PUTTING A DOLLAR VALUE ON URBAN FOREST BENEFITS

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Abstract

Many studies on the benefits of trees and urban green space have been completed in recent years, an increasing number of which calculate monetary value for what are currently non-market benefits. Published economic and financial benefits relate mainly to five services: amenity, shading, air quality, carbon sequestration and water management. Of these, amenity and shading provide the greatest economic benefit. Other benefits such as increased human productivity, reduced crime and enhanced biodiversity are increasingly being studied. Literature reports a massive increase in recent years in studies relating urban ecosystems to human health. Exposure to urban vegetation has been shown to be beneficial in terms of reducing the occurrence and seriousness of conditions including dementia, ADHD, and cardiometabolic disease, as well as being associated with healthier birth weights, better sleep, and increased physical exercise. Financial values have been calculated for these benefits. Other benefits, such as those related to childhood obesity, depression, and healthy gut microbiota, have not yet been quantified in economic terms. Other services such as those related to pollination, reduced wind velocity and amelioration of microplastics will also become better defined and quantified as further studies are done. Whilst these benefits and services are currently not paid for in the market, the consequences of loss of urban vegetation are being paid. Loss of urban vegetation results in increased stormwater discharge and related costs due to flooding, presentations for medical treatments for conditions which might otherwise have been prevented, and greater energy consumption and cost for home cooling and heating. This paper summarises the non-market benefits and services to which studies have either attached a dollar value, or to which a dollar value can be attributed.

Introduction

Studies on the benefits of urban green space have shown it moderates environmental impacts of urbanism and provides significant physical and mental health benefits. There are two types of benefits and services derived from trees – market (or commercial) and non-market. Market benefits include tradeable goods such as food and timber that can be harvested from orchards or commercial forest and marketable services such as entry fees for parks or reserves or carbon dioxide sequestration credits. Non-market benefits may have economic or financial value, but these values may be less tangible and are not currently traded in markets.

Some urban tree or ecosystem services can be neatly measured in financial terms. A reduction in storm water infrastructure costs may be based on volume of rainwater retained by trees or ecosystems, for example. Other services provided by urban trees or ecosystems are not easily measured in financial terms, if at all. Some of these services may be measured in relative ways, using a 'cost-effectiveness analysis', for example. Such analyses compare the results of two or more courses of action, where outcomes themselves can be counted and compared. Examples could be

- in regard to physical or mental health costs, a reduced number of presentations for treatment, reduced cost of prescribed medication, or a reduced number of disability-adjusted life years;
- for urban heat island or climate change mitigation strategies, the decrease in temperature;
- for human development benefits, added IQ points or cognitive gains for children.

Other techniques which can be used to attribute monetary values to non-market services are broadly categorised under 'stated' or 'revealed' valuation methods. Stated valuation methods rely on surveys in which people are asked about their preferences. The two main stated valuations methods are the contingent valuation method and choice experiments. The contingent valuation method uses a hypothetical scenario to find out how much people are willing to pay to improve an outcome given a range of alternate costed scenarios.

Revealed valuation methods look at what consumers actually do and the prices they pay, rather than what they say they might do. The ‘hedonic method’ is a revealed valuation technique which relates market sales of a commodity to non-market benefits. For example, property sales prices when compared with proximity to green space often show higher prices for houses closer to the green space. This non-market value is termed the ‘amenity value’. The ‘travel cost method’ is another revealed valuation technique which is based on a comparison of the number of times a place is visited to the cost of visiting it. Methods to assess avoided costs such as foregone medical expenses if one maintains good health (or does not fall ill to a particular condition), or from averting undesirable behaviour, have also been heavily used in the literature regarding the impact of urban nature on human health.

Monetary value is among many values attributed to trees, and potentially of lesser importance than others. It is only one way of considering tree value and it may not be a suitable metric in some situations. Some attributes of trees may never be measurable financially, such as historical and cultural connections with Aboriginal shelter trees, canoe trees and others, and personal attachments to trees planted as memorials. Trees like the Tree of Knowledge in Barcaldine, Queensland, Melbourne’s Separation Tree, the Glebe Grey ironbark and Moreton Bay Figs in Sydney; South Australia’s Proclamation Tree, the Crowhurst Yew in Surrey, UK, Sir Isaac Newton’s Apple Tree, and the offspring of the Liberty Tree in the United States and the Lone Pine in Australia. Many such trees may be considered beyond price by some. Different methodologies to represent these values may need to be developed.

Attaching a monetary value to benefits and services provided by urban trees will, however, assist their incorporation as ‘green infrastructure’ in engineering and urban design related decision processes, as government and business decisions are often based in economics. As urban trees can provide a net economic benefit, then they should be included in benefit/cost analyses.

The benefit of urban greenspace during local or global crises has recently been highlighted during COVID-19 lockdowns. Access to public and private green space has been linked to better health and wellbeing and has been found to be an essential health resource in times of crisis (Poortinga et al., 2021). Lu et al. (2021) reported that higher proportions of green space were correlated with lowered rate of infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) across the USA. Lu et al. (2021) suggested that adequate provision of accessible and well-designed green space in urban areas, and preservation of natural green spaces across counties, should be incorporated into epidemic and pandemic resilience strategies for highly urbanized areas.

This paper summarises the results of reviews which identified benefits and services provided by urban trees at an individual tree level, species level, or broader urban forest (ecosystem) level. The focus of this paper was primarily on studies which attributed financial values to these services. The paper includes some project specific studies which related Australian data.

Method

As an initial investigation of the methods used to attribute monetary values to trees, this study sought to review the many papers published on the benefits of urban trees and vegetation in recent years. An initial literature search using keywords related to the economic value of urban trees in one database alone yielded 8,114 papers, the majority published since 2015. Given the scale of this literature, to capture the most relevant information this review focused on those papers which themselves were a review of other studies. The literature review was limited to papers published in the last 5 years; this included approximately 200 review papers. Abstracts of these review papers were first read to confirm their relevance to the topic. Peer reviewed academic papers specific to Australia and Australian technical reports, or papers considered to be of benefit due to their economic analyses, were selectively included. In this way, the resulting number of papers reviewed and summarised in this narrative was reduced to 60.

Literature Review

In a major seminal paper on the value of ecosystem services, the economic value delivered by natural systems across the global biosphere was assessed at US $33 trillion dollars annually (in 1994 values) (Costanza et al. 1997). Most of these services were non-market values. Since then, specific research on the economic value of a range of ecosystem services has been undertaken. The most recent reviews of monetary values associated with services provided by urban trees are summarised below. This is followed by further detail for specific services and benefits of trees and urban vegetation, apart from those specifically related to health. Health-related benefits are described in a separate section. Other benefits which have been highlighted by papers but have not yet had a monetary value placed on them are summarised at the end.

