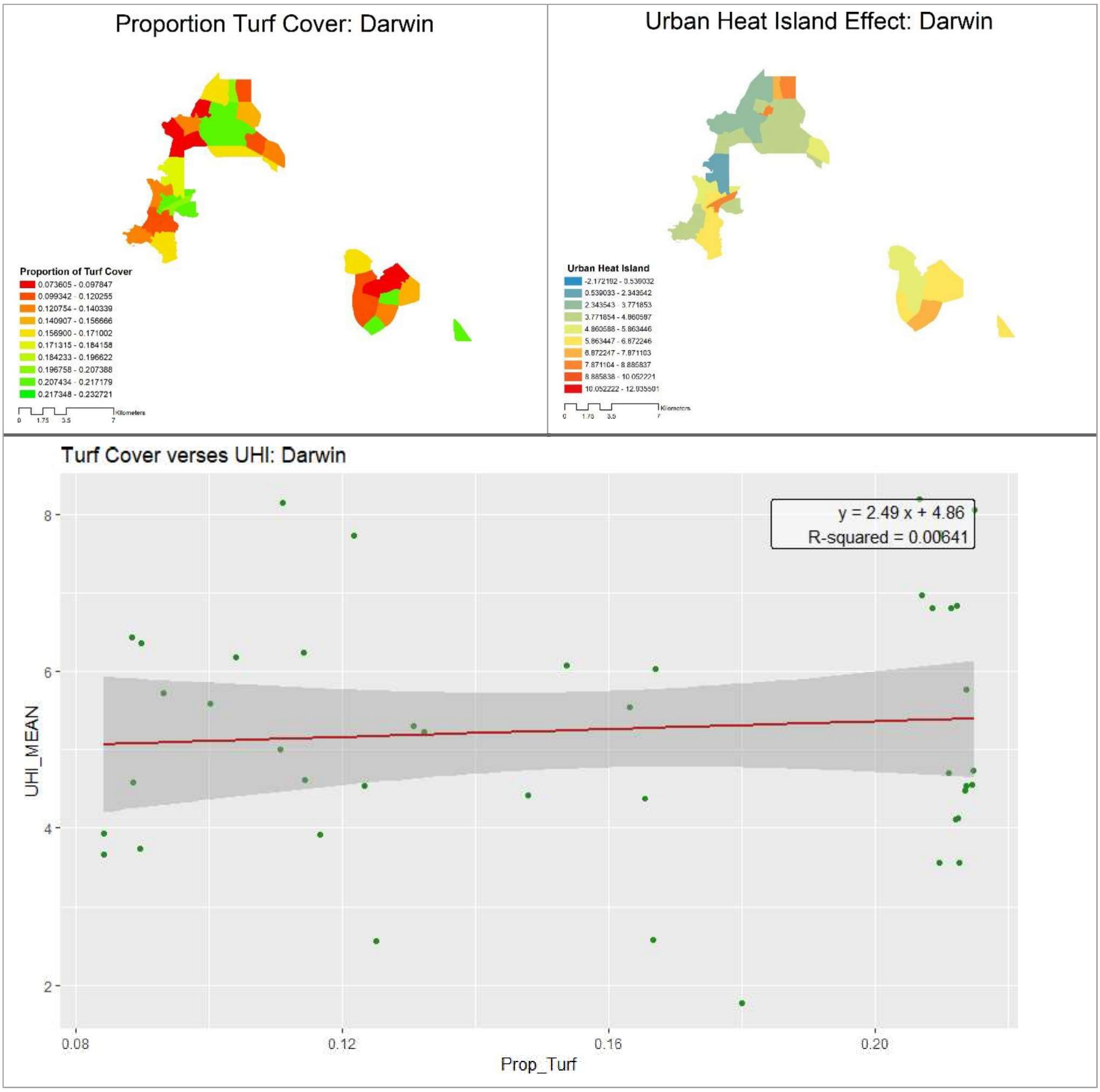
Table 27: Results of OLS regressions predicting mean UHI on turf cover and population density in Perth.

Variable (t-value)	Model 1	Model 2
Constant	1.87	2.13
Prop_Turf	0.89 (0.33) N.S.	0.28 (0.1) N.S.
Pop_Den		-0.92E-04 (-0.69) N.S.
R-Squared	.0004	.002
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

7.1.4 Turf Cover and UHI - Darwin

Figure 23 compares the measured average UHI and estimated total turf cover in Darwin by suburb.

Figure 29: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Darwin.



The OLS regression for Darwin correlating UHI on predicted turf cover and population density are reported in Table 26. Like Perth, neither turf cover or population density are significant predictors of UHI effects. It is possible that summers in Darwin are too humid to allow for the cooling effect of evapotranspiration to impact temperatures.

