The Benefits of Trees

By Jim Clark and Nelda Matheny

This article is excerpted from ISA's Municipal Specialist Certification Study Guide.

LEARNING OBJECTIVES

The arborist will be able to

- explain how trees sequester carbon and how the process benefits the environment
- clarify the direct and indirect benefits trees provide with regard to energy conservation
- describe the heat island effect and how trees help mitigate the phenomenon
- explain the psychological and social benefits of trees
- discuss how trees affect property values and enhance a community's economic stability.

CEUs for this article apply to Certified Arborist, Utility Specialist, Municipal Specialist, Tree/Worker Climber, and the BCMA science category.

In 1978, John P. Rousakis, mayor of Savannah, Georgia, opened the first National Urban Forestry Conference in the United States with the following statement:

> The time has come for urban communities to stop seeing the trees and start looking at the forest. I say this because the comprehensive environmental benefits . . . can be achieved only through a forest management program. They cannot be achieved through tree management programs designed solely to protect trees for an aesthetic or historic purpose. If municipalities are to have effective municipal forest programs that will produce the maximum public benefits, they must reorder their thinking. They should establish the improvement of the urban environment as the primary goal of such programs. . . . This means that we in municipalities must identify the qualities in the urban environment we wish to attain through our urban forestry programs, and then design these programs to attain these qualities.

The discipline of municipal arboriculture has grown in the past 30 years to encompass not only arboriculture, but also forestry, ecology, hydrology, atmospheric science, energy, and stormwater control—a multitude of environmental and engineering sciences that interact within cities. The scope will continue to evolve.

Benefits of Trees

Understanding the specific benefits trees provide—and being able to communicate them to the public and civic leaders—is fundamental to the arborist's profession. Over the past decade, there have been tremendous advances in our knowledge of the benefits of urban trees. Quantifying those benefits—environmental, social, or economic—has been the focus of much research.

For planted trees, the greatest benefits are derived from healthy, structurally sound trees planted in locations that support their development. Strategic planting maximizes benefits and minimizes costs.

For native vegetation, benefits are enhanced when intact stands of trees and their associated understory are retained. The planting and management of trees to maximize their benefits to the community should be the focus of a well-developed urban forest management plan.

Environmental Benefits

The environmental benefits provided by the urban forest can include enhanced air quality, carbon sequestering, energy conservation through shade and wind protection, reduction of stormwater runoff and erosion, and noise attenuation.

Air Quality

Vegetation improves air quality by intercepting particulate matter and absorbing gaseous contaminants through stomata. Many urban pollutants are produced through the combustion of fossil fuels for power, transportation, and other

There are many environmental, aesthetical, and social benefits of trees, including an improvement in air quality, energy conservation, the sequestering of carbon, and an increase in residential and business property values.

industrial processes, as well as wind erosion of bare soils. Each of the major pollutants, if present in high enough concentrations, may cause injury to tree foliage. But any effects on tree growth are secondary to the impact of poor air quality on human health.

The primary atmospheric contaminants are:

Sulfur dioxide (SO_2)—the most abundant gaseous pollutant, results from burning coal and oil. SO_2 can be a respiratory irritant. It is one of the major components of acid rain.

Nitrogen oxides—particularly nitrogen dioxide (NO_2), result from the high temperatures in internal combustion engines, which in turn cause atmospheric nitrogen to combine with oxygen. Nitrogen dioxide is partially removed by precipitation, contributing to acid rain.

Ozone—formed by a photochemical reaction of nitrogen oxides and volatile organic compounds (hydrocarbons) in ultraviolet sunlight and moisture.

Smog—a mix of atmospheric chemical compounds including ozone, peroxyacetyl nitrate (PAN), nitrogen oxides, and hydrocarbons that react chemically when exposed to ultraviolet light.

Particulates—solid rather than gaseous, generated by combustion of fossil fuels, construction and demolition, industrial processes, soil tillage and erosion, and complex reactions between sunlight and gaseous pollutants. Particulates have been associated with respiratory (asthma) and cardiopulmonary (heart attacks) diseases, and cancer.

