Urban Forestry & Urban Greening 102 (2024) 128576

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Original article

Increased monetary equity and health wellbeing benefits for marginal urban socioeconomic groups from access to green space

Adam Loch [a,*], Stuart Sexton [b], John Maclean [c], Patrick O'Connor [a], David Adamson [a,d], Glen Scholz [b]

[a] Centre for Global Food and Resources, School of Economics and Public Policy, University of Adelaide, South Australia, Australia
[b] South Australian Department for Environment and Water, Adelaide, South Australia, Australia
[c] The School of Mathematical Sciences, University of Adelaide, South Australia, Australia
[d] Royal Agricultural University, Cirencester UK

ARTICLE INFO

Keywords:
Green space
Wellbeing
Socioeconomic groups
Economic valuation

ABSTRACT

Health benefits from access to nature are well known and increasingly cited as a supporting argument for the conservation of biodiversity, particularly in cities. However, calculating the benefits from access to nature in economic terms is challenging due to a lack of data linking benefits, number of beneficiaries, and monetary values. This study used mobile phone 'ping' data to estimate the use of large biodiverse green spaces (e.g., metropolitan National Parks) surrounding Adelaide, the World's second National Park City. This ping data was combined with park user and general population data to calculate a health benefit from access to green spaces for citizens across socio-economic groups in the city. Additional data on health burden costs was then used to calculate reduced health costs from access to nature in 20 metropolitan National Parks by 2,842,503 visitors in 2018–19. Across all socio-economic groups, an estimated AU$140 million worth of reduced healthcare costs was generated through access to biodiverse green spaces adjacent to the city. This is equivalent to around 4 % of the total South Australian healthcare budget. Importantly, citizens from the relatively lowest 40 % of socio-economic areas in the metropolitan area received a disproportionately high reduced health cost from access to public green space, despite the additional private cost of accessing National Parks. This study thus provides an opportunity to frame both health and biodiversity conservation decisions at a city and state scale.

1. Introduction

This paper seeks to answer two questions. First, do humans experience health wellbeing benefits equally from access to and interaction with green spaces equally? Second, what does this study then suggest should be done by urban planners and managers to maximise those health wellbeing benefits, where present? Human wellbeing, defined as life satisfaction and people's state of physical and mental health and sufficiency in all aspects of their life, is positively related to increased access to nature in urban settings (Buckley, 2020). Careful urban planning can enhance the quantum of natural spaces providing a win-win (positive externalities) for both retained biodiversity and enhanced wellbeing that in turn increases economic welfare (Hsu et al. 2022). This increases access to, and use of, green listed sites as defined by the International Union for Conservation of Nature (IUCN, 2024), and hereafter designated as green spaces. However, careful planning remains a challenge as only 0.3 % of global urban infrastructure spending is allocated to supporting green space solutions that mitigate pollution, reduce flood and storm damage risks, and enhance healthier air, water and living conditions for residents, especially amongst relatively less well-off socioeconomic groups (Khatri, 2022). At a global level, the deficiency of access to natural and green spaces has seen nations agree to the Aichi Target 20 and Sustainable Development Goal 17 objectives to identify and secure public financing to address biodiversity and green space losses through urban restoration and conservation strategies (Waldron et al. 2017). Australia is one of seven OECD countries identified as facing severe current and future biodiversity and urban green space losses (Coffey et al. 2022). But are there differences between relative economic group members with respect to health and wellbeing benefits of interaction with green spaces? And if differences exist, can that inform future green space public funding and increased total wellbeing? As we'll see, this is a critical gap in recent literature.

To enhance the global and national policy debate concerning the positive externalities from increased urban biodiverse green space

* Corresponding author.

https://doi.org/10.1016/j.ufug.2024.128576
Received 31 May 2023; Received in revised form 5 November 2024; Accepted 7 November 2024
Available online 8 November 2024

access (i.e. health wellbeing benefits) further analysis is required. Such analysis requires a welfare economic perspective to understand the trade-offs, and outcomes for different socioeconomic groups (Xu et al. 2022), based on the foundations of welfare economics (Lange, 1942) as detailed later in the paper, in order to understand group preferences and values for urban biodiverse green spaces (Murakami et al. 2022). This should provide greater evidence to help public planners increase the quantum of biodiverse green space (Treasury, 2022) and its location. Importantly for those at the margins of society (e.g., those with lower incomes and time to interact with urban green spaces), differences in health wellbeing outcomes may also be exacerbated by reduced green space access (Cresswell et al. 2021) and differential utility gains or losses across different relative socioeconomic groups.

Yet to date little study has been undertaken into socioeconomic groups' value preference differences and wellbeing effects (Welling et al. 2023). Better measures of socioeconomic group differences may improve the information quality supporting public wellbeing investment choices, with additional lessons for OECD countries seeking improved wellbeing measurement frameworks (Treasury, 2022). In this paper, we calculate group wellbeing benefits using measures of self-reported health similar to previous studies (e.g., Murakami et al. 2022) based on survey data for visitors to urban biodiverse green spaces as a subset of green spaces where biodiversity is high (e.g., urban forests, parks, garden and lawn areas as common fealtures of cities as defined in Delgado-Baquerizo et al. 2023). Our study context is Adelaide, South Australia which has a high density of urban connected protected areas (biodiverse green spaces), and is the World's second National Park City (Green Adelaide, 2023). We begin with a brief review of the relevant literature on wellbeing and health, value preferences and drivers of ecosystem service urban public investment decisions, before detailing the study context and methodology.

2. Brief literature review

As stated above, wellbeing links closely with general healthiness and life satisfaction outcomes through positive physical and mental health benefits (AIHW, 2023). However, these benefits are both private and public in nature and wellbeing utility preferences are non-additive; that is, the total sum is worth more than the parts. A better understanding of this intersectionality (e.g. differences in socioeconomic or marginal group preferences) may create useful support or evidence for population-level policy change interventions (e.g. biodiverse green space investments) specific enough to be applied meaningfully within affected communities (Bauer, 2014). This capacity for change stems from the fact that policy and intervention choices remain anthropocentric, in that humans decide how much, and in what way, the interest of other living things are recognized (Chapron et al. 2019) and that the assignment of monetary values dominates the diagnosis of ecosystem service provision (Gómez-Baggethun, 2017; Dasgupta, 2021). This dominance continues to overrule several academic and government criticisms or rejections of monetary approaches to ecosystem service value preference estimations (e.g. Dehnhardt, 2013).

Yet policy-makers are thought to rely on a much wider set of factors when making decisions, extending beyond robustness or validity of preference valuation methods (Rogers et al. 2015). These decision-influencing factors may include politics, budgetary constraints, limited spatial separation, group preferences (Olukolajo et al. 2023; Welling et al. 2023) or status quo decision making where change is avoided (Samuelson and Zeckhauser, 1988). The clearer understanding of green space value preferences and links to wellbeing benefits across and within different socioeconomic groups—including links between ecosystem services and value preferences to inform public investment choices (Hou et al. 2013)—remains a key knowledge gap. This gap motivates research questions including what effect direct government biodiversity investment might have on public welfare benefits across heterogeneous groups in society (Herrmann-Pillath, 2023) and how to best use such information to guide public spending (Olukolajo et al. 2023; Welling et al. 2023). Such knowledge may even contribute to future tests of robustness and validity of value preference studies, where researchers have a greater perception than policy-makers of the accuracy and key role that methodology plays (Bishop and Boyle, 2019; Welling et al. 2023).

