Public greenspace and life satisfaction in urban Australia

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Abstract

This paper examines the influence of public greenspace on the life satisfaction of residents of Australia's capital cities. A positive relationship is found between the percentage of public greenspace in a resident's local area and their self-reported life satisfaction. On average, it is found that a resident has an implicit willingness-to-pay of $1,168 in annual household income for a one per cent (143m^2) increase in public greenspace. The relationship between public greenspace and life satisfaction however, is non-linear. Additional results suggest that the value of greenspace increases with population density and that lone parents, the less educated and those living in high rise dwellings benefit to a greater extent from the provision of public greenspace than the general population. In all, life satisfaction data supports existing evidence that public greenspace is welfare enhancing for urban residents and adequate allowance should be made for its provision when planning urban areas.

Keywords: Happiness; Household, Income and Labour Dynamics in Australia (HILDA); Geographic Information Systems (GIS); Greenspace; Life Satisfaction; Non-market Valuation.

JEL Classification: C21; Q51; R20

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1. Introduction

It is estimated that over 50 per cent of the world's population now reside in urban areas. Moreover, the United Nations (2010) projects that the world's urban areas will absorb all of the global population growth over the next four decades, as well as continue to draw some of the rural population. Policy makers and urban planners therefore face a significant challenge to design urban areas in such a way as to accommodate this growth, while maintaining residents' well-being.

One means of managing population growth is urban consolidation (i.e. increasing density in existing built environments). Advocates of urban consolidation (cf. Alexander and Tomalty, 2002; Bambrick et al., 2011) cite more efficient use of established infrastructure and services (such as water and energy), greater accessibility of service for a variety of people, reduced traffic congestion and pollution, as well as the mitigation of health and well-being risks associated with obesity and sedentary lifestyles. In contrast, opponents (cf. Forster, 2006; Randolph, 2006) observe the loss of precious public open space to urban infill, increased noise, gentrification, poorly matched preferences, concentrated social disadvantage, and potentially undermined social cohesion. These criticisms of urban consolidation are particularly strident when policy makers have not appropriately preserved the public domain and residential amenity (Bryne and Sipe, 2010).

The compensating hypothesis argues that urban consolidation should be accompanied by increases in public greenspace, as residents will seek to substitute public for private areas (Maat and De Vries, 2006). One of the key simplifications, and potential shortcomings, of the compensating hypothesis is that people living in high densities are assumed to be homogenous in regards to their need for greenspace. In this paper, using data from residents of Australian capital cities, we investigate the heterogeneity of preferences for greenspace (inferred from life satisfaction effects) across people depending on their characteristics or circumstances. This is consistent with the idea of taking a needs-based approach to the provision of greenspace, as advocated by Bryne et al. (2010). The paper proceeds as follows. The remainder of Section 1 examines existing evidence on the welfare effects of public greenspace, as well as the place of life satisfaction research in economics. Methodology and data form the subject of Section 2. Results are presented in Section 3 and discussed in Section 4.

1.1. Greenspace and well-being

A substantial body of evidence demonstrates the positive effect of greenspace on well-being. For example, in metropolitan centres in Italy and the United Kingdom, frequent visits to greenspace are found to generate significant improvements in the well-being of users during periods of heat stress (Lafortezza et al., 2009). In Stockholm and Göteborg, greenspace is found to mitigate the negative effect of road traffic noise on well-being (Gidlof-Gunnarsson and Ohrstrom, 2007). Some studies have suggested that accessible greenspace plays a role in promoting physical activity, yielding objective physical health benefits, performing a preventative role in cardiovascular and musculo-skeletal diseases, and inhibiting stroke and cancer (Newton, 2007). In the South Australian capital city of Adelaide, respondents who perceive their neighbourhood to be 'highly green' have 1.37 and 1.60 times higher odds of reporting better physical and mental health, as measured by derived SF-12 physical and mental component scores (Sugiyama et al., 2008). Similarly, Maas et al. (2006) in the Netherlands and Mitchell and Popham (2007) in England find greenspace to enhance perceived general health; the former finding the relationship to be stronger for lower-socio economic groups, with some residents such as the elderly, youth and those with low levels of education benefitting more from greenspace than the general population. For a broader review of the literature see Bell et al. (2008), Croucher et al. (2008; 2007) and Newton (2007).

The case for a positive relationship between greenspace and well-being is also made in the contingent valuation and hedonic property pricing literature (cf. Brander and Koetse, 2011; Crompton, 2001, 2005, 2007). For example, Jim and Chen (2010), employing the hedonic property pricing approach, find that residents of Hong Kong are willing-to-pay a substantial premium (USD 76,274)[3] for having a park nearby, and a further USD 9,962 for having a view of a park. In 15 cities across New Zealand, households are found to be willing-to-pay approximately NZD 184 per annum to avoid a 20 per cent reduction in the urban tree estate (Vesely, 2007). There is also evidence to suggest greenspace provides benefits indirectly, through increasing social cohesion and inclusion (see Kazmierczak and James (2007) for a review).

[3] As at 17 February 2012 1 AUD = 1.0751 USD; 1 AUD = 0.8187 EUR; 1 AUD = 1.2883 NZD. All figures are in AUD unless otherwise stated.

1.2. Life satisfaction in economics

Research into life satisfaction is increasingly the subject of a great deal of empirical investigation in economics. This is motivated, at least in part, by dissatisfaction with traditional means of measuring economic progress, as clearly evidenced by the findings of the Commission on the Measurement of Economic Performance and Social Progress (Stiglitz et al., 2009). This body of research also reflects a broader re-evaluation of the epistemological foundations of economics, as seen in 2002 by Daniel Kahneman (a psychologist) and Vernon Smith (the pioneer of experimental economics) together being awarded the Nobel Prize in economic sciences.

At an individual level, a great deal of effort has been devoted to better understanding what determines life satisfaction, with a number of stylised 'facts' becoming apparent. For example, a common finding is that men are less happy than women (cf. Blanchflower and Oswald, 2004). Age is U-shaped, with happiness reaching a minimum in a person's 30s and 40s (Blanchflower and Oswald, 2004). The impact of income on life satisfaction is overwhelmingly positive, although the coefficient is typically not large. Marriage improves a person's life satisfaction (cf. Evans and Kelley, 2004) however, Blanchflower and Oswald (2004) find second and subsequent marriages to be less happy than first marriages. Evidence on the effect of children is complex, although on the face of it life satisfaction decreases as the number of dependent children increases (cf. Margolis and Myrskyla, 2010; Shields and Wooden, 2003).

Poor health invariably lowers life satisfaction, as does unemployment (Frijters et al., 2004; Powdthavee and Van Praag, 2011). The influence of education is not straightforward; most authors find education in developed countries to have a negative or statistically insignificant influence on life satisfaction (Shields et al., 2009; Veenhoven, 1996). Helliwell (2003) explains this finding by providing evidence that the benefits of education flow less through a direct impact on life satisfaction than through its positive effects on the creation and maintenance of human and social capital. A comprehensive review of life satisfaction or happiness in economics is provided by Frey and Stutzer (2002a, b) and MacKerron (2011).

1.2.1. The environment and life satisfaction

In the environmental and ecological economics literature, life satisfaction data has been used to infer implicit monetary valuations of environmental amenities and disamenties. For example, Welsch (2002) uses cross-section data on reported well-being for 54 countries to value urban air pollution. The author finds that, on average, an individual needs to be given USD 70 per annum compensation in order to accept a one-kiloton per capita increase in urban nitrogen dioxide load. While the valuation of air quality has dominated the literature (cf. Ferreira and Moro, 2010; Luechinger, 2009, 2010; MacKerron and Mourato, 2009; Menz, 2011), other non-market environmental goods valued via the life satisfaction approach include airport noise (cf. van Praag and Baarsma, 2005), climate (cf. Ferreira and Moro, 2010; Frijters and van Praag, 1998; Maddison and Rehdanz, 2011), scenic amenity (cf. Ambrey and Fleming, 2011), floods (cf. Luechinger and Raschky, 2009) and droughts (cf. Carroll et al., 2009).

Very few studies have investigated greenspace and life satisfaction within this framework, with mixed results. MacKerron (2010) finds the accessibility of greenspace to have a statistically insignificant impact on the life satisfaction of London residents, whereas Smyth et al. (2008) find green area per capita in urban China to be positive and statistically significant for happiness. Our paper contributes to this body of literature.

1.3. Public greenspace and the case of urban Australia

Despite a large land mass and comparatively small population, Australia is heavily urbanised, with 89 per cent of the population living in towns and cities. Moreover, most future population growth is expected to be concentrated in existing urban centres (Commonwealth of Australia, 2010b). Within this context, a standards approach to the provision of public greenspace has been employed in urban environments in Australia since the 1940s, with the standard set at a level of 7 acres (3 ha) per 1,000 residents (Bryne et al., 2010). However, there are many instances where this standard has not been met. For example, in Sydney (Australia's largest city) the inner and middle suburbs have local open space per 1,000 residents ranging from 0.56 to 2.41 ha (Searle, 2011).

Somewhat surprisingly, given the wealth of evidence supporting the well-being benefits of greenspace, the provision of greenspace in urban environments does not appear to be high on the policy agenda. For example, the State of Australian Cities 2010 Report (Commonwealth of Australia, 2010b) barely mentions greenspace and the 2010 Intergenerational Report (Commonwealth of Australia, 2010a) all but ignores the issue (Bryne et al., 2010). Furthermore, policies of urban consolidation have concentrated medium to high density residential development in inner ring suburbs where greenspace is comparatively scarce. Exacerbating this scarcity are zoning and development regulations that allow a reduction of greenspace for higher density development (Bryne, 2012). This provides reason for concern about the adequacy of local open space planning to cope with intensified urban consolidation across Australian cities (Searle, 2011).

