Urban Planning and Ecology: The outcomes of poor urban planning

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# Introduction

Urban planning plays an important role in establishing ecosystem structure for local organisms and can even have cascading effects on human lifestyles. Urban planners utilize their knowledge of the environment and infrastructure to design how cities can be organized to ultimately benefit the individuals that interact with these structures daily. Ecologist for some time have attempted to integrate theory into the field of urban planning, but not much progress has been made to date. Niemelä describes a three-step process for successful integration, which includes a more methodical approach to urban planning resulting in improved conservation efforts (Niemelä 1999). By doing something as simple as going through a checklist, local environments can produce benefits for wildlife and humans. The advantages of these techniques span from improving human lifestyle to increasing global health in the form of reducing pollutants in various high-density areas. Additionally, the creation of Urban Green Spaces can also be beneficial to the ecology of a city, but these are influenced by a variety of factors (Aronson et al. 2017). Research on cities across the United States has also demonstrated that urban trees have the potential to remove 711,00 metric tons of total annual air pollution ($3.8 billion value) (Nowak et al. 2006). To further demonstrate the effect of air toxins, a comparison performed across six U.S. cities depicted that areas with higher levels of toxic compounds often lead to an increased susceptibility to cardiovascular events (Suwa et al. 2002). Cardiovascular events have the potential to lower the overall health and life expectancy of individuals present in affected communities. Research around these issues have revealed that regions with even the smallest decrease in air pollution can lead to an increase in around half a year of life (Pope III et al. 2009).

Urban planning plays an important role in terms of the environmental health of a region and the socio-economic effects on humans. Disorganized urban planning can result in a combination of heavily polluting facilities, which in turn can lead to an increased prevalence of various diseases. Due to this, individuals living in areas of cheap and accessible land for waste facilities often endure the heavier consequences of pollution. In a paper on environmental justice, Paul Mohai notes that there are socioeconomic effects of poor urban planning, indicating that some minority communities were often common sites for new waste facilities (Mohai et al. 2009). These social concerns led to many questions about the environmental conditions under which some minority communities have been forced into. Urban planning could be a route to resolving these potentially racial issues, but no research has concretely demonstrated that poorer or disadvantaged communities tend to be sites of low environmental health conditions. A journal article published a study using zip codes as areas of interest and demonstrated that race proved to be a critical variable but not the definitive variable, when determining the location of waste facilities (Cutter 1995). Along with this, researchers have often found that either race or socioeconomic status plays a role in the health and cleanliness of a community, indicating that though other variables may have an influence. Race seems to be the key to differences in pollution levels.

One of the many pollutants in disadvantaged communities is the presence of chemical toxins generated by waste facilities, factories, and vehicles. A study of roadside metal contaminants performed in Shanghai, China identified that some toxic metals have the potential to become “chemical time bombs” which could alter the urban ecosystem structure and eventually affect human health and safety (Shi et al. 2008). Further, research has identified that high levels of exposure to airborne particulate matter is correlated with increases in mortality and hospital admission (Brunekreef and Holgate 2002). Occurrences similar to this, wherein individuals are affected due to a collective polluting effort have become commonplace around the world regardless of socioeconomic status. The prominent issue stemming from this is that socioeconomically disadvantaged individuals have a much harder time avoiding the negative effects of pollution. Researchers have argued that through the accumulation of property and governmental influence, privileged Americans have constructed a hierarchy of status based on race and class (Hurley 1995). These barriers to economic ascension have enhanced the issue of ecological deterioration as the disadvantaged become more disadvantaged. Access to green spaces across the world has become an environmental justice issue. Studies have analyzed the relationship between green space creation and neighborhood health and have determined that although green spaces are beneficial they can be counterproductive and increase housing costs or property values (Wolch et al. 2014).