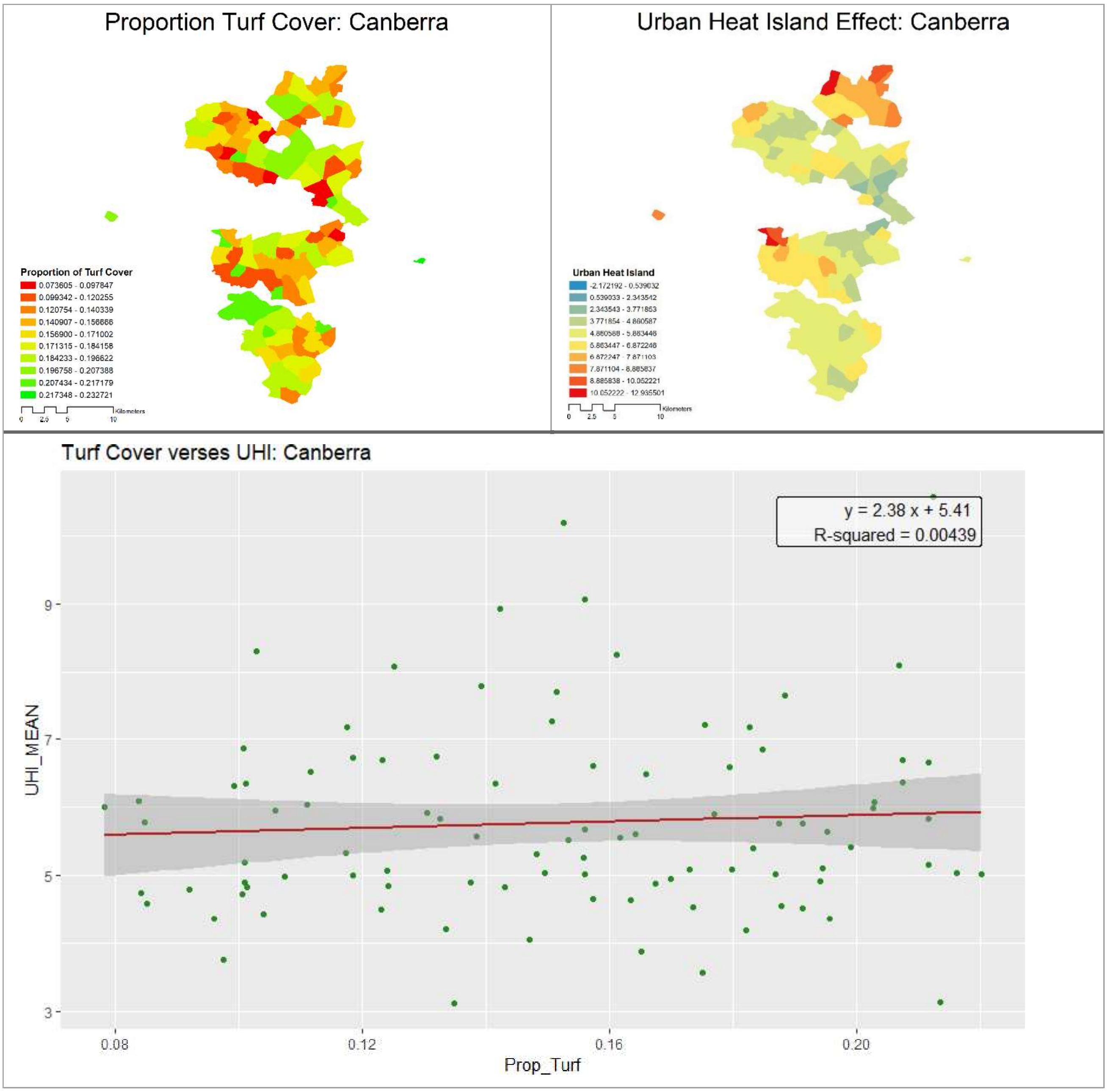
Table 28: Results of OLS regressions predicting mean UHI on turf cover and population density in Darwin.

Variable (t-value)	Model 1	Model 2
Constant	4.86	4.32
Prop_Turf	2.49 (0.51) N.S.	2.61 (0.54) N.S.
Pop_Den		0.0003 (0.83) N.S.
R-Squared	.006	.023
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

7.1.5 Turf Cover and UHI - Canberra

Figure 24 compares the measured average UHI and estimated total turf cover in Canberra by suburb.

Figure 30: Maps and scatter plot illustrating the relationship between the proportion of a suburb covered in turf and the average heat island effect in summer in Darwin.



The OLS regression for Canberra correlating UHI on predicted turf cover and population density are reported in Table 27. Like Melbourne, the results indicate that there is potentially a positive relationship between turf cover and the UHI even when population density is accounted for. UHI effects in Canberra a highest in the northernmost suburbs such as Moncreiff and Bonner, which are relatively newly established. As mentioned earlier, our model of turf cover is static through time, and does not take into account the age of suburbs, which are related to the maturity and establishment of cooling vegetation which could reduce temperatures. If this is the case, then we could expect that as turf grasses (and other plant species) are maintained in newer suburbs, then the UHI effect could be reduced.

