Improving L.A.'s Air: An analysis of Heat Island Mitigation, Urban Forestry, and Landscape Management as Strategies for Air Quality Management

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Executive Summary

The purpose of this study is to examine the costs, benefits, and barriers to implementation of three strategies for air quality management. This report includes an analysis of heat island mitigation, urban forestry, and landscape management as methods to mitigate air pollution. These research applies specifically to how these strategies can be and are being employed in the city of Los Angeles, and how their implementation can be expanded or improved.

The main findings of this research were as follows: that the three aforementioned strategies can be used to ameliorate air quality if implemented effectively; that these strategies, when combined, have a greater overall positive impact on air quality as well as a greater amount of benefits when compared to costs; in implementing any combination of these three strategies there are definite barriers that a project must overcome first in order to be successful; and finally that while the city of Los Angeles is attempting a large-scale urban forestry project through the Million Trees Los Angeles initiative, the project could be more successful if it overcame the existing barriers to implementation.

Air quality mitigation projects would be more successful in Los Angeles if they involved a broad strategy that intentionally encompassed heat island mitigation, urban forestry, and landscape management together from the initial planning phase. The program would benefit even more if it was implemented by a single city entity rather than indirectly through a number of separate departments. In addition, proper community encouragement and education, a reduction in the risks and responsibilities imposed on property and business owners from these strategies, and a clear method of evaluation and follow-up are recommended planning procedures when conducting any or all of these

interventions. Lastly, these interventions should be considered a supplement, not a substitute, for other air quality control methods.

Table of Contents

I. Introduction

Los Angeles is a dirty city. For years it has been the worst city in the US in terms of year-round air quality.[1]. Part of this pollution stems from the goods movement. With the nation's busiest port in terms of container traffic, ocean vessels, loading and docking equipment, trains, and most of all trucks contribute dramatically to the substandard air quality in LA.

In conducting this study my original intent was to explore various ecological planning methods for air pollution mitigation as they relate to the goods movement. I was particularly interested in the areas of Wilmington and San Pedro because of the political climate around the ports. My friend had a logistics company in Wilmington, and every time we went down there we dealt with the issues of traffic and air pollution that came directly from the goods movement. Furthermore, recent changes in policy that attempting to address these issues ultimately lead to the loss of my friend's company. Part of the goal of the Clean Air Action Plan (CAAP), a city measure to air pollution caused by the goods movement, was to require all independent owner operators to become permanent employees of logistics companies[2]. While initially I wanted to research how this would harm small businesses, after further investigation I realized that the increased governmental regulation of the logistics industry is a definite necessity if any improvements are to be made in terms of air quality. My friend's business was about 50 feet from a school and a soccer field where children played; yet every day there were about 30 trucks coming in and out of his property, polluting the air. This air

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1"City Mayors: The Most Polluted U.S. Cities" *City Mayors Environment.* 04 05 2008. American Lung Association. 19 April 2009

2"Program Overview and Benefits" *The Port of Los Angeles Clean Trucks Program.* The Port of Los Angeles. 19 April 2009

pollution has real health consequences; it literally costs people their lives. The CAAP and CTP would protect children and community members, making businesses responsible for the negative externalities caused by their operations.

While the CAAP is a strong first step for air quality management in LA County, it is primarily focused on reducing emissions, and maintaining a minimum level of air quality. Though we absolutely as a city need some form of emissions control, it is also necessary to note that even at these controlled levels, there is still a need to further clean the air as a matter of public health.

Given the limited scope of the CAAP, I then sought to study whether or not other methods of air pollution mitigation could be used to address air pollution from the goods movement as a supplement. This became problematic; however, since the programs I examine, namely heat island mitigation, urban forestry, and landscape management, have several issues that need to be addressed before they can be effectively implemented. Pollution levels are also so high in these areas that these interventions may not be the best overall strategy for air quality improvement. Thus, my project evolved into an evaluation of the three mitigation strategies, and an examination of the barriers to implementation using an existing program, the Million Trees Los Angeles initiative.

In this study, I am defining heat island mitigation as the attempt to reduce the urban heat island effect, through planting programs, infrastructure change, and a variety of other strategies. The heat island effect, described in depth in later chapters, is a phenomenon in which a city's average air temperature tends to be a few degrees higher than its surrounding, non-urban areas with similar climates. This results in air pollution, and a number of other impacts that damage the environment and public health.

For all intents and purposes, I am defining urban forestry in this study as the management of existing trees and other vegetation within an urban area, as well as the strategic planning and implementation of further planting projects, bearing in mind the overall health and well-being of the community.

It is necessary to explain first how urban forestry can be used as an air pollution mitigation measure. There are three ways in which urban forests can have a positive impact on air quality.

Trees remove pollutants by absorbing them through pores on the surface of their leaves. This process is called deposition of pollutants to the vegetation canopy. Trees filter these particulate pollutants mainly through their leaves; each tree uses the air for photosynthesis, and the pollutants are carried to the ground during rainfall as waste[3]. In general, the trees that absorb the most pollutants are the ones with the most total surface area of leaves[4]. This would lead one to expect the best trees for pollutant removal are those with the largest, widest leaves; however, most studies have shown a higher removal rate of pollutants by evergreen trees, because they have a much higher total number of leaves, increasing the overall porous surface area for more absorption capacity[5].

Trees also have a tremendous impact on air quality through the removal of CO2, a greenhouse gas, from our atmosphere. In a process called sequestration, trees store CO2 in their trunks and branches (aka woody biomass), while at the same time producing clean oxygen for us to breathe[6]. Urban trees can only store this CO2 as long as they

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3"Trees and Air Quality." *California Environmental Protection Agency Air Resources Board.* 08 16 2007. California Environmental Protection Agency. 19 April 2009.

4 "Trees and Air Quality," 19 April 2009

5 "Trees and Air Quality," 19 April 2009

6"Carbon Sequestration in Agriculture and Forestry." *United States Environmental Protection Agency.* 10 19 2006. US Environmental Protection Agency. 19 April 2009.

remain alive; when they start to decompose, the CO2 is released back into the atmosphere[7]. However, by caring for urban forests and choosing to plant species with longer life spans and higher sequestration rates, this CO2 storage system can be extremely beneficial if properly implemented and maintained.

Another benefit to air quality of urban forests, particularly useful in Los Angeles, is that urban forests serve as a measure to reduce summer time air temperatures. This indirectly serves to mitigate air quality. Higher temperatures serve as a catalyst, speeding up chemical reactions; in terms of air quality management this is bad news because higher temperatures increase the rate at which ozone is formed[8]. The cooling effect of trees on air temperature not only ameliorates this problem, but also lowers emissions from plants providing electricity for air conditioning, and provides shade. This is one way in which urban forestry serves to mitigate the urban heat island effect.

Most of the existing data evaluates the overall effect of urban forests on cities and communities and measures their benefits, showing in almost every case that the benefits of the urban forest system outweigh its costs and maintenance. But more recently governments, nonprofit organizations, and others have been attempting to design projects that would ameliorate air pollution through large-scale planting efforts.

One existing project is the Green Philippine Highways Project, started in 2006 by the Department of Environment and Natural Resources (DENR) in the Philippines. This is one of the largest public health programs focused on air pollution mitigation currently in existence, which is focused on control through the use of urban forestry. DENR

7Hartel, Dudley. "Community Trees and Carbon Sequestration." *2008 NADF Conference- Urban Carbon Markets (Atlanta).* 11 19 2008. Partners in Community Forestry. 19 April 2009.

8Vasishth, Ashwani. "An Integrated Ecosystem Approach to A More Sustainable Urban Ecology: Heat Island Mitigation, Urban Forestry, and Landscape Management Can Reduce the Ecological Footprint of Our Cities." 2006.

estimates that in the Philippines, at least 10 trees will need to be planted to reverse the effect of one vehicle's emissions[9]. The effort incorporates funding, community organizing, and advertising to gain public support for the project; during one day in August of 2006, the Philippine community collectively planted about 800,000 seedlings along its three major highways[10]. The community involvement goes further in that community groups and individuals are expected to "adopt a tree" by caring for it for three years following the planting, which is the average amount of time trees need to be cared for before they will grow successfully on their own.

In the Philippines, about 70% of air pollutants come from vehicular emissions[11]. An estimated 50 million trees total would be needed to fully sequester all the carbon dioxide caused by vehicular emissions[12]. Assuming a 100% survival rate of all 800,000 trees planted, the program would actually serve to sequester 1.6% of the total atmospheric carbon in the country when the trees reach full maturity. Of course, average survival rates are usually much lower; however it is difficult to project what the survival rate would be without a full evaluation of the program. While this number may seem small initially, it is important to note that this 1.6% of translates to a reduction in all atmospheric carbon dioxide caused by vehicular emissions throughout the entire country.

The most recent data shows that in 2004, the Philippines emitted 80.5 million metric tons of carbon dioxide.[13] If seventy percent of the emissions are caused by motor vehicles, this means cars caused about 56.35 million metric tons of carbon dioxide,

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9 "Forest Management Bureau Supports Green Philippines Highway Project." *Forest Management Bureau.* 2006. Department of Environment and Natural Resources Forest Management Bureau. 19 April 2009

10 "Forest Management Bureau Supports Green Philippines Highway Project," 2006.

11 "Forest Management Bureau Supports Green Philippines Highway Project," 2006

12 "Forest Management Bureau Supports Green Philippines Highway Project," 2006

13 "Forest Management Bureau Supports Green Philippines Highway Project," 2006

meaning when the trees planted by the Green Philippine Highways project reach full maturity, 901,600 metric tons per year of carbon dioxide will be removed from the atmosphere. This is particularly significant considering that aside from the actual planning phase of the project, the planting only took one day. If the project were made an annual program, in as little as 63 years all the atmospheric carbon dioxide caused by vehicular emissions could be removed, assuming emissions levels remained constant.

So urban forestry is clearly a very powerful tool in air pollution mitigation. The final strategy I will analyze in this report is landscape management, which involves restructuring of the natural landscape both to minimize the heat island effect (which impacts air pollution) as well as include urban forests into a city's infrastructure.
In this study, I will evaluate case studies illustrating how the strategies of heat island mitigation, urban forestry, and landscape management can be and have been used to mitigate air pollution. Using these studies, I will show how the same methods could potentially be used in Los Angeles to offset the negative impacts of air pollution. In addition, I will explore the current Million Trees Initiative in Los Angeles as well as independent sources to identify and discuss some of the barriers to urban forestry as a solution to air pollution problems in Los Angeles; in other words, what obstacles exist when using urban forestry as an air pollution mitigation strategy. In comparing the three strategies with barriers to implementation, I hope to show how Los Angeles can overcome these barriers by integrating the three strategies as a means to combat air pollution.