General reviews of non-market values

Song et al. (2018) systematically examined literature which jointly analysed both the costs and benefits of urban trees. Thirty-four original research papers published between 1992 and 2016 were reviewed and, where multiple studies reported values, their monetary values were reported as averages. Most of the studies were based in North America.

Monetary values reported related mainly to five services provided by urban trees: amenity, shading, air quality, carbon sequestration and storm water management. Overall Song et al. (2018) reported that the majority of the research focused on values which did not provide the greatest economic benefits of trees. They found aesthetic, amenity, and shading benefits of trees were less studied but of greater economic value than those related to air quality and carbon regulation. They noted that the studies available in the literature were 'snapshots' in time for the benefits and costs of urban trees, whereas trees are often long lived and can change over time. Of the 26 papers they reviewed which undertook a benefit cost analysis, 22 showed the benefits outweighed the costs. The mean benefit:cost ratio across all studies was 5.43, and the median 2.72.

In keeping with this finding, two South Australian studies (Smart Rd, Modbury and Felixstow wetlands, Felixstow), calculated urban vegetation-related monetary values in relation to health, water quality, stormwater run-off attenuation and amenity (termed 'neighbourhood character') (Martinez et al. 2019). The highest monetary benefit was calculated for amenity, based on '*willingness to pay for living in a greener neighbourhood',* by using residential property values as a surrogate measure. Using extensive evidence associating close proximity to green infrastructure with higher property values, they estimated a 4% increase in the value of those properties for each 10% increase in greening.

In another 'willingness to pay' review, Bockarjova et al. (2020) considered 60 primary studies on economic valuations of green and blue nature in cities worldwide. Suggesting that the willingness to pay method captured a wider variety of use and non-use values than revealed preference studies which only captured direct use values, Bockarjova et al. (2020) found green and blue space values for recreation, preservation, aesthetics, climate regulation, noise reduction, flood regulation and cultural services. Interestingly, the values related to Gross Domestic Product (GDP) per capita. GDP is generally higher in developing countries and often associated with higher urbanisation and reduced connection to nature, so these values are likely to increase with expected further growth in per capita GDP and continued urbanization globally.

Mangroves were found to 'provide many ecosystem services including provisioning (e.g. timber, fuel wood and charcoal), regulating (e.g. flood, storm and erosion control; prevention of salt water intrusion), habitat (e.g. breeding, spawning, and nursery habitat for commercial fish species, biodiversity), and cultural services (e.g. recreation, aesthetic, non-use)' (Brander et al. 2012). Monetary values attributed to these services are detailed in later sections.

Green space and natural urban areas such as wetlands, and other spaces that assist in the management of surface water, often overlap with values and benefits attributed to 'water sensitive urban design' (WSUD). WSUD aims to minimize negative influences of urban development on the hydrological cycle through green engineering to deliver economic, environmental and social benefits (Castonguay et al., 2018). A review of 194 studies from around the world which valued non-market benefits of water sensitive urban systems identified over 400 non-market values (Gunawardena et al. 2020). Of these non-market values attributed to WSUD, 30% related to green infrastructure values related mainly to urban amenity and recreational opportunities.

In recent years, studies of the human health benefits of urban trees and green space have added significantly to previously published values. Literature published up to the end of September 2019 was reviewed by Chen et al. (2020); it revealed correlations between urban nature and positive health effects on humans, but reported that few studies attributed financial values to these benefits. 4 peer reviewed journal papers, 1 book chapter and 5 reports from the US, UK and South Korea reported that very substantial financial savings could be made by using urban nature to improve human health or to prevent harm. Health-related values are described in a later section.

Values of specific benefits and services

Findings which attributed monetary values to specific benefits and services of urban trees and vegetation are presented in this section. Dollar values were converted to 2021 $AUD values except in some few cases where it was more appropriate to specify US dollar values. Averaged values and Australian research data are presented below; all attributed values that were identified are listed in Appendix 1.

Averaged monetary values of the most frequently studied benefits are given in Song et al. (2018) and presented in Figure 1. These benefits were incrementally added to a value based on the physical structure of a tree (nominally $3,500 in Figure 1). This base value would be calculated using methods such as the Burnley Method, Helliwell or Standard Tree Evaluation Method, or other such methods. The $3,500 base value presented in Figure 1 is considered highly conservative and representative of a relatively small tree.

The additional monetary values are based on 20 years of tree service life, as averages of values that would likely be lost should an established tree, with for example a nominal life of 60 years, be removed 20 years prematurely. Such values might be considered if a healthy tree is removed prematurely, as the loss would not be limited to the structural value of the tree but also to loss of benefits in the replacement tree's sapling stage until it matures, i.e. seedlings and saplings do not provide the same services as a 40-year-old tree. However, as trees reach 20 years of age, they will be contributing benefits including some with financial value. In Figure 1 a simplistic approach is taken, and it is assumed that around 20 years of financial services from an established tree will be lost if it is removed and replaced. As an example, if the amenity or shading benefit is $250 per tree per year on average, this would equate loss of benefit worth $5,000 ($250 x 20 years) per tree. A calculation of how many new trees it takes to offset the removal of a healthy mature specimen might be based more reliably on leaf area, as proposed in Nowak and Aevermann (2019), as this attribute dominates in determining structural and functional value of trees. However, no single attribute can yield an indication of all tree-related services so calculated values will likely remain conservative.

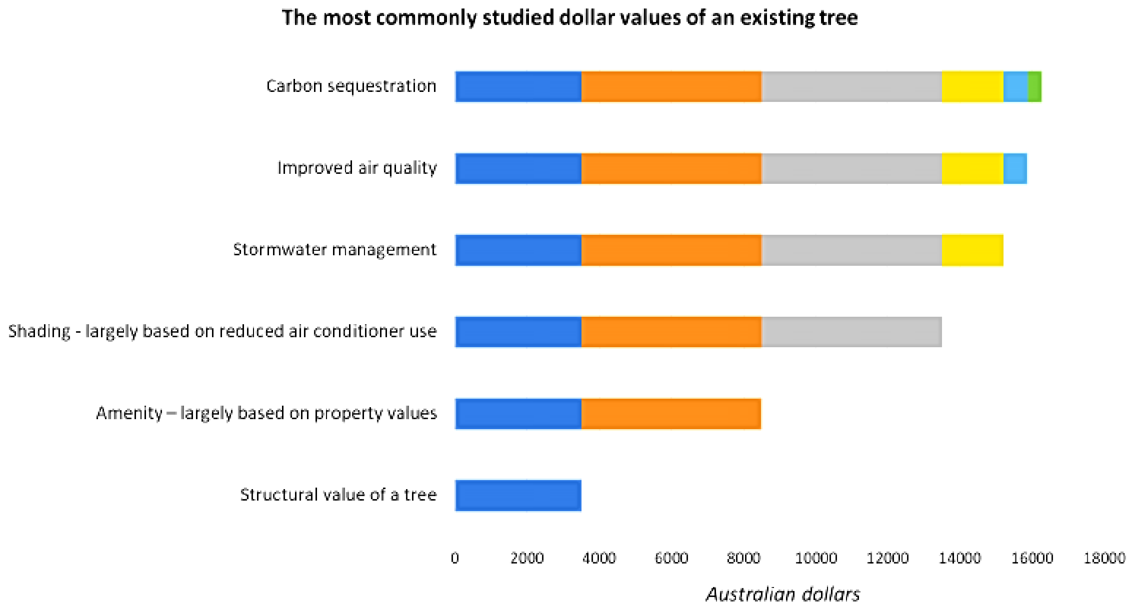

Figure 1. Averaged monetary values of the most studied benefits showing the monetary values that can be added to the structural base value of a tree (from Song, et al. 2018). The additional monetary value for every benefit is based on 20 years of tree services that would be lost should an established tree be replaced.

