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LETTER

Could urban greening mitigate suburban thermal inequity?: the role of residents' dispositions and household practices

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Abstract

Over the past decade research on urban thermal inequity has grown, with a focus on denser built environments. In this letter we examine thermal inequity associated with climate change impacts and changes to urban form in a comparatively socio-economically disadvantaged Australian suburb. Local urban densification policies designed to counteract sprawl have reduced block sizes, increased height limits, and diminished urban tree canopy cover (UTC). Little attention has been given to the combined effects of lower UTC and increased heat on disadvantaged residents. Such impacts include rising energy expenditure to maintain thermal comfort (i.e. cooling dwellings). We used a survey of residents ($n = 230$) to determine their perceptions of climate change impacts; household energy costs; household thermal comfort practices; and dispositions towards using green infrastructure to combat heat. Results suggest that while comparatively disadvantaged residents spend more on energy as a proportion of their income, they appear to have reduced capacity to adapt to climate change at the household scale. We found most residents favoured more urban greening and supported tree planting in local parks and streets. Findings have implications for policy responses aimed at achieving urban climate justice.

1. Introduction

Global patterns of urbanisation have concentrated people in cities (Seto *et al* 2010, Roberts 2011, Chen *et al* 2014) at a time of escalating climate change, with heatwaves increasingly impacting many cities across the planet (Mcgeehin and Mirabelli 2001, Tong *et al* 2014, Vardoulakis *et al* 2014). Cities magnify heat through built form and reduced vegetation cover. This urban heat island (UHI) effect results in substantially higher temperatures in the urban core than in suburbs and hinterlands (Harlan *et al* 2007, Mccarthy *et al* 2010, Maller and Strengers 2011, Xiang *et al* 2014). As a result of uneven social geographies, urban heating disproportionately impacts lower-income and ethno-racially marginalised populations—a phenomenon termed 'thermal inequity' (Mitchell and Chakraborty 2014, Mitchell and Chakraborty 2015). Such populations can become spatially concentrated in hotter urban environments (Harlan *et al* 2007), and may not be able to afford to cool their homes due to lower-incomes, an energy security concern (Byrne and Portanger 2014). Thermal inequity has emerged as an important climate justice issue in recent research.

Climate justice refers to efforts to overcome the inequitable distribution of climate change burdens and benefits among populations, and also to actions intended to remedy unfair responsibilities for mitigation and adaptation at the national scale (Adger 2001, Duus-Otterstrom and Jagers 2012). Proponents of climate justice contend that steps must be taken to limit environmental inequities stemming from climate change, especially in cities (Stone *et al* 2012, Battaglia *et al* 2014, Bulkeley *et al* 2014). For example, actions to mitigate thermal inequity include urban greening (hereafter green infrastructure) designed to reduce the disproportionate impact of urban heat on marginalised and vulnerable populations (Wolch *et al* 2014, Byrne *et al* 2015). Researchers have found that green infrastructure, such as street trees and parkland, can significantly reduce direct and ambient temperatures (Lafortezza *et al* 2009). Although there has been some attention to modelling thermal inequity at the metropolitan scale, using remote sensing for example, less attention has been given to understanding how urban residents experience thermal inequity at the local scale, especially energy costs associated with cooling (Byrne and Portanger 2014). Little policy-oriented research has considered how green infrastructure might mitigate thermal inequity (Gill *et al* 2007, Hamin and Gurran 2009, Gaffin *et al* 2012, Norton *et al* 2015). Fewer studies have assessed how residents' environmental values might shape their disposition towards urban greening for climate justice (Kirkpatrick *et al* 2012). And less is known about suburban contexts.

Gold Coast City, like other Australian cities, is presently taking steps to reduce urban sprawl by reducing lot sizes, increasing building heights and focusing development within existing urban footprints. For many Australian cities, UTC is highest on private, not public land (Shanahan *et al* 2014). Urban consolidation policies often reduce UTC (Brunner and Cozens 2013), potentially leading to inequities in access to ecosystem functions, services and benefits. In the context of increasing urban heat—associated with changes to both built form and local climate—it is important to better understand the processes that create thermal inequity and how best to gauge the efficacy of potential local-scale policy interventions, such as green infrastructure (Jenerette *et al* 2011).

This article reports the results of research examining suburban residents' awareness of heat impacts associated with climate change and their receptiveness to urban greening as an adaptive response. By examining residents' self-reported awareness of climate change, level of concern about associated risks (e.g. heat), and perceived capacity to adapt, the study expands knowledge of thermal inequity at the household scale. Three objectives informed the research: (i) to determine if a comparatively socio-economically disadvantaged population in a suburban environment with low urban tree canopy cover may be inequitably exposed to heat; (ii) to determine if this population is disproportionately impacted by energy costs and thus has less capacity to adapt (e.g. via air-conditioning); and (iii) to determine if this population is favourably disposed towards using green infrastructure to mitigate heat exposure. The study extends existing research by focusing on the household scale, a suburban locale, and on residents' perceptions.

2. Data and methods

2.1. The case study area: Upper Coomera, Queensland, Australia

The presence of thermal inequity rests on two conditions: (i) greater exposure of a population to climate change related temperature increases and/or to UHI effects and (ii) the lower-socio-economic and/or ethno-racial minority status of that population. We selected a single case study based on an assessment conducted by the City of Gold Coast Council that the suburb exhibited socio-economically marginalised residents vulnerable to heat stress due to social and physical characteristics (Gold Coast City Council 2011a). This locality is within a rapidly expanding city. Planning policies directed at curtailing sprawl are increasing heat-island effects. As we discuss below, land clearing prior to development removed tree canopy cover. The built form of the neighbourhood—including roof colour, building materials, yard sizes, and building density—now traps heat and without greening, will continue to do so in the future. The unit of analysis is a suburb, as defined by the local municipality, which is a sub-area of the larger statistical local area of the same name.

Upper Coomera is situated in the northern corridor of Gold Coast City, South East Queensland (SEQ). SEQ accommodates 70% of Queensland's total population and is one of Australia's fastest growing metropolitan areas. Gold Coast City was the largest contributor to population growth in SEQ between 1991 and 2013 (Queensland Treasury 2015 p 5). Council is presently investigating feasibility of using green infrastructure to combat heat island effects as part of its draft Urban Greenspace 2030 planning strategy. The study area is bounded by four major roads. Reserve Road to the south intersects with Old Coach Road along the western boundary (see figure 1). To the north is Days Road, which intersects with the M1 Pacific Motorway to the east. The topography of the study area is gently undulating, with the land becoming increasingly steep towards the western boundary (Gold Coast City Council 2011b, p 1). The neighbourhood is bisected by a vegetation corridor, adjacent to Yaun Creek, important to state and locally significant species such as Koalas (Department of Natural Resources and Mines 2015).

2.1.1. Climate and socio-demographic characteristics of Upper Coomera

The climate of Gold Coast City is warm, humid subtropical, with average summertime temperatures of 28 °C (82 F) and winter averages of 21 °C (70 F). There are localised temperature variations with suburbs further inland (including Upper Coomera)

