The Benefits of Urban Trees

A summary of the benefits of urban trees accompanied by a selection of research papers and pamphlets.

WARWICK DISTRICT COUNCIL

The Benefits of Urban Trees

Introduction

Trees in towns bring with them both benefits and costs. Whilst many of the costs are well known to managers of urban trees, who watch the budgets and answer the phone to disgruntled residents, the benefits can be seen as nebulous and difficult to quantify or justify. Never the less, a considerable and expanding body of research exists on the benefits that urban trees bring. This briefing note is an attempt to summarise some of the benefits of urban trees. A number of papers relevant to the subject of the benefits of urban trees have, with the kind permission of their authors, been included in the appendices.

Economic Benefits

Consumer behaviour

A study by the University of Washington established a number of benefits in terms of consumer experiences of business districts with trees (Wolf, 1998(a), Wolf, 1999 and Wolf, 2003). Consumers reported consistently higher ratings for a number of categories related to their perception of business districts with trees. They reported a willingness to pay more for parking in landscaped car parks and on average reported a willingness to pay an average of about 11% more for goods in a landscaped business district than a non landscaped district, with this figure being as high as 50% for convenience goods.

Both the business community and consumers were found to favour business districts with good landscaping (Wolf, 1998(b)).

The quality of landscaping along approach routes to business districts has also been found to positively influence consumer perceptions (Wolf, 2000).

Inward investment

The attractiveness of an environment is an important factor in attracting inward investment. Both consumers and businesses have been found to favour districts with high tree cover and the increase in retail prices that can be commanded in well landscaped areas can reasonably be assumed to be a positive benefit in attracting businesses to the district.

Property values

Several studies in the USA have analysed the effect of tree cover on the price of residential house sales, finding that values of properties in tree lined areas may be up to 6% greater than in similar areas without trees (Wolf, 1998 (c)).

The market in the UK is different and a direct translation of these data is not possible. Never the less, an informal telephone survey of estate agents in the Warwick area suggests that tree cover has a positive effect on saleability, if not directly on price. Properties on tree lined street were said to be in more demand and to sell faster.

Social Benefits

Crime reduction

The conventional wisdom has been that trees and other vegetation have a negative impact on crime because they provide cover for criminals and reduce opportunities for casual surveillance.

Research in a particularly deprived area of inner city Chicago has suggested that this is in fact not the case and that appropriate vegetation cover can lead to reduced crime rates (Kuo and Sullivan, 2001(a)). The study dealt largely with mown grass and high canopy trees, which do not provide cover in the same way as, for example, shrub planting. It looked at an area with relatively homogenous architecture and a relatively homogenous population but with differing levels of vegetation. Areas with higher vegetation cover were found to have lower rates of crime, as measured by reports to the police.

Two mechanisms are suggested by which crime rates might be reduced by trees. The first is through an increase in surveillance, essentially because public open space with trees tends to be used much more than space without trees. The second mechanism relates particularly to violent crime and relates to evidence that vegetation has a mitigating effect on mental fatigue, itself often a precursor of outbursts of anger and violence (Kuo and Sullivan, 2001(b)).

Other social benefits

A wealth of research has been undertaken by the Human-Environment Research Laboratory at the University of Illinois and has identified numerous beneficial effects that trees have on society. A good summary of these is a paper by Frances E. Kuo, "*The Role of Arboriculture in a Healthy Social Ecology*", which is attached (Kuo, 2003).

Many of these benefits relate to encouraging people out of their homes and into public open space, where they react more with others and build stronger social relationships. An additional benefit of interest is the positive effect that contact with nature can have on children with Attention Deficit Disorder (ADD) (Taylor, Kuo, Sullivan, 2001).

Dr Rachel Kaplan has found that desk workers who can see nature from their desks experience 23% less time off sick than those who can not see any nature. Desk workers who can see nature also report greater job satisfaction (reported by Wolf, 1998(d)), whilst hospital patients with views of trees have been found to recover significantly faster than those who can not see any natural features.

Environmental Benefits

Pollution interception

Research undertaken in the West Midlands by Lancaster University (Hewitt *et al*, undated) has established that trees can remove a number of pollutants from the atmosphere, including ozone, nitrogen dioxide and particles. The news is not all good though. Trees also produce volatile organic compounds, VOCs, which in combination with some man made pollutants can lead to an increase in ozone, particulates and other pollutants.

Different species of tree have different net effects on air quality. Willows, poplars and oaks can potentially worsen air quality during hot weather, whilst ash, alder and birch have amongst the greatest beneficial effects.

The study estimates that doubling the number of trees in the West Midlands would reduce excess deaths due to particulate pollution by up to 140 per year.

Carbon sequestration

It is well known that trees, in common with all vegetation, absorb carbon dioxide (one of the principal greenhouse gases) and release oxygen during the process of photosynthesis. The carbon absorbed by trees in this process is stored in the wood.

Whilst this most well known of benefits is real it seems it is often overstated. The study by Lancaster University of trees in the West Midlands estimated that the total amount of carbon stored in trees within the conurbation represents the equivalent of about three weeks worth of CO_2 emissions. Never the less, trees do have an important role to play in reducing the effects of greenhouse gases, not only through carbon sequestration but perhaps more importantly through the effects that careful planting can have on fuel use.

Fuel use

Careful tree planting can reduce the amount of fuel used on both heating and cooling buildings. A considerable amount of research has been undertaken to quantify this in the United States, but little such research has been undertaken in the UK. Clearly differences in climate mean that figures here can not be directly related to any part of the USA.

Trees provide shelter and reduce windspeed, thus reducing heat loss from buildings during winter. They also provide shade in the summer, whilst the evapo-transpiration of water from the leaf surface has a general cooling effect on surrounding air. This can significantly reduce the need for air conditioning during hot weather.

Noise reduction

Trees and other vegetation can play an important role in attenuating noise through reflecting and absorbing sound energy. One estimate suggests that 7db noise reduction is achieved for every 33m of forest (Coder, 1996) whilst other reported field tests show apparent loudness reduced by 50% by wide belts of trees and soft ground (Dwyer *et al*, 1992).

Hydrology

Trees have a number of hydrological effects. These include reducing erosion and improving water quality through interception of pollution. Perhaps the most important effect in Britain at present, given the trend for increasing winter flooding, is the reduction in ground water run-off. One study has estimated that for every 5% increase in tree cover area, run-off is reduced by 2% (Coder, 1996).

Wildlife Benefits

Trees are an important wildlife habitat. They provide nesting sites for birds and support a wide range of insects that are an important food source for birds and other wildlife. Trees that bear berries are also a direct source of food for many bird species.

In an urban setting, linear corridors of habitat are among the most important, connecting otherwise isolated areas to each other and out to the rural surroundings. Trees and other vegetation along highways, waterways and railways are particularly important to wildlife in the respect.

Other Benefits

Road safety

Trees can help improve road safety in a number of ways.

Trees lining streets give the impression of narrowing the street and encourage slower driving.

The stress reduction effects of trees (Wolf 1998(d), Kuo and Sullivan 2001(b)) are likely to have the effect of reducing road rage and improving the attention of drivers.

Trees along streets also provide a buffer between pedestrians and vehicular traffic.

Road surfaces

Managers of both trees and highways are well aware of the detrimental effects that trees can have on the surface of footways and carriageways through direct damage by roots. Less well known is the fact that the shade cast be trees can significantly increase the life of road surfaces by reducing the temperatures which the surface reaches during hot weather.

Acknowledgements

Thanks are due to all those involved in research investigating the benefits and costs of trees. In particular thanks go to following for permission to reproduce articles, factsheets and leaflets relating to this area: Kathleen Wolf of the Center for Urban Horticulture at the University of Washington, Frances Kuo of the Human Environment Research Laboratory at the University of Illinois at Urbana-Champaign, Nick Hewitt of Lancaster University, Kim Coder of the University of Georgia, David Nowak of the USDA Forest Service Northeastern Research Station and the International Society of Arboriculture.