Aesthetic/amenity values

Amenity values for trees attributed using hedonic methods ranged between $13 and $270 per tree (Song et al. 2018). Pandit et al. (2013) reported that median property prices in Perth, Western Australia, increased by $23,290 due to broad leaved trees on street verges. Pandit et al. (2014) found that a 10% increase in tree canopy cover on adjacent public space increased properties by around 1.8% of the median property price. This equated to an increase of AUD $18,400 to the median property price (Gunawardena et al., 2020).

Analysis of 2,299 house sales across Brisbane, Queensland, found that houses with 50% or greater tree cover on the footpath within 100 m sold for 3.7% more than other houses (Plant et al. 2017). The price increase for a 1% increase in footpath tree cover within 100 m was between US $312–$393, or a premium of between 0.08–0.10% when evaluated at median house price. Flow-on effects in 2009-2010 to property tax revenues were estimated at $US 0.84–0.87 million in annual rates revenue to the council, and an estimated $US 0.87–0.98 million in stamp duty revenue to the state government.

Local values of green infrastructure stated in Martinez et al. (2019) for roadside greenery in five suburbs in South Australia were based on a 4% increase in property value for every 10% increase in greenspace. In 2019, the addition of trees, raingardens and wetlands along various stretches of road resulted in an overall calculated benefit from $28,277 (Florence St, City of Unley) to $ 4,426,523 (Felixstow wetlands, Felixstow) within the project's first 30 years.

Shading and temperature reduction

Song et al. (2018) reported that the benefit with the second highest economic value (second to amenity value) was due to reduced use of air conditioning in response to increased shading. Net energy savings of between 12 kWh and 919 kWh per tree per year were reported, supporting customer savings of between $6 and $270 per tree per year.

Nowak et al. (2017) indicated reduced energy use of residential buildings due to the shade, evapotranspiration cooling impact and wind velocity reduction of trees around buildings in the US. Overall, the US urban/community forest annually decreased energy use by 7.2%. This equated to savings to consumers of US$ 7.8 billion per year. Of this, savings of US$ 4.7 billion resulted from reduced electricity use for cooling and US$ 3.1 billion for heating. Shading also improves urban forest resilience, and protects asphalt roads and footpaths from heat-related degradation. Detailed investigation of these benefits is required.

Mitigation of the Urban Heat Island effects

Urban heat island effects are increasingly reported and quantified globally; urban areas become significantly warmer than surrounding rural regions during the day and radiate additional heat during the night. Studies have reported strong correlations between urban heat island effects, increased heat-related morbidity and other negative outcomes including impacts on human health, energy costs, thermal comfort, labour productivity, and antisocial behaviour (Yenneti et al. 2020). Urban heat island intensities (the temperature difference between urban and peri-urban areas) ranged between 1.0 °C to 13.0 °C (Yenneti et al. 2020), and for every degree rise in temperature above 18 °C energy consumption for cooling increased by 0.5% to 8.5%. The cooling energy demand of urban buildings was at least 13% higher than similar rural buildings. Urban overheating may also impact the Australian economy by reducing labour productivity (Yenneti et al., 2020).

Bayulken et al. (2020) included reviews of literature which showed urban heat can be reduced by 3◦ to 5◦ C across different cities and urban settings by increasing tree canopy. In Australia, Yenneti et al. (2020) found that urban greenery, especially trees and hedges, had high potential for urban heat island mitigation. The economic value of urban heat island mitigation was calculated for a precinct in Melbourne - a maximum greening scenario resulted in 2 degrees of cooling, which was valued at over AUD$1,500 per household over the 50 year study period (Newton and Rogers, 2020; Whiteoak and Saigar, 2019). Gunawardena et al. (2020) noted a lack of research on the economic value of urban heat island mitigation through greening.

Storm water management

Trees can intercept, absorb and adsorb rainfall on their leaves, branches, and bark, and stem-flow increases soakage into the soil beneath their canopies. This interception decreases the volume of water entering the drainage system during rainfall events. Infrastructure can also divert stormwater to provide passive irrigation for trees, which can result in savings for water management downstream (Nowak et al. 2018).

The scale and cost of stormwater management infrastructure can be reduced by using urban green spaces, trees and other vegetation. Bayulken et al. (2020) reported runoff from impermeable surfaces of between 50% and 90%, compared with runoff from vegetated areas of 13% (Elmqvist et al., 2015). Tree canopies can intercept between 4% and 50% of annual or seasonal rainfall depending on their canopy size, leaf area index, the local climate, and the intensity of urban heat island effects (Vilhar 2017). Song et al. (2018) reported stormwater mitigation costs could be reduced by between $0.45 and $88 per tree per year, based solely on rainfall interception by tree canopies. Stormwater management benefits of urban greening at the street scale in 5 different localities in South Australia were calculated to be up to $473,693 over 30 years (Martinez et al. 2019); the benefit due to attenuating of stormwater flows which reduced cost associated with flood damage.

Carbon sequestration

Carbon sequestration through biomass growth and storage, plus reduced carbon emission due reduced electricity usage for heating and cooling, has been reported as an economic benefit valued at between $0.50 to $22 per year per tree (Song et al. 2018). The value of carbon sequestration by urban forests in Canberra during 2008–2012 were reported in the range of $70–$236 per tree (Brack, 2002 in Gunawardena et al. 2017). Another Australian study investigated willingness to pay to implement climate change mitigation options and found residents in Canberra were willing to pay $191 per household per month to support a national emissions trading scheme (Akter and Bennett 2009). Salem and Mercer (2012) reviewed 73 studies of mangrove ecosystem service valuations and reported a mean financial value of $1560 per hectare per year for carbon sequestration.

Improved air quality

Trees can absorb and filter particulate matter, oxides and sulphides of nitrogen, and other pollutants to improve air quality (Samson et al. 2017). Estimated average economic benefits of improved air quality ranged from $1.00 to AUD $34 per tree per year (Song et al. 2018). The studies reviewed in Song et al. (2018) accounted for benefits in relation to ozone (O3), nitrogen dioxide (NO2), sulphur dioxide (SO2) and particulate matter less than 10 µm in size. Financial values of water and air purification by mangroves of $7,660 per hectare per year have been reported (Salem and Mercer, 2012).