While these mitigation strategies are effective tools to ameliorate air quality, on their own they will not be enough to ensure clean air in the future. Those looking to

employ these strategies should be aware that they will have the strongest impact on air quality when viewed as a supplement to other forms of pollution prevention and control. Along with these strategies, in order to make a significant positive impact on air quality, governments must strive to reduce point source pollution and tighten emissions standards, while individuals need to be aware of how they can take personal responsibility and action to reduce their contribution to air pollution.

Research Methods:

The methods used in this study were mainly qualitative. Secondary research consisted of an extensive literature review on air pollution and its causes, and possible strategies to mitigate air pollution. I examined the various air quality management strategies--heat island mitigation, urban forestry, and landscape management-- by conducting an in-depth analysis of existing studies where these strategies had been implemented, attempted to be implemented, or modeled.

To discover which studies best illustrated each mitigation strategy, I consulted several nonprofit organizations that deal with issues of urban forestry and advocate for tree planting. I initially contacted and mainly corresponded with these organizations through email although sometimes we communicated through phone. Of the recommended studies, I selected those that I felt were best representative of each mitigation strategy and thorough in quantifying all aspects of costs and benefits of each method.

To identify barriers to implementation of these strategies, I did an evaluation of Los Angeles' Million Trees Initiative to assess its effectiveness and struggles to implementation. This was done mainly through primary research. Through interviewing

experts in the field of urban forestry, as well as city officials, I was able to gain an understanding of what problems existed for the project and what lessons we can learn to use these strategies more effectively for air pollution mitigation. I also did some secondary research, evaluating both the media perspective on the project as well as the main project overview and statistics, again through literature review.

I initially contacted interviewees through email. The majority of interviews were done over the phone, although some were in person. In addition, follow-up questions to certain participants were conducted through email. Participants were first given an overview of the project and then asked to answer questions. Questions varied for each interview based on the organization each individual represented or their area of expertise. Participants were informed that this study would be published and that they may be quoted or cited in this work.

Using the analyses of the three mitigation strategies in combination with my interviews, I was able to detect where the plan in Los Angeles had been successful and where it was struggling. I then used these findings to suggest alternative considerations for implementing an urban forestry project, focused especially on using the methods of landscape management and heat island mitigation in conjunction with urban forestry to maximize the benefits of such a program, both on air quality and in other areas as well.

II. *Intervention Method: Heat Island Mitigation*

What is an urban heat island, and why should Los Angeles residents be worried about it? An urban heat island is a recurring climate change throughout the country, where urbanized areas are typically between two and ten degrees warmer than surrounding, non-urbanized areas.

Although the temperature differences do not initially seem that drastic, it is important to note that changes of even one or two degrees have the power to dramatically alter ecosystems and influence the survival of species. Not only ecosystems can suffer. In Eric Klinenberg'sbook, "Heat Wave," the author explores the causes of a heat wave in July of 1995 that killed 521 people living in the city of Chicago.[14] Mayor Richard Daley of Chicago appointed a commission to study what caused the heat wave and why it was so devastating. Along with the high temperature, heat index, and cloudless night skies, they found the heat island effect to be one of the major causal factors of this meteorological phenomenon. Aside from the vast number of deaths, there were power outages, water shortages, and such a large number of heat-related injuries and illnesses that hospitals were so overcrowded to the point that they were unable to admit patients quickly enough to save their lives. While the urban heat island effect only causes a few degrees in temperature change, with the right conditions this effect can be deadly, given what happened in Chicago in 1995. Furthermore, there are many negative impacts to the environment that are caused by the heat island effect.

What causes the heat island effect? Changes in temperature between urban and non-urban areas with identical climate occur because of alterations to the natural

14 Klinenberg, Eric. *Heat Wave: A Social Autopsy of Disaster in Chicago.* Chicago: University of Chicago Press, 2002

environment. According to William Lowry's classic article on the subject, "the city itself causes these differences."[15] Asphalt, a black material used in pavement; especially for roads and freeways, absorbs sunlight, causing its temperature to rise between 50 and 70 degrees higher than the surrounding, ambient air.[16] Indeed, on average, most of a city's buildings and streets are able to conduct heat at three times the rate of soil.[17] The combined effect of the increased absorption capacity of these materials is a rise in the surrounding, ambient air temperature as these surfaces struggle to transfer heat.

Like building materials, the actual shape or architecture of a city causes a temperature increase. Because cities have more variety and orientation of surfaces than the natural environment, the built materials absorb heat while also reflecting it onto other absorbing materials, further magnifying the heat island effect.

Another causal factor of this effect is that in cities, unlike in the natural environment, there are many man-made sources that give off heat. For example, factories, cars, and even residential buildings cooling systems give off heat, leading to a greater rise in ambient air temperature.

Also, cities have their own systems that drain precipitation, sewers and drain pipes, etc. Reduced precipitation means a reduced amount of evaporation that occurs in the city. Since heat energy is used during evaporation, this is a place where heat is removed in the natural environment. However, city infrastructure prevents a certain amount of evaporation, thereby allowing heat that would have been lost to this process to remain. Particle matter and air pollution exaggerate the heat island effect in urban areas because although they reflect sunlight, reducing the amount of heat that reaches surfaces,

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15 Lowry, William. "The Climate of Cities." *Scientific American* 217(1967): 15-24.
16 Vasishth, "An Integrated Ecosystem Management Approach."
17 Vasishth, "An Integrated Ecosystem Management Approach."

they also serve as a barrier to trap heat and keep it from leaving the ambient air. The overall net effect is an increase in temperature.

Building materials and materials for roads also contribute to the heat island effect because they replace preexisting vegetation. Vegetation naturally cools the atmosphere by surface cooling and cooling of the surrounding soil, in a process called evapotranspiration. Evapotranspiration occurs when vegetation and trees lose water through their stomata and leaves. This water is evaporated into the air, producing a cooling effect on the surrounding atmosphere. When cities are built, replacing natural existing vegetation, this loss of vegetation further contributes to the heat island effect because of the loss of benefits of evapotranspiration.

Heat island impacts vary on a municipal level versus on a regional level. On a global scale, a recent study found that between 1980 and 2002, approximately half the trend in world temperature increase was caused solely by the urban heat island effect.[18] On a regional scale, the urban heat island effect can be further exacerbated by the fact that many cities, Los Angeles, included, are very spread out over a large area. In this regard, the entire metropolitan area surrounding Los Angeles is also a few degrees warmer than other areas with similar climates because of the heat island effect. This is similar to the Tri-State metropolitan area encompassing New York City, parts of northern New Jersey and most of Connecticut. Finally, we have the urban heat island effect on a local scale, which is very area-specific and probably the easiest to model and to mitigate.

Urban heat islands contribute to air pollution in two ways; through the increase of both primary and secondary pollutants entering the atmosphere. First, as previously

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18 McKitrick, Ross. "Quantifying the Influence of Anthropogenic Surface Processes and Inhomogenities on Gridded Global Climate Data." *Journal of GeoPhysical Research-Atmospheres* (2007)

stated, the increase in temperatures increase the demand for air conditioning and electricity, thus increasing output from power plants and their consequent air pollution. In Los Angeles, most of the electricity supplied is from sources outside of the city; however, we should not ignore this source of pollution, but rather be aware that though it has less of an impact on local air quality, in a more globalized context Los Angeles can reduce its impact on other areas by decreasing electricity consumption.

The urban heat island also contributes to poor air quality through an increase in secondary pollution, which in LA tends to mean an increase in the rate of formation of smog. These heat islands indirectly encourage the formation of smog, particularly in California where it has historically been a devastating problem for air quality management. Smog forms when ultraviolet radiation of the sun dissociates NO2, forming NO and a radical oxygen atom. The radical oxygen then combines with molecular oxygen to form O3, or ozone[19]. For a more detailed summary of the formation of ozone and chemical reactions involved, please refer the appendix of this report. The chemical reactions at every step are sped up because of the increased ambient air temperature. In other words, the heat acts as a catalyst for the formation of smog; in an area where there is already an abundance of NO and CO ready to react, because of the high concentration of air pollution. .

With increasing amounts of air pollution in Los Angeles, the cycle continues. Air pollution increases absorption of radiation in the troposphere, helping to create an atmospheric inversion layer.[20] This inversion layer blocks rising air, preventing it from

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19"How is Ozone Formed?." *The Formation of Ozone.* 19 April 2009

20Slanina, Sjaak. "The Formation of Ozone in the Troposphere and Stratosphere." *Encyclopedia of Earth.* 2008. Encyclopedia of Earth 19 April 2009.

cooling at its normal rate; similarly it blocking the dispersion of air pollution into the atmosphere, keeping it closer to the ground and more concentrated.

To better understand how urban heat island mitigation can be used as a measure to benefit air quality, I will examine an instance where this has already been accomplished. Rosenwig et al. studied the same process in New York City.

NYC's heat island currently averages about 7.2 degrees Fahrenheit over the surrounding suburban area during summer months. The heat island effect is further exacerbated during heat waves[21]. The study aimed at answering several key questions. For our purposes we will analyze the results of the select questions that pertain to this report. First, the study aimed to show whether or not there were viable options that existed that could be used to reduce elevated near-surface air temperatures associated with urban heat islands. Next, they wanted to know what options existed that had the potential to reduce temperature on a per-unit basis; in other words, out of the strategies tested, which is the most effective for reducing air temperature directly in the area where the mitigation strategy was taking place, versus which strategy is most effective for reducing the urban heat island effect city-wide. The study also examines what the costs are associated with each strategy of heat island mitigation, as well as which strategy provides the greatest benefits overall in terms of reduced air temperature and demand for energy for air conditioning.

