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Review Paper

The role of urban forest in the protection of human environmental health in geographically-prone unpredictable hostile weather conditions

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INTRODUCTION

The structure of urban forest

Few people know how many or what kind of trees are found in urban areas, or the effect these trees have on a city's environment and the health and well being of its inhabitants. In order to understand the urban forest structure and its function in environmental improvement 5 major landscape elements, i.e., building and hard pavement surface, water, road, urban forest, and general green land in the area (Brazel *et al.*, 2000, Wu *et al.*, 2003) must be considered. Hence, larger pieces (1.5-3.0 hm2) of urban forest patch should be built, and more urban forests should be established in the cities. Based on field data from 10 USA cities and national urban tree cover data (Nowak *et al.*, 2002), it is estimated that urban trees in the coterminous USA currently store 700 million tonnes of carbon ($14,300 million value) with a gross carbon sequestration rate of 22.8 million tC/yr ($460 million/year). Urban forests in the north central, northeast, south central and southeast regions of the USA store and sequester the most carbon, with average carbon storage per hectare greatest in southeast, north central, northeast and Pacific northwest regions, respectively. The national average urban forest carbon storage density is 25.1 tC/ha, compared with 53.5 tC/ha in forest stands. These data emphasizes the potential role of urban forests in reducing atmospheric carbon dioxide, a dominant greenhouse gas. (Nowak *et al.*, 2001). This review is aimed at assessing and evaluating urban forest resources, understanding how urbanization impacts local forest stands, and in assisting city planners in developing appropriate management plans. Hence, the structure, composition, and health of the urban forest resources and how the can be changed, and the factors of the environment could effects these changes. Structural data have been used to determine the effects of urban forest on air quality air, water quality, building energy use, urban climate, ultraviolet radiation, etc. Understanding and quantifying the impact of urban trees is an important prerequisite to managing city vegetation to improve tree health and optimize beneficial forest effects.

Effects of urban forest on urban climate

Atmospheric composition and climate conditions are of great importance for health. Increasing consumption of fossil fuels ever since the industrial revolution has resulted in higher contents of greenhouse gases in the atmosphere (Kanestrom, 1999). Primarily, this will increase the global temperature. Secondarily, it may change the patterns of precipitation and droughts. Higher extreme temperatures will have a negative effect on health. Climate changes can also change the living conditions of undesirable insects and microbes. The ozone gas in the atmosphere acts as a shield against the harmful ultraviolet radiation from the sun. Chlorofluorocarbons contribute to reduction of the ozone layer and increase ultraviolet radiation. Increased exposure of the skin to this radiation may cause damage such as sunburn and skin cancer (Kanestrom, 1999). In order to avoid damage, it is of importance to wear protective clothing or use effective sunshades.

Effects of urban forest on energy conservation

What impacts do trees have on building energy use, and how can they be optimally configured to reduce building energy use and consequent pollutant emissions from power plants? Trees reduce building energy use by lowering temperatures and shading buildings during the summer, and blocking winds in winter. However, they also can increase energy use by shading buildings in winter, and may increase or decrease energy use by blocking summer breezes. Thus, proper tree placement near buildings is critical to achieve maximum building energy conservation benefits. When building energy use is lowered, pollutant emissions from power plants are also lowered. While lower pollutant emissions generally improve air quality, lower nitrogen oxide emissions, particularly ground-level emissions, may lead to a local increase in ozone concentrations under certain conditions due to nitrogen oxide scavenging of ozone. The cumulative and interactive effects of trees on meteorology, pollution removal, and VOC and power plant emissions determine the overall impact of trees on air pollution.