Biodiversity

In summarising studies which reported values attributed to biodiversity, Gunawardena et al. (2017) noted general willingness to pay to protect biodiversity and ecology. A choice experiment conducted in Tasmania found people willing to pay $4.70, on average, to increase native vegetation along one kilometre of riverside and $10.00 per species to protect rare native plants and animals (Kragt and Bennett, 2011). Morrison and Bennett (2004) found people were willing to pay $11 per household for an additional fish species in rivers.

Plants have been the single greatest source of natural product drugs in recent decades. Three quarters of all anti-bacterial products approved by the USFDA between 1981 and 2010 can be traced back to natural product origins (Romanelli et al. 2015). The proportion of newly approved anti-virals and anti-parasitics was reported as similarly high, but to date only a small fraction of plant species have been studied to assess their pharmacologic potential.

Human productivity

Students who can view and observe nature during school have been shown to have higher standardized test scores, graduation rates and intent to pursue tertiary studies and reduced likelihood of involvement in future criminal behaviour (Chen, 2020). Improved performance at school can directly benefit individual students and society as a whole. The annual benefit in terms of increased average income, of the increased number of high school graduates due to the presence of urban nature whilst attending school, has been estimated at US$1.3 billion (Chen, 2020). The further economic benefit which would undoubtedly arise from additional spending due to this increased income has not been calculated. A study by Lee et al. (2017) reviewed in Gunawardena et al. (2017) noted observations that viewing nature during brief breaks helped restore and sustain employees' mental acuity throughout the workday, thus improving productivity.

Crime

Lower crime rates have been associated with greener neighbourhoods (Chen, 2020). Wolf et al. (2015) state Urban nature in US cities with populations over 500,000 potentially yielded savings of between US $340 and US $899 million due to reduced criminal activity during in 2012 (Wolf et al. 2015). The types of crime investigated included robbery, aggravated assault, burglary, and theft. The saving due to reduced aggravated assault alone ranged between US $340 and US $502 million in 2012 (Chen, 2020).

Coastal storm protection

Mangroves act to buffer coastlines and they significantly reduce damage during storm events. During cyclonic events mangroves significantly reduce water flow velocity (29–92%) and surge height (4–16.5 cm) (Dasgupta et al. 2019), potentially delivering significant savings from the avoided or reduced rehabilitation and maintenance expenses. Cyclone damage for villages in the 'mangrove shadow' has been shown to be approximately half that of villages not protected by mangroves (Akber et al. 2018); the value of this protection was calculated at $1676 per household (based on avoided damage repair expense). A meta-analysis reported in Salem and Mercer (2012) listed the mean financial value of coastal protection by mangroves as $5027 per hectare per year.

Tourism and recreation

A financial value has been attributed to recreation and tourism benefits in relation to mangroves of US $37,927 per hectare per year (in 2012 values) (Salem and Mercer 2012). No other literature was identified which specifically related tourism and recreation benefits in relation to urban trees.

General

A whole-of-life benefit–cost analysis was undertaken using the System of Environmental Economic Accounting (SEEA) framework, to estimate stocks and flows ecosystem services benefits of urban forests and irrigated open spaces in Canberra, Australia. The analysis used spatial data, i-Tree Eco, and benefit transfer methods for the period from 2018 to 2070. The analysis indicated that a 30% expansion of tree canopy cover yielded the highest benefit–cost ratio, while the business as usual scenario (loss of 400 trees expected per year) offered the lowest benefit–cost ratio (Tapsuwan et al. 2021).

A cost-benefit analysis relating to urban infill comparing no trees planted per allotment, one tree planted per allotment, or a tree funded to be planted off-site was undertaken for South Australia in 2020 (Econsearch, 2020). Using a very conservative number of benefits, it was found that the scenario involving planting a tree on every allotment would return $1.70 to the community for every $1 invested (a cost-benefit ratio of 1.7).

Monetised health values

The biophilia hypothesis suggests that human beings have an innate affinity withthe natural world and have evolved with a preference for the natural environments that are essential to wellbeing (Wilson, 1984). Recent studies have begun to quantify relationships between the natural world and human health, many of which have been investigated in terms of their monetary value. This affinity has economic implications; a review of 12 studies identified that urban citizens were willing to pay between $11 and $30 annually for not postponing or losing an outdoor experience and for walking in local environments (Lynch et al. 2020).

Mental health benefits

A survey reported in Dean et al. (2018), which involved 1,538 residents of Brisbane, Queensland, found that enjoyment of nature was consistently associated with reduced ill health. A marginal increase in visitation of public green space, of as little as once per week for thirty minutes per resident, was shown to be linked to a 7% reduction in the incidence of depression (Shanahan et al. 2016). With an estimated annual cost in Australia of $12.6 billion in 2010 (LaMontagne et al. 2010), or $16.9 billion in in 2021 dollar value, a 7% reduction would saving $1.2 billion.

Positive impacts of urban nature specifically on mental health have been documented in a review of twenty five papers by Callaghan et al. (2021). Mental health presentations in emergency departments have significantly increased since 2004, with over a quarter due to stress-related disorders (Tran et al., 2020). Depression accounts for 4.3% of the global burden of disease and is among the largest causes of disability worldwide, particularly for women (Romanelli et al., 2015).

Benefits worth between US $2.7 billion and US $6.8 billion could potentially be achieved across the United States from urban vegetation-related reductions in incidence and treatment costs in relation to ADHD, improved performance of high school students, crime reduction, reduced cardiovascular disease, reduced incidence of Alzheimer's disease, and health benefits accruing to newborns health benefits accruing to newborns (Wolf et al. 2015). The value of these benefits is likely to be conservative, as the estimates did not account for all of the known beneficial effects of urban nature (Chen 2020). Potential cost savings in Australia and globally due to the presence of urban nature are significant and should be further quantified.

Increased physical activity

Lack of physical activity increases risk of cardiovascular disease, diabetes, osteoarthritis, some forms of cancer, obesity and other diseases. Studies have shown decreased medical expenditure per physically active US citizen of between US $ 354 (in 2003 values) and US $ 564 (in 1998 values) (Chen 2020). Reduced health care costs and reduced morbidity due to increased physical activity were estimated to be valued at US $ 20 million in 2007 in Sacramento and US $ 69 million in Philadelphia.