Murakami et al. (2022) agree that benefits from urban green spaces are valued differently across diverse regions and groups, suggesting that perceptions of benefit rely on measures of life expectancy, gender equality, and individual conditions such as relative income and subjective wellbeing; similar to past valuation studies (e.g., Bishop and Boyle, 2019). In another study, Xu et al. (2022) highlight the possible improved green space wellbeing benefits that accrue to residents from in-depth understanding of the driving mechanisms of human socioeconomic activities on the equality of public facilities (e.g. parks and reserves). A recent study has shown that of the characteristics of green spaces, biodiversity, structure, and naturalness are most strongly associated with reported benefits to human well-being through improvements in health (Reyes-Riveros et al. 2021). Greater access to urban green spaces has significant potential to reduce health inequalities (Rigolon et al. 2021) and create wider triple-bottom line welfare returns as economic, environmental, and social benefits to individuals and society. Therefore, by identifying regions and facilities with unequal resource distributions we may provide scientific support to adjust and better manage public facilities to promote coordinated development with wellbeing benefit gains.

Similar to Buckley (2020), we hypothesize that spending time in green spaces can lead to higher reported levels of wellbeing and general health by contrast to people in the population who do not visit green spaces. This in turn can lead to lower private health costs (e.g. visits to a general practitioner) and less reliance on public health services (e.g. visits to publicly funded clinics). A greater understanding of the health benefits associated with using green spaces can then assist governments to better account for the external costs and benefits across alternative (e.g. investments in roads and transport) or related options (e.g. investments in different green space infrastructure) (Campbell et al. 2014). The specific contributions of the manuscript then follow as per Lange's (1942) guidance. To explore the value of green spaces we combine a travel cost analysis (TCA) of individual and group willingness to pay (i.e. private costs) to visit urban biodiverse green spaces in and around Adelaide, and increased wellbeing (i.e. private health benefits) as measures of welfare variations from engaging with green spaces. Private health benefit measures for individuals and groups are estimated from modelled differences between the self-reported health (SRH) status for surveyed green space visitors, and those from general state-level census data. The objective is to calculate the reduced healthcare advantages accruing to the state government (i.e. both public health costs and benefits). Finally, we explore any equality and preference differences across and within socioeconomic group profiles for Adelaide urban areas. This process is detailed below.

3. Methods

3.1. Study context

We focus on the 20 most visited National Parks and Reserves in the Adelaide metropolitan area (full list provided in Appendix A) over the 2018–19 financial year, providing a pre-COVID baseline for future comparisons. The South Australian Tourism Commission characterises any travel greater than 50 kilometres (or more than one hour) as tourism, while all travel below that threshold is considered recreational. We therefore limit our models to green space visits within a 60-kilometre radius of the Adelaide CBD Post Office, which represents around 90 % of all visitors (see Fig. 1 and Table A1 / Figure A1 in Appendix A). As data is not collected from the same individuals each year (an unbalanced panel) we apply the postcode-based Index of Relative

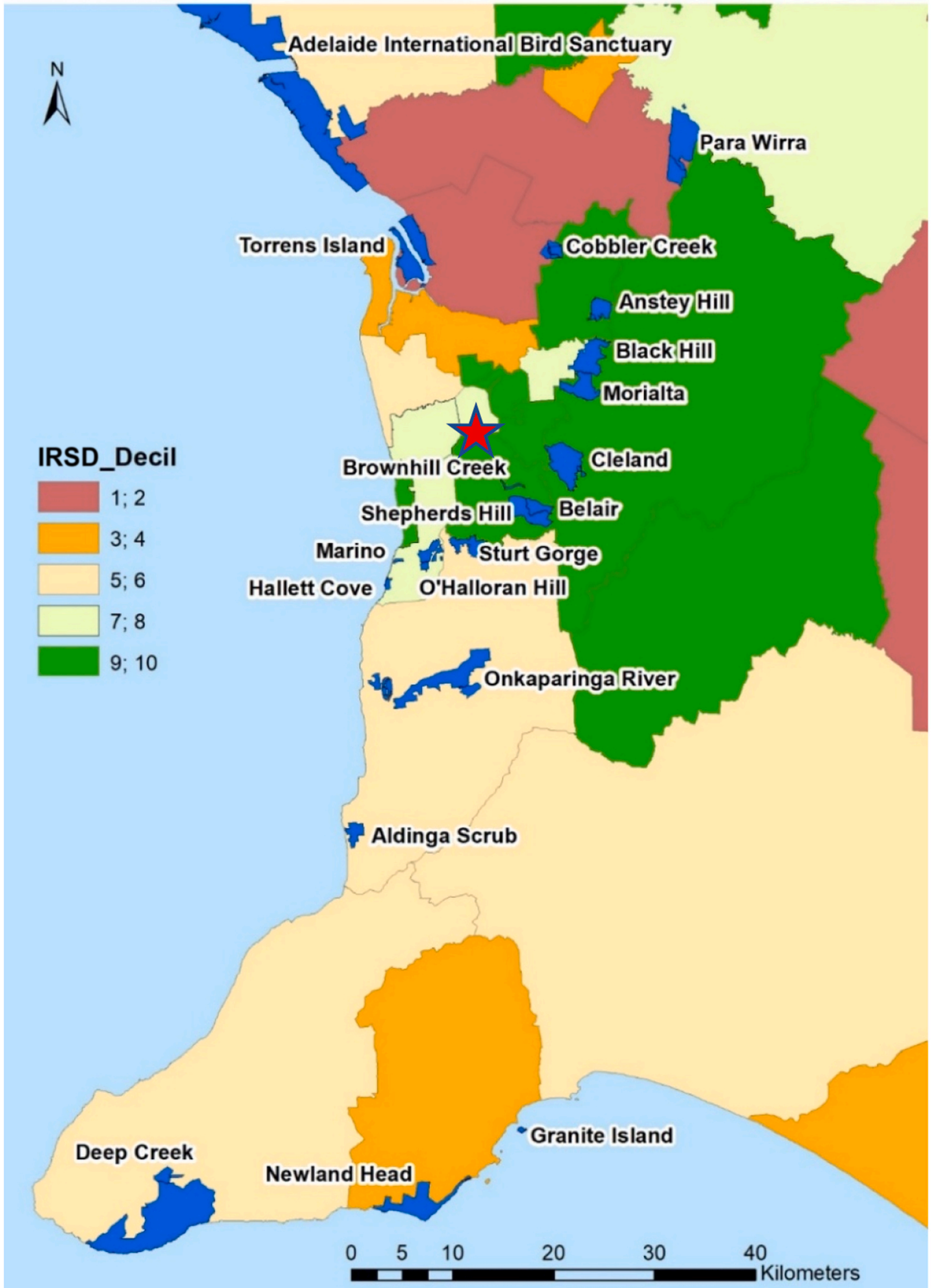

Fig. 1. Location of studied sites (royal blue) relative to Adelaide GPO - City Centre, shown as star (source: SA Dept. for Environment and Water data interpolation).

Socioeconomic Disadvantage (IRSD) provided by the Australian Bureau of Statistics (ABS) to group areas and participants. Fig. 1 includes IRSD zones for the Adelaide metropolitan area, combined to create five value groups (normally 10 in total—detailed below). Higher index values equal a higher relative socioeconomic status (Adams et al. 2009).

Total economic values for green spaces, as well as insight into how to accommodate trade-offs in allocating resources between them, can be informed by evaluating the net economic demand or values generated at each site (Mayer, 2014; Richardson et al. 2018). Estimating the economic benefits of green spaces assists in prioritising public investments by way of evaluating options, and communicating and supporting management choices (Loomis, 2002). We adopted three analysis methods.