Some trees produce pollutants known as biogenic volatile organic compounds (VOCs) that can contribute to the formation of ozone and carbon monoxide. Their existence has been cause for a broad concern about "pollution-causing trees."

Species vary widely in their production of these compounds. Concerns that trees cause pollution should be balanced with their ability to improve air quality. In the South Coast Air Basin (California), 12 percent of the hydrocarbons were from trees and shrubs; 88 percent were from human sources (Herr 1992). Although trees emit hydrocarbons that can enhance ozone formation, they lower overall ozone levels.

Carbon Uptake and Storage

The concentration of carbon dioxide in the earth's atmosphere has been increasing since the beginning of the industrial age. Associated with this increase is a warming of global temperatures. Estimates of U.S. carbon dioxide emissions for 1996 were 5.5 billion tons (McPherson and Simpson 1999).

Trees have been considered as a tool to mitigate increases in atmospheric carbon dioxide. As they grow, trees remove carbon dioxide from the atmosphere. Through photosynthesis, carbon is initially stored as sugar. A fraction of the stored carbon dioxide is released back to the atmosphere during respiration. Over time, however, the tree accumulates atmospheric carbon in the form of wood, thereby sequestering the carbon. The amount of carbon stored in a tree is a function of the amount of woody material (stems and roots) as well as its quality. This carbon is not released into the atmosphere until the wood is decomposed by fungi, burned, or otherwise chemically destroyed.

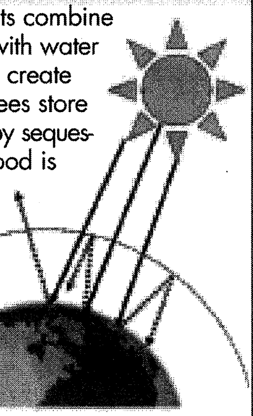
Good arboriculture (that is, selecting trees appropriate for the location and providing maintenance) makes for the maximal carbon storage. In 1999, McPherson and Simpson authored Carbon Dioxide Reduction Through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters. This report summarizes how arborists, urban foresters, and volunteers in the United States might select, site, and maintain trees in order to maximize carbon storage. Informational tables are provided from which the carbon storage can be calculated.

The Greenhouse Effect and Carbon Sequestering

The greenhouse effect is the rise in temperature that the earth experiences because certain gases in the atmosphere—the greenhouse gases (such as water vapor, carbon dioxide, nitrous oxide, and methane)—trap energy from the sun. Incoming radiation passes through the Earth's atmosphere, but some of the outgoing infrared radiation (heat) is blocked. This process occurs naturally and has kept the Earth's temperature about 60°F warmer than it would otherwise be. Because of how they warm the earth, these gases are referred to as greenhouse gases.

Because of heavy use of fossil fuels over the past century, the concentration of carbon dioxide has been steadily increasing. The increased carbon dioxide blocks more infrared radiation from escaping through our atmosphere, causing a rise in the earth's temperature.

Through photosynthesis, plants combine carbon dioxide from the air with water using energy from sunlight to create carbohydrates for growth. Trees store carbon in woody tissue, thereby sequestering the carbon until the wood is decomposed or burned. *By removing carbon dioxide from the air, trees help improve air quality and reduce global warming.*



Energy Conservation—Direct Benefits

Properly placed trees can reduce building heating and cooling needs. In summer, energy used for cooling is reduced by tree shade. Although use of heating energy in winter can increase because of reduced solar gain caused by tree shade, sheltering of buildings from cold winds by nearby trees tends to reduce heating energy use. These localized shade and wind effects are sometimes referred to as direct effects.

Energy Conservation—Indirect Benefits

Urban areas are known to be 4°F to 10°F (-15.5°C to 12.2°C) warmer than adjacent rural locations and produce more smog. This phenomenon is known as the urban heat island. While the heat island effect may be beneficial in cold climates such as Chicago and Oslo, in locations with warm summers it adds significantly to the cost of energy and atmospheric pollution. The heat island effect may increase air-conditioning demands by 50 percent in warm summer areas.

