AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

How green is green enough? Landscape preferences and water use in urban parks

Claire A. Doll[a*], Michael P. Burton[a], David J. Pannell[a] and Curtis L. Rollins[a]

[a]UWA School of Agriculture and Environment, The University of Western Australia, Crawley, WA 6009, Australia

*E-mail address: Claire.doll@uwa.edu.au

16 May 2022
Working Paper 2201
UWA Agricultural and Resource Economics
http://www.are.uwa.edu.au

Citation: Doll, C.A., Burton, M.P., Pannell, D.J. and Rollins, C.L. (2022) *How green is green enough? Landscape preferences and water use in urban parks*, Working Paper 2201, Agricultural and Resource Economics, The University of Western Australia, Crawley, Australia.

© Copyright remains with the authors of this document.

How green is green enough? Landscape preferences and water use in urban parks

Claire A. Doll, Michael P. Burton, David J. Pannell and Curtis L. Rollins

Abstract

With climate change, it is becoming more challenging for water-limited cities to sustain historic watering levels in urban parks, leading park managers to consider changes to park designs. But whether and to what extent the public value parks that deviate from conventional designs featuring large areas of irrigated lawn remains uncertain. We use a choice experiment to assess public preferences for different park groundcovers in Perth, Australia. With a scale-adjusted latent class model, we identify optimal groundcover compositions for four preference classes. We find that while having some watered grass in urban parks is important, the public are also accepting of non-irrigated alternatives. Incorporating at least 40% native vegetation cover can increase the utility the public derives from parks and conserve water. Park managers also have a degree of flexibility in designing parks that vary from the optimal groundcover composition but that still deliver near-optimal benefits to communities.

Keywords

Urban park design, native vegetation, water use, sustainable cities, choice experiment, latent class analysis

JEL classifications

Q25, Q51, Q56, R52

1. Introduction

Cities featuring urban parks that are dominated by lawns can be found in many regions around the world (Ignatieva & Hedblom, 2018). This landscape trend can be attributed to cultural norms shaping public expectations for the groundcover (Ignatieva et al., 2020; F. Yang et al., 2019), given beliefs that having watered grass in parks is critical in delivering social and aesthetic benefits to the public (Fam et al., 2008; Ignatieva et al., 2015; Sugiyama et al., 2008), and conventions of having lawns as the default groundcover (Gildemeister, 2002). However, while lawns in urban parks may deliver important public benefits, they often also require financial and water resources for their maintenance. This water use is of particular concern in cities with arid or semi-arid climates that experience low levels of summer rainfall and that require extensive irrigation to keep grass green year-round (Mennen et al., 2017).

Park managers in water-limited cities are beginning to explore the transition from urban parks dominated by watered grass to alternative park groundcover compositions that reduce or eliminate water inputs (Çetin et al., 2018; Sovocool et al., 2006; J. Yang & Wang, 2017). Alternative groundcovers in these cities can include native, drought-resistant vegetation or mulch (organic material typically comprised of wood chips, shredded bark, or recycled wood product materials that is typically placed around the edges of parks or around trees), both of which conserve water through reduced irrigation inputs and reduced evapotranspiration loss (Brandes et al., 2006; Wescoat, 2013). Grass can also be left without watering to go brown across dry months seasonally, or in response to specific instances of severe drought (Pitman, 2010). These groundcover alternatives to lawns have been shown to reduce water use in parks by 20-100% (Vickers, 2001) while also yielding reductions of 50% or more in park construction and annual maintenance costs (Çetin et al., 2018). Still, whether and to what extent the public would value parks that use less water by deviating from conventional watered lawn-dominant designs remains uncertain. Here we address this uncertainty using stated preference valuation techniques.

Stated-preference valuation methods have examined public preferences for parks in a wide range of applications, including for the establishment of new park areas (Andrews et al., 2017; Krekel et al., 2016), recovery of lost urban greenery (Lo & Jim, 2010), or avoidance of reduced park access (Henderson-Wilson et al., 2017). Regarding park design in Norway, through choice-based conjoint analysis, the area of grass and number of trees have been found to have a greater influence on people's utility than have the area of bushes, number of flower beds, presence of water features, and number of park visitors (Nordh et al., 2011).

Through best-worst scaling techniques in Portugal, richness in plant species has been identified as the second most important greenspace characteristic, after cleanliness and maintenance (Madureira et al., 2018). Arnberger and Eder (2015) performed a choice experiment and compared six generalized park-design classifications in a wider assessment of factors influencing park preferences in Austria. The authors found that more manicured green spaces, which were characterized by mowed lawns, were preferred over other classifications such as forests with dense understories and meadow landscapes. These examples of stated-preference studies demonstrate the wide scope of factors contributing to park design preferences.

Within Australia, there is a small body of literature that has specifically examined trade-offs between alternative park groundcovers and watering requirements. One early stated-preference study found that households would be willing to pay an extra $18 annually in water costs to improve park groundcover appearances from 'brown' to 'some brown' (Blamey et al., 1999) in the Australian Capital Territory. Preferences for public open space designs in relation to groundwater use have also been considered more recently in Western Australia by van Bueren and Blamey (2019). The authors presented members of the public with a baseline scenario of a 20% reduction in the proportion of watered parks and verges, and found that the public did positively value maintaining greenness during the summer. On average, the public was willing to pay $1.00 per person per annum to avoid a 1% reduction in the proportion of green park areas. The public was also willing to pay to convert grassed areas to native groundcover, rather than letting those spaces go brown, at $0.87 per annum per 1% area of grass converted. Our study builds on the work of van Bueren and Blamey (2019) by expanding both the number of groundcover alternatives and the possible ranges of different groundcover options also considering tree cover. Furthermore, we model preferences for these groundcover types with a non-linear functional form to investigate threshold effects, and utilize a flexible payment scale in order to allow for the consideration of perceived positive and negative changes to park designs.

In this study we explore public preferences for alternative park landscape designs that differ in their watering needs. We employ stated-preference valuation techniques, using a discrete-choice experiment (Adamowicz et al., 1998), to estimate how individuals make trade-offs between different types and levels of park groundcovers and costs. Our objective is to assess the optimal extents of different types of watered and non-watered groundcovers in urban parks in order to assist park managers in creating climate-resilient parks that benefit the public.

2. Case Study Background

The metropolitan region of the city of Perth in Western Australia is our case-study area. Perth has a Mediterranean climate with hot and dry summers and is also experiencing further reductions in summer rainfall levels with climate change (CSIRO & Australian Bureau of Meteorology, 2018). Water scarcity is already raising tensions between competing water resource users and causing financial stress for park and facilities managers (Glover, 2011). As the imbalance of water supplies and demands intensifies in the future, these tensions are expected to escalate.

In the state of Western Australia, 550 gigalitres (GL) per year, or 17% of urban water use, goes towards watering parks and gardens, with this expected to increase by a further 250 GL per year by 2050 (Government of Western Australia Department of Water, 2016). Given these projections, governments are interested in understanding whether there are opportunities to use less water in new and existing public open spaces. Shifting from watered-lawn-dominant urban parks to alternative groundcover compositions is one such potential approach to water conservation.

We focus our investigation on optimal groundcover compositions in nature and recreation parks, under the classifications of local and neighbourhood parks (Government of Western Australia Department of Planning, 2015). These parks are small- to medium-sized spaces (under 5 hectares) designed to serve populations that live or work within 800 meters (5-10 minute walk) of the park (Government of Western Australia Department of Sport and Recreation, 2012). We limit our analysis to these park types as we wanted to make it clear to the survey respondents that changes to the extent of turf in sporting ovals, which is typically found in district and regional sport parks, are not being considered. This decision was made in consultation with local stakeholders, who highlighted the unique and important role that sporting parks play in community development, and that reducing the amount of sporting oval turf area is not within the scope of future park planning considerations. Furthermore, to mitigate against confounding preferences between substitute sites, our choice experiment is framed to elicit preferences for general landscape design preferences in local and neighbourhood parks, rather than considering changes to a single park.

3. Theoretical Framework

Stated-preference approaches to nonmarket valuation widely utilize questionnaires to assess the public's willingness-to-pay (WTP) for environmental quality improvements, or willingness-to-accept (WTA) compensation for environmental quality decreases associated with policy changes or projects (Carson et al., 2001). We apply a choice-experiment format, presenting respondents with a choice between discrete policy alternatives that vary in the level of attributes, including price (Hanley et al., 1998). These methods are useful in testing new policy ideas for which there is no revealed-preference information available on past observable choices and behaviour (Burton et al., 2020). The format allows for the estimation of preferences for different attributes (Adamowicz et al., 1998), factoring in trade-offs between marginal utilities of the cost and attribute levels to the calculation of marginal WTP and WTA values (Hanley et al., 1998).

