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A Comparison Of Disadvantage and Urban Heat Island Effect In Melbourne, Australia

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ABSTRACT

The Australian Bureau of Statistics' 2016 Index of Relative Socio-economic Disadvantage scores were compared against the urban heat island effect of all 27 'city' local government areas in metropolitan Melbourne in Victoria, Australia. It found a correlation (r^2 value of 0.4435) between disadvantage and urban heat.

15 of the 16 variables that generated the Index of Relative Socio-economic Disadvantage were then calculated and compared against the urban heat island effect for those same local government areas. It found correlations (r^2 values of more than 0.4) between urban heat and four variables including people with low household income.

The equivalised income of each household in those local government areas as reported in the Australian Bureau of Statistics' 2016 Census was then compared against the urban heat island effect. It found a strong correlation (r^2 value of 0.7405) between high incomes and low urban heat and vice versa. For example, households in the lowest bracket earning $1 to $7,799 each year live in an area with an urban heat island effect of 8.77ºC compared to 8.17ºC for households in the highest bracket earning $156,000 or more each year.

The implications for policymakers responsible for addressing urban heat are that data should be used to target interventions at local government areas with high levels of disadvantage and high urban heat island effect. For example, the City of Brimbank has the highest UHI effect (+10.75ºC) in Melbourne and the second lowest IRSD score (921).

Keywords: disadvantage, urban heat island effect, equity, Melbourne

Introduction

Extreme heat does not impact people equally. An individual's vulnerability to the direct and indirect impacts of extreme heat is determined by their exposure, their sensitivity, and the resources at their disposal to prepare, respond, and recover (adaptive capacity).

Extreme heat can have a direct illness impact, causing heat exhaustion and heat stroke, disrupting medication, and exacerbating existing health conditions (DHHS, 2020). Extreme heat can also result in death in severe cases – the January 2009 heatwave in Victoria contributed to 374 excess deaths and the January 2014 heatwave in Victoria led to 167 excess deaths (DH 2014). The indirect impacts of extreme heat include mental illness, violence, financial stress, power outages, public transport disruptions, poor air quality, and service cancellations (Jones et al, 2018).

High exposure, high sensitivity, and low adaptive capacity increases the risk and severity of harm from these impacts. Demographic factors that can increase an individual's vulnerability to extreme heat include (VCOSS, 2021):

- Financial disadvantage; e.g., low incomes, financial hardship.

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- Housing quality; e.g., private rental properties, public housing, homelessness.
- Location; e.g., urban heat island (UHI) effect, public transport access.
- Age; e.g., young children and older people.
- Disability and chronic health conditions.
- Cultural and linguistic diversity; e.g., low English language skills, recent migration.
- Employment; e.g., outdoor work and insecure work.
- Gender; e.g., family violence and pregnancy.

A factor that increases an individual's exposure to extreme heat is the UHI effect, which describes the higher temperatures observed in urban areas compared to nearby rural areas. The UHI effect is caused by urban surfaces absorbing and retaining heat, urban structures trapping heat, urban areas reducing wind flow, and human activity generating heat (Sachindra et al, 2016).

The first aim of this paper is to test whether people experiencing various forms of disadvantage are more likely to live in an area with a high UHI effect.

A factor that reduces an individual's adaptive capacity to extreme heat is earning a low income. Experiencing financial hardship means households have less resources to protect themselves on hot days. For example, they are less able to afford (VCOSS, 2021):

- to improve the energy efficiency of their home
- air-conditioning (including installation and running costs) to keep cool
- a car (including petrol costs) to avoid walking in the heat
- to turn down a work shift where they might be at risk on a hot day

The second aim of this paper is to test whether a household's income, specifically, is correlated with the urban heat island effect of the local government area in which they live; i.e., if households with low incomes are more likely to live in areas with high urban heat and vice versa.

The geographic area of focus is metropolitan Melbourne in Victoria, Australia.