Bibliography

Papers marked * are included in the appendices.

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Appendices

The following factsheets, pamphlets and scientific papers provide some of the background to the topics discussed here. They are reproduced with the kind permission of the authors and / or publishers.

Identified Benefits of Community Trees and Forests

by Dr. Rim D. Coder, University of Georgia
October 1996

Community trees and forests are valuable. To the 75% of the United States population that now live in urban and suburban areas, trees provide many goods and services. Values are realized by the people that own the trees, by people nearby, and by society in general. People plant, maintain, conserve, and covet trees because of the values and benefits generated.

Tree benefits can be listed in many forms. The bottom-line is humans derive not a single-user value from community trees and forests, but a multi-product / multi-value benefit. Some of these benefits stem from components and attributes of a single tree, while other benefits are derived from groups of trees functioning together. What is the value of these multiple benefits? A 1985 study concluded that the annual ecological contribution of an average community tree was $270.

Values, functions, goods and services produced by community trees and forests can be evaluated for economic and quality of life components. While quality of life values are difficult to quantify, some of the economic values can suggest current and future negative or positive cash flows. In assessing changes in dollar values, concerns for tree evaluation are most prevalent within: risk management costs (liability and safety); value-added / capital increases to tree values; appreciation of tree and forest assets; maintenance costs of tree and forest assets; and, level of management effectiveness and efficiency (total quality management of community trees and forests -- TTQM).

Below are listed a selected series of goods, services, and benefits community trees across the nation and forests provide. These bullets of information are taken from a diversity of individual research projects and, as such, are individually meaningless except under similar conditions. These items together do suggest trends and concepts of value.

OUTLINE OF SELECTED BENEFITS

Environmental Benefits

Temperature and Energy Use
- Shade
- Wind Control
- Active Evaporation

Air quality
- Oxygen Production
- Pollution Reduction
- Carbon Dixoide Reduction

Hydrology
- Water Run-Off
- Water Quality / Erosion

Noise Abatement
- Glare Reduction
- Animal Habitats

Economic / Social / Psychological Benefits
- Economic Stability
- Property Values
- Product Production
- Aesthetic Preferences
- Visual Screening
- Recreation
- Health
- Human Social Issues

Environmental Benefits

Temperature and Energy Use

Community heat islands (3 to 10 degrees F warmer than surrounding countryside) exist because of decreased wind, increased high density surfaces, and heat generated from human associated activities, all of which requires addition energy expenditures to off-set. Trees can be successfully used to mitigate heat islands. Trees reduce temperatures by shading surfaces, dissipating heat through evaporation, and controlling air movement responsible for advected heat.

Shade

- **20** degrees F lower temperature on a site from trees.
- 35 degrees F lower hard surface temperature under tree shade than in full summer sun.
- 27% decrease in summer cooling costs with trees.
- 75% cooling savings under deciduous trees.
- 50% cooling energy savings with trees. (1980) 20 degrees F lower room temperatures in uninsulated house during summer from tree shade.
- $242 savings per home per year in cooling costs with trees.
- West wall shading is the best cooling cost savings component.
- South side shade trees saved $38 per home per year.
- 10% energy savings when cooling equipment shaded (no air flow reduction).
- 12% increase in heating costs under evergreen canopy
- 15% heating energy savings with trees, (1980)
- 5% higher winter energy use under tree shade
- $122 increase in annual heating costs with south and east wall shading off-set by $155 annual savings in cooling costs.
- Crown form and amount of light passing through a tree can be adjusted by crown reduction and thinning.
- Shade areas generated by trees are equivalent to $2.75 per square foot of value (1975 dollars).

Wind Control

- 50% wind speed reduction by shade trees yielded 7% reduction in heating energy in winter.
- 8% reduction in heating energy in home from deciduous trees although solar gain was reduced.
- $50 per year decrease in heating costs from tree control of wind.
- Trees block winter winds and reduces “chill factor.”
- Trees can reduce cold air infiltration and exchange in a house by maintaining a reduced wind or still area.
- Trees can be planted to funnel or baffle wind away from areas -- both vertical and horizontal concentrations of foliage can modify air movement patterns.
- Blockage of cooling breezes by trees increased by $75 per year cooling energy use.

Active Evaporation

- 65% of heat generated in full sunlight on a tree is dissipated by active evaporation from leaf surfaces.
- 17% reduction in building cooling by active evaporation by trees.
- One acre of vegetation transpires as much as 1600 gallons of water on sunny summer days.
- 30% vegetation coverage will provide 66% as much cooling to a site as full vegetation coverage.
- A one-fifth acre house lot with 30% vegetation cover dissipates as much heat as running two central air conditioners.

Air Quality -- Trees help control pollution through acting as biological and physical nets, but they are also poisoned by pollution.

Oxygen Production -- One acre of trees generates enough oxygen each day for 18 people.

Pollution Reduction

- Community forests cleanse the air by intercepting and slowing particulate materials causing them to fall out, and by absorbing pollutant gases on surfaces and through uptake onto inner leaf surfaces.
- Pollutants partially controlled by trees include nitrogen oxides, sulfur dioxides, carbon monoxide, carbon dioxide (required for normal tree function), ozone, and small particulates less than 10 microns in size.
- Removal of particulates amounts to 9% across deciduous trees and 13% across evergreen trees.
- Pollen and mold spore, are part of a living system and produced in tree areas, but trees also sweep out of the air large amounts of these particulates.
- In one urban park (212 ha), tree cover was found to remove daily 48 lbs particulates, 9 lbs nitrogen dioxide, 6 lbs sulfur dioxide, and 1/2 lbs carbon monoxide. ($136 per day value based upon pollution control technology).
- 60% reduction in street level particulates with trees.
- One sugar maple (one foot in diameter) along a roadway removes in one growing season 60 mg cadmium, 140 mg chromium, 820 mg nickel and 5200mg lead from the environment.
- Interiorscape trees can remove organic pollutants from indoor air.

Carbon Dioxide Reduction

- Approximately 800 million tons of carbon are currently stored in US community forests with 6.5 million tons per year increase in storage ($22 billion equivalent in control costs).
- A single tree stores on average 13 pounds of carbon annually.
- A community forest can store 2.6 tons of carbon per acre per year.

Hydrology

- Development increases hard, non-evaporative surfaces and decreases soil infiltration -- increases water volume, velocity and pollution load of run-off -- increases water quality losses, erosion, and flooding.

- Community tree and forest cover intercepts, slows, evaporates, and stores water through normal tree functions, soil surface protection, and soil area of biologically active surfaces.

Water Run-Off

- **7%** of winter precipitation intercepted and evaporated by deciduous trees.
- 22% of winter precipitation intercepted and evaporated by evergreen trees.
- 18% of growing season precipitation intercepted and evaporated by all trees.
- For every 5% of tree cover area added to a community, run-off is reduced by approximately 2%
- 7% volume reduction in six-hour storm flow by community tree canopies.
- 17% (11.3 million gallons) run-off reduction from a twelve-hour storm with tree canopies in a medium-sized city ($226,000 avoided run-off water control costs).

Water Quality / Erosion

- Community trees and forests act as filters removing nutrients and sediments while increasing ground water recharge.
- 37,500 tons of sediment per square mile per year comes off of developing and developed landscapes -- trees could reduce this value by 95% ($336,000 annual control cost savings with trees).
- 47% of surface pollutants are removed in first 15 minutes of storm -- this includes pesticides, fertilizers, and biologically derived materials and litter.
- 10,886 tons of soil saved annually with tree cover in a medium-sized city.

Noise Abatement

- 7db noise reduction per 100 feet of forest due to trees by reflecting and absorbing sound energy (solid walls decrease sound by 15 db)
- Trees provide “white noise," the noise of the leaves and branches in the wind and associated natural sounds, that masks other man-caused sounds.

Glare Reduction

- Trees help control light scattering, light intensity, and modifies predominant wavelengths on a site.
- Trees block and reflect sunlight and artificial lights to minimize eye strain and frame lighted areas where needed for architectural emphasis, safety, and visibility.

