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Capturing residents' values for urban green space: Mapping, analysis and guidance for practice.

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Abstract

Planning for green space is guided by standards and guidelines but there is currently little understanding of the variety of values people assign to green spaces or their determinants. Land use planners need to know what values are associated with different landscape characteristics and how value elicitation techniques can inform decisions. We designed a Public Participation GIS (PPGIS) study and surveyed residents of four urbanising suburbs in the Lower Hunter region of NSW, Australia. Participants assigned dots on maps to indicate places they associated with a typology of values (specific attributes or functions considered important) and negative qualities related to green spaces. The marker points were digitised and aggregated according to discrete park polygons for statistical analysis. People assigned a variety of values to green spaces (such as aesthetic value or social interaction value), which were related to landscape characteristics. Some variables (e.g. distance to water) were statistically associated with multiple open space values. Distance from place of residence however did not strongly influence value assignment after landscape configuration was accounted for. Value compatibility analysis revealed that some values co-occurred in park polygons more than others (e.g. nature value and health/therapeutic value). Results highlight the potential for PPGIS techniques to inform green space planning through the spatial representation of complex human-nature relationships. However, a number of potential pitfalls and challenges should be addressed. These include the non-random spatial arrangement of landscape features that can skew interpretation of results and the need to communicate clearly about theory that underpins results.

1. Introduction

Green spaces in urban environments are vital green infrastructure for a raft of environmental, social and economic benefits (Hunter & Luck, 2015; Jorgensen & Gobster, 2010; Swanwick, Dunnett, & Woolley, 2003). In the past few years, scholars have sought to understand the specific characteristics of green spaces that promote visitation (Grahn, Stigsdotter, & Berggren-Bärring, 2005), health benefits (McCormack, Rock, Toohey, & Hignell, 2010) and mental restoration (Nordh, Hartig, Hagerhall, & Fry, 2009). Recent reviews of the literature have shown that green spaces are indeed important for human health and well-being and environmental sustainability, although the specific mechanisms or pathways for these benefits are often complex (Kabisch, Qureshi, & Haase, 2015; Konijnendijk, Annerstedt, Nielsen, & Maruthaveeran, 2013). Social benefits of green spaces in particular have been shown to be influenced by a complex set of factors such as access, maintenance, amenities and perceptions of aesthetic attractiveness and safety (Konijnendijk et al., 2013; McCormack et al., 2010).

In contrast to the study of the health and environmental benefits of green space, social values and attitudes towards green spaces and the cultural services they offer have received less attention (Hitchings, 2013). In their review of empirical research on urban ecosystem services, Luederitz et al. (2015) found that cultural services were the least represented group. The values people assign to landscapes can be understood as an expression of these cultural services (Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013). On a theoretical level, these values exist in the "relational realm", where value "emerges from the interaction between a subject and an object" (Brown, 1984). Assessing the values people assign to natural areas is a critical component in sustainable landscape management (Kenter et al., 2015; Plieninger et al., 2015), yet the importance of places to urban residents will not necessarily be evident from their use patterns alone (Ives & Kendal, 2014; Swanwick, 2009). Indeed, Tyrväinen et al. (2007) in their study of green space values in Helsinki found open spaces that were identified by local residents to be their favourite were not the most frequently used green spaces.

Applying assessments of green space values and benefits to planning and management has been identified as an area in need of further research (Luederitz et al., 2015; Tratalos, Haines-Young, Potschin, Fish, & Church, 2015). Historically, a variety of approaches have been used to plan and manage green space networks (Maruani & Amit-Cohen, 2007), yet there is a need for greater knowledge of how specific landscape variables influence green space values and how these insights can be applied to planning practice. A challenge of urban landscape planning is reconciling knowledge on how landscapes function (i.e. what *is*) with normative assertions about desired future states and actions towards them (i.e. what *ought to be*) (Campbell, 2012). Lindholst *et al*. (2015) identify three scales at which reconciliation between research and planning practice can take place: (i) the conceptual level, where scholarly ideas influence planning frameworks and paradigms, (ii) the policy level, where knowledge can inform planning policies, and (iii) the applied level, where insights on human interactions with ecosystems can provide guidelines and practical advice on planning and management actions. When relating evidence on landscape values to practice, it is therefore important to consider the level at which this integration should occur.

If intangible values for green spaces are to be understood and integrated into planning practice, there is a need for methods to capture these values in ways that can be readily applied. Public

Participation Geographic Information System (PPGIS) methods are growing in popularity in applied landscape research because of their ability to engage stakeholders and capture spatially-explicit information on intangible landscape values that can be integrated with existing planning approaches (Brown, 2012; Van Herzele & van Woerkum, 2011). PPGIS is a field of geographic information science that focuses on the use of geospatial technologies by the public (such as mapping) to participate in public processes (Tulloch, 2008). Mapping activities have been commonplace in community planning for some time, such as the use of maps as stimuli for group dialogue or allowing community members to draw significant landscape features on maps themselves in a deliberative setting (Wates, 2014). While these methods promote deep engagement with the planning process and elicit nuanced local knowledge of an area, the PPGIS method explored in this study is oriented towards greater quantification of this knowledge and broader community representation. Such GIS-based approaches are able to spatially represent community landscape perceptions within a form of data commonly used in decision-making. Kabisch et al. (2015) therefore called for greater use of these techniques in urban environment research because of their ability to connect research with practice.

However, while the number of scientific studies using PPGIS has increased over time, there remains some resistance to the use of participatory approaches by planning professionals because expert opinion is seen as superior or more reliable than ‘crowd-sourced’ information (Brown, 2015). Future empirical research that uses PPGIS techniques should therefore consider not only scientific or theoretical issues, but also how PPGIS can be applied in landscape practice.

A number of studies have applied PPGIS techniques to urban systems in recent years with some key insights beginning to emerge. First, a diversity of values have been shown to be assigned by residents to green spaces (Brown, 2008; Tyrväinen et al., 2007), lending empirical support to the notion of landscape value plurality (see Zube, 1987) within urban landscapes. Yet not all mapped values for green space are of equal significance. For example, Kyttä et al. (2013) found the most positive values were associated with attractiveness, ease of walking/cycling and presence of nature, while Tyrväinen *et al*. (2007) found 'opportunities for activity' and 'beautiful landscape' to be the most frequently assigned social values in green spaces. Second, geographic factors influence the strength and diversity of mapped values. This led Brown (Brown, 2008) to develop a ‘theory of urban park geography’ using data from a public survey where residents of Anchorage, Alaska identified places on a map of their local area that they valued. Brown (2008) found strong support for the theory that the diversity of park values is positively related to green space size (area), and weak support for a negative relationship between value diversity and the distance of a green space from concentrated human habitation. Similar results were found by Brown et al. (2014) who found that larger green spaces contained more mapped benefits and activities from an online survey in Adelaide, Australia. The influence of geographic proximity as a variable lends support to the theory of spatial discounting of place values (Norton & Hannon, 1997). Finally, other PPGIS studies have shown that specific biophysical and management characteristics of green spaces influence assignment of values. For example, green space classification has been related to the values assigned to the spaces and the activities undertaken within them (Brown et al., 2014; Brown, 2008), and green spaces located in close proximity to a shoreline being found to also be assigned more positive values (Balram & Dragićević, 2005;

Kyttä et al., 2013). Given PPGIS remains a relatively new technique for assessing relationships between people and green spaces, there is a need for further empirical research on these issues.