Our model is based on random utility theory, which proposes that the level of utility associated with alternative choice options can be estimated as a factor of the characteristics of the decision-maker and the attributes of the choice options, plus some degree of randomness (McFadden, 1973). When presented with alternative policy options that differ in the levels of their attributes, it is assumed that individuals will attempt to select the option that maximizes their utility. The probability of a respondent making a choice between alternatives is based on a comparison of utility levels, which are comprised of deterministic and random components (Train, 2009).

In the context of this choice experiment, respondents are presented with a series of park design scenarios and are asked to select their preferred scenario between a baseline *status quo* policy scenario and a single alternative. The baseline and alternative scenarios are composites of groundcover types, extents of tree cover, and associated council rate or rent changes. Council rates are annual taxes passed on property values that are used to fund local government activities. We analyse trade-offs in choices to estimate payment values that leave respondents indifferent between accepting proposed changes in park designs.

4. Survey Design and Data

We administered an online survey to members of the general public in the Perth metropolitan region. The survey design process followed recommendations from Johnston et al. (2017), including multiple rounds of expert and public interviews in designing the stated preference instrument. The survey includes background information about water use in parks and groundwater supplies, along with future possible park management changes. Before the choice scenarios, the survey describes the baseline *status quo* park design, steps through an example choice task, and presents a "cheap talk" script (presented in the *Supplementary*

Materials) to remind respondents their money is scarce and could be spent on other goods and services (Carlsson et al., 2005). The choice experiment then follows.

The choice experiment includes 60 choice sets, blocked into 10 groups of 6. Within each randomly assigned group, the order of the 6 binary discrete-choice questions is also randomized. The experimental design uses D-optimality criteria (see Kuhfeld (2010)) with priors set to zero[1] (Araña et al., 2008; Hole, 2008). The experimental design was prepared using Ngene (Rose & Bliemer, n.d.). Our choice scenarios present variations in park groundcover, tree cover, and local council or rent rates, relative to a standard increase in annual council rates or rent of $200. For context, annual council rates in the Perth metropolitan region typically range between $1250 and $2500, depending on the Local Government Area. This tax level and the park attributes (levels of watered grass, mulch, and tree cover) were re-centred around 0 from the status quo conditions prior to model estimation. The groundcover options are restricted to sum to 100% to account for limitations in total park extent and consider trade-offs across groundcovers. The complete set of attributes and levels are presented in Table 1. The attributes, possible levels, and *status quo* park conditions (bolded in Table 1) were developed in consultation with park managers from councils in the case study region.

To assist the public in visualizing different park designs in the choice scenarios, we include detailed images representing the baseline and alternative scenarios. Visualizations have been found to reduce choice-task complexity where the public may not be familiar with the proposed environmental changes (Bateman et al., 2009), which may be the case with alternative vegetation types. There is evidence that using visualizations in choice tasks can lead to the public being more responsive (Bishop & Lange, 2005) and may lead to greater levels of respondents' confidence in stating preferences for landscape changes (Matthews et al., 2017). We commissioned a landscape architect consultant to produce 38 unique park images that captured the different combinations of environmental attributes. These images accompanied the 60 choice sets (see the *Supplementary Materials* for the full selection of images depicting the range of possible park design changes). The survey also includes a series of follow-up questions to unpack choice decisions, including questions assessing cost

[1] We acknowledge that finding efficient designs by completing a pilot to estimate priors under D-efficiency criteria is the most common practice in the literature (Mariel et al., 2021). However, the cost of generating the graphical images needed for each choice set meant that it was only possible to produce one set, and hence the iterative process could not be followed.

and attribute non-attendance (Champ et al., 2003) and consequentiality (Lloyd-Smith & Adamowicz, 2018). The survey concludes by collecting socio-demographic information.

Table 1

Choice experiment attributes and levels (status quo levels in bold)

Attribute	Description	Levels
Groundcover: Watered Grass	% park area with watered grass	0, 20, 40, 60, **80**, 100
Groundcover: Non-watered Grass	% park area with non-watered grass	**0**, 20, 40, 60, 80, 100
Groundcover: Native Vegetation	% park area with native vegetation	**0**, 20, 40, 60, 80, 100
Groundcover: Mulch	% park area with mulch	0, **20**, 40
Tree cover	Extent of tree canopy cover (%)	Low (10), **Medium (30)** High (50)
Tax	$ increase in annual local council rate or rent	0, 50, 100, 150, **200**, 250, 300, 350, 400

The survey was tested in 12 one-hour individual phone interviews[2] with members of the public, where participants had completed the survey prior to the interview. A key change that resulted from the interviews related to the tax levels. The baseline council rate change was initially set to $0 and rates could either increase or decrease relative to this level, but interviewees were sceptical of the probability of councils actually reducing their council rates. We therefore changed the baseline park scenario to align with a typical annual council rate or rent increase of $200, and then the rate change options were deviations from this level. An example choice scenarios outlining the cost and environmental attributes is presented in Figure 1.

[2] Due to Covid-19 restrictions, face-to-face focus group settings were not possible.

CURRENT DESIGN	PROPOSED DESIGN
80% Watered Grass Ground cover	**100% Watered Grass** **Ground cover**
20% Mulch Ground cover	-
Moderate Tree Canopy cover	**High Tree** **Canopy cover**
$200 INCREASE in annual council rate or rent	**$300** **INCREASE in annual council rate or rent**
	

Figure 1 Example choice scenario

Survey recruitment was conducted in April 2021 through a panel managed by a market research company. Participants were required to be at least 18 years of age and to reside in the Perth metropolitan region (postcodes 6000-6176). We had a total of 1626 survey completions; 94 of which were identified as protest responses based on selecting the status quo in each choice scenario and based on follow-up questions (presented in the *Supplementary Materials*).

We analyse a final sample of 1532 responses, approximately representative of the Western Australian State population. The *Supplementary Materials* include a detailed demographic breakdown of the sample and population. Summary statistics of key variables of interest are presented in Table 2, including concern over future water scarcity, which is calculated as a factor score from the correlation matrix of three questions with 5-point Likert responses. The questions asked respondents to indicate their level of agreement with the following statements: *In the next 5 years, I expect that issues relating to water scarcity will negatively affect i) me/ my family; ii) people in Perth; iii) people in Australia*. The responses ranged from strongly agree (1) to strongly disagree (5). Higher factor scores indicate disagreement with the statements, while low (negative) factor scores reflect expectations that different populations will be negatively affected by water scarcity in the future.

Table 2

Summary statistics of select variables

Variable	Mean	Standard Deviation
Not included in econometric models		
Proportion of sample reporting using urban parks for the following purposes:		
Exercise	0.63	-
Relaxing	0.60	-
Appreciating nature	0.60	-
Included in econometric models		
Age (years)	47	17
Visit: visits a park at least once per month (yes=1, no=0)	0.60	-
$: considered budget (yes1, no=0)	0.59	-
WS: future water scarcity concern	-0.01	0.92

5. Empirical Framework

We use the survey responses to estimate a utility function based on the proportion of the park that is occupied by each of the groundcover types (watered grass, non-watered grass, native vegetation, mulch) and the proportion of tree cover. We included level and squared terms for the groundcover variables and tree cover to account for non-constant marginal utility. To avoid issues with linear dependencies across the four groundcover types, we drop the level mulch term and estimate marginal utilities of the remaining land covers relative to mulch. We include the squared mulch term in order to ensure that the resulting model estimates are not dependent on the base groundcover type. Each respondent faces a choice among *J=2* alternatives in *T=6* choice occasions. Individual *i'*s utility associated with alternative *j* in each choice situation *t* is represented as:

$$U_{ijt} = \beta_i' x_{ijt} + \varepsilon_{ijt} \qquad (1)$$

Where:

- β_i' is a coefficient vector of estimated parameters for price increases, price decreases and non-price attributes;
- x_{ijt} is a vector of attributes of the choice alternatives and includes an alternative specific constant; and
- ε_{ijt} is the error term that captures the unobserved factors that impact utility.