The focus of this study is the amount of trees in prominent regions of San Francisco. A study on tree cover across 20 cities in the U.S. demonstrated that 17 of these had a significant decrease in tree cover, indicating not only a decrease in lumber resources, but a reduction in biodiversity in these cities as well (Nowak and Greenfield 2012). Decreases in tree density in metropolitan areas has been identified as a common occurrence worldwide for sometime now, with various researchers arguing different perspectives as to why conservation is important. Findings relating to urban tree conservation have hinted at many ways to protect these unique species (Jim 2004). Recent studies on the nature of modern urban planning have identified that urban densification processes, like consolidation and infill development, have a large influence in the potential green space available or created later on (Haaland and Den Bosch 2015).

To further investigate the relationship between economic status and environmental health, I proposed a study involving the quantification of carbon dioxide emissions from various governmental and community departments of San Francisco. In this report, I specifically looked at the emissions from various sources and whether these play a role in the decreased presence of green life density in selected areas of San Francisco. Based on previous research performed in similar scenarios, I predicted that areas with a greater density of toxic pollutants will have fewer trees because of the limited ability to plant in regions of the city that range in presence of toxins. To properly assess these questions, I analyzed data collected in the field to identify trends in socioeconomic class in San Francisco. Using this data, correlations were found with usages and emissions from the city departments and community organizations. This data revealed interesting information about San Francisco such as the evident disparity across communities that are just a few miles apart. Additionally, results revealed a disproportionate presence of significant-trees across the city as well as a disproportionate usage of commodities among municipal and community groups.

# Methods

Data from this report was collected from various online databases. Data was added into the Rstudio project folder and analyzed using ggplot2 as well as other packages from Rstudio. A difference in social class was established using data collected from field in the Marina and Central Richmond neighborhoods. Additionally, this was used to demonstrate discrepancies in pollution among neighboring regions of San Francisco. Cleanliness, trash, and noise data were used to directly compare Marina and Central Richmond regions.

I investigated data sets containing information about the tree density and presence in the city. For this, maps were generated to depict the trends in tree presence and whether these trees were considered significant or not according to the Department of Public Works. Additionally, the top species of trees in the maps were identified based on the quantity of trees present throughout the city.

Greenhouse gas data on both community-wide and municipal-wide scales were used to determine the relationship among emission values and regions of San Francisco. Data were analyzed using ggplot. This was compared to emission values from the Municipal Greenhouse Gas data set using commodity types and sector or department use. Commodity types are defined as a type of fuel used or waste disposed to landfill. Emission of CO2 was averaged among commodity type or info for Community and Municipal data respectively. Aside from greenhouse data, a comparison among tree percent cover and PM2.5 particulate matter was made. Association of both these values was established based on percent of land area within 0.25 miles of a contamination risk.

## Field Sampling

To collect data in the field two sites were selected, the Marina and Central Richmond districts. The sampling sites were selected by designating one main street in the neighborhood of interest and one perpendicular street. The direction of the perpendicular street was chosen at random via a coin toss. For the toss, heads was designated as “right” and tails “left” when facing either north or west. Data were collected at each site on two separate days. At each site, data were collected in groups split into cleanliness, noise pollution, and garbage. For these the following protocols were used.

### Cleanliness

Cleanliness was measured using a scale of 1 to 5, with 5 labeled as perfectly clean. To judge the cleanliness of a neighborhood only areas on the sidewalk and streets were taken into account, any individuals that may be present in areas of data collection were not taken into account on the scale. Data transcription began on one extreme of the main street. Afterward, researchers proceeded to the far end of the perpendicular street. Finally, the opposite extreme of the main street was judged based on the scale. Scale ratings were defined as follows:

1. Visible litter seen throughout, stagnant water, dead animals or presence of human waste, pronounced unpleasant odors.
2. Animal waste, overall unpleasant smells.
3. Even distribution of both clean areas and litter.
4. Very minimal smell and litter present.
5. No smell, no litter, no biological waste materials.

### Noise

Noise pollution was documented using the application NIOSH SLM. When measuring the noise content of a neighborhood, phones were held at arm’s length to minimize interference from the data collector. GPS coordinates were also recorded. Data collection began at one corner of the main street, data was collected by pointing phone’s microphone towards street median. Noise measurements were compiled for seven minutes and were repeated at the opposite corner and middle of the main street. These same three measurements were taken on the perpendicular street as well.