3.2. *Analysis methods*

A good structured example of economic analysis can be found in Mayer (2014), which we use in part to identify our modelling, conduct the TEV analysis, and explore the hypothesised links between green space engagement and associated health outcomes.

3.2.1. *Willingness to pay: travel cost approach*

Where a person makes a conscious decision to expend their limited disposable income according to their preferences this is a signal of the relative opportunity costs and benefits of that (public or private) good to the individual. This is described as the willingness to pay (WTP) for that good. Hence, travel costs provide an estimate of the 'price' that individuals are willing-to-pay to visit. Travel cost approaches (TCA) for estimating WTP are widely used to value recreational and other (e.g. amenity) ecosystem services (Heagney et al. 2019). However, in the case of metropolitan green spaces, the distances associated with travel to these sites is relatively small for most visitors (see Fig. 1 for example), as they are close to both the Adelaide city and suburban residents that engage with them. Conversely, for interstate or international visitors the travel costs will be higher based on larger distances to be (potentially) travelled, and higher relative travel costs than domestic residents (e.g., cost to hire a car as opposed to residents who have their own transport options). We take this into account in our assumptions around visitor costs based on their origin when we estimate the associated relevant accommodation, incidental meal, or other expenses for domestic versus interstate or international visitors (see data section).

3.2.2. Mobility Bayesian modelling approach

Studies of individual sites offer limited insights for managers whose networks encompass tens or even hundreds of locations (Pendleton, 1999). Studies commonly focus on small or high-profile and thus highly visited sites or an incomplete number of sites that may ignore context-specific attribute differences, remoteness, and local community factors in addition to the availability of substitute sites within the surrounding region. These biases are problematic, as estimates at high-profile sites may obscure the attributes driving visitation, and limit informed decision-making (Heagney et al. 2018). This necessitates application of econometric analysis techniques capable of handling high rates of zero-value responses (e.g., zero-one inflated beta techniques, see Loch et al. (2014) for an example). Moreover, value estimates from on-site surveys cannot be easily scaled up to provide a total estimate of tourism and recreation without robust data on total visitor numbers; and such data is usually absent from sites or public sources (Heagney et al. 2019).

To address these issues, we employed a Bayesian model (see Loch et al. 2023 for detail) to estimate visitation and visitor origins from limited observations based on estimating the number of green space visitors based on mobile phone ping data obtained from a commercial third-party supplier (see data section below) and conditioned on known visitation to a number of sites (e.g., bookings or ticket sales equated to approximately 20 % of all sites in the study area). The model sought to understand visitation statistics (Schmeidler, 1989) by estimating:

$$p\left(\propto_{ij}|y_{ijk}, \quad n_{ijk}\right) \tag{1}$$

In this expression, α is the likelihood of a mobile phone device being recorded, y is an aggregate count of visitors from mobility records, and n is the known total number of visitors at a training site. Subscript i refers to a particular site, subscript j refers to the origin of a visitor (meaning their LGA if the visitor was from SA), and subscript k refers to the month of the visit. Therefore, the model used data from sites with known visitation to estimate the likelihood α of a mobile ping being recorded, including an uncertainty measure for that estimate. Total visitors at the above sites were estimated by upscaling the mobile phone ping counts using the assigned range of values of α. Modelled visits to the 20 green space sites totalled 1,453,271; visits to botanic gardens totalled 1,389,232 and the aggregate for all sites was 2,842,503 visits. On average, upper and lower 95 % CI bounds fall within 3.3 % of the median. This process enabled the calibration and development of bounded site visitation levels to aggregate the final WTP values.

3.2.3. Reduced healthcare cost modelling

A common approach to estimating wellbeing benefits or reduced healthcare costs is the examination of quality adjusted life years (QALY) to identify the value of activity undertaken by individuals to maintain their health (Buckley et al. 2019). However, these estimates may not aggregate well across groups (Pettitt et al. 2016) especially where datasets are unbalanced, and other researchers have questioned if the conditions that QALY estimates represent preferences that hold in general, inflating reported social preference values (Bleichrodt and Quiggin, 2013). Usefully, the government partner for the research study (South Australian Department for Environment and Water, or DEW) conducts an annual survey of metropolitan green space users that includes measures of life satisfaction and self-reported health (SRH) status. Where used to estimate preference values for these sites, the results can be safely aggregated with other preference values (e.g. WTP) without any risk of double-counting (FIT, 2018). Comparisons of SRH status for park users with SRH measures from the general population allows researchers to calculate differences associated with green space access and use—including any differences across individuals and groups, where grouping is possible. Modelling the SRH scores for those that visit metropolitan Adelaide green spaces with general population SRH scores allows us to isolate associated reductions to healthcare costs, where this remains a small proportion of the total associated physical and mental health improvements that could be achieved via increased green space access and use (FIT, 2018). This may especially true for lower socio-economic groups (e.g. 1–2 IRSD decile values) who bear an higher incidence of chronic disease burden, and do not have close proximate access to green space sites (Dadvand and Nieuwenhuijsen, 2019).

3.3. Data sources, preparation, and assumptions

Several data sources—both private and public—provided the data basis for our study:

3.3.1. WTP data

For residents of South Australia the cost of travel to green spaces was estimated using the per kilometre rate data derived from the Australian Tax Office’s (ATO) 2019–11 travel determination for 2018–19. The applicable vehicle rate for that period was AU$0.68 cents per kilometre including decline in vehicle value, registration, insurance, maintenance, repairs, and fuel costs. For visitors from international origins, we assume travellers arrived by flights into Adelaide, starting any visits to green spaces from the Adelaide GPO. For interstate visitors we assume that a green space visit is a recreational event and not the primary purpose for travel to SA; therefore, travel is also assessed from the Adelaide GPO. However, not all interstate visitors will stay in commercial accommodation, as some will instead stay with friends and relatives at little to no cost. The most common proportion reported for those that stay with friends and family is around 20 % (see Seaton and Palmer, 1997 for detail; Backer, 2012); hence we adopt 80 % as the accommodation proportion in the model to reduce the total population of interstate or international visitor estimates.

To calculate the final WTP weighting we determine the actual distance in kilometres to each site centroid (central location coordinates) and then multiply that distance by the associated travel charge. The process thus factors the higher costs of vehicle rental hire into the WTP for interstate and international visitors, which are then applied site by site to arrive at a set of specific travel cost values.

3.3.2. Annual green space survey

Data was drawn from the annual McGregor Tan (2020) survey of South Australian National Park and Reserve Visitors that measures South Australians’ perceptions about their health, overall life satisfaction, the number of times they have visited a green space in the last year, which sites they have visited, the general values they place on sites (i.e. what activities they use green space for, what experiences are of value to

Table 1
Expenditure estimates – Interstate or International visitors.

Example secondary expenditure	Rate applied
Adelaide accommodation	$157/night
Adelaide meals & incidentals	$133.75/day
Adelaide City full rate	**$290.75**

Table 2
Green sites by distance – Interstate or International visitors. We calculate modifiers to apply to total visitor numbers and costs from Table 1.

Weighted travel costs	Sites @	Sites @	Sites @	Sites @
	Within 5 km	**5 – 25 KMS**	**25 – 60 KMS**	**60–110 KMS**
% of total Visitors	80 %	80 %	80 %	80 %
ATO proportional costs	33 %	33 %	67 %	100 %
WTP travel weighting	Actual distance to site centroid x Average per km charge			

them from engaging with such sites), and their residential postcode details to connect to IRSD. The full database comprises a large sample of the South Australian population (n = 5720 observations), which is reduced to the 2017–2019 periods (n = 3557) to align with the 2018–19 baseline year. Overall, i) 75 % of South Australians had visited a state managed site, ii) the average median visitation rate was 4.0 times in 2019 with patterns of visiting 1–3 times p.a. (41 %), 4–11 times p.a. (43 %), and some 12 or more times (16 %), iii) only 1 % stated that parks were not important, iv) that protection of native plants and animals, as well as cultural heritage, was the main reason for visiting (53 %) followed by enjoyment of community recreation and health benefits (46 %), and v) 83 % self-reported their health as excellent, very good or good with an average life satisfaction score of 7.3 (out of 10).