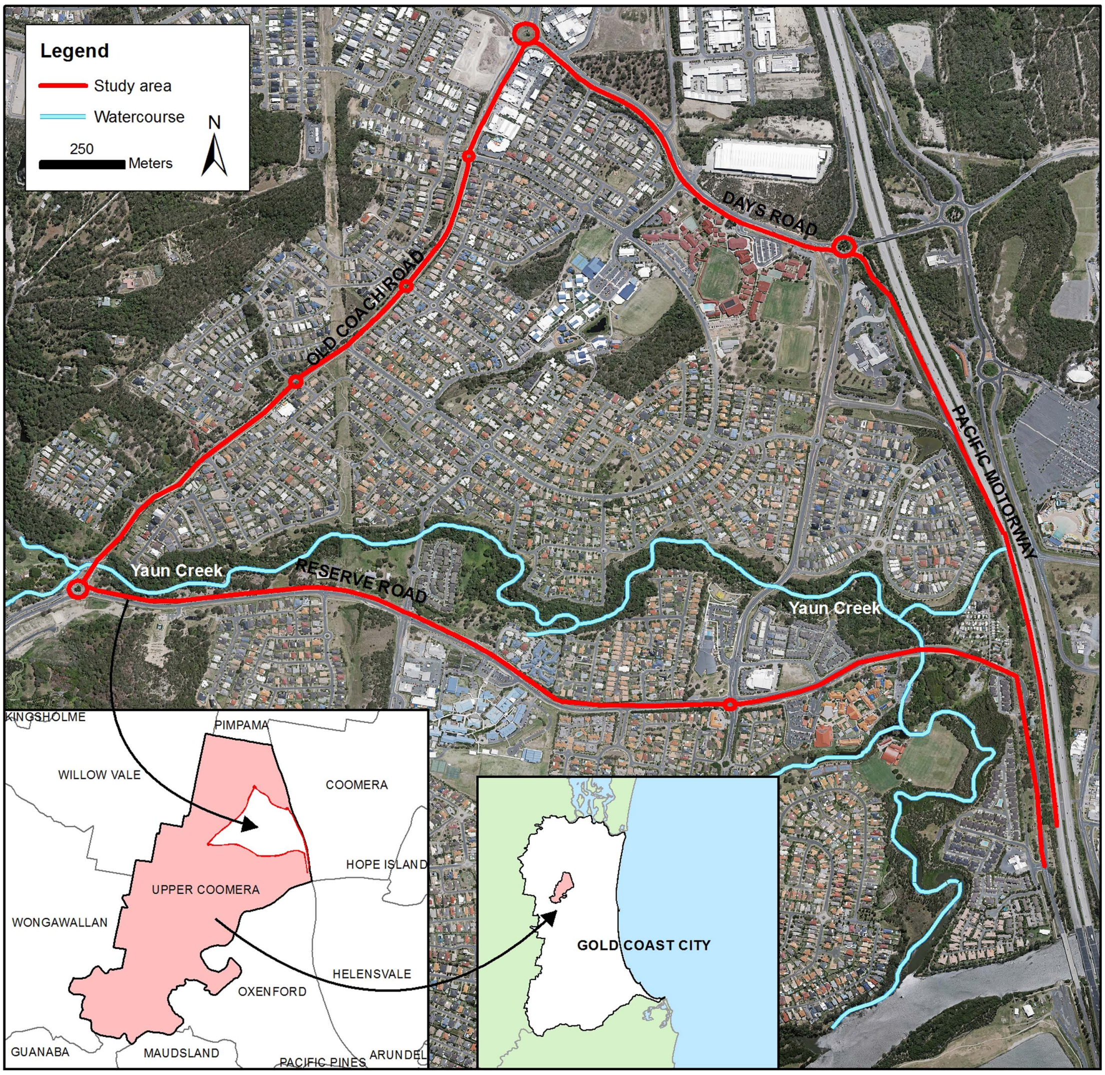

Figure 1. The Upper Coomera study area.

experiencing hotter and more humid temperatures. The maximum recorded temperature is above 40 °C, and relative humidity above 85%—conditions conducive to heat stress (Gaffen and Ross 1998). Granger and Hayne (2001) note that South-East Queensland, including Gold Coast City, is particularly vulnerable to heatwaves. The Commonwealth Scientific and Industrial Research Organisation (CSIRO 2016) climate analogues website shows that Gold Coast City will continue to experience heatwaves as climate change intensifies in the coming decades.

The current population of Upper Coomera is 21 136 people (Australian Bureau of Statistics 2013). The suburb's socio-demographic profile exhibits several markers of social vulnerability generally, and vulnerability to heat specifically. Almost three quarters (71%) of residents identified as a couple or single parent household with children (Australian Bureau of Statistics 2013). Children (0–14 years old) comprise almost a third (29%) of the suburb's population (Australian Bureau of Statistics 2013). A small proportion of elderly residents (5%) also reside in the suburb. Younger children and older people are especially vulnerable to heat (Maller and Strengers 2011). Children adjust to changes in environmental heat more slowly than adults. Elderly people (65 years or more) can also be prone to heat stress, due to pre-existing medical conditions and prescription medicines that may impair temperature regulation (Centres for Disease Control and Prevention 2015). Socio-economic disadvantage can reduce household capacity to afford electricity for cooling, and may reduce access to energy efficient appliances, heightening thermal inequity (Moore *et al* 2016). Occupation may also exacerbate thermal inequity. For example, trade workers who spend extended periods of time outdoors can be exposed to dangerous levels of heat (Ohs Reps 2015).

The Australian Bureau of Statistics (ABS) has developed the Socio-Economic Indices for Areas (SEIFA) to assess comparative disadvantage (Australian Bureau of Statistics 2014). We assessed SEIFA in the study area using a geographic information system. Pockets of concentrated disadvantage exist within Upper Coomera (figure 2), as well as broader

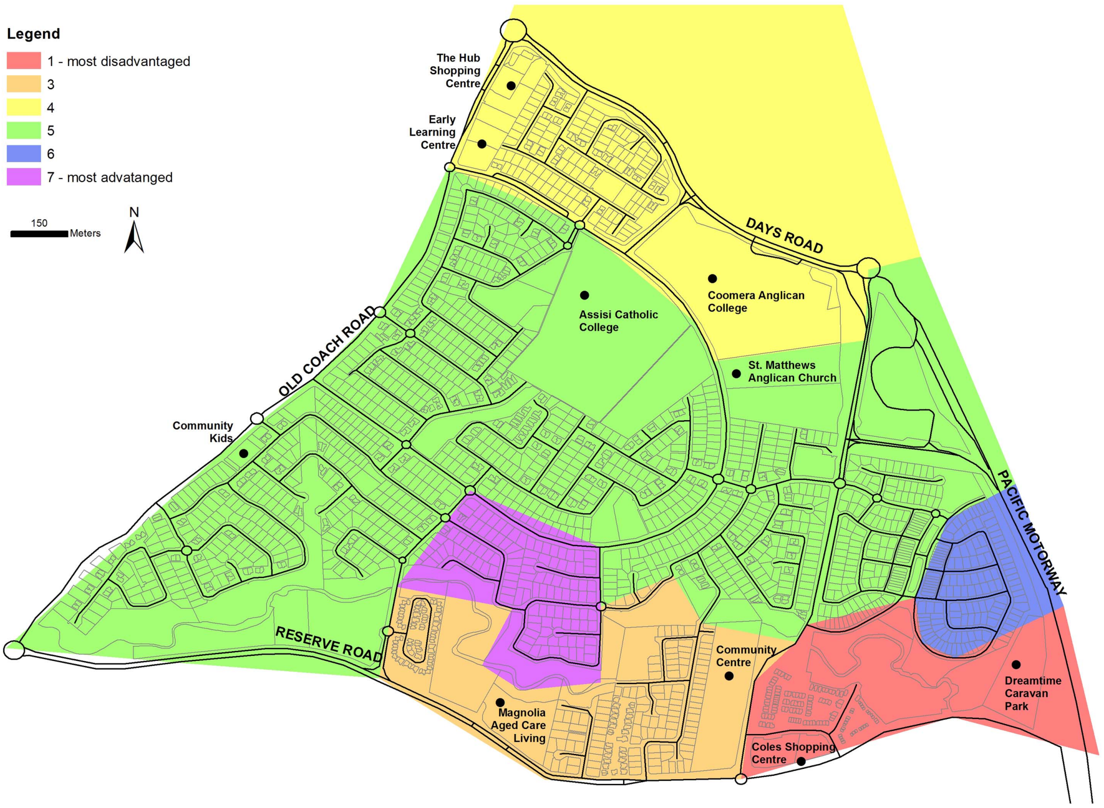

Figure 2. Relative disadvantage within the Upper Coomera study area.

areas of comparative disadvantage (with some pockets of comparative advantage). Compared to the state average, Upper Coomera exhibits fewer residents with ‘white collar’ jobs and more technical and trade workers (Australian Bureau of Statistics 2013). Based on the aforementioned criteria, the study area can reasonably be characterised as possessing many of the key socio-demographic indicators of thermal inequity.