There are some key outstanding research gaps in the application of PPGIS information on urban green spaces to urban planning. Relevant questions include (i) how applicable are the findings from the few existing PPGIS studies on social values for green space to other regions? (ii) how can statistical techniques be refined to better accommodate the type of data collected in PPGIS studies and what might these tell us about the nature of relationships between mapped values and biophysical green space characteristics? and (iii) what challenges might need to be overcome in order to better apply spatially-mapped social values for green spaces to landscape planning practice? This article addresses these gaps by pursuing the following objectives: (1) assess the spatial representation of positive and negative social values for green space in an urbanising region, (2) analyse their statistical relationships to key environmental values and one another, and (3) consider how PPGIS techniques and these results might be applied to green space planning. We pursue these objectives through undertaking a PPGIS survey of residents' values for green spaces (defined here as open spaces with grass or other vegetation but excluding private gardens and street trees) in an urbanising region of eastern Australia.

2. Methods

2.1 Study area

Four suburbs within two Local Government Areas (LGAs) in the Lower Hunter Valley, New South Wales, Australia were selected for the study. The Lower Hunter Valley was experiencing significant land use change, and at the time of the survey was the subject of an extensive regional planning process that would consider priorities for economic activities, urban growth and conservation (see Raymond & Curtis, 2013 for details). The four suburbs selected were Charlestown and Toronto (within the Lake Macquarie LGA), and Nelson Bay and Raymond Terrace (within the Port Stephens LGA) (Fig. 1). These suburbs were chosen because they are areas of current and future urban growth and contain a variety of green spaces. Population statistics for the four suburbs were as follows (suburb initials used for brevity): (i) Population – C 12411, T 5433, NB 5396, RT 12725; (ii) Median age - C 39, T 44, NB 47, RT 35; (iii) Number of private dwellings - C 5326, T 2472 NB 4083, RT 5082; (iv) Median weekly household income (AUD) - C $1244, T $816, NB $930, RT $1003 (Australian Bureau of Statistics, 2011). The total number of formal green spaces delineated in our study area was 323.

2.2 Survey administration

Survey instruments were developed to ascertain the values that residents in the Lower Hunter Valley assigned to the green spaces in their local area. Survey packets were mailed to a total of 1,000 residents from the four suburbs in July 2013. Survey recipients had expressed willingness to participate via initial screening telephone calls from a larger database of residents phone numbers. Recipients were asked to indicate their age to ensure that >20 % were 18-35 and >20 % 35-55 as a way of minimising the bias towards an older demographic which is typical in survey respondents. 418 surveys were returned from a possible 972 (43%) (28 of the 1000 survey packets were returned to sender). The percentage of responses differed slightly between suburbs as follows: Raymond Terrace 18.4 %; Nelson Bay 28.9 %; Charlestown 27.8 %; and Toronto 24.9 %. Of the respondents, 50.6 % were male and 43.3 % were female (7.1% did not specify their sex). 93 % of respondents nominated the contact address as their principle place of residence. The median respondent ages for the four suburbs were as follows (with the census median age given in parentheses): Raymond Terrace 57 (census = 35); Nelson Bay 60.5 (census = 47); Charlestown 62 (census = 39); Toronto 61 (census = 44). We observed an older respondent profile despite efforts to recruit younger participants (see supplementary material S1), however, the difference may not be as pronounced as it appears since the Australian census data includes those under 18 years old.

The survey instrument contained the following components: (i) a paper map of the resident's suburb displaying official municipal green spaces, significant roads and walkways and extant tree cover (scale = 1:13,500); (ii) an interactive map legend with descriptions of green space values and negative qualities corresponding to numbered marker dots for participants to stick to the map (red, 6 mm diameter, six per value attribute); and (iii) a series of socio-demographic questions including gender, age, education, occupation, income and housing status. For the interactive mapping component, participants were instructed to stick the marker dots denoting specific values to green spaces on the map. Participants could assign as many or as few marker dots as they wished (up to the maximum of six per value type), and were not restricted to placing dots in formally identified green spaces.

The 'values for green spaces' associated with the stickers on the map legend were adapted from existing typologies developed for PPGIS studies in the context of urban green spaces (see Brown, 2008; Tyrväinen et al., 2007). The specific value classes and definitions were further refined to ensure content validity and contextual relevance after interviewing key stakeholders such as government, industry and Non-Governmental Organisation representatives from the

Hunter Valley area, meeting with local government staff, and undertaking focus groups with community members from both municipalities. The final typology of values and negative qualities was as follows:

- Aesthetic / Scenic (e.g. places that are visually attractive)
- Activity / Physical Exercise (e.g. places you value because they provide opportunities for physical activity)
- Native Plants and Animals (e.g. places you value for the protection of native plants and animals)
- Nature (e.g. places to experience the natural world)
- Cultural Significance (e.g. opportunities to express and appreciate culture or cultural practices such as art, music, history or indigenous traditions)
- Health/Therapeutic (e.g. places you value for mental or physical restoration)
- Social Interaction (e.g. opportunities for you to interact with other people)

The ‘negative qualities of green spaces’ were:

- Unappealing (e.g. neglected, damaged, unaesthetic, ugly)
- Scary/Unsafe (e.g. dangerous or threatening)
- Noisy (i.e. disturbingly loud or noisy)
- Unpleasant (unpleasant or exposed to the elements, i.e. too hot, too windy, no shade or shelter etc.)