Animal Habitats

- Wildlife values are derived from aesthetic, recreation, and educational uses.
- Lowest bird diversity is in areas of mowed lawn -- highest in area of large trees, greatest tree diversity, and brushy areas.

- Highest native bird populations in areas of highest native plant populations.
- Highly variable species attributes and needs must be identified to clearly determine tree and community tree and forest influences.
- Trees are living systems that interact with other living things in sharing and recycling resources -- as such, trees are living centers where living thing congregate and are concentrated.

Economic / Social / Psychological Benefits

Economic Stability Community

- Community trees and forests provide a business generating, and a positive real estate transaction appearance and atmosphere.
- Increased property values, increased tax revenues, increased income levels, faster real estate sales turn-over rates, shorter unoccupied periods, increased recruitment of buyers, increased jobs, increased worker productivity, and increased number of customers have all been linked to tree and landscape presence.
- Tree amenity values are a part of real estate prices.

Property Values -- Real Estate Comparisons

- Clearing unimproved lots is costlier than properly preserving trees.
- 6% ($2,686) total property value in tree cover.
- $9,500 higher sale values due to tree cover.
- 4% higher sale value with five trees in the front yard -- $257 per pine, $333 per hardwood, $336 per large tree, and $0 per small tree.
- $2,675 increase in sale price when adjacent to tree green space as compared to similar houses 200 feet away from green space.
- $4.20 decrease in residential sales price for every foot away from green space.
- 27% increase in development land values with trees present.
- 19% increase in property values with trees. (1971 & 1983)
- 27% increase in appraised land values with trees. (1973)
- 9% increase in property value for a single tree. (198 1)

Property Values – Tree Value Formula (CTLA 8th edition)

- Values of single trees in perfect conditions and locations in the Southeast range up to $100,000.
- $100 million is the value of community trees and forests in Savannah, GA
- $386 million is the value of community trees and forests in Oakland, CA (59% of this value is in residential trees).

Product Production

- Community trees and forests generate many traditional products for the cash and barter marketplace that include lumber, pulpwood, hobbyist woods, fruits, nuts, mulch, composting materials, firewood, and nursery plants.

Aesthetic Preferences

- Conifers, large trees, low tree densities, closed tree canopies, distant views, and native species all had positive values in scenic quality.
- Large old street trees were found to be the most important indicator of attractiveness in a community.
- Increasing tree density (optimal 53 trees per acre) and decreasing understory density are associated with positive perceptions.
- Increasing levels of tree density can initiate feelings of fear and endangerment -- an optimum number of trees allows for visual distances and openness while blocking or screening developed areas.
- Species diversity as a distinct quantity was not important to scenic quality.

Visual Screening

- The most common use of trees for utilitarian purposes is screening undesirable and disturbing sight lines.
- Tree crown management and tree species selection can help completely or partially block vision lines that show human density problems, development activities, or commercial/ residential interfaces.

Recreation

- Contact with nature in many communities may be limited to local trees and green areas (for noticing natural cycles, seasons, sounds, animals, plants, etc.) Trees are critical in this context.
- $1.60 is the willing additional payment per visit for use of a tree covered park compared with a maintained lawn area.

Health

- Stressed individuals looking at slides of nature had reduced negative emotions and greater positive feelings than when looking at urban scenes without trees and other plants.
- Stressed individuals recuperate faster when viewing tree filled images.
- Hospital patients with natural views from their rooms had significantly shorter stays, less pain medicine required, and fewer post-operative complications.
- Psychiatric patients are more sociable and less stressed when green things are visible and immediately present.
- Prison inmates sought less health care if they had a view of a green landscape.

Human Social Interactions

- People feel more comfortable and at ease when in shaded, open areas of trees as compared to areas of hardscapes and non-living things.
- People's preferences for locating areas of social interactions in calming, beautiful, and nature-dominated areas revolve around the presence of community trees and forests.
- Trees and people are psychologically linked by culture, socialiition, and coadaptive history.

Reference for most of this material: Literature Review for the QUANTITREE computer program -- "Quantifiable Urban Forest Benefits and Costs; Current Findings and Future Research." In a white paper entitled Consolidating and Communicating Urban Forest Benefits. Davey Resource Group, Kent, OH. 1993. Pp.25.

THE UNIVERSITY OF GEORGIA COOPERATIVE EXTENSION SERVICE FOREST RESOURCES UNIT PUBLICATION FOR96-39

WASHINGTON STATE DEPARTMENT OF
Natural Resources

TreeLink

DNR COMMUNITY FORESTRY PROGRAM ✦ NUMBER 14 ✦ SPRING 1999

Grow for the Gold

Trees in Business Districts

By Kathleen L. Wolf, Ph.D.
Center for Urban Horticulture
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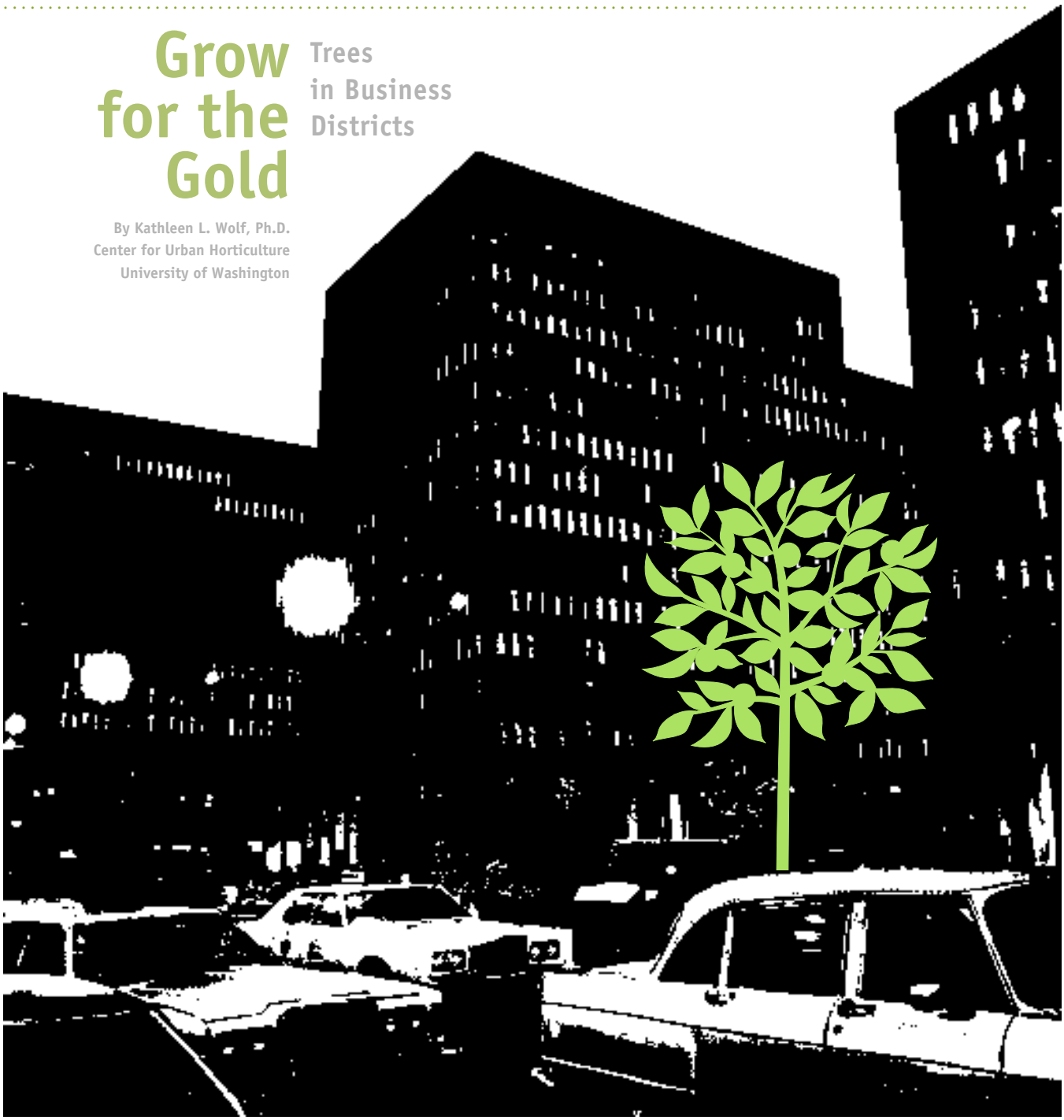
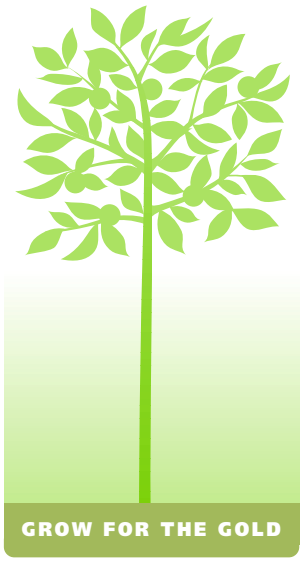