We estimate the base conditional logit model in Stata 16 (StataCorp, 2019). The probability that an individual i chooses an alternative j, conditional on β_i' is estimated through maximum likelihood estimation and is captured by Equation 2.

$$L_{ijt}(\beta_i') = \frac{\exp(\beta_i' x_{ijt})}{\sum_{n=1}^{N} \exp(\beta_i' x_{ijt})} \qquad (2)$$

We also conduct a latent class analysis to account for individual heterogeneity in preferences by trying to identify the source of heterogeneity (Boxall & Adamowicz, 2002). There are other ways of accounting for preference heterogeneity, for example by using a random parameter mixed logit model (Train, 2009), but we choose the latent class model because it offers insights into the potential impacts of park design changes by characterizing different groups, or classes, of respondents. Under the latent class model, preferences are assumed to be homogeneous within groups and may vary across groups (Heckman & Singer, 1984). Furthermore, we account for heterogeneity in the error variance using a scale-adjusted latent class model (Magidson & Vermunt, 2007), where the scale factor indicates how consistent respondents are when making selections in the discrete-choice experiment (Davis et al., 2019). The probability of individual i selecting alternative j within a choice set, given the scale factor σ, and conditional on the latent class membership c and scale class membership k, can be expressed as the following:

$$\text{Prob}(y_{it} = j |\, c, k) = \frac{\exp(\sigma_k \beta_c X_{ijkt})}{\sum_{n=1}^{N} \exp(\sigma_k \beta_c X_{inkt})} \qquad (3)$$

Where:

- N are the options in the choice set;
- t is the choice situation;
- σ_k is the scale factor; and
- $\beta_c X_{ijkt}$ is the deterministic portion of the utility functions, with X capturing the composite attributes and β capturing class-specific marginal utilities.

The probability of individual i making choices across t scenario is dependent on S_{ic}, the probability of individual i's class membership in c out of the number of classes C, and W_{ik}, the probability of individual i's scale class membership in k out of the number of scale classes K and is represented as Equation 4.

$$P(y_i) = \sum_{k=1}^{K} W_{ik} \sum_{c=1}^{C} S_{ic} \prod_{t=1}^{T} P(y_{it}|c, k) \qquad (4)$$

We estimate a scale-adjusted latent class model using LatentGOLD Choice 6.0 (Vermunt and Magidson 2021). The estimated proportions in each class S_{ic} and the response probabilities by class $P(y_{it}|c)$ are estimated through maximum likelihood estimation. We test a range of models differing by number of membership classes between 1 and 6 and number of scale classes between 1 and 2. The final model includes 4 membership classes and 2 scale classes, as selected using Bayesian Information Criteria (BIC). BIC is considered to be preferred over Akaike Information Criteria for these identification purposes (Nylund et al., 2007). Respondent age, whether they visited local or neighbourhood parks at least once per month, whether they indicated concern over future water scarcity, and whether they considered their budget when responding to the choice scenarios are used as the factors explaining probability of class membership. These variables were selected to capture a subset of demographics, behaviour, awareness of environmental issues, and cost attendance.

Given the non-linearities and the zero sum considerations of the groundcover attributes in the choice design, where the level groundcovers must sum to 100%, we estimate welfare impacts for changes in park groundcover by class c using a compensating surplus approach (Hanemann, 1984). We follow this approach because WTP or WTA estimates of marginal changes are dependent on the particular levels of the attributes, due to the inclusion of squared terms in the utility function. The compensating surplus approach considers changes from the baseline groundcover scenario (U_b) to a given groundcover composition (U_m), and the estimated coefficient on tax p, as per Equation 5. U_b is based on the estimated coefficients for watered grass, watered grass squared and mulch squared, with 80% watered grass and 20% mulch, as per the baseline scenario attributes. U_m considers alternative combinations of watered grass, watered grass squared and mulch squared, and could additionally be comprised of the remaining groundcover attributes of non-watered grass, non-watered grass squared, native vegetation, and native vegetation squared. Given our focus on park design in relation to groundcovers, when calculating compensating surplus, we do not consider variations in the level of tree cover across the baseline and alternative scenarios.

$$\text{CS} = -\frac{U_{mc} - U_{bc}}{\beta_{pc}} \qquad (5)$$

6. Results

The base conditional logit model results (Table 3) show that respondents are responsive to both tax increases and decreases, and that in general, respondents are more likely to prefer park designs with more watered grass and native vegetation, relative to mulch (organic materials). The tax parameter estimates for both Tax (+) and Tax (-) are negative, as expected. In the case of the presented tax decreases, the tax levels are coded as negative 50 to negative 200, therefore the estimated parameter relates to a negative decrease. Park designs with greater proportions of tree cover are also preferred over designs with lower extents of tree cover. We find there are diminishing returns associated increasing extents of all three of the aforementioned attributes. No strong preferences between mulch and non-watered grass are observed.

Table 3

Conditional logit model results

	Estimate	**Standard Error**
Status quo	0.023	0.100
Tax (+)	-0.007***	0.001
Tax (-)	-0.005***	0.001
Tree	0.085***	0.011
$Tree^2$	-9.92 e^{-4}***	1.75 e^{-4}
Watered grass	0.048***	0.007
Non-watered grass	0.002	0.007
Native vegetation	0.029***	0.007
Watered $grass^2$	-4.81 e^{-4}***	-3.40 e^{-5}
Native $vegetation^2$	-2.06 e^{-4}***	-3.25 e^{-5}
Non-watered $grass^2$	-7.95 e^{-5}**	-3.51 e^{-5}
$Mulch^2$	-1.20 e^{-4}	1.67 e^{-4}

*** $p < 0.01$, ** $p < 0.05$

BIC based on log-likelihood = -5169.910

The scale-adjusted latent class model results, presented in Table 4, indicate that there are different groundcover preferences across four classes of respondents. Class 1 displays preferences for watered grass over mulch and for mulch over non-watered grass, with no distinct preferences between mulch and native vegetation. In contrast, Class 2 appears to be relatively indifferent between the four groundcover types, except for preferences that no particular groundcover type should dominate park designs, as captured by the negative parameter estimates on the squared groundcover terms. Class 3 prefers watered grass, non-watered grass, and native vegetation over mulch, each with decreasing marginal utility. For this class, the magnitude of the watered grass coefficient is much higher than for those of non-watered grass and native vegetation. However, the magnitude of the negative coefficient on the squared term is also larger. For the level groundcover terms, Class 4 only displays preferences for watered grass over mulch. The unexpected positive coefficient estimate on the squared native vegetation term suggests that as the proportion of native vegetation increases, it becomes increasingly preferred over the alternative groundcovers.

Outside of the groundcover attributes, we observe preferences for tree cover. Individuals in Classes 1, 3, and 4 are statistically more likely to select designs with higher proportions of tree cover. Because of the nonlinear relationship between utility and tree cover, with a squared continuous tree cover accounting for threshold effects, we can use the estimated utility functions for each class to derive their utility-maximizing tree-cover level. These utility maximizing tree cover levels are 37%, 50%, 40%, and 50% for Classes 1, 2, 3 and 4, respectively. These optimizations are constrained to be less than or equal to 50% cover, as this was the maximum level presented in the choice experiment.

We also observe different status quo effects across classes. For Class 3, the utility derived from the status quo option is higher than one would predict, given the attribute levels, implying some form of status quo bias. Meanwhile Class 1 gains higher utility simply from having changes in park designs than one might expect.

Our study design captures responsiveness to price increases and price decreases. As expected, the estimated tax coefficients are negative in both cases (including for negative decreases), but the estimated coefficient on tax increases between $50 and $200 are only different from zero (in the sense of being statistically significant at the 5% level) for Classes 1 and 2. Tax decreases between -$50 and -$200 are only significant for Classes 1, 2, and 4. It is possible that some respondents did not actually believe they could avoid having their council rates increased. We only discuss compensating surplus valuation estimates in relation to tax increases for Classes 1 and 2.

Class 1 captures the largest share of the sample (43%), while Classes 2, 3, and 4 are similar in size at 22%, 18%, and 17%, respectively. Individuals who did not express concern over future water scarcity and who stated that they did not consider their budget in the choice exercises are more likely to be in Class 1 (Table 5). In line with the lack of concern over future issues related to water scarcity, this class displays preferences for watered grass park covers. Meanwhile, respondents who don't visit parks at least once per month, did not express concern over future water scarcity, and did consider their budget when making decisions are more likely to be in Class 2. While this group captures non-users, individuals in this class preferred having parks with a balance of groundcovers. Individuals who expressed concern over future water scarcity and did not consider their budget are more likely to fall under Class 3. This group prefers having some, but not too much, watered grass, and has native vegetation as their second-most preferred park groundcover. Meanwhile Class 4 is linked to individuals who did not consider their budget, but displays strong preferences for watered grass in parks. Age was not found to be an important consideration in explaining class membership.

