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Research paper

How green is your garden?: Urban form and socio-demographic factors influence yard vegetation, visitation, and ecosystem service benefits

B.B. Lin[a,*], K.J. Gaston[b], R.A. Fuller[c], D. Wu[d], R. Bush[e], D.F. Shanahan[c]

[a] CSIRO Land and Water Flagship, PMB 1, 107-121 Station Street, Aspendale, Victoria 3195, Australia
[b] Environment & Sustainability Institute, University of Exeter, Penryn, Cornwall TR10 9EZ, UK
[c] School of Biological Sciences, University of Queensland, St Lucia 4072, Australia
[d] Remote Sensing Research Centre, School of Geography, Planning and Environmental Management, University of Queensland, St Lucia 4072, Australia
[e] Healthy Communities Research Centre, University of Queensland, Brisbane, Queensland 4072, Australia

HIGHLIGHTS

- Urban form and demographic factors influence ecosystem service benefits from yards.
- Benefits also differ depending on passive or active interaction with yards.
- Yard size, age, and social advantage were positively associated with vegetation availability and use of yards.
- Greater vegetation cover in the yard was not associated with higher use.
- People with high nature-relatedness scores received both passive and active benefits.

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ABSTRACT

Private yards provide city residents with access to ecosystem services that can be realized through passive (vegetation availability) and active (time spent in yards: frequency and duration) means. However, urban densification is leading to smaller yards with less vegetation. Here, we examine how urban form and socio-demographic factors affect the potential ecosystem service benefits people can gain via passive (e.g. climate regulation) and active (e.g. recreation) pathways. Two measures of vegetation cover (0.15–2 m, >2 m) are used as a proxy for passive ecosystem service benefits, and two measures of yard use (use frequency, total time spent across a week) are used for active ecosystem service benefits. We use survey and GIS data to measure personal and physical predictors that could influence these variables for 520 residents of detached housing in Brisbane, Australia. We found house age and yard size were positively correlated with vegetation cover, and people with a greater nature relatedness and lower socio-economic disadvantage also had greater vegetation cover. Yard size was an important predictor of yard use, as was nature relatedness, householder age, and presence of children in the home. Vegetation cover showed no relationship, indicating that greater cover alone does not promote ecosystem service delivery through the active use pathway. Together our results show that people who have higher nature relatedness may receive greater benefits from their yards via both passive and active means as they have more vegetation available to them in their yards and they interact with this space more frequently and for longer time periods.

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1. Introduction

With the world's urban population continuing to grow rapidly, many cities are transitioning to higher density, compact housing (Loibl & Toetzer, 2003; Radeloff, Hammer, & Stewart, 2005). Urban growth will inevitably lead to changes in urban vegetation cover and access to private green space – that is, people's private (domes-

* Corresponding author.
E-mail addresses: Brenda.Lin@csiro.au, bbclin@gmail.com (B.B. Lin), k.j.gaston@exeter.ac.uk (K.J. Gaston), r.fuller@uq.edu.au (R.A. Fuller), d.wu@uqconnect.edu.au (D. Wu), r.bush@uq.edu.au (R. Bush), danielleshanahan@gmail.com (D.F. Shanahan).

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tic) gardens, back yards, and front yards (herein referred to as 'yards'). In areas of high residential density, yards are likely either to disappear or decline in size, while people living in the sprawling outskirts of cities may still have the opportunity to choose both the size and natural content of these spaces (Conway & Hackworth, 2007; Lowry, Baker, & Ramsey, 2012). Private yards are important because they provide city residents with immediate access to urban green space (Gaston, Warren, Thompson, & Smith, 2005; Shanahan, Lin, Gaston, Bush, & Fuller, 2014). However, they also have a significant role in contributing to overall vegetation cover in cities, as residential areas make up more than 50% of all available green space in many cities (Gaston et al., 2005; Lin, Meyers, & Barnett, 2015; Loram, Tratalos, Warren, & Gaston, 2007; Mathieu, Freeman, & Aryal, 2007; Shanahan et al., 2014).

