Greening City - Mitigate Heat Stress with Urban Vegetation

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CSIRO Ecosystem Sciences

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Dong Chen
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MEDIA SUMMARY

Extreme environmental temperatures can have serious health impacts. The January 2009 heat wave in Melbourne is estimated to have claimed 374 excess deaths over what would normally have been expected for that period. This research is 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 the Commonwealth Scientific and Industrial Research Organisation (CSIRO) working closely with the Nursery & Garden Industry Australia (NGIA). The research involved modelling of vegetation and mortality relationships for present climate and projected future climates in 2030 and 2050 for Melbourne, Brisbane and Parramatta NSW. The team found some differences among the results for the present and future years in different cities, but the overall trend was that urban vegetation can potentially reduce excess heat related mortality. Urban vegetation is recommended to be an important strategy for heat wave mitigation and for climate adaptation.

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TECHNICAL SUMMARY

Heat wave has been recognised as one of the major natural hazards and kills more Australians than any other natural hazards. The combined impact of climate change and urban heat island will likely lead to more frequent and intense heat waves in Australia. This research is one of the first attempts to develop quantitative estimates of the potential benefit of urban vegetation in reducing the impact of heat waves and urban heat island in three Australian cities. Using urban climate and building modelling tools, the effects of ten different urban vegetation schemes on local micro-climate and indoor thermal stress were investigated for the present climate and the projected future climates in 2030 and 2050 for Melbourne, Brisbane and Parramatta NSW. It was shown that for the three cities, increasing in urban vegetation can potentially reduce the average summer daily maximum temperature. It was also found that although the results vary in different cities for different years, the overall trend is that urban vegetation has the potential to reduce excess heat related mortality in the three cities. Urban vegetation is recommended to be an important strategy for heat wave mitigation and for climate adaptation. Further research has also been suggested to improve the methodology used in this research and further exploring the benefit of urban vegetation in mitigating heat stress.

1. INTRODUCTION

Heat wave has been recognised as one of the major natural hazards and kills more Australians than any other natural hazards. 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). 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.

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, an active strategy is to mitigate the thermal stress in the first place, such as through the improvement in urban vegetation coverage and the use of cool roofs.

Cadot et al. (2007) reported that 74% of excess deaths during the 2003 summer heat wave in Paris occurred among those who were living at home. They also reported that woman over 75 years old and living alone were those among the highest risk of dying. Although there is no available information on the locations of heat stress related excess deaths in Australia, the situation in Australia may be similar to that in Paris considering that the most vulnerable population is the elderly people group (Loughnan et al., 2010). Consequently, more research effort should be directed towards the indoor thermal environment, particularly those housing with vulnerable populations, and mitigating the heat stress in residential buildings.

The current study aims at quantitatively estimating the potential benefit of urban vegetation in mitigating summer ambient temperature and heat-related mortality in three Australian cities through improvement to the indoor thermal environment.

2. METHODOLOGIES AND MODELLING RESULTS

2.1 Urban Climate Modelling

In this study, an Urban Climate Model - The Air Pollution Model (UCM-TAPM) (Thatcher and Hurley, 2012) was used for the investigation of urban vegetation impact on local climate. UCM-TAPM couples an urban canopy model based on the Town Energy Budget (TEB) model with The Air Pollution Model (TAPM) (Hurley et al., 2005) developed by CSIRO. The UCM includes an efficient big-leaf model to represent in-canyon vegetation in the predominately suburban component of Australian cities. In UCM-TAPM, a 1×1km grid tile of the land surface, for example, can be assigned one of 39 surface types that include a wide range of natural and built surface types such as water body, forest, shrub land, grassland, pasture, CBD, urban, and industrial. The characteristics of the surface types such as the average building height, building height to street canopy width ratio, vegetation coverage, leave area index, surface Albedos etc can be adjusted for specific urban surface conditions.

Using UCM-TAPM, the impact of different urban vegetation schemes on the local climate may be quantified as the changes in the monthly-mean ambient temperature, monthly-mean daily maximum temperature and daily minimum temperature relative to the CBD scheme, respectively. UCM-TAPM allows us to predict the effects of different urban vegetation schemes in mitigating the summer maximum ambient temperature. In this study, the effect of ten different urban vegetation schemes on local climate were investigated which include:

1. Forest (low sparse): approximate low density forest parkland;
2. Shrub-land: approximate shrub parkland;
3. Grassland: approximate grass parkland;
4. Urban (generic): urban area with average urban vegetation;
5. Urban (leafy): leafy urban area;
6. CBD: CBD area with existing vegetation coverage;
7. CBD (with 1/3 Vegetation): CBD area with 1/3 of the existing vegetation coverage;
8. CBD (Double Vegetation): CBD area with double vegetation coverage;
9. CBD (50% Green Roof): CBD area with existing vegetation coverage and 50% of roofs with green roof;
10. CBD (Double Vegetation + 50% Green Roof): CBD area with double vegetation and 50% green roof coverage.