Consumers said they would be willing



Trees and business — it's a love-hate relationship! There are certainly costs that come with having trees on streets. Yet, a new study provides evidence that trees have positive effects on consumers. Despite their costs, trees do provide indirect benefits to businesses.

About 70% of America's gross domestic product is attributed to purchases of individuals. Consumers consider many factors when deciding on what products and services to buy. Value, quality and convenience are major messages that marketers communicate about their products. Often overlooked is the importance of the retail place on shopping decisions. A pleasant, welcoming retail environment is important to consumers.

How does the community forest influence consumers? A national study, conducted by social scientists at the University of Washington, used survey questionnaires to investigate public perceptions about the role of trees in revitalizing business districts. Surveys were sent to selected districts in cities of the Pacific Northwest, Austin, Los Angeles, Chicago, Pittsburgh and Washington DC.

The project outcomes can help us plan and manage urban forests to better meet business needs. They also will help businesses focus their green investment for highest returns. Here are highlights of the research results.

to pay, on average, 12% higher for products in districts with trees.

Exploring Public Preferences

Preference surveys are a proven tool used to assess public values. The survey showed retail settings with different amounts and arrangements of vegetation. People were asked to rate scenes on how much they liked them (1 = not at all, to 5 = very much). The ratings do express an aesthetic judgment, but the basis of the judgment is very important — the capacity of a place to meet the needs and concerns of a person.

☞ *Ratings of business people and the general public were statistically compared to better understand how their values for the urban forest may differ.*

Low and High Ratings

Ratings were averaged for each of 32 scenes. Scenes with the lowest and highest mean ratings differ significantly in visual content. Highly valued scenes contain trees and accessory vegetation, including light and shade patterns associated with the plants. This result is consistent with preference evaluations of many landscape settings; the presence of trees generally enhances public judgment of visual quality. In this case a three point difference in means between the highest and lowest rated scenes is a striking example of how plants can affect consumers' judgments of place.

Perception Categories

Analysis also reveals categories of images based on similar patterns of response. Typically, differences in the categories can be attributed to both the content of the images and how the image elements are arranged. Five visual categories were identified (see photos at left).

Mean Ratings

Preference ratings increase with the presence of trees in the streetscape. Category "A" was rated lower, by far, than the other categories even though its images contain some vegetation. Category "B" images contain the most complex landscape plant blend, yet were valued least of the image categories containing trees. Meanwhile, larger trees are associated with higher preference, as in Categories "C", "D" and "E." Both open and dense canopied trees are valued. Finally, the latter three categories also appear more ordered; both trees and accessory vegetation are placed and managed to create distinct visual patterns.

Lowest Rated Scene

Comparing Business and Visitors

Both business and consumer survey groups gave higher ratings to scenes with trees. Yet, within all but one category (Category "E") business respondents significantly differed from visitors in their assessment of visual quality. Business ratings of Category "A" scenes were higher than visitor ratings, despite the grim, hard-featured character of the street setting. Meanwhile, business people consistently rated landscaped scenes on Categories "B" through "D" lower than visitors, suggesting that merchants have less appreciation for trees than the people they wish to welcome to their shops.

Highest Rated Scene

ALL PHOTOS BY KATHLEEN L. WOLF

Research support provided by the USDA Forest Service and National Urban and Community Forestry Advisory Council.

Consumer Perceptions and Behavior

Often taken for granted, our surroundings, both outdoor and indoor, affect the course of our daily lives. Physical features define how we move and get around in any space. In addition, elements of an environment send cues that can influence our attitudes and behavior within a place. The study evaluated how the character of a place influences shoppers' behavior in a business district. People were asked a series of questions about three hypothetical business districts. What do consumers read from the visual cues of a place? Here are some of the results.

Place Perceptions

Four perception categories emerged from participants' ratings of the three business districts:

- amenity and comfort,
- interaction with merchants,
- quality of product,
- maintenance and upkeep

Consumers' ratings for each of the categories were significantly higher for districts that had street trees and other landscape improvements. For instance, *amenity and comfort* ratings were about 80% higher for a tree lined sidewalk compared to a non-shaded street. Also, *quality of product* ratings were 30% higher in districts having trees over those with barren sidewalks. *Interaction with merchants* items included customer service issues; ratings were about 15% higher for districts with trees.

Patronage Behavior

Actions follow our impressions of a place. Respondents were asked to give opinions of their behavior within the three shopping districts, including travel time, travel distance, duration of a visit, frequency of visits and willingness-to-pay for parking. Again, trees make a difference. Considering all behaviors, higher measures were reported in the districts having trees. For instance, respondents claimed they would be willing to pay more for parking in a well landscaped business district. This suggests greater revenues from shaded parking could offset the costs of parking space loss, a frequent objection to trees by merchants.

Pricing Patterns

Do trees influence how much people are willing to pay for goods? Contingent valuation methods were used to assess how amenity values relate to customers' price valuations. Survey respondents were asked to specify a price for each of 15 items in a basket of goods in the business districts. The survey participants consistently priced goods significantly higher in landscaped districts. Prices were, on average, about 12% higher for products in the landscaped district compared to the no-tree district. This was true of low-price, impulse-buy convenience goods (e.g. lunch sandwich, flower bouquet), as well as bigger ticket, comparison-shopped items (e.g. sports shoes, new glasses). Given the low profit margins of most retail businesses, trees appear to provide a significant amenity margin.

Growing Trees and Revenue for Business

A goal of 15% tree canopy cover is recommended by American Forests for business districts; most American retail environments have 5% or less. How can we encourage business leaders to become advocates for trees? While there are few direct cost benefits, support of the urban and community forest provides other indirect returns. A healthy, vital urban forest sends messages that welcome shoppers. Other studies confirm that the presence of trees may boost worker productivity and that trees boost property values. The community forest is an asset for entire retail communities, as well as individual business owners. A tree program should be a part of any business improvements campaign.

Washington Community Forestry Council

The Washington Community Forestry Council was organized by the Washington State Department of Natural Resources (DNR) in 1991. Its goal is to provide leadership and vision to help citizens preserve, plant and maintain community trees and forests. The Council consists of a general membership and an Executive Advisory Committee to the State Forester. Join by calling **1-800-523-TREE.**

"TreeLink" is a quarterly publication of the DNR Community Forestry Program. The goal of the program is to assist communities in building self-sustaining urban forestry and tree care programs with strong local support.

Editor: Kevin LeClair, Resource Protection, DNR.
Graphic Design: Luis Prado, Communications Product Development, DNR.
Funding provided by DNR and the USDA-Forest Service.

