Property value returns on investment in street trees: a business case for collaborative investment in Brisbane, Australia.

Lyndal Plant [a]*, Alicia Rambaldi [b] and Neil Sipe [a]

[a] School of Geography, Planning and Environmental Management, University of Queensland, QLD 4072, Australia

[b] School of Economics, University of Queensland, QLD 4072, Australia

Address of corresponding author:
*University of Queensland, c/o School of Geography, Planning and Environmental Management, University of Queensland, Brisbane, St Lucia, QLD 4072, Australia

E-mail addresses:
lyndal.plant@uq.edu.au (L.Plant), a.rambaldi@uq.edu.au (A. Rambaldi), n.sipe@uq.edu.au (N. Sipe)

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1. Introduction

Many cities are seeking to optimise the ecosystem service benefits of urban trees by incorporating goals for increasing tree canopy cover into strategies that promote liveability and urban sustainability. In Australia, for example, the City of Melbourne is aiming to increase tree canopy cover in public streets and parks from 22% in 2014 to 40% by 2040, to help reduce urban heat island (UHI) impacts on human health (City of Melbourne, 2013). Just as tree canopy cover targets need to be context specific, the business cases needed to help justify investment in the tree planting, maintenance and management required to achieve such targets should also be relevant and robust. Techniques that quantify and value the supply of ecosystem services (ES), such as air quality improvement, UHI cooling and energy conservation, have developed through interdisciplinary scholarship and been applied to urban forest management for more than three decades (Chen and Jim, 2008; Dwyer, et al., 1991; Kollin and Schwab, 2009; Roy, et al., 2012; McPherson, 1992; McPherson, 1998; McPherson and Simpson, 2003; Nowak and Dwyer, 2007; Rowntree and Nowak, 1991). Some targets themselves have been based on ES provision forecast from technical assessments of capacity and feasibility for increasing tree canopy cover (McPherson, et al., 2011; McPherson, et al., 2016). However, less attention has been paid to the demand for ES by residents, especially the opportunity to test local preferences for existing and target levels of tree canopy cover and the use of the values implied by those preferences to build ES demand based benefit/cost analyses. We assert that decisions to invest in increasing tree canopy cover can be better informed when both the level of resident support for the targets themselves and estimates of returns to the range of beneficiaries and investors are included in the business case.

This study explores home-buyers preferences for existing and target levels of footpath tree canopy cover in the subtropical city of Brisbane, Australia. We adapt an existing technique, hedonic price modelling, to reveal home-buyers willingness to pay (WTP) for levels of footpath tree canopy coverage in 2010, compared to 2031 target levels and translate the 2010 implied pricing to an annual property value premium and "property tax" revenues, to compare to annual costs. We ask, do home-buyers preferences reveal a level of support for existing and/or target levels of tree canopy cover? Is ongoing investment in increasing footpath tree canopy cover justified by property value premiums and returns to investors? Could urban forest valuations better account for local demands for ES and therefore be applied to both canopy cover policy evaluation and business case development? We contribute to a growing literature on the application of urban ES valuation techniques to policy evaluation and investment strategies for green infrastructure and urban forests.

Previous studies have identified that home-buyers preferences for tree canopy cover vary depending on the amount, type, age, condition and proximity of the trees (Anderson and

Cordell, 1988; Anthon, et al., 2005; Conway, et al., 2010; Dombrow, et al., 2000; Donovan and Butry, 2010; Morales, 1980; Netusil, et al., 2014; Pandit, et al., 2014; Pandit, et al., 2013; Payton, et al., 2008; Sander, et al., 2010; Sander and Zhao, 2015; Tyrväinen, 1997; Tyrvainen and Miettinen, 2000; Escobedo, et al., 2015) and the size, uses and tenure of the land they grow on (Drake-McLaughlin and Netusil, 2010; Kong, et al., 2007; Luttik, 2000; Melichar and Kaprová, 2013; Melichar, et al., 2009; Saphores and Li, 2012; Wachter and Bucchianeri, 2006; Wolf, 2007) and that these variations often interact with other features of the neighbourhood such as population density, home ownership, household structure, income, education, connection with nature and ethnicity (Anderson and West, 2006; Conway and Bang, 2014; Sander and Zhao, 2015). Homebuyers preferences for trees on the property itself have varied from negative to positive and insignificant, depending on thresholds of canopy coverage of the site (Drake-McLaughlin and Netusil, 2010; Netusil, et al., 2014; Pandit, et al., 2014; Sander, et al., 2010; Saphores and Li, 2012). Small gains in property value from nearby green cover in Los Angeles were attributed to home-buyers indifference when levels of existing greenspace are high (Conway, et al., 2010). Despite the use of similar hedonic price methods, marginal increases in mean levels of street tree canopy cover within 20 metres of houses sold in Perth in 2009 added a 1.8 % premium to median sale price (Pandit, et al., 2014), whereas street tree canopy cover within a similar proximity (30.5 metres) of houses in Portland added a 3 % premium in 2006-2007 (Donovan and Butry, 2010). Types of tree planting programs and age of plantings have also influenced the extent of property value gains from street trees (Netusil, et al., 2014; Wachter, et al., 2006; Wachter and Bucchianeri, 2006). Trends amongst these interactions highlight the challenge for urban forest planning and policy-making to recognise both spatial, social and temporal variations in the demand for TCC (Sander and Zhao 2015); including the risk of perpetuating inequity in the supply of ES because of greater demand for tree canopy cover in advantaged communities (Heynen, et al., 2006; Wolch, et al., 2014).

Hence, contextual insights provide valuable guidance to urban greening strategies (Mäler, et al., 2008).

Hedonic price modelling reveals a form of non-market valuation expressed in homebuyers WTP for a marginal change in the amount, condition or proximity of tree canopy cover, while accounting for the effects of other attributes. Building a business case for municipal investment in urban greening, however, requires translating WTP into annual benefits to each of the beneficiaries that can be compared to annual costs/investment levels. For example, the value of street trees as suppliers of public goods such as improved stormwater management (Berland and Hopton, 2014; Coutts, et al., 2013; Kadish and Netusil, 2012; Water by Design, 2010; Zhang, et al., 2012) and human health and well-being benefits (Kardan, et al., 2015; Tzoulas, et al., 2007; Wegner and Pascual, 2011; Wolf, et al., 2015), estimated from annual avoided costs, have been used to help justify investment in strategic urban greening and ongoing tree maintenance. To date, translations of WTP, as an expression of the demand for these and other services, to estimates of annual benefits to homeowners and "property tax" returns to municipal investors and others have used different approaches. For example Donovan and Butry (2010) applied the positive and significant effects of street tree cover out front and nearby (within 30.5 m) house sale sites to all houses in Portland to suggest annual flow-on effects of $US54 m in property values and a further $US15.3 m in property tax revenue, compared to annual street tree maintenance costs of $US 4.61 m. The popular i-Tree Streets (previously known as STRATUM) urban forest valuation software applies a property value increase per street tree, using algorithms translated from an estimate of a 3.5-4.5 % increase in median house sale price associated with the average of five large "front-yard" trees in Athens, Georgia in 1988 (Anderson and Cordell, 1988). Based on the estimated annual change in the leaf surface area of street trees as the local unit of input, i-Tree Streets has been used to estimate annual property value improvements for several other U.S cities and internationally (i-Tree, 2014; McPherson, et al., 1999; McPherson, et al., 2016; Peper, et al., 2007; Soares, et al., 2011). The strength of the translations we apply to hedonic pricing outputs in this study is firstly in the use of context relevant effects of street trees on property values, rather than a benefit transfer approach. Second, we estimate realised, rather than latent, annual property value premiums to home-owners from the effects of footpath tree cover on the number of houses sold in the year of cost comparison. Third, we recognise increases in property taxes as a cost to home-owners but a gain to both municipal investors and the state government in the Australian context.

The following section of this paper reviews the limited literature on valuing urban forest benefits in Australian cities and describes the study area, including an overview of Brisbane's urban forest cover, governance and property tax structure. We then outline the sources and preparation of the house, property, neighbourhood and tree cover data, the methods used to explore the effects of tree cover on house sale price and subsequent valuation and return estimates. Finally, we provide the results in relation to other studies along with the contribution of this research to the literature on valuing and applying ecosystem service benefits to urban forest investment strategies.

2. Background

2.1 Valuing urban forest benefits in Australian cities

John French, a trained forester, was perhaps first to forecast the benefits of trees in Australian cities (French and Sharpe, 1976). His suggestion of the role of urban trees and tree canopy cover in stormwater runoff reduction and treatment for water sensitive Australian cities has been confirmed (Denman, et al., 2011; Tapper, 2010). Implementing "greener" stormwater management practices required by the Queensland State Government was recently estimated to return premiums in land values that outweigh installation costs (Water by Design, 2010).

In Australia, the carbon sequestration values of trees have become more topical in the carbon economy (Australian Government, 2013a). However, it is interesting to note that the value of carbon sequestration by Canberra's 400,000 publicly managed trees was estimated to be worth just $US 300,000 per year, compared to $US 1.57 million worth of energy and avoided emission savings from the cooling effects of their shade (Brack, 2002a). Climate amelioration benefits of urban tree cover, including tree shaded streets, cooling urban heat islands, improving walkability (Bowler, et al., 2010; Dumbaugh, 2006; Leuzinger, et al., 2010; Mayer, et al., 2008; Nagendra and Gopal, 2010; Sarkar, et al., 2015; Shashua-Bar, et al., 2010; Drake-McLaughlin and Netusil, 2010) and other associated health benefits (Pyper, 2004; Tarran, 2009) are particularly relevant to the climate change challenges facing Australian cities (Coutts, et al., 2013).

A few contemporary Australian studies have gained insight into community preferences for greenspace and urban trees using a range of valuation techniques, including "life-satisfaction" valuations (Ambrey and Fleming, 2014). Homebuyers in Perth and survey respondents from cities across Australia strongly support the provision of leafy streets and access to a diversity of public greenspaces (Ambrey and Fleming, 2014; Planet Ark, 2014; Pandit, et al., 2013).

While environmental, social and economic benefits and functions of urban trees in Australian cities, are beginning to be recognized (Ely, 2010; Moore, 2009), they have seldom been quantified or valued (Amati, et al., 2013; Planet Ark, 2014; Brack, 2002a; Dobbs, et al., 2014; Pandit, et al., 2014; Pandit, et al., 2013; Brack, 2002b; Victorian Institute of Strategic Economic Studies (VISES), 2015; Polyakov, et al.) beyond estimates inferred from other studies (Killicoat, et al., 2002; Moore, 2009; Moore, 2011; Stringer, 2007; Mekala, et al., 2015). Urban tree managers are looking to the Australian version of "i-Tree" software (Arboriculture Australia, 2013; Fairman, et al., 2010; NGIA, 2015) as an urban forest valuation tool to help apply the multiple values and benefit/cost scenarios to investment and decisionmaking for street and park tree assets (Davison and Kirkpatrick, 2014). However, inferred estimates and those based on generic relationships between tree cover and ecosystem services provision fall short of the rigor required to justify ongoing government investment in an increasingly competitive funding environment.

