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Urban Vegetation and Heat Related Mortality

In this month's Nursery Paper, Dr Dong Chen and the team from Commonwealth Scientific and Industrial Research Organisation (CSIRO) look at urban vegetation and its impact upon heat related mortality. This research represents one of the first attempts to develop quantitative estimates of the potential benefit of urban vegetation in reducing heat related mortality. It was undertaken by a research team from CSIRO working closely with the NGIA, and involved modelling of vegetation and mortality relationships for the summer of 2009 and projected future climates in 2030 and 2050 for the city of Melbourne. The team found some differences among the results for 2009, 2030 and 2050, but the overall trend was that urban vegetation can potentially reduce excess heat related mortality. Different urban vegetation scenarios were tested, with the forest scheme predicted to achieve 60-100% reduction in excess mortality rate in comparison with the CBD vegetation scheme. From these results it is recommended that urban vegetation be a key component in heat wave mitigation and for preventative health.

Urban Vegetation and Heat Related Mortality

Extreme environmental temperature can cause serious health impacts and can lead to increased mortality. The heat wave event in Melbourne during the summer of 2009 is estimated to have claimed 374 excess deaths over what would normally have been expected for that period (DHS, 2009). The relationship between heat and mortality has long been recognised (Haines et al. 2006) and several researchers have attempted to quantify this relationship for the city of Melbourne. Nicholls et al. (2008) analysed the mortality rate in Melbourne for people over 65 from 1979 to 2001. They reported that excess heat related mortality amongst the population over 65 may increase rapidly when the mean daily temperatures (the average of yesterday's maximum and this morning's minimum) exceed 30°C. Consequently, a 30°C mean daily temperature was recommended for Melbourne's trigger point for its heat alert system. Chen and Wang (2012) also observed a triggering mean daily temperature of around 30°C for Melbourne based on analysis of historical mortality data from 1988 to 2009 for people over 75.

In almost all previous research, the focus has been on the linkage between ambient weather conditions and the mortality rate. Finding this linkage is important and can lead to improved public health alerts and emergency preparedness. However, with increasing focus on health prevention, a better strategy is to try and mitigate the heat stress in the first place, such as through improvements to urban vegetation coverage and the use of cool roofs. Cadot et al. (2007) reported that 74% of excess

Urban vegetation can potentially reduce excess heat related mortality.

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deaths during the 2003 summer heat wave in Paris occurred among those who were living at home. They concluded that the most important risk factors for dying was being a female ≥ 75 years old and living alone. Although there is little available information on the locations and specifics of heat stress related excess deaths in Australia, being old and living alone have been identified as significant heat related health risk factors. Consequently, more research effort should be directed towards the indoor thermal environment, particularly those housing vulnerable populations, and mitigating the heat stress in residential buildings. The current study aims at quantitatively estimating the potential benefit of urban vegetation in reducing heat related mortality through improvement to the indoor thermal environment.

The elderly are most at risk from excess heat related mortality.

2 Methodologies and Modelling Results

2.1 Weather Data Preparation

Using a CSIRO developed urban climate model known as UCM-TAPM (Thatcher and Hurley 2012), the impact of different urban vegetation schemes on the local climate can be estimated as the change in monthly-mean ambient temperature, monthly-mean daily maximum temperature and daily minimum temperature relative to the Melbourne CBD vegetation scheme. Table 1 lists the main characteristics of the urban vegetation schemes investigated in this study. The predicted changes in the above three mean air temperatures associated with different vegetation schemes were then used to modify the 2009 weather data and the projected 2030 and 2050 average weather data for Melbourne. Climate change projections used in the study were based on the MIROC global climate model using the A1FI emission scenario.

2.2 Sample Residential Buildings

In Melbourne, detached houses represent around 76% of the residential housing stock, while the remainder consists of semi-detached buildings, flats, units and apartments (ABS, 2011). In this study, three residential buildings were used which include a detached single-storey four bedroom house, a semi-detached three bedroom two-storey townhouse, and a two bedroom apartment at the top of a two-storey building. It was assumed there was no insulation in these buildings in order to represent low-end Melbourne housing stock and potential exposure of occupants to health risks during heat waves.