The study evaluated several various methods of heat island mitigation to attain these goals. They primarily focused on urban forestry; through both street tree planting

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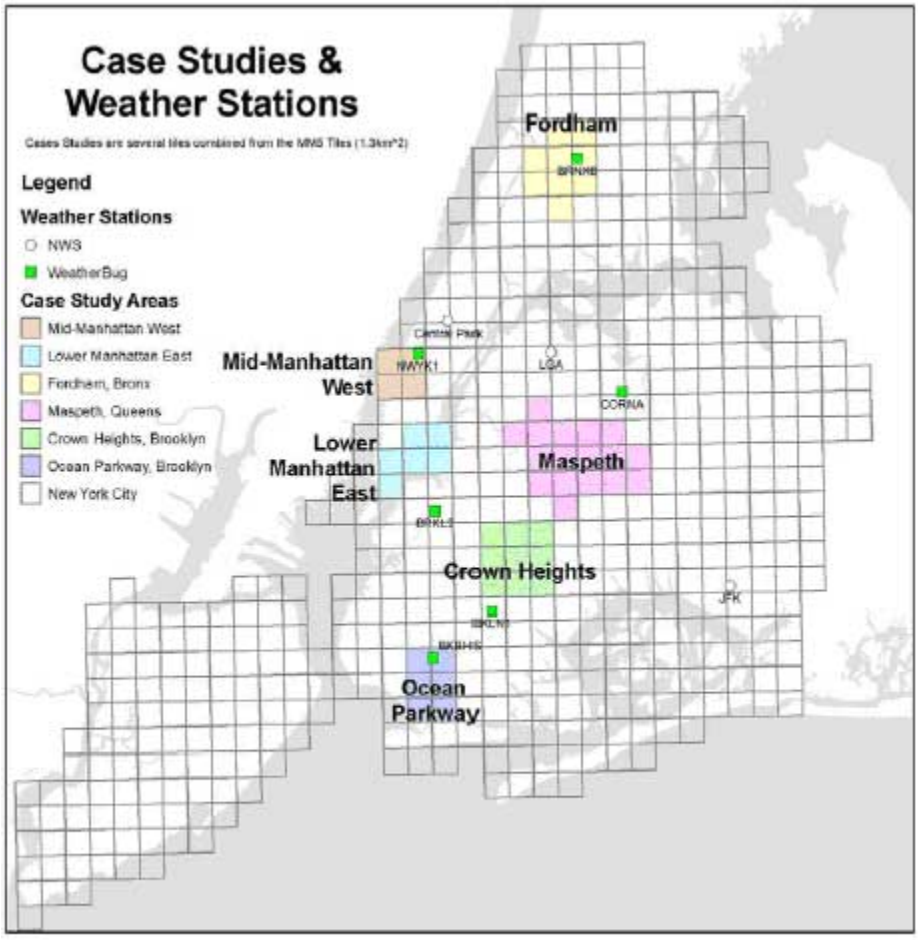
21 Rosenwig, Cynthia et al. "Mitigation New York City's Heat Island Effect With Urban Forestry, Living Roofs, and Light Surfaces." *NYSERDA-EMEP Project.* 10 2006. NYSERDA. 19 April 2009.

and open space planting, living roofs, and the use of light-colored roofing surfaces that absorb a low amount of heat as strategies to reduce the urban heat island effect.

Six sites were chosen in NYC for the heat island mitigation impact study: Fordham, Mid-Manhattan West, Maspeth, Crown Heights, Ocean Parkway, and Lower Manhattan East, as shown on the map below. The study, done in 2002, was conducted throughout three heat wave periods; from July 2nd- July 4th, July 28th- August 7th, and August 11- August 18th. A heat wave period was defined as any period during which the temperature measured in central park was over 90 degrees Fahrenheit for three consecutive days.



Case study areas and weather stations. Grid boxes correspond to the MM5 model 1.3 km grid.

The study created a GIS library using satellite data for surface temperatures, and spatially analyzed how the mean temperatures varied over a period of time in each study area. They identified three heat wave periods to use for the main analysis. Using their GIS library, they compared temperature and existing urban forest, canopy cover, and green roofs to identify any temperature correlations or patterns. They then compared a regional climate model to the satellite data, to determine its accuracy. It was found to be effective; so they used this model to determine the potential reductions in near-surface air temperature and surface temperature for each mitigation method during the three heat wave periods. Finally, they conducted a statistical analysis to see how well

environmental characteristics predicted surface temperatures, both city-wide and in the case study areas.

The study concluded that the mitigation strategies can reduce surface temperatures, thereby reducing near-surface air temperatures. They found that the most potential cooling occurred when implementing a combined strategy of planting street and open space trees and using green roofs. The street trees had the most potential for temperature cooling on a per-unit basis. This will become important in chapter five's discussion of an integrated ecological planning strategy.

I chose to analyze this study because of the similarities between NYC and LA during the summer. The heat island effect is exacerbated during high temperatures, low-wind speeds, and low cloud cover; the study, conducted in 2002, was done at a time when these conditions were prevalent. In Los Angeles, these conditions are similar during the summer months. Also, both cities have coastal climates and have very high populations, and have a high volume of traffic concentrated in very specific areas, (and consequently a high amount of air pollution).

Throughout the state of California as well as in the city of Los Angeles, there have been some attempts to mitigate the heat island impact, but on a broader, more general scale than the localized efforts achieved in the New York City case study. Currently in Los Angeles, LADWP is running two programs to mitigate the heat island effect; the Los Angeles Cool Schools Program and Trees for a Green LA.

The Cool Schools Program is a partnership between the DWP and LAUSD to educate students on biology, botany, horticulture etc. while engaging them in tree

planting on school property[22]. Currently, the program runs on a very small scale, mainly by LAUSD participation. In an interview with a DWP official, she stated that the schools mainly run the program and DWP serves as a tree supplier from their nursery, as well as provides material to help educate students.

Trees for a Green Los Angeles is a tree give-away program that developed as a segment of the Million Trees Los Angeles initiative, which is discussed in detail in later chapters of this report.

California and Los Angeles are taking steps to begin heat island mitigation. Statwide, the efforts will have a slow, positive impact. As new and replacement roofs must meet better standards for solar reflectance and thermal emission, older roofs that exacerbate the heat island effect will gradually phase out. The DWP is using more of a localized approach with urban forestry to mitigate the heat island; however, right now it is a city-wide effort, and independently these programs do not encompass a large enough scale to have a significant impact that would mitigate the regional heat island plaguing Southern California.

22"Cool Schools Program." *LADWP*. Los Angeles Department of Water and Power. 19 April 2009

III. *Intervention Method: Urban Forestry*

In addition to the massive tree planting program that recently took place in the Philippines, urban forestry programs are beginning to emerge as an air pollution mitigation strategy throughout the world, though this is still a relatively new mitigation measure. The first urban forestry conference in the United States was organized by the U.S. Forest Service in 1978.[23] At a later conference in Orlando in 1987, Rowen Roundtree , a U.S. Forest Service researcher voiced the idea and gave factual evidence of the benefits of the urban forestry, in terms of air pollution mitigation, groundwater recharge, and potential energy savings.[24] From then on, it became policy of the forest service to continue researching these topics. In 1995, the first GIS system tool for quantifying urban forests, called CITYGreen, was made available for use by the organization American Forests[25]. This revolutionized urban forestry as we know it today; because now the effects and scale of urban forests can more efficiently be measured.

In the US, most studies to date have focused on how the existing urban forest benefits cities and communities, in hopes that the proof of their benefits can be used to justify spending for care of the existing urban forest. In this section, I would first like to analyze a case study of Chicago's existing urban forest that highlights the benefits of the urban forest, and later examine another study in Arizona where urban forestry was actually used as an air pollution mitigation strategy.

There are two types of trees in the urban forest. Curbside, or street trees, are along sidewalks and therefore require changes to the built environment in order to plant

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23 Gangloff, Deborah. "Tracing the Rise of Urban Forestry." *American Forests* 2008 19 April 2009.
24 Gangloff, "Tracing the Rise of Urban Forestry."
25 Gangloff, "Tracing the Rise of Urban Forestry."

and care for them. Open space trees, in parks or grassy areas, require little infrastructure change, making them easier to implement as a strategy for mitigation. However, street trees are usually more effective at air filtration because of their proximity to idling cars and trucks, one of the primary sources of air pollution in Los Angeles.

In Chicago, as well as in several other cities including Tucson, Modesto, Sacramento, and the San Joaquin Valley the USDA Forest Service has conducted several studies to assess the benefits of the urban forest. These studies analyze how much money is actually saved due to the urban forest's offset of energy costs, how much water is saved because of the associated increase in recharge, and how much pollution is filtered out of our environment due to the urban forest.

The study in Chicago was conducted by the USDA Forest Service, entitled the urban forest climate project[26]. Over a three year period, scientists cataloged all the existing trees and vegetation in the city of Chicago, finding that there were 50.8 million trees in the city of Chicago and that about 66% of them were in good or excellent condition. They then measured the effect of the urban forest over three years on air quality mitigation, potential atmospheric carbon dioxide reduction, wind and temperature changes, local-scale energy and water exchanges, and potential building energy savings. Finally, they compared the costs and benefits of urban forest planting and tree care.

The study examined the urban forest's impact on air pollution in the form of carbon dioxide, Nox, SO2, ozone, and particulate matter.

Gaseous air pollution is removed from the atmosphere by three mechanisms; wet deposition, chemical reactions, and dry deposition. Wet deposition is when the pollutants

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26 McPherson, Gregory et al. "Quantifying Urban Forest Structure, Function, and Value: The Chicago Urban Forest Climate Project." *Urban Ecosystems* 1(1997): 49-61

are literally "rained out" and flushed down to the ground by precipitation. Chemical reactions can produce other forms of pollution such as smog which is then removed by either wet or dry deposition.[27] The pollution can also remain in the atmosphere and form carbon dioxide, water vapor, or a variety of other compounds.. Finally, dry deposition is the way in which the urban forest actually serves to remove pollutants from the atmosphere. In dry deposition, particulate matter and pollution settle out of the air and onto adjacent surfaces including trees and vegetation.

Plants uptake this pollution through their leaves, which is why in general plants that have a higher volume of leaves with larger surface areas are more effective at removing pollution from the atmosphere. During the day, plants leaves transpire water and take in carbon dioxide, as part of their nature life cycle. As they take in carbon dioxide, they ingest other gases and airborne pollutants; thus removing them from the atmosphere and debilitating their potential to cause harm to humans and communities impacted by air pollution.

Part of the aim of the Urban Forest Climate Project was to actually measure the rate at which each specific type of tree filtered each specific type of pollutant out of the atmosphere. To do this, they measured each tree's rate of removal of pollutants compared to actual pollution levels in Chicago during the time of the study. A more detailed outline of the process by which to gauge a tree's average impact on air pollution can be found in the appendix of this report***.**

The study essentially broke down the Chicago area into 117 smaller sections for an analysis on each of tree canopy cover and air pollution concentration. First, they measured how much of each of the main pollutants were in the atmosphere on average on

27 McPherson et al, "Quantifying Urban Forest Structure."

an hourly, daily, and monthly basis to calculate an average for each type of pollution. To get an accurate estimate of how much pollution the urban forest was actually removing, they had to know the local concentration of each pollutant as well as the deposition velocity, which is the rate at which the surface area of an individual leaf removes pollution from the atmosphere.