### Trash Count

Counting began at street corners and area counted included both sidewalk and road. Upon beginning the counting date, time, and location were all documented. To collect data, sampling was done walking along the streets on intersection. The group was split in half to facilitate the process, with each taking one side of the street. As the group walked along each piece of trash was recorded along with supporting information (type, size, and area found). The size of debris was measured and labeled as small (1-10cm), medium (10-25cm), or large(25cm or larger) relative to the size of the data collection journal. Garbage was categorized as landfill, compost, or recycling. Data collection ended when the group reached the next intersection.

## Data Analysis and Statistics

Linear regression models were used to test the value of data presented by individual figures. The summary() function was used to determine p-values of collected data from field and individual data sets found online.

# Results

## Differences in Neighborhoods of San Francisco

Initial data observations indicated similarities among the general cleanliness trends seen in both regions of San Francisco (Table 1). It was clear that the Marina district was incredibly clean after receiving perfect scores across all three locations of the intersection that were reviewed. On the other hand, though not much lower, there was a noticeable difference in cleanliness in the Central Richmond neighborhood. Additionally, data from trash counting (Figure 1) revealed findings similar to the cleanliness scores. Overall, the two neighborhoods were very similar in terms of trash pollution, with very minimal discrepancies among small-sized trash in the landfill, compost, and recyclable fields. The Central Richmond appeared to have a higher overall degree of recyclable trash. Across both locations and three categories of trash, small size was the most abundant. Landfill was substantially more present.

Using data collected in the field, a trend in noise pollution was established. Figure 2 depicts the strong correlation between the maximum level of noise collected in decibels compared to the equivalent (averaged every second) continuous sound levels measured as A-weighted decibels (dB(A)). On both field samples collected, a strong positive correlation can be seen. Furthermore, the overall value of both maximum level dB and equivalent continuous sound level were notably higher in the Central Richmond district with one outlier towards the lower range. From statistical tests, data was confirmed to have a p-value < 0.01, as shown in Table 2.

## Tree Density

Results from tree data revealed a skew in the density and quality of trees among various neighborhoods in the city (Figure 3). The most obvious finding was that the Outer Richmond and Sunset districts have little to no presence of trees qualified as significant according to the department of public works. Additionally, non-significant trees are equally regulated throughout the city by Public Works. Trees located in major parks, such as Golden Gate Park, seem to be outside of the scope of this department. Maintained trees that are not significant do seem to be more common around the outer edge of large parks or green spaces throughout the city.

## Gaseous Pollution in SF

Data on greenhouse emission in San Francisco revealed important information about the source of CO2 from various locations and functions. Figure 4 depicts the emission of CO2 directly from City of San Francisco affiliated groups. Data reveal that only the top 2 commodities produce more than 200000 metric tons of CO2 emission. On the other hand, there were 16 different kinds of commodities provided by the city that emitted some quantity of CO2, although the bottom six seem irrelevant compared to other commodities. Surprisingly, the bottom four commodities all corresponded to on-road transportation via MUNI or other public transportation service associated emissions, but on average the data did not appear substantial. Most commodity usage comes from the municipal sector.

Municipal data depicted a similar outcome to that of community data (Figure 5). The top source of carbon dioxide emission was Nitrogen discharge all coming from the Public Utilities Commission. Emission of carbon dioxide on behalf of the municipal data set contained a much more limited range of commodities emitting the CO2 as well as overall mean carbon dioxide emitted. People are a commodity seen in the municipal data but missing from community data, this commodity produces more than 200 metric tons of CO2 on average. The maximum emission from Nitrogen discharge was just over 500 metric tons, which is multiple factors of magnitude less than the community-wide emission data presented beforehand (Figure 4). There were 11 commodity types from the community data that produced less than 4000 metric tons of carbon dioxide.