Table 1 The main characteristics of the urban vegetation schemes investigated in this study

Urban Type	Vegetation coverage of entire land area (%)	Vegetation coverage fraction within vegetation area	Leaf Area Index	Green Roof Coverage of Building Roof Area (%)	Building Coverage over entire land area (%)	Building Height (m)	Irrigation
Forest (low sparse)	100	0.25	2.0	0	0	-	No
Shrub-land	100	0.50	2.6	0	0	-	No
Grassland	100	0.50	2.0	0	0	-	No
Urban (leafy)	49	1.00	3	0	40	6.0	Yes
Urban(generic)	38	1.00	3	0	45	6.0	Yes
CBD	15	1.00	3	0	65	12.0	Yes
CBD (with 1/3 Vegetation)	5	1.00	3	0	65	12.0	Yes
CBD(Double Vegetation)	33	1.00	3	0	62	12.0	Yes
CBD(50% Green Roof)	15	1.00	3 1.5 (GR)	50	65	12.0	Yes
CBD(Double Vegetation + 50% Green Roof)	33	1.00	3 1.5 (GR)	50	62	12.0	Yes

2.3 Indoor Thermal Performance Modelling

The residential building simulation software AccuRate developed by CSIRO (Delsante 2005) was used to calculate the indoor thermal environment in the three sample buildings with the generated weather data for 2009, 2030 and 2050. The buildings were assumed to be without space heating and air conditioning. It was also assumed that occupants would actively operate the windows and doors to minimise extremes in indoor air temperatures, based on the following assumptions about behaviour:

- Windows and doors are closed if indoor air temperature is below 22°C; and
- If indoor air temperature is above 24°C and ambient air temperature is below indoor air temperature, windows and doors are opened. Otherwise, windows and doors are closed.

Using the AccuRate software, hourly air temperatures in the living room and the master bedroom were predicted using the generated weather files, and recorded for use in the mortality rate analysis.

2.4 Impact on Mortality Rate

Historical mortality data from 1988 to 2009 were obtained from the Australian Bureau of Statistics (ABS) for the Melbourne Statistical Division. This data was organised by the place of usual residence, by sex, and by two age groups, i.e. 0-75 and 75+. The Melbourne Statistical Division covers the metropolitan area of Melbourne as well as its surrounding urban fringe, including the Dandenong Ranges, the Yarra Valley and the Mornington Peninsula. It defines an area with a population of over 3.5 million, and accounts for approximately 70% of the entire Victorian population.

To understand the potential linkage between indoor air temperature and mortality rate in Melbourne, hourly simulations were carried out for the 20 year period from 1st January 1988 to 31st December 2007 for the three buildings and four different building orientations (i.e. north, east, south and west).

Considering that occupants are normally in the living room during daytime and in the bedroom at night time, the mean daily indoor temperatures for a building were defined here as the average of yesterday's daytime (after 7am) maximum in the living room and this morning's (before 7am) minimum in the master bedroom. Over the 20 year period from 1st January 1988 to 31st December 2007 there was a total of 7305 days. These 7305 mean daily indoor temperatures for each building and four facing directions were then grouped into consecutive temperature bands of 0.5°C. The average mortality rates corresponding to a particular mean daily indoor temperature band were then obtained. For example, the average mortality rate corresponding to the mean daily indoor temperature band from 28°C to 28.5°C is the average of the mortality rates for all the days (in the 20 years) within that band.

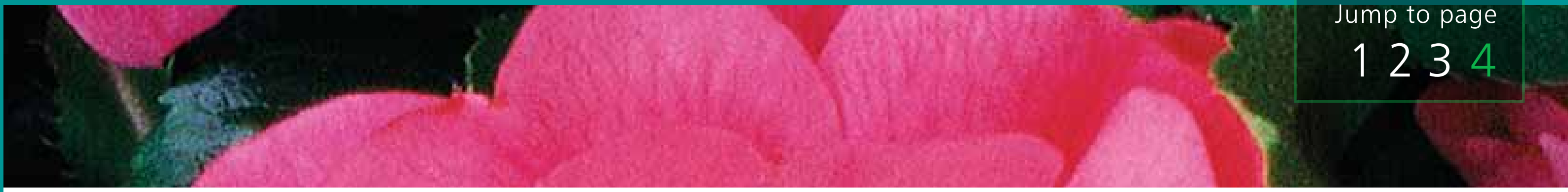
With the three different buildings and four building orientations, 12 sets of relationships between the mean daily indoor temperatures and average mortality rate can be established. Figure 1 shows the 4 sets of relationships for the house in four orientations between the average mortality rates for males and females over 75 years old and the mean daily indoor temperature. It is seen that high mean daily indoor temperature of the buildings corresponds to high average mortality rates. This is especially true for females over 75 years old. Based on these 12 relationships between the mean daily indoor temperatures and average mortality rate, the impact of urban vegetation can then be estimated using AccuRate simulations of the indoor thermal performance for the three buildings. The impact assessment considered the three buildings and their four orientations using the generated climate data for 2009, 2030 and 2050 with different urban vegetation schemes. The potential impact on excess mortality rate has been estimated in this research as the difference in the heat related mortality rate when the entire Melbourne metropolitan area has a specific urban vegetation scheme, as outlined in Table 1, relative to the Melbourne CBD vegetation scheme as a baseline.

