Can urban forestry really reduce air pollution? A field study on a city scale

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Introduction

Increasing urban greenspace has been proposed as a means of reducing airborne pollutant concentrations; however limited studies provide experimental data, as opposed to model estimates, of its ability to do so.

Many cities have plans for increasing their urban greenspace to reduce air pollution. The City of Sydney council is no exception, the City Council proposing to increase the city's urban canopy by 50 per cent from the current canopy cover of 15.5 per cent by 2030 (City of Sydney 2013). Sydney's urban forestry has not previously been investigated with respect to its ability to reduce urban air pollution.

The current project examined whether higher concentrations of urban forestry might be associated with quantifiable effects on ambient air pollutant levels, whilst accounting for the predominant source of localized spatial variations in pollutant concentrations, namely vehicular traffic.

Methodology

Monthly air samples for one year were taken from eleven sites in central Sydney, Australia.

Air pollutants monitored include Carbon dioxide (CO2), carbon monoxide (CO), total volatile organic compounds (TVOCs), nitric oxide (NO), nitrogen dioxide (NO2), sulfur dioxide (SO2), total suspended particulate matter (TSP), suspended particles <10 µm in diameter (PM_{10}) and particulate matter <2.5 µm ($PM_{2.5}$).

The sample sites exhibited a range of different traffic density, population usage, and greenspace / urban forest density conditions which were all quantitatively assessed.

The concentration of greenspace at the sites was estimated using satellite imagery within 100 m, 250 m and 500 m radii from the geographic centre of each sample site, forming areas of 3.14, 19.6 and 78.6 ha respectively. A stratified random sampling process was used to determine traffic densities at the sample sites among high, medium and low traffic density roadways. Traffic was sampled manually by counting vehicles passing the sample point for one 3 hour period per location, per month.

Quality assurance

-Air samples were conducted at least 30 m from roadways to allow the dispersal of pollutants sourced from the street.
-Rainy days were avoided
-No bare soil was present within 30 m proximity of sampling
-The order in which sites were sampled was randomised for every sampling day
-Reference data from three air quality monitoring sites operated by the State government were obtained for comparison on the days that samples were collected

Data analysis

Stepwise multiple linear regression was used to determine the traffic variable that had the strongest relationship with the air quality variables, which was traffic density within the 100 radii in all instances. The air quality variables were corrected for the effects of traffic by performing subsequent analysis on the residuals from linear regressions between the air quality variables and this traffic variable.

The presence and strength of linear associations between pollutant concentrations and environmental conditions were examined by computing Pearson correlation coefficients.

Results and Discussion

Traffic corrected total suspended particle concentrations were significantly negatively correlated with canopy coverage within a radius of 100 m (r= –0.293, P=0.001), canopy coverage within 250 m (r = – 0.221), P=0.011), percentage total greenspace cover measured at 100 m radii (r = –0.189, P=0.03), 250 m radii (r = –0.191, P=0.028) and 500 m radii (r= –0.181, P=0.038).

For traffic corrected TSP concentrations, the time since last rain event was the largest contributor to the overall variation in the model, explaining 17.41 % of the linear pattern in the TSP data (R^2=17.41). Adding canopy coverage within 100 m to the model explained an additional 9.86% of the variation, and adding canopy coverage within the 500 m radii added 2.94 % explanatory power. The three variable model thus explained 30.45% of the variability in the data set (R^2=30.45).