2.1.2. Built environment characteristics of the study area

Absorption of solar energy on roofs is influenced by roofing colour and material and is a key factor in determining the intensity of the urban heat island effect (Watkins *et al* 2007, p 90). So too are reduced tree canopy cover, smaller lot sizes, built form, and higher population density. Energy consumption within individual buildings is affected by design. The energy efficiency of a dwelling can, in turn, affect the health of its residents (Younger *et al* 2008, p 520). We assessed the composition of roof colour in the study area using high-resolution aerial photographs. The built form of the study area is comprised of mainly detached brick-veneer houses with tile roofs (68% of the building stock), which line narrow interlinking streets. Almost a fifth (17%), of the dwelling stock is comprised of duplexes, positioned on the corners of culs-de-sac. There are also three townhouse complexes (14%) and several low-rise apartment buildings (1%), dispersed throughout the study area. A third (34%) of residential buildings in the study area have dark roofs. Based on this assessment, the study area contains built environment features (higher density dwellings with brick construction and dark roofs) that, when combined with social disadvantage, can produce thermal inequity.

2.2. Survey design

A mail-back survey was undertaken in collaboration with the City of Gold Coast Council. The survey instrument was adapted from a previous study by Byrne *et al* (2015), which focused on parks and long-term climate change impacts in Hangzhou, China. That study examined similar issues that we sought to assess. The modified survey instrument consisted of 43 questions, divided into four parts: (i) urban greening, (ii) views of climate change, (iii) use of neighbourhood parks, and (iv) socio-demographic measures. The instrument included measures for walkability, neighbourhood support, environmental values and a thermal comfort index. Questions measuring energy use, energy type, and energy efficiency were included. An intercept pilot survey was conducted to test instrument efficacy, and the pilot data were used to check measures. Completion time was estimated between 15 and 18 min. The research protocol was approved by the home institution’s Human Research Ethics Committee (ENV/07/15/HREC).

Table 1. Socio-demographic characteristics of respondents and the study area.

Variables	Study area	Social Atlas 2011	GIS data	p-value[1]
Age				
Median	44 years	27 years		
Range	16–80 years	0–85 years		$<0.001^{**}$
Sex				
Female	69.6%	51.8%		$<0.001^{**}$
Male	30.4%	48.2%		
Education				
No qualifications	62.3%	59.7%		0.437
Qualifications	37.7%	40.3%		
Income				
Median	$71 499.50	$75 192.00		
Low income	13.7%	12.3%[2]		0.044^{*}
Middle income	62.6%	55.4%[2]		
High income	23.6%	32.3%[2]		
Tenure				
Owned by you or your family	60.3%	37.4%		$<0.001^{**}$
Rented	39.7%	62.6%		
Household type				
Detached house	69.5%		68.2%	0.216
Duplex	19.9%		17.1%	
Townhouse	9.7%		14.1%	
Apartment	0.9%		0.6%	
Household composition				
Single households	8.5%	12.6%		0.176
Family households	86.6%	82.5%		
Group households	4.9%	4.9%		
People per household				
Average	2.9	3.2		
Range	1–6 people			
Children				
Have children under 18 years	40.5%	57.0%		$<0.001^{**}$
Otherwise	59.5%	43.0%		
Roof colour				
White	3.8%		6.2%	0.318
Lightly coloured	62.3%		59.5%	
Dark	34.0%		34.3%	
PV solar panels				
Yes	23.6%		14.8%	0.002^{*}
No	76.4%		85.2%	

The survey design, based on the Dillman technique, employed steps to increase response rates (Dillman *et al* 2012). A pre-notice letter was posted to all households in the study area. Next, the survey was distributed to letterboxes together with a cover letter encouraging residents to respond. Finally, a reminder postcard was mailed two weeks after the survey to thank respondents, as well as to remind non-respondents to complete the questionnaire. Surveys were distributed to all 1921 households in the study area, comprising a mix of single-family houses, duplexes (attached dwellings) and apartments.

The equation below illustrates the calculation of the ideal sample size (Selvanathan *et al* 2011),

$$n = \frac{z_{\alpha/2} \cdot p \cdot (1 - p)}{E^2},$$

where n is the sample size, $z_{\alpha/2}$ is the z-critical value (1.96) for a two-tailed test, p is the expected proportion (0.50 or 50% is used in lieu of knowledge regarding the

Table 2. Model 1—dependent variable: respondent's concern about climate change.

	Coefficient	Std. error	p-value	Marginal effect
Years of age	−0.308	0.131	0.019**	−0.074
Male	0.293	0.337	0.385	0.070
High school graduate	0.544	0.419	0.195	0.131
University student	0.559	0.650	0.389	0.134
University graduate	0.471	0.429	0.272	0.113
Renter	0.149	0.363	0.681	0.036
Duplex	1.151	0.454	0.011**	0.277
Townhouse/low rise apartment	−0.030	0.474	0.949	−0.007
Years of occupancy	−0.034	0.047	0.466	−0.008
Annual household income	−0.011	0.007	0.144	−0.003
Quarterly energy costs	0.068	0.094	0.469	0.016
Live alone	−1.000	0.616	0.104	−0.240*
Couple with no children	−0.994	0.472	0.035**	−0.239
Single parent with children	−0.582	0.446	0.193	−0.140
Multigenerational household	−0.495	0.767	0.519	−0.119
Unrelated adults	−1.829	0.856	0.033**	−0.440
Number of children	−0.341	0.202	0.091*	−0.082
Gas	0.739	0.332	0.026**	0.178
Solar hot water	0.163	0.464	0.725	0.039
PV solar panels	0.527	0.444	0.235	0.127
Insulation	−0.054	0.341	0.874	−0.013
Energy efficient lighting	−0.641	0.344	0.062*	−0.154
Roof ventilation	−0.595	0.423	0.159	−0.143
Energy efficient appliances	0.896	0.292	0.002**	0.215
Pool	−0.438	0.443	0.322	−0.105
Dark roof	−1.203	0.352	0.001**	−0.289
Ecocentric	−0.166	0.181	0.358	−0.040
Anthropocentric	0.369	0.215	0.086*	0.089
Prob > χ^2	0.0209			
Pseudo R^2	0.3185			
Wald χ^2 (28)	45.23			
Observations	131			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

expected proportion (this conservative approach maximises the standard deviation of the estimate of p)) and E is the error of estimation (±0.05 or ±5%). The target size for a sample of residents from Upper Coomera was 196. A total of 230 surveys were returned during the 37 day survey collection period, yielding a 12% response rate. A suitable sample size was thus achieved.

Some limitations must be acknowledged. Self-selection bias is inherent in mail-back surveys. Respondents are not randomly selected and there are a greater number of non-responses (Veal 1992). The sample had a higher proportion of female respondents, an older median age, and fewer renters when compared with Australian Census data (see table 1). Relative disadvantage in the suburb may thus be higher than captured by the survey. Minor wording issues were found in the survey instrument. For one question, a number of mature aged respondents incorrectly checked 'high school student' as the highest level of educational attainment, misunderstanding the response options.

2.3. Analysis

Data were entered into Survey Monkey and then exported into SPSS (v.22) and Stata/IC (v.13) for analysis. Following Field (2009), the chi-square goodness of fit test was used to determine the representativeness of the survey data for the study area (see table 1). Ordinary least squares and probit regressions were used in the analysis. The use of probit regression appreciates the binary nature of many of the dependent variables, often taking a value of 0 or 1. Variance inflation factors were found to be below the conventional rule of thumb of 10, allaying any concerns about multicollinearity among the independent variables.

3. Results

Using the survey data, we examined residents' awareness of climate change impacts and perceived efficacy of various responses, energy use, thermal comfort and disposition towards green infrastructure (e.g. street trees, parks, urban greenery). Nine probit models were

Table 3. Model 2—dependent variable: suggestion to insulate dwelling as climate response.