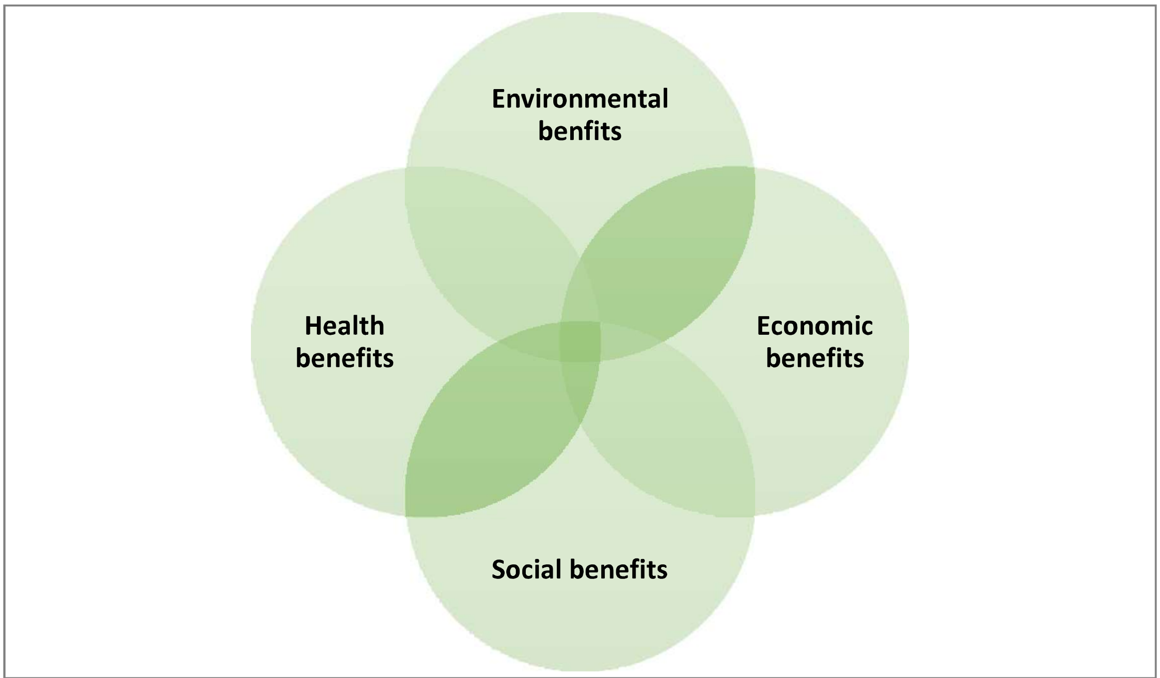
Table 29: Results of OLS regressions predicting mean UHI on turf cover and population density in Darwin.

Variable (t-value)	Model 1	Model 2
Constant	5.41	3.40
Prop_Turf	2.38 (0.64) N.S.	7.68 (1.96) *
Pop_Den		0.0008 (3.09) ***
R-Squared	.004	.097
***, **, * ==> Significance at 1%, 5%, 10% level (N.S. = not significant)		

8 APPENDIX 3: Literature Review

The benefits of turfgrass are wide ranging and in many cases overlap with each other, which can complicate attempts to separate and quantify them. Therefore, when we apply literature values to turfgrass here, BGA has taken the most conservative values and where possible eliminated the chances of double counting benefits.

The benefits described in this literature review will be used to calculate the total benefits attributable to different uses of turf – home lawns, parks, sports fields, median strips and easements, and roadside. The benefits will be compared to an alternative scenario without turf – which requires additional research prior to finalizing but is likely to be bare ground or impervious surface, such as concrete, asphalt, or household-type decking materials.



Each of the benefit streams relevant to turfgrass are examined in the following sections.

8.1.1 Economic Benefits

Economic benefits are those that, broadly speaking, generate measurable monetary value for people.

8.1.1.1 Cost savings from the reduction in cooling needs

Naeem et al (2018) and Bao et al (2016) assessed small region or district level responses to the presence of parks and urban greenspace (described by Naem et al as belts, urban parks and residential green) in a number of large urban cities. They find that the temperature response to a percentage increase in urban greenspace is between -0.04 and - X HowevexX , the specific effect of turf on local air surface temperatures is distinct from trees and woody vegetation and is heavily dependent on irrigation; Broadbent et al (2017) investigated the effect of land use on microclimates in Adelaide and found that v P] v •] v]] P u X / v v • U v] v P Z v • (who found that unirrigated grass in an urban area did not have an impact on the average local air temperatures.

For the purposes of this study, we take a value of -0.018 degrees Celsius to represent the expected reduction in average temperature that a suburb will experience as a result of a one percentage point increase in the proportion of land dedicated to irrigated turf. We also adopt the proportion of irrigated to un-irrigated turf that Broadbent et al measure in their study, which is 6.3%.

Pomerantz (2017) offers a formula for calculating the change in an area's air conditioning energy usage resulting from a change in surface coverage

$$= \frac{}{} \times \frac{2}{6} \quad 6 \times \quad 18$$

Where — is the change in electricity demand 2 due to a one degree increase in air temperature 6 6 is the change in an area's air temperature due to a change in surface coverage, and %18 is the number of cooling hours in a year (the number of hours in the year that the city has temperatures The temperature elasticity of demand for electricity in Australia is well documented, approximately 0.678KWh per day per unit increase in temperature over 20 C per household (AECOM, 2012). We generalize the formula given by Pomerantz to calculate what the average daily temperatures would be in the absence of the greenspace turfed areas provide. We assume that each day above 20 C is a cooling day, with daily energy usage rising for each degree increase above this threshold. We then apply the average summer retail electricity price to the increased demand, and take this value as the avoided cost of cooling as a result of turfed greenspace in each suburb.