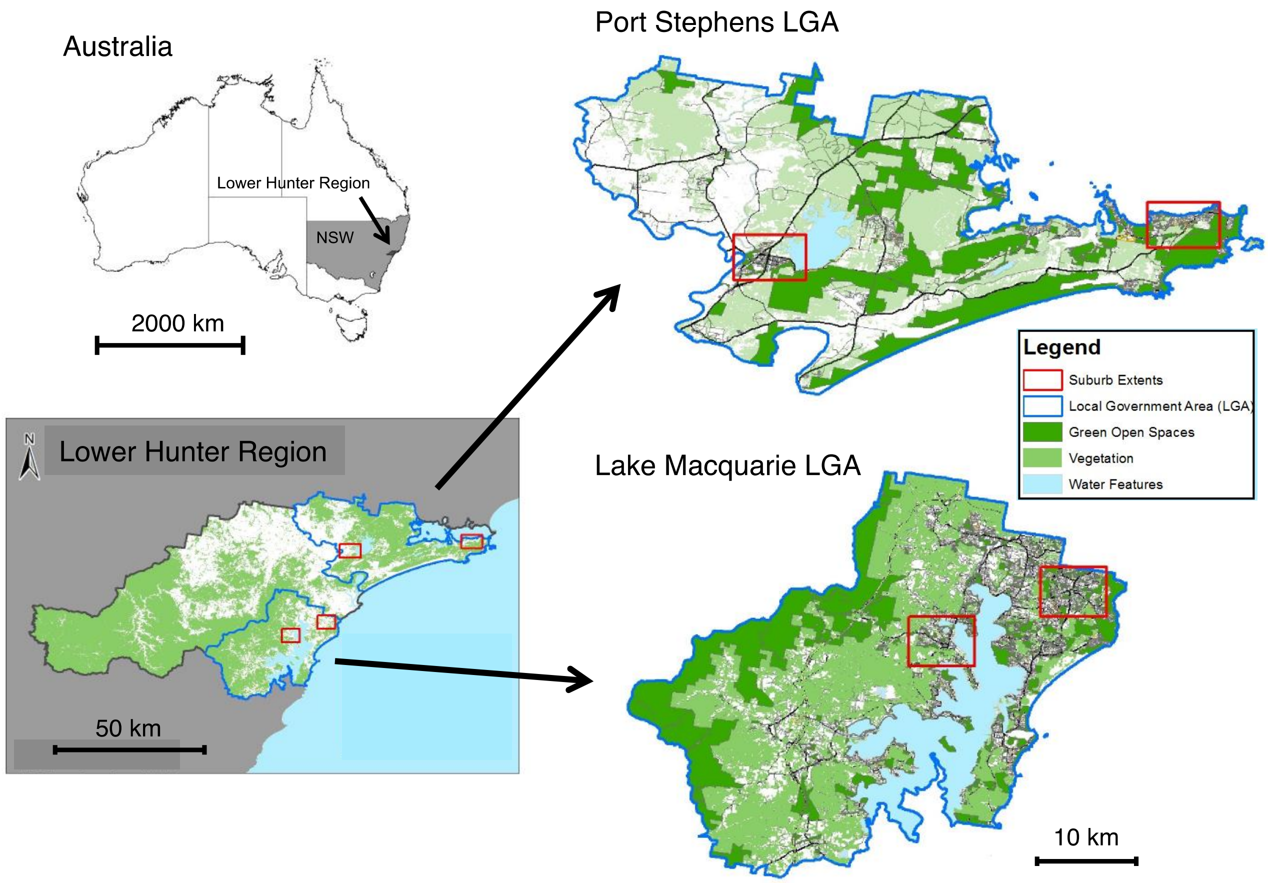


Figure 1. Maps of the location of the four study suburbs within the two Local Government Areas in NSW, Australia.

To maximise response rates, a series of incentives and reminders were employed according to the Dillman (2007) tailored design method. This included a gift of six packaged postal stamps, an opportunity to win a $100 AUD shopping voucher, and two reminder postcards and an additional complete survey packet for non respondents distributed at two week intervals where necessary. The survey design and administration procedure was reviewed and approved by [*identity hidden for peer review*] University's ethics board (project 06/13).

2.3 Data processing and spatial mapping

Returned paper maps were scanned at a resolution of 400 dpi and the location of mapped sticker dots digitised to enable spatial analysis in ArcGIS. Spatial data layers were obtained from local councils and the Australian and New South Wales Governments including maps of public open space lands, extant vegetation cover, roads and housing lots and aerial photographs. Google maps, Google street view imagery, and Gregory's Newcastle Street Directory (2012) was used to validate and edit council open space layers. Green space values (as indicated by marker dots) were assigned to green spaces they intersected with, with a spatial tolerance of 80 m (the width of the marker once assigned to the map). Address locations of survey respondents were manually digitised from volunteered addresses, or in cases where this was information was withheld, the nearest street corner.

For each suburb, 'heat' maps of the spatial concentration of assigned marker dots were generated by creating an Inverse Distance Weighted surface to indicate locations of high value for each variable of interest, using Spatial Analyst in ArcGIS. Inverse Distance Weighting determines the value of a cell by interpolating values from nearby cells, with those nearer to the focal cell being given greater weight than those further away. Geometric attributes of green space polygons (e.g. area, width etc.) were calculated using standard Spatial Analyst tools in ArcGIS. The 'near' tool was used to calculate the distance of green spaces from water bodies (sea, lakes, rivers and creeks) and resident's home addresses according to the closest point of approach between these features. Finally, the management categories that green spaces were classified as were assessed. Because the Local Environment Plans of the two LGAs contained different green space management classes, consistency between the LGAs was maintained by assigning green space polygons to one of three management categories based upon the original plans (see Table 1 for details of this reclassification).

Table 1. Management categories assigned to green spaces in the two LGAs studied.

Lake Macquarie Local Government Area	
Original Council Classes	*Classification for Analysis*
General Community	General
Natural Areas	Natural
Public Parks	General
Sportsfield	Sportsfield
Port Stephens Local Government Area	
Original Council Classes	*Classification for Analysis*
Cultural Significance	General
Foreshore	General
General Community	General
Natural Area	Natural
Sportsfield	Sportsfield
Urban Park	General

2.4 Statistical analysis

A range of statistical techniques were used to explain why green spaces varied in the number and type of value marker dots. Relationships between green space characteristics and mapped value markers were explored by treating the abundance of value markers within individual green space polygons as the response variable, and the green space characteristics as explanatory variables. The data has excessive zeros, with 100 green spaces (31%) containing no markers. Green spaces that did not receive markers were on average smaller (mean = 5.26 ha, s.d. = 10.06 ha) compared to those without markers (mean = 0.62 ha, s.d. = 1.48 ha), and had a smaller perimeter to area ratio (without markers: mean = 11.68, s.d. = 9.93; with markers: mean = 29.98, s.d. = 24.75), suggesting that smaller green spaces were less salient to respondents. The observed variance to mean ratios in the number of markers also demonstrated a clear over-dispersion, ranging from

10.57 to 43.25 across all types of positive value makers for green spaces. A *hurdle* model was deemed appropriate to deal with both these issues. Hurdle models analyse the zero and positive counts separately (Zeileis, Kleiber, & Jackman, 2008) by using a binomial process to model the likelihood that an observation will have a count of zero and a zero truncated distribution to model the positive counts. We chose a zero truncated negative binomial regression model to handle the over-dispersion. The analyses were conducted using the “pscl” package (Jackman, 2015; Zeileis et al., 2008) in R (R Development Core Team, 2015).

Environmental characteristics of green spaces were used as either continuous or categorical independent variables in our negative binomial regression model to predict value marker dot abundances. Multicollinearity was reduced by selecting environmental predictor variables to include in the model using a stepwise variance inflation factor (VIF) selection process. This operates in four iterative stages: (1) calculation of a VIF for each variable using the full set of explanatory variables; (2) removal of the variable with the highest VIF value and recalculation all VIF values with the new set of variables; (3) removal of the variable with the next highest VIF value; and (4) replication of the process until all VIF values are below the threshold (5 was selected as a reasonable trade-off between explained variance and model parsimony) (Beckmw, 2013). The set of variables selected for further modelling were: percentage of vegetation cover, distance from a significant water body, area, width, perimeter:area ratio, length:width ratio, and the presence/absence of a walking path.