Vegetation around the home can provide a variety of important ecosystem services that contribute to human and environmental health at local, neighborhood, and regional scales (Bolund & Hunhammar, 1999). First, urban vegetation has been shown to provide a range of services that can be delivered to people via passive pathways, in which people do not need to engage actively with the natural environment to gain benefits (Shanahan, Bush et al., 2015). For example, services such as climate regulation, shade and shelter benefits can be delivered passively even when the human recipient does not actively spend time in the yard (Bowler, Buyung-Ali, Knight, & Pullin, 2010). These benefits can reduce the energy requirements for air conditioning, peak loads of energy, and consumer costs in residential homes (McPherson, 1994). The physical presence of vegetation around the home can also provide benefits of privacy and noise reduction to buffer residential areas from urban noise pollution or unwanted views, as well as flood mitigation, where carefully designed vegetative systems reduce flood discharge by allowing greater levels of infiltration and recharge (Bolund & Hunhammar, 1999) regardless of time or desire to interact with yard vegetation. It is suspected that homes with a greater amount of vegetation surrounding them will provide a greater amount of these passive ecosystem service benefits to the residents whether or not they intentionally interact with the vegetation.

A second set of ecosystem services from yard vegetation provides a range of benefits that require active engagement for a person to gain the benefit, such as time spent in private yards leading to health and well-being benefits (Berman, Jonides, & Kaplan, 2008; Dallimer et al., 2012; Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007; Larson, Whiting, Green, & Bowker, 2014; Mitchell, 2013). In these cases, a specific human experience with the vegetation is required for the benefit to accrue, and because such experiences arise from time physically spent in green spaces, they depend on behavioural patterns of a person as well as the characteristics of the vegetation of a yard.

A range of factors influences the amount and type of vegetation in people's yards, and thus the potential ecosystem services they can gain from these spaces. For example, the presence and size of yards are inextricably linked to the history and types of urban development, which could in turn affect the availability of space for vegetation (Conway & Hackworth, 2007; Gill, Handley, Ennos, Pauleit, Theuray, & Lindley, 2008; Smith, Gaston, Warren, & Thompson, 2005). Detached housing (i.e. single-family homes) is a prevalent land use type across cities in much of the world (Davies et al., 2009; Gaston et al., 2005; Goddard, Dougill, & Benton, 2010), and compared to other urban land-use types it is generally associated with a large amount of vegetated area (Attwell, 2000; Gill et al., 2008).

However, factors beyond physical characteristics of cities also influence the abundance of vegetation around the home, leading to typically uneven coverage in Western cities (Kirkpatrick, Davison, & Daniels, 2012; Loram et al., 2007; Shanahan et al., 2014; Smith et al., 2005). Cultural background, demographics, housing type and ownership can all affect decisions to plant and maintain vegetation in private green spaces (Grove et al., 2006; Perkins, Heynen, & Wilson, 2004; Troy, Grove, O'Neil-Dunne, Pickett, & Cadenasso, 2007). For instance, people who own their own homes may be more likely to invest in tree cover to save money on heating and cooling or to enhance privacy (Bowler et al., 2010; Summit & McPherson, 1998). Suburb age also directly influences tree cover because in younger suburbs less time has elapsed for trees to be planted and become mature (Greene, Millward, & Ceh, 2011).

There is also a range of factors that can discourage new vegetation planting, or even encourage removal of old vegetation. For example, in some locations fear of increased potential for bushfires in hot and dry conditions can discourage planting around the home (Gilbert & Brack, 2007). Furthermore, the presence of urban vegetation can be associated with increased fear of crime (Gobster & Westphal, 2004; Nasar & Jones, 1997). Tree maintenance requires time, effort, and knowledge, as well as space that is a scarce commodity in densely populated areas (Kirkpatrick et al., 2012; Summit & McPherson, 1998). Vegetation around homes or near roads can also cause root damage or threaten other infrastructure with fallen limbs creating safety issues (Head & Muir, 2005; Nowak & Dwyer, 2007). Reflecting this range of motivations and barriers for planting and maintaining vegetation around the home, a growing body of research shows that socio-economic and demographic factors correlate with tree cover and species diversity within yards (Clarke, Jenerette, & Davila, 2013; Kirkpatrick, Daniels, & Zagorski, 2007; Shanahan et al., 2014; van Heezik, Freeman, Porter, & Dickinson, 2013).