For two sites in South Australia, Martinez et al. (2019) calculated avoided healthcare costs based on a 1% increase in the number of obese and overweight adults who participated in increased physical activity due to close proximity to green infrastructure. The researchers also calculated the likely monetary savings if 1% of insufficiently active adults increased their physical activity resulting in 2 additional life years per adult (the value of a statistical life year was estimated at AUD $187,000). They found the monetary value of health benefits amounted to $482,741. This conservative value considered only the adult population and a small proportion of the potential green space-related savings on health expenditure

Cardiometabolic diseases

Cardiometabolic diseases are the number one cause of death in the world (de Waard et al., 2018). Restoring local tree canopy in neighbourhoods may help to prevent these diseases. A study of 46,786 people aged over 45 years old found a 1% increase in tree canopy was associated with lower likelihood of diabetes, cardiovascular disease, incident diabetes and hypertension (Astell-Burt and Feng, 2020b).

Cardiovascular disease is a major component of public and private health care costs; between 25% and 30% of deaths in the US and UK respectively are caused by cardiovascular disease (Chen, 2020). Cardiovascular disease is more common in areas with reduced accessible green space, and a potential benefit worth US $1.43 billion (in 2021 values) has been reported as achievable through decreased cardiovascular treatments and morbidity in relation to males across the United States, if they have access to urban nature.

Air pollution

Air pollution causes adverse health conditions, with even brief exposure to particulate matter smaller than 2.5 µm (PM2.5) linked to increased hospital admissions for bronchitis, asthma, heart and lung problems, presentations for emergency medical treatments, and premature death. The potential transfer of micro-organisms and microbial species associated with particulate matter can increase human health problems. As an example, an analysis of severe smog events which caused rapid increases in patient presentations in hospitals in China due to respiratory issues revealed the existence of inhalable pathogens known to cause human respiratory diseases in air containing PM2.5 and PM10 particulates (Groulx et al., 2018).

Bayulken et al. (2020) reported 458,000 PM2.5-related deaths in urban populations across Europe in 2011. The European Union has set a limit on PM2.5 concentration of $25\mu g/m^3$ (averaged over a year) since 2015. A meta-analysis of ambient air pollution revealed that exposure to both NO_2 and PM2.5 particulates increased the likelihood of pregnancy-induced hypertension and preeclampsia (Melody et al. 2020). A potential to reduce incidence of 49 cardiovascular diseases through pollutant removal by trees has been proposed, with annual saving in treatment costs of US $1.8 billion predicted (Nowak, 2014). The benefit resulting from removal of air pollution by trees across the USA has been reported as being worth US $4.7 billion in 2010 (Nowak et al. 2014).

Dementia

Dementia is the second highest cause of death in Australia. Recent studies indicate incidence of all-cause dementia and Alzheimer's type dementia are related to air pollution, and particularly to fine particulate matter. A study of over 30 years involving 4,000 residents in Seattle USA reported an increase of 1 mg of fine particle pollution per cubic metre of air near residences was associated with a 16% higher incidence of dementia (Shaffer et al., 2021). A similar response was reported in a French study, and a direct association between air pollution and increased beta amyloid production has now been identified (Alzheimers Association, 2021). Urban trees role in reducing air pollution and fine particulate matter may, therefore, play a role in reducing risk of dementia.

Dementia patients who used 'wander gardens' more than the median use had a significant reduction in high-dose antipsychotics (Chen, 2020). It has been estimated that wander gardens or 'horticultural therapy' might replace 5% to 10% of medication prescribed for Alzheimer patients, equivalent to reducing the cost of medication by between US $724.6 million and US $1.45 billion across the Unites States (Chen, 2020). A 'willingness to pay' study identified that therapy-related horticultural activity and sensory experiences in gardens in South Korea were values at US $170 per month per patient.

Studies conducted by CSIRO and NATSEM predict at least a doubling in the number of Australians with dementia over the next 30 years to between 900,000 and 1.1 million. Direct and indirect costs related to this disease are projected to increase in the range of 150% to 300%, to between $33 billion and $48 billion (Brown et al. 2017). Nearly 800,000 people would be needed as either paid or informal carers for dementia sufferers in the 2050s. The impact on future economic costs to the Australian community of only a small reduction in the incidence of Dementia by urban trees could be significant; a reduction of 2% would potentially save between $660 million and $980 million.

Attention deficit and hyperactivity disorder (ADHD)

Attention deficit hyperactivity disorder (ADHD) is an increasingly diagnosed brain disorder that is often treated with medication. In a US study it was found that a 20 minute walk in a city park was roughly equivalent to the 'peak effect of an extended release stimulant medication methylphenidate' (the most common ADHD medication) (Chen, 2020). Based on the extent of this effect and the cost of the drug, financial savings possible by treating ADHD through interaction with urban nature have been estimated to be between US $383.5 million to US $1.9 billion per year (corresponding to 5% and 25% medication replacement).

Birth weight

Birth weight is correlated with newborn, childhood and long-term health (Wolf et al., 2015). Newborns with low weight often require additional medical care as children, suffer more disease as adults, and are more likely to have lower IQ and lower income. Higher birth weight has been correlated with greater tree canopy in the USA, Spain, Germany and Canada, with estimated potential savings due to lower medical costs in the first year of a newborns life of US $ 6.3 million (in todays values) (Wolf et al. 2015).

Sleep

Lack of sleep is associated with increased risk of coronary heart disease, stroke, diabetes, obesity, depression, neurodegenerative diseases, inflammation, cardiovascular diseases, metabolic syndrome, injuries and premature death (Shin et al., 2020; Feng et al., 2020). In the US, insufficient sleep resulted in a financial loss of US $411 billion, or 2.28% of GDP in 2015 and such losses were predicted to increase (Shin et al. 2020). A systematic review of studies which investigated association between greenspace and sleep found that green space exposure improved both sleep quality and quantity (Shin et al. 2020).

An Australian study involving 38,982 citizens and which analysed sleep and proximity to green space found people living in or near locations with higher tree canopy cover were more likely to getting better sleep (Astell-Burt and Feng 2020a). Urban greening strategies which prioritise tree canopy cover may help to support population-wide improvements in sleep. An economic value specifically relating to green space and sleep was not identified in this review.

Non-monetised health values

Reviews of the benefits of green space which identified benefits which are likely to have economic benefit but which did not quantify the benefit in monetary terms are reported below to provide further perspective on the value of urban trees and vegetation and to potentially inspire future research.

Human health

Nieuwenhuijsen (2020) highlight Studies have reported non-monetised health benefits associated with greening cities including increased life expectancy, reduced frequency and severity of mental health incidents, improved cognitive functioning and mood, and improved infant health. A study which followed 108,630 women, recorded 8,604 deaths between 2000 and 2008, and which adjusted for other morbidity risk factors, found women living within 250 m of areas in areas categorised with the highest 20% of green space had a 12% lower rate of all-cause non-accidental death than those living in areas in the lowest20% of green space category (James et al. 2016). The associations were strongest in relation to respiratory and cancer-related deaths. A systematic review of 60 studies found higher levels of walkability and green spacewere associated with lower risk of type 2 diabetes, while increased levels of noise and air pollution were associated with greater risk (Dendup et al. 2018).