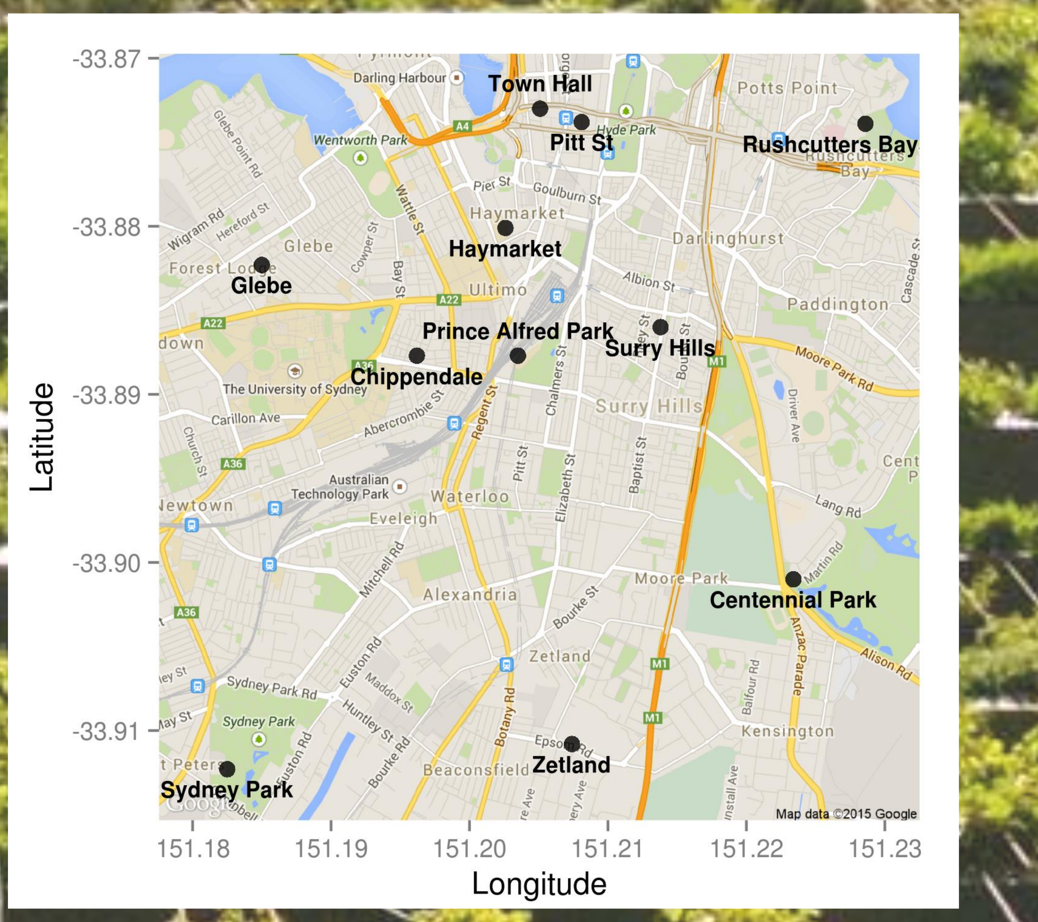

Figure 1 Map of central Sydney, showing the locations of the eleven sampling sites. Figure made using the packages ggplot2 and ggmaps for the program R (The R foundation, 2015), and static maps from Google Maps.