Effects of urban forest on air quality and greenhouse gases

Urban forest effects the local and regional air quality and atmospheric carbon dioxide, in many ways to which several strategies and designs are being researched into to maximize air quality improvement and minimize concentrations of greenhouse gases. The status of environment has been interfered with the volume of transportation systems and dynamism of urban development. Air pollution, which is generated by car traffic, various industrial and human activities impinge upon the general health of the population in particular and the ecosystem in general. Hence, people's physiological well being has become susceptible to adverse alterations. This has been demonstrated in several studies in vivo, in animal models or in human volunteers. The impacts of air pollution on human health and particularly on the respiratory system (e.g asthma or respiratory infections), are now known (Aubier, 1997). The role of urban forest in alleviating these effects is significant. For example, several studies have shown that urban forest leads to the improvement of the health of previously exposed children (Netriova *et al.*, 1990). It contributes to the care of the living environment and of elimination of noxious substances from the atmosphere by increasing the volume of urban forest trees. This is particularly very important in the center of the city where the consequence of the heavy motor vehicle traffic may lead to serious adverse health effects. A study of ambient air pollution differences over the residential and the effect of the morbidity of the population (Nikiforov and Boiadzhieva, 1993) showed correlation between the average concentrations of particulates, SO_2, NO_2, H_2S, phenol and lead, and the incidence of several groups of diseases among adults and children. These diseases may affect the immune system, the lung, eye and skin and could be more frequent among the residents of city areas situated next to industrial zones, while diseases of the cardiovascular, hemopoietic and endocrine systems are more typical in the city centers (Elliott *et al.*, 1999).

Effects of urban forests on temperature reduction

Tree transpiration and tree canopies affect air temperature, radiation absorption and heat storage, wind speed, relative humidity, turbulence, surface albedo, surface roughness and consequently the evolution of the mixing-layer height. These changes in local meteorology can alter pollution concentrations in urban areas. Although, trees usually contribute to cooler summer air temperatures, their presence can increase air temperatures in some instances. In areas with scattered tree canopies, radiation can reach and heat ground surfaces; at the same time, the canopy may reduce atmospheric mixing such that cooler air is prevented from reaching the area. In this case, tree shade and transpiration may not compensate for the increased air temperatures due to reduced mixing. Maximum mid-day air temperature reductions due to trees are in the range of 0.04 °C to 0.2 °C per percent canopy cover increase. Below individual and small groups of trees over grass, mid-day air temperatures at 1.5m above ground are 0.7 °C to 1.3 °C cooler than in an open area. Reduced air temperature due to trees can improve air quality because the emission of many pollutants and/or ozone-forming chemicals are temperature dependent. Decreased air temperature can also reduce ozone formation. Removal of Air Pollutants: Trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner leaf surfaces. Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree, though most particles that are intercepted are retained on the plant surface. The intercepted particle often is resuspended to the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall. Consequently, vegetation is only a temporary retention site for many atmospheric particles. In 1994, trees in New York City removed an estimated 1,821 metric tons of air pollution at an estimated value to society of $9.5 million (McPherson, 1992; 1994). Air pollution removal by urban forests in New York was greater than in Atlanta (1,196 t; $6.5 million) and Baltimore (499 t; $2.7 million), but pollution removal per m of canopy cover was fairly similar among these cities (New York: 13.7g/m/yr; Baltimore: 12.2 g/m/yr; Atlanta: 10.6 g/m/yr) (McPherson, 1992; 1994). These standardized pollution removal rates differ among cities according to the amount of air pollution, length of in-leaf season, precipitation, and other meteorological variables. Large healthy trees greater than 77 cm in diameter remove approximately 70 times more air pollution annually (1.4 kg/yr) than small healthy trees less than 8 cm in diameter (0.02 kg/yr) 15-16]. Air quality improvement in New York City due to pollution removal by trees during daytime of the in-leaf season averaged 0.47% for particulate matter, 0.45% for ozone, 0.43% for sulfur dioxide, 0.30% for nitrogen dioxide, and 0.002% for carbon monoxide. Air quality improves with increased percent tree cover and decreased mixing-layer heights. In urban areas with 100% tree cover (i.e., contiguous forest stands), short-term improvements in air quality (one hour) from pollution removal by trees were as high as 15% for ozone, 14% for sulfur dioxide, 13% for particulate matter, 8% for nitrogen dioxide, and 0.05% for carbon monoxide (Nowak, 1990 and McPherson, 1992; 1994).