Analysis of community resilience data set compared the average annual PM2.5 concentration from all sources to the percent tree cover, as recorded by the Bay Area Quality Management District and the San Francisco Planning Department respectively (Figure 6). From regression analysis (Table 3), an obvious negative correlation between the two variables was confirmed. Four potential outliers in the scatter plot were detected at ranges above 9.0 in the PM2.5 and above 0.4 in the percent tree cover. The scale bar indicates the percent of land area with a contamination risk, from this only one region is classified as an outlier. Treasure Island was at high risk of contamination with a risk value of 0.977, which was around 0.6 higher than the next closest neighborhood of the city. Regression analysis demonstrated that the p-value was significant for percent tree cover, p < 0.01.

# Discussion

Research on data sets and field data was done on the Marina and Richmond districts of San Francisco. Initially, the intention was to discover a correlation between tree density and pollution of toxics, measured via PM2.5. By demonstrating incidences or locations of high concentrations of toxins, urban planners can adjust community structures to improve overall health of the region. Additionally, data on community-wide pollution can help determine at risk communities for cardiac or respiratory diseases. Data indicated that there were some strong correlations among select variables differentiating the two regions.

Field data on the Marina and Central Richmond neighborhoods revealed interesting relationships and comparisons. The first such, there is a slight difference between the absolute cleanliness and pollution between both of these neighborhoods (Table 1). The Marina received perfect scores. When the trash count data (Figure 1) is taken into account the superficial findings of the cleanliness data are confirmed. Central Richmond had greater amounts of trash among all three classifications of size and type of trash. The trash count and cleanliness scores for the Marina seem to counter one another, this may be because cleanliness was judged on three set locations, while trash count as a continuous measure of the entire intersection of interest. Landfill and small size-trash were the most common type of trash encountered indicating that pollution is minimal, but trash presence maybe due to the random pedestrian waste. Overall both the Marina and Richmond districts had relatively moderate to high levels of cleanliness which could indicate a high level of city cleaning or high levels of citizen involvement.

Further, noise pollution data (Figure 2) elaborated on the trends seen among the trash and cleanliness data. The range of noise in the Central Richmond (shown as Geary & 23rd Avenue on the plot) is much wider than the Marina (shown as Fillmore & North Point on the plot) range. The Central Richmond also presents two outlier records with a maximum level dB less than 75 and less than 80, these two points could potentially be attributed to the time of day at which data was recorded. This neighborhood tends to be quieter from the hours of 12 PM-3 PM. Typically residents are at work or school during these hours, resulting in lower foot and vehicle traffic. The data revealed a strong positive correlation among the equivalent continuous sound level and the maximum level sound with a p-value < 0.01, suggesting that there is a correlated difference among the two neighborhoods.

Information regarding tree density reveals that there is a higher significant-tree density towards downtown and south San Francisco resulting in lower density in the Richmond and Sunset neighborhoods. This proves to be an example of well thought out urban planning, by concentrating significant-tree density in an area with high population density the increasing levels of carbon in urban settings can be reduced (Nowak 1993). Regions of the city that tend to be more residential and less urban have fewer significant trees. The reasons for this could range from lack of funding in Public Works, or because these residential areas do not produce a high carbon footprint, or potentially because of increasing rural-urban migration. Studies have discovered that movement of millions of citizens, from rural to urban areas, can produce an additional 1 gigaton of the carbon footprint for a country (Feng and Hubacek 2016).

Greenhouse data reporting emission from the community and the municipality revealed important differences in the metric tons of carbon dioxide emitted from various sectors and San Francisco City departments. The community data reported that most emissions were because of the municipal sector using gasoline as a commodity. Gasoline has been a subject of dispute in the last few decades because of obvious effects on the environment but additionally, the maintenance of roads for gasoline-powered vehicles can have cascading effects. A study found that paved roads consume petroleum in the form of asphalt but also reduce the ground’s capacity to retain rainfall, and can disturb the natural hydrologic cycle (Freund et al. 1993). Additionally, the transportation sector contributed to a large portion of emissions, mainly in the form of gasoline. This is understandable since the transportation department is mainly composed of Muni related services. Research on public transportation systems has indicated as well that a reduction in greenhouse gas emissions can be seen through rigorous administration of costs in these departments (Cheng et al. 2018). Further, there were a wide range of departments responsible for emission in the municipal data indicating that overall regulations on ecological limitations in the city government seem to be working.