2.2 Study area

Brisbane is the third most populated city in Australia with the largest population growth of any local government area (LGA) (Australian Bureau of Statistics, 2015). In 2010, 1.06 million people were living in just over 200 suburbs[1] of the LGA, with 81 % of residents living in houses (detached dwellings) (Australian Bureau of Statistics, 2011). Alongside Brisbane's 4,800 kilometres of roads and streets in 2010, street tree canopies covered an average of 35 % of the footpath zone (or verge) between property frontages and the road/street edge, yet street trees made up just 10 % of all tree canopy cover across residential suburbs (the balance growing mostly on private property – 63 %; and public parks/other lands). Rapid growth and changing patterns of residential development in Australian cities, however, is reducing the space for trees on private house lots, increasing reliance on community public greenspaces including streetscapes and parks (Byrne, et al., 2010; Daniel, et al., 2016; Hall, 2010). Like most local authorities in Australia, Brisbane City Council (BCC) has responsibility for the planning, planting, maintenance and protection of all trees on BCC land, including street trees. However, unlike other Australian capital cities, Brisbane is a consolidated metropolitan area whose jurisdiction includes 1,340 square kilometres of residential, industrial, commercial centres, rural land uses and greenspace. In the financial year 2009/10, BCC spent $US 9.3 million[2] on planting, maintaining and managing street trees across Brisbane. Their challenge, like many local government authorities, is to continue

[1] Suburbs in Australia are locations within a city, equivalent in scale to districts or neighbourhoods in the UK and US respectively

[2] 2010 exchange rate of $1.4 AUS per $US was used to convert all monetary figures to $US

to expand street and park tree cover, while maintaining and managing existing tree assets with limited resources. To support walking and cycling, BCC aims to increase tree shade along residential footpaths from 35%, measured in 2010, to 50% by 2031 by strategically targeting the most “shade-hungry” parts of the footpath network (Favelle and Plant, 2009). The study area for this research covers 80 sample sites of 500 metres by 500 metres in size across 52 Brisbane’s residential suburbs. Sample sites were chosen using stratified random sampling to account for the uneven distribution and density of street tree canopy cover across Brisbane (Plant and Sipe, 2016). These same sites had been used by BCC in a separate field based exercise to estimate street tree population, stocking level, structure and condition. Our study, therefore, also provided an opportunity to demonstrate how information about preferences and implied values could be added to a broader urban forest planning exercise. Figure 1 shows the location of 80 sample sites and house sales within sample sites.

Property “taxes” take two forms in Australia and include “rates” levied on property owners by BCC and “stamp duties” levied on property buyers by the state government. In 2010 residential property rates for single dwellings were based on an estimate of the unimproved value of the land. Unimproved land values are reviewed by the Queensland Government about every three years using vacant land and other property sales data. BCC reported $US 420 million in general rates revenue for the financial year 2009/10. Stamp duties, collected by the state government, are based on the purchase price of the property (Queensland Government, 2013) and may include discounts for first home buyers and other concessions.

3. Methods

3.1 Local hedonic price model

The hedonic pricing technique has become popular in the study of ES of urban forest and greenspace (Roy, et al., 2012; Saphores and Li, 2012) and is well suited to this research because of the availability of high resolution tree cover data (Saphores and Li, 2012) and other secondary sources of house, property and neighbourhood characteristics. However, not every characteristic can be measured and accounting for omitted variables and other assumptions of the modelling technique, relevant to this study, are provided later in this section.

We investigated if tree cover on the property or on nearby properties was contributing a premium to Brisbane house prices, while controlling for other house, property and location effects. The value that home-buyers express in their WTP for tree cover provided a form of local valuation for comparison with local costs and with similar studies in other cities. Even though home-buyers are a subset of the broader community, hedonic price models also provide insights about the relationship between preferences for tree cover and other neighbourhood characteristics that are equally important to urban forest planning (Stone, et al., 2015).

3.2 House, property and suburb variables

The sale price of 2,774 single residential property sales between 2008 and 2010 were identified within the 80 sample sites. Details about numbers of bedrooms, bathrooms and garage space house attributes were available for 2,326 of the house sales from RP Data[3]. Limited data was available about the age of each house sold in the sample areas, therefore approximate suburb age (Queensland Places, 2013), categorised into four eras, was used as a proxy.

Socio-economic variables were sourced at statistical local area (SLA) resolution from 2011 Census statistics (Australian Bureau of Statistics, 2011). Property location variables included Euclidean distances to the nearest park, major road, shops (defined as “MP4” area designation in BCC CityPlan 2000) and heavy industry calculated using ArcGIS.

3.3 Tree canopy cover variables

Tree attributes chosen for this study were similar to those used in studies that have investigated effects of tree cover both on the property and nearby (Donovan and Butry, 2010; Pandit, et al., 2013; Sander, et al., 2010). Rather than square metres of tree canopy cover or numbers of

[3] RP Data is a commercial provider of property information and analytics.

trees, percentage tree canopy cover was used to align with the measures used in Brisbane's footpath tree cover targets (Australian Government, 2013b) and to avoid variation in canopy area related solely to variation in the area of available land within a property, park or footpath. (Pandit, et al., 2013)

Measures for seven tree cover variables were calculated using Brisbane's citywide "Tree Cover 2010" data. The centre-point along the street frontage boundary was used to create 30 metre and 100 metre buffer areas surrounding the property sales site. Tree canopy cover was measured on the property, on the footpath frontage of the property and within 30 metre and 100 metre buffer areas from the property, excluding the footpath frontage.

Summary statistics of the data set are shown in Table 1 and descriptions and sources of variables used in the models listed in Table 2. The models were supported by a data set with a range of lot sizes, located in suburbs with a broad range of age of development, household income, education, and distance from the Brisbane Central Business District (CBD). On average, houses in the sample had 3.4 bedrooms, 1.7 bathrooms and a 1.5 garage, were around 200 metres from the nearest park, with a median sale price of $US 378,571 ($AU 530,000). Houses sold between 2008 and 2010 in the 80 sample sites had a range of tree canopy cover on public and private land, within and nearby the property. On average, tree canopy covered 28.5 % of the land area within properties, slightly less of the land area within 30 metres of the property and similar tree cover in the land area within 100 metres of the property. Mean tree cover on the front footpath was 29.9 %, yet 703 properties in the sample had no trees on the front footpath. Footpath tree cover within 30 metres and 100 metres of the property averaged 30.9 % and 31.9 % of footpath land areas, respectively.

3.4 Data preparation

Results of descriptive statistics analyses were used to check data accuracy, normality of the dependent variable, identification of extreme outliers and tests for multicollinearity. Data inaccuracies were detected from the descriptive statistics, with 37 outliers removed after confirmation from casewise diagnostics in the base model.

Prior to running the base model, collinearity of the variables was tested using Pearson's bivariate correlation coefficients. No serious collinearity of independent variables was observed, other than expected correlations between numbers of bedrooms, bathrooms and garage size, and between neighbourhood variables such as distance of the suburb from the CBD, age of suburb, household income and education level of the suburb. Tree cover on the property was significantly related to property area (0.201 coefficient > 99 % significance in Pearson's 2 tailed test), tree cover on the footpath was significant and positively related to suburb age, income and education levels (0.093, 0.074, 0.074) and negatively related to distance of the suburb from the CBD (- 0.220).

House sale prices were transformed to the natural logarithm to correct for positive skewness in the distribution of the house sale prices.

To control for expected variation in house sales prices between years, two time dummy variables (D_2009, D_2010) were used to capture house sale price changes between 2008 and 2010 not due to any other variables included in the model. Two suburb era dummy variables were used to account for house sale price changes in pre (average suburb development era less than or equal to 1910's) and post-war (average suburb development era 1940's-1970's) suburbs compared to sales in modern (average suburb development era 1980's and later) and inter-war (average suburb development era 1920-1930's) suburbs. In the second stage, distance to the nearest park and tree cover within the property, on the front footpath and nearby the property were also converted to dummy variables to reveal expected non-linear variations in the effects of these variables at different thresholds of proximity and amount of tree cover respectively.

3.5 Statistical analysis

The effect of tree cover on house sale prices in Brisbane was initially investigated using a log-linear model estimated by ordinary least squares linear regression (OLS). However, the spatial nature of residential datasets often leads to two types of spatial autocorrelation in hedonic price models - spatial error and spatial lag (Anselin and Bera, 1998; Conway, et al., 2010; Freeman III, et al., 2014; LeSage and Pace, 2009; Taylor, 2003) beyond the submarket heterogeneity already acknowledged by using dummy variables for the year of sale (Moran, 1948).

First, while several location variables were included in this study, not all location effects can be measured and those included may interact with each other, reducing the randomness of the error term of OLS estimations, resulting in bias or imprecision of the explanatory powers of variables of interest (Anselin and Bera, 1998). Spatially correlated omitted variable effects are termed spatial error. Second, functional relationships in the dependent variable among neighbouring properties are referred to as spatial lag (LeSage and Pace, 2009).

There are two approaches to choosing the most appropriate model specification. The first involves statistical tests, namely the Lagrange Multiplier test (LM-test), which "generalize those proposed by Burridge (1980) and Anselin (1988) and the robust LM-tests proposed by Anselin et al. (1996) from a cross-sectional setting to a spatial multi-observational setting" (Elhorst, 2014 pg 390). The second consists of testing the results of different types of spatial models against each other. Two models, with the same spatial weight matrix, were tested and parameters determined by maximum likelihood estimation - a spatial error model (SEM) and a spatial autoregressive model with a spatial lag of the dependent variable (SAR). The spatial Durbin model (SDM), which includes a spatial lag for the dependent variable as well as a spatial lag interacted with the explanatory variables was also considered and estimated. In all cases the spatial parameters (λ and ρ, see equations (3) and (4)) were significant (details are provided in Table 4). The estimated marginal effects of the variables of interests were virtually identical to those obtained from the SAR model and will not be presented[4]. Four of the explanatory variables are already locational which might be the reason why the interaction with the spatial weights did not lead to significant differences in the results.