Significant beneficial effects of green and blue space on childhood obesity through influencing physical activity and eating behaviour have been reported (Alejandre and Lynch, 2020). Increased incidence of childhood obesity, higher electronic media use by younger children, reduced levels of outdoor activity and higher levels of emotional distress have been reported in older children living without green spaces nearby (Poulain et al., 2020).

The length of time spent in outdoor activity in winter by older children also increased with increasing access to green space (Poulain et al., 2020). Green and blue space may, therefore, have the potential to support policy, social, economic, environmental, and organisational initiatives to help to reduce childhood obesity and related health conditions.

Literature presents an established and increasing body of evidence for the positive relationship between mental well-being and accessibility to green space and nature. Urban green space can be established and sustained to support improved mental health of individuals and communities, particularly those of low socio-economic status, and vulnerable populations such as military Veterans (Barakat and Yousufzai, 2020). It has been suggested that future research shouldspecifically include the financial impact of urban vegetation on depression and obesity, with studies covering larger geographical areas to account for heterogeneities across countries (Chen 2020).

Pollinators

It has been suggested that green spaces including parks and urban gardens might asrefuges which help to preserve particularly vulnerable species of pollinator insects (Ayers and Rehan, 2021). Methods by which green spaces might be manipulated to promote greater pollinator abundance and diversity, increase native floral abundance and richness, and to reduce management intensity were suggested, including establishingareas of bare earth to support ground-nesting bees and increasing green infrastructure to reduce fragmentation and allowpollinator movement. A significant increase in the number of studies on pollinators in urban ecosystems has been observed in recent years, particularly in temperate region in developed nations including the United States, United Kingdom and France (Silva et al., 2020). No literature was identified in the review which reported economic value in relation urban forests on pollinators.

Biodiversity

Ecosystem integrity increases resilience to future events. Resilience within ecosystems, the capacity to buffer the effects of environmental impacts while retaining social and ecological function, has been de- scribed as the insurance value of an ecosystem (Green et al., 2016). Many biodiverse gardens dispersed across and throughout urban areas can help to insure cities against impacts like climate change, for example. Green et al. (2016) noted that any ecosystem's contribution to a benefit-cost analysis would be understated if ecosystem service values did not include a component for insurance (increased resilience), but that applying a monetary figure to theinsurance value of an ecosystem remained problematic. Although calling for better recognition of the insurance value of ecosystems, Green et al. (2016) advised against monetizing this property, as this might support the notion that loss of insurance value through ecosystem degradation could be compensated with financial capital.

Microplastics

Certain types of greenspace can capture pollutants from stormwater before it enters aquatic ecosystems. Microplastics have been highlighted as a ubiquitous problem in the natural environment (Geyer et al., 2017).

The amount of anthropogenic debris, including microplastics, in stormwaterrunoff was quantified in a study by Werbowski et al. (2021); it found debris was more concentrated in stormwater than in wastewater treatment plant effluent. Fibres and black rubbery fragments (potentially tire and road wear particles) made up 85% of all particles across all samples. Stormwater from the inlet and outlet of a 'rain garden' or 'bioretention system' (a low-lying area composed of native vegetation, engineered soil and organic matter) was analysed during 3 storm events to assess the mitigation capacity of the rain garden. The rain garden removed 96% of anthropogenic debris including 100% of black rubbery fragments (Werbowski et al, 2021). The researchers suggested that rain gardens should be explored more thoroughly to quantify their value as a mitigation strategy for microplastic pollution.

Reducing wind velocity

Tree and branch failures in severe wind events are routinely highlighted in mainstream media, but the protection from high velocity winds that is provided by trees is rarely if ever publicised even though the ‘windbreak effect’ is widely known in rural areas. Wind speeds are reduced on both the upwind and downwind sides of trees, although the effect is greater downwind. A study in Vancouver, Canada, reported that removing all trees in a neighbourhood could increase wind speeds by a factor of two (Giometto et al. 2017), and that removing all trees from around buildings increased their energy consumption by as much as 10 percent in the winter and 15 percent in the summer. Heating and cooling costs were reduced as lower wind speed resulted in reduced energy loss through draughts, and even bare trees can slow wind speeds (Giometto et al. 2017).

Reduced wind velocity creates more comfortable conditions for people spending time outside or walking along the street. Although wind has been considered in terms of costs associated with reduced air-conditioning use due to trees (see Nowak et al., 2017), the effectiveness and benefit of trees in reducing wind speed has not been adequately costed.

Emerging values

The value of urban trees is likely to increase in value in the future, as their mitigating effects on adverse human health conditions become more widely known. Illness and death due to urban heat island-related effects are predicted to increase. The recent death of a nine year old girl was attributed to nitrogen dioxide air pollution from traffic (Bikomeye et al., 2021). Increased urban tree cover can make a significant contribution toward ameliorating the negative impacts of these environmental factors (Osborne et al., 2021).

Urban biodiversity has been associated with differences in human-associated microbiota, and subsequent differences in immune function and mental outlook (Prescott et al. 2018). Modern medicine has been so successful against infectious disease, through development of antimicrobials, vaccines, and public health strategies, that non-communicable diseases have become the leading cause of mortality worldwide. Mills et al. (2020) reports that many non-communicable diseases arelinked to reduced diversity in environmental and human microbiota, and are increasing markedly in highly urbanised nations, so much so that biodiversity and ecosystem loss threaten to counter the major health improvements made over the last century (Queenan et al. 2017). The restoration and protection of urban green spaces with biologically diverse communities should be considered as a way to reduce the incidence of non-communicable diseases.

Conclusion

There is a large and growing body of literature which identifies and quantifies the various and often newly acknowledged benefits of urban trees and ecosystems across diverse functions such as urban heat island amelioration; climate change mitigation; storm water and microplastics management; biodiversity conservation; urban resilience; cultural, social and historical values; and physical and mental health improvement. However, on summarizing 2,194 papers on green infrastructure, Ying et al. (2021) reported that amongst the many studies which considered environmental and social aspects of green infrastructure, economic valuation studies were rare. Many benefits remain unquantified or under-quantified in the literature, but while some may be difficult to quantify, others are able to be reasonably reliably assessed in financial or economic terms.

Under-quantification of non-market benefits will undoubtedly limit their consideration by policy and decision makers, and sustain current difficulties in performing and understanding reliable benefit - cost analyses in relation to urban trees and urban ecosystems. Papers that applied monetary values to non-market benefits were largely presented research undertaken in North America. While local research has revealed some similar benefits, most have not yet been quantified in Australia. There is a need to quantify these benefits in an Australian context, so that locally specific tools may be progressed, underpinned by robust local data, to inform policy and project decision-making. Data are required over the extended periods throughout which benefits delivered by trees accrue, and for benefits which may currently be outside policy makers’ areas of interest or regard.