Tree planting has been identified as one of the successful means of mitigating the heat island effect by lowering temperatures. Smog production increases 10 percent for each 10°F (12.2°C) increase in temperature. Even small reductions in air temperature can have a large impact on smog production.

Energy Conservation—Deferred Costs of Energy Production

Urban trees can help defer the costs of energy production. When trees are planted in locations that reduce air-conditioning demand in the summer by shading buildings, or heating needs in winter by shielding cold winds, peak energy demand is less. The need to build additional power plants to meet peak demand may be reduced. Any long-term management plan to shave demand will reduce the need for additional power plants, a major capital expense.

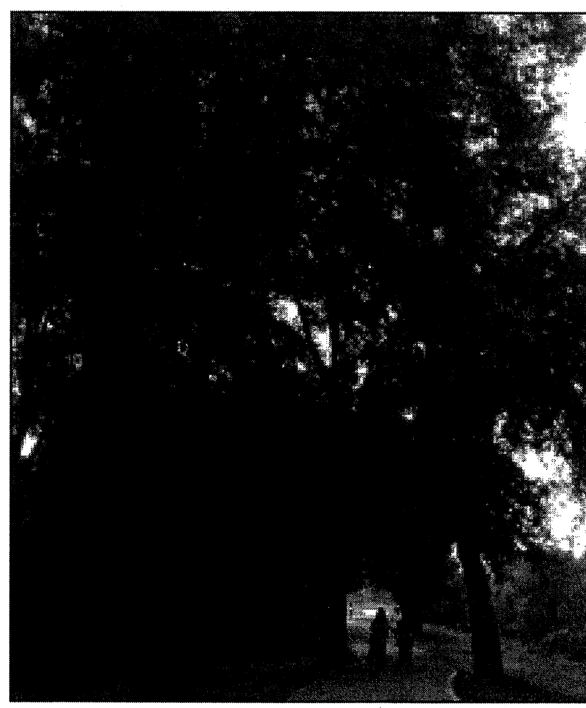
Street trees can provide energy savings for adjoining property owners.

Street trees are a major source of building shade. A well-developed street tree program can be linked directly to the energy-saving benefit accrued by the adjoining property owner.

McPherson and Rowntree (1993) estimated the extent that "well-placed" trees would reduce the costs of heating and cooling a residence in selected locations throughout the United States. Energy savings were influenced by the amounts of summer shade, winter sun, and wind, and were greatest in locations with hot summers. Total benefits provided by trees were greatest in Miami, Florida, and Fresno, California—locations with long, warm summers. The lowest energy savings were in Portland, Oregon, a location of cool summers and moderate winters. Savings associated with wind reduction were greatest in cold winter areas such as Minneapolis, Minnesota, and Boston, Massachusetts.

The size of any savings associated with heating and cooling is related not just to the geographic location but to the planting location within the site. The maximum savings (benefits) occur when trees are located so as to provide shade and block wind without reducing access to winter sun. Deciduous trees, hedges, and vines on trellises placed on the east and west sides of structures can provide summer shade while allowing the winter sun to penetrate. At high latitudes (above 30° north latitude), evergreen plants are also suitable on east and west walls because the sun angles in winter are such that these walls will not effectively collect heat, even though desired. In cool climates with limited solar radiation, shading the south side of a building may increase the amount of energy used, creating a liability rather than a benefit.

Another benefit associated with shade provided by trees is the reduced exposure to skin-damaging ultraviolet rays.



Humans respond to nature, greenspace, and landscape plantings, and our behavior is influenced by those factors. The mental fatigue we experience in modern urban life is relieved by greenspace.

Benefits of Trees Shading Parking Areas

Shading parking lots and streets not only makes us feel more comfortable in the summer heat by reducing temperatures, but it also prolongs the life of the paved surface and reduces pollution. The more extensive the tree canopy, the greater the benefits.

Parking lots are essentially mini heat islands. The Center for Urban Horticulture found that in Davis, California trees in parking lots reduced the surface temperatures of the asphalt by as much as 36°F, temperatures inside the cars by more than 47°F, and fuel-tank temperatures by almost 7°F.