Figure 2 shows the potential impact on excess mortality rate with different urban vegetation schemes in 2009, 2030 and 2050 relative to the Melbourne CBD vegetation scheme. While there are differences among the results for 2009, 2030 and 2050, the overall trends are consistent in finding that urban vegetation can potentially reduce the rate of excess heat related mortality. In general, the reduction in the excess mortality rate increases with an increase in vegetation coverage and intensity. The leafy urban scheme for the Melbourne region is predicted to reduce 20-60% mortality rate in comparison with the CBD vegetation scheme. The forest scheme (assuming the Melbourne Statistical Division is converted to forest) is predicted to achieve the best performance with a 60-100% reduction in excess mortality rate in comparison with the CBD vegetation scheme. Although total forest coverage for the Melbourne area is unrealistic, the research attempts to show the maximum benefit that may be achieved through urban greening.

This research serves as one of the first attempts to relate the indoor thermal environment with excess heat related mortality, quantifying the impacts of various urban vegetation schemes. The model established as part of this study is currently undergoing further testing, verification and development.

CONCLUSIONS

Simulations of indoor thermal environment were carried out using the AccuRate software to quantify the potential benefit of urban vegetation in reducing heat related mortality. This was done for the 2009 summer and also for projected 2030 and 2050 future climates in Melbourne. Results show that urban vegetation can potentially reduce excess heat related mortality. The forest scheme in particular, was predicted to deliver a 60-100% reduction in excess heat related mortality in comparison with CBD vegetation scheme. Urban vegetation is therefore recommended as a vitally important component of heat wave mitigation strategies for urban planning.



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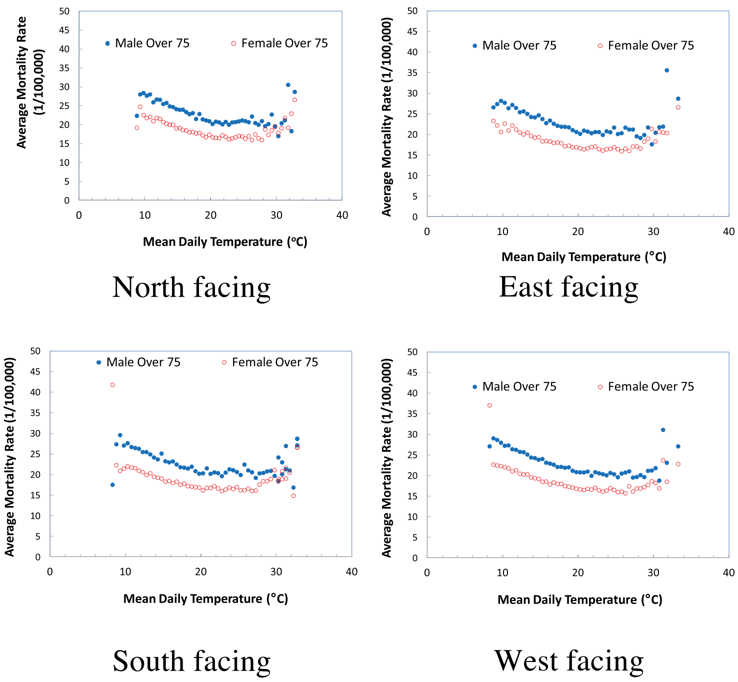

Figure 1. Relationships between mean daily indoor temperature of the house and average mortality rate in Melbourne from 1st January 1988 to 31th December 2007

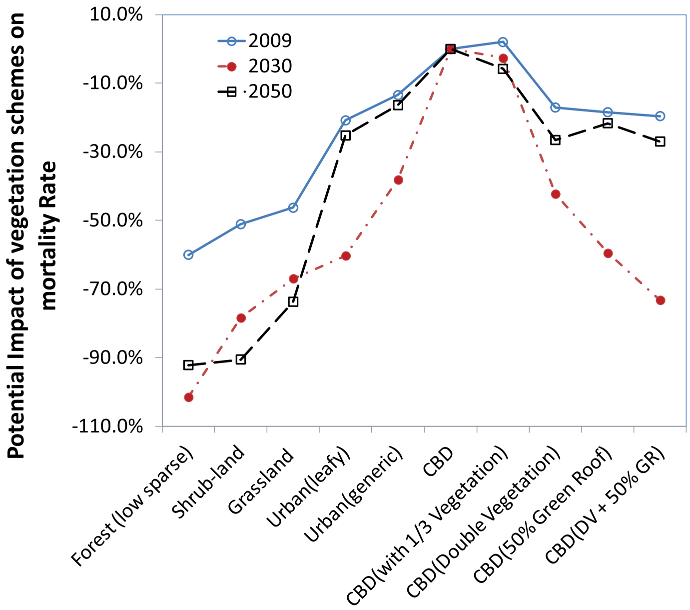

Figure 2. The potential impact on excess mortality rate with different urban vegetation schemes relatively to the CBD vegetation scheme

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