The log transformed house sale price was first regressed against house, property and suburb variables to develop a base model, represented in equation (1). It was expected that all house, property and suburb variables except distance to the nearest park, and distance to the city centre would have a positive relationship to house price.

$$lnP_i = \beta_0 + \mathbf{H}_i\boldsymbol{\beta}_1 + \mathbf{L}_i\boldsymbol{\beta}_2 + \mathbf{S}_i\boldsymbol{\beta}_3 + \sum_{t=2009}^{2010} \delta_{1t}\, DSaleYr_{it} + \sum_{E=1}^{2} \delta_{2E}\, DEra_{iE}$$

$$+ \sum_{D=1}^{2} \delta_{3D}\, DPark\_prox_{iD} + \epsilon_i \quad (1)$$

where,

$i = 1, \dots, n$ is the index for properties in the sample

lnP_i is the natural logarithm of the sale price of property i

$\mathbf{H}_i$ is a vector of attributes of the house at property i, including number of bedrooms, bathrooms and garage spaces

$\mathbf{L}_i$ is a vector of attributes of the land/property including size of the property, size of the nearest park, distance to shops and distance to arterial road

$DPark\_prox_{iD}$ is a dummy variable for proximity of the property to the nearest park. D1=1 if distance ≤ 200 metres and 0 otherwise, and D2=1 if distance ≥ 400 metres and 0 otherwise.

$DSaleYr_{it}$ is a dummy variable with value 1 if property *i* was sold in year *t*=2009 or 2010 and 0 otherwise.

$\mathbf{S}_i$ is a vector of attributes of the suburb in which property i is located, including average household income, and education level, and distance of the suburb from the Brisbane CBD,

[4] Available from the authors.

$DEra_{iE}$ is a dummy for the suburb vintage. E1=1 if the development era of the suburb was Pre-war and 0 otherwise, E2=1 if the development era of the suburb was Post-War and 0 otherwise.

$\beta_0, \boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \boldsymbol{\beta}_3, \delta_{1t}, \delta_{2E}, \delta_{3D}$ are parameters and vectors of conformable parameters to be estimated.

ϵ_t is a random error assumed to have zero mean

The second stage non-spatial models explored the effect of tree cover by adding these variables to the significant house, property, suburb and dummy variables of the base model, represented in equation (2a).

$$lnP_i = \beta_0 + \mathbf{H}_i\boldsymbol{\beta}_1 + \mathbf{L}_i\boldsymbol{\beta}_2 + \mathbf{S}_i\boldsymbol{\beta}_3 + \mathbf{T}_i\boldsymbol{\beta}_4 + \sum_{t=2009}^{2010} \delta_{1t}\, DSaleYr_{it} + \sum_{E=1}^{2} \delta_{2E}\, DEra_{iE}$$

$$+ \sum_{D=1}^{2} \delta_{3D}\, DPark\_prox_{iD} + \epsilon_i \quad (2)$$

Where $\mathbf{T}_i$ is a vector of attributes of tree cover, including tree cover on the property, tree cover nearby the property and tree cover on the front footpath and on nearby footpaths.

Effects may vary depending on the amount of tree cover. Tree cover on properties in two counties of Minnesota decreased home sale price up to around 23 % tree cover and thereafter increased home sale prices, and increases in tree cover within a 250 metre buffer increased home price up to the 60 % tree cover level, but then decreased at higher tree cover levels (Sander et al. 2010). In contrast, house sale prices in an extensive Portland study were maximised when on-property tree coverage was three percentage points less than the study area average (Drake-McLaughlin and Netusil, 2010). An alternative model (2b) replaced $\mathbf{T}_i$ with dummy variables to explore the effects of levels of tree cover above and below the mean of the sample and at the 50% target level of footpath tree cover. All tree cover levels were entered into the regression in units of % × 0.01.

Several of the tree variables captured some portion of the same tree cover and were therefore run in separate regressions within the development of the stage two models. Strong correlations were also found between some tree cover variables, which reinforced the iterative entry approach to the stage two analysis.

The two alternative spatial models presented in this study are represented by equations (3), SEM, and (4), SAR.

$$lnP_i = \beta_0 + \mathbf{H}_i\boldsymbol{\beta}_1 + \mathbf{L}_i\boldsymbol{\beta}_2 + \mathbf{S}_i\boldsymbol{\beta}_3 + \mathbf{T}_i\boldsymbol{\beta}_4 + \sum_{t=2009}^{2010} \delta_{1t}\, DSaleYr_{it} + \sum_{E=1}^{2} \delta_{2E}\, DEra_{iE} + \sum_{D=1}^{2} \delta_{3D}\, DPark\_prox_{iD} + \lambda \sum_{\boldsymbol{j}=\mathbf{1}}^{\boldsymbol{n}} w_{ij}\, \epsilon_j + u_i \quad (3)$$

where,

u_i is a zero mean spatially uncorrelated disturbance term

$\lambda \sum_{\boldsymbol{j}=\mathbf{1}}^{\boldsymbol{n}} w_{ij}\, \epsilon_i$ is the spatial error term with parameter λ and w_{ij} the spatial weight for property i and neighbouring property j.

$$lnP_i = \rho \sum_{\boldsymbol{j}=\mathbf{1}}^{\boldsymbol{n}} w_{ij}\, lnP_j + \beta_0 + \mathbf{H}_i\boldsymbol{\beta}_1 + \mathbf{L}_i\boldsymbol{\beta}_2 + \mathbf{S}_i\boldsymbol{\beta}_3 + \mathbf{T}_i\boldsymbol{\beta}_4 + \sum_{t=2009}^{2010} \delta_{1t}\, DSaleYr_{it} + \sum_{E=1}^{2} \delta_{2E}\, DEra_{iE} + \sum_{D=1}^{2} \delta_{3D}\, DPark\_prox_{iD} + \epsilon_i \quad (4)$$

ρ is the spatial autoregressive parameter.

The stratified plot design of the sample data was taken into account in the construction of the spatial weight matrix to represent the spatial relationship in house price responses among neighbouring properties. We used the nearest six neighbours, rather than twelve, to exclude neighbouring transactions from non-neighbouring sample plots from misrepresenting the specification.

For non-spatial models White-Heteroskedastic standard errors were calculated to ensure inferences from the models were valid even if heteroskedasticity was present (Hayes and Cai, 2007).

3.6 Implied benefit/cost estimates

The portion of benefits of footpath tree cover, capitalised into local property prices in 2010, were derived from the spatial model estimates (ie. SEM coefficients and estimates of the direct effects in the SAR[5]) of the increase in house sale prices from a change in footpath tree cover levels from the sample mean of 31.9 % to the 2010 average footpath tree cover level of 35 %, holding other significant explanatory variables at their mean levels. To obtain a realised, annual benefit we multiply this premium level by the total number of house sales in Brisbane in 2010 (15,777).

Flow-on effects of increased house sale prices in 2010 due to nearby footpath tree cover to estimates of property tax were then calculated. First, Council rates revenue estimates were based on the number of single dwellings in the Brisbane LGA reported in the Australian Census 2011 i.e. 269,880 (Australian Bureau of Statistics, 2011), and the proportion of property value estimated to be site/land value rather than structure/other values (66 %) (Rambaldi, 2015), then applied to BCC 2009-2010 differential general rates index for residential single dwellings of $AU 0.2978 per dollar. Second, income to the state government as stamp duty revenues from the portion of the 15,777 house sale prices attributed to the effect of leafy streets in 2010 were estimated using the Queensland Stamp Duty Calculator (Queensland Government, 2013).

Council costs of street tree management activities for the financial year 2009/10 (totalling $US 9.3 million), including planting ($US 1.2 million), early care, maintenance, removal, disposal, inspections (subtotalling $US 7.2 million) and costs of successful insurance claims for personal

[5] Direct effect is the term used by LeSage and Pace (2009). It is the average marginal effect of footpath tree cover taking into account the spatial multiplier effect.

and property damage by street trees, were obtained from BCC. The 2009/10 costs aligned with the year of the sample survey and the citywide tree cover data collection and were typical of street tree management costs for a moderate tree growth, storm season and budget year for BCC. In contrast, 2010/11, included a major flood in 2011 which impacted significantly and atypically on street tree expenditure and insurance claims.

While property taxes are a benefit in revenues to Council and state government, they are a cost to property owners and buyers, respectively. Therefore, benefits and costs to three different stakeholders: a) home-owners as a private beneficiary of street tree services, b) Council as the primary investor in street trees and a property tax beneficiary, and c) state government as a property tax beneficiary but not a current investor, were differentiated in the development of the business case in this study.

4. Results

Results of the non-spatial models are shown in Table 3 and spatial model results, including significance of the autocorrelation parameters λ and ρ are shown in Table 4. The non-spatial base model of house, property and suburb attributes estimated by OLS explained 65.9 % of the variance of log house sale prices. As expected, home buyers are willing to pay a premium for houses with more bathrooms, located in older suburbs, less than 200m from a park. Houses closer to shops sold for higher prices, however the effect was not significant, whereas, as expected, proximity to a busy road had the opposite effect, and was significant in this sample. The size of the house, indicated by the number of bathrooms, bedrooms and garage spaces, was also of much greater value than the size of the property. Suburbs where residents have higher household income and education level, attracted higher house sale prices. Median house price in 2010 was \$AU 40,000 higher than 2008 and \$AU 52,500 higher than 2009. The significant and positive coefficient for house sales in 2010, compared to these two previous years, confirms the alignment of our sample with annual variation in city-wide house sales in Brisbane between 2008 and 2010. The real estate market in Australia was only marginally affected by the Global Financial Crisis and the small decrease in prices was fully reversed by 2010.

4.1 Effect of tree cover on house sale price

While collinearity was forecast from the pre-regression correlations, none of the variance inflation factors (VIF) test results exceeded 5 (ranged from 1.489 to 4.024).

Only two of the seven tree cover variables, had a significant effect on house sales price - tree cover on the property and tree cover on the footpath within 100 metres of the property. Tree cover variables explained no more of the variance than the base house, property and suburb model, yet were significant characteristics that attracted a premium to house sale prices. Using only variables found to be significant in the non-spatial models, both spatial models were a better fit to the sample data, indicating the presence of spatial dependence.

Tree cover on the property was found to have a significant negative effect on sale price, while controlling for the effects of house, land and suburb variables. However, when tree cover on the property was less than 20 %, the effect changed to be significant and positive. These results are consistent with Pandit et al. (2013) and Saphores and Li (2012), and thresholds found by Drake-MacLaughlin and Netusil (2008) and Francois et al. (2002) and yet opposite to Sander et al. (2010) who found a significant positive effect of parcel level tree cover only when tree cover was greater than 23 % and others who found consistently positive effects of tree cover on house lots (Dombrow, et al., 2000; Donovan and Butry, 2010; Morales, 1980).