As temperatures rise, emission of reactive organic gases (ROGs), which are precursors of ozone, from parked cars increases. Shading parking areas to reduce temperatures will minimize ROGs, thus improving air quality and reducing ozone.

Cooler temperatures under shade trees also reduce the rate of volatilization of the oil binder in pavement. By slowing the rate at which pavement surface is degraded, the frequency of sealing the pavement is reduced. McPherson and others (1999) reported that where streets needed to be overlaid or slurry sealed every 7 to10 years when in full sun, refurbishment of pavement under dense shade may be deferred to every 20 to 25 years.

Stormwater Runoff and Erosion Control

Tree canopies intercept rain, snow, and other forms of precipitation. In so doing, they decrease the impact velocity of a raindrop hitting the ground and reduce the overall amount of precipitation that eventually hits the ground. Leaf litter that covers bare soil has a similar effect. The result of this moderating effect on precipitation is a reduction of runoff and soil erosion. The faster the moving water, the larger the particles that can be carried away and the more severe the erosion will be.

The scale and intensity of interception is directly related to the amount of canopy cover. Evergreen species are more effective than deciduous species, because they provide year-round cover.

Trees are most effective in intercepting rainfall during low-intensity storms. As the duration of precipitation increases, water drips from leaves and runs down stems. As with peak loading and energy conservation, one of the benefits from tree canopy interception of rainfall is reducing the intensity of stormwater runoff, that is, the peak loading of the stormwater system.

Another tree-based approach to stormwater management is to allow riparian corridors to overflow their banks and flood adjacent forested areas. Trees function as part of a natural floodplain, slowing water flow. Erosion is decreased, and water can enter the soil rather than be carried off. Tree species that tolerate periods of inundation must be selected for planting in these locations.

Noise Reduction

Plants are not very effective in reducing noise. To reduce noise levels appreciably, plantings must be dense, tall, and wide [80 to 115 ft (24.4 to 35 m)]. This limits the use of plants for noise reduction to large spaces, such as adjacent to freeways or industrial facilities.

Plantings close to the noise source are more effective than similar plantings farther from the source, because they increase excess attenuation; that is, they reduce (attenuate) noise more than simple distance will. Most species, however, do not differ greatly in their ability to reduce noise levels, although those with fleshy leaves and numerous branches are better than thin, sparsely leafed plants. Evergreen plants are best for year-round effectiveness.

There is, however, indirect evidence to suggest that plants create a psychological barrier that reduces the perception of noise. "Out of sight, out of mind" applies somewhat and may be of importance in confined spaces.

Habitat for Wildlife

Groups of trees and their understory provide habitat for wildlife, including amphibians, reptiles, mammals, and birds. Interaction with these creatures helps connect people to nature. In fact, bird watching is one of the fastest-growing recreational pursuits in North America.

Research Highlight

- The ability of trees to influence stormwater runoff in urban areas has been established in several studies.
- The 22 percent tree canopy cover in Dayton, Ohio, reduced runoff by 7 percent compared to no canopy cover (Sanders 1986). An increase of canopy cover would almost double this effect.
- In Austin, Texas, trees reduced stormwater runoff by 7 percent, a benefit equivalent to $230 million in costs of constructing retention ponds (Walton 1998).
- In Sacramento County, California, the urban forest canopy was more effective in moderating storms in summer than winter. Over the entire study area, about 1 percent of the annual precipitation was intercepted; with the tree canopy, up to 11 percent was (Xiao et al., 1998).

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Psychological, Health, and Social Benefits of Trees

Arborists and many nonarborists alike have a strong emotional attachment to trees. One need only attend a public meeting where a tree removal question is being debated to see firsthand the passions that trees evoke. Humans respond to nature, greenspace, and landscape plantings, and our behavior is influenced by those factors. The mental fatigue we experience in modern urban life is relieved by greenspace. The value of this benefit is only now being understood. The psychological value of trees and greenspace has been documented by several studies. These benefits range from quicker recovery from illness and injury, to improved mental health, greater job satisfaction, and less crime.