2. Data and methodology

The first step is to estimate a model where life satisfaction is a function of socio-economic and demographic characteristics, spatial variables and the extent of public greenspace. The model takes the form of an indirect utility function for resident *r* in location *k* as follows:

$$U_{r,k} = \beta_0 + \beta_1 \ln(y_{r,k}) + \beta_2 x_{r.k} + \beta_3 a_{r,k} + \beta_4 \delta_{r,k} + \varepsilon_{r.k} \quad r = 1 \ldots R, k = 1 \ldots K \qquad (1)$$

Where $y_{r,k}$ is household income, x is a vector of socio-economic and demographic characteristics including age, marital status, employment status, education and so forth, $a_{r,k}$ is the percentage of public greenspace in the resident's local area and $\delta_{r,k}$ is a vector of spatial controls, similar to those employed by Shields et al. (2009). In the micro-econometric life satisfaction function, the resident's true utility is unobservable; hence self-reported life satisfaction is used as a proxy. Table 1 provides a description of all variables employed. Descriptive statistics are provided as Appendix A.

[Insert Table 1 here]

As shown by Ferreira and Moro (2010) and Welsch (2006), it is possible to estimate the implicit willingness-to-pay (denoted WTP) for a marginal change in public greenspace by taking the partial derivative of public greenspace and the partial derivative of the natural log of household income, as follows:

$$WTP = \frac{\frac{\partial U_{r,k}}{\partial a_{r,k}}}{\frac{\partial U_{r,k}}{\partial ln(y_{r,k})}} = \frac{\partial a_{r,k}}{\partial ln(y_{r,k})} = \bar{y}\frac{\widehat{\beta_3}}{\widehat{\beta_1}} \qquad (2)$$

Where $\bar{y}$ is the mean value of household income. If discrete changes are to be valued, the Hicksian welfare measures of compensating and equivalent surplus can be employed. In this case, the compensating surplus is the amount of household income a resident would need to receive (pay) following a decrease (increase) in the level of public greenspace in his or her local area, in order to remain at his or her initial level of utility. Compensating surplus (denoted CS) can be calculated as follows:

$$CS = -\exp\left[\overline{\ln(y)} + \frac{\widehat{\beta_3}}{\widehat{\beta_1}}(\ln(a^1) - \ln(a^2))\right] + \bar{y} \tag{3}$$

Where a^1 is the initial, and a^2 the new level of greenspace. Similarly, the equivalent surplus is the amount of household income a resident would need to receive or pay in order to obtain the level of utility following a change, *if the change did not take place*. Equivalent surplus (denoted ES) can be calculated as follows:

$$ES = \exp\left[\overline{\ln(y)} + \frac{\widehat{\beta_3}}{\widehat{\beta_1}}(\ln(a^2) - \ln(a^1))\right] - \bar{y} \tag{4}$$

The next step is to augment the model estimated in Equation 1 with interactions,[4] in order to assess whether different residents in different situations, on average, have different implicit preferences for public greenspace. The augmented life satisfaction model takes the form of an indirect utility function for resident *r* in location *k* as follows:

$$U_{i,k} = \beta_0 + \beta_1 \ln(y_{r,k}) + \beta_2 x_{r.k} + \beta_3 a_{r,k} + \beta_4 a_{r,k}\lambda_{r.k} + \beta_5 \delta_{r,k} + \varepsilon_{r.k} \tag{5}$$

Where $\lambda_{r.k}$ is one of many possible characteristics unique to the resident or the resident's situation and all other variables are as previously defined. From Equation 5 we can proceed to derive the implicit willingness-to-pay, as shown in Equation 6.

$$WTP = \frac{\frac{\partial U_{r,k}}{\partial a_{r,k}}}{\frac{\partial U_{r,k}}{\partial ln(y_{r,k})}} = \frac{\partial a_{r,k}}{\partial ln(y_{r,k})} = \bar{y}\frac{\widehat{\beta_3}+\widehat{\beta_4}\bar{\lambda}}{\widehat{\beta_1}} \tag{6}$$

Where $\bar{\lambda}$ is the mean of the explanatory variable (for instance, population density in the local area) interacted with public greenspace.

[4] This methodological approach is similar to that undertaken by Kroll, C., 2011. Different things make different people happy: Examining social capital and subjective well-being by gender and parental status. Social Indicators Research 104, 157-177.

2.1. Estimation strategy

Similar to the estimation strategies employed by Brereton et al. (2008) and Stutzer and Frey (2008) among others, ordinary least squares (OLS) is employed for ease of interpretation and comparison with other studies. Implicit in this is the assumption that life satisfaction self-reports are cardinal and interpersonally comparable. See Kristoffersen (2010) for a recent survey of the existing literature on this point. Many authors (cf. Ferrer-i-Carbonell and Frijters, 2004) have shown that estimates of the determinants of life satisfaction are virtually unchanged whether one models the ordinal nature of the variable (as implied by the use of ordered probit) or treats the responses as cardinal (implied by the use of OLS); contingent on individual heterogeneity being addressed appropriately. To satisfy this condition we include the ‘Big Five’ personality trait controls: extraversion; agreeableness; conscientiousness; emotional stability; and openness to experience (Saucier, 1994).

The personality trait controls assist in mitigating potential bias in the income coefficient that may arise if, for example, extraverted people are both more likely to report higher levels of life satisfaction and be more productive in the labour market (Powdthavee, 2010). Nonetheless, despite further controls for job-related characteristics such as hours worked and commute time, downward bias in the income coefficient remains, as people compare their current income with both their past income and the income of others (Clark et al., 2008). On a separate note, it is possible that people self-select where they reside; suggesting that the public greenspace coefficient would be biased upwards. The magnitude of this effect is uncertain; however some authors (cf. Chay and Greenstone, 2005) observe that the empirical evidence indicates the bias is small. Together these biases may lead to larger than otherwise valuation estimates.

To address possible spatially omitted variable bias we include numerous controls for additional spatial factors for which data are available. Finally, as we include explanatory variables at different spatial levels, standard errors are adjusted for clustering (cf. Moulton, 1990).

2.2. Household, Income and Labour Dynamics in Australia

The measure of self-reported life satisfaction and the socio-economic and demographic characteristics of respondents are obtained from Wave 5 (2005) of the HILDA survey.[5] This data is then subset for Australia's capital cities (Adelaide, Brisbane, Canberra, Darwin, Hobart, Melbourne, Perth and Sydney). First conducted in 2001, by international standards the HILDA survey is a relatively new nationally representative sample and owes much to other household panel studies conducted elsewhere in the world; particularly the German Socio-Economic Panel and the British Household Panel Survey. See Watson and Wooden (2010) for a recent review of progress and future developments of the HILDA survey.

The life satisfaction variable is obtained from individuals' responses to the question: *'All things considered, how satisfied are you with your life?'* The life satisfaction variable is an ordinal variable, the individual choosing a number between 0 (totally dissatisfied with life) and 10 (totally satisfied with life).

Of particular importance to the valuation aspect of this paper is the definition of household income. The income measure employed is the natural log of self-reported nominal disposable household income with imputed values for missing data. Consistent with the findings of Wooden et al. (2009), we find no statistical difference between imputed and reported values. For further detail about the imputation method used, see Hayes and Watson (2010).

2.3. Spatial data

The measure of public greenspace (obtained using Geographic Information Systems) is the percentage of public greenspace in the resident's local area, defined at the level of the Collection District (CD).[6,7] Following Bell et al. (2008), public greenspace is defined to include public parks, community gardens, cemeteries, sports fields, national parks and wilderness area.

[5] Wave 5 is employed as it closely matches the date of collection of the spatial data. Further, Wave 5 includes a range of personality trait questions; thus allowing the Big Five personality traits to be controlled for in model estimation.

[6] The CD is the smallest spatial unit in the Australian Standard Geographical Classification. Australian Bureau of Statistics, 2010. Australian Standard Geographical Classification, Catalogue No. 1216.0, Canberra.

[7] Appendix B illustrates, for each capital city, the CD administrative boundaries and overlapping public greenspace.

The mean area of the CDs in the sample is 1.85km^2. Assuming each CD takes the shape of a circle, the median radius from the centroid or centre point is approximately 750m. Thus, the public greenspace measured is in close proximity to the resident's dwelling. As noted by Schipperijn et al. (2010), major factors influencing the use of greenspace are size *and* proximity; in using the percentage of public greenspace within the CD we have been able to conveniently synthesise these two factors into a single variable.

3. Results

The estimated results for Equation 1 are presented in Table 2. The explanatory power of the model, as measured by an adjusted R^2 of 0.1794, is comparable to other studies of this type (cf. Shields et al., 2009).

In regards to socio-economic and demographic characteristics, the results largely support the existing literature and *a priori* expectations. That is, life satisfaction is U-shaped in age, reaching a minimum when a resident is in their forties. Males are found to be more satisfied than women when personality trait controls are included; however in absolute terms males report lower levels of life satisfaction.

Immigrants from non-English speaking countries are found to be less satisfied than the native born, even after controlling for reported English speaking ability. In terms of marital status, being married is associated with higher levels of life satisfaction than being in a *defacto* relationship and people in a *defacto* relationship are more satisfied than resident's never before married. In contrast, separated and divorced residents experience much lower levels of life satisfaction than residents who have never been married. Being a widow is associated with higher levels of life satisfaction. Lone parents are found to have lower levels of life satisfaction, even after controlling for the number of children in the household, which itself has an adverse impact on a resident's life satisfaction.