Quadratic terms of continuous predictor variables were also included to test for non-linear relationships. Suburb was included and retained as a predictive factor in all the models to systematically account for any differences between the four study areas. The best models of different green space values were determined through the following process: (1) a negative binomial model was calculated using all predictors, (2) the variable with the highest *P*-value was removed and the model recalculated, (3) the two models were compared using the "vuong" function within the "pscl" R package, with the model with the lower AICc index retained, (4) variables were sequentially dropped using this process until no further improvement in AICc was found. We present only the model results for the positive counts because we are interested in identifying the factors that influence the strength and type of values of green spaces that receive marker dots, not the factors that determine whether or not green spaces receive marker dots at all. Results of the final model were displayed by plotting predictor variable effects to allow visual comparison of model differences. The influence of the green space management classification by local councils (general, natural, sportsfield) on green space values was analysed in separate models because it was not a physically observable variable associated with a green space. Results of models with green space management classification were also displayed graphically, with predicted means of value reported.

To analyse the effect of distance from home residence on the assignment of value dots, it was necessary to account for the configuration of green spaces in each suburb relative to the locations of the respondents. For example, if most green spaces occurred close to respondents' home addresses, the distance to green spaces for each respondent would tend to be small, potentially indicating a strong effect of green space distance. But this may be spurious as even if their true preference had no relationship to distance (or indeed their selection of value dots was completely random), respondents would likely select more green spaces close by if these were the majority of green spaces to choose from. To this end, a null model of green space values was generated for each suburb by randomly assigning 6 'dots' per respondent to green spaces in their suburb. The distribution of the distances between these dots and their home addresses was then calculated. The resulting output represented a distribution of green space distances that resulted solely from the spatial locations of the respondents relative to the green spaces rather than any sort of preference. This could then be compared to the real distribution from the mapped data, with any difference representing the effect respondent's preferences as opposed the effect of the geometry. To understand the difference between these two distributions, they were both plotted as histograms. One histogram was then subtracted from the other resulting in a histogram where the value of each bin represented the difference in the values for each bin of the histogram. The statistical differences between the two distributions were calculated via Chi-squared tests for given probabilities of histogram bins, using simulated p-value (based on 2000 replicates).

Finally, the compatibility between different green space values (defined here as the degree of co-occurrence of different value marker dots in individual polygons) was explored through Spearman rank correlations of the abundances of value marker dots, and by factor analysis. Factor analysis of mapped value markers was performed using the 'factanal' package in R (with varimax rotation), with the number of factors determined by viewing eigenvalues on a scree plot.

3. Results

3.1 Mapping marker dot abundance.

The four suburbs contained a total of 318 distinct green spaces, and 9,186 points were assigned to them by respondents out of a total of 9,691 points assigned to the maps. The most commonly assigned value marker type was "activity/physical exercise" (n = 1131) while "noisy" received the fewest dots (n = 131) (see Fig. 2)

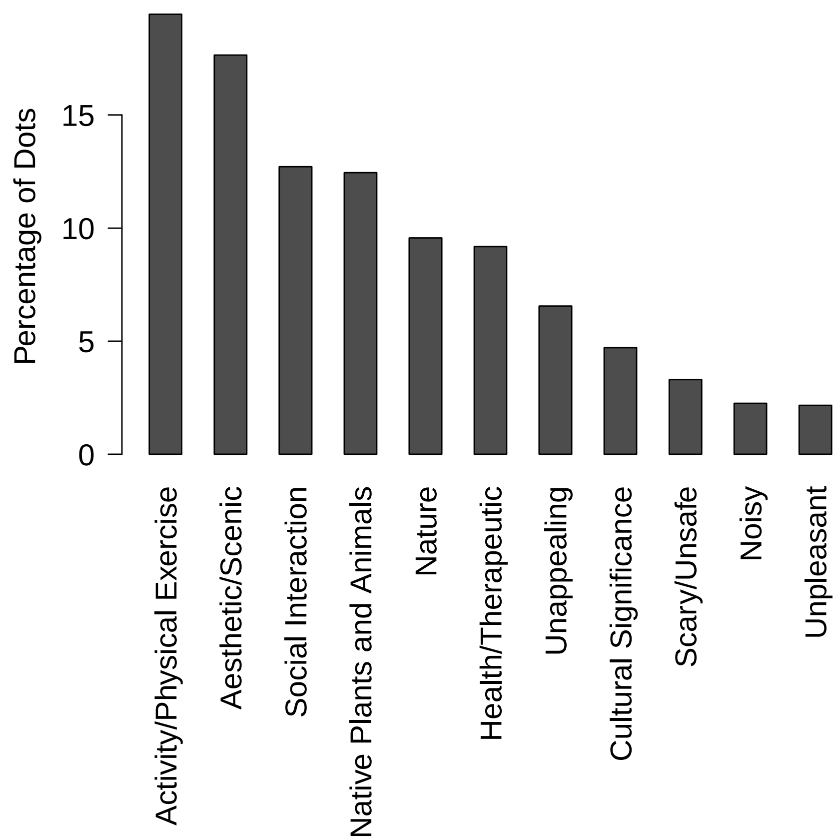


Figure 2. Proportion of mapped value marker dots across all suburbs.

Displaying the spatial location of value markers through the Inverse Distance Weighted surface reveals substantial variability in the location of the bulk of value markers. This technique is particularly useful for communicating results with landscape managers and for displaying visually the differences between various value markers. Examples of this mapping can be seen in Fig. 3, with a complete set of Inverse Distance Weighted maps for the 4 suburbs available as supplementary material S2.

Figure 3. Inverse Distance Weighted maps of the spatial locations of mapped points, aggregated for all respondents within Charlestown. The two panels demonstrate the differences between the two value attributes. The numerical 'value weighting' score is proportional to the density of marker dots at a location.

3.2 Environmental predictors of green space values.

Multivariate modelling revealed that different mapped values were related to different green space characteristics. The final suite of variables retained in the best models according to AICc indices is shown in Figure 4 (for full model statistics, see supplementary material S3). Distance from water was the most regularly selected variable, having an important negative effect on the abundance of marker dots in a green space (higher abundances in green spaces closer to water). Many variables were found to have a non-linear effect on mapped values, as indicated by the significant quadratic terms. Suburb was found to have a significant influence on half of the measured value types, with green spaces in Charlestown found to have more mapped value dots than the others in these cases. Regarding native plants and animals and nature values, the width of a green space was positively related to the abundance of mapped dots.