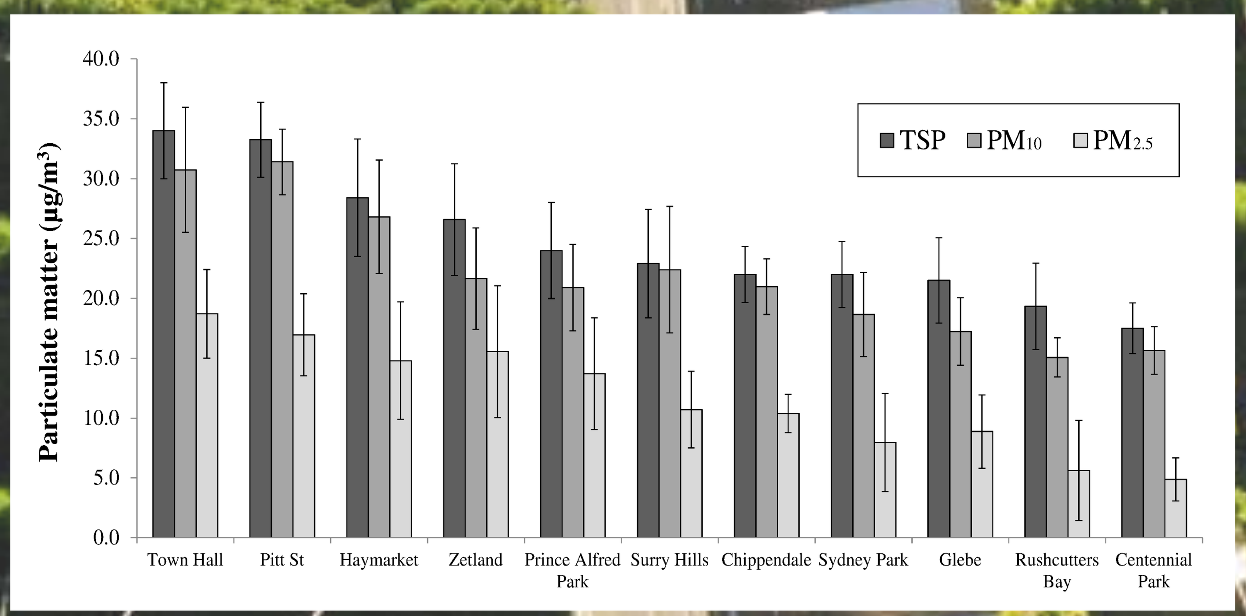

Figure 2: Average levels of atmospheric particulate matter fractions for each sampling site, over a 12-month period (Means ± SEM, n =12).

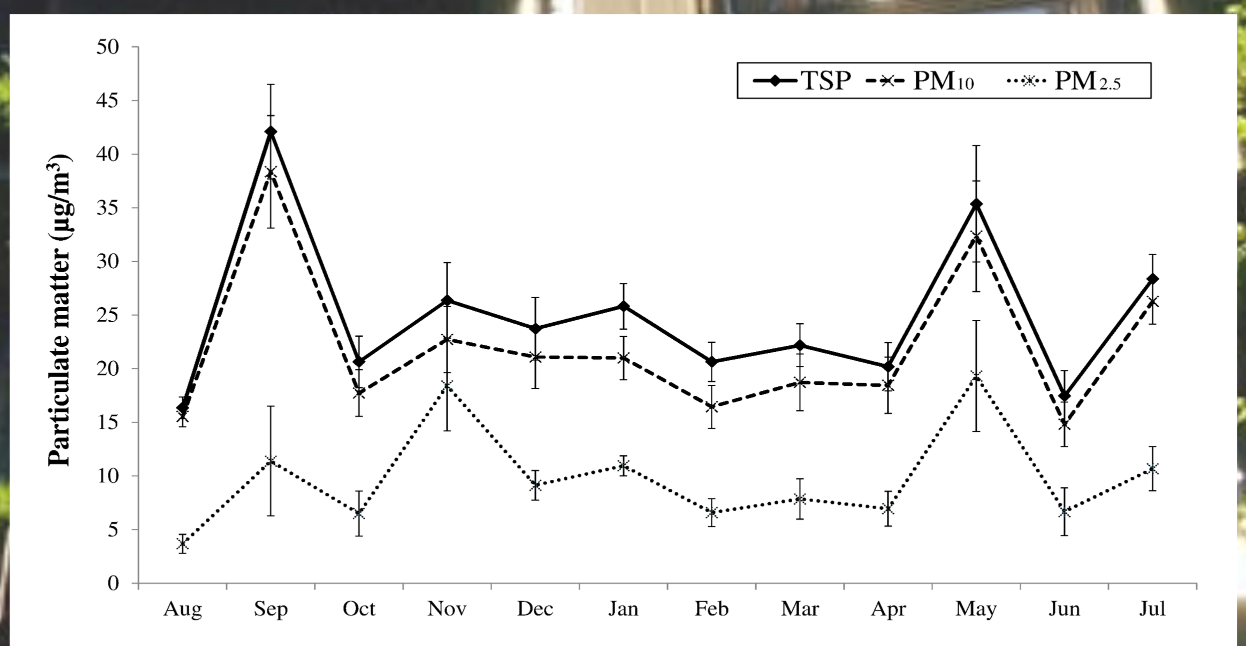

Figure 3:Average levels of atmospheric particulate matter fractions averaged across sites, over the 12-month sampling period (Means ± SEM, n = 11).