As expected, having a long-term health condition is associated with lower levels of life satisfaction, with the greatest impact felt by those with a severe health condition. Unemployment, even after controlling for income, appears to be quite detrimental to a resident's life satisfaction. Higher income has a positive effect, commuting time a negative effect.

Four of the Big Five personality trait variables are statistically significant at the one per cent level, with higher degrees of extraversion, agreeableness, conscientiousness and emotional stability all associated with higher levels of life satisfaction. Renters and residents living in other (non-standard) types of dwellings are found to have lower levels of life satisfaction than house owners and those living in a separate house.

Of the spatial variables employed, living within three kilometres of the coastline is associated with higher levels of life satisfaction, whereas living within three kilometres or between three and five kilometres of a major airport is found to detract from life satisfaction. With the exception of Melbourne residents, residents living in capital cities other than Sydney are generally found to have higher levels of life satisfaction, *ceteris paribus*.

Of particular importance to this study, public greenspace, as measured by the percentage of public greenspace in the resident's local area, is found to be welfare enhancing at a statistically significant level (p-value of 0.055), with an estimated coefficient of 0.00325.

[Insert Table 2 here]

Following the procedure described in Equation 2, the average implicit willingness-to-pay in terms of annual household income, for a one per cent increase in public greenspace, is $1,168. Given, on average, there are 2.5 people living in each household in the sample, this implies a per-capita implicit willingness-to-pay of $467. To put these results in context, on average, a one per cent increase in greenspace from the mean is equivalent to a 143m^2 increase in public greenspace in the CD.

Similarly, a one standard deviation (12.49 per cent) increase in public greenspace from the mean yields a compensating surplus of $12,755, thus suggesting, following such an improvement, a resident is able to sacrifice approximately $12,800 in annual household income and remain at his or her initial level of utility. The comparable equivalent surplus estimate is $16,799, suggesting a resident would require an increase in annual household income of approximately $16,800 for such an improvement *not to occur*.

3.1. Non-linear marginal utility of public greenspace

To explore the presence of a non-linear relationship between public greenspace and life satisfaction, CDs containing greenspace are assigned into quartiles depending upon the percentage of greenspace they contain (CDs without greenspace form the base case). Results suggest a strong non-linear functional form (Table 3).

[Insert Table 3 here]

Specifically, a movement from the base case to the first quartile produces the greatest gain in life satisfaction. However, an increase in greenspace from the second to third quartiles is associated with reduced life satisfaction; perhaps suggesting that the negative effects of additional greenspace (for example, noise and crime) outweigh the amenity value the additional greenspace provides (Crompton, 2001). Contrary to such reasoning, moving from the third to the fourth quartile again increases life satisfaction. We suggest this anomaly may reflect differences in the types of public greenspace in each of the quartiles. For instance, CDs in the fourth quartile are more likely to contain national parks, which may be less likely to confer the same negative effects as urban parks. This is an area worthy of future research.

3.2. Heterogeneity in preferences for public greenspace

We first use Equation 6 to examine how a resident's preferences may vary depending on the characteristics of their *local area*. The results indicate that for people living in more densely populated areas, public greenspace yields greater life satisfaction benefits, with the coefficient of the interaction term statistically significant. Employing average marginal effects, the mean implicit willingness-to-pay estimates at the 25th, 50th and 75th population density percentiles are \$1,268, \$1,828 and \$2,377 respectively.[8] These results accord with those of Anderson and West (2006) who, using the hedonic property pricing method, find that the value of proximity to neighbourhood parks rises with population density.

This may reflect a combination of factors, including scarcity rent and high initial marginal utility attributable to what little public greenspace is available in particularly densely populated areas. Furthermore, these results provide some supporting evidence for the compensating hypothesis, as residents compensate poor access to private greenspace by making more use of public greenspace (Maat and De Vries, 2006).

[8] It is worth noting that the welfare effects of public greenspace do not appear to depend on the socio-economic characteristics of the local area, as defined by the Australian Bureau of Statistics' Socio-Economic Indexes for Areas Index of Relative Socio-economic Disadvantage and also investigated using median income of the local area.

Again using Equation 6, we investigate how the welfare effects of public greenspace depend on the characteristics of the *resident*. Interaction coefficients are presented in Table 4.

[Insert Table 4 here]

The dominant finding is that many of the interactions do not yield statistically significant results. On the face of it, this suggests that preferences are perhaps not as heterogeneous as first anticipated. However, more complex interactions may still exist which, due to sample size constraints, are unable to be modelled with our data set. For example, high rise residents benefit more from public greenspace, yet the extent to which they benefit may depend on their level of income, and if they are retired and are in good health. Further, high rise residents with younger children may obtain greater benefits depending on the specific facilities and safety of the greenspace in question.

Focusing first on the statistically insignificant results, the benefits of public greenspace do not appear to depend on age, level of health or ethnicity. It may be the case that only particular health states can be enhanced by public greenspace and that less visibly different races derive greater benefits in terms of social inclusion (cf. Colic-Peisker, 2009; Kazmierczak and James, 2007). In future research it may be beneficial to further disaggregate these variables.

We do however, find some evidence of heterogeneity. For example, the results reveal public greenspace provides residents who are lone parents with moderating benefits. Notably, the sign of the coefficient is in stark contrast to the original linear specification of the lone parent variable. This lends some confidence to the role of urban greenspace in improving social inclusion. Furthermore, residents with a highest level of educational attainment of year 12 (completed secondary school) or below are found to derive greater benefits from public greenspace, suggesting that residents with lower levels of education are more sensitive to local physical environmental characteristics; a finding consistent with that of Maas et al. (2006).

Finally, we find evidence that residents in high rise dwellings (defined as apartments of four or more storeys) benefit to a far greater extent from the provision of public greenspace; providing further evidence that the value of proximity to neighbourhood parks rises with population density.

4. Discussion

This paper set out to investigate heterogeneity in preferences for greenspace (inferred from life satisfaction effects) in the context of capital cities throughout Australia. In so doing, this paper makes an important contribution to the spatial planning literature, as well as the small, but growing, body of literature employing the life satisfaction approach to value environmental goods and services. Furthermore, this study assists in addressing the challenge urban consolidation presents in terms of the sourcing, provisioning and management of urban greenspace.

Our main finding indicates that increased public greenspace enhances local residents' welfare, and that, on average, a resident has an implicit willingness-to-pay of approximately $1,168 in annual household income for a one per cent (143m^2) increase in public greenspace in their local area. The strength of this result depends on a number of factors, including the percentage of public greenspace in the local area, the population density of the local area, and, to some extent, the characteristics of the resident and their circumstances. The results suggest that there is some heterogeneity in preferences for public greenspace, with lone parents, residents with an education level of year 12 or below, and high rise dwellers all found to derive greater benefits from the provision of greenspace than other capital city residents. However, the dominant finding is that most interactions were not significant, suggesting that preferences for greenspace appear to be relatively homogeneous. An important caveat though, is that more complex dependencies are unable to be modelled with our data set. A further issue not addressed in this study, and thus an opportunity for further research, is that resident's preferences for public greenspace may depend on the specific characteristics of the greenspace in question.

While it is difficult to compare these valuations with existing studies employing more conventional non-market valuation techniques, it is worth noting that the estimates are at the lower end of environmental valuations employing the life satisfaction approach, yet at the upper end of valuations found in the literature for public greenspace specifically. In all, these findings illustrate the need for policy makers to consider the role of public greenspace in supporting well-being and the preferences of residents in urban areas when planning public greenspace.

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Table 1: Model variables

Variable name	Definition
Age	Dummy variable if respondent is between 15 and 19 years of age; between 20 and 29; between 40 and 49; between 50 and 59; and 60 years of age or greater
Male	Respondent is male
ATSI	Respondent is of Aboriginal and/or Torres Strait Islander origin
Immigrant English	Respondent is born in a Main English Speaking country (Main English speaking countries are: United Kingdom; New Zealand; Canada; USA; Ireland; and South Africa)
Immigrant non-English	Respondent is not born in Australia or a Main English Speaking country
Poor English	Respondent speaks English either not well or not at all
Number of children	Number of respondent's own resident children in respondent's household at least 50 per cent of the time and number of own children who usually live in a non-private dwelling but spend the rest of the time mainly with the respondent
Married	Respondent is legally married
Defacto	Respondent is in a defacto relationship
Separated	Respondent is separated
Divorced	Respondent is divorced
Widow	Respondent is a widow
Lone parent	Respondent is a lone parent
Mild health condition	Respondent has a long-term health condition, that is a condition that has lasted or is likely to last for more than six months and this condition does not limit the type or amount of work the respondent can do
Moderate health condition	Respondent has a long-term health condition limiting the amount or type of work that the respondent can do
Severe health condition	Respondent has a long-term health condition and cannot work
Year 12 or below	Respondent's highest level of education is Year 12 or below
Employed part-time	Respondent is employed and works less than 35 hours per week
Self employed	Respondent is self employed
Unemployed	Respondent is not employed but is looking for work
Retired	Respondent is retired
Home duties	Respondent performs home duties
Student	Respondent is a non-working student
Non-participant	Respondent falls into the other non-participant category including individuals less than 15 years old at the end of the last financial year
Disposable income (ln)	Natural log of equivalised disposable household income
Hours worked	Number of hours worked per week by respondent
Commute time	Number of hours spent travelling to and from paid employment per week by respondent
Extraversion	Degree of extraversion (scale 1 to 7)
Agreeableness	Degree of agreeableness (scale 1 to 7)
Conscientiousness	Degree of conscientiousness (scale 1 to 7)
Emotional stability	Degree of emotional stability (scale 1 to 7)