In 1991, one of the study years, the urban forest removed about 6,145 tons of pollution, providing an air quality benefit valued at about $9.2 million dollars. The study concluded that on average, Chicago's urban forest removes between 3.7 and 4.0 tons of SO2, between 4.2 and 4.6 tons of NO2, and between 8.9 and 9.8 tons of PM10; in addition to the removal of carbon dioxide, carbon monoxide, and ozone. Larger, healthier trees removed more pollution than smaller, less healthy trees, and in general, trees with more surface area in their leaves were more efficient at air pollution removal.

The benefits of urban forestry involve mitigation of economic externalities that local, state, and federal officials often do not take into account. However, the benefits are concrete and do have a definite economic value because they serve to offset negative externalities caused by the goods movement and other sources of pollution. The study used two methods to estimate the benefits and costs of maintaining Chicago's urban forest. First, through use of a computer simulation program, they analyzed the effects of trees on energy use for buildings to get a direct estimate of the monetary benefits. In addition, they used an "implied valuation" method to calculate the benefits and costs from other impacts of the urban forest. Essentially they used the current average cost of air pollution mitigation in Chicago by other methods, so that for every kilogram of pollution it cost x amount of money to remove it from the atmosphere, they multiplied the

tree's removal rate per kilogram of pollution by the current cost for pollution removal to calculate the monetary benefits.

What are the costs of an urban forestry solution to air pollution mitigation? The study compared the costs of pruning trees, removal of dead/dying trees, cost of planting each individual tree, irrigation, and initial purchase of the tree to be planted. These costs were compared with the potential benefits (pollution removal, energy-cost savings, etc.) previously examined in this study.

The study finally concluded that the monetary benefits of Chicago's urban forest was that each tree in good or excellent condition provided Chicago with benefits over twice the cost of planting and implementing the tree.

Along with assessing the value of the existing urban forest, new programs are beginning to take place that actually use urban forestry as an air pollution mitigation strategy. A similar cost benefit analysis was conducted in Tuscon, Arizona to justify a new planting program that introduced 500,000 new trees to the city's urban forest.

The purpose of this case study, done by Greg McPherson of the USDA forest service, was to analyze the costs and benefits of this proposed program as well as identify the most cost-effective locations for planting and strategies for maintenance, so that the maximum cost-benefit ratio could be achieved[28]. While we are discussing costs and benefits of urban forestry as a means to mitigate air pollution, it is important to note that the value of cleaning the air and thus preventing unnecessary death and illness is itself the primary goal and benefit of this research. However, it is important to take the dollar value of net benefits when considering an urban forestry program proposal because when

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28

funds become limited, as they are especially in today's economy it allows these programs to compete more successfully for limited resources.

The planting program in Tucson was proposed not by the local government but by an organization founded in 1989 called Trees for Tucson/Global Releaf. Its goal was to plant 500,000 trees in the Tucson area by 1996, directly for the purpose of air quality benefits as well as energy conservation. However, since trees need irrigation and water is such a scarce resource in desert areas like Tucson, the city's water utility provide Tucson Water expressed concerns over how these new trees would impact their dwindling water supply. Despite these concerns, they conceded to let the project move forward.[29]

What McPherson actually did in his Arizona study was adopt a model to simulate the costs of implementation and maintenance compared to the net expected benefits of the proposed program. He investigated three components of the planting project; the number of trees expected to be planted at each location, the size of the trees calculated by total leaf surface area, and the projected costs and benefits based on a per unit leaf area and per stem basis.

The project chose a uniform species of tree for planting, the velvet mesquite (Prosopis velutina), a species native to the area. It was chosen because of its relatively quick growth rate, tolerance to drought, and moderately dense shade.

The study analyzed the projected costs and benefits of the urban forestation program over a 40 year period. The annual average costs identified in the study were as follows. The average annual removal costs were $5.09 per tree, the cost of irrigation on average annually was $2.14 per tree, the cost of pruning on average was $2.02 per tree,

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and planting costs about $.36 per tree. This means the total cost of the program would be $9.61 per tree annually, or $4,805,000 per year, over a 40-year period.

During the first five years of the program, the costs would exceed the benefits, largely because of initial one-time planting costs. However, after the first five year period, benefits were found to be three or more times greater than the costs of the program.

On an average annual level, the benefits of the proposed urban forestation program were as follows. The average annual projected values of pollution removal and rainfall interception per tree were $4.16 and $0.18, respectively. In addition, average annual cooling savings were found to be about $21 per tree, with the total quantified projected benefits $25.09 per tree annually, $15.48 more than the projected costs per tree of the program. This translates to a projected total benefits value of $12,545,000 annually. Similarly, this means the city of Tucson could save $7.74 million every year on average for forty years just through a strategic, large-scale planting program of about 500,000 trees. With a city reserve of about $11 million in March of 2009, this would more than double the money in the city's reserves in a 7 year period (since during the first five years costs outweigh the benefits.)

The results of the study show a dramatic benefit in terms of monetary value to the Tucson area. In addition, the study found that each individual tree on average reduced atmospheric carbon by 400 pounds annually. The study does not take into account the projected monetary benefit of health impacts due to reduced air pollution, reduced costs of health care associated with negative health impacts from air pollution, and the value of heat island mitigation impacts and reduction in the formation of smog. While it is

difficult to quantify these benefits, it is important that we state them as alternative positive impacts of an urban forestry program because it shows how communities can further benefit from this as a mitigation strategy.

Since 1993, over 50,000 trees have been planted by Trees For Tucson[30]. This study was also integral in keeping the budget for the urban forestry program, because it proved that the benefits of the program greatly outweighed the costs. While the city does not directly oversee the program, it allows the large scale planting of trees to move forward, despite the concern that these trees would require too much water for irrigation. Even with a low water supply and therefore a high irrigation cost, the benefits still exceeded the costs of the program. Tucson Electric Power is the largest private contributor to the program, which shows how the results of the study were used to make significant change. While Trees For Tucson is still a long way from its initial goal of 500,000 trees, they continue to help maintain the urban forest and plant more trees as funds become available.

Though both these studies are very regionally specific, they show how urban forestry can be used as an air pollution mitigation strategy. In addition, each study concludes that the net costs of implementing such a program are far lower than the net benefits in terms of both monetary and social value.

30"Trees For Tucson." *Tucson Clean and Beautiful*. 2009. Tucson Clean and Beautiful Incorporated. 19 Apr 2009.

IV. *Intervention: Landscape Management*

Landscape management is another strategy that can be used to reduce air pollution, and leads to other benefits as well. This involves making changes to the built environment that redesign it to allow for more pollution prevention. For this study, I will define landscape management as both introducing vegetation to an area (and re-introducing native vegetation) as well as the built environment to better facilitate the dissolution of pollution. This is very similar to heat island mitigation, but with more of an emphasis on changing the built environment. Landscape management strategies include green roofing, dirt roofing, albedo modification, and changing the environment to include vegetation.

One example of landscape management for air pollution mitigation is green roofing. This strategy incorporates vegetation and plants onto roof structures instead of the usual heat absorbing roofing materials. Green roofs are attractive for business owners because of their aesthetic value. In addition, they provide a natural sound barrier, and shield roofing material from ultraviolet radiation so that the roof lasts longer. The insulation from green roofs lowers building heating and cooling costs. Apart from the benefits to building owners, green roofs, as we have seen in the chapter on heat island mitigation, serve to lower ambient air temperatures and reduce the urban heat island effect, thus reducing air pollution in the form of smog. Vegetation also sequesters carbon dioxide and removes air pollution in the form of particulate matter from the atmosphere. So green roofs are a fantastic landscape management strategy with a variety of benefits.

In 2006, the city of Los Angeles' Department of Environmental Affairs published a study on the benefits of green roofs and viability of implementation in Los Angeles.

They cited that the primary benefits of green roofs included air quality improvement, energy conservation, and storm water runoff management. The cost of installing a green roof was found to be $15-$25 per square foot on average for a retrofitted roof, and between $10 and $15 on average if incorporated into a new building[31].

Unfortunately in Los Angeles, this strategy would be hard to implement since there is low annual precipitation it would be difficult for any vegetation to survive; in addition to a low amount of shade and high exposure to sunlight for the duration of the day. An easier mitigation strategy that would be cheap and simple to implement is dirt roofs, which is basically covering existing roofing with a thick layer of soil (interview-Stephanie Pincetl). This method is inexpensive and requires little maintenance. It is cheaper than building a new roof with low absorbing materials. Indeed, many cities have composting programs and sites where you can pick up these materials free of charge, so the only cost would be transportation to and from the facility, truck rental and labor.

Another alternative is to change roofing and building material to one with a higher albedo and higher emissivity. Albedo is the ability of a material to deflect solar radiation and light, thus preventing temperatures within and outside a building from rising. Emissivity is the rate at which a material loses heat.

The state of California is already attempting to realize the benefits of a landscape management approach through legislation. In 2005 there was a statewide mandate that all new non-residential buildings and re-roofing projects that either involve more than a 50% replacement or are over 2000 ft in scale must now fit the energy efficiency code for a cool roof. The code defines a cool roof as a minimum solar reflectance of 70%, and a

[31] Allen, Detrich. "Green Roofs-Cooling Los Angeles." *LA Green Roofs Resources Guide*. 2006. Los Angeles Department of Environmental Affairs. 19 Apr 2009

minimum thermal emission of 75%; if it is made out of tile or concrete, the minimum solar reflectance is then considered 40%[32]. Effective August 1st of 2009, roofs with steep slopes have been added to the list of buildings that must comply, in addition to a new set of standards that increase overall building energy efficiency.

Landscape restructuring to include vegetation is another example of a landscape management intervention strategy. In Los Angeles, this occurs frequently through the simple mechanism of altering sidewalk space to incorporate a space to plant a tree or shrub. The issues surrounding street trees will be discussed in later chapters, but any time a street tree is planted in sidewalk space or public space this is an example of a landscape management strategy.