Method

UHI effect

Data for the UHI effect was obtained from the Clean Air and Urban Landscapes Hub's 'Urban Vegetation, Urban Heat Islands and Heat Vulnerability Assessment in Melbourne, 2018' report (Sun et al, 2019). Researchers calculated the UHI effect for all 31 local government areas (LGAs) in Melbourne by deriving land surface temperature data from Landsat 8 thermal infrared data collected by the United States Geological Survey.

This paper focuses on the 27 'city' LGAs in Melbourne and omits the four 'shire' LGAs. The conditions of these peri-urban 'shire' LGAs are specific to regional and rural Victoria, containing a high level of green space that significantly reduces the UHI effect.

Disadvantage

Data for disadvantage was obtained from the Australian Bureau of Statistics' (ABS) 2016 Census using the ABS's TableBuilder tool. The ABS generated an Index for Relative Socio-economic Disadvantage (IRSD) for all LGAs in Australia where scores of less than 1,000 indicate more disadvantage and scores of more than 1,000 indicate less disadvantage. The IRSD is calculated from 16 weighted variables (ABS, 2016a):

- INC_LOW: % of people with stated household equivalised income between $1 and $25,999 per year.
- CHILDJOBLESS: % of families with children under 15 years of age who live with jobless parents.
- NONET: % of occupied private dwellings with no internet connection.
- NOYEAR12ORHIGHER: % of people aged 15 years and over whose highest level of education is Year 11 or lower.
- UNEMPLOYED: % of people in the labour force who are unemployed.
- OCC_LABOUR: % of employed people classified as Labourers.
- LOWRENT: % of occupied private dwellings paying rent less than $215 per week (excluding $0 per week).
- ONEPARENT: % of one parent families with dependent offspring only.
- DISABILITYU70: % of people under the age of 70 who have a long-term health condition or disability and need assistance with core activities.
- SEPDIVORCED: % of people aged 15 years and over who are separated or divorced.
- OCC_DRIVERS: % of employed people classified as Machinery Operators and Drivers.
- OCC_SERVICE_L: % of employed people classified as low skill Community and Personal Service workers.
- NOCAR: % of occupied private dwellings with no cars.
- OVERCROWD: % of occupied private dwellings requiring one or more extra bedrooms.
- NOEDU: % of people aged 15 years and over who have no educational attainment.
- ENGLISHPOOR: % of people who do not speak English well.

INC_LOW is given the highest weighting in IRSD (-0.91 loading) and ENGLISHPOOR is given the lowest (-0.30 loading).

This paper calculated 15 of the 16 IRSD variables individually using the method specified in the ABS's 'Technical Paper: Socio-Economic Indexes for Areas (SEIFA) 2016'. Data was obtained using the ABS's TableBuilder tool. The OCC_SERVICE_L variable was excluded because data was unavailable.

Household income

Data for equivalised total household income was obtained from the ABS's 2016 Census using the ABS's TableBuilder tool. The ABS equivalises total household income by applying the modified OECD equivalence scale to facilitate comparison of income levels between households of differing size and composition (ABS, 2016b).

The ABS groups this data into 15 ranges from 'Nil income' to $156,000 or more each year. 'Nil income' was excluded as per ABS advice because this income bracket includes people who are experiencing a temporary financial setback or have significant savings to cover their living costs (ABS, 2017).

The average UHI effect experienced by households in each income range was then calculated. For example, for the $1 to $7,799 income range, the number of households in that range in the City of Banyule (405) was multiplied by the UHI effect in that LGA (8.25^{o}C). This was done for all 27 LGAs, summed (161,400.8), and then divided by the total number of households in that income range (18,411).

Correlation analysis

The relationship between the UHI effect and the IRSD scores in all 27 'city' LGAs in Melbourne was tested by calculating the square of the Pearson product moment correlation

coefficient (r^2). This was repeated between the UHI effect and 15 of the 16 IRSD variables, and then between the 14 income ranges and the average UHI effect experienced in each income range.