TREELINK, SPRING 1999. CPD JOB # 2.2.99

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Urban Forest Values: Economic Benefits of Trees in Cities

Many important decisions in American cities are based on careful cost and benefit analysis of options. Yet the values of trees and plants in our urban centers are often overlooked. Urban forests are a significant and increasingly valuable asset of the urban environment. Scientists have measured the treemendous returns that trees provide for people in cities. A complete assessment of both benefits and costs is challenging. Nonetheless, full understanding of this information is valuable if decision-makers wish to make cost effective policy and budget decisions. Investments in the planting and care of trees represent long term commitments of scarce dollars; improper plantings will increase costs and reduce benefits. Adequate resources for both planning and management of urban green is necessary if cities wish to optimize the values and benefits of the urban forest.

Environmental and Energy Savings

City-wide, the amount and quality of trees influence both biological and physical urban environments. Plants, if strategically placed and cared for, can become a "living technology," a key part of the urban infrastructure that contributes to more liveable urban places.

HEATING AND COOLING COSTS - A 25 foot tree reduces annual heating and cooling costs of a typical residence by 8 to 12%, producing an average $10 savings per American household. Also, buildings and paving in city centers create a heat-island effect. A mature tree canopy reduces air temperatures by about 5 to 10° F, influencing the internal temperatures of nearby buildings.

AIR QUALITY AND CLEANSING - A typical person consumes about 386 lb. of oxygen per year. A healthy tree, say a 32 ft. tall ash tree, can produce about 260 lb. of oxygen annually—two trees supply the oxygen needs of a person each year! Also, cooler air temperatures created by tree canopies reduce smog levels by up to 6%, producing savings in air clean-up campaigns.

The values of trees and plants in urban centers are often overlooked.

Finally, a mature tree absorbs from 120 to 240 lbs. of the small particles and gases of air pollution. In Sacramento, CA, for instance, this represents a value of $28.7 million.

IMPROVED WATER QUALITY - The canopy of a street tree intercepts rain, possibly reducing the amount of water that will fall on pavement and then must be removed by a stormwater drainage system. In one study, 32 ft. tall street trees intercepted rainfall, reducing stormwater runoff by 327 gallons. Savings are possible since cities can install surface water management systems that handle smaller amounts of runoff.

Retail and Commercial Environments

Businesses work hard to offer products and services that meet their customers' needs. The presentation or image of shops and business districts is also important. Trees help create a positive environment that attracts and welcomes consumers.

CONSUMER PATRONAGE - In a survey of one southern community, 74% of the public preferred to patronize commercial establishments whose structures and parking lots are beautified with trees and other landscaping.

COMMERCIAL LAND VALUES - Weyerhauser surveyed real estate appraisers and 86% of them agreed that landscaping added to the dollar value of commercial real estate. 92% also agreed that landscaping enhances the sales appeal of commercial real estate.

BOOSTED OCCUPANCY RATES - One study looked at 30 variables—architecture and urban design—of potential importance in determining office occupancy rates. Results suggest that landscape amenities have the highest correlation with occupancy rates, higher even than direct access to arterial routes.

Residential Property Values

House prices are also influenced by the presence of trees. Developers can maximize profits by retaining existing trees or replanting an urban forest after construction is completed.

INCREASED HOME SALES PRICES - Several studies have analyzed the effects of trees on actual sales prices of residential properties. Homes with equivalent features—square footage, num-ber of bathrooms, location—are evaluated. In one area a 6% increase in value was associated with the presence of trees; an increase of 3.5 to 4.5% was reported in another study.

TREE SIZE AND VALUE - A team of researchers compared tree size and public valuations of homes. Tree size did not affect the judgments of price for low price homes, but did affect values of more costly houses. For more expensive homes, small and medium-sized trees enhanced the public's perception of real estate value.

UNIMPROVED PROPERTY VALUES - Using a scale model of a land parcel, researchers found that there was a 30% difference in appraised value based on the amount and variation of tree cover. Taking into account the potential value of a house built on the site, the value increase would be close to 5%.

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Trees in Business Districts: Positive Effects on Consumer Behavior!

Trees are good for business! A recent study confirms that consumers respond positively to shopping environments having a healthy urban forest. Across our nation, many revitalizing business districts are working hard to create vibrant, vital consumer environments. Why should trees be a part of an action plan? Healthy and well-maintained trees send positive messages about the appeal of a district, the quality of products there, and what customer service a shopper can expect. They are an important component of any program to attract shoppers and visitors. Revitalizing districts must address urgent needs of security, sanitation, parking, and marketing. Attention to trees is a necessary part of any improvements program. And having the positive environment created by trees may actually ease some of the other issues. American Forests, a national tree non-profit, suggests a goal of 15% tree canopy cover in business districts; most retail environments in the U.S. have 5% or less. Research results suggest that investing in trees is good for the business bottom line!

Three Shopping Districts
Consumer Cues and Messages?

District 1 - No trees or accessory vegetation

District 2 - With trees, no accessory vegetation

District 3 - With trees and accessory vegetation

Research Project

The national study, conducted by the University of Washington, used survey questionnaires to investigate public perceptions about the role of trees in revitalizing business districts. Surveys were sent to selected districts in cities of the Pacific Northwest, Austin, Los Angeles, Chicago, Pittsburgh, and Washington D.C. Business owners and managers were invited to participate, and their responses were compared to survey responses from nearby residents, their potential patrons, and shoppers.

Our surroundings, both outdoor and indoor, affect the course of our daily lives. The physical features of a setting set up how we move and get around in any space. In addition, elements of an environment sends subtle cues that influence our attitudes and behavior within a place. This study evaluated how the character of a place influences how shoppers respond to a business district. People were asked a series of questions about their likes/dislikes and behavior within three hypothetical business districts. Highlights of the research results include information about place perceptions, patronage behavior, and pricing patterns.

Place Perceptions

Four categories of perceptions emerged from survey participants' ratings of the three business districts:

Amenity and Comfort
Interaction with Merchants
Quality of Products
Maintenance and Upkeep

Consumers' ratings on each of the categories was significantly higher for districts that had street trees and other landscape improvements! For instance, Amenity and Comfort ratings were about 80% higher for a tree-lined sidewalk compared to a non-shaded street. Also, Quality of Products ratings were 30% higher in districts having trees over those with barren sidewalks. Interaction with Merchants items included customer service issues; ratings were about 15% higher for districts with trees.

Patronage Behavior

Actions follow our impressions of a place. Respondents were asked to give opinions of their behavior within the three shopping districts, including **travel time, travel distance, duration of a visit, frequency of visits and willingness-to-pay for parking**. Again, trees make a difference! Considering ALL behaviors, higher measures were reported in the districts having trees. For instance, respondents claimed they would be willing to pay more for parking in a well landscaped business district. This suggests greater revenues from shaded parking would offset the costs of parking space loss, a frequent objection to trees by merchants.

Pricing Patterns

Do trees influence how much people are willing to pay for goods? Contingent valuation methods were used to assess how amenity values relate to customers' price valuations. Survey respondents were asked to specify a price for each of 15 items in a "basket of goods" in the business districts. Three **categories of goods—convenience, shopping, specialty**—were included. The survey participants consistently priced goods significantly higher in landscaped districts! Prices were, on average, about 11% higher for products in the landscaped compared to the no-tree district. This was true of low-price, impulse-buy convenience goods (e.g. lunch sandwich, flower bouquet), as well as bigger ticket, comparison-shopped items (e.g. sports shoes, new glasses). Given the low profit margins of most retail businesses, trees appear to provide a significant "amenity margin."

Acknowledgements:
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Trees in Business Districts: Comparing Values of Consumers and Business

Do business people and shoppers share an appreciation for trees? This was one of several questions in a recent national survey about the urban forest in business districts. Revitalizing business communities face many competitive challenges and have limited resources to address many needs. Despite their costs, trees provide many indirect benefits to businesses and communicate positive messages that can attract visitors and shoppers.

Recent research by social scientists at the University of Washington helps us to better understand the values of trees in a business community. Revitalizing districts were identified in eight cities around the United States. Both business people and nearby residents were asked to complete a survey. The project outcomes, based on analysis of responses, helps us to plan and manage urban forests that better meetbusiness needs in America's cities.