Emission of volatile organic compounds (VOCs)

Emissions of volatile organic compounds by trees can contribute to the formation of ozone and carbon monoxide. However, in atmospheres with low nitrogen oxide concentrations (e.g., some rural environments), VOCs may actually remove ozone. Because VOC emissions are temperature dependent and trees generally lower air temperatures, increased tree cover can lower overall VOC emissions and, consequently, ozone levels in urban areas. VOC emission rates also vary by species. Nine genera that have the highest standardized isoprene emission rate and therefore the greatest relative effect among genera on increasing ozone, are: beefwood (*Casuarina spp.*), *Eucalyptus spp.*, sweetgum (*Liquidambar spp.*), black gum (*Nyssa spp.*), sycamore (*Platanus spp.*), poplar (*Populus spp.*), oak (*Quercus spp.*), black locust (*Robinia spp.*), and willow (*Salix spp.*). However, due to the high degree of uncertainty in atmospheric modeling, results are currently inconclusive as to whether these genera will contribute to an overall net formation of ozone in cities (i.e., ozone formation from VOC emissions are greater than ozone removal). Some common genera in Brooklyn, NY, with the greatest relative effect on lowering ozone were mulberry (*Morus spp.*), cherry (*Prunus spp.*), linden (*Tilia spp.*) and honey locust (*Gleditsia spp.*) Because urban trees often receive relatively large inputs of energy, primarily from fossil fuels, to maintain vegetation structure, the emissions from these maintenance activities need to be considered in determining the ultimate net effect of urban forests on air quality. Various types of equipment are used to plant, maintain, and remove vegetation in cities. These equipments include various vehicles for transport or maintenance, chain saws, back hoes, leaf blowers, chippers, and shredders. The use and combustion of fossil fuels to power this equipment leads to the emission of carbon dioxide (approximately 0.7 kg/L of gasoline, including manufacturing emissions and other chemicals such as VOCs, carbon monoxide, nitrogen and sulfur oxides, and particulate matter. Trees in parking lots can also affect evaporative emissions from vehicles, particularly through tree shade. Increasing parking lot tree cover from 8% to 50% could reduce Sacramento County, CA, light duty vehicle VOC evaporative emission rates by 2% and nitrogen oxide start emissions by less than 1%

Synergistic effects

Changes in urban microclimate can affect pollution emission and formation, particularly the formation of ozone. A model simulation of a 20 percent loss in the Atlanta area forest due to urbanization led to a 14 percent increase in ozone concentrations for a modeled day. Although there were fewer trees to emit VOCs, an increase in Atlanta's air temperatures due to the urban heat island, which occurred concomitantly with tree loss, increased VOC emissions from the remaining trees and anthropogenic sources, and altered ozone chemistry such that concentrations of ozone increased. A model simulation of California's South Coast Air Basin suggests that the air quality impacts of increased urban tree cover may be locally positive or negative with respect to ozone. The net basin-wide effect of increased urban vegetation is a decrease in ozone concentrations if the additional trees are low VOC emitters. Modeling the effects of increased urban tree cover on ozone concentrations from Washington, DC to central Massachusetts reveals that urban trees generally reduce ozone concentrations in cities, but tend to slightly increase average ozone concentrations in the overall modeling domain. Interactions of the effects of trees on the physical and chemical environment demonstrate that trees can cause changes in pollution removal rates and meteorology, particularly air temperatures, wind fields, and mixing-layer heights, which, in turn, affect ozone concentrations.