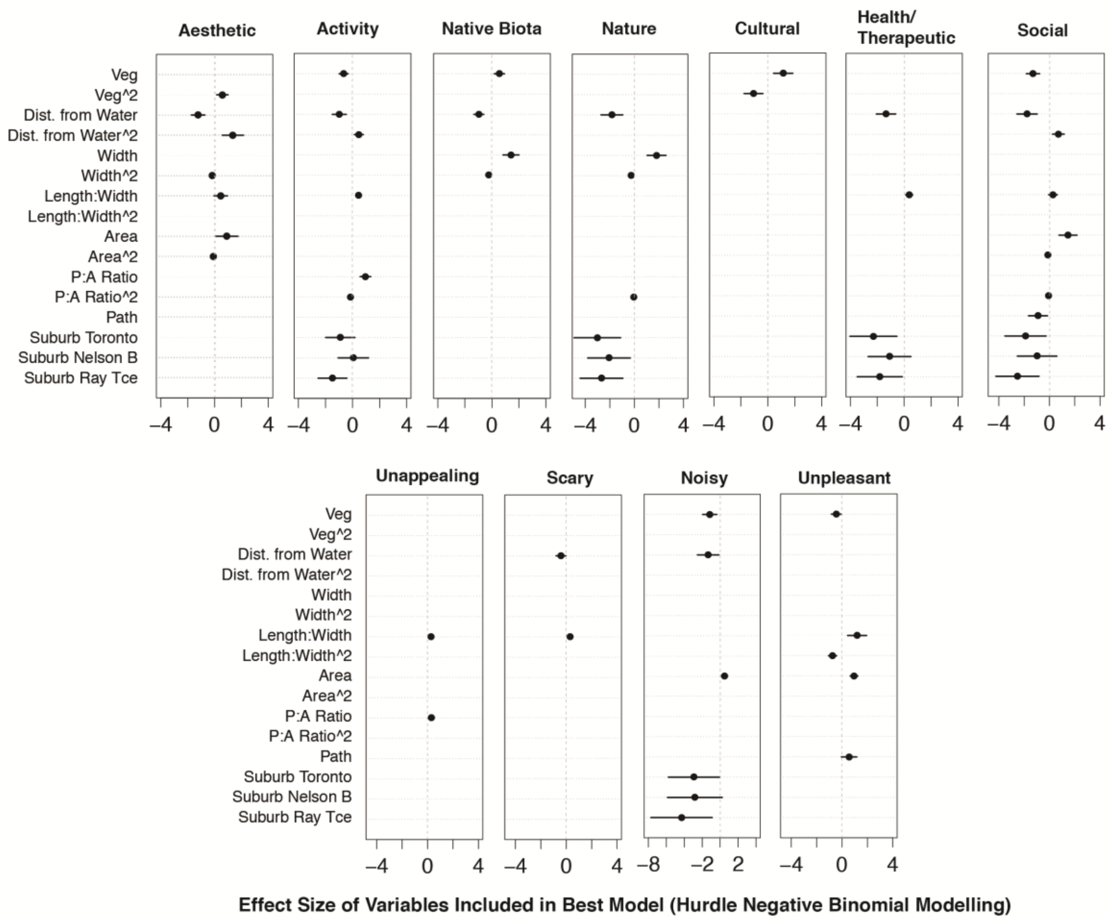


Figure 4. Models of the green space values (the response variable), with the effect sizes of different predictor variables (shown in each row). For variables retained in the final model, the mean effect size is indicated by a black dot, along with its 95% credible interval as indicated by the line. Quadratic terms are denoted by ^2.

3.3 Effect of green space type (management classification)

Despite its significance for green space management, municipal planning classification was not strongly related to the abundance of mapped marker dots for most values. Fig. 5 shows the expected mean abundance of all values according to planning category. This analysis used the same hurdle model as for other green space variables but included planning classification as the only covariate (for full model statistics, see supplementary material S4). Of particular interest is that green spaces designated as ‘natural’ areas did not have significantly more ‘native plants and animals' or 'nature' values assigned to them than areas designated for 'general' use, when considering the mean number of value markers at individual green space level

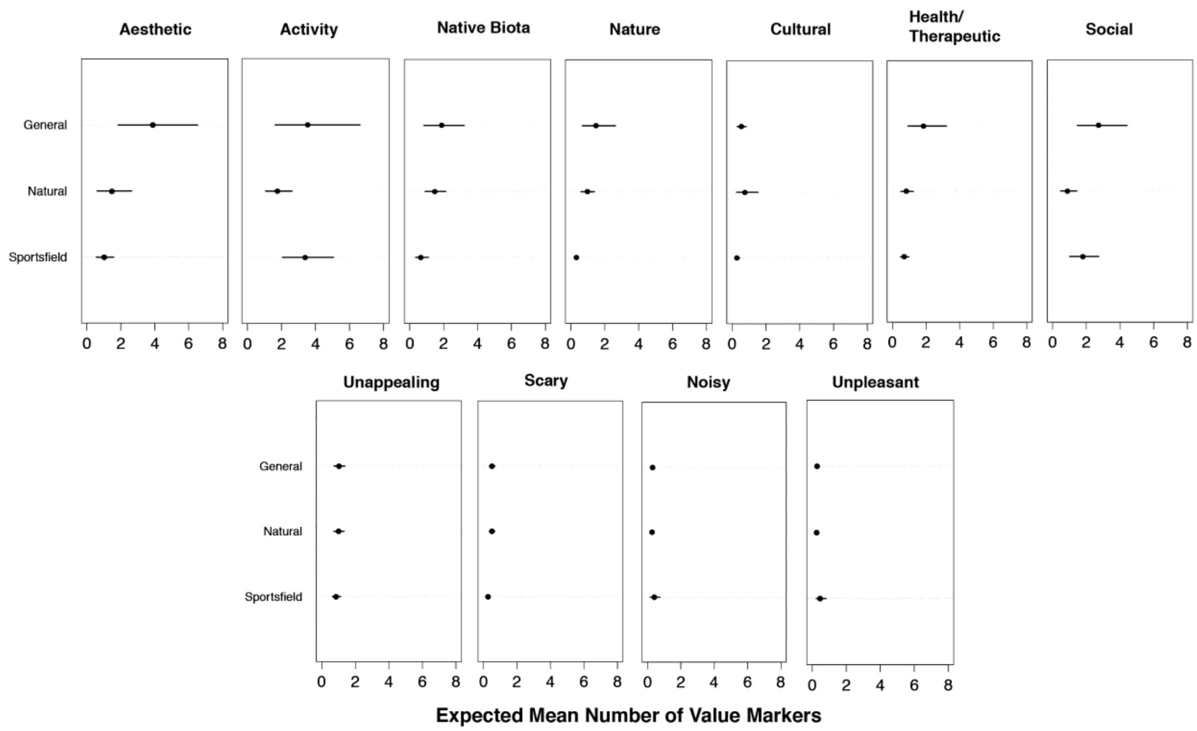
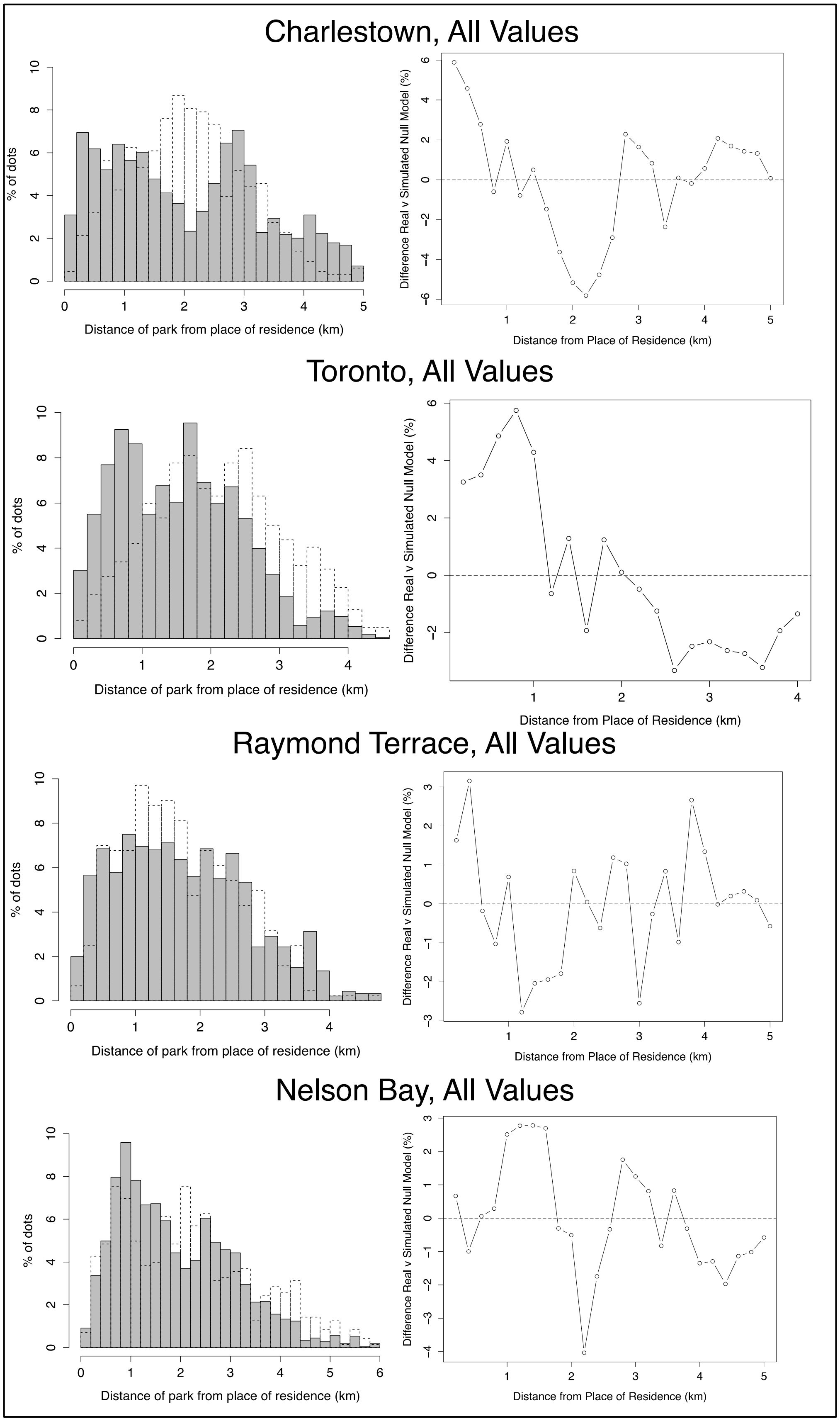