Although the size of the yard and the quantity of vegetation are important determinants of the potential ecosystem services people can gain from private yards via passive means, they could conceivably influence a person's use of these spaces and thus the delivery of ecosystem services by more active pathways (such as recreational use or psychological wellbeing benefits). Certainly, there is a growing body of evidence suggesting that the vegetation in public green spaces can influence visitation of these areas (Cohen et al., 2010 Ho et al., 2005; Shanahan, Lin, Gaston, Bush, & Fuller, 2015), and experiencing a more natural setting is a common reason that people state for engaging with public green space (Chiesura, 2004; Irvine et al., 2010; Irvine, Warber, Devine-Wright, & Gaston, 2013). Furthermore, considerable evidence now shows that socio-demographic factors (including gender, age, education, income and nature orientation) influence people's use of public green spaces (Ho et al., 2005; Lin, Fuller, Bush, Gaston, & Shanahan, 2014; Zanon, Doucouliagos, Hall, & Lockstone-Binney, 2013), with nature orientation highly influencing the amount of time that people spend in green spaces (Lin et al., 2014).

However, despite the potential importance of private yards for delivering ecosystem services through active use pathways, people's use of these spaces has received relatively little attention. One would suspect, similar to public green spaces, that the vegetation content of private yards and similar socio-demographic factors would lead people to spend more time in their private yards. The studies that do exist show that families tend to spend very little time in the outside areas of their homes (Arnold & Lang, 2007; Graesch, Broege, Arnold, Owens, & Schneider, 2006); for example, in Los Angeles parents and children rarely use their yards and often primarily carry out mundane tasks when they do (taking out trash, arrivals and departures; Arnold & Lang, 2007). Thus, key questions remain regarding the extent to which physical characteristics of yards, or the personal characteristics of people, influence actual use of private yards.

Here, we examine the extent to which physical (e.g. availability of space) and personal (e.g. age, socio-economic disadvantage) factors influence the potential ecosystem services people can gain from their private yards in Brisbane, Australia – a city undergoing rapid urban transition in a subtropical climate context. We examine this question by focusing first on the availability of vegetation within people's yards, which will be inextricably linked to the benefits people can gain through passive means. Second, we examine whether these factors have important associations with people's actual use of their yards and their ability to obtain a different set of ecosystem services through interaction effects.

2. Methods

2.1. Site description

Brisbane is located in subtropical Queensland, Australia, with the city's administrative area covering 1380 km^2, and with an estimated population in 2011 of 1,090,000 residents. The city is growing rapidly, with 156,000 additional dwellings forecast to be required within the greater Brisbane area by 2031 (up from a total of 397,000 dwellings in 2006; Queensland Government, 2009). There is rapid housing development on the outskirts of the city, but the highest housing densities occur in the inner suburbs, where large existing residential plots are subdivided to make way for multiple dwellings (Sushinsky, Rhodes, Possingham, Gill, & Fuller, 2013). Rapid housing development is common to many other growing cities around the world, but it must borne in mind that the subtropical climate context in this case is likely to exert specific effects on the types and levels of vegetation available in the city as well as people's patterns of behaviour.

2.2. Survey information

We conducted an urban green space interaction survey during late spring (November 2012), prior to the onset of higher summer temperatures, to obtain information on socio-demographic factors and exposure to green space and vegetation of Brisbane residents. This time period was deliberately selected because of ideal weather (mild temperatures, occasional rainfall) for outdoor use during the spring. The survey was administered over a two week period, ensuring that all responses were collected approximately contemporaneously in spring. The survey was delivered online through a market research company (Q&A Market Research Ltd) to a subset of people enrolled in their survey database. To see a full copy of the survey, please see Shanahan et al. (2016).

Participants fulfilled several nested stratification criteria that ensured the sample reflected a range of demographic groups, a broad socio-economic spread, and a relatively even spatial distribution of respondents across the city. The stratification rules were that (i) participants were between 18 and 70 years of age inclusive, (ii) the number of participants above and below 40 years of age was equal, (iii) the number of female and male participants was equal, (iv) the income quartiles of the participant group reflected those of the total Brisbane population as determined by 2011 Australian Census data, and (v) participants' addresses were spread evenly among four spatial zones reflecting the four quartiles of tree cover across the city.