Incorporating vegetation into the built environment can also go beyond the restructuring of sidewalks. Concrete, a material frequently used in the built environment of urban areas unfortunately gives off an immense amount of carbon dioxide, contributing to global warming and the urban heat island effect. It emits carbon both permanently (although gradually) while it is in the built environment, and the production of concrete also produces a large amount of carbon dioxide. However, many producers of cement of working on a solution to this problem. Two companies, Calera in California and Novacem in Britain are working on a way to form concrete so that it would actually serve to permanently sequester carbon dioxide from the atmosphere.[33] If correctly engineered and implemented, this would have a dramatically positive influence on carbon dioxide levels, and serve to mitigate the urban heat island and improve overall public

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[32] Prado, Racine. "Measurement of Albedo and Analysis of Its Influence On the Surface Temperature of Building Roof Materials." *Energy and Buildings* 3704 2005 295-300. Web.19 Apr 2009.

[33] Fountain, Henry. "Concrete Being Remixed With Environment In Mind." *New York Times* 30 03 2009 Web.19 Apr 2009.

health and quality of the environment. This example illustrates a landscape management approach to air quality control.

The Western Municipal Water District did a study on landscape management, focused on the benefit of water conservation. They created a one acre model project, called Landscapes Southern California Style, to show how a proposed project could be implemented and what the benefits would be in terms of water conservation and management[34]. The study was more focused on landscape management through the introduction of urban forests and vegetation than on using green building materials, but did try to incorporate both strategies.

Although they were mainly focused on water retention and conservation, the study did find that through planting trees, both the ambient air temperature (urban heat island effect) and the soil temperature were reduced. This provided the added benefit of more water retention in the soil and in plants and trees themselves, so less was required for irrigation. The study found that with proper landscaping of trees and plants, they could reduce water consumption by 25-50 percent. They also emphasized the need for tree species that were appropriate for the Southern California landscape. While water conservation does not directly correlate to air pollution mitigation, irrigation can become an expensive problem of any large-scale planting program. Therefore it is important to think about landscape management both in terms of water conservation and air pollution mitigation, to offset the costs of irrigation while providing an added benefit of water conservation.

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[34] "Landscapes Southern California Style." *Western Municipal Water District Online*. 2001. Western Municipal Water District. 19 Apr 2009

Since landscape management involves changes to the built environment, it is difficult to implement this strategy on a large-scale. The most successful way thus far has been policy requirements to make structures more conducive to the environment, thus reducing the urban heat island effect and having a positive impact on air quality. For example, parking lots must meet a minimum requirement for shade and amount of trees in the parking structure, usually before they have been built. As we see more policies put in place that mandate the use of porous, high emissive, low-absorbing materials, and incorporation of trees and vegetation, older aspects of the built environment that add to the urban heat island effect and negatively affect air quality will gradually phase out. For now, it is probably impractical and too costly to retrofit every building and incorporate space for trees and vegetation while changing a structure's material components. However, as new structures are built and older structures need to be upgraded, proper landscape management can ensure that these structures have the opportunity to help mitigate air quality, and provide other environmental benefits as well.

V. *The Integrated Method of Ecological Planning*

We have now looked at 3 different methods of air pollution mitigation through urban heat island mitigation, urban forestry, and landscape management. When integrated into urban planning, these methods can actually have a worthwhile impact in terms of filtering the air.

I interviewed Ashwani Vasisth Professor of Urban Studies at California State University in Northridge and a leading advocate for ecological planning and urban forestry as a solution to mitigate air pollution associated with the goods movement. In addition to teaching at CSUN, Professor Ashwani has been a regional environmental planner for SCAG, as well as given many talks to advocate for the issue. I was most interested in the responses of community and of policymakers when confronted with this solution. For selected interview text, please refer to the appendix of this report.

In order to have a magnified positive impact on air quality overall, an integrated method of heat island mitigation, urban forestry, and landscape management is definitely necessary. This combination of strategies leads to a maximization of the benefits.

The strategies are already somewhat interconnected, but if it became policy to view all three strategies as beneficial for air pollution reduction, we would see an increase in these program's monetary benefits, air quality benefits, and overall effectiveness. As seen in chapter two, an urban forestry component of a heat island mitigation program was found to be significantly effective for temperature decrease. This same urban forestry program can be used for air pollution mitigation; additionally, we have seen that when ambient temperatures are reduced there is a significant decrease

in the rate of formation of smog, therefore an added bonus of heat island mitigation is a positive impact on air quality.

One obstacle Vasisth mentioned to realizing an integrated approach to air quality management, using a combination of heat island mitigation, urban forestry, and landscape management was the difficulty in implementation. When people react to the idea, they inherently agree that these methods should be combined; however, since planning is usually specialized it is hard to view these concepts as part of a comprehensive strategy for air quality management. Having worked as a regional planner for Southern California Association of Governments (SCAG), Vasisth drafted a regional policy for this integrated ecological planning method, but since he left to teach at CSUN the project was never implemented. According to Vasisth, the largest challenge in implementing this type of project is that planning departments are set up by disciplinary practice. Since there is so much specialization, it is hard for people to view the collaborative method as a strategy that is achievable.

While this is a definite caveat for the ecological planning method, if planning departments took on a "big picture" approach this option would definitely be viable, and in their power to regulate.

When looking at the mitigation strategies as three separate options for air quality management, the potential benefits to a community that could be gained through a combination of all three are lost, if taken in separate steps. This will become apparent in the next chapter, that evaluates the implementation of the Million Trees Los Angeles initiative.

Even Vasisth himself is sometimes constrained by the limits of a specialized approach. In a separate report he advocates for the large scale planting of trees along the 710 freeway, as a mitigation measure for communities negatively impacted by the goods movement[35]. This report states the necessity of urban forestry so much that it does not consider other alternatives. In the area in question, he suggests that people living in these communities relocate (although to sustainable, transit-oriented developments with adequate property compensation) so that the mitigation measure can take place. This displacement of residents would probably not be necessary through an integrated approach. With a landscape management, heat island mitigation, and a partial forestation project focused on street trees, a mitigation project could be modeled in these areas that did not require residents to relocate.

More community resistance to an integrated strategy approach is the fear that this will be used as a substitute for other forms of air quality control. While these strategies, when taken together, do create significant benefits to air quality, in many neighborhoods there is a need for more control. Public opposition to this approach happens when people fear or rightly believe that a city will use this mitigation measure as an excuse to allow more pollution to come into an area. This strategy that integrates the three mitigation methods, should not be a primary form of pollution control. In order to be successfully implemented, it would have to address community concerns over air pollution and not be used to justify more incoming air pollution sources or as a substitute for pollution control and prevention.

If this type of integrated ecological planning project were to be implemented, all air quality benefits of these programs would be magnified so that there would be much

[35] Vasisth, Ashwani. "An Integrated Ecosystem Approach.."

more of a significant improvement. Up until now, there has not been an integrated ecological approach to urban planning for the purpose of air quality benefits. So while in California new buildings must meet certain requirements for albedo and emissivity, there may not be any urban planting projects occurring in the same area at the same time.

Under the current status quo, a green roof project for example could go underway in a city, with no measurement of its impact on the urban heat island. Some may argue that either way there will be an inherent benefit to heat island mitigation, regardless of whether or not it is measured. However, these are important implications to consider, because there are sure to be places where green roofs could more effectively mitigate the heat island effect while still filtering the same or a similar amount of air pollution. In addition, other entities working on heat island mitigation or urban forestry may focus on the same area with little collaboration with the green roof project.

Even integration of strategies is important. A program solely focused on air pollution mitigation through urban forestry may not take into account the benefits of a landscape management approach to water conservation. Thus the program would lose out on the benefits of water conservation, while at the same time spend more money on irrigation.

Focusing on individual mitigation strategies can be counterproductive for those conducting an air quality intervention program. For example, if one group was working on urban forestry, and a separate group was working on heat island mitigation in the same area, this would be an unwise use of resources, and other communities in need might go overlooked. Also, when justifying a budget for these types of programs, it is better to view the maximum net benefit, so governments can see how much their investment in

ecological planning will grow over time. Treated as separate measures with separate benefits, the net return on their investments will seem to be lower without considering the additional benefits of an integrated method.

VI. *Implementation in Los Angeles: The Million Trees Initiative*

Implementation is the driving force of opposition for mitigation programs that involve urban forestry. In this chapter, I will identify the barriers to implementing an urban forestry program, using the Million Trees Los Angeles Initiative (MTLA) to illustrate how separate forces serve to complicate something so seemingly simple as planting trees. For more information on the MTLA, visit their website (http://www.milliontreesla.org).

In Los Angeles, there are currently over ten million trees; of these, the city manages about two million. Seven hundred thousand of these trees can be found either along roads or sidewalks, and the city estimates that it removes 2,000 trees each year while planting 5,000 annually.

The million trees Initiative in Los Angeles, launched in May 2006 is a current city program that developed out of Mayor Villaraigosa's promise to plant over 300,000 trees in city parks if elected mayor. This campaign promise later developed into MTLA's official program to plant one million trees to "transform LA into a green, sustainable city."[36] The initiative recognizes the benefits of trees in terms of energy conservation, air quality mitigation, and an increase in property values. The program also recognizes the need for community involvement, both in planting and sustaining trees, and encourages individuals and non-profit organizations to get involved, as well as reaches out to form public-private partnerships in order to cover program costs. Several other cities in the continental United States including Chicago, Denver, and Baltimore have adopted similar policies. For this section of my research, I will look at the challenges faced in

[36] "About Million Trees Los Angeles." *Million Trees LA*. 2006. City of Los Angeles. 19 Apr 2009

implementing MTLA, so that we can identify what the barriers are to implementing an urban forestry program as an air pollution mitigation measure.

For this section, I interviewed Dr. Stephanie Pincetl, of UCLA's Institute of the Environment, who is doing research on the implementation of the Million Trees Initiative with a group of biologists to see how trees actually perform in the Los Angeles environment. As someone with a strong background in biology and ecology studying the program, I sought her opinion on the strengths and weaknesses of the project. Like Vasisth, she thought the largest problem was implementation of the program. Obstacles to effective implementation include adequate tree species selection and inter-cooperation between city departments on the program, among others. However, she wondered if there was an alternative way to implement this type of program; though there are definite problems within the MTLA, since there is no clear alternative it is a step forward for air quality management.

The MTLA's main goals were to plant as many trees as possible in the city of Los Angeles. This has been largely successful due to massive planting programs and the Green Trees for LA program tree giveaway. During the planting program, MTLA, in cooperation with the Urban Forest Research Station at UC Davis conducted a tree canopy analysis. The results showed that tree canopy cover was higher in affluent areas and lower in communities of color and low-income communities. The tree canopy cover in Los Angeles varies from 7% to 30% in some areas So part of the goal of MTLA is also to address these inequalities.