The avoided cost of energy usage for Australians due to the temperature reduction effect of turfed spaces can therefore be calculated as:

$$= \frac{}{} \times \frac{2}{6} \quad 6 \times \quad 20$$

Where —— is the change in daily electricity demand DP due to a one degree increase in average daily temperature AT, # 6 is the change in a suburb's average daily air temperature due to a change in surface coverage, and %20 is the number of cooling days in a year (the number of days in the year

Z Z] Z • u •

Air conditioner usage is also responsible for a high proportion of peak demand events in the energy market, especially in warmer climates, where demand for electricity can reach more than double its typical level on hot days. The frequency and severity of these peak demand events are primary determinants of energy infrastructure requirements, and therefore of electricity prices. AEMO (2018), the Australian Energy Market Operator, identified the changing impact of weather on energy demand as one of three key operational challenges facing the national market, highlighting the risks associated with both short-term demand peaks and the system stress caused by prolonged heatwaves. Citipower Melbourne (AECOM, 2012) estimated that its network sensitivity for peak demand is 36.6 MVA (Mega-volt-ampere) for every 1ºC increase in summer daily temperature, pointing to higher infrastructure requirements, lower reliability and increased equipment failures as costs associated with hotter weather.

The full cost savings associated with reductions in the heat island effect due to turfed areas is likely significantly higher than those occurring as a direct result in short-term reductions in individual households' energy usage.

8.1.1.2 Increased House Prices

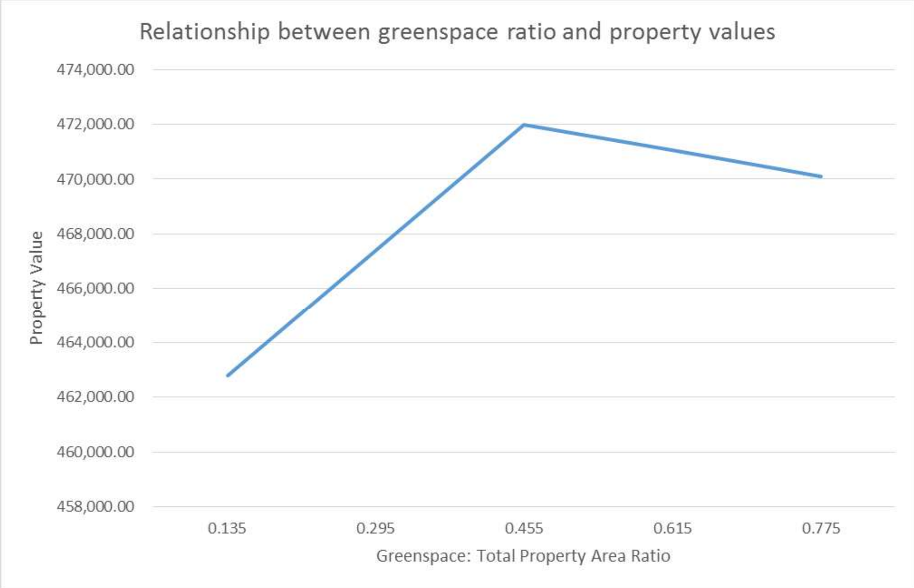
The value of private outdoor greenspace to house prices is widely acknowledged. For example, research has suggested that 82% of people consider the size of backyards to be a significant or very significant consideration when buying a house (Centre for Sport and Recreation Research, Curtin University, 2015), and a national survey of real estate agents suggest that lawns add a considerable margin to house prices (Turf Australia, 2012). However, efforts to empirically measure the exact nature and magnitude of this relationship have been complex and produced somewhat mixed results.

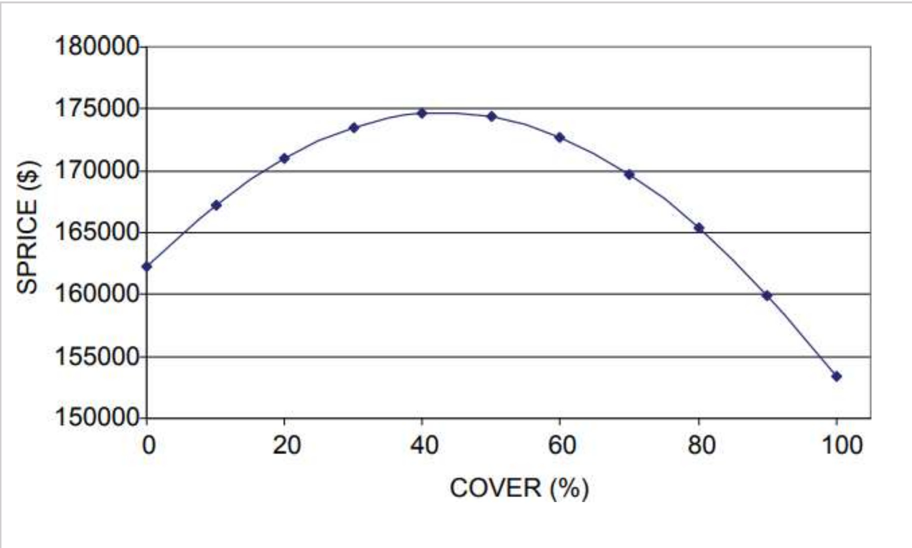
Des Rosiers et al (2002) conducted a study in Quebec and found that each percentage point increase in ground cover adds 0.2% to the sale price of a home. Sander and Haight (2012) examined the problem through investigating the relationship between property prices and the amount of lawn in a house's 'viewshed' and found that a 1-ha increase in the area of lawn that could be seen from a house from the mean, corresponded to a sale price increase of $1,742. Extrapolating Sander and Haight's values to multiple properties would require significant Digital Elevation Modelling and an understanding of garden fence heights and is therefore not replicated here. Sander and Haight's study also note that the mean percentage of tree cover on the parcel itself is not significantly related to the sale price, indicating that it is the amount of lawn that is important to house values not its vegetation composition per se.