Based on recent research and trends, the impact of quantifying non-market benefits on the monetary value of urban trees will be significant. For example, if projected annual costs of dementia in Australia of $48 billion are realised, a 1% reduction in air pollution resulting in a 1.6% reduction in dementia cases will deliver a saving in treatment and management costs of almost $770 million.

The rate at which studies are emerging, particularly in relation to personal benefits, health and the environment, suggest new direct and indirect benefits will continue to be identified and quantified. An important focus of future research should, therefore, be to develop methodologies and tools for agreed valuation metrics of benefits, that may not be financial or economic or may currently be poorly valued or aggregated, in order to inform certifiable comparisons across different projects, actions, opportunities or outcomes.

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Appendix 1. Table 1. Monetary values for urban tree services.

Value	Sub-value	Monetary valuations	Reference source	Notes
aesthetics and amenity	Hedonic - through property pricing	$7 to $165 per tree per year (US 2015 values)	Song et al (2018)	iTree or predecessor algorithms. Mostly from North America 1 year snapshot
	Hedonic - through property pricing	**Australia.** Property price increase from moving 1m closer to golf course, greenspace sport facility and coast was $0.54, $1.58 and $4.99 AUD respectively. Equates to US 2016 values of US$ 0.60, US$ 1.76 and US$ 5.56.	Mahmoudi et al. (2013) in Gunawardena et al (2017)	Looked at 40923 properties between years 2005 - 2008 in Adelaide metropolitan area
	Hedonic - through property pricing	**Australia.** Property price increase due to its postcode gaining green infrastructure equal to 1 standard deviation increase in enhanced vegetation index of US$ 34,195 to US$ 61,979 (in US 2016 values)	Rosseti (2013) in Gunawardena et al (2017)	Looked at 2,531,803 property transactions between years 2000- 2010 across Australia.
	Hedonic - through property pricing	**Australia.** A 10% increase in tree cover on adjacent public space resulted in a property price premium increase of about $14,500 AUD, equating to US 2016 values of US$ 13,188	Pandit et al (2014) in Gunawardena et al (2017)	Looked at 5606 properties in 2009 in central metropolitan Perth.
	Hedonic - through property pricing	**Australia**. Property price increase from increasing tree planting by 1% on footpaths within 100m of houses, was 0.082% to 1.03% of property price. 432.56	Plant et al. (2017) in Gunawardena et al (2017)	Studied 2774 houses in 2010 in Brisbane.
	Through 'experienced preference method' or 'life satisfaction approach'.	**Australia.** In 2016 values, an average implicit willingness to pay per household per year of US$ 940 for a 1% increase in public greenspace, and US$ 10,268 for 12.49% increase in public greenspace.	Ambrey and Fleming (2014) in Gunawardena et al (2017)	Studies all Australian capital cities, using Household Income and Labour Dynamics in Australia (HILDA) survey. (2005).
	Through contingency valuation and choice experiments	**Australia**. Annual willingness to pay per hectare of greenspace in 2003 was US $1,957 (2016 US values)	Brander and Koetse (2011) in Gunawardena et al (2017)	Based on 20 studies of urban or peri-urban open space across Australia, US, UK, Canada, China and Finland.
	Willingness to pay for preservation	**Australia**. Mean willingness to pay per person per annum for the local bushland in 2001 of US$ 14.79 (US 2016 values)	Pepper et al (2005) in Gunawardena et al (2017)	Results of over 500 questionnares in 2001 in Perth for preservation of bushland.
	Hedonic - through property pricing	Amsterdam. Homes 1 km or closer to green space sold at a price premium. The further the house from the green space, the lower the price premium. For example, they estimated a 7.1%–9.3% increase in price forhouses within 0.25 km from the nearest attractive green space to 1.7%–2.3% for houses located at 0.75–1.0km away	Daams et al (2019)	Using data on 35,298 home transactions in Amsterdam's urban core

	Hedonic - through property pricing	Leiden University in the Netherlands. Found on average people estimated house prices to be 5.05% and 6.07% greater for properties in a street with 25% and 50% tree cover respectively (compared to no tree cover)	Staats and Swain (2020)	surveyed 281 people
	Hedonic - through property pricing	Dalian in China. Found increased property values were estimated at AUD $1.6 million which equates to $34 per tree.	Wang et al (2018)	conducted a study of street trees using iTree in the main urban area
shading, evapotranspiration	Through reduced air-con use	$4 to $166 per tree per year (US 2015 values)	Song et al (2018)	
		US. Calculated reduced energy use of residential buildings **included impact of reduced wind** velocity and found urban/community forest annually decreased energy use by 7.2%. This equated to US$7.8 billion per year in energy costs. Of this, US$4.7 billion was from reduced electricity use and US$3.1 billion from reduced heating costs. Further to this, another US$ 357 per hectare year was saved from avoided emissions (equating to anadditional US$3.9 billion per year) derived from reduced emissions from power plants.	Nowak et al (2017)	
		New York City. Estimated that the 7 million trees in New York City, which create a canopy covering around 21% of the city, reduced annual residential energy costs by US$17.1 million per year in 2018.	Nowak et al (2018)	
		Dalian, China. Found avoided electricity and gas costs came to US$ 1.7 million, which on average equates to AUD$ 45/tree .Large-stature trees produced the greatest benefits - up to AUD$ 99 per tree.	Wang et al (2018)	iTree
air quality improvement	Through direct pollutant uptake and deposition.	-$0.68 to $21.28 per year per tree (US 2015 values)	Song et al (2018)	Used empirical mulitlayer and bigleaf models. Mostly from North America 1 year snapshot. To convert air quality benefits into monetary terms, most studies used shadow prices based on the cost of pollutant mitigation, while others estimated savings in healthcare.
	Savings to health care only	US$ 4.7 billion from pollution removal by urban forests and trees.	Nowak et al (2014) in Chen (2020)	

	PM2.5 reduction by trees	US$ 1.1 million to US$ 60.1 million. 12 different health incidences across 10 UScities, mostly from reducing mortality	Nowak et al (2013) in Chen (2020)	Investigated reduction of in-patient stays from potitive health impoact from reduced pollution due to urban trees. Other potential impacts such as direct and indirect exposure to nature and sensory stimuli from nature not investigated.
		Philadelphia. 15.7% canopy coverage annually removed 802 tons of air pollution valued at US$ 3.9 million	Nowak (2007) in Bayulken et al (2020)	
	Meta-analysis	Mangroves review. The mean financial values in regard to water and airpurification equate to AUD$ 7660 per hectare per year	Salem and Mercer (2012)	
		New York City. Estimated that the 7 million trees in New York City removes about 1,100 tons of airpollution per year which equates to a cost savings of US$ 78 million per year through avoided impacts on human health	Nowak et al (2018)	
		Dalian, China. Found the net benefits of air pollutant removal were valued at US $381,088/year or equivalent to AUD$ 10.19/tree	Wang et al (2018)	
	PM2.5 reduction by trees	US$ 1,876,000 in saved mediacl costs in US per year	Nowak et al (2014) in Chen (2020)	Estimated through saved medical costs in reduced cardiovscular hospital admissions.
carbon reduction	Through carbon sequestration of biomass	$0.34 to $13.38 per year per tree (US 2015 values)	Song et al (2018)	
		Canberra. Value of carbon sequestration by urban forests during 2008–2012 was estimated at $70–$236 per tree	Brack (2002)	
		Philadelphia. 15.7% canopy coverage provided carbon storage of 530,000 tons worth $9.8 million annually	Nowak (2007) in Bayulken et al (2020)	
	Meta-analysis	Mangrove ecosystems review. A mean financial value equivalent to AUD$ 1560per hectare per year for carbon sequestration.	Salem and Mercer (2012)	Undertook a meta-analysis on 73 studies (which totalled 352 observations) of mangrove ecosystem service valuations of either monetary or physical quantities
		New York City. Estimated that the 7 million trees in New York City removes about 51,000 tons of carbon per year (186,000 tons CO2/year), equating to a cost saving of US$ 6.8 million per year	Nowak et al (2018)	based on the economic impact of increased carbon emissions on factors such as agricultural productivity, human health, and property damages