An r^2 value of more than 0.4 was taken to indicate a correlation. An r^2 value of more than 0.7 was taken to indicate a strong correlation.

Results

The UHI effect of the 27 'city' LGAs in Melbourne ranged from +7.03°C (Maroondah) to +10.75°C (Brimbank). The IRSD scores ranged from 896 (Greater Dandenong) to 1,097 (Boroondara).

Table 1. The UHI effect and IRSD score in the 27 'city' LGAs in Melbourne

LGA	UHI effect (°C)	IRSD score
Banyule	8.25	1,055
Bayside	7.36	1,097
Boroondara	7.5	1,097
Brimbank	10.75	921
Casey	10.7	1,004
Darebin	8.53	1,004
Frankston	8.23	1,001
Glen Eira	8.63	1,074
Greater Dandenong	9.26	896
Hobsons Bay	7.94	1,015
Hume	9.23	947
Kingston	9.05	1,044
Knox	7.52	1,048
Manningham	7.95	1,066
Maribyrnong	9.35	995
Maroondah	7.03	1,045
Melbourne	7.94	1,010
Melton	10.7	994
Monash	8.43	1,045
Moonee Valley	9.63	1,035
Merri-bek (Moreland)	9.2	1,014
Port Phillip	7.4	1,069
Stonnington	7.56	1,087
Whitehorse	7.93	1,049
Whittlesea	9.4	991
Wyndham	9.18	1,009
Yarra	8.27	1,035

The r^2 value from comparing UHI effect against IRSD score is 0.4435. This was taken to indicate a correlation.