Tree cover on footpaths up to 100 metres away from the house price had a small, positive and significant (99 % probability) direct effect in the SAR model and marginally significant (89% probability) in the SEM model. The marginal implicit price and monetary values of footpath tree cover are presented using the SEM and SAR spatial model direct effect estimates. The SEM provides the lower and the SAR the upper bound, respectively, of all estimates from the models, spatial and non-spatial, tested for the study. Therefore, the results will be presented as a range with the lower bound being that computed from SEM and the upper bound that computed from SAR. Though nearby footpath tree cover was only marginally significant in the SEM model, the model coefficient is highly significant, indicating there is not enough empirical evidence to conclude that footpath tree cover is not significant in this model. Model intercepts and coefficients for other explanatory variables also remained consistent between spatial and the non-spatial models.

The marginal implicit price for a one percent increase in footpath tree cover within 100 metres (ie. a change from the sample mean level of 31.9% to 32.9%) was $US 307-404, representing a 0.081-0.107% premium when evaluated at median house price. When evaluated at the means of tree cover, these results were within the range reported for studies in Perth (a 0.18% premium found for a one % change in tree cover on the street verge within 20 metres of homes) (Pandit, et al., 2014) and similar to studies in Quebec (0.1% premium on house sale prices for a one % change in mature tree cover within 100 metres of homes) (François, et al., 2002), Minnesota, (0.048% premium for a one % increase in tree cover within 100 metres of homes) (Sander, et al., 2010) and Los Angeles (Conway, et al., 2010) (0.07% for greenspace within 200-300ft (60-90 metre) zone. However, unlike the threshold of 44% for the positive effect of all tree cover within 100 metres of house sales in Minnesota counties, houses with 50% (the Brisbane target level for 2031) or greater footpath tree cover within 100 metres in our study area sold for 5.05% higher than median sale price.

We also find that neither tree cover on neighbouring private properties 30 metres and 100 metres away from the house sale, nor tree cover on the front footpath or footpath up to 30 metres away, had a significant effect on house prices. In contrast, Anderson & Cordell (1988) reported a 3-4.5% premium for an average of five front yard trees, Donovan and Butry (2010) a 2.4% premium for each tree on the frontage, and Pandit (2013) a 4.27% premium for a broad-leaved street tree on the frontage.

4.2 Benefit/cost estimates and returns on investment

Translated to realised benefits, home-buyers demand for footpath tree cover in Brisbane in 2010, was valued at $US 19.16 – 20.45 million. Flow on effects to property tax revenues were estimated at $US 0.65 – 0.69 million in annual rates revenue returned to BCC, and an estimated $US 0.72 – 0.88 million in stamp duty revenue returned to the state government in 2009-2010 as a consequence of Brisbane's leafy streets. Returns to BCC on their $US 9.3 million investment in total street tree management costs in 2009-2010 were 7.0-7.4%. Net benefits to home-owners totalled $US 18.51 – 19.76 million in 2010 (ie. a benefit/cost ratio of 29:1). This is much higher than the 12:1 benefit/cost ratio reported by Donovan and Butry (2010) for Portland's 236,000 street trees, where property owners contribute to street tree maintenance, and also higher than estimates for New York City's 592,130 street trees at 2.43:1 (Peper, et al., 2007), where the generic algorithm in STRATUM (now i-Tree Streets) was applied to all street trees.

Discussion

The lack of significant effect of tree cover on nearby private properties and the front footpath on house prices, yet a willingness to pay a premium for a limited extent of tree cover on the property and a small premium for houses in leafier streets in the study area, revealed insights about homebuyer preferences for trees in Brisbane.

5.1 Preferences for tree cover on the property

While Brisbane residents have rated the city's greenspace as one of the most important quality of life factors (Brisbane City Council, 2013), positive effects of tree cover on private property, revealed in home-buyers preferences, were limited to no more than 20% tree cover on the house site. That threshold was eight percentage points lower than the average tree cover on properties in the study sample. The shape of Brisbane is changing rapidly to accommodate thousands of new dwellings, especially within existing residential suburbs. Our results suggest that space for tree cover on private property is becoming too small and too valuable for trees. There are two reasons for this assumption. First, a strong correlation between tree cover on property and property size was found in the study area. Second, the effect of tree cover on property and house sale price was consistent with studies in Perth (Pandit, et al., 2014) and Los Angeles (Saphores and Li, 2012) where the high value of available space on private property was suggested as a factor ($US 700/square metre Brisbane, $US 1,069 /square metre Perth, $US 735/square metre LA). Negative attitudes such as perceived risks, encroachment on solar access or views and disservices such as the maintenance burden of trees in close proximity to houses, reported within and outside of Australia may be just as relevant in Brisbane (Camacho-Cervantes, et al., 2014; Fraser and Kenney, 2000; Jones, et al., 2012; Kirkpatrick, et al., 2012; Kirkpatrick, et al., 2013; Lohr, et al., 2004; Mansfield, et al., 2005; Morales, 1980; Conway, 2014; Summit and McPherson, 1998; Zhang and Zheng, 2011). A threshold of 20% private property tree cover could therefore also be an expression of the perceived balance point between benefits and costs of trees on private property in Brisbane.

Perhaps a caveat to the proximity principle of urban greenery (Crompton, 2005) is heralded – "not too much and not too close".- similar to variations in revealed preferences found for different sizes and types of urban parks (Mansfield, et al., 2005; Troy and Grove, 2008). In the Australian context, urban tree cover on private property is also influenced by the original use of the land, the age of the suburb and the lifestyle/aesthetic preferences of owners (Kirkpatrick, et al., 2012) who may move up to four times in their lifetime (Australian Bureau of Statistics, 2015).

5.2 Preferences for tree cover on the footpath

Any of the same factors limiting the positive effects of private tree cover on house sale prices may have overflowed to the lack of significant effect of trees on the front footpath observed in the non-spatial house price models. In addition, most residents in Brisbane choose to keep their verge tidy even though the municipal authority is responsible for the front verge, including its street trees. Although the impact of street trees on property owner perceptions of "tidiness" is likely to vary considerably, tree cover in front of someone else's property, collectively contributing to leafiness of the street, was preferred. It is also important to note that almost one third of properties in the study sample had no street trees on their frontage.

Therefore, unlike comparable studies in Perth and Portland, where effects of street trees were greatest when they were growing on the front footpath, street trees in Brisbane only became a desirable feature when they were growing within 100 metres of the property, excluding the front footpath. This small, but significant WTP a premium for houses with nearby footpath tree canopy cover in Brisbane was similar to revealed preferences in other studies, despite Brisbane having much more street tree cover than those cities (Brisbane average was 31.9%, Minnesota was 14.5% and Perth 20.0%). Conway et al. (2010) suggested that the more existing greenspace in a city, the lower the premium paid for increments of green cover. However, other factors such as the size, condition, age and level of community involvement in the planting of Brisbane's street trees (Plant and Sipe, 2016) not included in our explanatory variable set, are known to influence attitudes and preferences about street trees (Donovan, et al., 2013; Gorman, 2004; Lorenzo, et al., 2000; Wachter and Bucchianeri, 2006), and may have led to the unique response by Brisbane homebuyers.

5.3 Implied benefits and returns on investment in leafy streets

The values that home buyers were expressing in their WTP for 35% footpath tree cover in 2010 was by far exceeding the portion of property taxes passed to home owners through the Council's rate charges. Home buyers were also expressing their preference for the 50% target level of footpath tree cover. This is especially significant to forecast returns and future community engagement strategies of BCC's Neighbourhood Shadeways program, which aims to achieve 50% footpath tree cover by 2031. Home-buyers may be signalling their support for desirable features such as shadier and attractive footpaths and more walkable neighbourhoods that come with leafier streets, as suggested by Wachter and Gillen (2006).

Even accounting for additional costs, such as footpath, kerb and sewer repairs, estimated at 25% of annual street tree maintenance expenses in Californian cities (McPherson and Peper, 1996), but not available in this study, footpath tree cover was already highly valued by homebuyers in 2010 and providing annual returns, through property value impacts, on Council's investment. Considered in terms of the costs of street tree planting and establishment alone ($US 1.2 million), BCC recovered around two thirds of their investment in 2010 from property tax revenues associated with the demand for leafy streets.

Current and potential returns to the range of beneficiaries highlight the opportunity to encourage partnerships with those who gain from the benefits of greener, more attractive and cooler pathways through improved uptake of active and public transport and the associated health and well-being benefits to urban residents (Ely and Pitman, 2014; Favelle and Plant, 2009; Sarkar, et al., 2015; Wolf, et al., 2015). For example, if the state government invested the equivalent of the estimated annual stamp duty returns, expressed by the demand for leafy streets in Brisbane, to support Neighbourhood Shadeways planting programs along the most "shade-hungry" walk to school, shops, bus and train stations, BCC could reinvest those savings into the maintenance of the expanding street tree population. Likewise, a greater share of investment in streetscape by developers in high growth areas, where their returns are escalated by the larger volume of new dwellings, could allow local government investment to target "shade-hungry" footpaths in areas of lower development activity. If forecast losses of tree cover on private property in high growth urban areas are to be compensated to any extent by more trees in parks, streets and other local public places, broader investment partnerships and community support will be required.

5.4 Improving the accuracy of property value impacts in urban forest valuation software

The Brisbane result was yet another example of the geographic and contextual variations in demand for ES from urban forest components like street trees and an important caution against inferring results from one city to estimate benefits in another, even within the same country or climate. While it is empirically sound to develop generic algorithms from the relationship between leaf area of the urban forest and the biophysical features of a location to measure the avoided costs of regulatory ES such as air quality improvement and stormwater runoff reduction, property value premiums, as a measure of ES demands, must account for a range of market factors and home-buyer preferences revealed in this and similar studies.

The methods used in this research, in particular, the collection of house sales, property, neighbourhood and tree cover data within the same sample areas, for the same time period, as a structural assessment of the street tree population, suggest an alternative, value-added approach. A local hedonic price model, rather than a generic algorithm, fed by additional data inputs from a study area, could sit within urban forest software tools such as “i-Tree”. This “model within a model” approach allows simultaneous exploration of local preferences, values expressed by those preferences, and other factors influencing street tree distribution, alongside the assessment of broader urban forest structure, needs, ES supplies and costs. Such combinations of data collection and assessment can build an appropriate, local suite of evidence and evaluation that make better use of limited funds. Advances in the extent of accessible information available from remote sensing, and on-line property data sources, makes this approach to urban forest assessment and valuation software improvements worthy of further investigation.

5.5 Limitations

Net benefits and returns in the single-dwelling housing market significantly underestimated the total value of street trees in residential areas in two ways. First, this research excluded attached dwellings, like units/apartments, as well as rental price premiums, both shown to be significant and positive in revealed preference studies elsewhere (Donovan and Butry, 2011; Melichar and Kaprová, 2013). Second, while property value impacts of footpath tree cover may have captured a measure of home-buyers preferences for living in greener, cooler and cleaner neighbourhoods, supplies of such environmental, commercial and social ES and disservices were excluded from this study (Escobedo, et al., 2011). For example, health and well-being benefits of living amongst leafy streetscapes may exceed impacts on property values several fold (Kardan, et al., 2015; Wolf, et al., 2015).