3.3.3. IRSD decile data

The ABS Socio-Economic Indexes for Australia (SEIFA) 2016 datasets provided the IRSD score for each South Australian postcode collected from the McGregor Tan survey. This supplied a IRSD score of between 1 (relatively highly disadvantaged area) and 10 (relatively highly advantaged area) to the survey database, and ultimately these were consolidated further into five IRSD decile groups (i.e. 1–2, 3–4, 5–6, 7–8 and 9–10) to improve model interpretability. As the survey data did not feature a balanced (consistent) panel of respondents over time the use of IRSD deciles allowed us to group respondents and then compare changes within those groups (rather than across time for individuals) as a basis for the WTP comparisons. IRSD grouping was also relevant for the subsequent reduced healthcare cost model, where national or state data on health costs is generally provided by IRSD score.

3.3.4. Australian health data

To prepare for the reduced healthcare cost (RHC) model a number of publicly available datasets were employed, consistent with previous studies (e.g., Ding et al. 2016). The ABS 2017–18 National Health Survey – Australia IRSD dataset was used to collate observations on all long-term health conditions for the entire Australian population (ABS, 2020). As this data is also available in subsets for each state and territory, we collected observations for South Australia (i.e. the ABS 2017–18 National Health Survey by State and Territory and IRSD) (ibid.). This data allows calculation of average health burdens experienced by citizens in each IRSD group across ten major long-term chronic disease categories that contribute a significant proportion of the annual total public health expenditure (AIHW, 2021). The most expensive community chronic diseases include mental health, cancer, back problems, diabetes, heart and vascular diseases, and kidney disease. Finally, the Australian Institute of Health and Welfare (AIHW) website offered important data on the total costs of health procedures and other population-level data (e.g., AIHW HWE-81 Disease Expenditure in Australia 2018–19) (AIHW, 2021).

3.3.5. Mobility data

Mobility data describes information generated by activities, events or transactions using GPS-enabled mobile devices or services (e.g., smartphones). These recorded events can be allocated to individual sites, indicating visits. Mobility data utilise geolocation data whereby a device using mobile applications (apps) periodically transmits the device location via pings or periodic connections to cell-towers, yielding terabytes of location information available through the recording of these pings. The collection of location data transmitted by devices can therefore be viewed as another means of sampling a population in space and time (Xu et al. 2016) and, as with any population sampling regime, the information gained via these data represents only a fraction of the population; hence the Bayesian modelling requirements based on the ping data received. Fig. 2 provides an illustrated concept of the health analysis. For the 2018–19 baseline period we report the results across: the aggregated WTP estimates, the reduced healthcare cost model estimates, and an exploration of distances travelled and the frequency of site visitation by individual IRSD decile groups to better understand spatial relationships with selected green spaces.

4. Results

4.1. 2018–19 aggregate WTP

Using the weighting methods and assumptions detailed above and applying them to the total 2018–19 visitation estimates derived from the mobility data, we aggregate the WTP value for each site. In total, the 2018–19 travel cost value of green spaces was AU$48 million spread across the three main value categories as shown in Table A2 of the Appendix section.

South Australian domestic visitor travel costs for return trips to Adelaide green spaces totalled AU$15.5 million in 2018–19. The picture for interstate and international visitors is different with respect to their travel costs, but similar in terms of broad site WTP. In 2018–19, the estimated travel costs by interstate visitors to travel to green spaces was AU$16.6 million, while for international visitors to Adelaide the estimated total WTP was AU$15.9 million. If we think about these numbers, they may seem low, but we must remember the relatively low median distances travelled in each case (i.e. between 9 and 35 kilometres), and

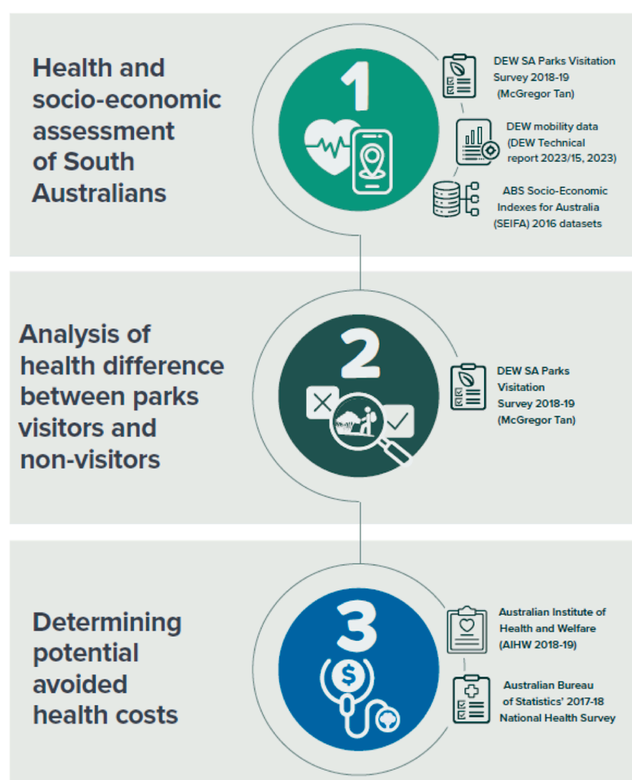

Fig. 2. Illustrated methodology process (DEW, 2024).

that only basic vehicle costs are reflected here as opposed to other studies' assumptions (i.e. accommodation, meals, fuel, and vehicle costs). The visitor opportunity cost is also quite low reflecting the moderate costs for people to engage with (largely free to access and use) green spaces. The estimated opportunity cost WTP values for domestic visitors totalled AU$1.1 million in 2018–19. This tells us that, relative to the next-best alternative expense on which South Australians could spend their disposable income (e.g., going to the cinema), those engaging with green spaces are willing to spend more money to do so. Yet again, the cost is not high, which is a good social welfare outcome with equity benefits.

Of the 20 sites studied, eight account for most of this travel cost value, which should not surprise to those who are familiar with them. Cleland National Park (including Cleland Wildlife Park) tops the list (AU $17.24 million). The next highest WTP sites are Hallett Cove (AU$8.27 million), Onkaparinga (AU$5.07 million), Deep Creek (AU$3.03 million), and Belair National Park (AU$2.4 million). Botanical Gardens results are reported in the Appendix (Table A3).

4.2. Reduced healthcare costs

As shown in Fig. 3, when we deduct SRH scores for visitors to green spaces from those that do not, a pattern of differences emerges. That is, the health for those that visit green spaces is less likely to be Poor or Fair, about equally likely to be Good, but far more likely to be Very Good and Excellent by comparison. There are some distinct differences across the IRSD groups as we might expect, but this is helpful for our modelling of reduced healthcare costs.

Table 3 presents the model estimates for reduced healthcare costs in 2018, separated by IRSD for Australia's ten major long-term chronic disease categories. Lower relative socioeconomic groups (i.e., IRSD decile 1–2 and 3–4) share a large proportion of the total health burden, at around 45 % combined. These groups also experienced the highest total health costs in 2018–19; approximately AU$800 million in each case. However, they also self-reported the highest levels of health difference from that of non-green space visitors; that is, between around 2 and 5 % consistent with other studies (e.g., Buckley, 2020). In total, visits to national parks are associated with significant healthcare cost reductions of around AU$60 million—or approximately 43 % of the estimated benefits from site activity.