Macdonald et al (2010) investigate the ratio of private green space (lawn and garden) to total property area for a number of homes in Adelaide and find that for the median house price and private greenspace:property ratio, the value of outdoor greenery accounted for 3% of the property value. Given the applicability of the Macdonald et al's values to the Australian context, and the relatively straightforward interpretation of the results, we use their study for the purposes of calculating the value of Australian properties. The conclusion that it is the amount of private greenspace, but not the type of vegetation that is significant is supported by results from Stigarll and Elam (2009) that show a similar effect on house prices when increases in tree cover are considered, when compared to Macdonald et al's results– peaking at approximately 40-45% of total lot coverage of greenspace or tree cover, and then declining (Figure 25).

Figure 31: BGA work product adapted from Macdonald et al (2010) (top) showing the impact on property prices due to varying proportions of the lot dedicated to outdoor greenspace for a suburb in Adelaide. And figure (bottom) from

Stirgall and Elam (2009) showing the impact on property prices in a suburb of Texas due to varying proportions of the lot with tree cover.





Sources: BGA Work Product; Stirgall and Elam (2009)

8.1.2 Environmental Benefits

Environmental benefits capture the values that a healthy environment provides through ecosystem services – air and water filtration, habitat, and so forth. Humans place value on the ecosystem services, and literature values can be used to capture these benefits. Several are relevant to the turf industry.

8.1.2.1 Impact of Runoff from Turfed Surfaces

Rainwater runoff is an issue in urban environments for a multitude of reasons. Excess runoff can trigger flooding, as well as carry sediments and chemicals that have adverse effects on water quality in rivers and coastlines. Managing storm water also entails the construction of considerable water transport and storage assets, which require maintenance and periodic replacement. The costs of constructing and maintaining stormwater systems may place strain on urban authorities' (LGAs, metropolitan authorities) budgets as the pace of urbanisation and densification accelerates.

Zhang et al (2012) calculated that the value of rainwater reduction per hectare of urban greenspace was 21.77 thousand RMB (2018AUD $132,839.81), on the basis of the costs of rainwater storage, as well as water treatment, in Beijing. Similarly, Crompton (2012) estimates that the avoided cost of storm water treatment in Houston, Texas is $0.00065/gallon (2018AU$**0.00024/L**) based on a study of urban greenspace connectivity infrastructure. However, these do not explicitly define the concentration of nutrients in runoff from turfed and impervious areas – these are provided by Baron and Donn, CSIRO, (2010) who find that the volume of TN in runoff from turfed and impervious surfaces are 3.76mg/L and 0.45mg/L respectively. Completing the picture requires an understanding of how runoff from turfgrass differs from impervious serfaces.

Krenitsky et al (1998) examined the total amount of runoff compared with bare soil and found that turf grass reduced the volume of runoff by 61%. Hoffman and Dozier also examined the effect of turf grass on runoff and found that the average suburban lot of turf (10,000 sq. ft.) can absorb more than 6,000 gallons of water without noticeable runoff. Zhang et al (2012) provide a number of rainfall runoff coefficients indicating the percentage of precipitation that appears as runoff for public greenspace (12.1%), roadside greenspace (25.3%), and residential greenspace (9.9%). However, the amount of rainfall captured by turf is highly dependent on the magnitude of individual rainfall events, as well as the capacity for the soil to absorb moisture. The runoff curve number has been developed by the USDA Natural Resources Conservation Service (NRCS) (1986), given by:

$$3 = \frac{(\ 2\ \ 0.1755)^{6}}{2\ \ 3.56}$$

Where Q is the runoff (mm) associated with a precipitation event, P (mm). The constants are calculated based on a standard initial abstraction coefficient (I) of 0.05, and a standard Curve Number (CN) coefficient, 74, associated with soils that are slow to infiltrate when thoroughly wet in fully developed urban areas covered by turf (>75% ground cover) in good condition. Under these conditions, turf will capture between 45% of rainfall during a 5mm rainfall event, and 13% of rainfall in a 25mm rainfall event. We calculate, using data from the Bureau of Meteorology, the average rainfall event for each suburb using the average annual rain days over 1mm divided by the average annual rainfall.