5. Conclusions

Our application of a well advanced technique, hedonic price modelling, revealed strong support for local footpath tree canopy cover targets and informed a business case for ongoing investment, based on local demands for ES. Differentiating the benefits and costs to a range of stakeholders, also provides an example of the types of collaborative investment and engagement strategies that are needed to optimise and sustain leafy streetscapes in compacting forms of residential development.

The strength of our approach comes from using revealed local preferences for both municipal policy evaluation and demand based valuations (reflecting, to some extent, the needs of the community), to add to knowledge about the structure of local street tree populations (ie. the needs of the trees), by using the same sample sites for data collection. Incorporating local revealed preference spatial modelling into open-source software tools may further advance the scope of urban forest assessment and provide robust evidence better suited to strategic investment. We have highlighted an important ongoing role for the ecological economics discipline in not only adding to the suite of urban forest valuation techniques, but also offering adaptations and applications of existing techniques to evolving policy and partnership contexts.

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References

Amati, M., Brack, C., Ghosh, S., Kachenko, A., McManus, P., Saldariagga, N., Shrestha, K., Wang, M. and Yung, S. H. 2013. Understanding the carbon and pollution mitigation potential of Sydney's urban forest. National conference proceedings, 2013 Canberra The Institute of Foresters of Australia, 139-146.

Ambrey, C. L. and Fleming, C. M. 2014. Valuing ecosystem diversity in South East Queensland: A life satisfaction approach. *Social indicators research,* 115**,** 45-65. http://dx.doi.org/10.1007/s11205-012-0208-4

Anderson, L. M. and Cordell, H. K. 1988. Influence of trees on residential property values in Athens, Georgia (U.S.A.): A survey based on actual sales prices. *Landscape and Urban Planning,* 15**,** 153-164. http://dx.doi.org/10.1016/0169-2046(88)90023-0

Anderson, S. T. and West, S. E. 2006. Open space, residential property values, and spatial context. *Regional Science and Urban Economics,* 36**,** 773-789.

Anselin, L. and Bera, A. K. 1998. Spatial dependence in linear regression models with an introduction to spatial econometrics. *In:* Giles, A. U. a. D. E. (ed.) *Handbook of applied economic statistics.* New York: Marcel Dekker.

Anthon, S., Thorsen, B. J. and Helles, F. 2005. Urban-fringe afforestation projects and taxable hedonic values. *Urban Forestry & Urban Greening,* 3**,** 79-91. http://dx.doi.org/10.1016/j.ufug.2004.09.004

Arboriculture Australia. 2013. *i-Tree* [Online]. Available: http://arboriculture.org.au [Accessed 30 Jun 2013].

Australian Bureau of Statistics. 2011. *Census Quick Stats, Brisbane - dwellings* [Online]. Available: http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/3001?opendocument&navpos=220 [Accessed 9 June 2014.

Australian Bureau of Statistics. 2015. *Housing Mobility and Condition, 2007-08* [Online]. Available: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Latestproducts/4130.0.55.002Main%20Features22007%E2%80%9308?opendocument&tabname=Summary&prodno=4130.0.55.002&issue=2007%E2%80%9308&num=&view= [Accessed 12 Aug 2015].

Australian Government. 2013a. *"Carbon Farming Initiative"* [Online]. Department of Agriculture, Fisheries and Forestry. Available: http://www.daff.gov.au/climatechange/cfi [Accessed 28 Jun 2013].

Australian Government. 2013b. *State of Australian Cities 2013* [Online]. Department of Infrastructure and Development. . Available: https://infrastructure.gov.au/infrastructure/pab/soac/ [Accessed 18 Nov 2015].

Berland, A. and Hopton, M. E. 2014. Comparing street tree assemblages and associated stormwater benefits among communities in metropolitan Cincinnati, Ohio, USA. *Urban Forestry and Urban Greening,* 13**,** 734-741. 10.1016/j.ufug.2014.06.004

Bowler, D. E., Buyung-Ali, L., Knight, T. M. and Pullin, A. S. 2010. Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning,* 97**,** 147-155. http://dx.doi.org/10.1016/j.landurbplan.2010.05.006

Brack, C. L. 2002a. Pollution mitigation and carbon sequestration by an urban forest. *Environmental pollution,* 116**,** S195-S200. http://dx.doi.org/10.1016/S0269-7491(01)00251-2

Brack, C. L. 2002b. Pollution mitigation and carbon sequestration by an urban forest. *Environmental Pollution,* 116, Supplement 1**,** S195-S200. 10.1016/s0269-7491(01)00251-2

Brisbane City Council. 2013. *CityShape* [Online]. Available: http://www.brisbane.qld.gov.au/planning-building/planning-guidelines-and-tools/neighbourhood-planning/neighbourhood-planning-and-urban-renewal/listening-to-the-community/brisbane-cityshape-2026/index.htm [Accessed 26 Aug 2013].

Byrne, J., Sipe, N. and Searle, G. 2010. Green around the gills? The challenge of density for urban greenspace planning in SEQ. *Australian Planner,* 47**,** 162-177. http://dx.doi.org/10.1080/07293682.2010.508204

Camacho-Cervantes, M., Schondube, J. E., Castillo, A. and MacGregor-Fors, I. 2014. How do people perceive urban trees? Assessing likes and dislikes in relation to the trees of a city. *Urban Ecosystems***,** 1-13. http://dx.doi.org/10.1007/s11252-014-0343-6

Chen, W. Y. and Jim, C. Y. 2008. Assessment and Valuation of the Ecosystem Services Provided by Urban Forests

In: Carreiro, M. M., Song, Y.-C. & Wu, J. (eds.) *Ecology, Planning, and Management of Urban Forests*

New York: Springer

City of Melbourne. 2013. *Urban Forest Strategy* [Online]. Available: http://www.melbourne.vic.gov.au/Sustainability/UrbanForest/Pages/About.aspx [Accessed 17 Jun 2013].

Conway, D., Li, C., Wolch, J., Kahle, C. and Jerrett, M. 2010. A Spatial Autocorrelation Approach for Examining the Effects of Urban Greenspace on Residential Property Values. *The Journal of Real Estate Finance and Economics,* 41**,** 150-169. http://dx.doi.org/10.1007/s11146-008-9159-6

Conway, T. M. 2014. Individual households and their trees: Fine-scale characteristics shaping urban forests. *Urban Forestry & Urban Greening,* 13**,** 136-144. http://dx.doi.org.ezproxy.library.uq.edu.au/10.1016/j.ufug.2013.11.004

Conway, T. M. and Bang, E. 2014. Willing partners? Residential support for municipal urban forestry policies. *Urban Forestry & Urban Greening,* 13**,** 234-243.

Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M. and Demuzere, M. 2013. Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography,* 37**,** 2-28. http://dx.doi.org/10.1177/0309133312461032

Crompton, J. L. 2005. The impact of parks on property values: empirical evidence from the past two decades in the United States. *Managing Leisure,* 10**,** 203-218. http://dx.doi.org/10.1080/13606710500348060

Daniel, C., Morrison, T. H. and Phinn, S. 2016. The governance of private residential land in cities and spatial effects on tree cover. *Environmental Science & Policy,* 62**,** 79-89.

Davison, A. and Kirkpatrick, J. 2014. Re-inventing the Urban Forest: The Rise of Arboriculture in Australia. *Urban Policy and Research,* 32**,** 145-162. http://dx.doi.org/10.1080/08111146.2013.832669

Denman, E., May, P. and Moore, G. The use of trees in urban stormwater management. *In:* Lawry, D. & Merrett, B., eds. Proceedings of 12th National Street Tree Symposium, 2011. University of Adelaide, Australia, 57-66.

Dobbs, C., Kendal, D. and Nitschke, C. R. 2014. Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and sociodemographics. *Ecological Indicators,* 43**,** 44-55. http://dx.doi.org/10.1016/j.ecolind.2014.02.007

Dombrow, J., Rodriguez, M. and Sirmans, C. 2000. The market value of mature trees in single-family housing markets. *Appraisal Journal,* 68**,** 39-43.

Donovan, G. H. and Butry, D. T. 2010. Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning,* 94**,** 77-83. http://dx.doi.org/10.1016/j.landurbplan.2009.07.019

Donovan, G. H. and Butry, D. T. 2011. The effect of urban trees on the rental price of single-family homes in Portland, Oregon. *Urban Forestry & Urban Greening,* 10**,** 163-168. http://dx.doi.org/10.1016/j.ufug.2011.05.007

Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatziolis, D. and Mao, M. Y. 2013. The Relationship Between Trees and Human Health: Evidence from the Spread of the Emerald Ash Borer. *American Journal of Preventive Medicine,* 44**,** 139-145. http://dx.doi.org/10.1016/j.amepre.2012.09.066

Drake-McLaughlin, N. and Netusil, N. R. Valuing Walkability and Vegetation in Portland, Oregon. *In:* Haefen, R. H. V., ed. Benefits and Costs of Natural Resources Policies Affecting Public and Private Lands Twenty-Second Interim Report and Proceedings from the Annual Meeting, 2010 Tucson, AZ. Department of Agricultural and Resource Economics, 173-201.

Dumbaugh, E. 2006. Design of safe urban roadsides: An empirical analysis. *Transportation Research Record: Journal of the Transportation Research Board***,** 74-82. http://dx.doi.org/10.3141/1961-09

Dwyer, J. F., Schroeder, H. W. and Gobster, P. H. 1991. The significance of urban trees and forests: toward a deeper understanding of values. *Journal of Arboriculture,* 17**,** 276-284.

Elhorst, J. P. 2014. Matlab Software for Spatial Panels. *International Regional Science Review,* 37**,** 389-405. http:/dx.doi.org/10.1177/0160017612452429

Ely, M. and Pitman, S. 2014. Green Infrastructure: Life support for human habitats. *A review of research and literature. Prepared for the Green Infrastructure Project, Botanic Gardens of Adelaide.* [Online]. Available: http://www.botanicgardens.sa.gov.au/greeninfrastructure [Accessed 10 March 2015].

Ely, M. E. 2010. *Integrating Trees into the Design of the City: Expert Opinions on Developing More Sustainable Practices for Planting Street Trees in Australian Cities.* PhD thesis, The University of Adelaide.