In total for the 2018–19 period, the model estimates that all IRSD decile groups generated approximately AU$140 million worth of reduced healthcare costs, or around 4 % of the total South Australian healthcare budget.[1] We next examined these predictions in depth. While the reduced healthcare cost results for IRSD groups 1–2 and 3–4 amount to approximately 45 % of the total 2018 health costs for South Australia, these groups invest relatively higher costs to visit green spaces for recreation. However, this group also obtains over four-times as much reduced healthcare costs (AU$40.1 million or 43 % of total) from their engagement with green spaces. Finally, Table 4 provides the national health expenditure across the ten major chronic diseases together with the South Australian portion of those costs (ABS, 2020). Total health expenditure for Australia was AU$41.2 billion in 2017–18 Census, of which South Australia represented AU$3.6 billion or approximately 8.7 %. As argued earlier, where green spaces are preferred by individuals for increased physical and mental health-related activities those sites may reduce the incidence and costs associated with some of these health issues (e.g., diabetes, heart disease and mental health issues—or around 67 % of the most expensive chronic diseases).

[1] Healthcare expenditure is the largest state budget cost in South Australia, representing 27.5 % of total spend (AU$14.7 billion in 2018–19) (SA Treasury, 2019).

4.3. IRSD decile group results

If we multiply single trip WTP values by visit frequencies we can arrive at a rough estimate of the annual WTP values, again across the different IRSD decile groups (Table 5). In some cases (e.g. those that have only visited green spaces once in the last year) the annual WTP values do not appear differ significantly—as we might expect given the earlier results. However, in other instances the annual WTP values can fluctuate significantly across the IRSD groups with WTP ranging up toAU$315 p.a. (IRSD 9–10). The other IRSD groups spend around AU $53 per year each. This breakdown is important for dispelling perceptions that, for example, any one single socioeconomic group (e.g. IRSD 9–10 decile) engages with green spaces more highly than those from other groups. In any of the 2018–19 group examples dominant WTP values may emerge from any one IRSD decile.

Again, this is interesting as, for the 2018–19 data, annual WTP results for *At least weekly* visits suggest those in the relatively lower IRSD decile groups are willing to spend their money to visit and engage with green spaces in line with most other IRSD groups. This is perhaps due to green space providing a healthy and cheap source of exercise, interaction with nature, play space for children, and an opportunity to socialise either with family or friends. These motives are explored further below.

4.4. Assessing motives for visiting green spaces

While the above WTP investigation did not indicate patterns regarding the 'price' values by different socioeconomic groups, our study can reveal both the amount of money spent visiting sites plus the distances travelled by representatives from each IRSD group, with some clear patterns. Distance travelled is important to explore as it may yield information about the accessibility of sites to each of the groups within the metropolitan region. We consider the total number of visits and the median distance travelled per IRSD group. Fig. 4 shows clearly that the number of visits increase with IRSD group, and the median distance travelled decreases. This pattern is not surprising, as most sites are within or adjacent to the highest socioeconomic classification (IRSD 9–10 group). Only six sites are within 15 km of a local government area (LGA) which is classified as IRSD group 1–2, while a small number of sites are local to the mid-range IRSD decile LGAs. Given that the median distance travelled to a site across the 1.3 million visits (within 60 km of the GPO) was 13 km (Figure A1), it is prudent to explore this apparent discrepancy in availability of sites to lower socioeconomic groups to better understand if the distance travelled is equitable among groups.

As anticipated, our analysis shows that residents of LGAs that fall within IRSD 1–2 (on average) must travel the farthest to visit a site (36 km). IRSD groups 7–8 and 9–10 both have the same median distance to travel (11 km). However, IRSD group 9–10 demonstrates a higher TCA contribution indicating residents from these LGAs engage more with green spaces. Further analyses of relationships between IRSD groups and distances demonstrated several key patterns in the relationship between IRSD groups, their proximity to a site, and the level of visitation made by each group:

- All socioeconomic groups are more likely to visit (in greater numbers) if a site is close to their location. This is true for both smaller local, and larger drawcard, sites.
- Lower relative socioeconomic groups appear to be more likely to visit if a site is close to their location but may also travel further distances from home at relatively higher costs to engage with other metropolitan green spaces.
- IRSD 9–10 have the widest selection of close sites to choose from, which is reflected in both the sheer number of visits undertaken, and some of the higher WTP.
- Lower socioeconomic groups are prepared to travel to green spaces, but a concentration of parks at more distant locations (e.g. within

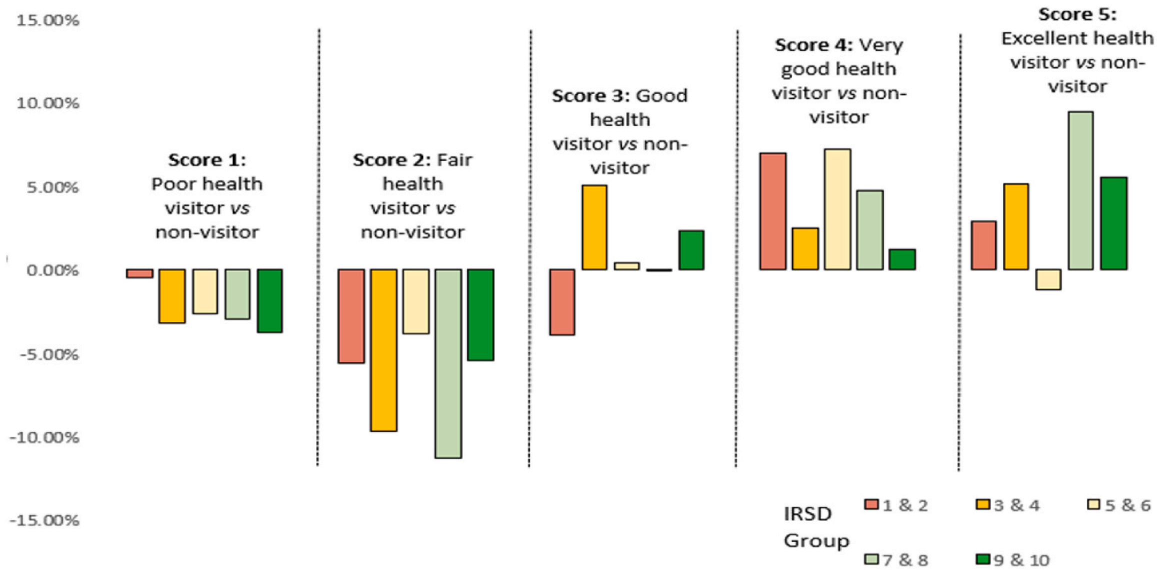

Fig. 3. : Proportion of visitors to green spaces SRH score minus those that did not.

Table 3
Average disease burden by IRSD, total costs and percentage reduction, 2018–19.

IRSD Decile	Average Disease Burden	Total Costs	% Reduction	Reduced Health Costs ($millions)
1–2	23 %	$821,402,939	2.41 %	$19.8
3–4	22 %	$817,895,614	5.13 %	$41.9
5–6	19 %	$666,041,539	2.60 %	$17.3
7–8	19 %	$695,285,218	5.68 %	$39.4
9–10	17 %	$585,840,215	3.65 %	$21.4
			3.89 %	
Estimated total reduced healthcare costs, South Australia 2018–19				**$140.0***

* Numbers not add due to rounding.

10–15 km) may limit the opportunity for these groups to improve their health benefits.