We collected information about socio-demographic variables that could influence decisions around private green space management and use including participant's age, gender, personal annual income, their highest qualification, the presence of children under 16 in the home, the primary language spoken at home, length of time in home, and the ownership status of the home (Table 1). We also obtained an estimate of the socio-economic disadvantage of the neighbourhood in which each respondent lived using the Australian census-derived Index of Socio-economic Disadvantage (IRSD), calculated for the finest possible spatial scale to which individual addresses could be assigned (Statistical Area 1; Australian Bureau of Statistics, 2008).

Survey participants provided either their exact address or a general address description for privacy reasons if desired. Participants were asked to report on the frequency of visits to their yards in the last year as well as the duration of time spent there across the week directly before the day they took the survey. Survey participants also completed the Nature Relatedness Scale (Nisbet, Zelenski, & Murphy, 2009), one of several scales that attempts to assess individual differences in connections to nature (Tam, 2013), in order to evaluate the participant's orientation toward nature. This scale requires participants to complete a series of questions that assess the affective, cognitive, and experiential relationship individuals have with the natural world (Nisbet et al., 2009). Participants rate 21 statements using a five-point Likert scale ranging from one (disagree strongly) to five (agree strongly). Responses to each of the 21 questions were scored and then the average was calculated according to the system outlined by Nisbet et al. (2009). A higher average score indicates a stronger connection with nature. The scale has been demonstrated to differentiate between known groups of nature enthusiasts and those not active in nature activities, as well as those who do and do not self-identify as environmentalists. It also correlates with environmental attitudes and self-reported behaviour and appears to be relatively stable over time and across situations (Mayer & Frantz, 2004; Nisbet et al., 2009). For a greater understanding of the topic and term, please refer to (Bratman, Hamilton, & Daily, 2012; Mayer & Frantz, 2004; Tam, 2013). In this paper, we use the term 'nature relatedness' to refer to the wider construct encompassing connectedness and relationships with nature.

2.3. Physical characteristics of yards

We measured the variability of size, tree cover, and understorey cover of private yards, focusing only on respondents who have sole use of a private yard (i.e. detached housing), and restricted the analysis to respondents who provided their exact address information. A total of 520 participants satisfied these inclusion criteria.

We geolocated the address of each respondent and derived a number of measures for their yard. Each house was identified in Google Earth, and property boundaries and building outlines were manually delineated. Estimates of yard area and tree cover within yards were then estimated within ArcGIS. Data on the distribution and height of vegetation were derived from airborne LiDAR, in which a laser mounted on an aircraft detects the height of objects on the ground. We used an adaptation of the method described by Miura and Jones (2010) to process the LiDAR data to characterise vegetation structure in the yards. As opposed to calculating the number of returns for each vertical layer and then dividing by the total number of returns in each of the calculating units, the modified approach divides the number of returns from each vertical layer by the total number of returns below the maximum height of that layer. This takes into consideration that the LiDAR pulse may not penetrate dense canopies. This approach calculates the proportion of LiDAR beams that are returned from within predetermined vegetation structural layers, providing an indication of whether vegetation was present or not in that layer. Two measures of vegetation were estimated within the yards: low vegetation cover >0.15 m but <2 m, and tree cover $\geq$2 m. We could not reliably distinguish vegetation below 15 cm from the ground, and the 2 m cut-off point was chosen because it approximates the height of a person, and hence the line of site and access and movement through the space. The nominal vertical accuracy of the airborne LiDAR data was $\pm$0.15 m at 1 sigma and the measured vertical accuracy was $\pm$0.05 m at 1 sigma (determined from check points located on open clear ground).

Table 1
Descriptions of the variables.