Openness to experience	Degree of openness to experience (scale 1 to 7)
Others present	Someone other than the respondent was present during the interview
Renter	Respondent is renting the home or is involved in a rent to buy scheme
Rent free	Respondent resides in the home rent free
Medium rise	Respondent resides in a townhouse, or one to three storey apartment
High rise	Respondent resides in a four or more storey apartment
Other dwelling	Respondent resides in other dwelling, for instance, a non-private dwelling, a caravan, or a houseboat
Years at current address	Number of years the respondent has lived at current address
Inner regional	Respondent resides in inner regional Australia
Outer regional or remote	respondent resides in outer regional or remote Australia
Population density	Number of individuals per square kilometre in the CD
SEIFA index	The Australian Bearu of Statistics' (ABS) Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Disadvantage measured in deciles for the CD, where a higher decile is relatively less disadvantaged and conversely a lower decile is relatively more disadvantaged
Public greenspace	Percentage of public greenspace in the CD
Proximity to coastline	Dummy variable = 1 if respondent resides within 3km; between 3km and 5km; between 5km and 10km of a coastline
Proximity to river	Dummy variable = 1 if respondent resides within 3km; between 3km and 5km; between 5km and 10km of a river
Proximity to lake	Dummy variable = 1 if respondent resides within 3km; between 3km and 5km; between 5km and 10km of a lake
Proximity to creek	Dummy variable = 1 if respondent resides within 3km; between 3km and 5km; between 5km and 10km of a creek
Proximity to airport	Dummy variable = 1 if respondent resides within 3km; between 3km and 5km; between 5km and 10km of an airport
Proximity to railway	Dummy variable = 1 if respondent resides within 3km; between 3km and 5km; between 5km and 10km of a railway station
Proximity to major road	Dummy variable = 1 if respondent resides within 1km and between 1km and 3km of a major road
Melbourne	Respondent resides in Melbourne
Brisbane	Respondent resides in Brisbane
Adelaide	Respondent resides in Adelaide
Perth	Respondent resides in Perth
Hobart	Respondent resides in Hobart
Darwin	Respondent resides in Darwin
Canberra	Respondent resides in Canberra

Omitted cases are: Age (30-39); Female; Not of indigenous origin; Country of birth Australia; Speaks English well or very well; Never married and not de facto; Not a lone parent; Does not have a long-term health condition; Beyond year 12; Not self employed; Employed working 35 hours or more per week; No others present during the interview or don't know – telephone interview; Owns/paying off mortgage on home; Separate house; Major city; Greater than 10km from the coastline; Greater than 10km from a river; Greater than 10km from a lake; Greater than 10km from a creek; Greater than 10km from an airport; Greater than 10km from a railway station; Greater than 3km from a major road; Sydney.

Table 2: Model 1 results

Variable name	OLS estimate (standard error)	Variable name	OLS estimate (standard error)
Constant	2.64107*** (0.49121)	Renter	-0.10636* (0.05447)
Age (15-19)	0.43352*** (0.09412)	Rent free	-0.01752 (0.14488)
Age (20-29)	0.11431* (0.06065)	Medium rise	-0.01748 (0.06791)
Age (40-49)	-0.13181** (0.05264)	High rise	-0.03660 (0.15353)
Age (50-59)	-0.03367 (0.06930)	Other dwelling	-0.47549* (0.24858)
Age (60+)	0.22408** (0.09161)	Years at current address	0.00179 (0.00213)
Male	0.09552** (0.03748)	Inner regional	0.09129 (0.11053)
ATSI	0.11806 (0.16654)	Outer regional or remote	-0.09651 (0.21921)
Immigrant English	-0.00129 (0.05738)	Population density	0.00000 (0.00000)
Immigrant non-English	-0.11747* (0.06059)	SEFIA index	0.00694 (0.00044)
Poor English	-0.18078 (0.19346)	Public greenspace	0.00325* (0.00169)
Number of children	-0.06947*** (0.02356)	Proximity to coastline ($\delta_{r,k} \leq 3$ km)	0.24478*** (0.08420)
Married	0.28832*** (0.06768)	Proximity to coastline ($3 < \delta_{r,k} \leq 5$ km)	0.07383 (0.09204)
Defacto	0.16382** (0.07219)	Proximity to coastline ($5 < \delta_{r,k} \leq 10$ km)	0.09850 (0.07215)
Separated	-0.59977*** (0.16000)	Proximity to river ($\delta_{r,k} \leq 3$ km)	-0.04900 (0.09236)
Divorced	-0.25452** (0.10524)	Proximity to river ($3 < \delta_{r,k} \leq 5$ km)	-0.01957 (0.09650)
Widow	-0.29715** (0.13593)	Proximity to river ($5 < \delta_{r,k} \leq 10$ km)	-0.06721 (0.08054)
Lone parent	-0.37097*** (0.13981)	Proximity to lake ($\delta_{r,k} \leq 3$ km)	-0.02416 (0.15508)
Mild health condition	-0.15285** (0.06305)	Proximity to lake ($3 < \delta_{r,k} \leq 5$ km)	-0.11159 (0.15403)
Moderate health condition	-0.57862*** (0.06260)	Proximity to lake ($5 < \delta_{r,k} \leq 10$ km)	0.03988 (0.13794)
Severe health condition	-1.08984** (0.44681)	Proximity to creek ($\delta_{r,k} \leq 3$ km)	0.11147 (0.11927)
Year 12 or below	0.04551 (0.04029)	Proximity to creek ($3 < \delta_{r,k} \leq 5$ km)	0.03610 (0.12252)
Employed part-time	0.03513 (0.06031)	Proximity to creek ($5 < \delta_{r,k} \leq 10$ km)	0.05274 (0.10108)

Self employed	-0.12096 (0.07519)	Proximity to airport ($\delta_{r,k} \leq 3$ km)	-0.73179** (0.34613)
Unemployed	-0.41045*** (0.15481)	Proximity to airport ($3 < \delta_{r,k} \leq 5$ km)	-0.27823* (0.14542)
Student	0.10511 (0.11808)	Proximity to airport ($5 < \delta_{r,k} \leq 10$ km)	-0.09992 (0.07395)
Non-participant	-0.18649 (0.22729)	Proximity to railway ($\delta_{r,k} \leq 3$ km)	-0.12756 (0.12778)
Retired	0.09896 (0.11482)	Proximity to railway ($3 < \delta_{r,k} \leq 5$ km)	-0.05983 (0.12678)
Home duties	0.08090 (0.10627)	Proximity to railway ($5 < \delta_{r,k} \leq 10$ km)	0.00946 (0.12185)
Disposable income (ln)	0.14742*** (0.03037)	Proximity to major road ($\delta_{r,k} \leq 1$ km)	0.10077 (0.09570)
Hours worked	-0.00240 (0.00191)	Proximity to major road ($1 < \delta_{r,k} \leq 3$ km)	0.04261 (0.09149)
Commute time	-0.01535*** (0.00570)	Melbourne	0.63894 (0.04257)
Extraversion	0.08734*** (0.01741)	Brisbane	0.68158*** (0.18664)
Agreeableness	0.18006*** (0.02458)	Adelaide	0.89250* (0.48290)
Conscientiousness	0.09704*** (0.01853)	Perth	1.39848*** (0.50679)
Emotional stability	0.22752*** (0.02120)	Hobart	0.76615*** (0.22025)
Openness to experience	-0.01826 (0.02084)	Darwin	1.95700*** (0.32440)
Others present	0.02474 (0.04083)	Canberra	0.57378*** (0.20391)
Summary statistics			
Number of observations	6156		
Adjusted R^2	0.17937		

*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Omitted cases are: Age (30-39); Female; Not of indigenous origin; Country of birth Australia; Speaks English well or very well; Never married and not de facto; Not a lone parent; Does not have a long-term health condition; Beyond year 12; Not self employed; Employed working 35 hours or more per week; No others present during the interview or don't know – telephone interview; Owns/paying off mortgage on home; Separate house; Major city; Greater than 10km from the coastline; Greater than 10km from a river; Greater than 10km from a lake; Greater than 10km from a creek; Greater than 10km from an airport; Greater than 10km from a railway station; Greater than 3km from a major road; Sydney.

Table 3: Disaggregated model results

Variable name	**OLS estimate** (standard error)
1st quartile $(0 < a_{r,k} \leq 2.10806)$	0.15129** (0.05950)
2nd quartile $(2.10806 < a_{r,k} \leq 6.34934)$	0.19590*** (0.06526)
3rd quartile $(6.34934 < a_{r,k} \leq 15.16243)$	0.11337* (0.060661)
4th quartile $(15.16243 < a_{r,k})$	0.27154*** (0.05801)
Summary Statistics	
Number of observations	6156
Adjusted R^2	0.18145

*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Omitted case: No public greenspace ($a_{r,k} = 0$).