5. Discussion and conclusions

Our findings suggest that, while average WTP values are mostly homogeneous, there are differences in the travel costs for relatively lower socioeconomic groups that inflate their WTP values. This confirms that green spaces can be valued differently in different regions and by different groups, as detailed in other studies (Murakami et al. 2022). Further, the increased frequency of visits to green spaces does not appear to change WTP values. However, for individuals that do visit more frequently (e.g. IRSD 9–10) the relative value they ascribe to green space activity is more positive. Additionally, the location of green spaces relative to visitor residence locations affect use patterns. These patterns are reflected in the associated site travel costs and the distribution of visitors from different IRSD groups to individual parks within the network. This raises the issue of access to green and biodiverse spaces as a justice and equity issue (Richardson et al. 2013; Hsu et al. 2022). Importantly, our study illustrates that biodiverse green spaces in Adelaide are relatively easy to access, involve relatively low travel costs, and are well visited for recreational purposes. Relative ease of access is true for both local (metropolitan Adelaide) and interstate or international visitors in higher relative socioeconomic groups; although lower relative socioeconomic groups from metropolitan Adelaide may incur relatively higher travel costs to engage with the biodiverse green spaces provided by the protected reserve system. This study illustrates that despite a relatively high density of biodiverse green spaces accessible to the metropolitan area through national parks, there remain distributive concerns (as discussed under different conditions by Schlosberg, 2004; Jennings et al. 2019) for this 'National Parks City'.

Our hypothesis that access to, and engagement with, biodiverse green spaces in Adelaide has positive health benefits thus appears to be supported. We find support for the suggestion that increased access to green spaces has significant potential to reduce health costs and inequalities. This has been previously indicated with survey data alone (Buckley (2020). However, our study used a visitation quantification approach made possible using mobile phone 'ping' data to improve the accounting, demonstrating the mechanism of health and wellbeing gains from access to biodiversity and green space remains a challenge despite a very large number of studies exploring the topic (Zhang et al. 2020). In our 2018–19 baseline study year, the broad positive self-reported health differential between South Australians that visited green spaces and those that do not was around 2–5 %. There are also distinct patterns across the IRSD groups, where some groups gain more benefit than others. However, groups that visit biodiverse green spaces report better health than those who do not. On face value, these health differences may not seem high. But it is the scope of annual public health expenditure, and the large number of site visits, that makes this difference meaningful in monetary terms. The 2–5 % reduction is associated with AU$140 million in value, or nearly 4 % of the AU$3.59 billion 2018 public healthcare budget to address chronic diseases in 2017–18. At global scales, the burden of disease has been estimated to sum to 2.88 billion disability-adjusted life-years (DALYs) in 2021 (Ward and Goldie, 2024). Reducing healthcare costs through facilitating access to nature may therefore have far reaching benefits in terms of both health expenditures as well as nature conservation. The analysis approach used deals with a lack of data linking health differences resulting from one activity among many possible activities to health expenditures at population levels. These limitations should be considered in the context of the challenge of connecting pe[1]rsonal behavioural data to a wide range of expenditures.

5.1. Study limitations

Finally, there are other limitation issues that will remain following this work. For example, Yu et al. (2018) report physical and mental wellbeing benefits from immersive virtual sessions with forest environments, which was not considered relevant in this case and needs to be

Table 4
2018–19 Chronic disease condition list of health expenditure (AIHW, 2021).

	Arthritis (c)	Asthma	Back Problems	Cancer	Respiratory Disease	Diabetes Melitus	Heart and Vascular Disease	Kidney Disease	Mental Health	Osteoporosis
National health costs	$880,744,530	$787,400,472	$2124,399,770	$9204,263,326	$858,615,344	$3758,346,169	$9253,309,732	$3161,717,591	$9574,971,168	$1619,973,570
South Australia portion of total costs	$76,624,774	$68,503,841	$184,822,780	$800,770,909	$74,699,535	$326,976,117	$805,037,947	$275,069,430	$833,022,492	$140,937,701
IRSD Decile										
1–2	$17,302,437	$14,558,431	$37,728,959	$190,792,697	$20,319,758	$88,071,395	$179,710,280	$63,626,941	$179,525,828	$29,766,215
3–4	$17,720,839	$15,119,542	$40,320,632	$184,836,242	$17,660,751	$78,002,931	$199,500,012	$53,460,338	$179,886,184	$31,388,142
5–6	$14,707,494	$12,164,186	$37,920,762	$151,703,461	$13,158,991	$55,127,603	$136,367,979	$52,774,949	$165,763,668	$26,352,446
7–8	$14,821,604	$13,900,839	$36,957,071	$155,053,967	$11,773,834	$58,363,895	$153,231,061	$52,660,717	$170,362,495	$28,159,736
9–10	$12,072,401	$12,760,843	$31,895,356	$118,384,542	$11,786,201	$47,410,292	$136,228,615	$52,546,486	$137,484,318	$25,271,162
Total South Australian health costs – chronic diseases	$3586,465,526									

addressed more carefully. Additionally, the ping data analysis has been modified since this study, creating new opportunities and information to consider. It is likely that this work will continue with smaller levels of government, and that future work may consider such issues.

6. Conclusions

The findings of this study address one of the problems of whole-of-government decision-making where factors other than preference values are involved in budgetary allocations (e.g. Herrmann-Pillath, 2023). The study seeks to make benefits from access to biodiverse nature explicit in monetary terms where they have traditionally been implicit and difficult to include in budgeting. This aligns with a growing body of work seeking to make the economic benefits to people from the environment explicit through accounting (e.g., SEEA) and policy innovation (Zheng et al. 2023).

Clear heterogeneous spatial differences in green space preference values can assist planning needs and promote development or protection of green spaces in under allocated areas. At present, estimated South Australian benefits from tourism and recreation direct revenue, indirect travel costs, plus reduced healthcare costs derived through access to the protected area network was worth around AU$562 million in 2018–19 (Loch et al. 2022). It is likely that the total economic value of these assets is far higher, making a compelling argument for their protection, proper management, and future existence.

Even at the highest individual annual average opportunity cost WTP level for this study (i.e. AU$315 p.a. for IRSD decile 9–10 in the daily site visitation category), the relative opportunity cost to access nature through green space visit expenditure is a small fraction of what people expend on health goods and services. Health expenditures in Australia were estimated to be $9365 per person in 2022 (AIHW, 2023), with approximately 70 % of the expenditure being government funds. Deployment of assets such as biodiverse green spaces and National Parks to reduce health expenditures may provide much needed policy innovation as health expenditures rise: they are currently 10.5 % of total economic activity in Australia (ibid.). Green spaces can therefore be characterised as an affordable good, decreasing the often higher-cost characteristics of private physical and mental health services and creating spaces for environmental distributive justice (Hsu et al. 2022). The fact that many green spaces are also increasingly the main way in which many of us interact with natural settings—and experience the outdoors—as urban migration grows over time, also highlights the importance placed on preserving them for current and future generations.

Finally, green spaces also increase health equality, as shown by the reduced health cost analysis. The lower relative IRSD decile groups carry a higher burden of chronic diseases and associated costs. These groups will also have a higher probability of needing to rely on the public health system by contrast to higher IRSD decile groups. And yet when the relatively lower IRSD groups use green spaces they may improve their health; again at a higher relative rate to other IRSD groups as might be expected and in line with other jurisdictions (e.g. Queensland as studied by Driml et al. 2019). Thus, green spaces can provide an environmental justice benefit across different socio-economic groups as a truly public good with communal benefits. More work must be done in this space.