	Coefficient	Std. error	*p*-value	Marginal effect
Years of age	−0.108	0.114	0.341	−0.031
Male	0.399	0.332	0.229	0.116
High school graduate	0.176	0.385	0.646	0.051
University student	0.585	0.568	0.303	0.169
University graduate	0.721	0.418	0.084*	0.209
Renter	−0.528	0.337	0.117	−0.153
Duplex	0.238	0.353	0.500	0.069
Townhouse/low rise apartment	−0.425	0.447	0.342	−0.123
Years of occupancy	0.011	0.041	0.795	0.003
Annual household income	−0.014	0.006	0.029**	−0.004
Quarterly energy costs	−0.086	0.084	0.307	−0.025
Live alone	−0.030	0.639	0.962	−0.009
Couple with no children	−0.400	0.430	0.352	−0.116
Single parent with children	0.804	0.543	0.139	0.233
Multigenerational household	−0.831	0.534	0.120	−0.240
Unrelated adults	−0.457	0.680	0.501	−0.132
Number of children	−0.124	0.168	0.459	−0.036
Gas	0.298	0.301	0.322	0.086
Solar hot water	0.485	0.394	0.219	0.140
PV solar panels	0.267	0.404	0.508	0.077
Insulation	0.807	0.319	0.012**	0.234
Energy efficient lighting	−0.271	0.319	0.397	−0.078
Roof ventilation	0.249	0.387	0.521	0.072
Energy efficient appliances	−0.034	0.280	0.903	−0.010
Pool	−0.193	0.377	0.609	−0.056
Dark roof	0.041	0.308	0.895	0.012
Ecocentric	−0.238	0.165	0.150	−0.069
Anthropocentric	0.267	0.168	0.112	0.077*
Prob > χ^2	0.0048			
Pseudo R^2	0.2292			
Wald χ^2 (28)	51.18			
Observations	131			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

employed to better understand what factors or variables may underpin or explain differences in respondents': (i) concern about climate change, (ii) perceptions of effective climate change responses, (iii) energy security, and (iv) energy consumption and how these vary with respondents' socio-demographic characteristics, environmental values, and dwelling type. Marginal effects are reported throughout the paper and are interpreted in terms of a percentage change in the likelihood of reporting the dependent variable outcome for a one-unit or discrete change (for example, from 0 to 1) in the independent variable. For instance, table 2 column 1 indicates that a one-unit increase in a resident's years of age (where one unit is 10 years of age) is associated with a 7.4% reduction in the likelihood of reporting that they are concerned about climate change (all things being equal).

Model 1 (see table 2) sought to establish the characteristics of respondents who were more concerned about climate change. The results show that individuals living in duplexes, households with energy efficient appliances or supplied with natural gas, and people with a greater degree of anthropocentric belief (instrumental view of nature), are *more likely* to be worried about climate change. In contrast, households with unrelated adults, individuals living alone, couples with no children, and those with an extra 10 years of age, are *less likely* to be worried about climate change. Households with dark roofs or energy efficient lighting, and those who have an additional child, are also *less likely* to be worried about climate change. It may the case that this result reflects that people who are more concerned about climate change are already taking action to protect themselves against expected impacts.

Model 2 (table 3) explored the characteristics of respondents linked to a respondent's inclination to insulate their dwelling as a climate change response. The model shows university students, households with insulation, or individuals with more anthropocentric values (p-value $= 0.112$) are *more likely* to suggest insulating their dwelling. In comparison, individuals who have an additional \$1000 in annual household income are 0.4% *less likely* to suggest

Table 4. Model 3—dependent variable: suggestion for energy efficient appliances as climate response.

	Coefficient	Std. error	p-value	Marginal effect
Years of age	−0.127	0.117	0.279	−0.028
Male	−0.597	0.372	0.108	-0.132^{*}
High school graduate	0.342	0.400	0.394	0.076
University student	−0.016	0.540	0.977	−0.003
University graduate	1.131	0.503	0.024^{**}	0.251
Renter	0.534	0.387	0.167	0.118
Duplex	−0.261	0.373	0.484	−0.058
Townhouse/low rise apartment	−1.262	0.528	0.017^{**}	−0.280
Years of occupancy	0.065	0.049	0.189	0.014
Annual household income	−0.003	0.007	0.633	−0.001
Quarterly energy costs	−0.112	0.094	0.233	−0.025
Live alone	−0.346	0.711	0.626	−0.077
Couple with no children	−0.526	0.522	0.314	−0.117
Single parent with children	0.058	0.485	0.905	0.013
Multigenerational household	−0.844	0.583	0.148	−0.187
Unrelated adults	−1.010	0.717	0.159	−0.224
Number of children	−0.281	0.173	0.103	−0.062
Gas	0.103	0.384	0.788	0.023
Solar hot water	0.204	0.496	0.681	0.045
PV solar panels	−0.374	0.500	0.454	−0.083
Insulation	0.953	0.342	0.005^{**}	0.211
Energy efficient lighting	0.002	0.361	0.995	0.000
Roof ventilation	0.799	0.523	0.126	0.177
Energy efficient appliances	0.475	0.300	0.113	0.105^{*}
Pool	1.206	0.480	0.012^{**}	0.268
Dark roof	−0.189	0.344	0.584	−0.042
Ecocentric	−0.064	0.193	0.742	−0.014
Anthropocentric	0.402	0.193	0.037^{**}	0.089
Prob $> \chi^2$	0.0206			
Pseudo R^2	0.2854			
Wald χ^2 (28)	45.29			
Observations	131			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

insulating their dwelling. This is a statistically significant, albeit marginal difference, which suggests that wealthier people may either already have insulation, or can afford to do without it (perhaps because they are well-placed to bear the costs associated with running their air-conditioning).

Model 3 (table 4) investigated the relationship between respondents' inclination to buy energy efficient appliances as a climate change response and those characteristics of a respondent thought to potentially have a bearing on a respondent's answer. University graduates, individuals with a pool/spa or insulation, as well as those who have a higher degree of anthropocentric belief are *more likely* to suggest buying energy efficient appliances. However, males (p-value = 0.108), individuals living in townhouses, and those who have an additional child in the household (p-value = 0.103), are *less likely* to suggest buying energy efficient appliances. This finding could be attributable to comparatively less wealthy residents being unable to afford energy efficient appliances, given other more salient competing demands (e.g. child-rearing, mortgage payments). It is also possible that an individual's wealth, which is often tied to housing, as distinct from income, is incompletely captured by the income variable.

Model 4 (table 5), identified factors that may dispose respondents to suggest using fans instead of air conditioners as a climate adaptive response. Results indicate that males and individuals with solar hot water (p-value = 0.107) or roof ventilation are *more likely* to suggest using fans instead of air conditioners. Conversely, couples with no children, single parents and respondents who have an additional child in the household are less likely to suggest using fans. Households with a pool/spa, individuals with an extra 10 years of age, and those who spend an additional $100 on energy per quarter (p-value = 0.110) are also *less likely* to suggest using fans instead of air conditioning. Awareness may play a role here, with individuals already taking adaptive responses being more likely to take further adaptive actions.

Model 5 (table 6) examined the characteristics of respondents who are receptive to having a light-

Table 5. Model 4—dependent variable: suggestion for fans instead of air conditioners as climate response.

	Coefficient	Std. error	p−value	Marginal effect
Years of age	−0.203	0.115	0.077*	−0.058
Male	0.628	0.300	0.037**	0.178
High school graduate	0.624	0.439	0.155	0.177
University student	0.618	0.523	0.237	0.175
University graduate	0.203	0.421	0.630	0.057
Renter	−0.474	0.341	0.164	−0.1344
Duplex	0.084	0.340	0.806	0.024
Townhouse/low rise apartment	0.071	0.466	0.879	0.020
Years of occupancy	0.045	0.046	0.322	0.0128
Annual household income	−0.002	0.007	0.801	0.000
Quarterly energy costs	−0.138	0.086	0.110	−0.039*
Live alone	−0.070	0.630	0.912	−0.020
Couple with no children	−1.092	0.462	0.018**	−0.309
Single parent with children	−0.748	0.417	0.073*	−0.212
Multigenerational household	−0.681	0.516	0.187	−0.193
Unrelated adults	−1.328	0.731	0.069*	−0.376
Number of children	−0.454	0.195	0.020**	−0.128
Gas	0.236	0.311	0.447	0.067
Solar hot water	0.608	0.377	0.107	0.172*
PV solar panels	0.312	0.369	0.398	0.088
Insulation	−0.117	0.324	0.718	−0.033
Energy efficient lighting	−0.404	0.327	0.216	−0.114
Roof ventilation	0.674	0.359	0.061*	0.191
Energy efficient appliances	0.343	0.281	0.223	0.097
Pool	−1.197	0.450	0.008**	−0.339
Dark roof	−0.136	0.298	0.648	−0.039
Ecocentric	−0.107	0.154	0.485	−0.030
Anthropocentric	−0.038	0.175	0.827	−0.011
Prob > χ^2	0.0096			
Pseudo R^2	0.2603			
Wald χ^2 (28)	48.45			
Observations	131			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

coloured roof as a climate change adaptation. Individuals with solar hot water or roof ventilation (p-value = 0.120) are *more likely* to suggest using light-coloured roofs, whereas university students (p-value = 0.102) are *less likely* to suggest such an intervention. The results show that respondents' implementing other energy efficiency measures are more likely to suggest having light-coloured roofs as an adaptive response to climate change, perhaps because they are pre-disposed to taking energy efficiency actions. While university students may be more aware of climate change impacts (Wachholz *et al* 2014), they often face financial stress (whether living with their parents or renting), and/or may have less personal investment in a property, potentially impacting their receptiveness to this intervention (Watson *et al* 2015).