Figure 5. Expected mean abundance of value marker dots per green space polygon according to green space management category. The black dots indicate the mean value and the lines indicate the 95% credible interval.

3.4 Distance from home

Histograms of the proportion of marker dots assigned at different intervals from respondents' place of residence showed peaks at between 1 km and 2 km for all suburbs (see Fig. 6, solid grey bars). However, similar patterns were also observed for the randomised, null models (Fig. 6, dashed bars). Chi-squared tests comparing the histogram bars of the two distributions revealed that the two distributions were significantly different (Charlestown $\chi^2 = 398.98$, d.f. = 24, $P = <0.001$; Nelson Bay $\chi^2 = 2243.80$, d.f. = 29, $P = <0.001$; Raymond Terrace $\chi^2 = 700.41$, d.f. = 23, $P = <0.001$; Toronto $\chi^2 = 1017.6$, d.f. = 22, $P = <0.001$). Plots of the differences between histogram bars for real and null distributions showed a disproportional abundance of value markers nearer to place of residence for all values (particularly for distances <2 km), but this pattern was relatively weak and more pronounced in some suburbs more than others (e.g. Toronto) (see Fig. 6). Although some value attributes showed the strongest densities within 1 km of respondents' place of residence (e.g. social interaction value), others (especially negative qualities) displayed no relationship with distance from home (see supplementary material S5).



Charlestown, All Values
% of dots
Distance of park from place of residence (km)
Difference Real v Simulated Null Model (%)
Distance from Place of Residence (km)
Toronto, All Values
% of dots
Distance of park from place of residence (km)
Difference Real v Simulated Null Model (%)
Distance from Place of Residence (km)
Raymond Terrace, All Values
% of dots
Distance of park from place of residence (km)
Difference Real v Simulated Null Model (%)
Distance from Place of Residence (km)
Nelson Bay, All Values
% of dots
Distance of park from place of residence (km)
Difference Real v Simulated Null Model (%)
Distance from Place of Residence (km)

Figure 6. Plots of the association between assigned values (all marker dots) and distance from place of residence. Histograms on the left-hand side show the proportion of marker dots at different distances from respondents' place of residence. Differences between real and null models (see methods) can be seen by comparing the solid grey bars (real data) with the dashed bars (null models). Plots on the right-hand side show the difference between real and null-models for the proportion of marker dots.

3.5 Values compatibility.

Some pairs of values were found to be more compatible (tended to co-occur in green spaces) more than others. Some of the highest compatibility scores from the Spearman rank correlation analysis were between Aesthetic & Health/Therapeutic Value (Spearman's $\rho = 0.714$; $P < 0.001$), Native Plants/Animals & Nature Value ($\rho = 0.745$; $P < 0.001$), Activity/Physical Exercise & Social Interaction Value ($\rho = 0.674$; $P < 0.001$), Activity/Physical Exercise & Health/Therapeutic Value ($\rho = 0.681$; $P < 0.001$), and Native Plants/Animals & Health/Therapeutic Value ($\rho = 0.572$; $P < 0.001$). Factor analysis of mapped values identified three factors with eigenvalues >1 (see Table 2). These correlations are confirmed, with the first factor receiving highest loadings of nature and culture values, the second health and activity values, and the third negative values. Interestingly, the fact that some green spaces are considered noisy does not seem to compromise their activity, social interaction or health values (see factor 2). In contrast, the other negative qualities all loaded on a single factor, suggesting that these rarely are found alongside other values in green spaces.

Table 2. Exploratory factor analysis of mapped values, with loadings >0.4 reported. Although there is some overlap of values between factors, the factors help identify values that tend to co-occur in green spaces.