Variable name	Description
Age	Respondent's age in years, selected from 11 categories. Treated as an ordinal factor.
Gender	Gender, for analysis purposes male = 0, female = 1.
Income	Personal income selected from categories defined based on the income question provided in the Australian census (categories included weekly income of: nil or negative; $1–$199; $200–$299; $300–$399; $400–$599; $600–$799; $800–$999; $1000–$1249; $1250–$1499; $1500–$1999; $2000+). For analysis purposes the variable was treated as an ordinal factor.
IRSD	The Index of Socioeconomic Disadvantage (IRSD), a census derived indicator provided by the Australian Bureau of Statistics. Variable is continuous (between 650–1150 in this sample), with low scores indicating greater deprivation. The neighbourhood value for each respondent's address was used at the finest available spatial scale (Australian Census Statistical Area 1).
Nature-relatedness score	The affective, cognitive, and experiential relationship individuals have with the natural world. A higher average score indicates a stronger connection with nature.
Children in home	The presence or absence of people living in a respondent's home who were under 16 years at the time of the survey. (Binary)
Total # months in home	Total time in months the respondent has lived at the address
Own or Rent	Own = 1, rent or other (e.g. boarding) = 0
Number of people in the home	Total number of people (including children) living in the home
Highest qualification	The highest formal educational qualification achieved by the respondent, grouped into ten categories (10 = highest qualification possible, e.g. post-graduate qualification; 1 = lowest qualification possible, e.g. year 8 of school).
Language (non-English = 1)	An indication of the language primarily spoken at home. For analysis purposes 0 = English, 1 = not English.
Build year of the home	House build year estimated based on style (Brisbane City Council, 2004) Google Earth historical imagery where possible. Split into four categories including pre-war (WWII), post-war-1980, 1980–2001, and post-2001.
Yard area	The available yard area was estimated by subtracting the house area which was manually digitized in Google Earth from the total lot size.
Yard visitation duration	Average time spent during each yard visit reported for the survey week.
Yard tree cover	Vegetation cover data layers derived from LiDAR for vegetation >0.15 m, but <2 m.
Yard understorey cover	Vegetation cover data layers derived from LiDAR for tree cover $\geq$2 m.
Yard visitation frequency	Ordinal variable indicating the self-reported frequency of yard visitation selected from categories, including: never; once a year; once every three months; once a month; 2–3 times a month; once or more per week.

Each house was categorised to a broad building age estimate based on key building design features from local patterns of development (Brisbane City Council, 2004). Using these parameters, houses were aged to three categories: pre c1940, c1940-1970, c1970-2000. A further category was created as 2001+, which was derived through assessment of Google Earth historical images where new buildings could be directly identified. Google Earth was used to delineate boundaries and house outlines, and Google Street view was used to help age the house. These categories were treated as ordinal factors in analyses as they were unequal in duration.

2.4. Statistical analysis

We first used an information theoretic approach based on linear regression to assess the extent to which key demographic and social factors were associated with the availability of vegetation within private yards, and so the potential benefits that could be delivered via passive means. To do this we considered two response variables; the percentage of low vegetation cover, and the percentage of tree cover. We created a full set of models which included every possible combination of a range of predictor variables with an expected influence on the vegetation within yards. For this predictor model set we excluded variables that could not possibly be generalised to the whole household, such as age and sex, but included personal level variables that could provide an indicator of the household, such as education, nature relatedness, or language. The final predictor variables included build year, nature relatedness, IRSD, own/rent status, number of people in home, children in home, months in home, and highest qualification (Table 1). We then generated the model averaged coefficient for each predictor (i.e. the average coefficient across all models in which the predictor was present). We calculated the relative importance of each predictor by calculating the summed Akaike weights across all models in which it occurred (Burnham & Anderson, 2002), and then standardised these summed weights between 0 and 1 (a high value indicates that a variable consistently appeared in the more parsimonious models).

Second, we examined the association between a range of predictor variables and each respondent's use of the yard; this included the total time spent in this space across the survey week, and the usual frequency of use. We used ordinal logistic regression models to test the association between the predictor variables and the response variables, because respondents were required to select from ordered categories in answering the relevant questions. The predictor variable set included both physical characteristics of the yard (tree cover, understorey cover, yard size), and personal or household-level characteristics (nature relatedness, children in home, highest qualification, language, IRSD, age, gender, and income; Table 1). All analyses outlined here were conducted in the R statistical software package (R Core Team, 2012).