The cost of increased runoff to public infrastructure is the most measurable and direct cost to society that is avoided due to having turfed green spaces. We assume that society as a whole builds storm water management infrastructure to the point where the negative externalities associated with runoff, including nutrient loads, sedimentation, and other poor environmental outcomes are socialised.

Foraste et al (2011) define the total costs of runoff in terms of dollars per cubic foot per year, taking into account life cycle and asset replacement costs, best management practice, operations and maintenance, as well as the avoided costs of alternative strategies, equivalent to 2018AUD$0.034/mgTN/year. The costs associated with runoff from turf grass are calculated on the difference between the amount of runoff captured by turf in each suburb compared to the base case of that same area being bare ground, that is, with a CN coefficient of 91. However, while we measure and cost the impact of nutrient runoff from turfed compared to impervious surfaces, it is important to note that the impervious surfaces we are comparing to are a combination of paved and synthetic turf. Synthetic turf is a significant source of other types of pollution, such as microplastics. A single sports field loses between 1.5-2.5 tonnes of rubber into the environment each year, the full economic, environmental, and social impacts of which is still under-studied (Kole et at). Significantly, while stormwater systems are typically designed to allow nutrients such as nitrogen to break down, microplastics are persistent in the environment for much longer.

8.1.2.2 Carbon Sequestration

The benefits of carbon sequestration are difficult to define, as they are wide ranging and impact on every aspect of the built and natural environment. The precise level at which greenhouse gases should be priced is matter of continuing debate, however the 2011 AUD$30/tonne of carbon dioxide nominated by Garnaut (2011) is aimed at the price it would have to be assigned in order to meet Australia's targets for greenhouse gas reduction. Despite the fact that greenhouse gas targets have changed since then, with the ratification of the Paris Agreement, the absence of an implicit or explicit market price of carbon dioxide in Australia means that we adopt Garnaut's 2011 estimate, noting that the "real" market price for carbon is likely to have increased since that date due to more ambitious targets.

Qian and Follett (2012) examine the ability of turf grass to sequester carbon dioxide in urban ecosystems, and find that during the first 25-30 years, turf can be expected to sequester 0.34-1.4 Mg/ha/yr. We therefore apply this rate of carbon sequestration to turf throughout Australia, along with Garnaut's nominated price on carbon.

8.1.3 Emotional and Physical Well-Being

The array of benefits that turf brings to people is a long list of public goods that range from the creation of community spaces that allow people to socialise outdoors, the opportunities to engage in sport and physical recreation, and the mental health benefits that arise from these, as well as the health benefits associated with moderated urban heat island effects. These benefits cross over, and interact with each other, to the effect that separating out values for each of them in neat baskets is impossible. For example while we might attempt to value benefits to mental health, it is unclear how much of that is due to being able to have a picnic with family, or playing sport, or just knowing that green places exist in the city.

Economists call the aggregate benefits that turf grass might bring somebody its amenity value. Amenity values encompass many benefits, such as the ones that are discussed here, but may also capture benefits unknown to us. For example, it may be that people simply enjoy the colour green, or playing in the sprinklers in the park. All these, and more, are captured in the Willingness-To-Pay (WTP) for turf in one's neighbourhood in the form of public parks and sports fields. However greenspace does not just include turf, but may also include trees, shrubs, and flowerbeds. Nordh et al (2011) investigated the different components of public parks that visitors found were important when using them for 'psychological restoration', and found that grass was the most important component (Figure 26).

Figure 32: Figure from Nordh at al (2011) illustrating the differing levels of important visitors placed on different components of a park they visited for recreational purposes.

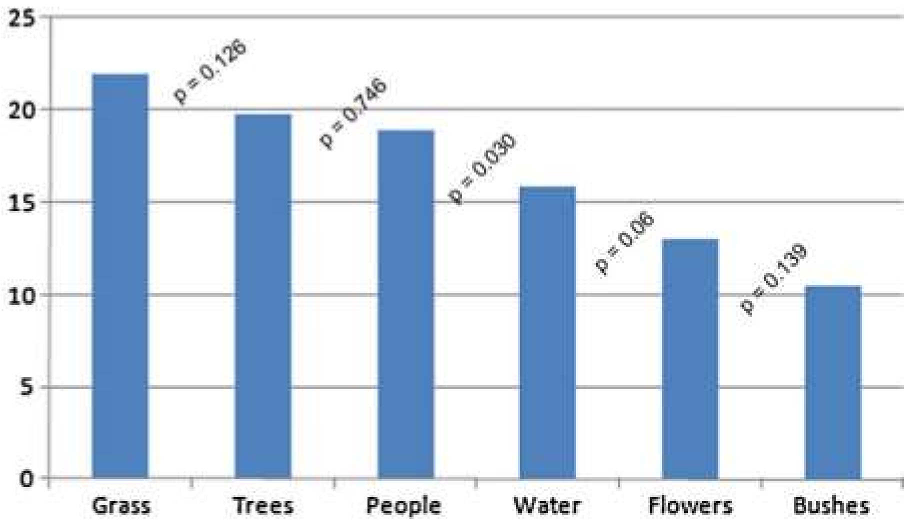


Fig. 5. Average importances for the six park components. As presented in the figure, grass is the most important component, followed by trees and people. In the choice situation the respondents put the least emphasis on bushes. All components sum to 100%, which reflects the whole park alternative. The *p*-values refer to the differences in average importances between adjacent components.