CRediT authorship contribution statement

John Maclean: Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation. **Patrick O'Connor:** Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Funding acquisition, Conceptualization. **Adam James Loch:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Stuart Sexton:** Writing – original draft, Visualization, Validation, Software, Resources,

Table 5
2018–19 Annual and Average Visit WTP, by IRSD and Visitation Frequencies.

	IRSD Decile Group					
Visit Frequency	**1–2**	**3–4**	**5–6**	**7–8**	**9–10**	**Average**
1–3 times per annum (Once in last year)	$4.55	$3.85	$4.21	$3.28	$3.42	$3.86
4–6 times per annum (Occasional visitor)	$11.01	$6.70	$5.16	$7.86	$6.97	$7.54
7–24 times per annum (At least monthly)	$36.57	$38.89	$24.75	$18.97	$32.32	$30.30
25–52 times per annum (At least weekly)	$51.00	$52.91	$57.23	$171.02	$48.33	$76.10
53+ times per annum (Daily visitor)	$-	$33.98	$252.63	$105.41	$315.00	$141.40

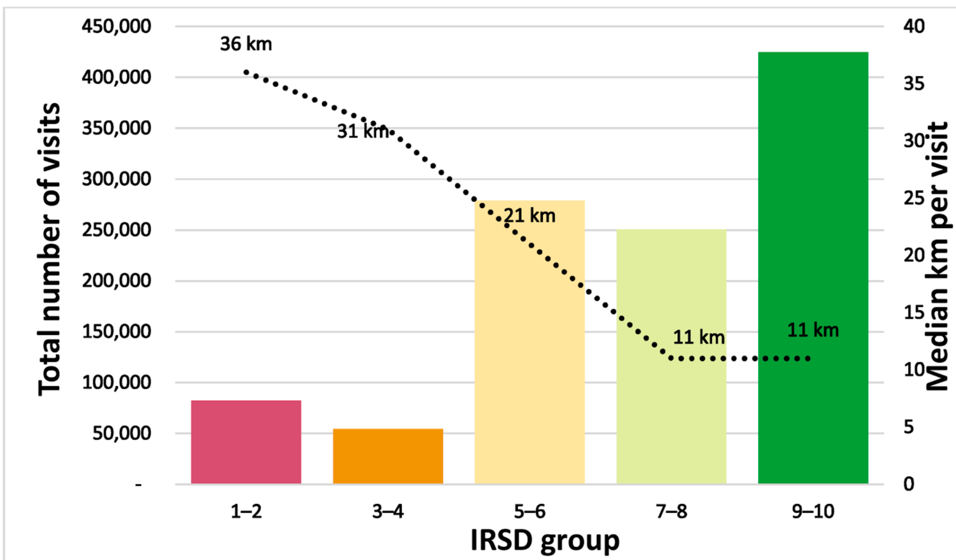

Fig. 4. Total number of visits (coloured bars, left axis) and median distance travelled (dotted line, right axis) by each IRSD decile group.

Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **David Adamson:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation. **Glen Scholz:** Writing – original draft, Resources, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

No conflicts or funding issues to declare for any of the authors.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128576.

References

ABS (2020). National Health Survey: First results, 2017-18 - Australia. Australian Bureau of Statistics, Hobart, Tasmania.
Adams, R.J., Howard, N., Tucker, G., Appleton, S., Taylor, A.W., Chittleborough, C., Gill, T., Ruffin, R.E., Wilson, D.H., 2009. Effects of area deprivation on health risks and outcomes: a multilevel, cross-sectional, Australian population study. Int. J. Public Health 54, 183–192.
AIHW (2021). Disease expenditure in Australia 2018-19. Australian Institute of Health and Welfare, Canberra, ACT.
AIHW (2023). Health expenditure Australia 2021-22. Australian Institute of Health and Welfare, Canberra, ACT, pp 111.
Backer, E., 2012. VFR travel: It is underestimated. Tour. Manag. 33, 74–79.
Bauer, G.R., 2014. Incorporating intersectionality theory into population health research methodology: challenges and the potential to advance health equity. Soc. Sci. Med. 110, 10–17.
Bishop, R.C., Boyle, K.J., 2019. Reliability and validity in nonmarket valuation. Environ. Resour. Econ. 72, 559–582.
Bleichrodt, H., Quiggin, J., 2013. Capabilities as menus: a non-welfarist basis for QALY evaluation. J. Health Econ. 32, 128–137.
Buckley, R., 2020. Nature tourism and mental health: parks, happiness, and causation. J. Sustain. Tour. 28, 1409–1424.
Buckley, R., Brough, P., Hague, L., Chauvenet, A., Fleming, C., Roche, E., Sofija, E., Harris, N., 2019. Economic value of protected areas via visitor mental health. Nat. Commun. 10, 5005.
Campbell, D., Vedel, S.E., Thorsen, B.J., Jacobsen, J.B., 2014. Heterogeneity in the WTP for recreational access: distributional aspects. J. Environ. Plan. Manag. 57, 1200–1219.
Chapron, G., Epstein, Y., López-Bao, J.V., 2019. A rights revolution for nature. Science 363, 1392–1393.
Coffey, B., Damiens, F.L., Hysing, E., Torabi, N., 2022. Assessing biodiversity policy designs in Australia, France and Sweden. Comp. Lessons Transform. Gov. Biodivers. ?, *J. Environ. Policy Plan.*1 14.
Cresswell, I., Janke, T. and Johnston, E. (2021). Australia state of the environment 2021: overview, independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra.
Dadvand, P., Nieuwenhuijsen, M., 2019. Green Space and Health. In: Nieuwenhuijsen, M., Khreis, H. (Eds.), Integrating Human Health into Urban and Transport Planning: A Framework. Springer International Publishing, Cham, pp. 409–423.
Dasgupta, S.P. (2021). The Economics of Biodiversity The Dasgupta Review Abridged Version.
Dehnhardt, A., 2013. Decision-makers' attitudes towards economic valuation–a case study of German water management authorities. J. Environ. Econ. Policy 2, 201–221.
Delgado-Baquerizo, M., García-Palacios, P., Bradford, M.A., Eldridge, D.J., Berdugo, M., Sáez-Sandino, T., Liu, Y.-R., Alfaro, F., Abades, S., Bamigboye, A.R., Bastida, F., Blanco-Pastor, J.L., Duran, J., Gaitan, J.J., Illán, J.G., Grebenc, T., Makhalanyane, T. P., Jaiswal, D.K., Nahberger, T.U., Peñaloza-Bojacá, G.F., Rey, A., Rodríguez, A., Siebe, C., Teixido, A.L., Sun, W., Trivedi, P., Verma, J.P., Wang, L., Wang, J., Yang, T., Zaady, E., Zhou, X., Zhou, X.-Q., Plaza, C., 2023. Biogenic factors explain soil carbon in paired urban and natural ecosystems worldwide. Nat. Clim. Change.