Model 6 (table 7) examined the characteristics of respondents associated with an inclination to use photo voltaic (PV) solar panels as an adaptive response. The model shows that individuals with a pool/spa, roof ventilation and solar hot water (p-value = 0.108), as well as those occupying their home for an additional year, are *more likely* to have solar panels. On the other hand, individuals who spend an extra $100 on energy per quarter are less likely to have solar panels. Renters would be unlikely to install photovoltaic solar panels because they do not own the dwelling. Homeownership is typically necessary for solar panel installation due to necessary property rights for modifying a dwelling and to the ability to access finance (O'Doherty *et al* 2008, Parkinson *et al* 2009). Further, some households with a pool (and likely higher wealth) may be acting to offset operating and maintenance expenses by installing PV panels. Households who are unable to afford energy efficiency measures are likely to incur higher energy expenses, potentially limiting their disposable income available for adaptive responses such as PV solar panels.

Model 7 (table 8) investigated the characteristics of respondents associated with the use of insulation in their dwellings. The results indicate that individuals occupying their home for an additional year are 2.18%

Table 6. Model 5—dependent variable: suggestion for light-coloured roofs as climate response.

	Coefficient	Std. error	p-value	Marginal effect
Years of age	−0.129	0.113	0.252	−0.033
Male	0.500	0.321	0.120	0.126
High school graduate	−0.283	0.431	0.512	−0.071
University student	−0.815	0.499	0.102	−0.206*
University graduate	−0.430	0.458	0.347	−0.108
Renter	−0.290	0.365	0.428	−0.073
Duplex	−0.053	0.346	0.878	−0.013
Townhouse/low rise apartment	−0.577	0.633	0.362	−0.145
Years of occupancy	−0.058	0.042	0.168	−0.015
Annual household income	−0.010	0.007	0.157	−0.003
Quarterly energy costs	−0.100	0.080	0.211	−0.025
Live alone	−0.232	0.558	0.677	−0.059
Couple with no children	−0.245	0.439	0.577	−0.062
Single parent with children	0.608	0.463	0.190	0.153
Multigenerational household	0.201	0.527	0.703	0.051
Number of children	−0.213	0.153	0.164	−0.054
Gas	−0.162	0.315	0.608	−0.041
Solar hot water	1.342	0.379	0.000***	0.338
PV solar panels	0.010	0.358	0.979	0.002
Insulation	0.391	0.357	0.273	0.099
Energy efficient lighting	−0.485	0.339	0.152	−0.122
Roof ventilation	0.576	0.371	0.120	0.145*
Energy efficient appliances	0.032	0.301	0.916	0.008
Pool	−0.276	0.421	0.513	−0.070
Dark roof	−0.091	0.318	0.774	−0.023
Ecocentric	−0.002	0.172	0.993	0.000
Anthropocentric	−0.210	0.175	0.231	−0.053
Prob > χ^2	0.0242			
Pseudo R^2	0.2131			
Wald χ^2 (27)	43.33			
Observations	131			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

more likely to have insulation. While university graduates (p-value = 0.102), renters, households with unrelated adults, individuals who have an additional child in the household, or those who spend an extra $100 on energy per quarter are *less likely* to have insulation. These findings broadly support those of Model 2 and Model 5 relating to a respondent's inclination to respectively insulate their dwelling and to have a light coloured roof, as a climate-adaptive response. Comparatively more disadvantaged households with lower disposable income appear to be located in dwellings that are more vulnerable to heat.

Model 8 (table 9) sought to reveal the characteristics of respondents that are associated with a respondent's energy demand, specifically dependence upon grid electricity and the use of a pool or spa. Model 8 addresses the issue of energy security by focusing on respondents who only use grid electricity. Results generally support the findings from Model 7. The model shows that males, individuals who live in duplexes, and those who spend an extra $100 on energy per quarter are *more likely* to only use grid electricity. However, individuals with a pool or spa are 37% less likely to only use grid electricity. Because households with higher energy costs seem more likely to be restricted to grid electricity, this raises concerns about energy security problems facing renters and lower-income households. They may be especially vulnerable to rising electricity costs—particularly if they reside in a dwelling with low thermal efficiency—and thus may be unable to afford to cool their dwellings (Moore *et al* 2016).

The final regression, Model 9 (table 10) assessed which variables may be associated with a respondent's use of a pool or spa. Results show that high school graduates, individuals with an extra 10 years of age, and those occupying their home for an additional year (1%), are *more likely* to have a pool or spa. Likewise, individuals living in townhouses, households with PV solar panels or dark roofs are also *more likely*. In contrast, renters, individuals who live in duplexes, and households with solar hot water are *less likely* to have a pool or spa. Some owner-occupiers and renters of low-rise apartments may have access to a pool that is

Table 7. Model 6—dependent variable: actual use of PV solar panels.

	Coefficient	Std. error	*p*-value	Marginal effect
Years of age	0.159	0.149	0.285	0.031
Male	0.186	0.352	0.597	0.036
High school graduate	0.371	0.423	0.380	0.072
University student	0.550	0.463	0.235	0.106
University graduate	0.118	0.473	0.802	0.023
Duplex	−0.316	0.342	0.355	−0.061
Years of occupancy	0.093	0.038	0.015**	0.018
Annual household income	0.005	0.007	0.492	0.001
Quarterly energy costs	−0.353	0.106	0.001**	−0.068
Live alone	−0.093	0.604	0.877	−0.018
Couple with no children	0.037	0.487	0.939	0.007
Single parent with children	0.351	0.517	0.497	0.068
Multigenerational household	0.429	0.559	0.442	0.083
Number of children	0.207	0.198	0.297	0.040
Gas	−0.211	0.357	0.555	−0.041
Solar hot water	0.790	0.492	0.108	0.153*
Insulation	0.286	0.350	0.413	0.055
Energy efficient lighting	−0.405	0.362	0.263	−0.078
Roof ventilation	0.892	0.344	0.009**	0.172
Energy efficient appliances	0.041	0.328	0.901	0.008
Pool	0.980	0.421	0.020**	0.189
Dark roof	−0.111	0.378	0.769	−0.021
Ecocentric	0.231	0.159	0.145	0.045
Anthropocentric	0.167	0.256	0.515	0.032
Prob $> \chi^2$	0.0145			
Pseudo R^2	0.3416			
Wald χ^2 (24)	41.54			
Observations	138			

*Significance at 0.10 level; **Significance at 0.05 level; ***Significance at 0.01 level.

on common property. Older respondents appear *more likely* to be homeowners, and thus to have a pool. The literature suggests that education may be strongly related to awareness of climate change (Lee *et al* 2015), and those respondents with only a high-school education may not have made dwelling-choices with energy efficiency and/or climate change in mind.

It is important to note here the disposition of respondents towards urban greening as a potential climate adaptation response (table 11). We found that almost two-thirds of respondents either agreed (36.2%) or strongly agreed (27.7%) with the statement that more tree planting should occur in local parks and streets, and over half either disagreed (37.35) or strongly disagreed (23.2%) with the statement that there is sufficient shade on local streets.

We also examined respondents' perceptions of the benefits and costs of trees (table 12). Many respondents reported shade (90%) as a benefit and over half (52.5%) reported temperature reduction as a perceived benefit. Most respondents (71.2%) perceived maintenance costs as a perceived disadvantage of trees. As noted above, a potential policy response to urban heat is to deploy various forms of green infrastructure to cool direct and ambient temperatures in built environments. There appears to be strong support among respondents for urban greening.