Public Preferences

Preference surveys are a tool used to assess public values for different landscape settings. In this study people were asked to rate 32 scenes for how much they liked the scenes (scale of 1=not at all to 5=very much). While the ratings express an aesthetic judgment, the basis of the judgment is very important—the capacity of a place to meet the needs and concerns of a person.

The scenes show retail settings with different amounts and quality of vegetation. Analysis of the ratings helps us to understand the characteristics of streetscapes that are judged to have high visual quality. We can also statistically compare the ratings of business people and the general public to better understand how their values for the urban forest may differ.

LOW AND HIGH RATINGS – Ratings were averaged for each of 32 scenes. Scenes with the lowest and highest mean ratings differ significantly in visual content. While they differ somewhat architecturally, their difference in appearance is influenced by the presence of trees and accessory veg-etation, including light and shade patterns associated with the plants. A three point difference in means (on a scale of 5) is a striking example of how plants affect consumers' judgments of place. Across many studies of diverse landscapes the presence of trees enhances public judgment of visual quality.

Lowest rated scene
Mean 1.38

Highest rated scene
Mean 4.35

Perception Categories

Analysis also reveals categories of images based on similar patterns of response. Typically, differences in the categories can be attributed to both the content of the images and how the image elements are arranged. Five visual categories were identified in this study.

Category 1:
Little/No Vegetation
Visitor Mean: 1.95
Business Mean: 2.17

Category 2
Naturalistic
Visitor Mean: 3.17
Business Mean: 2.70

Category 3
High, Open Canopy
Visitor Mean: 3.59
Business Mean: 3.42

Category 4
Low, Dense Canopy
Visitor Mean: 3.68
Business Mean: 3.42

Category 5
Formal Foliage
Visitor Mean: 3.70
Business Mean: 3.57

MEAN RATINGS – Preference ratings increase with the presence of trees in the streetscape. Category 1 was rated lower, by far, than than the other categories even though its images contain some vegetation. Category 2 images contain the most complex landscape plant blend, yet were valued least of the image categories containing trees. Meanwhile, larger trees are associated with higher preference, as in Categories 3, 4, and 5. Both open and dense canopied trees are valued. Finally, the latter three categories also appear more ordered; both trees and accessory vegetation are placed and managed to create distinct visual patterns.

COMPARING BUSINESS AND VISITORS – Both business and consumer survey groups gave higher ratings to scenes with trees. Yet, within all but Category 5 business respondents significantly differed from visitors in their assessment of visual quality (t-tests, $p<.05$). Business ratings of Category 1 scenes were higher than visitor ratings, despite the grim, hard-featured character of the street setting. Meanwhile, business people consistently rated landscaped scenes on Categories 2 through 4 lower than visitors, suggesting that merchants have less appreciation for trees than the people they wish to welcome to their shops.

Design and Planning

Results suggest that consumers enjoy having trees in retail shopping districts! An orderly and well maintained planting scheme of both trees and accessory vegetation produces highest visual quality ratings. The public prefers both dense and more open canopied trees, thus careful pruning can be used to thin and open up a tree canopy. This permits more visibility of signs and storefronts while providing the forest amenities that consumers appreciate.

Acknowledgements:
RESEARCH FUNDING: National Urban and Community Forestry Advisory Council, International Society of Arboriculture and USDA Forest Service

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Community Image: Roadside Settings and Public Perceptions

Social scientists often study the relationship of people to place. The form and character of a place can shape the moods, attitudes, and responses of the people who spend time in them. More recently, com-munities have begun to consider the effects of character of place on both residents and visitors. Business communities, in particular, take an interest in the image that their community projects to consumers.

We all rely on environmental cues to inform our judgments about new situations or people. We attribute certain characteristics to places based on impressions. A pilot study, conducted at the University of Washington, attempted to test the judgments that people make about an unfamiliar place based on its appearance from a freeway or highway.

While driving, people consider where to stop, shop, or return to explore later. Does the view from the road influence these decisions? This research offers preliminary answers to this question and offers suggestions for both transportation and community planning.

Perceptions of Place

Community 1 - Little planning for landscape or green space has occurred.

What can the view from the road tell us about a community?

Community 2 - Planning for quality landscape and green space has occurred.

A mail survey of licensed drivers in Washington State was used to evaluate the perceptions of place that people may associate with roadside landscape. As people drive from place to place, a freeway or highway roadside is the first introduction to a community that many people experience. Can the amount of green space and vegetation along the road and in a community influence what people think of that place? While study results should be considered preliminary, they do suggest that visual character influences the image of a community. Research outcomes are summarized below.

Consumer Appeal

Each survey participant viewed one of two community settings and rated how much they agreed with a series of statements about the consumer environment of the place. The statements contained information about merchants, products, and services. Statistical analysis produced three categories based on response patterns:

Business Quality
Appealing Character
Shopping Convenience

Furthermore, mean ratings on each category differed significantly ($p<.001$), with the community images containing more green space having higher values. Ratings of Appealing Character were 50% higher for the more landscaped setting. Potential consumers probably infer other characteristics of a community based on visual cues. Ratings of both Business Quality and Shopping Convenience were 13-20% higher in the community having more green space and vegetation.

Business Environment

Those surveyed were also asked how much they agreed with a list of statements about how businesses interacted with the community in the two settings. Two statistical categories were identified:

Civic Commerce
Community Health

Civic Commerce included statements such as "merchants care about the community" and "public and private organizations work together." Higher levels of agreement for this category was associated with the green setting. Issues of Community Health (e.g. financial condition, crime rate) were also judged to be better in the greener community.

Pricing Patterns

Contingent valuation is a method economists use to value things that can not be bought and sold on the market. In this study people were asked to specify what they would pay for a collection of goods and services. Resulting pricing patterns are indirect indicators of the value of green space to communities. Do trees influence how much people are willing to pay for goods? The answer from this study is "yes!" For all eight listed items, higher stated prices were given for goods in the green community. For instance, sports shoes were priced 7% higher in the green setting, while a sit-down dinner or a flower bouquet were assigned 10% higher prices. Green makes a difference! The presence of trees and green space may positively influence both consumers' attitudes about the character of a place and the prices that shoppers are willing to pay as they shop there.

Acknowledgements:
RESEARCH FUNDING: National Urban and Community Forestry Advisory Council, USDA Forest Service and the Washington State Department of Transportation

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Social Aspects of Urban Forestry

PUBLIC RESPONSE TO THE URBAN FOREST IN INNER-CITY BUSINESS DISTRICTS

by Kathleen L. Wolf

Abstract. Revitalization programs are under way in many inner-city business districts. An urban forestry program can be an important element in creating an appealing consumer environment, yet it may not be considered a priority given that there are often many physical improvements needs. This research evaluated the role of trees in consumer/environment interactions, focusing on the districtwide public goods provided by the community forest. A national survey evaluated public perceptions, patronage behavior intentions, and product willingness to pay in relationship to varied presence of trees in retail streetscapes. Results suggest that consumer behavior is positively correlated with streetscape greening on all of these cognitive and behavioral dimensions. Research outcomes also establish a basis for partnerships with business communities regarding urban forest planning and management.

Key Words. Urban/community forestry; public perceptions; retail business.

In many U.S. inner cities, local business districts are working toward revival and revitalization. Improvements needs are many—building upgrades, street and sidewalk improvements, sanitation, security—and place extreme demands on limited resources. Despite the environmental benefits provided by trees in cities, tree programs are often not a high priority for merchants in struggling business communities.

Urban trees provide few, if any, marketable products that generate direct returns on investment for businesses. Rather, indirect benefits are likely and are difficult to assess. A research project was conducted to evaluate the potential economic contributions of trees to retail settings in revitalizing business districts. Survey outcomes suggest that trees are important components of a welcoming, appealing consumer environment. Such information can aid urban forestry agencies and professionals in efforts to enlist business support for creating and stewarding a city's urban forest.

BACKGROUND AND LITERATURE

While many studies have documented the multiple benefits and satisfactions of urban vegetation (Dwyer et al. 1994), most have focused on parks and residential settings (Sommer et al. 1990; Schroeder 1992), overlooking the importance of the urban forest to private enterprise (Dwyer et al. 1992). Little is known about the perceived benefits and values of the urban forest in retail and commercial districts, a void addressed by this research.