3. Results

People who had larger yards, older houses, and lived in more advantaged neighbourhoods (indicated by higher IRSD) tended to have greater tree cover and understorey cover around their homes (Table 2). People with high nature relatedness scores also tended to have greater tree cover. Thus, residents who had access to larger

Table 2
Model averaged coefficients, and relative importance (as defined by the summed Akaike weights of the models in which each variable appears) of physical and social factors as predictors of tree cover and understorey cover in yards, calculated from linear regression models using all possible combinations of predictor variables (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Response variable		Build year (ordinal)	Yard size	Nature Relatedness	IRSD	Own (1)/rent (0)	Number of people in home	Children in home (binary)	Language (non-English = 1, English = 0)	Months in home	Highest qualification
Tree cover (>2m)	Model averaged coefficient	***	0.03***	3.49**	2.60*	−2.06	−0.75	−1.41	−2.39	0.00	0.48
	Relative importance	1	1	0.96	0.91	0.51	0.47	0.35	0.38	0.27	0.55
Understorey cover (0.15–2 m)	Model averaged coefficient	***	0.01**	−0.09	0.04***	1.35	−0.42	−0.50	−1.01	0.00	0.27
	Relative importance	1	1	0.27	1	0.36	0.32	0.28	0.29	0.47	0.34

yards, older houses, greater social advantage, and higher nature relatedness tended to have higher levels of vegetation immediately around their home, leading to a greater potential for passive ecosystem services.

We also discovered that residents with larger yards, those with higher nature relatedness scores, and those who are older in age (Tables 3 and 4) tended to spend more time in their yards and visit more frequently. Additionally, visitation frequency was higher when there were children present in the home (Table 4). Such results show that age demographics and yard size may play a large role in determining the ability or inclination of residents to spend time within their yards.

Although residents with larger yards spent more time in them, increased vegetation cover was not related to the amount of time or frequency of visits to these spaces. Higher nature relatedness scores were associated with greater tree cover and yard size (potential ecosystem services delivered by a passive pathway) as well as time spent in the yard and the visitation frequency (ecosystem services delivered via an active pathway).

4. Discussion

Our results show that physical and personal variables are associated with the potential ecosystem service benefits people can receive from their private yards. People with high levels of vegetation cover in their yards can potentially gain ecosystem service benefits through passive means (e.g. temperature regulation, noise reduction), and we have shown that vegetated cover in the yard is greater for people with older residences, larger yards, greater social advantage, and higher nature relatedness scores (Table 2). The ecosystem service benefits people gain from their yards may be broadened and enhanced when residents also spend time in their yards and actively interact with the yard vegetation. People who spent more time in their yards tended to have larger yards, higher nature relatedness scores, and were of older age (Table 3), and increased frequency of use occurred when children were in the household (Table 4). Interestingly, higher levels of yard vegetation cover were not associated with increased time spent in yard or frequency of yard visitation.

Our results agree with patterns found in several other studies that have demonstrated a link between higher social advantage and greater vegetation cover. This pattern may arise for many reasons; for example, advantaged households may be able to afford larger properties in older neighbourhoods, and thus, higher levels of vegetation cover could be driven by the greater space availability or the presence of more mature vegetation (Kirkpatrick et al., 2007; Lowry et al., 2012; Pham, Apparicio, Landry, Seguin, & Gagnon, 2013; Smith et al., 2005). Householders with greater social advantage might be more aware of, and take advantage of, tree planting programs (Luck, Smallbone, & O'Brien, 2009) or may possess greater social capital to influence private and public street tree planting in their neighbourhoods (Merse, Buckley, & Boone, 2009). Such patterns point to a trend in the spatial distribution of vegetation that disproportionately favours those with existing socio-economic advantage, raising environmental equity concerns (Perkins et al., 2004; Tooke, Klinkenberg, & Coops, 2010), and the results may be important to consider in urban planning of new green spaces or when selecting locations to amend vegetation cover.

We found that survey participants of older age or with children at home were more likely to use their yards. Such results may indicate that people in their middle years of life or without children do not have the time to spend in yards, while older adults may have more time for this activity and people with children have an extra motivation to spend time in these areas (Arnold & Lang, 2007). A study on leisure time activities in Los Angeles showed that working parents with pleasant, furnished, private outdoor spaces rarely spent time in their yards, and any time spent there was often with their children (Arnold & Lang, 2007). We did not find any indication that greater social advantage (i.e. higher income or IRSD) led to more time spent in the yard or increased visitation frequency, which supports the results of Arnold and Lang's (2007) study.