Table 4
Scale-adjusted latent class model results: utility function estimates for Scale Class 1

	Class 1	**Class 2**	**Class 3**	**Class 4**
SQ	-7.163***	0.994	21.015***	1.525
	(2.379)	(6.689)	(6.809)	(2.187)
Tax (+)	-0.136***	-0.193***	-0.013*	-0.006
	(0.036)	(0.057)	(0.007)	(0.007)
Tax (-)	-0.018**	-0.223***	-0.004	-0.028**
	(0.008)	(0.076)	(0.009)	(0.013)
T	1.099***	0.451	1.531***	0.343***
	(0.283)	(0.840)	(0.550)	(0.107)
T^2	-0.015***	-0.001	-0.019***	-0.001
	(0.004)	(0.014)	(0.007)	(0.002)
WG	0.274***	-0.025	2.519***	0.611**
	(0.092)	(0.214)	(0.756)	(0.246)
NWG	-0.269*	-0.352	1.338***	0.181
	(0.161)	(0.336)	(0.412)	(0.149)
NV	0.025	-0.374	1.510***	0.261
	(0.088)	(0.341)	(0.478)	(0.169)
WG^2	-0.002***	-0.006**	-0.024***	-0.004***
	(0.001)	(0.003)	(0.007)	(0.001)
NV^2	-3.0 e^{-4}	-4.0 e^{-4}	-0.008***	0.003**
	(2.0 e^{-4})	(0.002)	(0.003)	(0.001)
NWG^2	-0.001	-0.003*	-0.012***	0.001
	(0.001)	(0.002)	(0.004)	(0.001)
M^2	-3.0 e^{-4}	-0.014*	0.004	0.004
	(0.002)	(0.007)	(0.003)	(0.004)
Class Size				
	43.09%	22.23%	17.64%	17.04%

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

BIC based on log-likelihood= 9516.234

Standard errors in parentheses

$WG(^2)$= watered grass(^{2}), $NWG(^2)$= non-watered grass(^{2}), $NV(^2)$= native vegetation(^{2}), M^2= mulch^2

We also consider heterogeneity in the error variance or the degree of randomness in responses as part of the scale-adjusted latent class model. Class membership and scale parameter results are presented in Table 5 and show that approximately 57% of the sample belongs to Scale Class 2. Scale Class 2 has a scale factor of 0.073, while the scale factor for Scale Class 1 is normalized to be equal to 1. The larger scale factor in Scale Class 1 is associated with a smaller error variance. The scale-adjusted latent class model estimates presented in Table 4 are associated with Scale Class 1. The larger error variance associated with Scale Class 2 is associated with coefficient estimates scaled to be closer to zero. The outputs presented in Tables 4 and 5 are jointly estimated in a single model, but presented in separate tables for clarity.

Table 5

Class membership and scale parameters

	Class 1	**SE**	**Class 2**	**SE**	**Class 3**	**SE**	**Class 4**	**SE**
Preference class membership parameter estimates								
Int.	0.958**	0.411	-1.435**	0.566	0.419	0.547	0	.
Age	-0.001	0.006	0.0055	0.007	-0.004	0.600	0	.
Visit	-0.169	0.250	-0.707**	0.294	-0.152	0.331	0	.
WS	0.226**	0.109	0.384***	0.135	-0.203	0.155	0	.
$	0.327	0.206	2.677***	0.363	-0.219	0.270	0	.
Preference class marginal effects								
Age	-4.0 e-4	0.001	0.001	8.0 e-4	-7.0 e-4	9.0 e-4	1.0 e-4	8.0 e-4
Visit	0.033	0.040	-0.085***	0.028	0.012	0.036	0.039	0.034
WS	0.036**	0.018	0.042***	0.014	-0.057***	0.017	-0.022	0.015
$	-0.141***	0.037	0.370***	0.040	-0.132***	0.027	-0.098***	0.025
Scale class estimates								
		Scale Class 1		SE	Scale Class 2		SE	
Scale factor		1		.	0.073***		0.211	
Probability of class membership								
		Scale Class 1			Scale Class 2			
		0.427			0.573			

*** p < 0.01, ** p < 0.05, * p < 0.10

Visit= respondent visits local or neighbourhood parks at least once per month, on average

WS= concern over future water scarcity, with negative values for concern

$= whether respondents considered their budget in the choice exercises

SE= Standard error

A necessary condition of our model setup is that the sum of level groundcovers must equal 100%. Because of this constraint and the quadratic functional form of our utility equation, we can assess the utility-maximizing levels and combinations of groundcovers for each class using a nonlinear optimisation algorithm (additional details in the *Supplementary Materials*). Figure 2 displays these optimal mixes of groundcovers for each class. In each case, the preferred proportion of watered grass (0%-62%) is less than the current conventional park design (80%). We also consider optimal groundcover proportions from the perspective of the community as a whole. Figure 2 shows optimal groundcover proportions using parameter estimates from the base conditional logit model from Table 3 (labelled CL), which also show that the preferred proportion of watered grass (44%) is lower than current typical extents in local and neighbourhood parks.

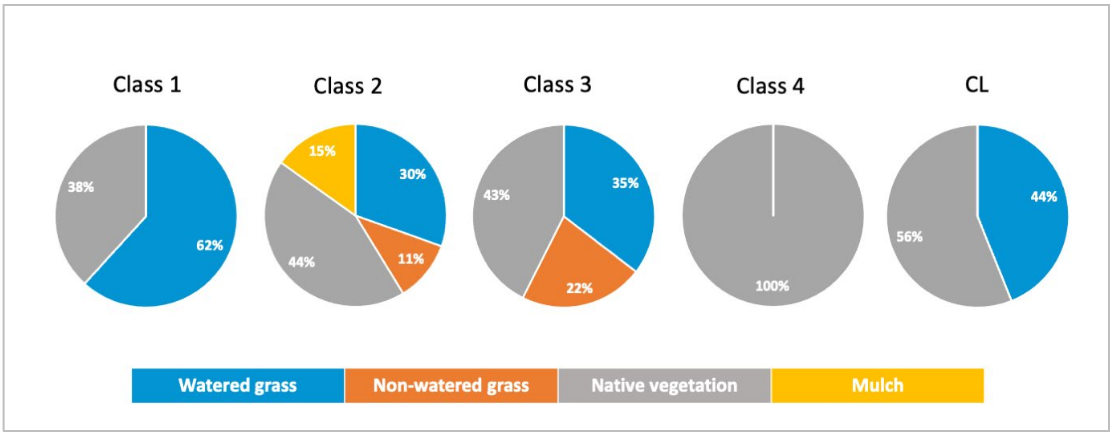

Figure 2 Utility-maximizing combination of groundcovers by class and on aggregate

Another way of exploring preferences for alternative park designs beyond the static utility-maximizing park composition is to vary the extent of watered grass in the park and optimize for the remaining park groundcover compositions at each constrained level of watered grass. These results, which constrain watered grass between 0% and 100% at intervals of 10% and solve for the utility-maximizing remaining groundcover mixes using a nonlinear optimization algorithm, are presented in Figures 3-6. We observe different optimal groundcover combinations for each class and at each level of constrained watered grass proportions because we are re-calculating the utility-maximizing groundcover combination at each step along the curve. For Class 1 (Figure 3), combinations of native vegetation and mulch are included alongside the constrained area of watered grass. For Class 2 (Figure 4), there is an accompanying mix of native vegetation, mulch, and non-watered grass in the remainder of the park area that is not occupied by watered grass. Class 3 (Figure 5) displays native vegetation and non-watered grass at different constrained levels of watered grass. Finally, for Class 4 (Figure 6) utility declines with each additional 10% portion of watered grass in the constrained optimization, as the optimal groundcover was 100% native vegetation.

Figures 3-5 are relatively flat in the vicinity of the peak of the curves, which implies that park managers have some flexibility; there is a wide range of park designs that provide utility close to the maximum. For example, for Class 1, alternative groundcover combinations that yield utility levels within 10% of the maximum utility lie between 50% and 80% watered grass. For Class 2, the groundcover combinations yielding utility within 10% of the maximum range between 10% and 50% watered grass. Similarly, for Class 3, this range is between 20% and 50% watered grass. Class 4 has a more narrow range of between 0% and 10% of watered grass to achieve within 10% of the maximum utility level. The remaining groundcover types outside of watered grass at these levels are different across groups, but have a common trend of at least 20% native vegetation as part of the remaining constituent groundcovers, where the constrained levels of watered grass allows.