Table 4: Public greenspace interaction results

Interaction term	OLS estimate (standard error)
Age (15-19) x Public greenspace	-0.00829 (0.00706)
Age (20-29) x Public greenspace	-0.00044 (0.00453)
Age (40-49) x Public greenspace	-0.00727 (0.00474)
Age (50-59) x Public greenspace	-0.00427 (0.00582)
Age (60+) x Public greenspace	-0.00510 (0.00523)
Male x Public greenspace	-0.00145 (0.00348)
ATSI x Public greenspace	-0.00674 (0.01376)
Immigrant English x Public greenspace	-0.00257 (0.00508)
Immigrant non-English x Public greenspace	-0.00526 (0.00498)
Number of children x Public greenspace	-0.00044 (0.00163)
Lone parent x Public greenspace	0.02313** (0.01082)
Mild health condition x Public greenspace	-0.00234 (0.00474)
Moderate health condition x Public greenspace	0.00200 (0.00422)
Severe health condition x Public greenspace	0.02857 (0.03083)
Year 12 or below x Public greenspace	0.00879*** (0.00303)
Unemployed x Public greenspace	0.00595 (0.01252)
Renter x Public greenspace	0.00109 (0.003982)
Rent free x Public greenspace	0.00635 (0.00610)
Medium rise x Public greenspace	-0.00489 (0.00616)
High rise x Public greenspace	0.01428* (0.00735)
Other dwelling x Public greenspace	-0.01941 (0.01324)

Hours worked x Public greenspace	0.00005
	(0.00008)
Summary Statistics	
Number of observations	6156
Adjusted R^2	0.18003

*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

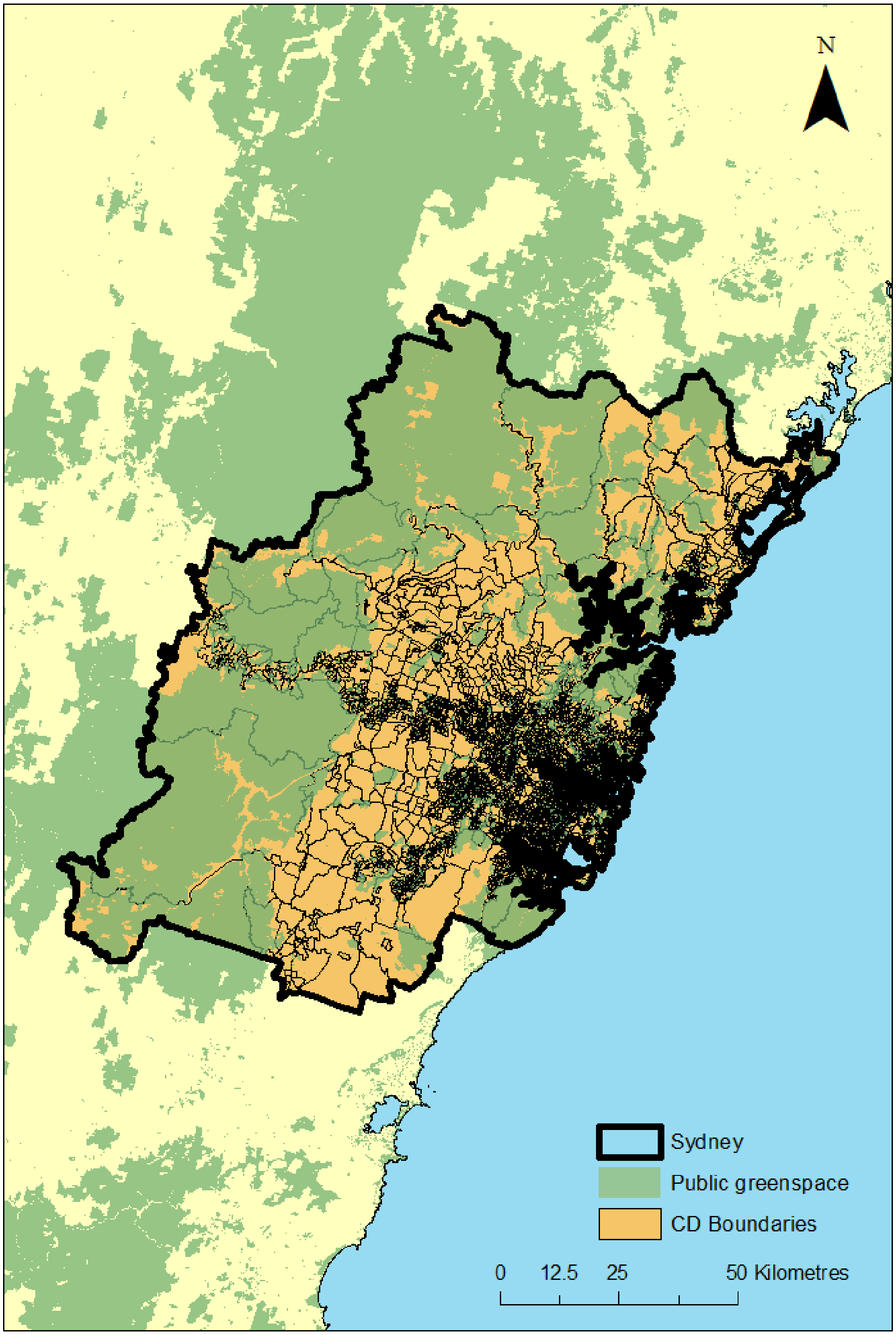
Appendix A: Descriptive statistics

Variable name	Mean	Minimum	Maximum	Standard deviation	Percentage Values 1	Percentage Values 0
Age	42.88532	15	100	17.80279	n.a.	n.a.
Male	0.46280	0	1	0.49865	46.3	53.7
ATSI	0.01494	0	1	0.12134	1.5	98.5
Immigrant English	0.11777	0	1	0.32236	11.8	88.2
Immigrant non-English	0.14068	0	1	0.34772	14.1	85.9
Poor English	0.01023	0	1	0.10065	1.0	99.0
Number of children	0.70338	0	11	1.08624	n.a.	n.a.
Married	0.49935	0	1	0.50004	49.9	50.1
Defacto	0.11485	0	1	0.31886	11.5	88.5
Separated	0.02339	0	1	0.15116	2.3	97.7
Divorced	0.06384	0	1	0.24449	6.4	93.6
Widow	0.04516	0	1	0.20767	4.5	95.5
Lone parent	0.01966	0	1	0.13883	2.0	98.0
Mild health condition	0.09097	0	1	0.28759	9.1	90.9
Moderate health condition	0.16309	0	1	0.36948	16.3	83.7
Severe health condition	0.00504	0	1	0.07079	0.5	99.5
Year 12 or below	0.45647	0	1	0.49814	45.6	54.4
Employed part-time	0.21849	0	1	0.41325	21.8	78.2
Self employed	0.05523	0	1	0.22845	5.5	94.5
Unemployed	0.02778	0	1	0.16435	2.8	97.2
Retired	0.15854	0	1	0.36528	15.9	84.1
Home duties	0.07294	0	1	0.26005	7.3	92.7
Student	0.04727	0	1	0.21224	4.7	95.3
Non-participant	0.01494	0	1	0.12134	1.5	98.5
Disposable income (ln)	10.8779	1	13.94900	0.82959	n.a.	n.a.
Hours worked	1.90162	0	71.18324	4.47224	n.a.	n.a.
Commute time	2.92781	0	40	3.77074	n.a.	n.a.
Extraversion	4.46082	1	7	1.08083	n.a.	n.a.
Agreeableness	5.39078	1	7	0.92147	n.a.	n.a.
Conscientiousness	5.09724	1	7	1.05008	n.a.	n.a.
Emotional stability	5.16379	1	7	1.07452	n.a.	n.a.
Openness to experience	4.29878	1	7	1.06482	n.a.	n.a.
Others present	0.32489	0	1	0.46837	32.5	67.5
Renter	0.26852	0	1	0.44322	26.9	73.1
Rent free	0.01624	0	1	0.12642	1.6	98.4
Medium rise	0.13791	0	1	0.34484	13.8	86.2
High rise	0.01771	0	1	0.13189	1.8	98.2
Other dwelling	0.00981	0	1	0.09901	1.0	99.0
Years at current address	10.21456	0.01000	82.38000	11.35492	n.a.	n.a.

Inner regional	0.07229	0	1	0.25898	7.2	92.8
Outer regional or remote	0.01030	0	1	0.10300	1.1	98.9
Population density	2634.26100	0.49816	61017.20000	2648.34800	n.a.	n.a.
SEIFA index	6.18281	1	10	2.68085	n.a.	n.a.
Public greenspace	7.68934	0	12.493	12.49300	n.a.	n.a.
Proximity to coastline						
($\delta_{r,k} \leq 3$ km)	0.18827	0	1	0.39096	18.8	81.2
($3 < \delta_{r,k} \leq 5$ km)	0.09129	0	1	0.28805	9.1	90.9
($5 < \delta_{r,k} \leq 10$ km)	0.16975	0	1	0.37545	17.0	83.0
Proximity to river						
($\delta_{r,k} \leq 3$ km)	0.20273	0	1	0.40207	20.3	79.7
($3 < \delta_{r,k} \leq 5$ km)	0.09844	0	1	0.29793	9.8	90.2
($5 < \delta_{r,k} \leq 10$ km)	0.21248	0	1	0.40909	21.3	78.7
Proximity to lake						
($\delta_{r,k} \leq 3$ km)	0.71589	0	1	0.45103	71.6	28.4
($3 < \delta_{r,k} \leq 5$ km)	0.14474	0	1	0.35186	14.5	85.5
($5 < \delta_{r,k} \leq 10$ km)	0.11387	0	1	0.31768	11.4	88.6
Proximity to creek						
($\delta_{r,k} \leq 3$ km)	0.31368	0	1	0.46402	31.4	68.6
($3 < \delta_{r,k} \leq 5$ km)	0.10754	0	1	0.30982	10.1	89.9
($5 < \delta_{r,k} \leq 10$ km)	0.21670	0	1	0.41203	21.7	78.3
Proximity to airport						
($\delta_{r,k} \leq 3$ km)	0.00601	0	1	0.07730	0.6	99.4
($3 < \delta_{r,k} \leq 5$ km)	0.03899	0	1	0.19358	3.9	96.1
($5 < \delta_{r,k} \leq 10$ km)	0.13954	0	1	0.34654	14.0	86.0
Proximity to railway						
($\delta_{r,k} \leq 3$ km)	0.66309	0	1	0.47269	66.3	33.7
($3 < \delta_{r,k} \leq 5$ km)	0.13954	0	1	0.34653	14.0	86.00
($5 < \delta_{r,k} \leq 10$ km)	0.11826	0	1	0.32294	11.8	88.2
Proximity to major road						
($\delta_{r,k} \leq 1$ km)	0.72401	0	1	0.44705	72.4	27.6
($1 < \delta_{r,k} \leq 3$ km)	0.20029	0	1	0.40025	20.0	80.0
Melbourne	0.29386	0	1	0.45565	29.4	70.6
Brisbane	0.15270	0	1	0.35972	15.3	84.7
Adelaide	0.10396	0	1	0.30524	10.4	89.6
Perth	0.11533	0	1	0.31945	11.5	88.5
Hobart	0.02485	0	1	0.15569	2.5	97.5
Darwin	0.00682	0	1	0.08232	0.7	99.3
Canberra	0.03401	0	1	0.18443	3.4	96.6