Urban forest management

Urban forest management strategies to help improve air quality include: increase the number of healthy trees (increases pollution removal), sustain existing tree cover (maintains pollution removal levels), maximize use of low VOC emitting trees (reduces ozone and carbon monoxide formation), sustain large, healthy trees (large trees have greatest per tree effects), use long-lived trees (reduces long-term pollutant emissions from planting and removal), use low maintenance trees (reduces pollutants emissions from maintenance activities), reduce fossil fuel use in maintaining vegetation (reduces pollutant emissions), plant trees in energy conserving locations (reduces pollutant emissions from power plants), plant trees to shade parked cars (reduces vehicular VOC emissions), supply ample water to vegetation (enhances pollution removal and temperature reduction), plant trees in polluted areas or heavily populated areas (maximizes tree air quality benefits), avoid pollutant sensitive species (increases tree health), and utilize evergreen trees for particulate matter reduction (year-round removal of particles). The scientists and urban planners should carry out timely devise cost effective urban forest model that would allow individual communities and cities to easily, accurately, and cost-effectively quantify their urban forest structure and its effect on air quality and atmospheric carbon dioxide. Already in this regard, digital cover mapping technology is being used to carry out remote sensing and collect data that could be used to develop high-resolution maps of vegetation and artificial surfaces in urban areas. These research scientists and urban planners should at the national level, collaborate with other agencies to develop cover maps for the entire United States using satellite data with higher 3-dimensional resolution.

REFERENCES

Abdollahi, K. K. and Ning, Z. H., (1996). Research update on environmental influences of trees on mitigating air pollution effects and improving urban air quality. In: Sustaining people, sustaining forests: Proceedings of the 1995 Society of American Foresters Convention. 1995 October 28-November 1, Portland, ME. Bethesda, MD: Society of American Foresters, 177-185.

Grimmond, C. S. B., King, T.S., Cropley, F. D., Nowak, D. J. and Souch, C., (2002). Local-scale fluxes of carbon dioxide in urban environments:methodological challenges and results from Chicago. Environ. Pollut., **116**, S243-S254.

Nowak, D. J., (2000). Impact of urban forest management on air pollution and greenhouse gases. In: Proceedings of the Society of American Foresters 1999 national convention; 1999 September 11-15; Portland, OR. SAF Publ. 00-1. Bethesda, MD: Society of American Foresters, 143-148.

Nowak, D. J., (2000). Tree species selection, design, and management to improve air quality. In: Scheu, Diane L. comp. 2000 ASLA Annual Meeting Proceedings; 2000; St. Louis, MO. Washington, DC: American Society of Landscape Architects, 23-27.

Nowak, D. J., (1994). Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G., Nowak, D.J., Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 83-94.

Nowak, D. J., (1993). Atmospheric carbon reduction by urban trees. J. Environ. Manage., **37** (3), 207-217.

Nowak, D. J., (1992). Smog check your trees: clouding the issue. Arborist News, **1** (1), 13, 15.

Nowak, D. J., Cardelino, C. A., Rao, S. T. and Taha, H., (1998). Discussion: Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models. Atmospheric Environment, **32** (14-15), 2709-2711.

Rowntree, R. A., (1990). Urban forestry, carbon dioxide and global climate change. In: Forestry on the Frontier: Proceedings of the 1989 Society of American Foresters National Convention, September 24-27, 1989, Spokane, Washington. Bethesda, MD: Society of American Foresters, 429-433.

Rowntree, R. A. and Nowak, D. J., (1991). Quantifying the role of urban forests in removing atmospheric carbon dioxide. J. Arbori., **17** (10), 269-275.

Dwyer, J. F., McPherson, E. G., Schroeder, H. W. and Rowntree, R. A., (1992). Assessing the benefits and costs of the urban forest. Journal of Arboriculture **18**(5), 227-234.

Elliott-Fisk, D. L., Rowntree, R. A. and Stephens, S. L., (1996). Lake Tahoe case study. In: Sierra Nevada Ecosystem Project: Final Report to Congress, Addendum. Davis, CA: University of California, Centers for Water and Wildland Resources, 217-276, (NA).

Hughes, M. K., (1982). Urban forestry in Dayton, Ohio. Dayton Climate Project Working Paper, Dayton, Ohio: City of Dayton, 31.

McPherson, E. G., (1994). Benefits and costs of tree planting and care in Chicago. In: McPherson, E.G., Nowak, D.J., Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 115-133.