Escobedo, F. J., Adams, D. C. and Timilsina, N. 2015. Urban forest structure effects on property value. *Ecosystem Services,* 12**,** 209-217. 10.1016/j.ecoser.2014.05.002

Escobedo, F. J., Kroeger, T. and Wagner, J. E. 2011. Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution,* 159**,** 2078-2087. http://dx.doi.org/10.1016/j.envpol.2011.01.010

Fairman, T. A., Livesley, S. J., Summers, J., Shears, I. and Pohls, O. 2010. *Using STRATUM to estimate the benefits of street trees in Melbourne, Victoria.* Masters thesis, University of Melbourne, Parkville.

Favelle, H. and Plant, L. 2009. The importance of shade for healthy places and spaces. *Australian Planner,* 46**,** 16-17. http://dx.doi.org/10.1080/07293682.2009.9995304

François, D. R., Marius, T., Yan, K. and Paul, V. 2002. Landscaping and house values: an empirical investigation. *Journal of real estate research,* 23**,** 139-162.

Fraser, E. and Kenney, W. A. 2000. Cultural background and landscape history as factors affecting perceptions of the urban forest. *Journal of Arboriculture,* 26 (2)**,** 106-113.

Freeman III, A. M., Herriges, J. A. and Kling, C. L. 2014. *The measurement of environmental and resource values: theory and methods*, Routledge.

French, J. R. J. and Sharpe, R. Urban forests for Australian cities. Trees and Forest for Human Settlements, 1976. FAO, 123-135.

Gorman, J. 2004. Residents' opinions on the value of street trees depending on tree location. *Journal of Arboriculture,* 30**,** 36-44.

Hall, T. 2010. *Life and death of the Australian backyard,* Collingwood, Victoria, CSIRO Publishing.

Hayes, A. F. and Cai, L. 2007. Using heteroskedasticity-consistent standard error estimators in OLS regression: An introduction and software implementation. *Behavior research methods,* 39**,** 709-722. http://dx.doi.org/10.3758/BF03192961

Heynen, N., Perkins, H. A. and Roy, P. 2006. The political ecology of uneven urban green space the impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. *Urban Affairs Review,* 42**,** 3-25.

i-Tree. 2014. *Tools for assessing and managing community forests* [Online]. Available: http://www.itreetools.org/ [Accessed 27 Apr 2014].

Jones, H. P., Hole, D. G. and Zavaleta, E. S. 2012. Harnessing nature to help people adapt to climate change. *Natural Climate Change,* 2(7)**,** 504-509. http://dx.doi.org/10.1038/nclimate1463

Kadish, J. and Netusil, N. R. 2012. Valuing vegetation in an urban watershed. *Landscape and Urban Planning,* 104**,** 59-65. http://dx.doi.org/10.1016/j.landurbplan.2011.09.004

Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L. J., Paus, T. and Berman, M. G. 2015. Neighborhood greenspace and health in a large urban center. *Scientific Reports,* 5. http://dx.doi.org/10.1038/srep11610

Killicoat, P., Puzio, E. and Stringer, R. The Economic Value of Trees in Urban Areas: Estimating the Benefits of Adelaide's Street Trees. *In:* Treenet, ed. Proceedings of 3rd National Street Tree Symposium, 2002. Adeliade University, Australia, 90-102.

Kirkpatrick, J. B., Davison, A. and Daniels, G. D. 2012. Resident attitudes towards trees influence the planting and removal of different types of trees in eastern Australian cities. *Landscape and Urban Planning,* 107(2)**,** 147-158. http://dx.doi.org/10.1016/j.landurbplan.2012.05.015

Kirkpatrick, J. B., Davison, A. and Harwood, A. 2013. How tree professionals perceive trees and conflicts about trees in Australia's urban forest. *Landscape and Urban Planning,* 119**,** 124-130. http://dx.doi.org/10.1016/j.landurbplan.2013.07.009

Kollin, C. and Schwab, J. 2009. Bringing nature into the city. *In:* Schwab, J. C. (ed.) *Planning the Urban Forest: Ecology, Economy, and Community Development.* Chicago,IL: American planning Association.

Kong, F., Yin, H. and Nakagoshi, N. 2007. Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: A case study in Jinan City, China. *Landscape and Urban Planning,* 79**,** 240-252. http://dx.doi.org/10.1016/j.landurbplan.2006.02.013

LeSage, J. and Pace, R. K. 2009. *Introduction to Spatial Econometrics,* Boca Raton, Florida., Chapman and Hall, CRC Press.

Leuzinger, S., Vogt, R. and Körner, C. 2010. Tree surface temperature in an urban environment. *Agricultural and Forest Meteorology,* 150**,** 56-62. http://dx.doi.org/10.1016/j.agrformet.2009.08.006

Lohr, V. I., Pearson-Mims, C. H., Tarnai, J. and Dillman, D. A. 2004. How urban residents rate and rank the benefits and problems associated with trees in cities. *Journal of Arboriculture,* 30(1)**,** 28-35.

Lorenzo, A. B., Blanche, C. A., Qi, Y. and Guidry, M. M. 2000. Assessing residents' willingness to pay to preserve the community urban forest: A small-city case study. *Journal of Arboriculture,* 26(6)**,** 319-325.

Luttik, J. 2000. The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape and Urban Planning,* 48**,** 161-167. http://dx.doi.org/10.1016/S0169-2046(00)00039-6

Mäler, K.-G., Aniyar, S. and Jansson, Å. 2008. Accounting for ecosystem services as a way to understand the requirements for sustainable development. *Proceedings of the National Academy of Sciences,* 105**,** 9501-9506. http://dx.doi.org/10.1073/pnas.0708856105

Mansfield, C., Pattanayak, S. K., McDow, W., McDonald, R. and Halpin, P. 2005. Shades of green: measuring the value of urban forests in the housing market. *Journal of forest economics,* 11**,** 177-199. http://dx.doi.org/10.1016/j.jfe.2005.08.002

Mayer, H., Kuppe, S., Holst, J., Imbery, F. and Matzarakis, A. Human thermal comfort below the canopy of street trees on a typical Central European summer day. *In:* Mayer, H. & Matzarakis, A., eds. 5th Japanese–German Meeting on Urban Climatology, 2008 Ber des Meteorol Inst der Universität Freiburg. 211-219.

McPherson, E. G. 1992. Accounting for benefits and costs of urban greenspace. *Landscape and Urban Planning,* 22**,** 41-51.

McPherson, E. G. 1998. Atmospheric carbon dioxide reduction by Sacramento's urban forest. *Journal of Arboriculture,* 24**,** 215-223.

McPherson, E. G. and Peper, P. P. 1996. Costs of street tree damage to infrastructure. *Arboricultural Journal,* 20(2)**,** 143-159. http://www.tandfonline.com/doi/abs/10.1080/03071375.1996.9747110

McPherson, E. G. and Simpson, J. R. 2003. Potential energy savings in buildings by an urban tree planting programme in California. *Urban Forestry & Urban Greening,* 2**,** 73-86.

McPherson, E. G., Simpson, J. R., Peper, P. J. and Xiao, Q. 1999. Benefit-cost analysis of Modesto's municipal urban forest. *Journal of Arboriculture,* 25**,** 235-248.

McPherson, E. G., Simpson, J. R., Xiao, Q. and Wu, C. 2011. Million trees Los Angeles canopy cover and benefit assessment. *Landscape and Urban Planning,* 99**,** 40-50. 10.1016/j.landurbplan.2010.08.011

McPherson, E. G., van Doorn, N. and de Goede, J. 2016. Structure, function and value of street trees in California, USA. *Urban Forestry and Urban Greening,* 17**,** 104-115. 10.1016/j.ufug.2016.03.013

Mekala, G. D., Jones, R. N. and MacDonald, D. H. 2015. Valuing the Benefits of Creek Rehabilitation: Building a Business Case for Public Investments in Urban Green Infrastructure. *Environmental Management,* 55**,** 1354-1365. 10.1007/s00267-015-0471-7

Melichar, J. and Kaprová, K. 2013. Revealing preferences of Prague's homebuyers toward greenery amenities: The empirical evidence of distance–size effect. *Landscape and Urban Planning,* 109(1)**,** 56-66. http://dx.doi.org/10.1016/j.landurbplan.2012.09.003

Melichar, J., Vojáček, O., Rieger, P. and Jedlička, K. 2009. Measuring the value of urban forest using the Hedonic price approach. *Regional Studies,* 2**,** 13-20.

Moore, G. Urban trees: worth more than they cost. *In:* Lawry, D., Gardner, J. & Bridget, M., eds. Proceedings of the 10th National Street Tree Symposium, 2009. University of Adelaide, Australia, 7–14.

Moore, G. The Value of urban trees during climate change. 87th Annual Conference of the international Society of Arboriculture, 2011 Sydney, Australia.

Morales, D. 1980. The contribution of trees to residential property value. *Journal of Arboriculture,* 6**,** 305-308.

Moran, P. A. 1948. The interpretation of statistical maps. *Journal of the Royal Statistical Society. Series B (Methodological),* 10**,** 243-251.

Nagendra, H. and Gopal, D. 2010. Street trees in Bangalore: Density, diversity, composition and distribution. *Urban Forestry and Urban Greening,* 9**,** 129-137. http://dx.doi.org/10.1016/j.ufug.2009.12.005

Netusil, N. R., Levin, Z., Shandas, V. and Hart, T. 2014. Valuing green infrastructure in Portland, Oregon. *Landscape and Urban Planning,* 124**,** 14-21. http://dx.doi.org/10.1016/j.landurbplan.2014.01.002

NGIA. 2015. *Where are all the trees* [Online]. Available: http://202020vision.com.au/ [Accessed 12 Oct 2015].

Nowak, D. J. and Dwyer, J. F. 2007. Understanding the Benefits and Costs of Urban Forest Ecosystems

Urban and Community Forestry in the Northeast. *In:* Kuser, J. E. (ed.). Springer Netherlands.

Pandit, R., Polyakov, M. and Sadler, R. 2014. Valuing public and private urban tree canopy cover. *Australian Journal of Agricultural and Resource Economics,* 58**,** 453-470. http://dx.doi.org/10.1111/1467-8489.12037

Pandit, R., Polyakov, M., Tapsuwan, S. and Moran, T. 2013. The effect of street trees on property value in Perth, Western Australia. *Landscape and Urban Planning,* 110**,** 134-142. http://dx.doi.org/10.1016/j.landurbplan.2012.11.001

Payton, S., Lindsey, G., Wilson, J., Ottensmann, J. R. and Man, J. 2008. Valuing the benefits of the urban forest: A spatial hedonic approach. *Journal of Environmental Planning and Management,* 51**,** 717-736. http://dx.doi.org/10.1080/09640560802423509

Peper, P. J., McPherson, E. G., Simpson, J. R., Gardner, S. L., Vargas, K. E., Xiao, Q. and WATT, F. 2007. New York City, New York: Municipal Forest Resource Analysis. Center for Urban Forest Research,USDA Forest Service, Pacific Southwest Research Station. : .