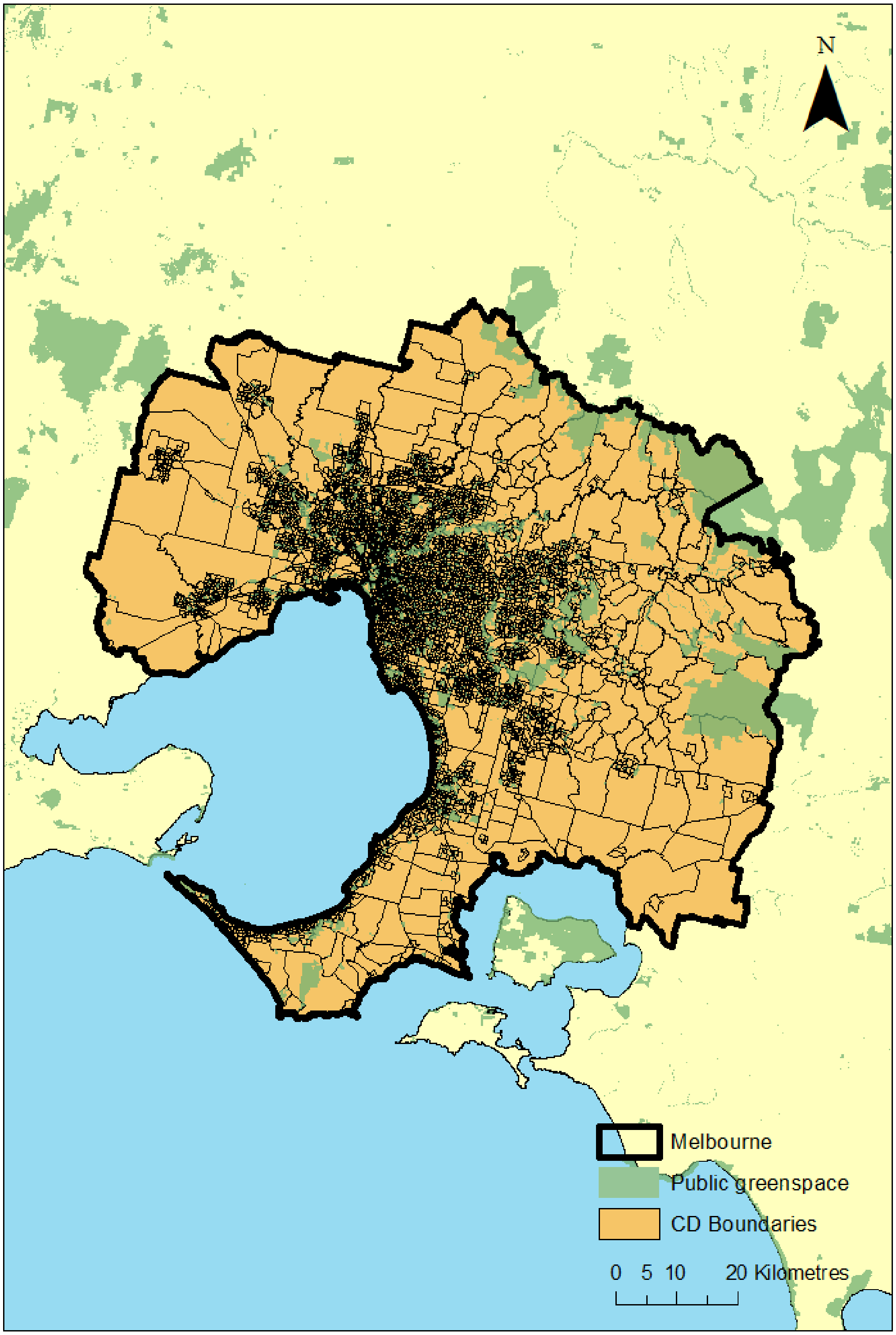
Appendix B: Australian capital cities and public greenspace

Figure A1: Sydney



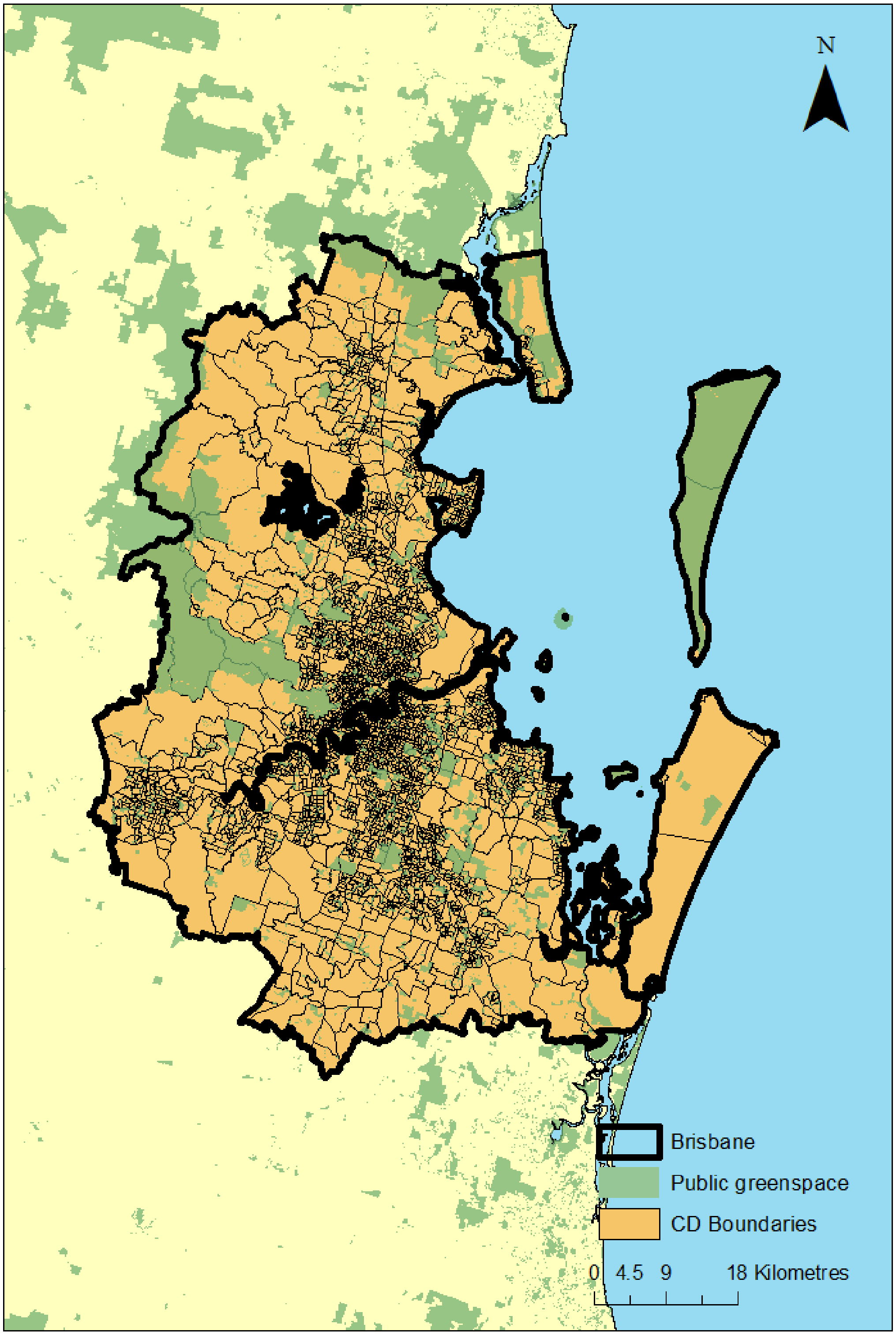
Source: NAVIGATE Pty Ltd (2010)