Research Highlight

People benefit from being around trees, as demonstrated by these studies:

- One study (Ulrich 1986) found that patients who had a view of a wooded scene recovered more quickly from abdominal surgery, required less pain medication, and had fewer complications than those whose view was of a brick wall. If window views of plants could shorten postoperative hospitalization by the 8.5 percent experienced in Ulrich's study, annual health cost savings in the United States would total several hundred million dollars.
- Kaplan et al. (1988) revealed that office workers with views of natural elements experienced less job pressure and greater job satisfaction than colleagues with no view or views of the built environment.
- Inmates at a large federal prison who viewed the prison interior from their cells sought health care more often than prisoners who had a view of farmland (Moore 1982).
- Kuo and Sullivan (2001) observed that vegetation may mitigate psychological precursors to crime, such as irritability, inattentiveness, and impulsive behavior. The restorative power of nature in cities reduces these precursors. They analyzed crime patterns in a community in Chicago and found fewer crimes (violent and property) occurred in areas of dense trees and grass.

In addition to the recuperative benefits of viewing trees, greenspace provides recreational areas in which people can be active. Activity is directly linked to health and well-being.

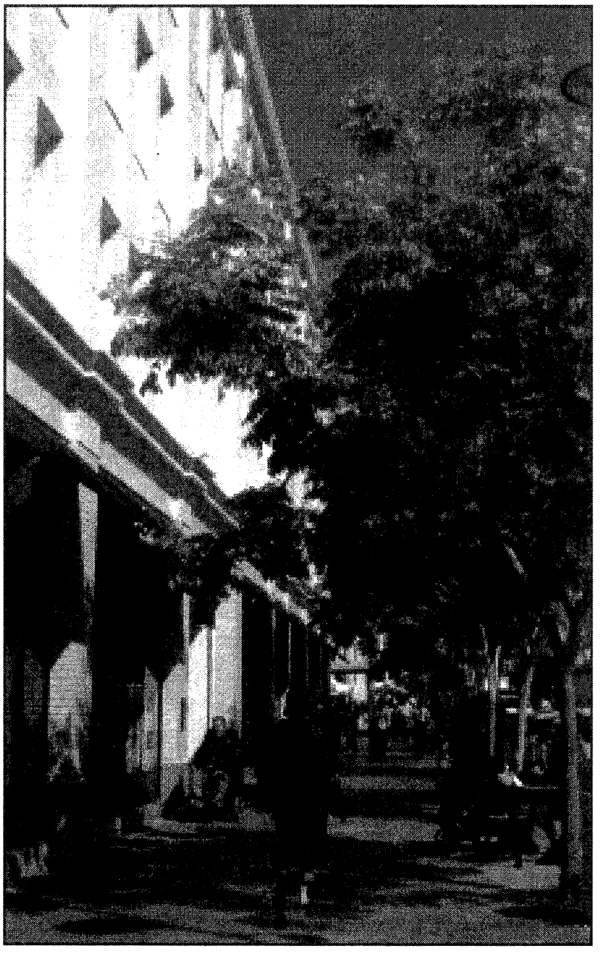
Municipal arborists who have worked with volunteer organizations and programs offer direct testimony to the power of planting and caring for trees as a restorative event. There is the sense of doing something positive, of making a contribution that is clear and powerful. Leaders of volunteer-based tree groups would add that the restoration extends beyond the individual to encompass the neighborhood and community. There is a potential to use urban forestry activities as a vehicle to heal and restore communities and to bring residents together to create a sense of community.

One of the traditional views of greenspace in urban areas has been that it detracts from a sense of safety. This fear is reinforced by police studies showing that some criminals do use this type of landscaping for concealment. As a result, many greenspaces and landscape plantings have been cleared from inner cities.

Kuo and Sullivan (2001) examined how inner-city residents perceive and respond to trees and greenspace. Results indicate a preference for landscapes of trees and lawn without dense shrubs and screen plantings. Kuo and Sullivan suggest that this form of greenspace allows for increased surveillance, first by creating more inviting, livable places, and second by serving as a "territorial marker."