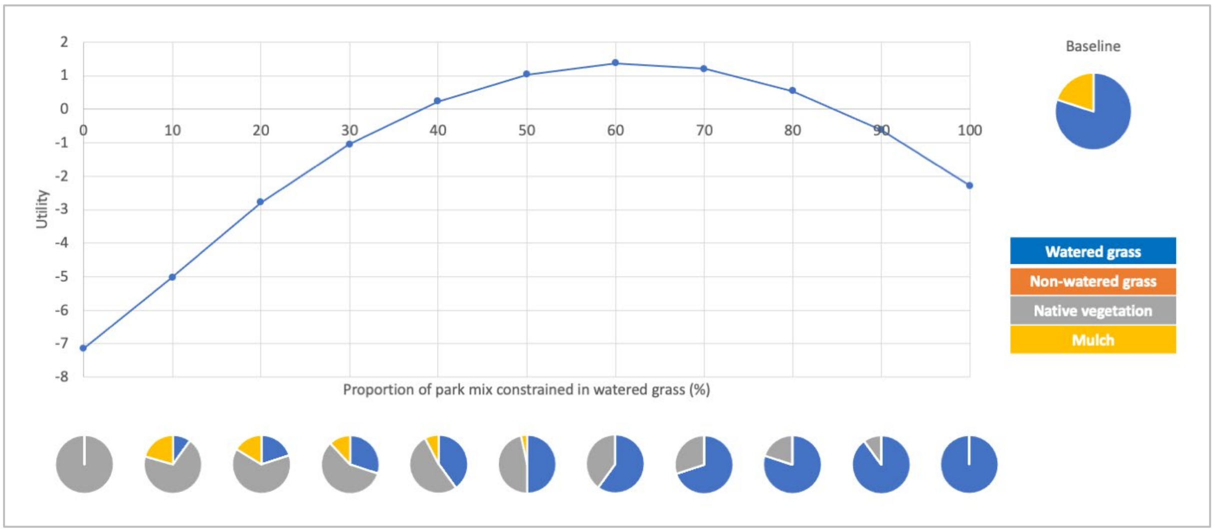

Figure 3 Exploring Class 1 utility levels for optimal groundcover compositions, relative to the baseline scenario, given constrained watered grass levels

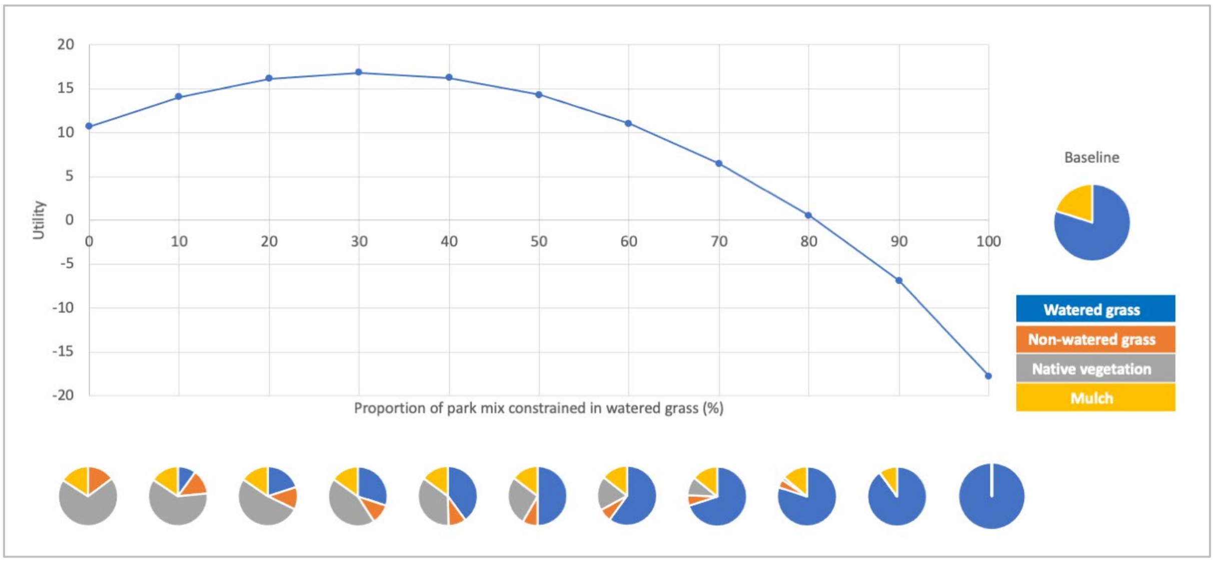

Figure 4 Exploring Class 2 utility levels for optimal groundcover compositions, relative to the baseline scenario, given constrained watered grass levels

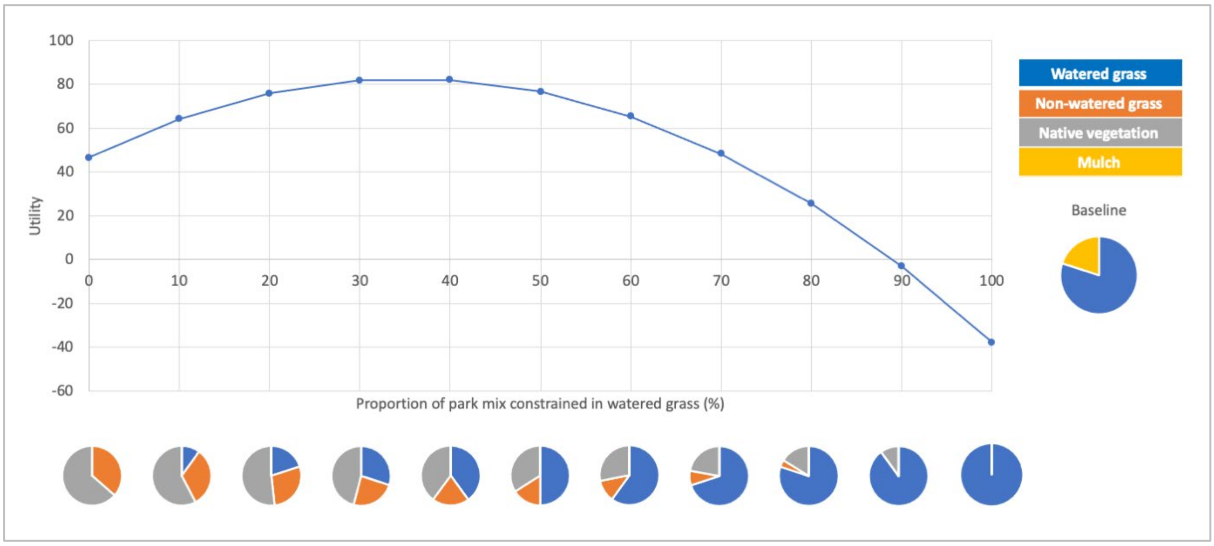

Figure 5 Exploring Class 3 utility levels for optimal groundcover compositions, relative to the baseline scenario, given constrained watered grass levels

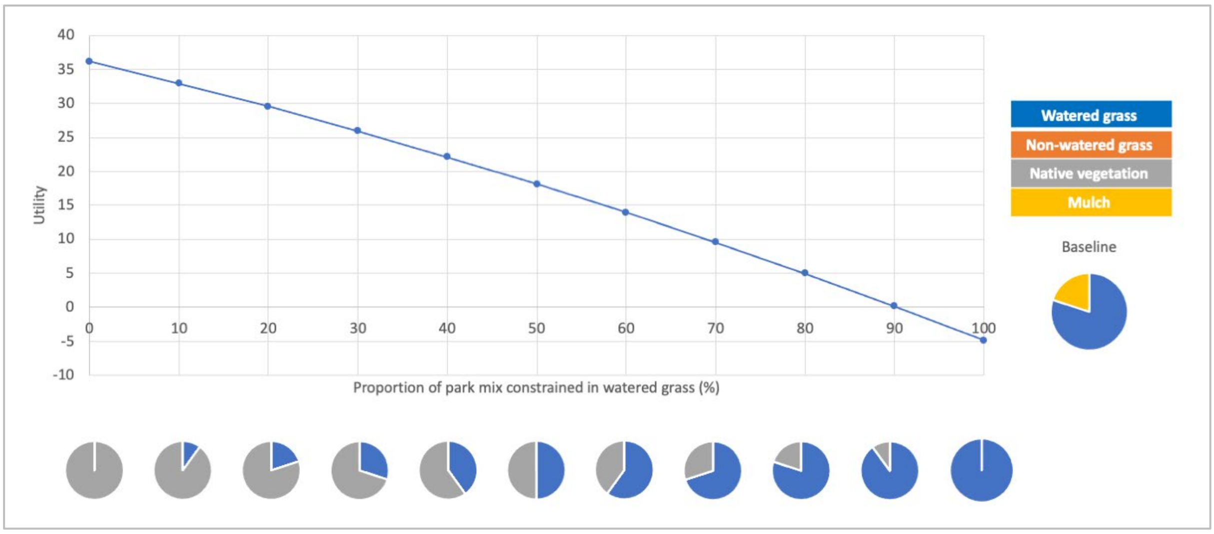

Figure 6 Exploring Class 4 utility levels for optimal groundcover compositions, relative to the baseline scenario, given constrained watered grass levels

Estimating monetary values associated with changes between different park groundcover compositions requires the consideration that our functional form includes both level and squared groundcovers, and that level groundcovers must sum to 100%. We therefore explore WTP values (as $AUD/ household/ year) using a compensating surplus approach. The compensating surplus measure represents the payment level required to compensate for a change in utility between two alternative park groundcover states. The compensating surplus is estimated for a bundle of park attributes, namely the utility-maximizing combinations of groundcovers depicted for the four latent classes in Figure 2 relative to the baseline scenario of 80% watered grass and 20% mulch. Table 6 summarizes these WTP values for Classes 1 and 2 only. The estimated values are $47.24 for Class 1 $87.18 for Class 2. We do not present WTP values for Classes 3 and 4, given that their price increase coefficient estimates were not statistically different from 0 at the 5% level, so we cannot relaiably identify their WTP. As an additional point of comparison, we consider compensating surplus estimates for changes from the baseline park to the optimal groundcover mix derived from the aggregate conditional logit mode. Here the estimated WTP is higher, because it includes the entire sample (i.e. including portions of the sample that were captured by Class 3 and Class 4 in the scale-adjusted latent class analysis), and is estimated to be $213.59. Differences in WTP estimates reflect differences in the subset of the sample included in the calculation, the marginal utility of money, and differences between optimal and baseline groundcover configurations.