Planet Ark. 2014. *Valuing Trees: What is Nature Worth?* [Online]. Available: http://treeday.planetark.org/documents/doc-1170-valuing-trees-report---full-final.pdf [Accessed 23 June 2015.

Plant, L. and Sipe, N. 2016. Adapting and applying evidence gathering techniques for planning and investment in street trees: A case study from Brisbane, Australia. *Urban Forestry & Urban Greening,* 19**,** 79-87. http://dx.doi.org/10.1016/j.ufug.2016.07.005

Polyakov, M., Fogarty, J., Zhang, F., Pandit, R. and Pannell, D. J. The value of restoring urban drains to living streams. *Water Resources and Economics*. http://dx.doi.org/10.1016/j.wre.2016.03.002

Pyper, W. 2004. Do green cities mean healthier people. *Ecos,* 119**,** 9-11.

Queensland Government. 2013. *Stamp Duty Calculator* [Online]. Available: https://www.qld.gov.au/housing/buying-owning-home/how-to-calculate-transfer-duty [Accessed 14 Jul 2013].

Queensland Places. 2013. *Historical database* [Online]. Available: http://queenslandplaces.com.au/home [Accessed 18 Apr 2013].

Rambaldi, A. N., McAllister, Ryan R. J., Collins, Kerry and Fletcher, Cameron S. 2015. Decoupling land values in residential property prices: smoothing methods for hedonic imputed price indices. Discussion Papers Series 549. School of Economics, The University of Queensland, Australia.

Rowntree, R. A. and Nowak, D. J. 1991. Quantifying the role of urban forests in removing atmospheric carbon dioxide. *Journal of arboriculture,* 17**,** 269-275.

Roy, S., Byrne, J. and Pickering, C. 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban Forestry & Urban Greening,* 11**,** 351-363. http://dx.doi.org/10.1016/j.ufug.2012.06.006

Sander, H., Polasky, S. and Haight, R. G. 2010. The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics,* 69**,** 1646-1656. http://dx.doi.org/10.1016/j.ecolecon.2010.03.011

Sander, H. A. and Zhao, C. 2015. Urban green and blue: Who values what and where? *Land Use Policy,* 42**,** 194-209. http://dx.doi.org/10.1016/j.landusepol.2014.07.021

Saphores, J.-D. and Li, W. 2012. Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA. *Landscape and Urban Planning,* 104**,** 373-387. http://dx.doi.org/10.1016/j.landurbplan.2011.11.012

Sarkar, C., Webster, C., Pryor, M., Tang, D., Melbourne, S., Zhang, X. and Jianzheng, L. 2015. Exploring associations between urban green, street design and walking: Results from the Greater London boroughs. *Landscape and Urban Planning,* 143**,** 112-125. http://dx.doi.org/10.1016/j.landurbplan.2015.06.013

Shashua-Bar, L., Potchter, O., Bitan, A., Boltansky, D. and Yaakov, Y. 2010. Microclimate modelling of street tree species effects within the varied urban morphology in the Mediterranean city of Tel Aviv, Israel. *International journal of climatology,* 30**,** 44-57. http://dx.doi.org/10.1002/joc.1869

Soares, A., Rego, F., McPherson, E., Simpson, J., Peper, P. and Xiao, Q. 2011. Benefits and costs of street trees in Lisbon, Portugal. *Urban Forestry & Urban Greening*.

Stone, E. A., Wu, J. and Alig, R. 2015. Urban green space and vibrant communities: exploring the linkage in the Portland Vancouver area.

Stringer, R. The benefits of Adelaide's street trees revisited. *In:* Lawry, D., Gardner, J. & Smith, S., eds. Proceedings of the 8th National Street Tree Symposium, 2007. University of Adelaide, 41-46.

Summit, J. and McPherson, E. G. 1998. Residential tree planting and care: a study of attitudes and behavior in Sacramento, California. *Journal of arboriculture (USA)*.

Tapper, N. How trees save lives. The role of a well watered landscape in liveable cities. *In:* Lawry Oam, D. & Merrett, B., eds. Proceedings of 11th National Street Tree Symposium, 2010. University of Adelaide, 1-12.

Tarran, J. People and trees: providing benefits, overcoming impediments. *In:* Lawry Oam, D., Gardner, J. & Merrett, B., eds. Proceedings of the 10th National Street Tree Symposium 2009 Adelaide, Australia. Adelaide University, 63-82.

Taylor, L. O. 2003. The hedonic method. *In:* Champ, P. A., Boyle, K. J. & Brown, T. C. (eds.) *A primer on nonmarket valuation.* New York: Springer Science.

Troy, A. and Grove, J. M. 2008. Property values, parks, and crime: A hedonic analysis in Baltimore, MD. *Landscape and urban planning,* 87**,** 233-245. http://dx.doi.org/10.1016/j.landurbplan.2008.06.005

Tyrväinen, L. 1997. The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape and Urban Planning,* 37**,** 211-222. http://dx.doi.org.ezproxy.library.uq.edu.au/10.1016/S0169-2046(97)80005-9

Tyrvainen, L. and Miettinen, A. 2000. Property prices and urban forest amenities. *Journal of environmental economics and management,* 39**,** 205-223. http://dx.doi.org/10.1006/jeem.1999.1097

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J. and James, P. 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning,* 81**,** 167-178. http://dx.doi.org/10.1016/j.landurbplan.2007.02.001

Victorian Institute of Strategic Economic Studies (VISES) 2015. Green Infrastructure Economic Framework. . Victoria University, Melbourne.

Wachter, S., Gillen, K. and Brown, C. R. 2006. Public Investment Strategies: How they Matter for Neighborhoods in Philadelphia. . *unpublished paper*: Wharton School, University of Pennsylvania.

Wachter, S. M. and Bucchianeri, G. W. 2006. What is a tree worth? Green-city Strategies and Housing Prices. *Social Science Research Network,* July 2006. http://dx.doi.org.ezproxy.library.uq.edu.au/10.2139/ssrn.931736

Water by Design. 2010. *A Business Case for Best Practice Stormwater Management* [Online]. Available: http://waterbydesign.com.au [Accessed 27 Apr 2012].

Wegner, G. and Pascual, U. 2011. Cost-benefit analysis in the context of ecosystem services for human well-being: A multidisciplinary critique. *Global Environmental Change,* 21**,** 492-504. http://dx.doi.org/10.1016/j.gloenvcha.2010.12.008

Wolch, J. R., Byrne, J. and Newell, J. P. 2014. Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning,* 125**,** 234-244. http://dx.doi.org/10.1016/j.landurbplan.2014.01.017

Wolf, K. L. 2007. City trees and property values. *Arborist News,* 16**,** 34-36.

Wolf, K. L., Measells, M. K., Grado, S. C. and Robbins, A. S. T. 2015. Economic values of metro nature health benefits: A life course approach. *Urban Forestry & Urban Greening,* 14**,** 694-701. http://dx.doi.org/10.1016/j.ufug.2015.06.009

Zhang, B., Xie, G., Zhang, C. and Zhang, J. 2012. The economic benefits of rainwater-runoff reduction by urban green spaces: A case study in Beijing, China. *Journal of Environmental Management,* 100**,** 65-71. 10.1016/j.jenvman.2012.01.015

Zhang, Y. and Zheng, B. 2011. Assessments of citizen willingness to support urban forestry: An empirical study in Alabamay. *Arboriculture and Urban Forestry,* 37(3)**,** 118-125.

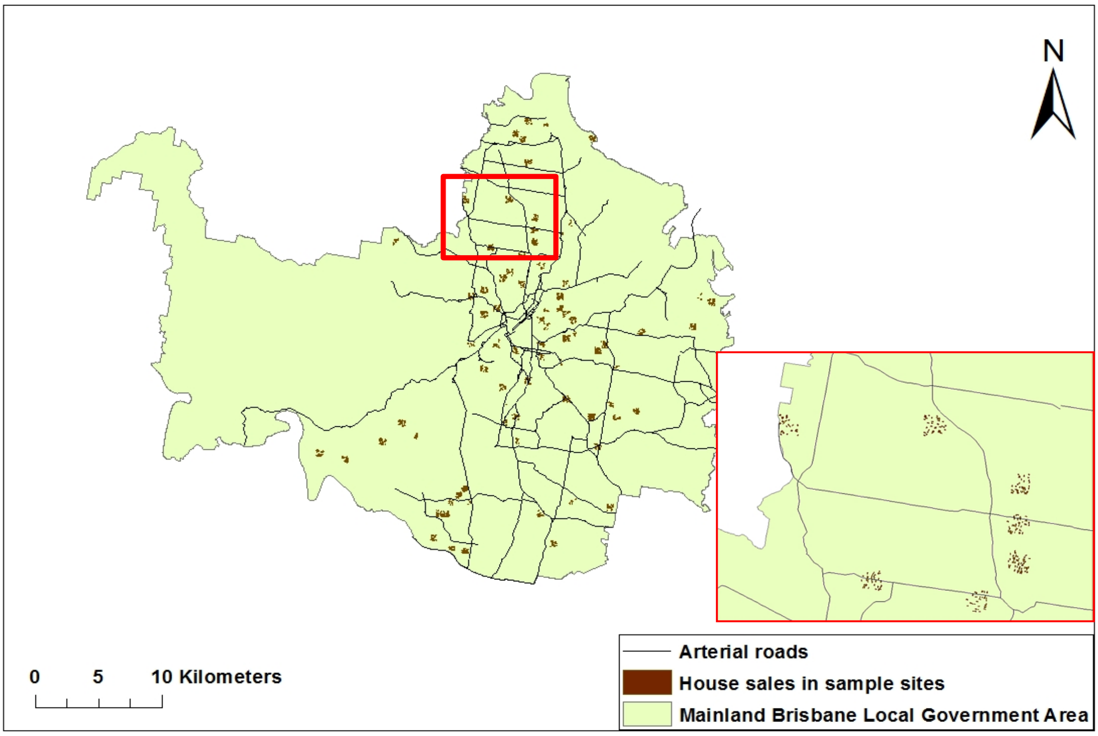

Figure 1. Location of the 80 Brisbane sample areas and house sale sites within sample areas.