City infrastructure and available public space is another issue with which MTLA or any urban planting program must contend. In the case of street trees, they can often be

more of an encumbrance than a benefit. According to the Bureau of Street services, in Los Angeles, 4,620 out of 10,750 miles of sidewalk are cracked[37]; so about 43% of all LA sidewalks are cracked, largely from tree roots. Also, there is currently no policy in place in Los Angeles to replant trees that have died; as a result, many available spaces in sidewalks where trees could be planted remain empty.

Roots from street trees can also damage sewage systems, for which the property owner is held responsible, regardless of whether they planted the tree or not. In addition, it is a requirement in Los Angeles that if any street tree is planted, the property owner must give permission as well as pledge to care for and water the tree for five years. This can become a problem because homeowners are sometimes unwillingly to take on the responsibility of tree care, especially if they risk losing so much money. When planting a tree on property, one must consider the size of the tree, because if the tree grows too high it can interfere with power lines. Large trees can also be a threat to properties during storms; if the wind blows a branch onto your car or lightning strikes down a tree onto a house, there is no compensation for the homeowner, (except at times through their private insurance company) (interview-Stephanie Pincetl). In this regard, trees can actually be a potential property risk as well as something that can be beneficial. To avoid this drawback, the city could encourage more participation in planting if it took away the policies holding property owners accountable for damage from trees.

Property owners are also often hesitant to plant trees, especially in areas of high crime since there is a worry that criminals will be able to hide from police in trees. Similarly, they worry that the trees will actually attract crime since they are convenient

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[37] Gonzalez, George. "New ideas for Sidewalk Management In Los Angeles." *Preserving the Urban Forest.* 2005. City of Los Angeles. 19 Apr 2009

hiding places. Indeed, the LAPD cites that criminals have used trees on private property in attempts to hide; however, there is no data that suggests trees serve to increase crime rates. In fact, the opposite usually happens; areas with a higher number of trees in general see a rise in property values, and consequently have safer neighborhoods where the crime rate is lower. With more public education of this fact, the city could potentially address the issue of public fear of an increase in crime rate if trees were planted.

Businesses also are often against street trees in front of their stores. Owners fear that the trees will block their signs, rendering customers less likely to notice or be able to find their location. In addition, they worry that the tree roots will crack sidewalks in front of businesses, making them look unattractive and unprofessional to customers. However, there are small trees available that will not block signs or damage sidewalks if strategically placed near businesses.

Part of the problem of finding appropriate, native tree species in Los Angeles is that there never was an urban forest on a large scale in Los Angeles. Indeed, the list of tree species native to Los Angeles is small in comparison to other areas with more abundant, diverse vegetation. The city of Los Angeles' Bureau of Street Services Urban forestry division issued an ordinance in 2004 protecting native species; among them many species of Oak, Black Walnut, California Bay, and California Sycamore. However, the selections are limited, and while these trees remain protected, planting efforts have not been focused on getting more of these native trees into the urban forest, but rather on adding as many trees as possible. Two species cited in an *LA Times* article covering the tree distribution process were an African Sumac and an Olive Tree. Currently, there are forty different tree species being given away as part of the program.

While the tree giveaway program, formally known as Green Trees for Los Angeles, faces challenges in implementation, according to a program representative they are now conducting random audits to see whether the trees have actually been planted and maintained. In addition, people wishing to receive trees as part of the giveaway program must now complete a twenty-minute tree care training program online. The DWP also helps consumers in the tree selection process by stating the potential benefits and drawbacks of each tree (if it has a high amount of pollen, if it can get messy, etc.) and guidelines on where you should and shouldn't plant them. Also, they have a list of what trees are appropriate for which climate zone and a map of the climate zones, so even though not all the trees are native species, they have chosen trees that are adaptable to specific climates.

The issue of native trees is also a problem for Los Angeles because although the city officially recognizes the previously listed species as native, there is a debate over whether oak savannas or chaparral initially dominated the natural landscape of California. However, it is clear that since the early 20th century there have been no native forests in existence in Los Angeles, therefore the million trees program is an afforestation program[38]. The USDA lists native trees of coastal southern California include the Torrey Pine, California Laurel, and Coastal Live Oak as appropriate for tree planting programs.

Native trees are essential in any urban forestry program because in general they have a higher survival rate since they are naturally adapted to the area. In addition, since LA is an area with little annual precipitation, this becomes especially important since the cost to irrigate the trees is higher.

[38] Pincetl, Stephanie. "Implementing Municipal Tree Planting: Los Angeles Million-Tree Initiative." (2009)

The tree giveaway program probably offers so many other non-native species of trees so that property owners who chose to plant these trees have more of a choice on what they want to plant. DWP provides information to consider when planting each tree; for example, whether or not it would do well in certain climates, as well as how to determine what size tree is appropriate for a property and if trees have a lot of pollen, litter from fruit, or any other factors property owners may want to consider before planting. Although not all the trees on their list are native, this is a good strategy for the giveaway program, because it encourages people to plant trees by giving them more options.

In Los Angeles, the tree mortality rate is currently 36.5% on average. Some factors that influence whether or not a tree will survive are how root characteristics, tree size, insect infestation, etc. Unfortunately these qualities of trees cannot be changed or planned around, because varying sizes and root capacities are appropriate for different planting areas. However, factors that the program can influence in tree survival are if the tree is native, whether or not the tree is planted properly, and if it will receive adequate care. Air pollution levels also influence whether or not a tree will be able to survive; since in Los Angeles we have very high levels of pollution, initial survival rates may be lower than anticipated. As the program progresses, with more trees filtering the air, we will likely see an increase in survival rates as the trees will have less pollution to contend with in order to survive.

Which brings us to one of the main problems of any planting initiative—cooperation between departments . While outside the MTLA, the city's urban forestry division is part of the department of public works (DPW), the MTLA is actually a

separate entity controlled by the mayor's office. The DPW has control over the funding for the project, the Million Trees Foundation; on top of this, the department of water and power essentially has a tree nursery of all unplanted trees. When trees are ordered by the MTLA or other programs, DWP is in charge of ordering and distributing the trees. In addition, the DWP works with the Department of Recreation and Parks so that if trees in their nursery get to old or to large to continue to care for, they hand them over for planting in parks.(interview, DWP staff member) In addition, the port authority has separate control of an urban forestry program that is not related to MTLA or the urban forestry division. (interview, urban forestry division staff member.) Also, the Community Redevelopment Agency (CRA) is involved in planting trees as part of the program, and the DWP is undergoing separate planting with the Cool Schools Program, as mentioned in the previous chapter on heat island mitigation.[39].

The problem with dispersing the control of the urban forestry program is that there is often little communication and cooperation between city departments. Also, each department has their own agendas to worry about; so that conflicts of interest can arise between departments. The stated goal of the planting program on the MTLA's website is essentially the addition of the maximum number of trees possible; the Department of Public Works is more focused on street trees and urban forest management; the Department of Recreation and Parks would obviously like to see more trees in public park space; and for DWP, the "main purpose of [the planting program] is air conditioning consumption reduction, through more shading of buildings." (interview, DWP staff manager).

To add to the confusion, the plan for MTLA was that most of the program be

[39] Pincetl, "Implementing Municipal Tree Planting."

carried out through a number of non-profit organizations[40]. NorthEast Trees, The Hollywood Beautification Team, Korean Youth and Community Center, the Los Angeles Conservation Corps, and TreePeople were all put in charge of the project. More importantly, all of these groups have separate goals from each other as well as from the city. Though compensated by MTLA, the nonprofit organizations had to adjust their programs to fit the MTLA's needs and divert resources from their own goals. In addition, according to Pincetl's report, when nonprofit groups agreed to participate there was a risk that donations to the groups would decrease because contributors would associate their groups with the city.

With so many conflicting interests, many of the intended goals of the program may be unclear and thus remain unattained. What we are seeing is many large-scale planting efforts, so that while a number of trees are being planted, there is little correlation between one group's actions and another group's to move towards a specific set of goals. A more coordinated effort integrating the three mitigation strategies would provide greater benefits to the city in terms of air quality. This can be accomplished through designating control of ecological planning to a separate entity to oversee mitigation, or by encouraging more interdepartmental cooperation; we will explore this more in the conclusion of this report. According to the DWP for every dollar spent on trees, the city gets a seven dollar return (interview-DWP staff); therefore while the planting efforts could be more coordinated to maximize benefits, the planting overall will still generate a positive impact.

In addition, when there is a localized emphasis on the project, there tends to be only a local benefit; predictably some communities will likely end up receiving different

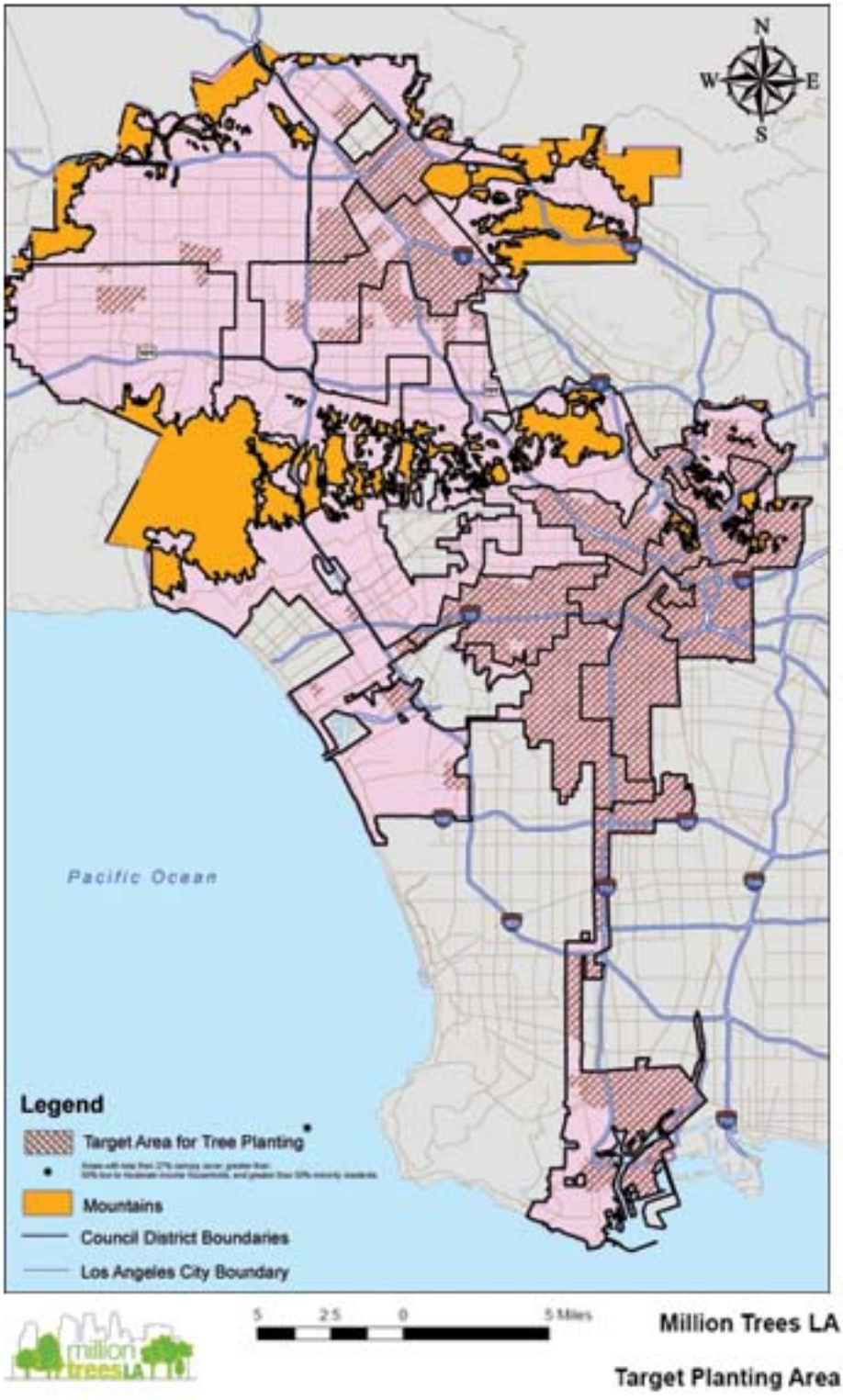
[40] Pincetl, "Implementing Municipal Tree Planting."