Table 6

Compensating surplus ($/household/year) for a change from the baseline conventional local and neighbourhood park groundcover composition of 80% watered grass and 20% mulch, to the optimal groundcover combination.

	Class 1	Class 2	Conditional Logit
Ground cover	Optimal proportion of park		
Watered grass	62%	30%	44%
Non-watered grass	0%	11%	0%
Native vegetation	38%	44%	56%
Mulch	0%	15%	0%
WTP for optimal composition, relative to baseline	$47.24	$87.18	$213.59

Using the parameter estimates from the conditional logit model, we take an additional look at compensating surplus value estimates for six alternative park landscape designs. These alternatives have constrained levels of watered grass ranging between 0 and 100%, at 20% intervals. Holding constrained each level of watered grass, the remaining proportions of groundcover types were determined based on the utility-maximizing combinations. The alternative mixes (represented as Alt.1 to Alt 6 in Table 7) are: 1) 75% native vegetation, 19% non-watered grass, and 6% mulch, 2) 71% native vegetation, 9% non-watered grass, and 20% watered grass, 3) 60% native vegetation and 40% watered grass 4) 60% watered grass and 40% native vegetation, 5) 80% watered grass and 20% native vegetation, and 6) 100% watered grass. With these park groundcover proportions, we can also calculate aggregate compensating surplus values. These values, presented in Table 7, are positive for all cases excelt Alternative 6, which increases the proportion of watered grass cover to 100%.

Table 7 Compensating surplus ($/household/year) for a change from the baseline conventional local and neighbourhood park groundcover composition to 6 alternative groundcover compositions.

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Compensating surplus value ($)	42.49	158.94	211.83	187.14	81.22	-105.92

7. Discussion

We find that optimal park groundcover compositions vary by class, and include a mix of watered grass, native vegetation, non-watered grass, and mulch. For each of our identified classes, the optimal composition differed from the baseline design (reflecting current common practice). Native vegetation did not appear in the baseline park design scenario, but appeared in the optimal park compositions at 38%, 44%, 43%, and 100% for Classes 1, 2, 3, and 4, respectively. Meanwhile, the optimal extent of watered grass across the four classes ranges between 0% and 62%, representing an 18% to 80% percentage point decrease in watered grass groundcover, relative to the baseline. While we observe general trends indicating preferences for some watered grass and native vegetation in park designs, heterogeneity in the optimal groundcover composition across classes also reveals some conflicts in preferences, as no single design will be optimal for all groups.

In addition to estimating the utility maximizing groundcover combinations, we also explore how deviations from optimal groundcover compositions impact resulting utility levels, when compared to the utility derived from the baseline park design. The resulting ranges of utility levels offers more information to land manager than reports of marginal changes. The ranges are relatively flat about the optimum, indicating that park managers can be flexible in establishing park groundcovers that differ from the optimal compositions with minimal loss of utility.

To explore park designs that could maximize the welfare of communities as a whole, we also consider optimal park groundcover compositions for the sample in aggregate using the results of the base conditional logit model. Results show that the optimal groundcover mix includes 44% watered grass and 56% native vegetation. These results suggest that local and neighbourhood park design guidelines should continue including some watered grass groundcover, but that parks could potentially be improved by including a substantial proportion (i.e. 38% or greater) of native, drought-resistant vegetation that, once established, does not need watering. This recommendation aligns with planning directions to better manage water supplies while supporting a liveable green city (Department of Water and Environmental Regulation (DWER), 2019), and to include alternatives to watered grass in urban parks that are not designed for sport (Government of Western Australia Department of Planning, 2015).

There are several potential explanations for the observed dominance of watered grass and native vegetation in the optimal park groundcover compositions. Watered grass serves a function for certain activities such as exercise, a park function which 63% of our sample reported engaging in. Park exercising either may not be possible with alternative groundcover types, for example with native vegetation gardens that are not traversable, or potentially less appealing, as may be the case with non-watered grass with different sensory characteristics. Preferences for substantial proportions of native vegetation groundcover in parks could be linked to the 60% of our sample who use urban parks for relaxing and the 60% of our sample that use parks to appreciate nature. Studies have found that more wild or natural landscapes lead to more psychological restoration (Peschardt & Stigsdotter, 2013) and native vegetation is more likely to provide biodiversity benefits and habitats to facilitate wildlife viewing (Francis et al., 2012; Ives et al., 2017; McDonald et al., 2016). Water conservation concerns may also be associated with preferences for native vegetation and other low-or no-irrigated groundcovers, relevant to the 57% of respondents who indicated that in the next five years they expected themselves or their family would be negatively impacted by issues related to water scarcity.

In addition to presenting utility-maximizing park groundcover compositions, we estimate compensating surplus values. These values are estimated as changes in utility relative to the baseline park design with 80% watered grass with 20% mulch. Our compensating surplus values range between $47.24 and $213.59 per household per year for the changes in groundcover bundles from the status quo baseline to the class or model-specific optimal compositions. These estimates are higher than those reported by van Bueren and Blamey (2019), whose results for a 20% conversion of watered park areas to native vegetation yielded a household WTP of $17.40. However, our WTP estimates capture proposed park design changes for greater proportions of park landscape design changes, including introducing up to 56% native vegetation cover in park designs. Across households within a community, these figures suggest that public welfare could be substantially increased by changing park groundcovers. But these figures only tell one side of the story, as we have not incorporated differences in costs associated with park establishment and maintenance with different proportions of groundcovers. Such an analysis would require highly detailed costing information and is an area for future research.

A limitation of our analysis is that we only consider a single local or neighbourhood park and do not account for potential substitutes and complements across parks with different groundcover compositions in the same area. This could be important as individuals may express preferences for local neighbourhood park to have high proportions of native vegetation knowing that they are also located close to a district or regional park with having mostly watered grass groundcover. Understanding the full set of trade-offs between urban park groundcovers would require spatial optimizations that consider the systems of parks available to the public, and their characteristics, with associated travel costs. Furthermore, our analysis did not include other factors relevant to park preferences such as facilities, amenities, and general quality and maintenance. Future work could optimize urban park offerings based both on groundcover and these additional park attributes.

Where areas of watered grass may be replaced with native vegetation (either in an existing or new parks) it is important to consider how much water, and over what time period, these plants require during establishment. Likewise, a full understanding of the watering requirements for watered grass establishment and maintenance would need to be considered. If park groundcovers were to change to include less watered grass, it will also be important that irrigation systems are operating effectively to ensure that only the intended park areas are watered. Better accounting for differences in watering needs and irrigation best practices could also contribute to a full benefit cost analysis of alternative park landscape designs. Such an analysis could also be expanded into a wider optimization model that considers potential changes to wildfire risk and urban heat effects associated with alternative park designs (Broadbent et al., 2019; J. Yang & Wang, 2017).

8. Conclusion

Here we find that park greenness is important, but less green than current practices is green enough. The optimal extents of watered grass in urban parks differ according to preference class and range between 0% and 62%. Meanwhile, on aggregate, having 44% watered grass and 56% native vegetation groundcover in parks is optimal for communities. Based on this analysis of the benefit side alone, we recommend that future urban local and neighbourhood park design policies promote parks with no more than 60% watered grass and at least 40% native vegetation. Our finding that councils may be able to conserve water while also increasing public welfare by re-defining park design norms to include substantially less watered grass is promising in planning for sustainable cities as both the public and the environment could benefit from the same management changes.

By exploring ranges of utilities associated with changing groundcovers from the baseline mix to alternative combinations, we find that park managers do not need to deliver parks with the exact utility-maximizing groundcover breakdowns in order to provide value to the public. This flexibility allows planners and park managers a wide margin of error in decision-making (Pannell, 2006). If councils are prioritizing water conservation, given the flatness of the compensating surplus curves, it may be possible to further conserve water by reducing watered grass even more beyond the optimal extents, at little utility cost to the public.