		Dalian, China. Found the net annual CO2 removed by street trees totaled 36,111t, which equates to US $935,205. On a per tree basis, the carbon reduction benefits were on average equivalent to AUD$ 25	Wang et al (2018)	iTree
	Willingness to pay	Australia. Respondents in Canberra were willing to pay $191/household/month to support a national emissions trading scheme known as the Carbon Pollution Reduction Scheme	Akter and Bennett (2009)	
lowers crime		US$ 340.6 million to US$ 899.4 million from reduction in health care costs	Wolf et al (2015) in Chen (2020)	
stormwater management	Through canopy rainfall interception	$0.28 to $54.61 per tree per year	Song et al (2018)	Numerical model by Xiao et al (1998, 2000) which analysed reduced volume of water entering stormwater system through rainwater interception by canopies of individual trees.
		Portland Oregon. Project saved US $63 million by retaining and infiltrating storm water annually.	Bayulken et al (2020)	
		New York City. Estimated that the 7 million trees in New York City reduce runoff by 69 million cubicfeet/year which equates to a savings of $4.6 million/year through avoided surface water runoff.	Nowak et al (2018)	
		Dalian, China. A study of street trees in the main urban area found total stormwater runoff reduction benefits to Dalian were US $459,457, with an average value equivalent to AUD$ 12.35/tree		iTree
		South Australia. Cumulative benefit of greening a street in 5 different localities in South Australia would create a monetary benefit of AUD$ 473 693, to be reached within the project's first 30 years. This is due to water drainage attenuation reducing average annual flood damage costs.	Martinez et al (2019)	
coastal storm surge reduction		Bangladesh. Mean avoided damages from one cyclone (Sidr) for villages inmangrove shadow was US$ 938.4 (2007 values) per household.	Akbar et al (2018)	
horticlulture therapy		On average US$ 170/month per person willing to pay	Lee et al (2008) in Chen (2020)	

newborn birth weight		US$ 5.3 million savings (in 2012 value) for first year of all newborn baby's life in the US	Wolf et al (2015) in Chen (2020)	Reduction in medical costs due to correlation between tree canopy coverage of mother's home and increase in birth weight of singleton newborns. Monetary effects of later stages of their life has not been estimated.
promotes physical activity	**green assets promoting cycling**	£ 184.24 per extra cyclist due to reduced mortality (in UK?)	Green Infrastructure Northwest (2011) in Chen (2020)	
	green assets promoting cycling	NPV over 5 years is £ 0.6 million for cycling benefits in Erith Marshes and Belvedere	Green Infrastructure Northwest (2011) in Chen (2020)	
	green assets promoting walking	NPV over 5 years is £ 1.4 million for walking benefits Erith Marshes and Belvedere	Green Infrastructure Northwest (2011) in Chen (2020)	
	green assets promoting general physicality	US$ 1,98,71,863 in year 2007 in Sacramento	Chen (2020)	
	green assets promoting general physicality	US$ 1,94,19,000 in Philadelphia	Chen (2020)	
	A 1% reduction in the sedentary population	£ 1.44 billion per year in UK (equals a mean of £ 2,423 per additional active person a year)	CJC Consulting (2005) in Chen (2020)	
reduces cardiovascular disease		US$ 1.2 billion from reduced mortality costs	Wolf et al (2015) in Chen (2020)	Includes economic cost due to lost productivity, and correlation with populations living in greenest areas.
dementia/alzheimers		US$ 725 million to US$ 1.5 billion from reduced medical costs of Alzheimersdisease	Wolf et al (2015) in Chen (2020)	Wander gardens are outdoor confined spaces which permit unrestrained activities and prevent agitation in dementia patients. Wander have been shown to decrease falls and higher users require less medication. Costs are based on replacing between 5% and 10% of medication.
ADHD		Between US$ 383.5 million and US$ 1.9 billion	Wolf et al (2015) in Chen (2020)	Range relates to 5% and 25% possible medication replacement due to urban nature's effect of reducing ADHD symptoms.
increases school performance		US$ 1.3 billion per year	Wolf et al (2015) in Chen (2020)	In terms of increased income from higher secondary school performance due to urban natures effect on performance and capacity to direct attention. Does not include potential macro-economic effects.

sleep		US. A financial loss of $ 411 billion, or 2.28% of the GDP in 2015, was associatedwith insufficient sleep. These losses are projected to increase	Shin et al (2020)	Lack of sleep is associated with high risks of coronary heart disease, stroke, diabetes mellitus, obesity,depression, neurodegenerative diseases, inflammation, cardiovascular diseases, metabolic syndrome, injuriesand premature mortality (Shin et al., 2020; Feng et al., 2020)
tourism	meta-analysis	Mangrove review. Mean financial value of mangroves for recreation and tourism is US$ 37,927 per heactre per year (in 2012 values)	Salem and Mercer (2012)	
mental health		**Brisbane, Australia**. Results suggest that up to a further 7% of depression cases could be prevented if all city residents were to visit green spaces at least once a week for an average duration of 30 minutes or more. In 2007, estimated societal costs of depression were AUD$ 12.6 billion per annum for employed Australians alone (LaMontagne et al., 2010). This is equivalent to AUD$ 16.9 billion in 2021.	Shanahan et al (2016)	Used a population sample of 1538 residents of Brisbane City, Australia. It was found that a longer duration of individual nature experiences was significantly linked to a lower prevalence of depression. A higher frequency of green space visitation was also an important predictor for increased social cohesion.
gut biome health		no value found		
cognitive fatigue in		no value found		
general and child obesity		no value found		
pollination		no value found		
noise reduction		no value found		
recreation		no value found		
tourism		no value found		
wind reduction		no value found		
road maintenance		no value found		
humidifier		no value found		
biodiversity		no value found		