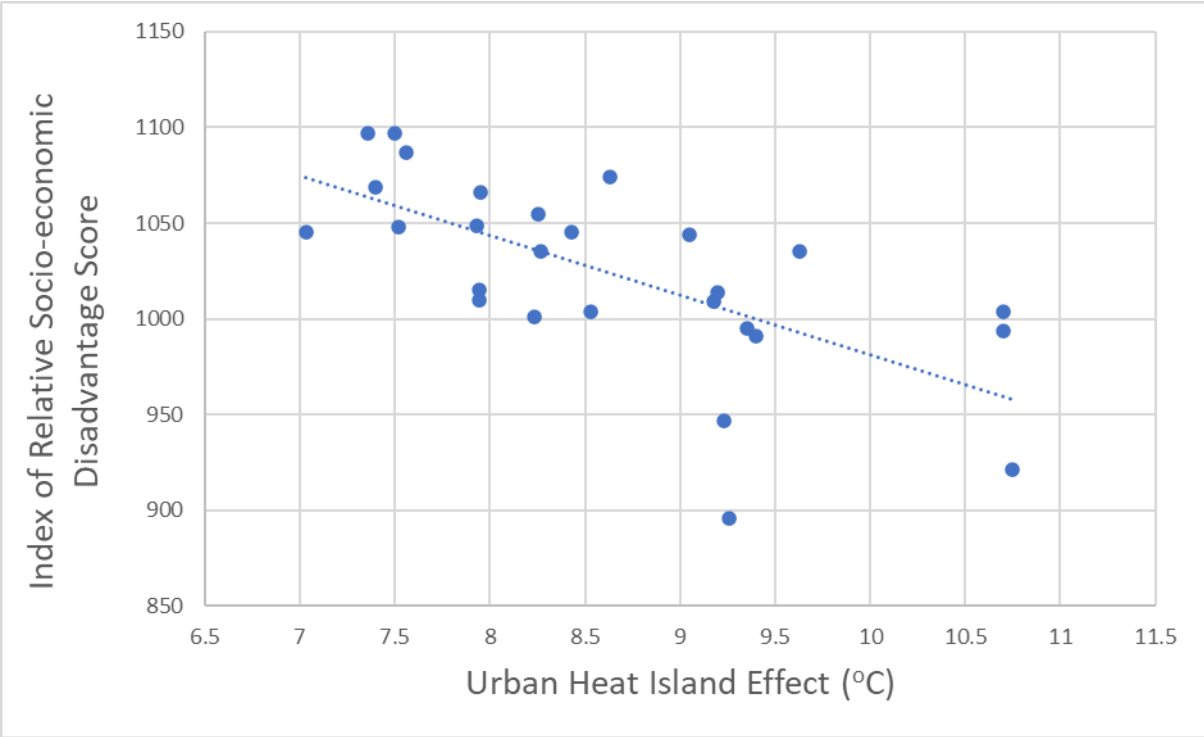

Figure 1. The UHI effect of the 27 'city' LGAs in Melbourne compared to their IRSD score.

Of the 15 variables used to generate IRSD scores and calculated in this paper, four variables produced r^2 values of more than 0.4 when compared with the UHI effect, indicating a correlation: OCC_DRIVERS (0.5318), CHILDJOBLESS (0.4739), OCC_LABOUR (0.4441), and INC_LOW (0.4406).

Table 2. The correlation between IRSD variables and UHI effect in the 27 'city' LGAs in Melbourne

IRSD variable	r^2 value
INC_LOW	0.4406
CHILDJOBLESS	0.4739
NONET	0.2125
NOYEAR12ORHIGHER	0.3797
UNEMPLOYED	0.2702
OCC_LABOUR	0.4441
LOWRENT	0.0057
ONEPARENT	0.3029
DISABILITYU70	0.3747
SEPDIVORCED	0.0264
OCC_DRIVERS	0.5318
OCC_SERVICE_L	N/A
NOCAR	0.0591
OVERCROWD	0.1978
NOEDU	0.3057
ENGLISHPOOR	0.1857

Households earning equivalised total annual income of $1 to $7,799 experience an average UHI effect of 8.77°C. Households earning equivalised total annual income of

$156,000 or more experience an average UHI effect of 8.17°C. From the $26,000 to $33,799 bracket onwards, households experience a lower average UHI effect as income rises.

Table 3. The average UHI effect experienced by households in each equivalised total annual income range

Equivalised total annual household income ($)	Average UHI effect (°C)
1-7,799	8.77
7,800-15,599	8.89
15,600-20,799	8.91
20,800-25,999	8.90
26,000-33,799	8.91
33,800-41,599	8.90
41,600-51,999	8.88
52,000-64,999	8.81
65,000-77,999	8.72
78,000-90,999	8.63
91,000-103,999	8.53
104,000-129,999	8.40
130,000-155,999	8.32
156,000 or more	8.17

The r^2 value from comparing equivalised total annual household income against the average UHI effect experienced by each household in that range is 0.7405. This was taken to indicate a strong correlation.