Figure 1 shows the reduction in the predicted averaged summer daily maximum temperature (ASDM temperature) for a present year and three projected future years 2047, 2050 and 2090 relative to the CBD vegetation scheme in Melbourne CBD, Brisbane CBD and Parramatta NSW respectively. Here, ASDM temperature is the averaged summer daily maximum temperature over December, January and February.

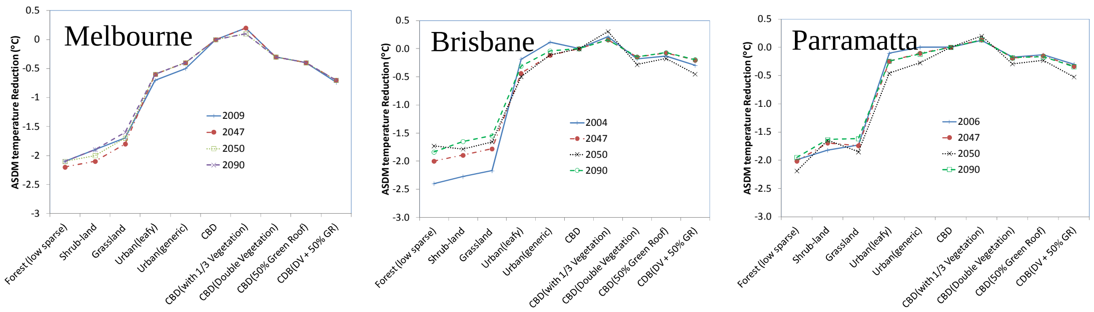

Figure 1. Predicted reductions in the ASDM temperature in 2009, 2047, 2050 and 2090 for different urban forms and vegetation schemes in Melbourne, Brisbane and Parramatta NSW

It was found that in general, increasing in the vegetation coverage result in a reduction in the ASDM temperature. ASDM temperature reduction in the range of 0.1 – 0.7 °C may be achievable with proper urban vegetation coverage in these cities.

2.2 *Weather Data Preparation for Indoor Thermal Performance*

UCM-TAPM predicts the change in monthly-mean ambient temperature, monthly-mean daily maximum temperature and daily minimum temperature relative to the existing CBD vegetation scheme. The predicted changes in these three mean air temperatures associated with different vegetation schemes were then used to modify a recent year weather data and the projected 2030 and 2050 average weather data for Melbourne, Brisbane and Parramatta NSW. Climate change projections used in the indoor thermal performance study were based on the MIROC global climate model using the A1FI emission scenario.

2.3 *Sample Residential Buildings*

In Australia, detached houses represent the majority 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 to represent the residential building stock. They 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.

2.4 *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 a recent year, 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. 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 impact analysis.

2.5 *Impact on Mortality Rate*

Historical mortality data from 1988 to 2007 were obtained from the Australian Bureau of Statistics (ABS) for the Melbourne, Brisbane and Sydney Statistical Divisions. The data were 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. The Sydney Statistical Division is the unofficial metropolitan area which includes the Central Coast, the Blue Mountains, and national parks and other unurbanised land. It covers 12,145 km^2 and has a population of 4.4 millions in 2008 (ABS). The Brisbane Statistical Division includes Brisbane City, Caboolture, Redcliffe, Ipswich and Logan, which has a population over 2 millions in 2009 (ABS). In order to calculate the mortality rate, the corresponding populations by sex by the two age groups from 1988 to 2007 in Melbourne, Sydney and Brisbane were also obtained from ABS.

To understand the potential linkage between indoor air temperature and mortality rate, 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) in the three cities. Considering that occupants are normally in the living room during daytime and in the bedroom at night time, a mean daily indoor temperatures for a building were defined here as the average of daytime (after 7am) maximum in the living room and 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 for each city.

Figure 2 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 in Melbourne. It is seen that high mean daily indoor temperature of the buildings corresponds to high average mortality rates. Based on these 12 relationships between the mean daily indoor temperatures and average mortality rate, the impact of urban vegetation may be estimated using AccuRate simulations of the indoor thermal performance for the three buildings for different years. The impact assessment considered the three buildings and their four orientations using the generated climate data for a present year, 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 heat related mortality rate when the entire Statistical Division area has a specific urban vegetation scheme relative to the CBD vegetation scheme as a baseline.