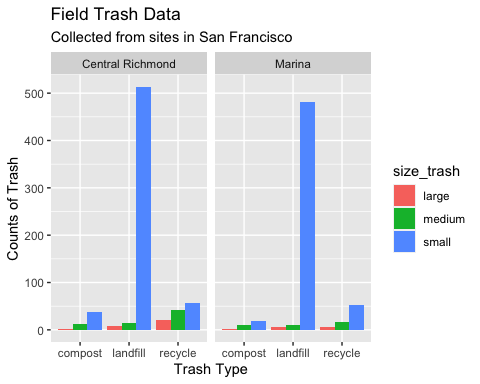
Research has found that tree canopy, specifically in urban forests, is related to carbon presence within the area (Nowak and Crane 2002). Data on the percent tree cover of the city and the particulate matter (PM2.5) demonstrated a relationship among tree cover and the toxics within a relative area of San Francisco. The number of facilities that could potentially lead to a risk of contamination was extremely low throughout all neighborhoods, with only Treasure Island demonstrating a substantial risk of contamination relative to other neighborhoods. The negative correlation in this data set is interesting considering researchers have found that tree density can serve to increase the concentration of PM2.5 within certain urban street canyons (Jin et al. 2014), while other papers claim that tree density can serve to decrease the PM2.5 (Nowak et al. 2013). These findings should be worrying to the population given that PM2.5 is strongly associated with visibility and health effects (Pui et al. 2014).

Research was performed to discover a relationship between the neighborhood of San Francisco and the pollution in the general area relative to the availability of trees. The role of urban planning has greatly influenced metropolitan cities throughout the country and in the case of this study, San Francisco. The initial prediction was that there was a direct correlation among the density of plants found relative to the neighborhood of San Francisco under consideration, but due to the limited amount of data available on location of trees and pollution hot spots, no definitive claim can be made on the relationship among tree density and pollution concentration. According to the data, there is a definite difference in pollution and tree density among neighborhoods in the city, but more research is required to reach a conclusion. Urban planning and ecology can collectively improve the environmental health of a community, but further work is needed to determine the what factors have the larger influence over ecological health in urban systems. Specifically, research must delve into the importance of tree and plant density in regions with high contamination risks to deter the negative consequences of pollution. Metropolitan cities around the country must follow San Francisco’s example and continue to reduce the amount of pollution from both the community and municipality, and urban planning can serve as the platform through which this occurs.

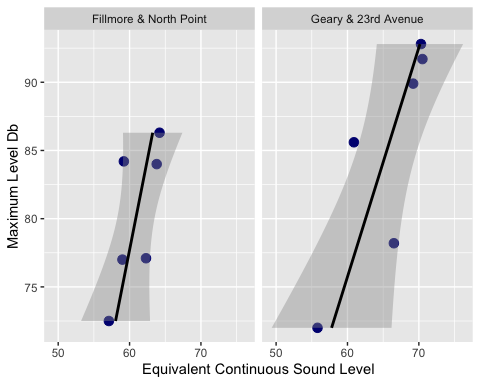
# Figures and Tables

|  |  |  |  |
| --- | --- | --- | --- |
| Neighborhood | CS 1 | CS 2 | CS 3 |
| Central Richmond | 4 | 3 | 5 |
| Marina | 5 | 5 | 5 |

**Table 1:** Cleanliness scores of Marina and Central Richmond districts. CS = cleanliness score, average score differed by 1 (Marina = 5, Central Richmond = 4).