Designing urban parks with more diverse groundcover compositions that differ in their watering needs is just one aspect of sustainable public open space management practices and water-sensitive urban design in water-limited cities. Other approaches to sustainable water management in urban parks include adhering to water budgets, using efficient irrigation systems, and applying soil amendments (Lee & Fisher, 2016), along with using treated wastewater for irrigation (Wescoat, 2013), using native warm-weather grasses for turf (Nouri et al., 2013), and hydrozoning, the practice of grouping plants with similar water requirements together to reduce water waste (Brandes et al., 2006). Together these approaches can help conserve water under increased exposure to water scarcity, so that water-limited cities can enhance their climate resilience while continuing to provide urban parks that benefit the public.

Funding acknowledgement

This article draws on research supported by the Forrest Research Foundation, the Social Sciences and Humanities Research Council of Canada, and the Government of Western Australia Department of Water and Environmental Regulation. The funding sources had no role in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

References

Adamowicz, W., Boxall, P., Williams, M., & Louviere, J. (1998). Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation. *American Journal of Agricultural Economics*, *80*(1), 64–75. https://doi.org/10.2307/3180269

Andrews, B., Ferrini, S., & Bateman, I. (2017). Good parks-bad parks: the influence of perceptions of location on WTP and preference motives for urban parks. *Journal of Environmental Economics and Policy*, *6*(2), 204–224. https://doi.org/10.1080/21606544.2016.1268543

Araña, J. E., León, C. J., & Hanemann, M. W. (2008). Emotions and decision rules in discrete choice experiments for valuing health care programmes for the elderly. *Journal of Health Economics*, *27*(3), 753–769. https://doi.org/10.1016/J.JHEALECO.2007.10.003

Arnberger, A., & Eder, R. (2015). Are urban visitors' general preferences for green-spaces similar to their preferences when seeking stress relief? In *Urban Forestry and Urban Greening* (Vol. 14, Issue 4, pp. 872–882). Elsevier GmbH. https://doi.org/10.1016/j.ufug.2015.07.005

Bateman, I. J., Day, B. H., Jones, A. P., & Jude, S. (2009). Reducing gain-loss asymmetry: A virtual reality choice experiment valuing land use change. *Journal of Environmental Economics and Management*, *58*(1), 106–118. https://doi.org/10.1016/j.jeem.2008.05.003

Bishop, I., & Lange, E. (Eds.). (2005). *Visualization in Landscape and Environmental Planning: Technology and Applications*.

Blamey, R., Gordon, J., & Chapman, R. (1999). Choice Modelling: Assessing the Environmental Values of Water Supply Options. *Australian Journal of Agricultural and Resource Economics*, *43*(3), 337–357. https://doi.org/10.1111/1467-8489.00083

Boxall, P. C., & Adamowicz, W. L. (2002). Understanding heterogeneous preferences in random utility models: A latent class approach. *Environmental and Resource Economics*, *23*(4), 421–446. https://doi.org/10.1023/A:1021351721619

Brandes, O. M., Maas, T., & Reynolds, E. (2006). *Thinking Beyond Pipes and Pumps: Top 10 Ways Communities Can Save Water and Money*.

Broadbent, A. M., Coutts, A. M., Nice, K. A., Demuzere, M., Scott Krayenhoff, E., Tapper, N. J., & Wouters, H. (2019). The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1.0): An efficient and user-friendly model of city cooling.

Geoscientific Model Development, *12*(2), 785–803. https://doi.org/10.5194/gmd-12-785-2019

Burton, M., Cooper, B., & Crase, L. (2020). Analysing Irrigation Farmers' Preferences for Local Governance Using a Discrete Choice Experiment in India and Pakistan. *Water 2020, Vol. 12, Page 1821*, *12*(6), 1821. https://doi.org/10.3390/W12061821

Carlsson, F., Frykblom, P., & Lagerkvist, J. C. (2005). Using cheap talk as a test of validity in choice experiments. *Economics Letters*, *89*(2), 147–152. https://doi.org/10.1016/J.ECONLET.2005.03.010

Carson, R. T., Flores, N. E., & Meade, N. F. (2001). Contingent valuation: Controversies and evidence. *Environmental and Resource Economics*, *19*(2), 173–210. https://doi.org/10.1023/A:1011128332243

Çetin, N., Mansuroglu, S., & Önaç, K. (2018). Xeriscaping Feasibility as an Urban Adaptation Method for Global Warming: A Case Study from Turkey. *Polish Journal of Environmental Studies*, *27*(3), 1009–1018. https://doi.org/10.15244/pjoes/76678

Champ, P. A., Boyle, K. J., & Brown, T. C. (2003). *A Primer on Nonmarket Valuation* (Second Edi). Springer.

Davis, K. J., Burton, M., & Kragt, M. E. (2019). Scale heterogeneity and its implications for discrete choice analysis. *Land Economics*, *95*(3), 353–368. https://doi.org/10.3368/LE.95.3.353

Department of Water and Environmental Regulation. (2019). *Waterwise Perth Action Plan*. https://www.wa.gov.au/system/files/2020-06/Waterwise-perth-action-plan.pdf

Fam, D., Mosley, E., Lopes, A., Mathieson, L., Morison, J., & Connellan, G. (2008). *Irrigation of Urban Green Spaces: a review of the Environmental, Social and Economic benefits*.

Francis, J., Wood, L. J., Knuiman, M., & Giles-Corti, B. (2012). Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Social Science & Medicine*, *74*, 1570–1577. https://doi.org/10.1016/j.socscimed.2012.01.032

Gildemeister, H. (2002). *Mediterranean gardening: a waterwise approach*. University of California Press.

Glover, M. (2011). *Landscape Master Planning-A Strategic Framework for Adapting to Climate Change*.

Government of Western Australia Department of Planning. (2015). *Liveable Neighbourhoods Draft 2015*.

Government of Western Australia Department of Sport and Recreation. (2012). *Classification Framework for Public Open Spaces*.

Government of Western Australia Department of Water. (2016). *Water for Growth Urban: Western Australia's water supply and demand outlook to 2050*.

Hanemann, W. M. (1984). Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses. *American Journal of Agricultural Economics*, *66*(3), 332–341. https://doi.org/10.2307/1240800

Hanley, N., Wright, R. E., & Adamowicz, V. (1998). Using Choice Experiments to Value the Environment Design Issues, Current Experience and Future Prospects 1. In *Environmental and Resource Economics* (Vol. 11, Issue 4).

Heckman, J. J., & Singer, B. (1984). Econometric duration analysis. *Journal of Econometrics*, *24*(1–2), 63–132. https://doi.org/10.1016/0304-4076(84)90075-7

Henderson-Wilson, C., Sia, K.-L., Veitch, J., Staiger, P., Davidson, P., & Nicholls, P. (2017). Perceived Health Benefits and Willingness to Pay for Parks by Park Users: Quantitative and Qualitative Research. *International Journal of Environmental Research and Public Health*, *14*(5), 529. https://doi.org/10.3390/ijerph14050529

Hole, A. R. (2008). Modelling heterogeneity in patients' preferences for the attributes of a general practitioner appointment. *Journal of Health Economics*, *27*(4), 1078–1094. https://doi.org/10.1016/J.JHEALECO.2007.11.006

Ignatieva, M., Ahrné, K., Wissman, J., Eriksson, T., Tidåker, P., Hedblom, M., Kätterer, T., Marstorp, H., Berg, P., Eriksson, T., & Bengtsson, J. (2015). Lawn as a cultural and ecological phenomenon: A conceptual framework for transdisciplinary research. *Urban Forestry and Urban Greening*, *14*(2), 383–387. https://doi.org/10.1016/j.ufug.2015.04.003

Ignatieva, M., Haase, D., Dushkova, D., & Haase, A. (2020). Lawns in Cities: From a Globalised Urban Green Space Phenomenon to Sustainable Nature-Based Solutions. *Land*, *9*(73).

Ignatieva, M., & Hedblom, M. (2018). An alternative urban green carpet. *Science*, *362*(6411), 148–149. https://doi.org/10.1126/science.aau6974

Ives, C. D., Oke, C., Hehir, A., Gordon, A., Wang, Y., & Bekessy, S. A. (2017). Capturing residents' values for urban green space: Mapping, analysis and guidance for practice. *Landscape and Urban Planning*, *161*, 32–43. https://doi.org/10.1016/j.landurbplan.2016.12.010

Johnston, R. J., Boyle, K. J., Vic Adamowicz, W., Bennett, J., Brouwer, R., Ann Cameron, T., Michael Hanemann, W., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., & Vossler, C. A. (2017). Contemporary Guidance for Stated Preference Studies. *Journal of the Association of Environmental and Resource Economists*, *4*(2), 319–405. https://doi.org/10.1086/691697

Krekel, C., Kolbe, J., & Wüstemann, H. (2016). The greener, the happier? The effect of urban land use on residential well-being. *Ecological Economics*, *121*, 117–127. https://doi.org/10.1016/j.ecolecon.2015.11.005

Kuhfeld, W. F. (2010). *Marketing Research Methods in SAS* (SAS 9.2 Ed).