4. Discussion and concluding comments

This research sought to determine whether thermal inequity might exist in an Australian suburb, extending environmental justice research from North America (Mitchell and Chakraborty 2014, Mitchell and Chakraborty 2015) based primarily upon higher density and inner-city locales (Jesdale *et al* 2013). We tested statistical associations between indicators of social disadvantage and measures of climate change awareness, concern and perceived efficacy in adapting to impacts, as well as residents' energy expenditure, perceived thermal comfort, and disposition towards use of green infrastructure as a policy intervention to lessen heat in built environments.

Respondents were very aware of climate change; many expressed concern about anticipated impacts. As temperatures increase due to climate change, more suburban households in the case study area will likely experience thermal discomfort (Holmes and Hacker 2007). An expected response would be the use of air-conditioning for cooling and thermal comfort.

Table 8. Model 7—dependent variable: actual use of insulation.

	Coefficient	Std. error	*p*-value	Marginal effect
Years of age	0.027	0.103	0.795	0.006
Male	0.389	0.304	0.200	0.089
High school graduate	−0.059	0.413	0.885	−0.014
University student	0.512	0.553	0.355	0.118
University graduate	−0.722	0.442	0.102	−0.166*
Renter	−1.039	0.357	0.004**	−0.2389
Duplex	−0.138	0.353	0.695	−0.032
Townhouse/low rise apartment	0.329	0.455	0.470	0.076
Years of occupancy	0.095	0.047	0.045**	0.0218
Annual household income	0.001	0.007	0.941	0.000
Quarterly energy costs	−0.130	0.075	0.083*	−0.030
Couple with no children	−0.593	0.414	0.153	−0.136
Single parent with children	0.114	0.524	0.828	0.026
Multigenerational household	−0.487	0.512	0.342	−0.112
Unrelated adults	−1.616	0.671	0.016**	−0.372
Number of children	−0.274	0.164	0.094*	−0.063
Gas	0.287	0.332	0.387	0.066
Solar hot water	0.534	0.604	0.377	0.123
PV solar panels	−0.371	0.393	0.345	−0.085
Energy efficient lighting	−0.338	0.313	0.281	−0.078
Roof ventilation	0.164	0.349	0.638	0.038
Energy efficient appliances	0.034	0.277	0.902	0.008
Pool	0.021	0.397	0.959	0.005
Dark roof	−0.004	0.284	0.988	−0.001
Ecocentric	0.083	0.160	0.604	0.019
Anthropocentric	0.075	0.198	0.706	0.017
Prob $> \chi^2$	0.0168			
Pseudo R^2	0.2612			
Wald χ^2 (26)	43.58			
Observations	137			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

Indeed, there is already a 93% uptake of air-conditioning in the study area. But this response could be maladaptive for disadvantaged households. Increasing electricity prices (associated with upgrading distribution networks for peak demand and climate resilience) will likely widen an existing gap between those who can afford to run air-conditioning and those who cannot (Nierop 2014, Powells *et al* 2014).

We expected to find a relationship between income, energy security, family composition, and home ownership. Poorer people are often renters rather than owners (and may be more likely to live in low-rise apartments). For those with children, raising a child is financially demanding and can be associated with comparative financial disadvantage, especially for single parents (Cutter 2006). Poor households are more likely to be energy insecure (Byrne and Portanger 2014). Older and wealthier residents (often home-owners) may choose to use air-conditioning for perceived thermal comfort benefits, despite operating costs. Those respondents with children may regard their child's health and wellbeing as more important than energy costs, and/or be concerned with getting a good night's sleep and/or preserving household routines. As such, these respondents may be less inclined to suggest using fans instead of air-conditioners, as has been found in recent Australian research (Nicholls and Strengers 2015).

Although we found that renters have lower annual incomes, there was no statistically significant difference for residents in a 'townhouse/low rise apartment'. Nor did we find a statistically significant relationship between dwelling type and household attitudes towards energy efficiency. These results may be due to renters having little control over the appliances installed in their dwellings; it is landlords who make that decision. Landlords may act to limit financial outlays and to maximise their rental returns, seeing limited value in installing high-end, energy efficient appliances that could be damaged by tenants. Operating costs are not their concern because they are passed onto tenants (who pay for electricity). So renters may have little experience of the benefits provided by energy efficient appliances, thus explaining the finding that they do not appear to regard such appliances as an efficacious climate change response.

Table 9. Model 8—dependent variable: grid electricity dependence.

	Coefficient	Std. error	*p*-value	Marginal effect
Years of age	−0.156	0.113	0.168	−0.046
Male	0.525	0.301	0.081^{*}	0.156
High school graduate	0.007	0.338	0.983	0.002
University student	−0.655	0.481	0.173	−0.194
University graduate	−0.135	0.374	0.718	−0.040
Renter	0.247	0.316	0.435	0.0733
Duplex	0.822	0.347	0.018^{**}	0.244
Townhouse/low rise apartment	0.261	0.417	0.531	0.077
Years of occupancy	−0.004	0.042	0.928	−0.0011
Annual household income	−0.009	0.006	0.157	−0.003
Quarterly energy costs	0.252	0.078	0.001^{**}	0.075
Live alone	−0.290	0.559	0.604	−0.086
Couple with no children	0.072	0.434	0.869	0.021
Single parent with children	0.006	0.460	0.989	0.002
Multigenerational household	−0.616	0.624	0.324	−0.183
Unrelated adults	0.872	0.794	0.272	0.259
Number of children	0.089	0.178	0.618	0.026
Insulation	−0.198	0.331	0.550	−0.059
Energy efficient lighting	0.212	0.315	0.501	0.063
Roof ventilation	−0.172	0.297	0.563	−0.051
Energy efficient appliances	0.236	0.259	0.362	0.070
Pool	−1.246	0.401	0.002^{**}	−0.370
Dark roof	−0.131	0.295	0.657	−0.039
Ecocentric	−0.046	0.151	0.760	−0.014
Anthropocentric	−0.180	0.181	0.320	−0.054
Prob $> \chi^2$	0.0020			
Pseudo R^2	0.2385			
Wald χ^2 (25)	50.21			
Observations	137			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

Our results suggest that there are already emergent social vulnerabilities to heat in Upper Coomera that will be potentially worsened by climate change. The suburb exhibits financially stressed renters, lower-income earners, trades-workers and people living in higher-density dwellings with dark roofs and no insulation. Tree canopy cover is low. This combination of social vulnerability and built form that traps heat can lead to heat stress. Heat-stress can have pernicious consequences, including increased morbidity and mortality (Maller and Strengers 2011). Studies have found that violence and aggression tend to increase during heatwaves (e.g. Smoyer-Tomic *et al* 2003). Our findings suggest the need to reduce energy expenditure for vulnerable residents, to maintain or improve levels of neighbourhood conviviality, and to help prevent avoidable illness and death. Using green infrastructure would be a logical policy response, although there may be challenges (Stone *et al* 2012, Battaglia *et al* 2014).

Green infrastructure offers a potential remedy to thermal inequality. International studies show that tree canopy cover can be lower in comparatively disadvantaged neighbourhoods, like the one we assessed (Landry and Chakraborty 2009, Jesdale *et al* 2013). Residents of such neighbourhoods may have less access to the ecosystem services, functions and benefits of trees (Schwarz *et al* 2015), although some researchers have found cases where tree canopy cover is higher in poorer neighbourhoods. Yet residents in disadvantaged neighbourhoods may be concerned about tree maintenance expenses (Heynen *et al* 2006). We found that parts of the study area are moderately disadvantaged, with higher levels of disadvantage in some pockets. Most survey respondents identified maintenance costs as their primary concern with trees, corroborating findings from the literature. But we also found most residents were in favour of more urban greening. The majority recognised that trees provide shade, although fewer linked this with temperature reduction and thermal comfort.

Using green infrastructure as a policy response could improve the thermal comfort of residents and assist in mitigating thermal inequity. For example, studies have found that the provision of parks in urban areas can reduce ambient temperatures and increase residents' thermal comfort (Jenerette *et al* 2011, Gaffin *et al* 2012, Norton *et al* 2015). Recent research from cities with subtropical and warm temperate climates

Table 10. Model 9—dependent variable: use of a pool or spa for thermal comfort.