Economic Values

How trees affect the value of a property is one of the important variables in urban forests. A healthy, attractive urban forest enhances the economic stability of a community by attracting visitors, businesses, and new residents. Research has shown that people tend to linger and shop longer when



A healthy, attractive urban forest enhances the economic stability of a community by attracting visitors, businesses, and new residents.

streets are shaded by trees. Apartments and offices that are surrounded by trees tend to rent more quickly and have lower vacancy rates.

Several studies have examined this question of economic value. Research has followed two paths. The first deals with hypothetical situations in which real estate appraisers and prospective home buyers view photographs of properties with and without trees.

The second approach uses statistics of actual home sales. Anderson and Cordell (1988) concluded, based on their results and those of other researchers, that a reasonable estimate of contribution of trees would be a five percent greater sales price. They cautioned that, while their results were comparable with similar studies, the five percent increase in sales prices associated with trees could reliably be used on the east coast of the United States. There may be significant variation in areas of the country where tree cover and climate are different.

It is not only the sites with trees that have higher sales prices. Developers in the San Francisco area acknowledge that homes adjacent to lots with large trees on them also sell for higher prices. Homes near greenbelts and parks also have higher sales value.

Appraisal of the Value of Landscape Trees

Another approach to estimating the value of trees and shrubs in landscape settings is that of the Council of Tree and Landscape Appraisers (CTLA), whose Guide for Plant Appraisal (2000) provides a methodology for individual trees. CTLA represents seven landscape and horticultural industry groups.

One of two methods is recommended, depending on the size of the tree in question. The replacement cost method is for plants that can be replaced by one of the same size and species. The trunk formula method is for trees considered too large to replace. A basic value is calculated by adding the cost of replacing the largest commonly available tree of the same or comparable species to the increase in value based on the difference in trunk areas of the appraised tree and the replacement tree.

In both methods, the value obtained is adjusted by condition and location ratings of the tree to obtain its appraised value. The costs are based on growing and handling practices of plants in the particular region.

Appraisals based on the CTLA procedure are used for settling insurance claims, civil suits, and property condemnations. They are also used for establishing the value of plants for inventory purposes or for replacement should they be damaged during construction. The U.S. Internal Revenue Service has accepted tree casualty losses of replacement-size trees, but has yet to fully recognize losses based on the basic value formula for larger trees.

The Arboricultural Association in Great Britain recently updated its Amenity Valuation of Trees and Woodlands (Helliwell 2000). Six factors are identified for a tree, plus any special factors such as historical value. Each of these factors is given a score from one to four points. The monetary value of an individual tree is determined by multiplying the factors and then multiplying that product by the monetary value (£10 in 1990) assigned to one unit of that product. Tree size, one of the factors, is determined by the product of the mean crown diameter and tree height.

Research Highlight

The contribution of trees and landscaping to property values has been evaluated in several studies:

- Real estate appraisers and prospective home buyers in Amherst, Massachusetts, viewed photographs of identical homes on lots that varied in landscaping. The hypothetical sales price increased by an average of 7 percent (range 5 to 15 percent) for homes that were landscaped with trees (Payne 1973).
- Anderson and Cordell (1988) examined the sales price of 844 single-family residences in Athens, Georgia, finding that "landscaping with trees was associated with a 3.5 to 4.5 percent increase in sales prices." The increase in price was attributed to large trees.
- Henry (1994) examined the influence of landscaping on the price of single-family homes in Greenville, South Carolina, finding that homes with excellent landscaping had sales prices 4 to 5 percent higher than those with good landscaping, which in turn had sales prices 8 to 10 percent higher than those with poor landscaping.

Other appraisal methods include the Burnley approach in Australia (Moore 1991), the Standard Tree Evaluation Method (STEM) in New Zealand (Flook 1996), and Norma Granada in Spain (Asociation Española de Parques y Jardines Publicos 1999). A joint standard for Australia and New Zealand, Amenity Trees–Guide to Valuation, has been developed and is in the review stage.