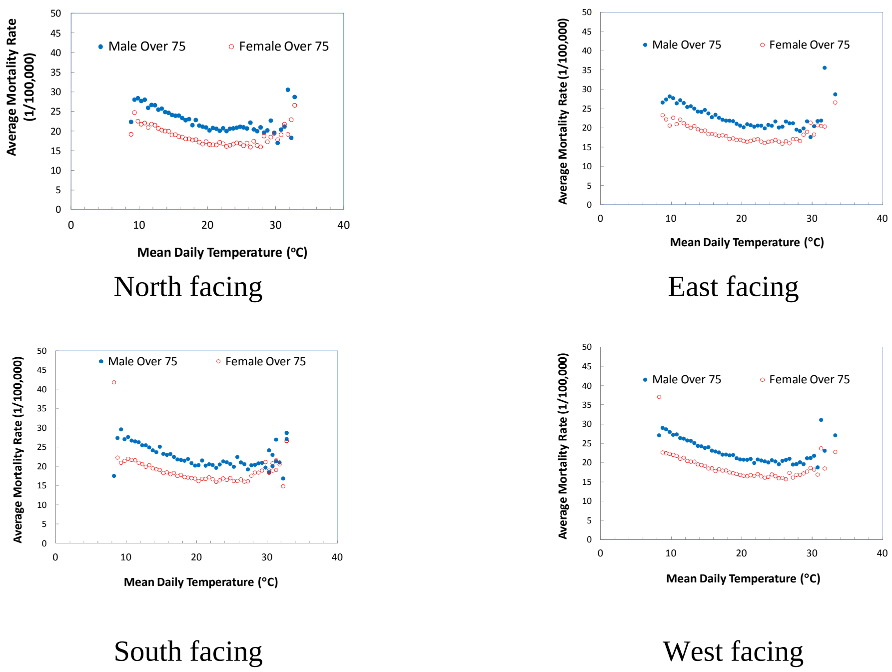

Figure 2. Relationships between mean daily indoor temperature of the house and average mortality rate in Melbourne from 1st January 1988 to 31th December 2007

Figure 3 shows the potential impact on excess mortality rate with different urban vegetation schemes in a present year, 2030 and 2050 relative to the CBD vegetation scheme for Melbourne, Brisbane and Parramatta NSW respectively. While there are differences among the results for different years and for different cities, 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 heat related mortality rate increases with an increase in vegetation coverage. For example, the leafy urban scheme for the Melbourne region is predicted to reduce around 20-60% mortality rate in comparison with the CBD vegetation scheme. The forest scheme (assuming the Statistical Division is converted to forest parkland) is predicted to achieve the 60-100% reduction in excess mortality rate in comparison with the CBD vegetation scheme. Although total forest coverage for an entire Statistical Division 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.

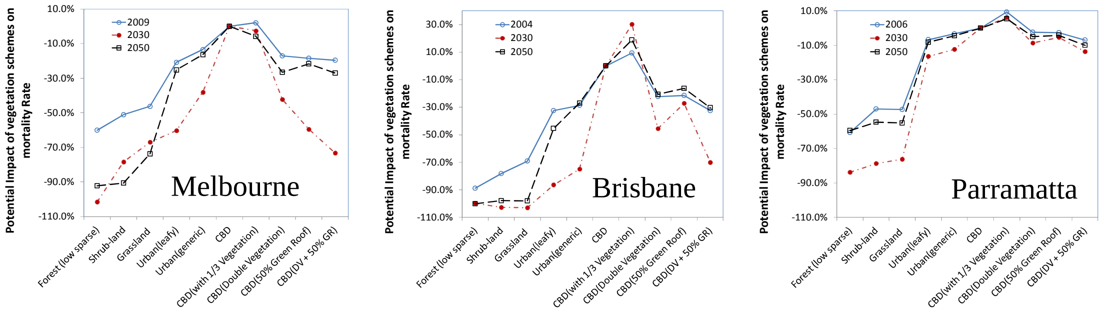

Figure 3 The potential impact on excess mortality rate with different urban vegetation schemes relatively to the CBD vegetation scheme

3. CONCLUSIONS AND RECOMMENDATIONS

Using urban climate and building modelling tools, the effects of ten different urban vegetation schemes on local micro-climate and indoor thermal stress were investigated for the present climate and the projected future climates in 2030 and 2050 for Melbourne, Brisbane and Parramatta NSW. It was shown that increasing in urban vegetation can potentially reduce the average summer daily maximum temperature and excess heat related mortality in the three cities. Urban vegetation is recommended to be an important strategy for heat wave mitigation and for climate adaptation.

It is noted that the current research is an initial attempt in quantitatively relating the indoor thermal environment with excess mortality rate due to heat stress for various urban vegetation schemes. The model established in this study is still in its early development. Further research is recommended to improve the methodology and resolution.

The current project is designed for an overall evaluation of vegetation effect at the metropolitan scale. The heat mitigation effect identified in this project is an average effect over a relatively large urban scale. The optimisation of tree and vegetation schemes and designs at neighbourhood and building scales may offer further potential for heat stress mitigation, particularly through targeting hot landscapes and buildings. Further detailed studies has been recommended to demonstrate and exemplify how appropriate vegetation schemes at different scales can maximize the mitigation of urban heat island effect and subsequently reduce the vulnerability to heat waves.

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