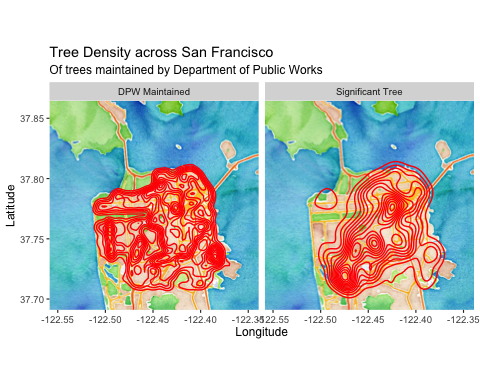
**Figure 1:** Amount of trash seen from cross streets analyzed in Marina and Central Richmond districts, trash was sorted into compost, landfill, or recyclable. There are equal proportions of trash between the neighborhoods, with slightly higher counts for the Central Richmond.



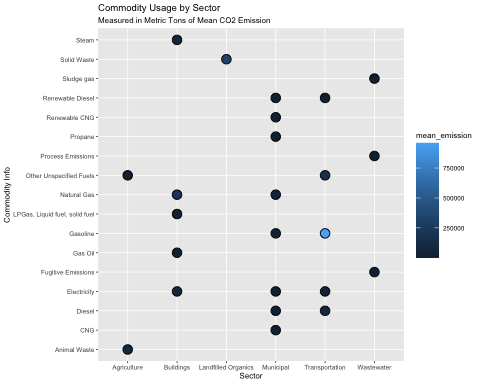
**Figure 2:** Difference in noise pollution from two different locations in San Francisco. Notably, the range of sound levels tend to be higher in the Central Richmond area.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Term | Estimate | Std. Error | Statistic | p Value |
| (Intercept) | 15.0963 | 10.6326 | 1.4198 | 0.1861 |
| maximum\_level\_db | 0.5827 | 0.1283 | 4.5428 | 0.0011 |

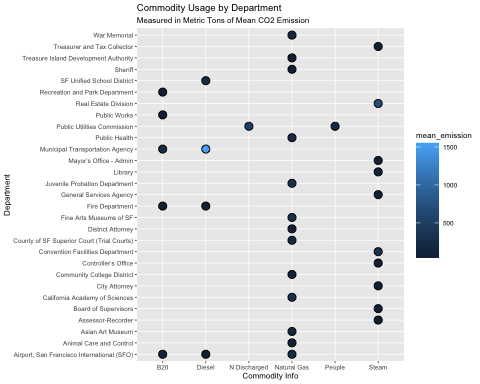
**Table 2:** Results from regression analysis on noise pollution in Marina and Central Richmond. Maximum level (dB) has p-value < 0.01.



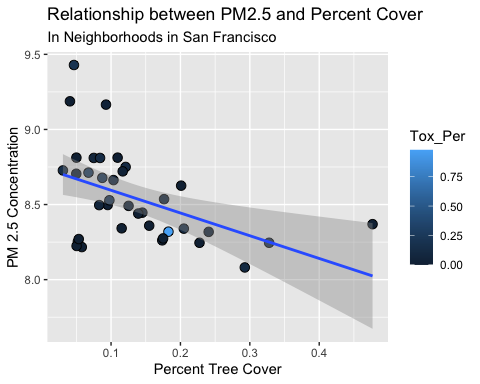
**Figure 3:** Density maps of significant-trees and other trees maintained by Public Works. The city department makes an effort to single out significant-trees, most of these which are towards downtown, mainly excluding the Sunset and Richmond regions.



**Figure 4:** There is a large difference in the emission of CO2 between the top 10 commodities and the remaining. Gasoline emits almost twice as much as the next closest commodity, solid waste.



**Figure 5:** Average emission, measured in metric tons of carbon dioxide, from various commodities in the San Francisco Municipality. Unlike the community data, scale of x-axis is much smaller, reaching only 500 metric tons.