Nature relatedness (a measure of people's connection to nature; Nisbet et al., 2009) was an important predictor for all three models indicating that people with high nature-relatedness scores had more vegetation in their yards, spent more time in their yards, and visited their yards more frequently. Thus, people with high nature relatedness scores have the potential to receive high levels of yard vegetation benefits through both passive and active means. Such results are supported by previous research showing that people with high nature relatedness scores spend more time in both public and private green spaces as well as live in areas with more vegetation cover (Lin et al., 2014). Literature from the environmental psychology field also shows that appreciation for nature is a significant motivation for people to spend time in the yard (Clayton, 2007). These results point to an important socio-demographic variable that highlights a specific set of people who are receiving greater benefits from their passive and active interaction with vegetation. Although little is known about the development of nature orientation in individuals, the encouragement of positive nature orientation points to a potential public health intervention using urban nature as a pathway to promote health (Shanahan, Bush et al., 2015).

Vegetation variables (percent of tree and understorey cover) did not have a significant relationship with the time spent in the yard or yard visitation frequency, indicating that greater vegetation cover does not necessarily influence use. This lack of relationship between these two variables may be because people use their yards in many different ways and many uses of yards may not require

Table 3
Results from a multivariate ordinal logistic regression examining the relationship between time spent in private yards (within the survey week) and a range of social and physical predictor variables (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

	Estimate	Std. Error	t value	p-value
Tree cover	0.00	0.01	0.25	0.8
Understorey cover.	−0.00	0.01	−0.13	0.89
Yard area	0.00	0.00	2.80	0.00**
Nature relatedness	0.70	0.13	5.17	0.00***
Children in home	0.33	0.18	1.78	0.07
Highest qualification	−0.00	0.04	−0.01	0.99
Language (non-English = 1)	−0.26	0.27	−0.96	0.33
IRSD	0.00	0.00	0.21	0.83
Age	0.03	0.01	4.59	0.00***
Gender	−0.31	0.16	−1.90	0.06
Income	0.03	0.03	0.85	0.39

Table 4
Results from a multivariate ordinal logistic regression model examining the relationship between usual frequency of private yard use and a range of social and physical predictor variables (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

	Estimate	Std. Error	t value	p-value
Tree cover	0.00	0.01	0.17	0.86
Understorey cover.	−0.00	0.01	−0.10	0.92
Yard area	0.00	0.00	2.33	0.02*
Nature relatedness	0.62	0.14	4.48	0***
Children in home	0.38	0.19	1.99	0.04*
Highest qualification	−0.02	0.04	−0.52	0.6
Language (non-English = 1)	−0.42	0.27	−1.57	0.11
IRSD	0.00	0.00	0.20	0.84
Age	0.03	0.01	5.47	0.00***
Gender	−0.30	0.17	−1.87	0.06
Income	0.01	0.03	0.29	0.77

high levels of vegetation (Larson, Casagrande, Harlow, & Yabiku, 2009). However, a number of studies on physical activity indicate that they can be an important interaction space for recreation and health benefits. In a study on preferred physical activity locations in Georgia, USA, a state with historically high levels of physical inactivity and obesity, self-reported data showed that homes and yards were used most frequently for physical activity, followed by neighbourhood settings (Larson et al., 2014). Research on physical activity in children has also found that outdoor time spent in their own yards may be as effective as neighbourhood playgrounds and sports fields in promoting physical activity (Dunton, Liao, Intille, Wolch, & Pentz, 2011). Although we did not specifically ask people what activities they performed in their yards, research from other regions suggests that increased yard use has the potential for increasing physical activity and positively impacting health and well-being.

5. Conclusions

Decreasing lot sizes, increasing housing footprints, socio-economic inequity, and low leisure time among the urbanized population may be negatively impacting the ability of urban residents to gain ecosystem service benefits from their yards by diminishing private outdoor green spaces and the motivation or ability to visit them. However, we have shown that people with high nature relatedness typically have greater vegetation cover around their home as well as spend more time within these spaces, at least in the city of Brisbane. Thus, people with high levels of nature relatedness are potentially gaining the vegetation related benefits from their private yards through passive and active pathways. Our results pave the way for further research that explores how a connection to nature relatedness might best be fostered, a challenge that could become increasingly difficult as urban systems lose more natural spaces and people have fewer opportunities to experience nature and build connections to it (Miller, 2005).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2016.07.007.

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