Source: Nordh et al (2011)

However Dwyer et al (1989) found that people were willing to pay more to visit parks that were more heavily wooded rather than those which had more turf. Table 1 illustrates a comparison of three different types of parks, using Dwyer et al's WTP values, one with moderately scattered trees with some dense woods, one with mowed grass but very few trees anywhere, and one with mowed grass, very few trees and an athletics field. The results suggest that without the amenity provided by trees, parks and sports fields would have a value approximately 93% and 62% of what we would consider to be the 'typical' park.

Table 30: Calculated values adopted from Dwyer et al (1989) outlining the proportional value of different types of parks with different levels of turf and facilities. Dollar values are in 1989USD.

Park Type	Description	Willingness to Pay	Proportional Value Compared to the Typical Park
Typical Park	Mowed grass with some scattered trees, some dense wood. Contains a picnic area and facilities as well as children's play equipment and biking trails.	$14.14	100%
Predominantly Turf Park	Mowed grass with very few trees anywhere. Contains a picnic area and facilities as well as children's play equipment and biking trails.	$13.15	93.0%
Predominantly Turf Sports Field	Mowed grass with very few trees anywhere. Contains athletics fields.	$8.73	61.7%

Ambrey and Flemming (2014) conducted a study investigating the link between public greenspace (which includes parks, community gardens, cemeteries, sports fields, national parks, and wilderness) and life satisfaction in urban Australia, and found that the implicit WTP per household per year for a 1% increase in public greenspace (143m^2 on average) in the local area was 2012AUD$1,172 – equating to an average marginal WTP for greenspace of approximately $8.19/m^2. However, conventional wisdom suggests that the value of greenspace per metre squared is likely to be larger where there is less greenspace, and smaller where there is more greenspace. This is of particular relevance, given the average suburb surveyed by Ambrey and Flemming constituted less than 1% public greenspace, which in turn may partially explain the high marginal value they report as an "average".

We apply Ambrey and Flemming's WTP value to find the marginal value for 1m^2 of any greenspace in a suburb and use that value to calculate the total value of turfed greenspace in that suburb. However, we take a conservative approach to its use, noting that the value of public greenspace in their model is statistically significant only at the 10% level, and has a wide standard error[3]. We therefore modify the WTP value, taking a lower estimate of the public greenspace coefficient one standard deviation below the mean[4], that is, a WTP of 2018AUD$614 for a 1% increase in public greenspace.

We apply this value to public parks and sports fields in Australia as an umbrella value for all benefits that flow from emotional and physical well-being. However we also modify the values using the proportions derived from Dwyer et al's study, described in table 27, to arrive at a value of 2018AUD$571 for a 1% increase in greenspace that are turfed public parks, and 2018AUD$381 for a 1% increase in greenspace that are turfed sports fields. In order to give context and meaning to these values, we examine these benefits in greater detail below.

8.1.3.1 Social Benefits – The Creation of Community Spaces

Frances et al (1998) conducted a study of inner-city neighbourhood common spaces and found that greenness in and around apartments was correlated with the assessments residents made of their

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[3] Co-efficient of Public Greenspace modelling life satisfaction: 0.0032* (S.E. 0.0017)

[4] $(\frac{.44\ 4\ 7.4\,6\ 4\ 5}{.44476}) \times \$1,172$

neighbourhood's social ties. Sugiyama et al (2008) found a statistically significant association between local social interaction (the number of days engaged in social interaction) and neighbourhood greenness. Sugiyama et al also extrapolated relationships between neighbourhood greenness, social interaction, physical activity, and mental health, finding all of them to be highly interdependent, confirming that urban green space, including turfed areas, is a nexus for multiple public goods.

8.1.3.2 Physical Health and Well-being

Mekala et al (2015) in their study of business cases for public investments in urban green infrastructure draw upon a number of non-market benefits for greenspaces. These include the avoided health cost benefits through increased physical activity levels. They adopt literature values that suggest that the average cost of physical inactivity in Australia is approximately 2015AUD$757 per physically inactive person[5] per year. Mekala et al (2015) extrapolate to estimate the effect of a single park on increasing the number of physically active people in its catchment between 10-15% and find that the avoided social health costs could range between $11,574 and $75,049 per year.

Coombes et al (2010) investigate the relationship between physical activity and accessibility of greenspace. Using their results, we can infer that the difference in likelihoods of people meeting the physical activity guidelines in the 1st quartile (people close to greenspace) and those in the 4th quartile (people far away from greenspace) was approximately 5%.

If we took the step of assuming that the number of people who were physical inactive throughout Australia would increase by 5%[6] in the absence of all turfed public areas, from 66% to 71%[7], the associated social costs would amount to 2015AUD$944,704,168 per year – almost one billion dollars.