Consumer/Environment Interaction

Psychological theory of person/environment dynamics constituted the core of this study, with focus on consumer/environment interaction. Social scientists distinguish the physical-tangible domain of an environment from interpersonal and sociocultural domains (Stokols 1978; Wapner 1987). Some person/environment research is premised on stimulus-response assumptions; other investigations maintain an interactional perspective (Moore 1987).

Response to environments arises from a person's myriad assessments of a physical setting. Observers interpret rather literal characteristics of a place to make judgments of function (e.g., school versus hospital) or wayfinding. Observers also make connotative or inferential judgments about the quality or character of a place and the people who inhabit it (Nasar 1998). People cognitively overlay physical form with meanings or representations, integrating mediating information gained from observers' prior experiences, social learning, and attitudes.

Retailers rely on the tangible, physical setting of their business to attract consumers to their products and services. Surprisingly, there is little information about the role of outdoor environment in consumer behavior, despite extensive marketing and retail science studies on store interiors and products. While general person/environment interaction has been studied since the 1940s, the area of consumer/environment interaction has attracted relatively few research efforts (Everett et al. 1994).

Urban Trees and Public Goods

Knowledge about urban tree benefits and services has grown considerably in recent decades. Easily observed measures of value, such as those expressed through market pricing dynamics, do not exist for such public goods (Fausold and Lilieholm 1996; Prato 1998).

One vein of benefits research focuses on environmental improvements and enhancement such as surface water management and air quality (McPherson 1995). Dollar values have been derived from extrapolations of environmental benefits and the substitutability of forest-derived "nature's services" for goods and services having market-based values (Daily 1997).

In addition, the psychosocial benefits that accrue as people encounter trees and nature in cities are extensive. Scientific evidence confirms that experiences of nature are associated with enhanced worker productivity (Kaplan 1992), traffic stress reduction (Parsons et al. 1998), emotional stress mitigation (Ulrich 1986), and restoration of cognitive capacities needed for basic functioning and productivity (Kaplan and Kaplan 1989; Cimprich 1992).

Public goods estimations derived from environmental and psychosocial benefits may not be particularly salient to business audiences. In retail and commercial settings, the urban forest is often regarded along a spectrum from annoyance or nuisance to actual business detriment (Wolf 1998). Such attitudes incite behaviors that eliminate or preclude urban forest programs in many retail settings. American Forests (1999) recommends that urban retail and commercial districts have a 15% canopy cover; the national average is approximately 5%.

Tree Amenity Valuation

A variety of scientific methods have been employed to assess public preference and perceptual response regarding diverse landscapes (Ulrich 1986; Kaplan and Kaplan 1989). Economists have also developed contingent valuation methods (CVM), which O'Doherty (1996) regards as a "monetized technique for eliciting public preferences." Contingent valuation surveys have been used to assess public willingness to pay for use, conservation, or restoration of urban and rural resources. Nonetheless, empirical applications of CVM to elicit values for public goods associated with urban forestry are few (Tyrväinen and Väänänen 1998).

The problems of CVM survey design have been widely discussed and carefully documented (Mitchell and Carson 1989; Prato 1998). Bishop and Heberlein (1990) identify six design elements for maintaining the reliability of CVM surveys and results. First, know whose and which values will be estimated. Also, respondents must be provided with a clear and meaningful description of the good. A realistic and neutral payment method must be used to ask valuation questions. A suitable question format must be developed that gives reliable values. Additionally, the survey should collect information on other factors that affect values. Finally, the data must be analyzed using valid statistical procedures.

Research Program

A multiphase, national research program was conducted to evaluate several dimensions of consumers' experiences of inner-city business districts. Qualitative interviews, preference evaluations, and perceptual responses were elicited; perceptual results are reported here. Four research questions provided a framework for the research design:

1. What is the relationship between street landscape and consumers' perceptions of associated businesses?
2. Are there any differences in consumers' patronage behavior related to a shopping environment's visual amenities?
3. Does the presence of trees in retail environments influence what consumers would be willing to pay for products?
4. What demographic factors are associated with differences in district perceptions, patronage behavior, and pricing valuation?

Answers to these questions are directly related to the "bottom line" fiscal interests of business and commerce and provide insights as to how forest benefits may align with retail enterprise.

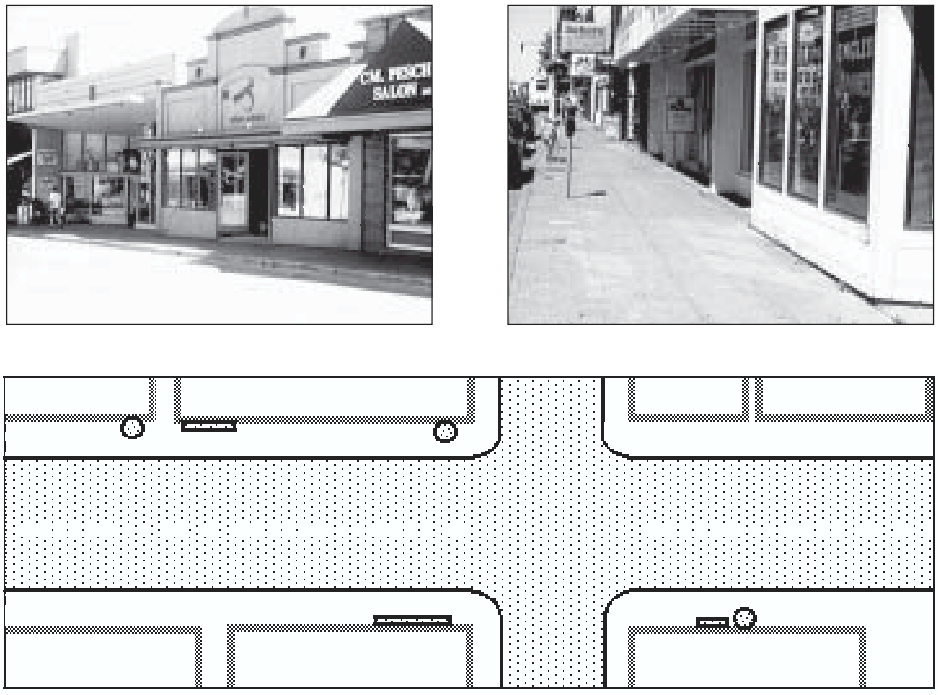
RESEARCH METHODS

Psychometric and econometric survey methods were employed to assess consumer response to streetscape conditions in revitalizing inner-city business districts. Three hypothetical scenarios of neighborhood business district streetscapes were presented using composites of photographic images and a plan view sketch. The three scenarios differed with respect to the quantity, location, and complexity of vegetation. Other scene content was controlled because secondary visual features (e.g., building age, utility lines) can be distractors and affect viewer response (Smardon 1988; Herzog and Shier 2000).

In the *No Trees* scenario (Figure 1) the district is devoid of vegetation, and scenes contain uninterrupted arrays of storefronts. The *Traditional Trees* scenario (Figure 2) depicts a similar street scene with equidistantly placed street trees of medium height. No conflicts of trees with structures or infrastructure are directly apparent. Finally, the *Mixed Vegetation* scenario (Figure 3) contains a vegetation complement of mixed species composition and diverse structure. Accent planters, shrubs, and trees are intermixed and informally placed within the pedestrian zone.