McPherson, E. G., (1992). Environmental benefits and costs of the urban forest: two examples from Tucson, Arizona. In: McCulloch, J., ed. Proceedings of International Conference on Cities and Global Change. 1991 June 12-14: Toronto, Canada. Washington, D.C.: The Climate Institute, 218-224.

McPherson, E. G., (1992). Environmental benefits and costs of the urban forest. In: Rodbell, Phillip D., ed. Proceedings of the 5th National Urban Forest Conference.; 1991 November 15-19; Los Angeles, CA. Washington, DC: American Forestry Association, 52-54.

Nowak, D. J. (1990). USDA Forest Service research in urban forests. In: Trees for Texas cities: Proceedings of the Fourth Annual Texas Urban Forestry Conference. May 9-11, 1990, Houston, Texas. College Station, TX. Texas Forest Service, 8.

Rowntree, R. A., (1988). Ecology of the Urban Forest: introduction to part III. Landscape and Urban Planning **15**, 1-10.

DeWalle, D. R., Heisler, G. M. and Jacobs, R. E., (1983). Energy needs for heating and cooling at forest home sites. Journal of Forestry **81** (2), 84-88.

Heisler, G. M., (1986). Energy savings with trees. Journal of Arboriculture. **12** (5), 113-125.

Mattingly, G. E., Harrje, D. T. and Heisler, G. M., (1979). The effectiveness of evergreen windbreaks for reducing residential energy consumption. ASHRAE Transactions, **85** (2), 428-444.

Brazel and Heisler, (2000). Some considerations in using climate data from existing weather stations or installing stations for research in Baltimore and Phoenix urban LTER sites. In: 3rd symposium on the urban environment; 2000 August 14-18; Davis, CA. Boston, MA: American Meteorological Society, 187-188.

Zhu, W., He, X., Chen, W., Chen, Y., Zhang, Y. and Ning, Z., (2003). [Quantitative analysis of urban forest structure: a case study on Shenyang arboretum] Ying Yong Sheng Tai Xue Bao. 2003 Dec., **14** (12), 2090-4.

Nowak, D. J., Pasek, J. E., Sequeira, R. A., Crane, D. E. and Mastro, V. C., (2001). Potential effect of Anoplophora glabripennis (Coleoptera: Cerambycidae) on urban trees in the United States. J Econ Entomol. 2001 Feb., **94** (1): 116-22.

Nowak, D. J. and Crane, D. E., (2002). Carbon storage and sequestration by urban trees in the USA. Environ Pollut., **116** (3), 381-9.

Gao, W., Grant, R. H. and Heisler, G. M. (1996). Spectral radiative properties of various tree species in ultraviolet wavelengths and irradiance modeling implications. In: Preprints, 22nd. Conference on Agriculture and Forest Meteorology and 12th Conference on Biometeorology and Aerobiology: 1996 January 28 - February 2; Atlanta, GA. Boston, MA: American Meteorological Society, 417-418.

Grant, R. H. and Heisler, G. M. (2000). Estimation of ultraviolet-B irradiance under variable cloud conditions. J. Appl. Mete., **39**, 904-916.

Grant, R. H. and Heisler, G. M., (1997). Obscured overcast sky radiance distributions for ultraviolet and photosynthetically active radiation. J. Appl. Mete., **36**, 1336-1345.

Grant, R. H., Heisler, G. M. and Ehrlich, C., (2002). The solar ultraviolet radiation environment in the Washington-Baltimore metropolitan area. In: 4th. symposium on the urban environment; May 20-24; Norfolk, VA. Boston, MA: American Meteorological Society, 92-93.

Grant, R. H., Heisler, G. M. and Gao, W., (2002). Estimation of pedestrian level UV exposure under trees. Photochem. Photobio., **75** (4), 369-376.

Grant, R. H., Heisler, G. M. and Gao, W., (1997). Clear sky radiance distributions in ultraviolet wavelength bands. Theoretic. Appl. Clima., **56**, 123-135.

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