Figure A2: Melbourne



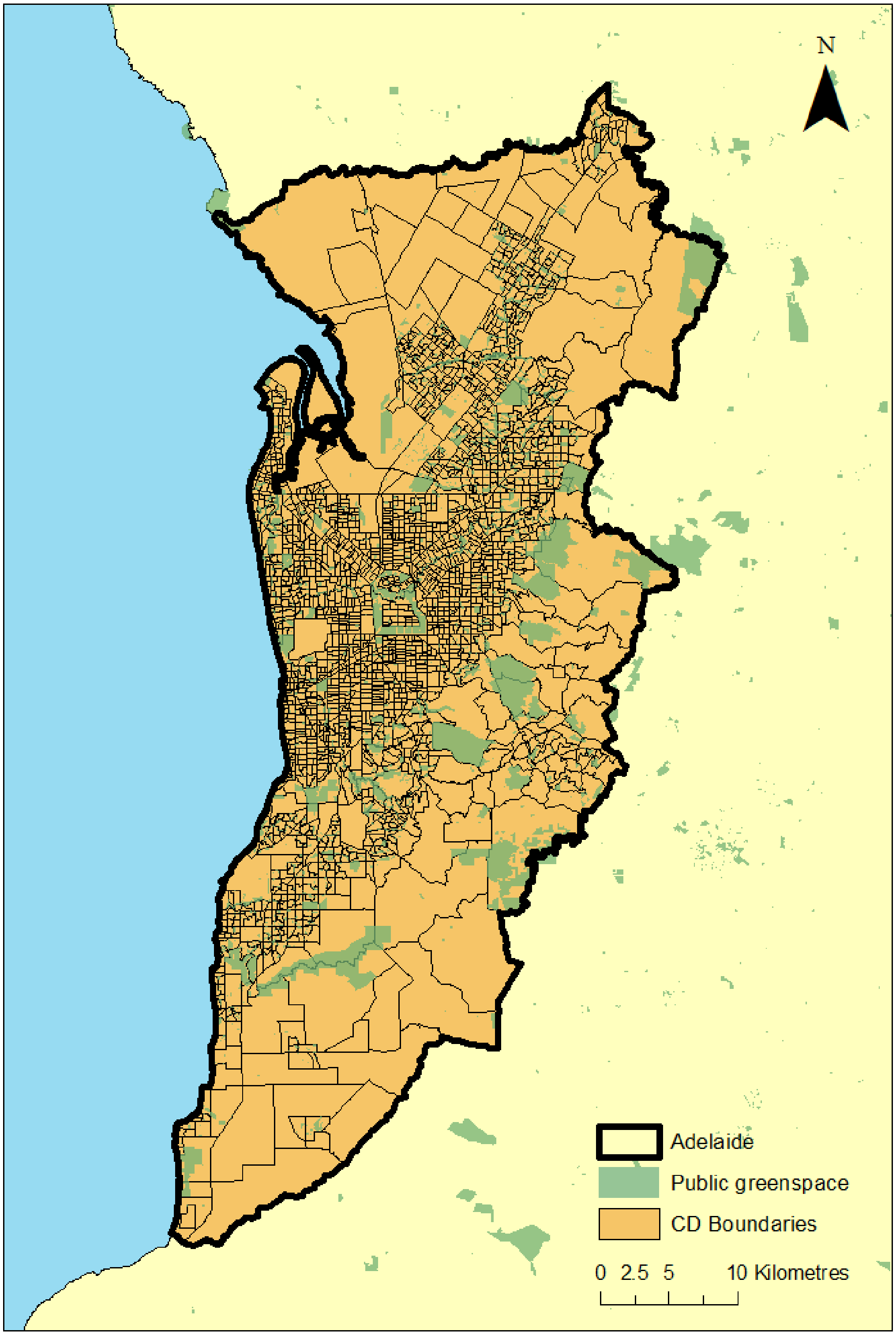
Source: NAVIGATE Pty Ltd (2010)

Figure A3: Brisbane



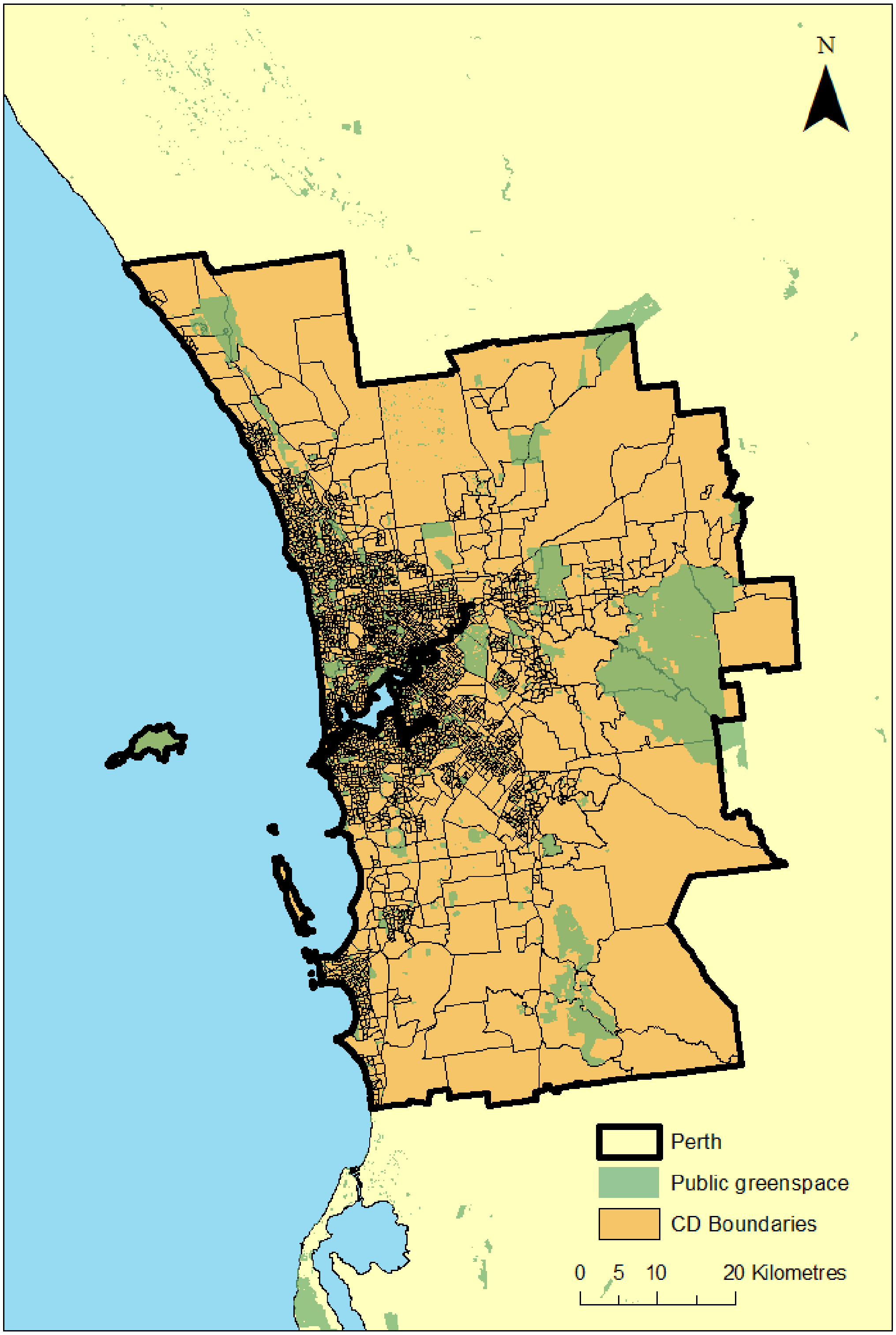
Source: NAVIGATE Pty Ltd (2010)

Figure A4: Adelaide



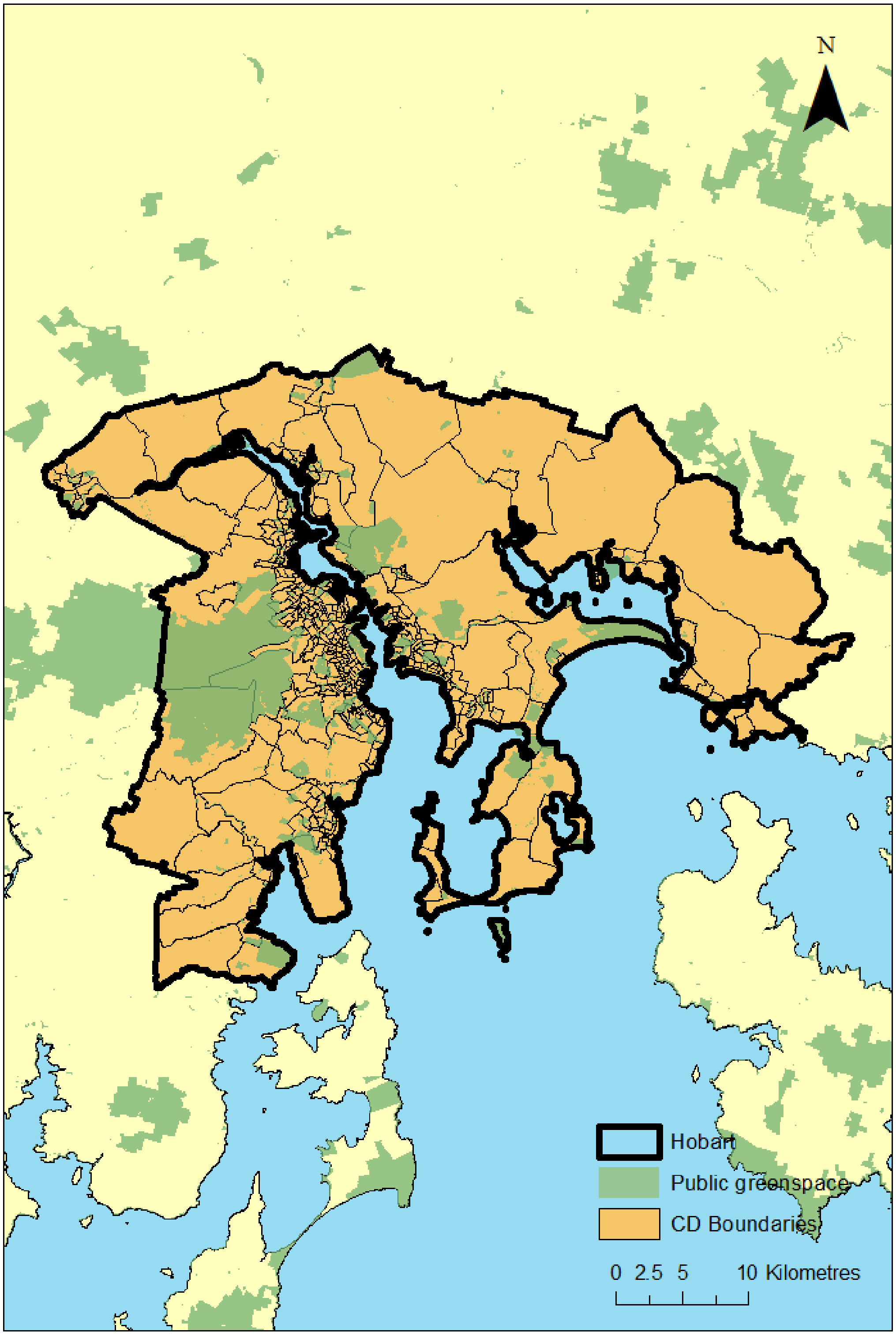
Source: NAVIGATE Pty Ltd (2010)