Extend Life of Pavement

The asphalt paving on streets contains stone aggregate in an oil binder. Without tree shade, the oil heats up and volatizes, leaving the aggregate unprotected. Vehicles then loosen the aggregate and, much like sandpaper, the loose aggregate grinds down the pavement. Streets should be overlaid or slurry-sealed every seven to 10 years over a 30 to 40-year period, after which reconstruction is required. A slurry seal costs approximately $0.27 per square foot (0.09 square meters) or $50,000 per linear mile (1.6 km).

Because the oil does not dry out as fast on a shaded street as it does on a street with no shade trees, shaded streets require less frequent maintenance. The slurry seal can be deferred from every 10 years to every 20 to 25 years for older streets with extensive tree canopy cover.

CONTINUING EDUCATION UNIT

A Final Note

Arborists now speak about trees and the variety of environmental, ecological, psychological, and other benefits they provide. In so doing, we must not lose sight of what the public sees as benefits—that trees are beautiful and enhance the appearance of the street and our homes. We also describe the negative, irritating side—lifting pavement and producing litter.

Some business owners view trees as mixed blessings. On one hand, trees create a positive mood, distinguish the setting, and improve the community's image. On the other, trees screen their buildings from view and are a source of litter.

The public may understand energy reduction and air pollutant removal, but they describe tree benefits in aesthetic terms. Whether this is a matter of educating the public about the specific contributions trees make or a reflection of an emotional tie that we have yet to understand is unclear. What is clear is that we should remember to speak to the public in the terms the public uses.

Select References

Anderson, L.M. and Cordell, H.K. 1988. "Influence of Trees on Residential Property Values in Athens, Georgia (USA): A Survey Based on Actual Sales Prices." Landscape and Urban Planning 15:153–64.

Asociacion Española de Parques y Jardines Publicos. 1999. Metedo Para Valoración de Árboles y Arbustos Ornamentales. Norma Granada. Asociacion Española de Parques y Jardines Publicos, Madrid, Spain.

Council of Tree and Landscape Appraisers (CTLA). 2000. Guide for Plant Appraisal. 9th edition. International Society of Arboriculture, Champaign, IL. 143 pp.

Flook, R. 1996. A Standard Tree Evaluation Method (STEM). Ron Flook. Tahunanui, Nelson, New Zealand.

Helliwell, D.R. 1967. Amenity Valuation of Trees and Woodlands. Arboricultural Association, Hampshire, UK.

Herr, S. 1992. Trees Cause Smog? California Releaf Remarks (San Francisco) 3 (1):1–3.

Kuo, F. and Sullivan, W. 2001. "Environment and Crime in the Inner City: Does Vegetation Reduce Crime?" Environment and Behavior 33(3):343–367.

McPherson, G. and Rowntree, R.A. 1993. "Energy Conservation Potential of Urban Tree Planting." Journal of Arboriculture 19:321–31.

McPherson, G. and Simpson, J. 1999. Carbon Dioxide Reduction Through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters. USDA Forest Service. Pacific Southwest Research Station. General Technical Report PSW-GTR-171. 237 pp.

Moore, G. 1991. "Amenity Tree Evaluation: A Revised Method." In: The Scientific Management of Planting in the Urban Environment. Proceedings of the Burnley Centenary Conference. Centre for Urban Horticulture, Melbourne, Australia. pp. 166–171.

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Next, complete the registration information, ***including your certification number***, on the answer form and send it to ISA, P.O. Box 3129, Champaign, IL 61826-3129. Answer forms for this test, **The Benefits of Trees**, may be sent for the next 12 months.

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CEUs for this article apply to Certified Arborist, Utility Specialist, Municipal Specialist, Tree/Worker Climber, and the BCMA science category.