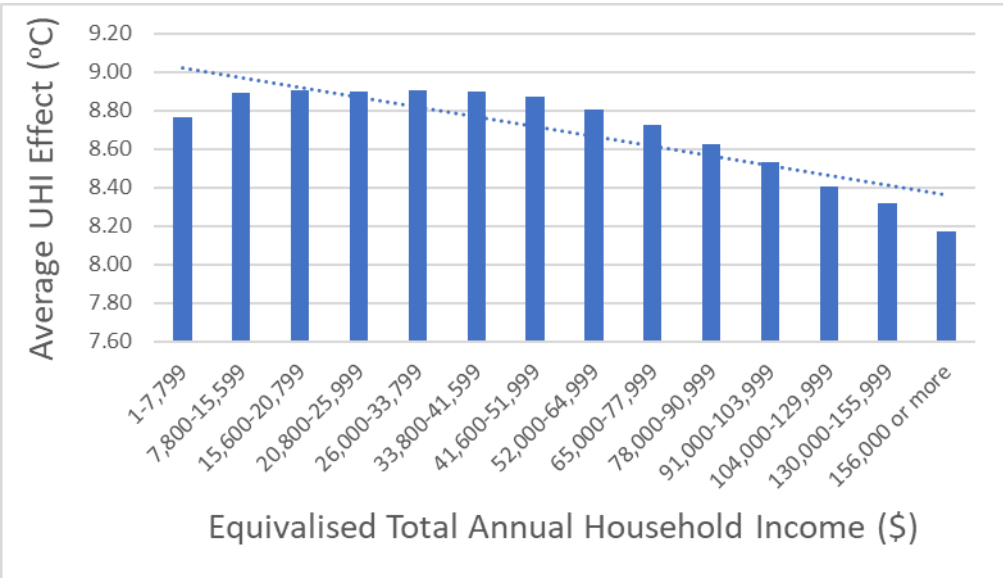

Figure 2. The average UHI effect experienced by households in each equivalised total income range.

Discussion

There is a correlation between disadvantage and living in an area with a high UHI effect in Melbourne. For example, the six disadvantaged LGAs (IRSD scores less than 1,000) were also within the eight hottest areas. This is concerning because people experiencing

disadvantage are likely to be more vulnerable to extreme heat yet are more likely to live in the areas of Melbourne where they are most exposed.

An implication for policymakers responsible for addressing urban heat is that they should target interventions at the LGAs with low IRSD scores and high UHI effect such as the City of Brimbank, which has the highest UHI effect (+10.75^{o}C) in Melbourne and the second lowest IRSD score (921).

A caveat, however, is that not all IRSD variables are clearly linked with increased heat vulnerability. Therefore, future research could create a separate heat vulnerability index generated by indicators related to the nine demographic factors listed in the Introduction that influence exposure, sensitivity, and adaptive capacity; i.e., income, housing quality, location, age, disability and chronic health conditions, cultural and linguistic diversity, employment, and gender. This work could also use data at the Statistical Area 2 (SA2) or Statistical Area 1 (SA1) level instead of LGA to provide more granular detail.

The heat vulnerability index could be analysed against the UHI effect to generate a priority score to inform policymakers where urban heat interventions should be targeted. The variables for the index could also be compared against the UHI effect to determine whether there are correlations that might be driving heat vulnerability, similar to the process used in this paper.

Four IRSD variables indicated a correlation with UHI effect: OCC_DRIVERS, CHILDJOBLESS, OCC_LABOUR, and INC_LOW. INC_LOW is given the biggest weighting in the IRSD and is also a variable with a clear link to heat vulnerability because low incomes reduce a household's ability to adapt and keep cool.

Further analysis showed that a household's income is strongly correlated with the UHI effect in the area they live. A household in the lowest income bracket (up to $7,799 per year) lives on average in an LGA 0.6^{o}C hotter than where a household in the highest income bracket (over $156,000 per year) lives.

The factors that lower the UHI effect might make homes more desirable and therefore less affordable for low-income households; i.e. more parks, more trees, less development, further away from major roads. Low-income households might also have less time and confidence to participate in local planning decisions and campaign against high density development. Regardless, this relationship is concerning because low-income households have lower adaptive capacity yet are located in hotter areas of Melbourne, which increases their exposure to extreme heat and compounds their risk of harm.

Conclusion

People experiencing disadvantage in Melbourne are more likely to live in LGAs with higher UHI effects. For example, the City of Brimbank has the highest UHI effect (+10.75^{o}C) in Melbourne and the second lowest IRSD score (921).

Low-income households in Melbourne are more likely to live in hotter areas. For example, households earning up to $7,799 per year live in an area 0.6^{o}C hotter on average than households earning over $156,000 per year.

Policymakers can use these findings to help target interventions at areas where households have high heat vulnerability. Further analysis is also needed to generate a broad heat vulnerability index at an SA2 or SA1 level.

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