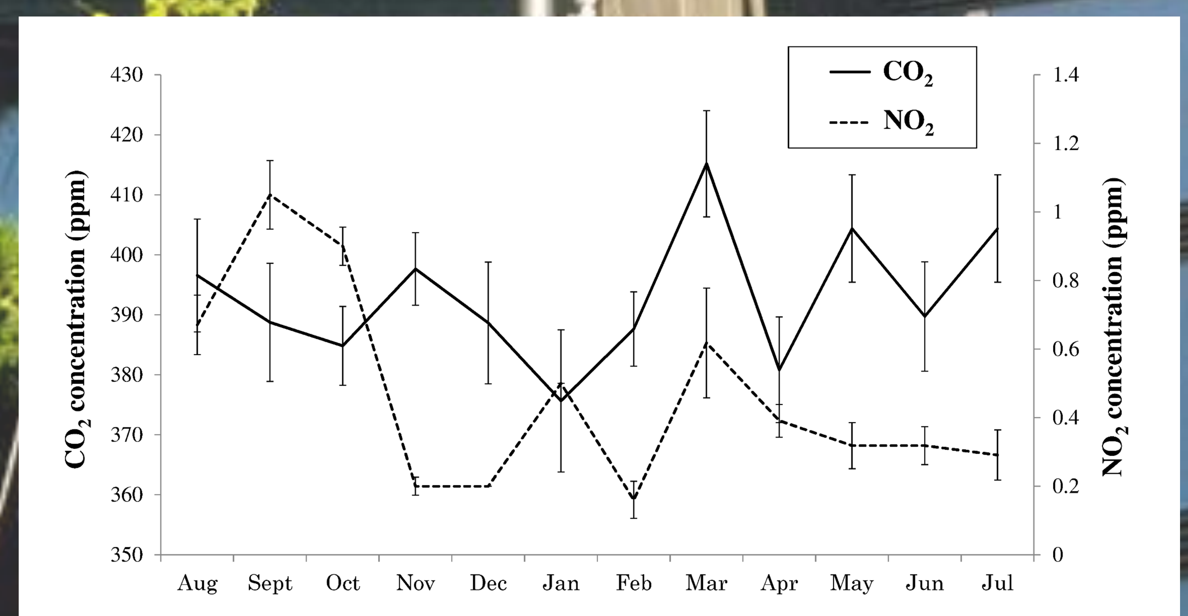

Figure 4. Temporal concentrations of ambient atmospheric CO2 and NO2 averaged across sites, over the 12-month sampling period (Means ± SEM, n = 11).