1. What is the most abundant gaseous pollutant that results from burning coal and oil?
   a. ozone
   b. sulfur dioxide
   c. smog
   d. nitrogen dioxide

2. The carbon stored in a tree's woody material is released from the atmosphere when the wood is
   a. decomposed by fungi
   b. burned
   c. chemically destroyed
   d. all of the above

3. Maximum, direct energy conservation benefits occur when trees are placed to
   a. provide summer shade and block wind
   b. block all sunlight and reduce noise
   c. add aesthetic value in the landscape
   d. add year-round shade in cool climates

4. Each 10°F (5.5°C) increase in temperature increases smog production by
   a. five percent
   b. 10 percent
   c. 20 percent
   d. 30 percent

5. Tree planting in urban areas has been identified as a successful means of mitigating the
   a. heat index
   b. urban cooling phenomenon
   c. wind chill factor
   d. heat island effect

6. What is the pollutant produced by some trees that can contribute to the formation of ozone and carbon monoxide?
   a. particulates
   b. sulfur dioxide
   c. volatile organic compounds
   d. allelochemicals
7. Good arboriculture includes selection, placement, and maintenance of trees to
   a. maximize carbon storage
   b. maximize oxygen storage
   c. minimize carbon storage
   d. eliminate atmospheric carbon
8. The planting and caring for trees can be a restorative event, creating a sense of community.
   a. True
   b. False
9. What is the typical difference in air temperature between urban areas and adjacent rural locations?
   a. urban areas are 4°F to 10°F (2.2°C to 5.5°C) warmer
   b. the temperatures in urban areas do not differ from those in adjacent rural locations
   c. adjacent rural locations are 4°F to 10°F (2.2°C to 5.5°C) warmer
   d. it is difficult to measure, because temperatures only differ during extreme weather conditions
10. What is an atmospheric contaminant that is formed by a photochemical reaction of nitrogen oxides and hydrocarbons in ultraviolet sunlight and moisture?
   a. particulates
   b. sulfur dioxide
   c. ozone
   d. carbon dioxide
11. The interception of precipitation by tree canopies results in
   a. decreased impact velocity when raindrops hit the ground
   b. reduced runoff and soil erosion
   c. reduced intensity of runoff during peak loading of stormwater systems
   d. all of the above
12. According to the article, what is a documented psychological benefit of trees and greenspace?
   a. bird watching
   b. improved mental health
   c. reduced noise levels
   d. reduced air-conditioning demand
13. A study on the east coast of the U.S. concluded that landscaping with trees increased the sale price of homes by how much?
   a. two percent
   b. five percent
   c. eight percent
   d. 10 percent
14. The replacement cost method of appraising the value of landscape trees is a calculation that uses the difference in trunk areas of the appraised tree and the replacement tree.
   a. True
   b. False
15. CTLA is an acronym for
   a. Cultural Training for Landscape Appraisal
   b. Calculation Techniques for Landscape Architects
   c. Council of Tree and Landscape Appraisers
   d. Committee for Training of Landscape Assessors
16. Which factor in the Amenity Valuation of Trees and Woodlands (Helliwell 2000) is determined by the product of the mean crown diameter and tree height?
   a. tree value
   b. tree age
   c. tree volume
   d. tree size
17. What is the effect of extensive tree canopy cover over a street with asphalt paving?
   a. the stone aggregate is weakened and loosened by tree litter
   b. the shade extends the life of the asphalt, reducing maintenance costs
   c. the tree canopy has no significant effect on the asphalt paving
   d. the asphalt composition damages tree health, requiring increased tree maintenance
18. To reduce noise levels appreciably, the width of the plantings must be
   a. 20 to 40 ft (6 to 12.2 m)
   b. 45 to 75 ft (13.7 to 22.8 m)
   c. 80 to 115 ft (24.4 to 35 m)
   d. 120 to 150 ft (36.6 to 45.7 m)
19. Which atmospheric contaminant is solid rather than gaseous, and generated by fossil fuels, construction and demolition, industrial processes, soil tillage and erosion, etc.
   a. smog
   b. particulates
   c. nitrogen oxides
   d. ozone
20. In a 1993 study by McPherson and Rowntree, the two U.S. cities likely to receive the greatest total energy conservation benefits from well-placed trees were
   a. Portland, Oregon and Seattle, Washington
   b. Philadelphia, Pennsylvania and Chicago, Illinois
   c. Miami, Florida and Fresno, California
   d. Minneapolis, Minnesota and Boston, Massachusetts