8.1.3.3 Mental Health and Well-being

The link between greenspace and better mental health outcomes is generally viewed as being positive by researchers. Lee et al (2017) estimated that the annual cost of mental illness in Australia was $12,800,000,000 each year, including depression, anxiety, and substance use. Nutsford, Pearson and Kingham (2013) investigate the association between access to urban green space in New Zealand (parks and sports fields, not natural areas or private land), and find that every 1% increase in the proportion of green space within 3km was associated with a 4% lower anxiety/mood disorder treatment. While it may be possible to attempt to value each 1% proportion of urban land occupied by turfed greenspace in relation to a reduction in metal health disorder treatments, of approximately 4% of $1.535B ($61.4 million dollars a year), the change in the number of people seeking treatment does not necessarily lead to a proportional change in the costs of treating mental health disorders as a whole *per se*. When it comes to the larger cost to society, productivity losses, the relationship with greenspace and mental health disorder morbidity is far more tenuous.

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[5] Defined in the Social Health Atlas of Australia 2011

[6] Coombes et. al. (2010) used data from the 2005 Bristol Quality of Life in Your Neighborhood Survey to assess the relationship between physical activity to green space accessibility. They found an odds ratio of 0.88 for achieving physical activity guidelines for the quartile of respondents living nearest (<830 m) against those living furthest (>2250m) from their nearest formal green space. 39% of all respondents achieved physical activity guidelines. The difference in likelihood of an individual attaining physical activity guidelines when moving from the 4th to 1st distance quartile (Pr[active|close] - Pr[active|far]) was calculated using simultaneous equations assuming Pr[active|far]/Pr[active|close] = 0.88, (Pr[active|far]+Pr[active|close])/2 = 0.39. This gave a result of 0.0498, or approximately 5%.

[7] Australian Social Health Atlas, 2014-2015

Nutsford et al also suggest that the decline in mental health disorder treatments in relation to available greenspace is a mixture between active use and a 'background' effect – the view of greenspaces from the home or workplace, or simply knowing they exist. Gronewegen et. al. (2012) find that stress and social cohesion, and to a lesser extent physical activity levels, are the primary mediators of the relationship between greenspace and mental health. Sugiyama et. al. (2007) showed that while recreational walking and social coherence were strongly associated with self-evaluated mental health scores, perceived greenness remained a significant predictor of mental health once these variables were controlled for. This implies the presence of additional factors at work. The authors suggest that the 'residual' route of causation may be due to the naturally restorative effects of green or natural environments on human health. Such an effect could be partially or fully captured by the stress variable in Groenewegen's analysis.

8.1.3.4 Health Impacts due to Urban Heat Island Effects

The urban heat island (UHI) effect describes the elevated temperatures that occur around heavily urbanised areas due to their capacity to absorb heat and reduced capacity to release it. Urban green space is recognised as a way to reduce UHI effects through the provision of shade, and ability to lose heat through transpiration. The consequences for elevated temperatures can be dire, Nicholls et al (2008) examined the effects of elevated temperatures in Melbourne and found that when the mean] o u people aged 65 years orZ • Z over is between 15- A9 Z] P Z Z v • o U v Z mortality for that same cohort is between 19-21% greater.

The City of Melbourne (2012) estimated the cost of elevated temperatures to ambulance attendance, emergency department presentations and mortality to be $4,838,500 per year for the portion of the city which falls under its jurisdiction (mostly the Melbourne CBD and inner city suburbs). The study attributed the detrimental effects of the UHI effect to several pathways:

- Health
- Transport operation and infrastructure
- Energy demand and infrastructure
- Anti-social behaviour
- Trees and animals
- Major Events

Energy demand is dealt with in an earlier section of the literature review, and the Amenity value for greenspace is taken to represent to some degree the value that people place on living in cooler areas as a benefit to their health, and the social fabric of their neighbourhood.

Estrada, Botzen and Richard (2017) take into account the effect of climate change on the GDP of cities throughout the world under different climate change scenarios, taking into account the UHI effect. Table 2 summarises the reduction in GDP for the median city in 2050 and 2100 under two different climate change scenarios, illustrating that UHI effects may double the GDP costs of climate change under different scenarios.

Table 31: Results from Estrada, Botzen and Richard (2017) summarising the effects on city GDP due to climate change when the UHI effect is and is not taken into consideration.

		Climate Change Scenarios			
		RCP4.5		RCP8.5	
		No UHI Effect	UHI Effect Included	No UHI Effect	UHI Effect Included
Reduction in GDP of the median city in Year:	2050	0.7%	1.4%	0.9%	1.7%
	2100	1.2%	2.3%	3.9%	5.6%

Given that the GDP of Australia's major cities are considerable (Sydney, for example, had a GDP of $400B in 2015-16), the benefits of limiting UHI effects are likely to be material. Estrada et al take into consideration the Benefit Cost Ratios of various UHI abatement policies, including green roofs and cool pavements and find that all levels of investment they consider exhibit BCRs greater than 1.0, with option B: Moderate investment, having a BCR of 12.9 under the most conservative climate change scenario, and 6.0 in a no climate change scenario. The productivity costs of climate change for Australian cities are likely to reach billions of dollars by 2050, up to 50% of which will be attributable to the UHI effect, if we apply Estrada's assessment. Turf has a significant and highly valuable role to play in mitigating these costs

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