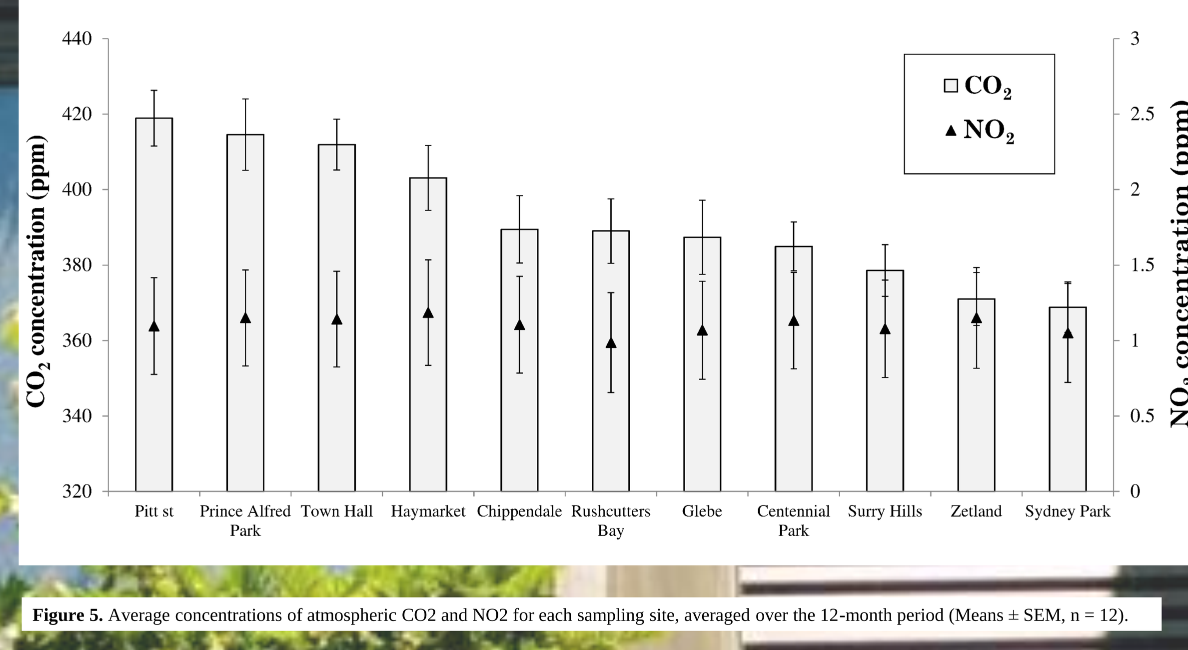

Figure 5. Average concentrations of atmospheric CO2 and NO2 for each sampling site, averaged over the 12-month period (Means ± SEM, n = 12).

It was found that air samples taken from sites with less greenspace frequently had high concentrations of all fractions of aerosolized particulates than other sites, whilst sites with high proximal greenspace had lower particulates, even when vehicular traffic was taken into account.

Some significant differences were present in CO_2 and NO_2 concentrations between months. No consistent pattern was observed across months, and amongst sites, the only significant difference observed being Pitt St, Prince Alfred Park and Town Hall recording significantly higher than those for Sydney Park and Zetland (GLM ANOVA, P<0.05 for all differences mentioned). There was no differences in NO_2 amongst sites. The temporal and spatial variation amongst CO_2 and NO_2 samples was not of a magnitude that warranted detailed multivariate analysis.

Data for NO, TVOC, CO and SO_2 were consistently below detection limits, and were thus not analysed individually. However, these air quality variables were used for the multivariate analyses, since there is evidence that multiple air pollutants may have additive effects

The statistical model utilised in this experiment did not fully explain majority of the variation in the data set, indicating that there were other variables not accounted for, and that determining all, or even most of the causative factors associated with urban air pollution experiments can be challenging. Thus there are clearly manifold environmental variables that influence air quality in a city environment at any one time and in any specific location. Whilst we cannot account for majority of the temporal and spatial variation in air quality with the environmental variables chosen for analysis in this study, the identification of greenspace as an important determinant of city airborne pollutants is a significant contribution to our understanding of urban air quality, and should assist in future air quality modelling exercises.

The findings indicate, first, that within the urban areas of a city, localized differences in air pollutant loads occur.

Secondly, we conclude that urban areas with proportionally higher concentrations of urban forestry may experience better air quality with regards to reduced ambient particulate matter; however, conclusions about other air pollutants are yet to be elucidated.

This work has been published as:
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References:
City of Sydney., 2013. Urban Forest Strategy 2013 . Available at: http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0003/132249/Urban-Forest-Strategy-Adopted-Feb-2013.pdf

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