	Coefficient	Std. error	*p*-value	Marginal effect
Years of age	0.314	0.159	0.048**	0.044
Male	−0.074	0.372	0.841	−0.010
High school graduate	1.352	0.471	0.004**	0.189
University graduate	−0.397	0.605	0.512	−0.056
Renter	−0.911	0.501	0.069*	−0.128
Duplex	−1.782	0.647	0.006**	−0.2497
Townhouse/low rise apartment	1.220	0.561	0.030**	0.171
Years of occupancy	0.084	0.051	0.099*	0.012
Annual household income	0.008	0.008	0.315	0.0011
Quarterly energy costs	0.136	0.115	0.237	0.019
Couple with no children	−0.082	0.500	0.870	−0.011
Multigenerational household	0.852	0.661	0.197	0.119
Number of children	−0.098	0.214	0.647	−0.014
Gas	0.558	0.381	0.143	0.078
Solar hot water	−1.138	0.669	0.089*	−0.159
PV solar panels	1.202	0.456	0.008**	0.168
Insulation	0.210	0.503	0.677	0.029
Energy efficient lighting	0.220	0.465	0.635	0.031
Roof ventilation	0.294	0.420	0.484	0.041
Energy efficient appliances	−0.360	0.381	0.345	−0.050
Dark roof	1.000	0.403	0.013**	0.140
Ecocentric	−0.024	0.188	0.897	−0.003
Anthropocentric	0.039	0.246	0.873	0.005
Prob > χ^2	0.0005			
Pseudo R^2	0.3986			
Wald χ^2 (23)	51.82			
Observations	137			

*Significance at 0.10 level; **significance at 0.05 level; ***significance at 0.01 level.

Table 11. Disposition towards urban greening ($n = 228$).

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
My neighbourhood has lots of greenery (e.g. trees)	15.4	**46.9**	25.4	11.4	0.9
My neighbourhood greenery is well maintained	7.9	**46**	25.9	14.5	5.7
I would like more tree planting in my local parks and streets[8]	27.7	**36.2**	26.9	7.9	1.3
My streets have enough shade on hot days	3.5	11.5	24.5	**37.3**	23.2
Trees in my neighbourhood make it beautiful	34.6	**38.1**	14.9	7.6	4.8
Large trees in neighbourhood damage streets and buildings	9.6	11.8	30.3	**32.9**	15.4

[8] For this measure $n = 227$. Scale reliability coefficient: 0.6518. Agreement reported in %.

suggests that parks can provide effective relief from heat, especially those with good tree canopy cover (Feyisa *et al* 2014, Byrne *et al* 2015). Our study found that survey respondents identified limited tree canopy cover as a problem with their local parks. Recent research has also demonstrated that urban greening can reduce temperatures, reduce wind speed, increase property values, lessen stress and anxiety, foster walking and cycling, mitigate flooding and calm traffic (Byrne *et al* 2015). However, less than half of survey respondents recognised these benefits.

Findings from our research point to the need for planners and tree managers to work with residents in Upper Coomera to help them appreciate the manifold advantages of urban greening. Targeted awareness raising campaigns and better citizen involvement in greening activities could yield positive dividends. The results also point to the need for comparative research, to ascertain whether our results are local particularities, or if disadvantaged residents in other cities might share similar perspectives and experiences. Our results suggest that thermal inequity is place-specific and context-dependent, manifesting differently based on built environment and socio-demographic characteristics. At the heart of thermal inequity and climate injustice is the disproportionate exposure of vulnerable communities that are least responsible for climate change and most unable to mitigate, or adapt to, its effects. A better comparative understanding of the drivers of thermal inequity at the local scale, the

Table 12. Perceived tree benefits and costs ($n = 221$).

Perceived tree benefits	Percent	Count
Provide shade	90.0%	199
Attract birds and wildlife	87.8%	194
Improve air quality	83.7%	185
Enhance neighbourhood beauty	79.2%	175
Improve scenery	78.7%	174
Add more oxygen	74.2%	164
Increase park use	70.1%	155
Reduce soil erosion	65.2%	144
Reduce pollution	52.9%	117
Reduce noise	52.9%	117
Reduce temperatures	52.5%	116
Improve people's health	49.3%	109
Make the area friendlier	46.2%	102
Reduce people's stress	43.9%	97
Increase property values	40.7%	90
Reduce wind speeds	36.7%	81
Facilitate walking/cycling	36.2%	80
Provide food	26.2%	58
Reduce flooding	20.8%	46
Make shopping more pleasant	18.6%	41
Improve neighbourhood safety	9.0%	20
Reduce car accidents	2.7%	6
Other	3.6%	8
Perceived tree costs		
Increase maintenance costs	71.2%	146
Damage footpaths	39.5%	81
Attract pests	36.1%	74
Increase risk of fire	33.7%	69
Increase storm damage	32.7%	67
Increase rates	31.7%	65
Cause allergies	27.8%	57
Attract nuisance wildlife	23.4%	48
Reduce sunlight	22.4%	46
Increase insurance costs	19.5%	40
Increase crime	13.2%	27
Increase asthma	13.2%	27
Increase traffic accidents	11.7%	24
Other (please specify)	7.8%	16
Reduce cooling breezes	4.4%	9
Make places too cold	3.9%	8
Reduce people use of parks	2.0%	4
Make people walk and cycle less	1.0%	2
Make areas less friendly	1.0%	2

efficacy of potential policy remedies in different places, and whether there are common barriers to urban greening is essential, if we are to develop climate justice in cities.

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References

Adger W N 2001 Scales of governance and environmental justice for adaptation and mitigation of climate change *J. Int. Dev.* **13** 921–31

Australian Bureau of Statistics 2014 *The Index of Relative Socio-Economic Advantage and Disadvantage* (*IRSAD*) (www.abs.gov.au/ausstats/abs@.nsf/Lookup/2033.0.55.001main+features100052011) (Accessed: 29 August 2016)

Australian Bureau of Statistics 2013 2011 *Census QuickStats—Upper Coomera Community Profile* (http://censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/SSC31686) (Accessed: 16 August 2016)

Battaglia M, Buckley G L, Galvin M and Grove J M 2014 It's not easy going green: obstacles to tree-planing programs in East Baltimore *Cities Environ.* **7** 6 (www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_battaglia_001.pdf) (Accessed: 29 August 2016)

Brunner J and Cozens P 2013 'Where have all the trees gone?'Urban consolidation and the demise of urban vegetation: a case study from Western Australia *Plan. Pract. Res.* **28** 231–55

Bulkeley H, Edwards G S and Fuller S 2014 Contesting climate justice in the city: examining politics and practice in urban climate change experiments *Glob. Environ. Change* **25** 31–40

Byrne J, Lo A Y and Jianjun Y 2015 Residents' understanding of the role of green infrastructure for climate change adaptation in Hangzhou, China *Landscape Urban Plan.* **138** 132–43

Byrne J and Portanger C 2014 Climate change, energy policy and justice: a systematic review *Anal. Kritik* **36** 315–43

Centers for Disease Control and Prevention 2015 *Heat Stress in Older Adults* US Department of Health & Human Services (http://emergency.cdc.gov/disasters/extremeheat/older-adults-heat.asp) (Accessed: 16 August 2016)

Chen M, Zhang H, Liu W and Zhang W 2014 The global pattern of urbanization and economic growth: evidence from the last three decades *PloS One* **9** e103799

Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2016 Climate Change in Australia: Projections for Australia's NRM Regions. Analogues Explorer (http://climatechangeinaustralia.gov.au/en/climate-projections/climate-analogues/analogues-explorer/) (Accessed: 16 August 2016)

Cutter S L 2006 *Hazards, Vulnerability and Environmental Justice* (London: Earthscan)

Department of Natural Resources and Mines 2015 *Draft City Plan Interactive Mapping* (online) Council of the City of the Gold Coast (http://cityplanmaps.goldcoast.qld.gov.au/CityPlan/index.html) (Accessed: 16 August 2016)

Dillman D, D De Leeuw E and Hox J 2012 *International Handbook of Survey Methodology* (London: Routledge)