Figure A5: Perth



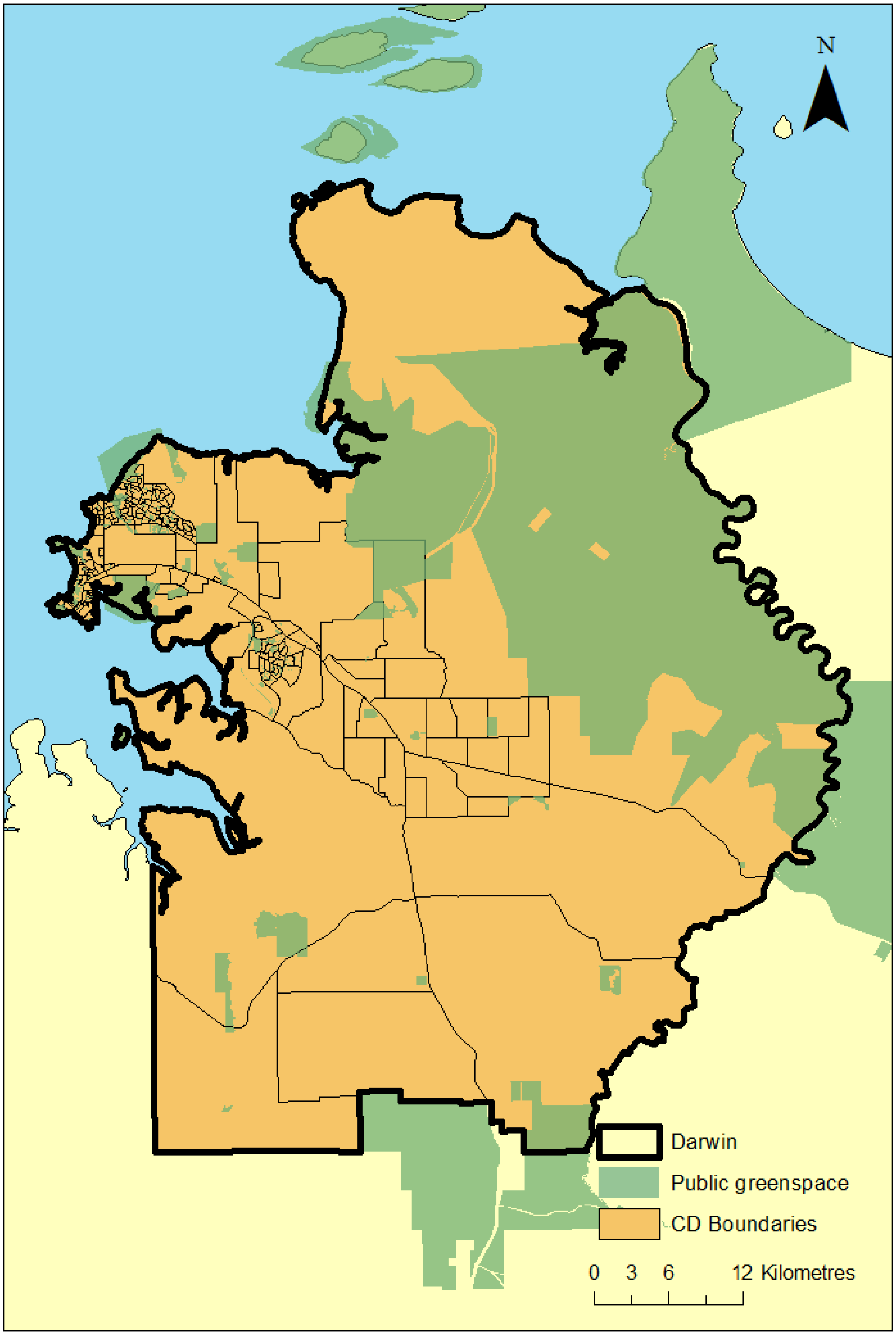
Source: NAVIGATE Pty Ltd (2010)

Figure A6: Hobart



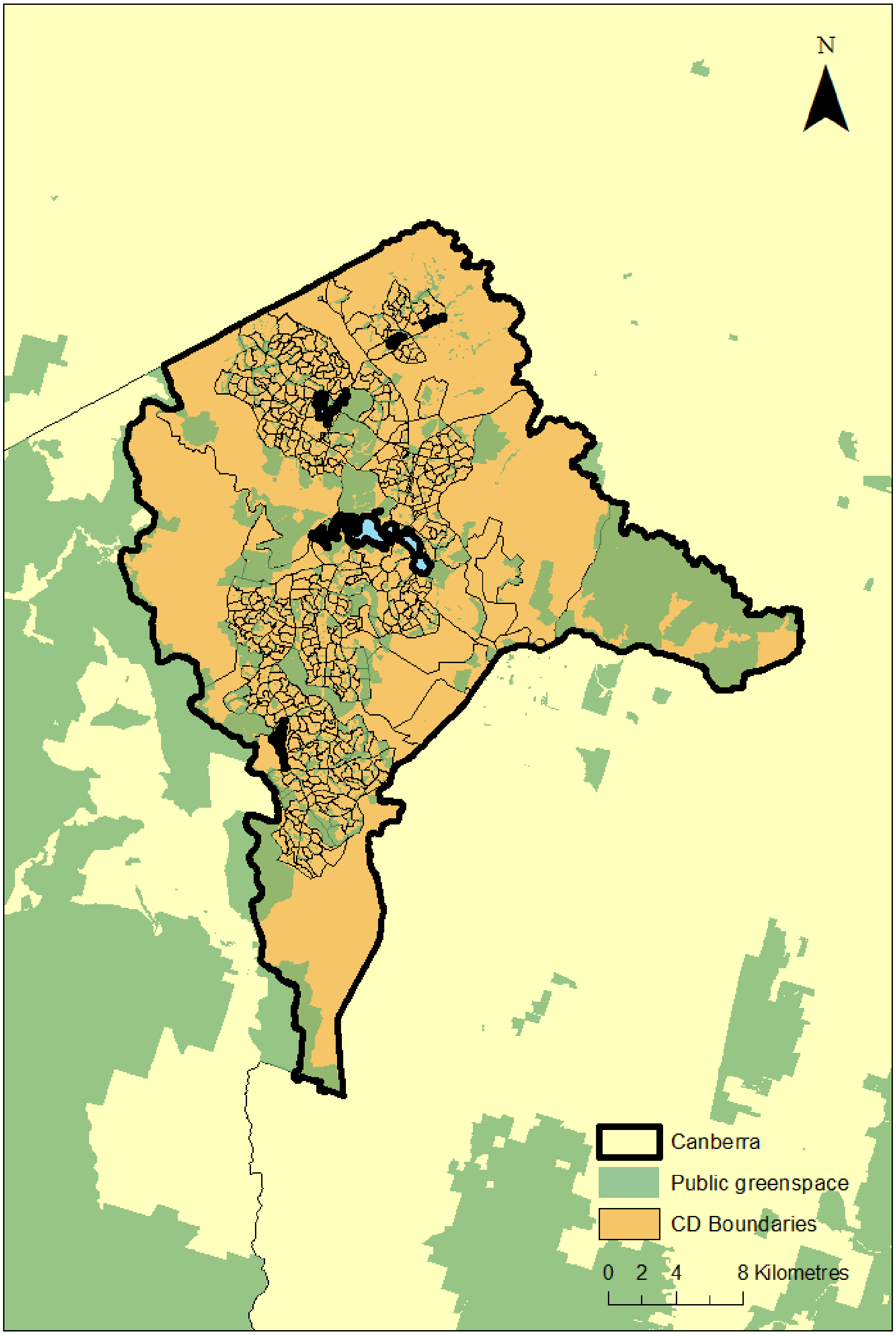
Source: NAVIGATE Pty Ltd (2010)

Figure A7: Darwin



Source: NAVIGATE Pty Ltd (2010)

Figure A8: Canberra



Source: NAVIGATE Pty Ltd (2010)