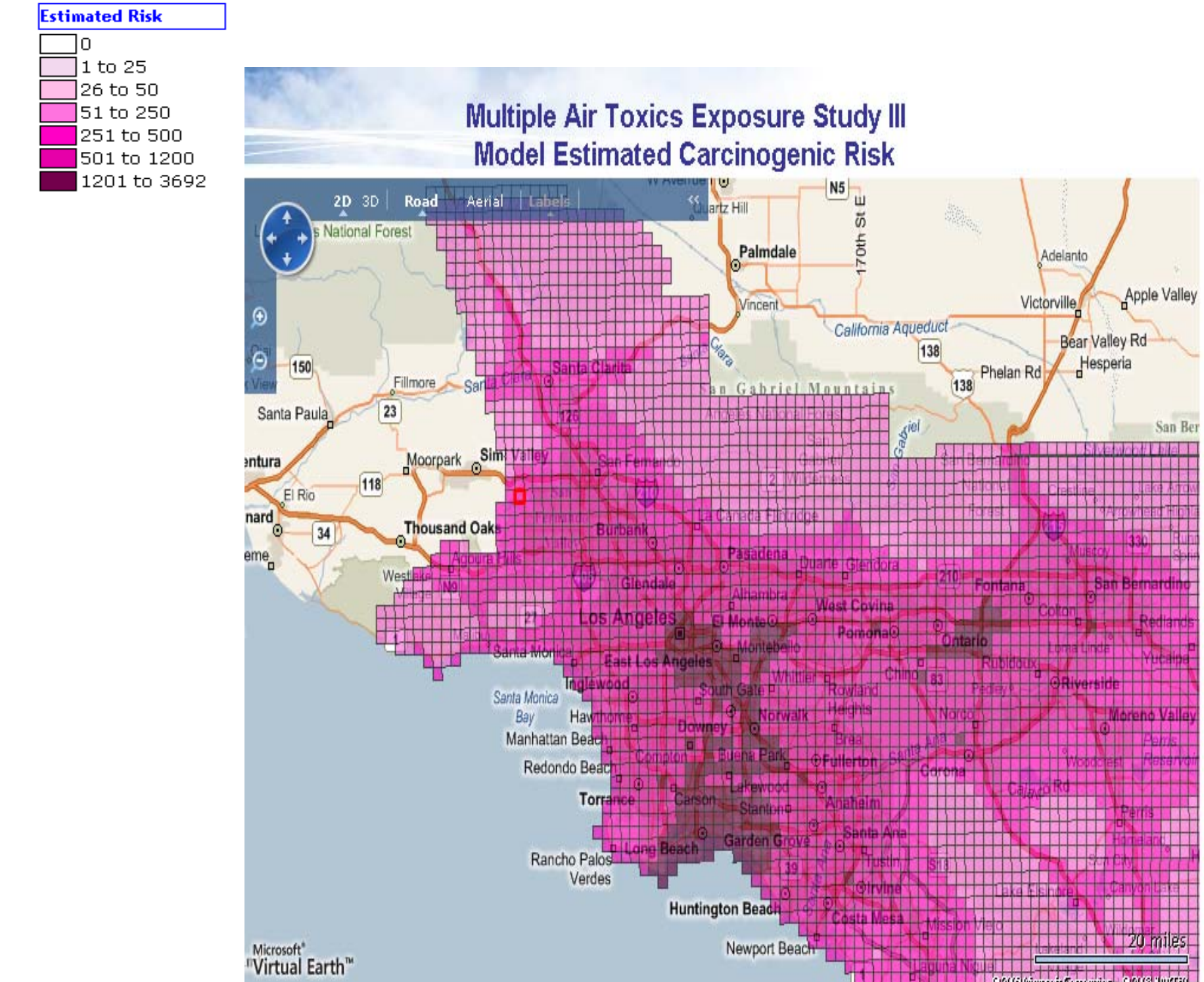
amounts of attention than others in terms of planting projects. To their credit, the city just underwent a cooperative effort with the USDA forest service to conduct a tree canopy analysis to determine where there was more of a need for canopy cover. Currently, Los Angeles has a 21% canopy cover, while the national city-wide average is 27%[41]. However, canopy cover alone is just one factor in determining where to place trees; thus far we have not seen any attempt to strategically place trees in areas of high concentration of air pollution, though one of the stated goals of the initiative was to plant trees because of their potential to mitigate air quality. American Forests recommends a tree canopy cover of 18% in the Southwest and dry regions.

Below is a map of the target areas for planting in the MTLA program. These areas were identified as target areas based on the tree cover canopy analysis. The majority of these areas have either a less than 10% or between 10-15% canopy cover. A detailed map of canopy cover by council district can be found in the appendix of this report. The map below it shows the South Coast Air Basin's estimated carcinogenic risk to individuals from exposure to multiple air toxins. In areas of low tree canopy cover (targeted areas for tree planting) there is a higher carcinogenic risk. Therefore, while the MTLA has not specifically assessed need for planting on an air quality basis, but rather on canopy cover, they are still planning to plant in areas most deeply at risk of health problems because of air pollution. This serves as further evidence of the link between urban forestry and air quality benefits, since the highest carcinogenic risk from exposure to air toxins is in general located in areas of low tree canopy. However, one caveat of this is that the entire Los Angeles area is at moderate to high risk.

[41] Pincetl, "Implementing Municipal Tree Planting."

City of Los Angeles Tree Planting Target Areas




Estimated Risk
0
1 to 25
26 to 50
51 to 250
251 to 500
501 to 1200
1201 to 3692
Multiple Air Toxics Exposure Study III
Model Estimated Carcinogenic Risk
2D 3D Road Aerial Labels
Palmdale
Vincent
Victorville
Apple Valley
Adelanto
Hesperia
Bear Valley Rd
Phelan Rd
California Aqueduct
170th St E
N5
138
150
23
118
34
210
Fillmore
Santa Paula
Santa Clarita
Moorpark
Simi Valley
El Rio
Thousand Oaks
Burbank
Pasadena
Glendale
Los Angeles
Fontana
San Bernardino
Ontario
Riverside
Moreno Valley
West Covina
Pomona
Montebello
East Los Angeles
Inglewood
Santa Monica Bay
Manhattan Beach
Redondo Beach
Torrance
Carson
Long Beach
Rancho Palos Verdes
Garden Grove
Santa Ana
Irvine
Huntington Beach
Costa Mesa
Newport Beach
Fullerton
Anaheim
Norwalk
Downey
Lakewood
Corona
20 miles
Microsoft Virtual Earth™

Also a huge obstacle the initiative faces is how to best engage the public to participate in the planting and care of trees. Organizers for the program were initially giving out free trees at public events and having people sign pledge cards to plant and care for the trees in the city of Los Angeles. According to an LA Times article, the problem with this strategy is that there is no follow-up plan to see how many trees were actually planted and survived, as well as if the trees were given to people that reside in Los Angeles or taken outside of the city[42]. In the article, they interviewed several individuals who had not planted and had no intention of planting their free trees. Some did not even live in the city of LA but had received free trees.

In addition to getting the community involved, there is a current debate over the costs and benefits of urban forestry programs for air pollution mitigation as well as other indirect benefits of such programs. Because the existing data we have on tree's ability to remove pollutants from the atmosphere is taken from trees living in a forest, not a polluted area, some question whether the trees' capacity for pollution removal will remain the same. A study done on tree mitigation in London had a more accurate calculation of pollution removal rates. Instead of using predetermined figures for rates, they physically went to a number of sites throughout the city and measured the amount of each type of pollution present over an extended time period[43]. Then, they physically collected leaf samples from trees already growing near the pollution test sites to see what the leaves had actually absorbed. While it was found that these trees did provide a net benefit, its debatable whether the cost-benefit analysis method using preexisting data from trees in

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[42] Zahniser, David. "THE STATE- A Million L.A. Trees: Will They Take Root?." *The New York Times* 24 09 2007 Web.19 Apr 2009.

[43] Powe, Neil. "Mortality and Morbidity Benefits of Air Pollution (SO2 and PM10) Absorption Attributable to Woodland in Britain." *Journal Of Environmental Management* 70(2004): 119-128.

forests will give an accurate account of the benefits. Also the figures for survival rate of the trees are largely dependent on what kind of care they receive. A better way to quantify the benefits would be to identify which trees the city or another organization intended to plant, and physically go measure pollution levels and tree pollution uptake rates to see which trees allow the maximum benefit in a specific area for a specific species, in this case in Los Angeles.