Duus-Otterstrom G and Jagers S C 2012 Identifying burdens of coping with climate change: a typology of the duties of climate justice *Glob. Environ. Change* **22** 746–53

Feyisa G L, Dons K and Meilby H 2014 Efficiency of parks in mitigating urban heat island effect: an example from Addis Ababa *Landscape Urban Plan.* **123** 87–95

Field A 2009 *Discovering Statistics Using SPSS* 3rd edn (London: SAGE Publications Ltd)

Gaffen D J and Ross R J 1998 Increased summertime heat stress in the US *Nature* **396** 529–30

Gaffin S R, Rosenzweig C and Kong A Y 2012 Adapting to climate change through urban green infrastructure *Nat. Clim. Change* **2** 704–704

Gill S E, Handley J F, Ennos A R and Pauleit S 2007 Adapting cities for climate change: the role of the green infrastructure *Built Environ.* **33** 115–33

2011a Gold Coast City Council (www.goldcoast.qld.gov.au/gcplanningscheme_1111/maps_local_area.html#90) (Accessed: 29 August 2016)

Gold Coast City Council 2011b Urban greenspace 2030: Improving our community, environment and economy through quality parks and streetscapes Draft Version

Granger K and Hayne M (ed) 2001 *Natural Hazards and the Risks they Pose to South-East Queensland* (Canberra: Geoscience Australia) (http://ga.gov.au/webtemp/image_cache/GA4218.pdf) (Accessed: 16 August 2016)

Hamin E M and Gurran N 2009 Urban form and climate change: balancing adaptation and mitigation in the US and Australia *Habitat Int.* **33** 238–45

Harlan S L, Brazel A J, Jenerette G D, Jones N S, Larsen L, Prashad L and Stefanov W L 2007 In the shade of affluence: the inequitable distribution of the urban heat island *Res. Soc. Problems Public Policy* **15** 173–202 (www.emeraldinsight.com/doi/abs/10.1016/S0196-1152%2807%2915005-5) (Accessed: 29 August 2016)

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 Rev.* **42** 3–25

Holmes M J and Hacker J N 2007 Climate change, thermal comfort and energy: meeting the design challenges of the 21st century *Energy Build.* **39** 802–14

Jenerette G D, Harlan S L, Stefanov W L and Martin C A 2011 Ecosystem services and urban heat riskscape moderation: water, green spaces, and social inequality in Phoenix, USA *Ecol. Appl.* **21** 2637–51

Jesdale B M, Morello-Frosch R and Cushing L 2013 The racial/ethnic distribution of heat risk-related land cover in relation to residential segregation *Environ. Health Perspect.* **121** 811

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 Urban Plan.* **107** 147–58

Lafortezza R, Carrus G, Sanesi G and Davies C 2009 Benefits and well-being perceived by people visiting green spaces in periods of heat stress *Urban Forestry Urban Greening* **8** 97–108

Landry S M and Chakraborty J 2009 Street trees and equity: evaluating the spatial distribution of an urban amenity *Environ. Plan.* A **41** 2651–70

Lee T M, Markowitz E M, Howe P D, Ko C-Y and Leiserowitz A A 2015 Predictors of public climate change awareness and risk perception around the world *Nat. Clim. Change* **5** 1014–20

Maller C J and Strengers Y 2011 Housing, heat stress and health in a changing climate: promoting the adaptive capacity of vulnerable households, a suggested way forward *Health Promotion Int.* **26** 492–8

Mccarthy M P, Best M J and Betts R A 2010 Climate change in cities due to global warming and urban effects *Geophys. Res. Lett.* **37** L09705

Mcgeehin M A and Mirabelli M 2001 The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States *Environ. Health Perspect.* **109** 185

Mitchell B C and Chakraborty J 2014 Urban heat and climate justice: a landscape of thermal inequity in Pinellas County, Florida *Geographical Rev.* **104** 459–80

Mitchell B C and Chakraborty J 2015 Landscapes of thermal inequity: disproportionate exposure to urban heat in the three largest US cities *Environ. Res. Lett.* **10** 115005

Moore T, Ridley I, Strengers Y, Maller C and Horne R 2016 Dwelling performance and adaptive summer comfort in low-income Australian households *Building Res. Inform.* 1–14 (in press)

Nicholls L and Strengers Y 2015 Changing demand: flexibility of energy practices in households with children *Final Report* Australian PolicyOnline (http://apo.org.au/node/52993)

Nierop S C A 2014 Envisioning resilient electrical infrastructure: a policy framework for incorporating future climate change into electricity sector planning *Environ. Sci. Policy* **40** 78–84

Norton B A, Coutts A M, Livesley S J, Harris R J, Hunter A M and Williams N S 2015 Planning for cooler cities: a framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes *Landscape Urban Plan.* **134** 127–38

O'Doherty J, Lyons S and Tol R S 2008 Energy-using appliances and energy-saving features: determinants of ownership in Ireland *Appl. Energy* **85** 650–62

Ohs Reps 2015 Sunlight—Ultraviolet (UV) Radiation Victorian Trades Hall Council (http://ohsrep.org.au/hazards/radiation/sunlight-ultraviolet-uv-radiation) (Accessed: 16 August 2016)

Parkinson S, Searle B A, Smith S J, Stoakes A and Wood G 2009 Mortgage equity withdrawal in Australia and Britain: towards a wealth-fare state? *Eur. J. Housing Policy* **9** 365–89

Powells G, Bulkeley H, Bell S and Judson E 2014 Peak electricity demand and the flexibility of everyday life *Geoforum* **55** 43–52

Queensland Treasury 2015 Population growth highlights and trends, Queensland regions, 2015 edn The State of Queensland

Roberts L 2011 9 Billion? *Science* **333** 540–3

Schwarz K, Fragkias M, Boone C G, Zhou W, Mchale M, Grove J M, O'neil-Dunne J, Mcfadden J P, Buckley G L and Childers D 2015 Trees grow on money: urban tree canopy cover and environmental justice *PloS One* **10** e0122051

Selvanathan E, Selvanathan S and Keller G 2011 *Business Statistics Australia New Zealand* 5th edn (Melbourne: Cengage Learning)

Seto K C, Sánchez-Rodríguez R and Fragkias M 2010 The new geography of contemporary urbanization and the environment *Annu. Rev. Environ. Resour.* **35** 167–94

Shanahan D, Lin B, Gaston K, Bush R and Fuller R 2014 Socio-economic inequalities in access to nature on public and private lands: a case study from Brisbane, Australia *Landscape Urban Plan.* **130** 14–23

Smoyer-Tomic K E, Kuhn R and Hudson A 2003 Heat wave hazards: an overview of heat wave impacts in Canada *Nat. Hazards* **28** 465–86

Stone B, Vargo J and Habeeb D 2012 Managing climate change in cities: will climate action plans work? *Landscape Urban Plan.* **107** 263–71

Tong S, Wang X Y, Yu W, Chen D and Wang X 2014 The impact of heatwaves on mortality in Australia: a multicity study *BMJ Open* **4** e003579

Vardoulakis S, Dear K, Hajat S, Heaviside C and Eggen B 2014 Comparative assessment of the effects of climate change on heat-and cold-related mortality in the United Kingdom and Australia *Environ. Health Perspect.* **122** 1285–92

Veal A J 1992 *Research Methods for Leisure and Tourism* (Essex, England: Pearson Education)

Wachholz S, Artz N and Chene D 2014 Warming to the idea: university students' knowledge and attitudes about climate change *Int. J. Sustainability Higher Educ.* **15** 128–41

Watkins R, Palmer J and Kolokotroni M 2007 Increased temperature and intensification of the urban heat island: Implications for human comfort and urban design *Built Environ.* **33** 85–96

Watson S J, Barber B L and Dziurawiec S 2015 The role of economizing and financial strain in Australian university students' psychological well-being *J. Family Econ. Issues* **36** 421–33

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 Urban Plan.* **125** 234–44

Xiang J, Bi P, Pisaniello D and Hansen A 2014 The impact of heatwaves on workers' health and safety in Adelaide, South Australia *Environ. Res.* **133** 90–5

Younger M, Morrow-Almeida H R, Vindigni S M and Dannenberg A L 2008 The built environment, climate change, and health: opportunities for co-benefits *Am. J. Prevent. Med.* **35** 517–26