	Factor 1	**Factor 2**	**Factor 3**
Aesthetic	0.618	0.697	
Activity	0.416	0.774	
Native plants and animals	0.928		
Nature	0.938		
Cultural significance	0.662		
Health	0.629	0.722	
Social interaction		0.895	
Unappealing			0.760
Scary or unsafe			0.777
Noisy		0.424	
Unpleasant			0.441
Loadings	3.286	2.858	1.813
Proportion variance	0.299	0.260	0.165
Cumulative variance	0.299	0.558	0.723

4. Discussion

In this study we sought to understand how people in a rapidly urbanising region assign value to green spaces and assess the influence of environmental variables on these values. These insights are important for building the evidence base from PPGIS research methods that are increasing in popularity. In particular, our study can provide guidance on how statistical methods can be appropriately applied to PPGIS data. Further, given some continuing resistance to the use of PPGIS methods by planning practitioners (Brown, 2015) a key research question of this study was to explore useful insights into how PPGIS assessment of green spaces can be applied in practice. These issues are discussed in turn below.

4.1 The impact of environmental variables on values for green spaces.

The values people assigned to green space were very positive overall, with comparatively few marker dots assigned that denoted negative qualities. This was true regardless of the type of management applied to the green spaces (Fig. 5). Although ambivalent attitudes towards urban green space have been observed (e.g. Bonnes, Passafaro, & Carrus, 2010), our result is consistent with the bulk of research that has shown green environments are generally perceived positively (Kellert & Wilson, 1995). For example, Kyttä *et al*. (2013) in their study of urban landscape values in Finland found that 80% of value markers placed in green spaces denoted positive attitudes.

The specific values assigned to green spaces were varied and responsive to a multiple environmental variables. This suggests that people interact with landscapes in complex ways and assign a plurality of values to them for different purposes, a result that has been found in other landscapes (Ives & Kendal, 2013; see Purcell, Lamb, Mainardi Peron, & Falchero, 1994). We encourage planners to consider the heterogeneity of green space values and stress that green space networks for urban populations will require a 'portfolio of places' (Swanwick, 2009).

For many value attributes, green spaces closer to water bodies were valued more strongly than those further away (see Fig. 4). This finding is consistent with most of the literature on public preferences for landscapes (Swanwick, 2009), with people's affinity for water explained by the theory that it enhances the perceived orderliness and naturalness of a scene (Kaplan & Kaplan, 1989), as well as adding to the coherence of a landscape (Litton, Tetlow, & Sorensen, 1974). However, there is evidence that preferences for waterscapes can differ according to type and context (Herzog, 1985). For example, a study in Victoria, Australia recently found that the public distinguished between six categories of wetlands according to the amount of water visible, presence of trees, water quality and habitat value (Dobbie & Green, 2012). Further, the literature on 'ecological aesthetics' suggests that public preferences to landscapes is the result of a combination of landscape features and individual factors like knowledge, values and attitudes (Gobster, Nassauer, Daniel, & Fry, 2007). Given the high compatibility observed between aesthetic values and other values (Table 2), it is likely that the visual preferences for green spaces near water lead to the assignment of other values in these places. There is therefore potential to include additional analysis of water body type and individual psychological factors in future PPGIS studies.

The proportion of vegetation present in a green space was related to the abundance of marker dots for many value types (Fig. 4), yet the nature of its influence varied. For native plants and animals, the relationship was a positive one, for social interaction values a negative relationship was observed, while a quadratic relationship was found for aesthetic values (Fig. 4). The factors behind the effect of vegetation on mapped values are likely to be highly complex, but some existing theories and recent empirical studies can provide insight. We suggest that the relationship between vegetation cover and mapped values may reflect landscape preference, environmental perception, mental restoration, and the suitability of spaces for certain activities. Recent research elsewhere from Brisbane, Australia, found that visitation of green spaces peaked at intermediate levels of vegetation cover (Shanahan, Lin, Gaston, Bush, & Fuller, 2015); a pattern they attributed to theories that landscape preference is highest in savannah-type landscapes (i.e. the information processing theory: Kaplan & Kaplan, 1989). The positive effect of vegetation on mental restoration has also been shown in a number of studies. For example, Nordh *et al.* (2009) showed greater likelihood of restoration in green spaces with increased cover of trees and bushes, and Peschardt and Stigsdotter (2013) found that the ‘natural’ components of urban green spaces (e.g. unstructured vegetation) were particularly important for increasing perceived restorativeness in stressed individuals. The positive relationship between assigned values for native plants and animals and vegetation cover is as would be expected, since people’s perception of biodiversity has been shown to relate strongly to vegetation cover (Dallimer et al., 2012), even though this does not always align with scientific measurements of biodiversity such as species richness. While there are many plausible theories that explain the results we have observed, there is a need for greater exploration in future research of the specific mechanisms that give rise to the observed mapped values.

Local governments in Australia regularly categorise green spaces according to their intended purpose or use. Our study showed that in our case study areas, these categories had little to no bearing on the abundance of value markers found in specific green spaces (Fig. 5). In particular, we observed no statistical difference in the average abundance of marker dots for nature values or native plants and animals values between green spaces designated as ‘natural areas’ and those for ‘general use’ (Fig. 5). Our results suggest that formal categories may not have a strong influence on the perceptions of local residents. This may either be because residents simply do not strongly distinguish between these classes when valuing green spaces, or because residents have little knowledge of the official designated purposes of the green spaces. Determining which of these is the more accurate explanation is an area for future research. In terms of biodiversity conservation, our findings present an opportunity for management agencies to maximise biodiversity across the whole landscape rather than focussing exclusively on formal nature protection areas since residents value nature on all different kinds of green spaces.

Distance from place of residence did not have a clear relationship to the assignment of values to green spaces, after accounting for landscape configuration (Fig. 6). Although distance from home has been found to be an important factor influencing green space visitation (Neuvonen, Sievänen, Tönnes, & Koskela, 2007; Shanahan et al., 2015), it appears that landscape values, at least in our case study, are quite different constructs and are less strongly influenced by spatial proximity. The established theory of geographic or spatial discounting of values (Norton & Hannon, 1997) supposes that PPGIS respondents will place disproportionately more markers closer to their home than more distal locations, as has been empirically shown by Brown et al. (2002). Although this pattern can be seen in the suburb of Toronto, it was not evident for the other suburbs. Thus, our analysis highlights the importance of accounting for the spatial bias in the locations of landscape features (for example via simulation) in order to further explore the spatial discounting hypothesis in relation to PPGIS.

Finally, we found that the compatibility between different value types (based on their co-occurrence in green space polygons) varied substantially between value types. The highest compatibility observed was between 'native plants & animals' and 'nature' values, suggesting that sampled residents do not distinguish substantially between these two concepts in the Australian context. Further, high compatibility was also observed between 'native plants & animals' and 'health/therapeutic' values. Interestingly, in their study of public perceptions of urban biodiversity, Voigt and Wurster (2015) found that 'diversity' was used to express a sense of well-being rather than an assessment of biological diversity or importance. This suggests that there is a need for further research into what people are actually mapping when indicating 'nature' or 'biodiversity' values in PPGIS studies, but may also help to explain the compatibility between nature and health values. Nevertheless, our results suggest that there is real potential for green space planners and managers to improve both biodiversity conservation and public health outcomes simultaneously (Lachowycz & Jones, 2012; Lee & Maheswaran, 2011).

