Air Pollution Removal and Temperature Reduction: A Case Study of Gainesville's Urban Forest[1]

Francisco Escobedo, Jennifer A. Seitz, Wayne Zipperer, and Basil Iannone[2]

Poor air quality is a common problem in many urban areas. It can lead to human health problems and reduced visibility, and it can impair the health of plants and wildlife. The urban forest can help improve air quality by removing pollutants and by reducing air temperature through shading and transpiration (Noward et al. 2006). Trees, however, also emit volatile organic compounds and other tree maintenance-related pollution emissions that can indirectly contribute to ozone formation and pollutants (Escobedo et al. 2011). So, to better understand this environmental benefit provided by trees, we used the USDA Forest Service's Urban Forest Effects (UFORE) Model and estimated air pollution removal by urban trees in Gainesville, Florida.

A tree is able to remove air pollution via its leaves in two ways. The first is by direct uptake through the leaf stomata. Once inside the leaf, gases diffuse into intercellular spaces. There they may be absorbed by water films to form acids or they may react with the surfaces of the inner-leaf. The second way leaves remove air pollution is by intercepting and retaining particles on the leaf surfaces. The intercepted particle often is re-suspended to the atmosphere by wind, washed off by rain, or deposited on the ground through leaf fall (Escobedo 2007).

Pollution removal by trees in Gainesville was estimated using field data from 93 sites and hourly pollution and weather data for 2000. The amount of pollution removal was calculated for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter less than ten microns (PM_{10}).

An average square meter of tree cover in Gainesville removes 6 grams of air pollutants in one year. Total pollution removal was greatest for ozone, followed by particulate matter less than ten microns, sulfur dioxide, nitrogen dioxide, and carbon monoxide. Figure 1 compares pollution removal for different pollutants and shows the economic benefits of pollution removal to society (pollution removal reduces health care costs because people breathe fewer harmful pollutants). It is estimated that in 2000 trees removed 390 metric tons of air pollution (CO, NO_2, O_3, PM_{10}, SO_2) per year. This translated to around $2 million in economic benefits. Air pollution removal estimates for several cities in the United States are presented in Nowak et al. (2006).

Trees can also reduce temperature for a given area based on the amount of tree density and cover (Escobedo et al. 2011; Nowak et al. 2006). Figure 2 demonstrates how increased trees in forests and forested vacant areas help reduce temperatures as opposed to transportation areas and parks and institutions with little tree cover. Shading and transpiration from trees can affect the overall microclimate of an

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2. Francisco Escobedo, former assistant professor; Jennifer A. Seitz, former Extension associate, School of Forest, Fisheries, and Geomatics Sciences; Wayne Zipperer, research scientist, USDA Forest Service; and Basil Iannone, assistant professor, Geospatial Analytics of Sustainable Human and Ecological Development, School of Forest, Fisheries, and Geomatics Sciences; UF/IFAS Extension, Gainesville, FL 32611.

area by modifying ambient temperature and solar radiation. In most cases transpiration and shading from trees reduce summertime temperatures, which may reduce the amount of energy used to cool buildings.

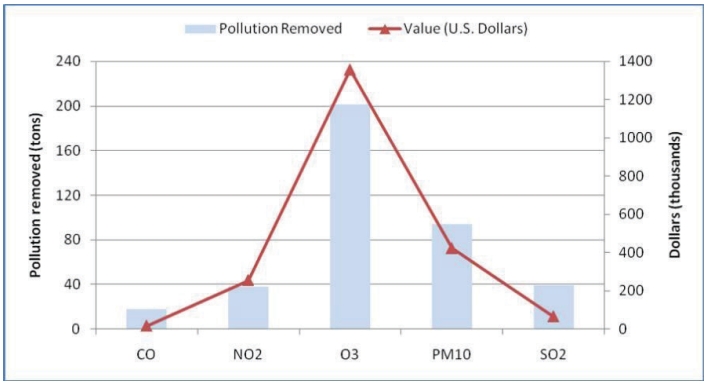

Figure 1. Comparison of the pollutants removed by the City of Gainesville's urban forests, by metric tons removed and by health care dollars saved.

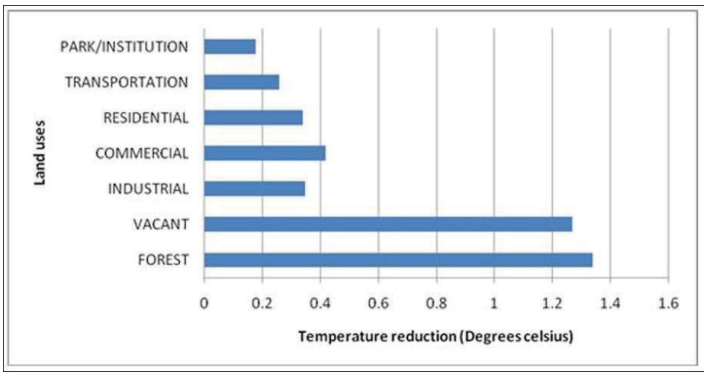

Figure 2. Temperature reduction due to tree cover in Gainesville, Florida's seven land use areas.

When vegetation is limited in a community, researchers have found that buildings and paved surfaces absorb energy from the sun, causing the surface temperature of urban structures to become 10–21°C (18–38°F) higher than the ambient air temperatures (Taha et al. 1992). As the surfaces become hotter, the overall ambient air temperature also increases, resulting in a phenomenon known as an "urban heat island." Urban heat islands can raise air temperature in a city by 1.1–4.5°C (1–8°F) (World Meteorological Organization 1984).

The urban heat island effect is caused by buildings, sidewalks, paved roads, and other non-natural surfaces that limit the amount of land covered with vegetation like grass and trees. Land surfaces with vegetation offer high moisture levels that cool the air when the moisture evaporates from soil and plants. Often a community has fewer vegetated areas and more water-resistant surfaces such as asphalt and building materials that absorb most of the sun's radiation. These surfaces hinder the natural cooling that would otherwise take effect with the evaporation of moisture from surfaces with vegetation.

The higher temperatures in urban heat islands increase air conditioning and can raise pollution levels. Natural compounds called volatile organic compounds are produced from certain trees in high temperatures during the summer. These compounds react with existing pollution under certain climatic conditions to form smog. Through shade provided by trees, ambient temperatures can be reduced, thus lowering the likelihood of smog being formed.

Management Recommendations

The function of the urban forest is dependent on its structure, cover, and urban morphology (for more information on these topics read the Gainesville Urban Forest Fact Sheet Series). Trees provide an important ecosystem service by helping to reduce air pollution and temperature. Escobedo et al. (2011) provide some other considerations when using urban forests to improve urban air quality. But land managers can take steps to maintain and improve air quality and reduce the demand for energy in cooling by following these management strategies:

- Increase the number of healthy trees to increase pollution removal.
- Plant trees on the west side of buildings to help shade during the hottest part of the day.
- Sustain existing tree cover to maintain pollution removal levels and provide shade.
- Sustain large, healthy trees since they have greatest per-tree effects.
- Use long-lived trees since they reduce long-term pollutant emissions from planting and removal.
- Use low-maintenance trees to reduce pollutant emissions from maintenance activities.
- Plant trees in polluted or heavily populated areas to maximize tree air quality benefits.
- Use pine and evergreen hardwood trees for particulate matter reduction since they keep their needles and leaves all year for year-round removal of particles.

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