**Figure 6:** Negative relationship between the percent tree cover and PM2.5 (p < 0.01). The scale bar also displays the percent of land area, within 0.25 miles, that is at risk of contamination, highest value displayed in light blue is Treasure Island YBI.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Term | Estimate | Std. Error | Statistic | p Value |
| (Intercept) | 8.746 | 0.079 | 111.214 | 0.000 |
| Tree\_Per | -1.514 | 0.488 | -3.105 | 0.004 |

**Table 3:** Results from regression analysis of Figure 6, note low Tree\_Per p value < 0.1.

# Sources Cited

Aronson, M. F., C. A. Lepczyk, K. L. Evans, M. A. Goddard, S. B. Lerman, J. S. MacIvor, C. H. Nilon, and T. Vargo. 2017. Biodiversity in the city: Key challenges for urban green space management. Frontiers in Ecology and the Environment 15:189–196.

Brunekreef, B., and S. T. Holgate. 2002. Air pollution and health. The lancet 360:1233–1242.

Cheng, H., C. Mao, S. Madanat, and A. Horvath. 2018. Minimizing the total costs of urban transit systems can reduce greenhouse gas emissions: The case of san francisco. Science Direct 66:40–48.

Cutter, S. L. 1995. Race, class and environmental justice. Progress in human geography 19:111–122.

Feng, K., and K. Hubacek. 2016. Carbon implications of china’s urbanization. Energy, Ecology and Environment 1:39–44.

Freund, P. E., G. T. Martin, and others. 1993. The ecology of the automobile. Black Rose Books Montreal.

Haaland, C., and C. K. van Den Bosch. 2015. Challenges and strategies for urban green-space planning in cities undergoing densification: A review. Urban forestry & urban greening 14:760–771.

Hurley, A. 1995. Environmental inequalities: Class, race, and industrial pollution in gary, indiana, 1945-1980. Univ of North Carolina Press.

Jim, C. Y. 2004. Green-space preservation and allocation for sustainable greening of compact cities. Cities 21:311–320.

Jin, S., J. Guo, S. Wheeler, L. Kan, and S. Che. 2014. Evaluation of impacts of trees on pm2. 5 dispersion in urban streets. Atmospheric Environment 99:277–287.

Mohai, P., D. Pellow, and J. T. Roberts. 2009. Environmental justice. Annual review of environment and resources 34:405–430.

Niemelä, J. 1999. Ecology and urban planning. Biodiversity & Conservation 8:119–131.

Nowak, D. J. 1993. Atmospheric carbon reduction by urban trees. Journal of environmental management 37:207–217.

Nowak, D. J., and D. E. Crane. 2002. Carbon storage and sequestration by urban trees in the usa. Environmental pollution 116:381–389.

Nowak, D. J., D. E. Crane, and J. C. Stevens. 2006. Air pollution removal by urban trees and shrubs in the united states. Urban forestry & urban greening 4:115–123.

Nowak, D. J., and E. J. Greenfield. 2012. Tree and impervious cover change in us cities. Urban Forestry & Urban Greening 11:21–30.

Nowak, D. J., S. Hirabayashi, A. Bodine, and R. Hoehn. 2013. Modeled pm2. 5 removal by trees in ten us cities and associated health effects. Environmental pollution 178:395–402.

Pope III, C. A., M. Ezzati, and D. W. Dockery. 2009. Fine-particulate air pollution and life expectancy in the united states. New England Journal of Medicine 360:376–386.

Pui, D. Y., S.-C. Chen, and Z. Zuo. 2014. PM2. 5 in china: Measurements, sources, visibility and health effects, and mitigation. Particuology 13:1–26.

Shi, G., Z. Chen, S. Xu, J. Zhang, L. Wang, C. Bi, and J. Teng. 2008. Potentially toxic metal contamination of urban soils and roadside dust in shanghai, china. Environmental Pollution 156:251–260.

Suwa, T., J. C. Hogg, K. B. Quinlan, A. Ohgami, R. Vincent, and S. F. van Eeden. 2002. Particulate air pollution induces progression of atherosclerosis. Journal of the American College of Cardiology 39:935–942.

Wolch, J. R., J. Byrne, and J. P. Newell. 2014. Urban green space, public health, and environmental justice: The challenge of making cities “just green enough”. Landscape and urban planning 125:234–244.