4.2 PPGIS in practice

In considering how the insights from this study should be applied to planning practice, it is useful to recognise the different scales at which research and planning practice can be reconciled as proposed by Lindholst *et al.* (2015). First we consider applying insights at the policy level (i.e. deriving general principles for planning green space), and second at the applied level (by providing guidance for practitioners considering using PPGIS in a local context).

4.2.1 Green space planning principles

According to the landscape character variables retained in our models of green space values (Fig. 4), our results suggest that when designing new green space networks, priority should be placed locating green spaces near water bodies where possible and ensuring green spaces are sufficiently large for meaningful social interaction. Managers of existing green spaces should seek to promote multiple values simultaneously in individual green spaces regardless of their management category (Fig. 5). Based on the value compatibility assessment (Table 2), some values may be promoted alongside one another more easily than others (e.g. health and social interaction, or nature conservation, aesthetics and culture). Practitioners should therefore carefully plant and maintain vegetation in ways that are visually appealing and help to promote biodiversity (Ives & Kelly, 2016). Of course, applying these general principles is only one element of good planning practice; practitioners should also seek to engage the community and encourage participation in the decision-making process, as difficult as this process can be (Chiesura, 2004). Indeed, the effect of 'suburb' on some of our models of open space values (namely activity value, nature value, health/therapeutic value, social interaction value, and noisy; see Fig. 4) suggests that the valuation of green spaces may be influenced by unique demographic and environmental characteristics of specific areas. It is imperative therefore that planners supplement any general principles with knowledge of the needs specific to a region.

4.2.2. Guidance for practitioners applying PPGIS

Many methods exist for public communication, consultation and participation, each with strengths and weaknesses depending on the decision-making context (Reed, 2008). We consider PPGIS to be a useful complement to existing methods for engaging communities in urban green space planning. PPGIS is more participatory than approaches that emphasise information dissemination such as town hall meetings or leaflets, more representative than charettes or community planning forums, more spatially nuanced than public surveys, and more quantitative than focus groups. Yet the mass collection of quantitative data can also mask certain issues and subtle complexities that emerge through more deliberative, qualitative methods. PPGIS is therefore likely to be a useful tool that builds upon existing understandings of the social-ecological landscape and feeds back into the planning process in order for a just and sustainable outcome to be reached.

Our study identified a number of potential challenges and pitfalls that need to be considered by urban landscape managers and planners seeking to apply PPGIS methods in a specific context. In their study of participatory green space planning processes in Finland, Kahila-Tani *et al.* (2016) noted that “though planners found the collected data and the analysis valuable, they still lacked the skills and institutional motivation to use the data effectively” (p. 195). Below we provide guidance along these lines that could assist urban planners in implementing PPGIS methods.

4.2.2.1 Evaluation of PPGIS design and analysis choices

If PPGIS data are used to inform decision-making, it is critical that they are accurate and reliable. This study has identified a number of issues that need to be considered. First, it is important that the sample frame is an accurate representation of the broader population’s spatial, temporal and socio-demographic variability. We strove to ensure a representative sample of participants, yet even with appropriate survey design and administration measures taken we found some demographic bias in our data. This has potential to overemphasise the importance of certain values and places since different demographic groups interact with landscapes in different ways (e.g. parents valuing safe areas for children to play). Any such bias should be recognised when applying results to planning practice. Second, the spatial arrangement of respondents and landscape features can impact results and their interpretation. By accounting for the relative spatial distribution of green spaces to the respondents in our study areas, we found that the distance of a green space from participants’ place of residence did not have a strong effect on marker abundance (Fig. 6). Failure to account for the relative locations of green spaces and respondents could in many cases lead to inaccurate conclusions about how distance impacts values, yet this kind of analysis is not a simple exercise for many management agencies. Finally, PPGIS studies are normally conducted at a single point in time. They typically do not capture how people's values for landscapes change temporally in response to seasonality, change in life circumstances, or landscape modification. Although a recent study found an overall consistency in the values for an Alaskan national forest indicated via PPGIS mapping over a 14 year time period (Brown & Donovan, 2014), this is a topic that has received little attention in the literature and is in need of further research, particularly in regards to individual responses and the psychological antecedents of value assignment.

Another challenge in undertaking effective PPGIS research for green space planning is the resources (time, money, expertise) it requires. Using physical paper maps is known to generate higher response rates than online PPGIS methods (Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012), yet printing and postal costs can be prohibitive for many small municipalities. The substantial time taken to digitise markers and analyse responses may also be problematic if it exceeds the personnel time allocated by management agencies for community engagement. A related challenge is ensuring agencies have the appropriate expertise (particularly statistical) required to appropriately analyse and interpret results. We encourage the continuing development of new methods to engage citizens using new technologies (e.g. smartphone apps) and assist practitioners in data analysis as a way of helping to meet these challenges. Additionally, if limited analytical skills are available, it may be more appropriate to simply use visualisations of mapped values to identify immediate management priorities or issues rather than seeking to extrapolate results to more generalised principles.

4.2.2.2 PPGIS in the context of different green space planning models

Planning for green space is a complex process that brings together various social, environmental and political considerations. Although the specifics of the planning process varies across different places and times, Maruani and Amit-Cohen (2007) identified five general open space planning models that have been applied in an urban context. In brief, these are (i) opportunistic (random allocation of land for open space according to availability), (ii) space standards (providing minimum area of open space for a given population), (iii) park systems (interrelated parks and gardens), (iv) garden city (a comprehensive approach based on Ebenezer Howard's principles), and (v) shape related models (such as green belts or green wedges). We suggest that PPGIS can help transition urban green space planning from traditional standards-based or shape-based planning models to a participatory, 'needs-based' planning approach: one that accounts for a population's "socio-demographic composition, their leisure and recreation preferences and those of various sub-groups" (Byrne & Sipe, 2010). Yet there is still some work needed to mainstream new deliberative-analytic processes in green space planning (Kahila-Tani et al., 2016). Combining PPGIS with other participatory tools for stakeholder engagement is likely to help overcome some of the methodological challenges discussed above and aid the inclusion of citizens' epistemological and ontological diversity (Kahila-Tani et al., 2016; Nahuelhual, Benra Ochoa, Rojas, Díaz, & Carmona, 2016).

5. Conclusion

This study has demonstrated that public values for green space are varied and respond in different ways to different suites of environmental variables. While some environmental variables seemed to exert a consistently positive effect on all environmental variables (e.g. distance from water), other variables (e.g. vegetation cover) were related only to a few value types. Further, existing management categories were shown not to have a strong bearing on the kinds of values people assign to green spaces. This research reveals a complex picture of how different values are assigned to green spaces, and highlights the need for green space planners to avoid the 'one size fits all' approach to the design of green space networks. We encourage planners to pursue participatory techniques such as PPGIS as a means of ascertaining the values and preferences of the urban public and planning for these accordingly. Yet we also emphasise the need for careful consideration of the design and analysis of these methods to ensure that the data used to inform decisions are accurate and reliable.

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