Lee, J., & Fisher, C. (2016). *Arid green infrastructure for water control and conservation. State of the Science and Research Need for Arid/Semi-arid Regions*. Environmental Protection Agency. EPA.600/R-16/146.

Lloyd-Smith, P., & Adamowicz, W. (2018). Can stated measures of willingness-to-accept be valid? Evidence from laboratory experiments. *Journal of Environmental Economics and Management*, *91*, 133–149. https://doi.org/10.1016/j.jeem.2018.07.003

Lo, A. Y., & Jim, C. Y. (2010). Willingness of residents to pay and motives for conservation of urban green spaces in the compact city of Hong Kong. *Urban Forestry and Urban Greening*, *9*(2), 113–120. https://doi.org/10.1016/j.ufug.2010.01.001

Madureira, H., Nunes, F., Oliveira, J., & Madureira, T. (2018). Preferences for Urban Green Space Characteristics: A Comparative Study in Three Portuguese Cities. *Environments*, *5*(2), 23. https://doi.org/10.3390/environments5020023

Magidson, J., & Vermunt, J. (2007). Removing the scale factor confound in multinomial logit choice models to obtain better estimates of parameters. *Proceedings of the SawtoothSoftware Conference*.

Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jette, ·, Jacobsen, B., Liebe, U., Søren, ·, Olsen, B., Sagebiel, J., & Thiene, M. (2021). *Environmental Valuation with Discrete Choice Experiments: Guidance on Design, Implementation and Data Analysis*. SpringerBriefs in Economics. http://www.springer.com/series/8876

Matthews, Y., Scarpa, R., & Marsh, D. (2017). Using virtual environments to improve the realism of choice experiments: A case study about coastal erosion management. *Journal of Environmental Economics and Management*, *81*, 193–208. https://doi.org/10.1016/j.jeem.2016.08.001

McDonald, T., Johnson, J., & Dixon, K. W. (2016). National standards for the practice of ecological restoration in Australia. *Restoration Ecology*, *24*(1), 4–32.

McFadden, D. (1973). Conditional logit analysis of qualitative choice behavior. In *Frontiers in Econometrics* (pp. 105–142). Academic press.

Mennen, S., Fogarty, J., & Iftekhar, S. (2017). The most cost-effective ways to maintain public open space with less water: Perth case study. *Urban Water Journal*, *15*(1), 92–96. https://doi.org/10.1080/1573062X.2017.1395896

Nordh, H., Alalouch, C., & Hartig, T. (2011). Assessing restorative components of small urban parks using conjoint methodology. *Urban Forestry and Urban Greening*, *10*(2), 95–103. https://doi.org/10.1016/j.ufug.2010.12.003

Nouri, H., Beecham, S., Hassanli, A. M., & Kazemi, F. (2013). Water requirements of urban landscape plants: A comparison of three factor-based approaches. *Ecological Engineering*, *57*, 276–284. https://doi.org/10.1016/j.ecoleng.2013.04.025

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural Equation Modeling*, *14*(4), 535–569. https://doi.org/10.1080/10705510701575396

Pannell, D. J. (2006). Flat Earth Economics: The Far-reaching Consequences of Flat Payoff Functions in Economic Decision Making. *Review of Agricultural Economics*, *28*(4), 553–566. https://doi.org/10.1111/j.1467-9353.2006.00322.x

Peschardt, K. K., & Stigsdotter, U. K. (2013). Associations between park characteristics and perceived restorativeness of small public urban green spaces. *Landscape and Urban Planning*, *112*(1), 26–39. https://doi.org/10.1016/j.landurbplan.2012.12.013

Pitman, S. (2010). Council Solutions. In C. Daniels (Ed.), *Adelaide: Water of a City* (pp. 511–528). Wakefield Press.

Rose, J., & Bliemer, M. (n.d.). *Ngene*.

Sovocool, K. A., Morgan, M., & Bennett, D. (2006). An in-depth investigation of Xeriscape as a water conservation measure. In *Water Works Association. Journal* (Vol. 98, Issue 2).

StataCorp. (2019). *Stata Statistical Software: Release 16*. StataCorp LLC.

Sugiyama, T., Leslie, E., Giles-Corti, B., & Owen, N. (2008). Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology and Community Health*, *62*(9). https://doi.org/10.1136/jech.2007.064287

Train, K. (2009). *Discrete Choice Methods with Simulation* (Second edi). Cambridge University Press.

Van Bueren, M., & Blamey, R. (2019). Community Values For Green Public Open Space: A Choice Modelling Analysis in Perth, Western Australia. *Water E-Journal*, *4*(4). https://doi.org/10.21139/wej.2019.029

Vickers, A. (2001). *Handbook of Water Use and Conservation*. Waterplow Press.

Wescoat, J. L. Jr. (2013). Journal of Landscape Architecture The "duties of water" with respect to planting: toward an ethics of irrigated landscapes. *Journal of Landscape Architecture*, *8*(2), 6–14. https://doi.org/10.1080/18626033.2013.864070

Yang, F., Ignatieva, M., Larsson, A., Zhang, S., & Ni, N. (2019). Public perceptions and preferences regarding lawns and their alternatives in China: A case study of Xi'an. *Urban Forestry and Urban Greening*, *46*, 126478. https://doi.org/10.1016/j.ufug.2019.126478

Yang, J., & Wang, Z.-H. (2017). Planning for a sustainable desert city: The potential water buffering capacity of urban green infrastructure. *Landscape and Urban Planning*, *167*, 339–347. https://doi.org/10.1016/j.landurbplan.2017.07.014

Supplementary Materials

The *Supplementary Materials* have five components. First, we present the "cheap talk" script presented in the choice experiment survey, along with the questions used to identify protest responders, and an overview of the representativeness of the sample. We then provide details on the optimization process used to derive the utility-maximizing combinations of groundcovers. Finally, we include the full set of park design images that appeared in the choice cards.

1. "Cheap talk" script included in the choice experiment survey

"Please try your best to answer as if the park changes and your decisions are real. If you choose an option that changes your council rate or rent from the base increase of $200, remember that you would have more/less money to spend on other things."

2. Identifying protest responses

Protest responders were identified as those that selected the status quo park design in each of the 6 choice scenarios, along with agreement with any of the following statements:

- "I believe funding for parks should come from somewhere other than my own pocket;
- I believe funding for parks should be collected by means other than my council rate or rent;
- I don't think any increase in funds would actually be used to manage parks;
- I don't think the funds would be used efficiently;
- I don't believe I should have to make these choices."

3. Representativeness of the non-protest respondents

Table S.1 Characteristics of the WA state population and the final sample

Quota Criteria	WA State Population	Final Sample
% Woman	50%	49.9%
% Man	50%	50.0%
% Non-binary	-	<0.01%
% Under 35	31.5%	29.5%

% 35-54	35.6%	34.1%
% 55+	32.9%	36.4%

4. Optimization process for deriving optimal park groundcover mixes

We solve for the utility-maximizing combination of level and squared terms of watered grass (WG), non-watered grass (NWG), native vegetation (NV) and the square of mulch (M) according to the following process:

Maximize

$\beta_{WG}\mathrm{WG} + \beta_{WG^2}\mathrm{WG}^2 + \beta_{NWG}\mathrm{NWG} + \beta_{NWG^2}\mathrm{NWG}^2 + \beta_{NV}\mathrm{NV} + \beta_{NV^2}\mathrm{NV}^2 + \beta_{M^2}\mathrm{M}^2$

Subject to:

WG + NWG + NV + M = 100

WG, NWG, NV, M ≥ 0

M ≤ 40

Where:

$\beta_{WG}, \beta_{WG^2}, \beta_{NWG}, \beta_{NWG^2}, \beta_{NV}, \beta_{NV^2}, \beta_{M^2}$ are estimated coefficients from the conditional logit and scale-adjusted latent class models

This maximization process is repeated for the parameter estimates from the conditional logit model, as well as each of the latent class estimates. We consider the groundcover mix that leads to the optimal utility for each of these cases. In addition, across the four latent class estimates, we constrain watered grass levels to be set between 0 and 100%, at 10% intervals, and solve for the remaining groundcover mix that maximizes utility

5. **Park landscape design images accompanying the choice sets**

Figure S1. Full set of images capturing different park groundcover mixes and tree canopy cover levels included in the experimental design