Table 1. Variable summary statistics (n= 2299)

Variable	Mean	Median	St. Dev.	Minimum	Maximum
Dependent variable					
Sale price ($AU)	599090	530000	297999	105000	3800000
Ln Sale Price	13.216	13.18	0.397	11.56	15.15
Transfer date	29-Jul-09	25-Aug-09		3-Jan-08	23-Dec-10
Independent/explanatory variables					
House variables					
Number of bedrooms	3.44	3	0.806	1	7
Number of bathrooms	1.7	2	0.73	0	6
Number of garage spaces	1.5	2	0.84	0	6
Property variables					
Lot size (metres $^{2)}$	580.56	596	222.63	108	3064
Distance to nearest park (metres)	195.08	168.61	134.2	3	813
Size of nearest park (metres $^{2)}$	44113	10088	93451	112	918680
Distance to shops (kilometres)	1.103	0.914	0.84	0	4.73
Distance to Arterial road (kilometres)	0.668	0.492	0.666	0.017	3.485
Suburb variables					
Suburb Housing age (years)	59.27	50	34.9	5	135
% Household income top quartile	10.32	9.8	5.89	0.7	26.2
% Yr 12 education level	50.29	50.3	9.5	26.1	80.1
Distance to city centre (Translink Code)	3.3	3	1.254	1	5
Tree cover variables					
% tree cover on property	28.54%	27.45%	16.99%	0%	94%
% tree cover within 30 m of property	23.10%	22.19%	10.80%	0.58%	77.16%
% tree cover within 100 m of property	28.44%	28.47%	8.60%	4.78%	60.37%
% street tree canopy at frontage	29.91%	21.74%	29.72%	0%	100%
% street tree canopy within 30 m	30.94%	28.95%	17.88%	0%	93.33%
% street tree canopy within 100 m	31.96%	31.71%	12.13%	3.06%	75.76%

Table 2. Variable descriptions and data sources

Variable (label)	Units	Definition	Data source
Dependent variable			
Sale price	$AU	Sale price of the house	Local government - BCC, property transfer data
Ln Sale Price	logarithmic	Natural Log of sale price	
Transfer date (dummies)			Local government - BCC, property transfer data
D_2009	0 or 1	Dummy variable_ Properties that were sold in 2009 (1) but not in 2008 or 2010 (0)	
D_2010	0 or 1	Dummy variable_Properties that were sold in 2010 (1) but not in 2008 or 2009 (0)	
Independent/ explanatory variables			
House variables			
Number of bedrooms	Number	Number of bedrooms in the house	Commercial property data provider - RP Data
Number of bathrooms	Number	Number of bathrooms in the house	
Number of garage spaces	Number	Number of car parking spaces in the garage of the house	
Property variables			
Lot size	metres²	Area of the property included in the house sale	Local government - BCC
Distance to nearest park	metres (m)	Euclidean distance from the centre-point along the street frontage boundary of property to the nearest park centroid	Local government - BCC
D_ < 200 m	0 or 1		
D_ > 400 m	0 or 1		
Size of nearest park	metres²	Area of the park located nearest in euclidean distance	Local government - BCC
Distance to shops	kilometres	Euclidean distance from the centre-point along the street frontage boundary of the property to centre point of street frontage of nearest shops (MP4 land-use zoning) and boundary of arterial road reserve.	Local government (BCC) land-use planning spatial data layers
Distance to Arterial road	kilometres		
Suburb variables			
Suburb Housing age	Era	Age era of the suburb where the house sale is located	Extracts fron Queensland Places (2013), descriptions of suburb history, categoried into Pre (before 1910's), Inter (1920-1930), Postwar (1940-1970) and Modern (1980-present) categories
D_Prewar	0 or 1		
D_Postwar	0 or 1		
Household income	%	Percentage of households in the suburb* with income levels in the top quartile for the suburb	Brisbane Census data at SLA scale (ABS 2011). * SLAs defined in 2011 Census were used to capture suburb scale resolution.
Education level	%	Percentage of households in the suburb* with occupants which have completed at least secondary school education level	
Distance to city centre	1 to 5	Zones of distance from the city centre defined for public transport pricing	Brisbane Translink Zones (https://translink.com.au/tickets-and-fares/fares-and-zones/zones)

Variable (label)	Units	Definition	Data source
Tree cover variables			
% tree cover on property	%	Tree canopy cover as a proportion of property area	Local government - BCC, 2010 tree cover data. "Tree Cover 2010" is remotely-sensed tree foliage projective cover data at two-metre pixel resolution obtained from analysis of World View 2 hyperspectral satellite imagery, acquired in 2010 and integrated with South East Queensland LiDAR aerial imagery from 2009 (Armston, et al., 2009)
D_ < 20%	0 or 1	Dummy variable_% tree cover on property < 20% (1), > 20%(0)	
D_ > 30%	0 or 1	Dummy variable_% tree cover on property > 30% (1), < 30%(0)	
% tree cover within 30 m	%	Tree canopy cover as a proportion of the land area within a buffer zone of 30 m and 100 m radius from the centre point along the street frontage boundary of the property	Local government - BCC, 2010 tree cover data. "Tree Cover 2010" overlaid with defined polygon boundaries using GIS ArcView V10
% tree cover within 100 m	%		
% street tree canopy at frontage	%	Tree canopy cover as a proportion of the land area of the front footpath zone (or verge) adjacent to the property	
D_>32%<50%	0 or 1	Dummy variable_% tree cover on frontage >32% < 50%(1), other (0)	
D_>50%	0 or 1	Dummy variable_% tree cover on frontage > 50%(1), other (0)	
% street tree canopy within 30 m		Tree canopy cover as a proportion of the land area of the footpath zone within 30 m and 100 m radius of the frontage centrepoint, excluding the front footpath zone	
% street tree canopy within 100 m			
D_>32%<50%	0 or 1	Dummy variable_% tree cover in footpath zones within 100 m, excluding front footpath zone >32% < 50%(1), other (0)	
D_>50%	0 or 1	Dummy variable_% tree cover on footpath zones within 100m, excluding front footpath zone >50%(1), other (0)	

Table 3. Non-spatial Tree cover model results with heteroskedastic standard errors (HSE).

	Base OLS (1)			Tree effects OLS (2a)			Tree Effects Dummy OLS (2b)		
Variable	**Coeff**	**HSE**	**Signif.**	**Coeff**	**HSE**	**Signif.**	**Coeff**	**HSE**	**Signif.**
Intercept	11.9710	0.0758	***	11.9390	0.0818	***	12.2081	0.0673	***
D_2009	-0.0190	0.0125		-0.0183	0.0125		-0.0228	0.013	*
D_2010	0.0308	0.0126	***	0.0333	0.0126	***	0.0351	0.013	***
House									
No. bedrooms	0.0574	0.0095	***	0.0555	0.0096	***	0.0528	0.0097	***
No. bathrooms	0.1488	0.0107	***	0.1425	0.0108	***	0.1366	0.0111	***
No. garage spaces	0.0206	0.0067	***	0.0205	0.0067	***	0.0179	0.0068	***
Land/Property									
Lot size	0.0003	0.0000	***	0.0004	0.0000	***	0.0003	0.0001	***
D_ < 200m from nearest park	-0.0405	0.0119	***	-0.0420	0.0119	***	0.0385	0.0121	***
D_> 400m from nearest park	0.0259	0.0239		0.0236	0.0237		0.0275	0.0254	
Distance to MP4	-0.0064	0.0101		0.0168	0.0101	*	-0.0048	0.0057	
Distance to Arterial	0.0176	0.0057	**	-0.0059	0.0057		0.0182	0.0101	*
Suburb									
D_Prewar	0.2327	0.0205	***	0.2446	0.0208	***	0.2413	0.0209	***
D_Postwar	0.0801	0.0142	***	0.0897	0.0144	***	0.0899	0.0143	***
Suburb household income	0.0195	0.0016	***	0.0192	0.0016	***	0.0195	0.0016	***
Suburb Education	0.0080	0.0010	***	0.0085	0.0010	***	0.0081	0.001	***
Location -distance to CBD	-0.0373	0.0086	***	-0.0357	0.0086	***	-0.0388	0.0085	***
Tree Cover (continuous vars)									
Tree cover on property				-0.0014	0.0004	***			
Tree cover on front footpath				0.0001	0.0002				
Tree cover within 30m property#				-0.0007	0.0005				
Footpath Tree Cover within 30m#				0.0004	0.0003				
Tree cover within 100m of property#				-0.0006	0.0006				
Footpath tree cover within 100m				0.0010	0.0005	**			
Tree Cover (dummy vars)									
D_Treecover <20% property							0.0478	0.0147	***
D_Treecover >30% property							-0.001	0.0142	
D_Treecover>32%<50% front fpath							0.0067	0.0126	
D_Treecover>50% front fpath							0.0042	0.013	
D_Tree cover_fpath within 100m >32%<50%							-0.0046	0.0109	
D_Tree cover_fpath within 100m >50%							0.0505	0.0183	***
Adjusted R 2	0.6588			0.6590			0.6360		
Standard Error of Estimate	0.2326			0.2319			0.2396		
Sum of Sq Residuals	123.553			122.5440			130.809		
F-stat	225.7049		***	234.5270		***	201.436		***
n	2299			2299			2299		
# run in separate regressions									
Signif. levels *** 1%, ** 5%, * 10%									

Table 4. Spatial SEM and SAR model results for significant tree cover variables.

	Spatial SEM Tree Model (3)				Spatial SAR Tree Model (4)		
Variable	**Coeff**	**SE**	**Signif**		**Direct eff**	**SE**	**Signif**
Intercept	11.8908	0.0052	***		11.919	0.0966	***
D_2010	0.0402	0.0092	***		0.0447	0.0106	***
House							
No. bedrooms	0.0527	0.0071	***		0.055	0.0077	***
No. bathrooms	0.1222	0.0083	***		0.1436	0.0089	***
No. garage spaces	0.0218	0.0054	***		0.0208	0.006	***
Land/Property							
Lot size	0.0004	0.0001	***		0.0003	0.0001	***
D_ < 200m from nearest park	-0.0316	0.0128	***		-0.0460	0.0109	***
D_ > 400m from nearest park							
Suburb							
D_Prewar	0.2197	0.0277	***		0.2452	0.0208	***
D_Postwar	0.0875	0.0204	***		0.0887	0.0179	***
Suburb household income	0.0186	0.0021	***		0.0192	0.0014	***
Suburb Education	0.0098	0.0008	***		0.0083	0.0009	***
Location -distance to CBD	-0.0395	0.0069	**		-0.038	0.0088	***
Distance to arterial road	0.0243	0.0132	*		0.0168	0.0083	**
Tree Cover (continuous vars)							
Tree cover on property	-0.0011	0.0003	***		-0.0013	0.0003	***
Footpath tree cover within 100m	0.0008	0.0005	*		0.0011	0.0004	***
Adjusted R 2	0.7113		***		0.6587		***
log-likelihood	1046.34				903.43		
rho					0.0023	0.0012	*
lambda	0.475	0.0106	***				
n	2299				2299		
Signif. levels *** 1%, ** 5%, * 10%							