DEW 2024). Value of South Australia's National Parks and Reserves: Study 2 - Recreational and Wellbeing Benefits of National Parks. in Scholz, G. (ed.). South Australian Department for Environment and Water, Adelaide, SA, pp 18.
Ding, D., Lawson, K.D., Kolbe-Alexander, T.L., Finkelstein, E.A., Katzmarzyk, P.T., Van Mechelen, W., Pratt, M. for the Lancet Physical Activity Series 2 Committee, 2016. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. Lancet 388, 1311–1324.
Driml, S., Brown, R., Silva, C.M. and Li, L. (2019). Estimating the value of National Parks to the Queensland economy: Methodology report. The University of Queensland, Brisbane, Qld.
FIT (2018). Revaluing parks and green spaces: Measuring their economic and wellbeing value to individuals, *Green Spaces for Good*. Fields in Trust, London, UK.
Gómez-Baggethun, E., 2017. Ecosystem services, *Routledge Handbook of Ecological Economics*. Routledge, pp. 445–454.
Green Adelaide (2023). Adelaide named the world's second National Park City. Green Adelaide, SA, Adelaide.
Heagney, E., Rose, J., Ardeshiri, A., Kovač, M., 2018. Optimising recreation services from protected areas–Understanding the role of natural values, built infrastructure and contextual factors. Ecosyst. Serv. 31, 358–370.
Heagney, E., Rose, J.M., Ardeshiri, A., Kovac, M., 2019. The economic value of tourism and recreation across a large protected area network. Land Use Policy 88, 104084.
Herrmann-Pillath, C., 2023. The universal commons: An economic theory of ecosystem ownership. Ecol. Econ. 208, 107822.
Hou, Y., Burkhard, B., Müller, F., 2013. Uncertainties in landscape analysis and ecosystem service assessment. J. Environ. Manag. 127, S117–S131.
Hsu, Y.-Y., Hawken, S., Sepasgozar, S., Lin, Z.-H., 2022. Beyond the backyard: GIS analysis of public green space accessibility in Australian metropolitan areas. Sustainability 14, 4694.
IUCN (2024). What is the IUCN Green List? The International Union for Conservation of Nature, Switzerland, pp Webpage.
Jennings, V., Browning, M.H., Rigolon, A., Jennings, V., Browning, M.H., Rigolon, A., 2019. Urban green space at the nexus of environmental justice and health equity. Urban Green. Space.: Public Health Sustain. U. S. 47–69.
Khatri, A., 2022. Message to Mayors: cities need nature. Nature 601, 299.
Lange, O., 1942. The foundations of economics welfare. Econometrica 10, 215–228.
Loch, A., Mclean, J. and O'Connor, P. (2023). Value of South Australia's National Parks and Reserves - Willingness to Pay and Reduced Healthcare Costs associated with Adelaide Metropolitan Parks; Final Report, Study 2: Recreational and Wellbeing Benefits of Metropolitan Parks. School of Economics and Public Policy Working Papers 2023-02, University of Adelaide, Adelaide, SA.
Loch, A., Scholz, G., Auricht, C., Sexton, S., O'Connor, P., Imgraben, S., 2022. Valuing Protected Area Tourism Ecosystem Services Using Big Data. *Environ. Manag.*14.
Loch, A., Wheeler, S., Boxall, P., Hatton-MacDonald, D., Adamowicz, W., Bjornlund, H., 2014. Irrigator preferences for water recovery budget expenditure in the Murray-Darling Basin. Land Use Policy 36, 396–404.
Loomis, J., 2002. Integrated public lands management. Columbia University Press, New York.
Mayer, M., 2014. Can nature-based tourism benefits compensate for the costs of national parks? A study of the Bavarian Forest National Park, Germany. J. Sustain. Tour. 22, 561–583.
McGregor Tan (2020). South Australian parks visitation survey report. A report prepared for the South Australian Department for Environment and Water, Adelaide, SA.
Murakami, K., Itsubo, N., Kuriyama, K., 2022. Explaining the diverse values assigned to environmental benefits across countries. Nat. Sustain. 5, 753–761.
Olukolajo, M.A., Oyetunji, A.K., Amaechi, C.V., 2023. A Scientometric Review of Environmental Valuation Research with an Altmetric Pathway for the Future. Environments 10, 30.
Pendleton, L., 1999. Reconsidering the hedonic vs. RUM debate in the valuation of recreational environmental amenities. Resour. Energy Econ. 21, 167–189.
Pettitt, D., Raza, S., Naughton, B., Roscoe, A., Ramakrishnan, A., Ali, A., Davies, B., Dopson, S., Hollander, G., Smith, J., 2016. The limitations of QALY: a literature review. J. Stem Cell Res. Ther. 6.
Reyes-Riveros, R., Altamirano, A., De La Barrera, F., Rozas-Vásquez, D., Vieli, L., Meli, P., 2021. Linking public urban green spaces and human well-being: A systematic review. Urban For. Urban Green. 61.
Richardson, E.A., Pearce, J., Mitchell, R., Kingham, S., 2013. Role of physical activity in the relationship between urban green space and health. Public Health 127, 318–324.
Richardson, L., Koontz, L., Peacock, B., 2018. For the benefit and enjoyment of the people: An exploration of the economic benefits of National Parks. Georg. Wright Forum 35, 42–52.
Rigolon, A., Browning, M.H., McAnirlin, O., Yoon, H.V., 2021. Green space and health equity: a systematic review on the potential of green space to reduce health disparities. Int. J. Environ. Res. Public Health 18, 2563.
Rogers, A.A., Kragt, M.E., Gibson, F.L., Burton, M.P., Petersen, E.H., Pannell, D.J., 2015. Non-market valuation: usage and impacts in environmental policy and management in A ustralia. Aust. J. Agric. Resour. Econ. 59, 1–15.
S.A. Treasury (2019). Final Budget Outcome: 2018-19. SA Department of Treasury and Finance, Adelaide, SA, pp 66.
Samuelson, W., Zeckhauser, R., 1988. Status quo bias in decision making. J. risk Uncertain. 1, 7–59.
Schlosberg, D., 2004. Reconceiving environmental justice: global movements and political theories. Environ. Polit. 13, 517–540.
Schmeidler, D., 1989. Subjective probability and expected utility without additivity. *Économ.: J. Econom. Soc.*571-587.
Seaton, A., Palmer, C., 1997. Understanding VFR tourism behaviour: the first five years of the United Kingdom tourism survey. Tour. Manag. 18, 345–355.
Treasury (2022). Statement 4: Measuring what matters. Australian Department of Treasury, Canberra, ACT.
Waldron, A., Miller, D.C., Redding, D., Mooers, A., Kuhn, T.S., Nibbelink, N., Roberts, J. T., Tobias, J.A., Gittleman, J.L., 2017. Reductions in global biodiversity loss predicted from conservation spending. Nature 551, 364–367.
Ward, Z.J., Goldie, S.J., 2024. Global Burden of Disease Study 2021 estimates: implications for health policy and research. Lancet 403, 1958–1959.
Welling, M., Dehnhardt, A., Aß, S.-M., 2023. Does validity matter for policymakers? Evidence from choice experiments on urban green. *J. Environ. Econ. Policy* Online Prepr. 16.
Xu, G., Gao, S., Daneshmand, M., Wang, C., Liu, Y., 2016. A survey for mobility big data analytics for geolocation prediction. IEEE Wirel. Commun. 24, 111–119.
Xu, R., Yue, W., Wei, F., Yang, G., Chen, Y., Pan, K., 2022. Inequality of public facilities between urban and rural areas and its driving factors in ten cities of China. Sci. Rep. 12, 13244.
Yu, C.-P., Lee, H.-Y., Luo, X.-Y., 2018. The effect of virtual reality forest and urban environments on physiological and psychological responses. Urban For. Urban Green. 35, 106–114.
Zhang, J., Yu, Z., Zhao, B., Sun, R., Vejre, H., 2020. Links between green space and public health: a bibliometric review of global research trends and future prospects from 1901 to 2019. Environ. Res. Lett. 15, 063001.
Zheng, H., Wu, T., Ouyang, Z., Polasky, S., Ruckelshaus, M., Wang, L., Xiao, Y., Gao, X., Li, C., Daily, G.C., 2023. Gross ecosystem product (GEP): Quantifying nature for environmental and economic policy innovation. Ambio 52, 1952–1967.