If we were to run a private program that accounted for maintenance and other costs, this would be different than the costs of a program where people and corporations volunteered to care for the trees, thus lower costs (although you would still have to train individuals in tree care). Right now that's essentially what MTLA is trying to achieve; however, they lack a concrete system of public accountability for tree care as well as an inherent training program, or a system of follow-up to see how many of the trees actually end up being planted. They are having people sign pledge cards to promise they will care for the trees; but that's placing a lot of trust in people that may just be trying to get something for free. Groups like NE Trees and Tree People are assisting MTLA by providing tree training in tree care, forestry retreats, and similar programs and resources to encourage community participation in the process.

Overall, MTLA is a step in the right direction, especially in terms of air quality management. The net environmental effects of one tree are positive, so any large-scale planting would likely benefit Los Angeles on a small scale, depending on how many trees actually survived. In order to maximize the benefits for Los Angeles, the MTLA should try and create solutions to these implementation barriers. Some, such as sidewalk and infrastructure barriers, as well as community sentiment, will be harder to change than

simply developing a system of follow-up for tree care. However, the existence of the MTLA shows the city's commitment to addressing the issue of air pollution, and issues of inequity, and deserves full credit as an innovative, meaningful first step mitigating air pollution through urban forestry.

VII. *Conclusion/Recommendations*

We have seen in earlier chapters that if implemented correctly, the strategies of heat island mitigation, urban forestry, and landscape management can all be used to effectively reduce air pollution. When combined, these strategies make for more cost-effective measures, with trees as more of an investment that grows over time. These strategies have benefits outside of air quality, including energy conservation, property value increases, and water conservation, among others.

From our examination of the MTLA initiative, there are clearly many factors that need to be considered before implementing any of these strategies, either on their own or in conjunction with one another.

Integration of Methods:

As discussed in previous chapters, an integration of the three methods is necessary to have the maximum impact on air pollution, especially in Los Angeles. In addition, when doing a cost-benefit analysis, the integrated ecological approach to planning gives the most net benefits and justifies these programs on a budget.

Logical Oversight:

Oversight for any air quality management program should be a separate entity that combines governmental departments, rather than each department acting on the same problem independently of one another with separate programs and measures. This will simplify areas to target will planned interventions, without competing interests and communication barriers to the project. The project will have clear goals of ameliorating air pollution through ecological planning rather than separate goals from separate departments.

Community Involvement:

Currently there are too many disincentives for property owners to want to plant trees on their property. Programs to educate property owners on potential energy savings, or even rebates or tax breaks for planting a certain number of trees on their property may be helpful to encourage individuals to start planting and maintaining trees on their property. In addition, people would be more encouraged to plant trees on their property if they were not held personally responsible for any infrastructure damage to sidewalks, sewage systems, power lines, etc. Careful planning in terms of what type of tree to plant and where can prevent these accidents, but if the property owner was not liable for these expenses they might be more willing to plant on their own property since there would be less financial risk.

There needs to be an education program for anyone considering planting a tree, beyond the online 20 minute tutorial on tree selection and care from DWP. While this is a helpful, useful tool, it would be more effective to approach the problem through public education on the benefits of trees for neighborhoods, emphasizing the health benefits that individuals and communities can receive from planting trees or using different materials when reroofing their homes. Tax breaks for those using green materials on homes and for businesses would make people more willing to consider this as an option when redeveloping property or building a new structure. Similarly, if planting trees was more incentivized, more people would be willing to participate. Furthermore, the public should be educated about the realities of trees effect on property values, and shown how this actually leads to a decrease in crimes in many areas. People will be more likely to accept a positive role in tree planting and care on their property after their fears are

addressed and they are shown how they will benefit.

Business owners should also receive education in tree planting and management, as well as landscape management techniques that will benefit business aesthetically as well as give air quality improvement to the area. The point is to work with small businesses in tree selection; smaller trees, with roots that minimally disrupt the sidewalk are more likely to be well received since they will not block signs or cause unsightly sidewalk damage and thereby deter customers.

In addition, community support is integral to any of these planting programs or any attempt at landscape management or redevelopment. Utilizing these methods as a supplement to other forms of pollution control or restrictions would garner more support than substituting these methods for any existing programs. In short, we should be doing an ecological planning method with heat island mitigation, urban forestry, and landscape management as an additional approach to improving air quality, but not use this as an excuse to reduce emissions requirements, for example.

Evaluation Tool:

There must be a clear mechanism in the program that develops to follow-up as to whether a tree has been planted, and whether or not the trees have survived. This evaluation is necessary as it will measure the success rate of the planting program. In addition, in areas where there is massive planting or landscape alterations, there needs to be air pollution monitoring before and after these changes are implemented. Once the program is proved to be successful, it will be easier to develop similar programs for ecological planning or expand the program to other areas.

Appropriate Species Selection:

While native species are ideal for any urban forestry program, other factors to consider in Los Angeles are tree height, pollen, maintenance costs, root expanse, and irrigation needs. In addition to all these factors, it is necessary to test how trees in the physical environment perform in terms of pollution reduction, energy conservation, and water management to better quantify the benefits. If a tree is not native but effective at air pollution reduction, it should still be considered for an urban forestry program, depending on whether or not it will do well in the target area. The tree giveaway program is a great idea because it allows consumers choices, but this variety of choice should only be used as an incentive to encourage individuals to plant on their own property. For open space and street trees planted by the city or another entity, the list of acceptable species should be more targeted to the native environment. Obviously programs should use native species where available.

There are also a number of factors influencing whether or not a tree will survive. Species for planting programs should be given preference if they have a higher survival rate. In addition, public education is key here too because trees are more likely to survive if planted and cared for properly. For a list of trees being given away by DWP with their survival rates, please see the appendix of this report.

By implementing a program with clear, structural planning that follows these guidelines, Los Angeles would see a significant improvement in air quality, as well as a decrease in energy consumption and an increase in water conservation. Though initial costs of these programs are quite high, over time the benefits of these mitigation

strategies greatly exceed the costs. In addition there are definite implied benefits of an air quality improvement program that Los Angeles should consider, such as the potential to save lives and reduce chronic illness associated with air pollution. In an era of continuing globalized economy and globalized pollution, measures to mitigate air pollution are should be considered essential to the survival of the human race. In Los Angeles, we should be doing everything we can to help improve air quality, as individuals and as a city. One way we can address this problem is through an integrated method of heat island mitigation, urban forestry, and landscape management.

VIII. *Appendix*

Formation of Smog/Ozone

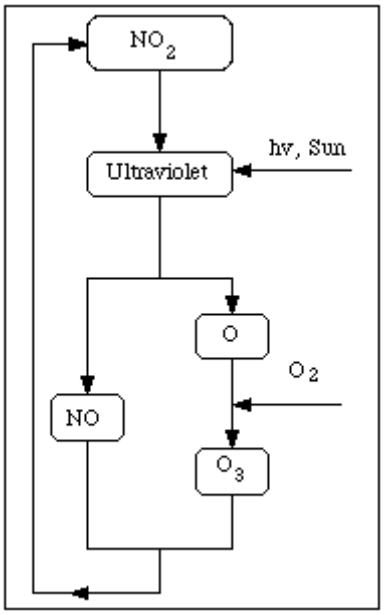
Step 1:
NO2 is dissociated by ultraviolet light, forming NO and a free radical. Then the free radical quickly combines with molecular oxygen to form ozone.

$$NO_2 + h\nu \Rightarrow NO + O^*$$
$$O^* + O_2 + M \Rightarrow O_3 + M$$

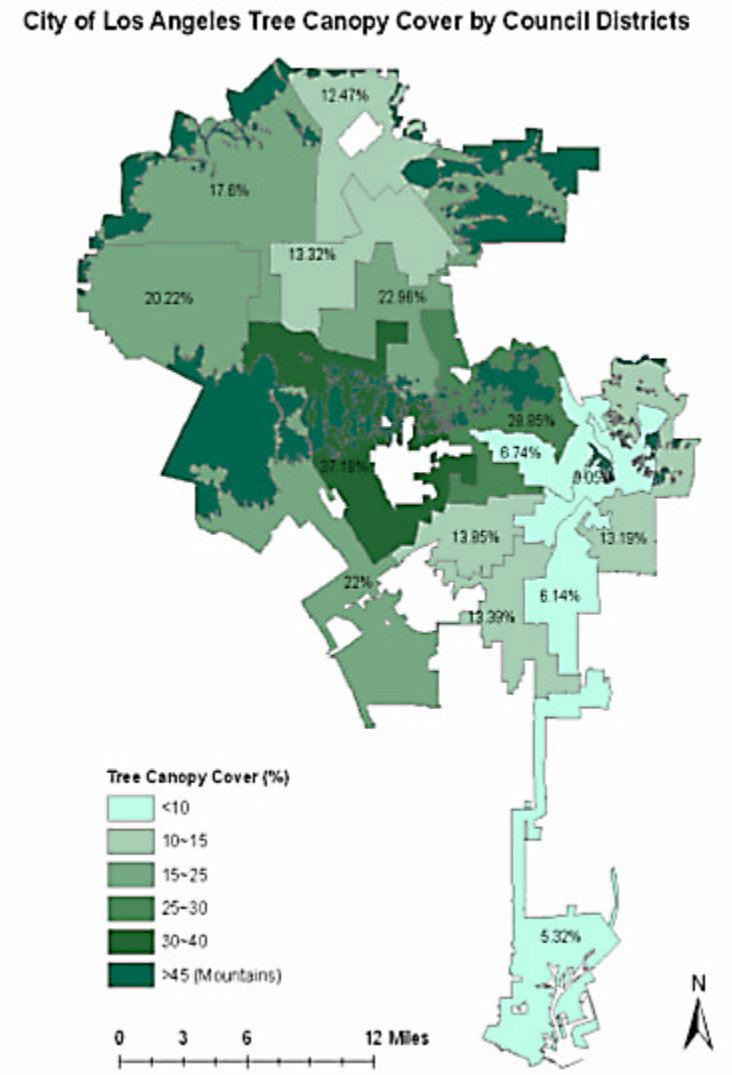
The M in this reaction represents any other molecule present which absorbs the energy of the reaction. Without the M, the radical oxygen and molecular oxygen would just be constantly substituting with each other back and forth.

Step 2:
The cycle completes when ozone reacts with nitrous oxide, forming NO2 and molecular oxygen.

$$O_3 + NO \Rightarrow NO_2 + O_2$$



A summary of the formation of ozone



A highlight of the tree canopy cover currently in LA County.

*For more information on the DWP's Green Tree For LA Program, please visit the Tree Giveaway Guide, at http://www.ladwp.com/ladwp/cms/ladwp009614.pdf

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