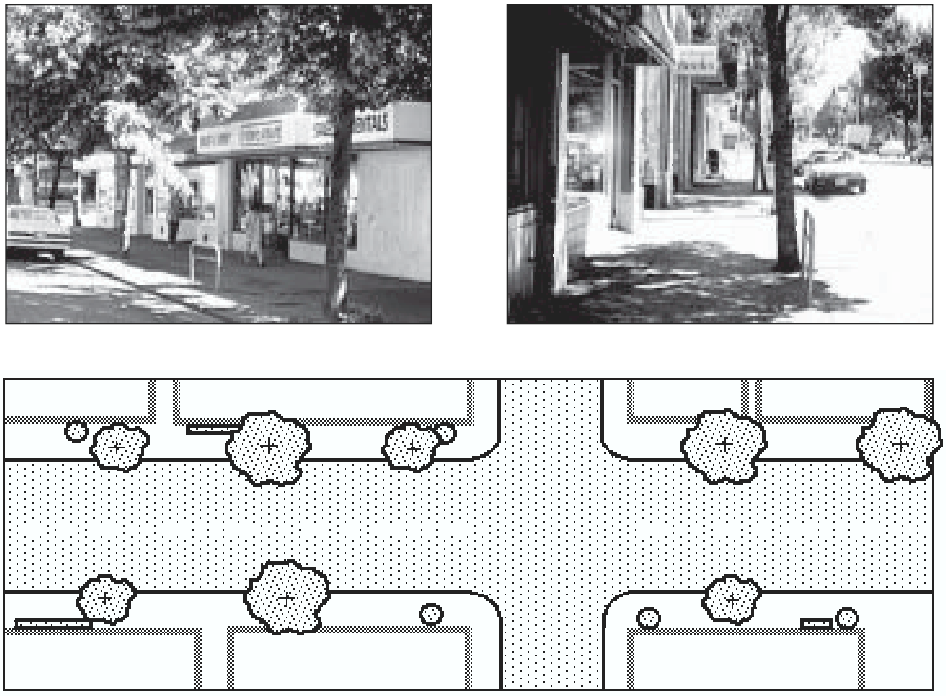
Each participant responded to two of the three scenarios. For each, participants were asked to provide ratings on a bank of perceptual descriptors. A second set of variables elicited patronage behavior response. Respondents also specified their willingness to pay (WTP) for items in a list of goods and services. Last were variables to determine participants' socioeconomic situation, shopping behavior patterns, and cultural background.

Following pretesting, the survey was distributed to residents of revitalizing neighborhood business districts in selected U.S. cities having populations greater than 100,000: Los Angeles, California; Washington, D.C.; Chicago, Illinois; Portland, Oregon; Pittsburgh, Pennsylvania; Austin, Texas; and Seattle, Washington. The sampling frame for survey mailing was determined by screening criteria at the city, then the business district level. Respondent sampling for ethnic and cultural diversity was pursued.



Plan view sketch of streetscape—not to scale.

Figure 1. Business district scenarios: No Trees scenario.



Plan view sketch of streetscape—not to scale.

Figure 2. Business district scenarios: Traditional Trees scenario.

Local partners in each of the cities were extremely helpful in identifying suitable locations for survey mailing and constructing mailing lists. Master address lists were assembled from organization membership lists, municipal records, and list broker purchases based on ZIP codes. A stratified random sample of addresses was generated.

Twenty-five hundred surveys were sent to residences within specified districts in winter 1998. Survey mailings were followed by reminder cards, then a second questionnaire mailing. Two-hundred seventy reasonably complete questionnaires were returned, while 309 were nondeliverable or returned without response. The 12% response rate is lower than typical landscape assessment return rates of 25% to 50% (Kaplan and Kaplan 1989; Sullivan 1994), even considering that return rates for inner-city surveys are usually lower (Dillman 2000).

ANALYSIS AND RESULTS

Data analysis is presented in four sections. Analytic investigations for each variable set included descriptive statistics, data reduction procedures, and between-scenario comparisons.

Trees and Perceptions

A set of Likert scaled response items included issues of place mood and security, shopping compat-

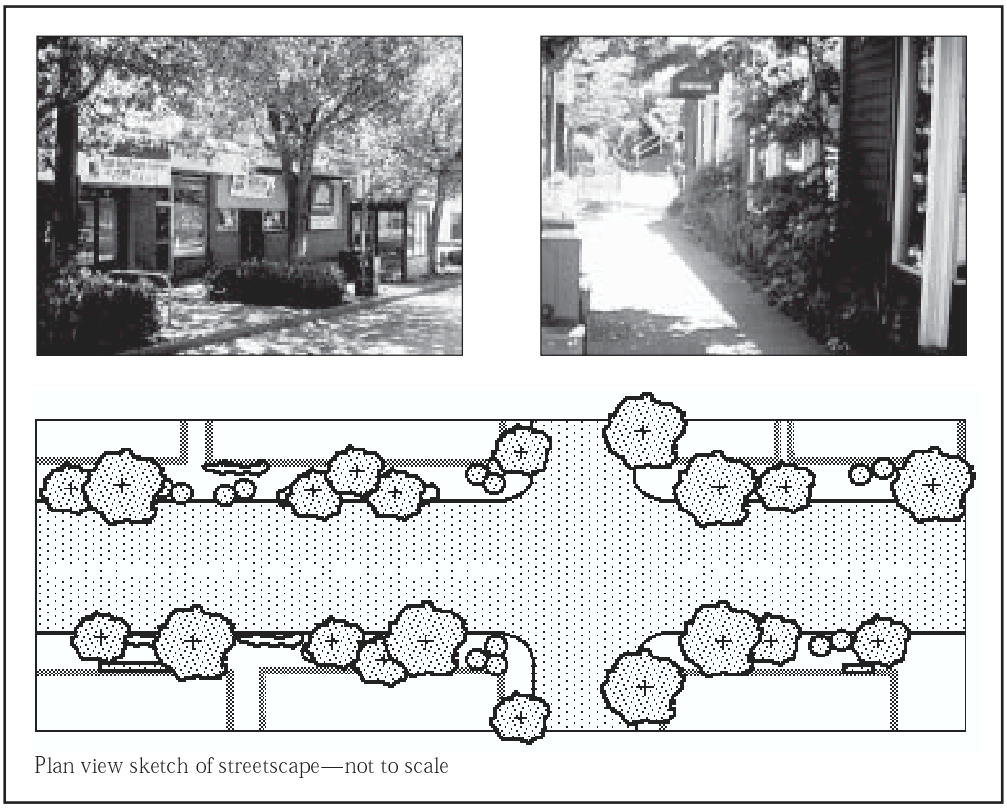


Figure 3. Business district scenarios: Mixed Vegetation scenario.

ibility, and merchant traits. Ratings for the 25 perceptual items ranged from 1 (indicating "strongly disagree") to 7 (specifying "strongly agree"), with 4 as a neutral point.

Using accepted decision rules (Kaplan and Kaplan 1989) to define and name underlying categories, data reduction entailed principal axis factor analysis with Varimax rotation. Four categories emerged—Amenity and Comfort, Merchant Interaction, Quality of Products, and Maintenance and Upkeep—accounting for 65% of the total variable variance. New variables were constructed by aggregating mean values across all category items for each respondent. Category means were compared between scenarios using one-way ANOVA and Bonferroni post hoc tests (Table 1).

Distinct patterns of ratings response characterize the relationships of the districts and the four perceptual categories. The *No Trees* scenario was consistently rated lowest on each of the perceptual scales. Respondents described the district as being "stark," "barren," and "bleak."

Meanwhile, the districts containing vegetation, *Traditional Trees* and *Mixed Vegetation*, had higher ratings, again across all perceptual categories. Respondents described the *Traditional Trees* district as "welcoming," "friendly," and being "neighborhoody" and observed that the *Mixed Vegetation* district appeared "relaxing," "inviting," and "well-kept."

It is expected that the contrast of trees or no trees in a consumer environment would influence consumers' judgments of Amenity and Comfort. The contribution of vegetation to other perceptual judgments of retail place merits closer attention. Representative images were carefully chosen to eliminate known confounds, including level of tendedness (Herzog and Gale 1996) and upkeep (Nasar 1987). Despite equivalence of streetscape tidiness, the presence of vegetation positively influenced appraisals of Maintenance and Upkeep.

As revealed by Merchant Interaction and Quality of Products categories, the presence of trees has significant positive influences on consumer inferences about a shopping environment. Marketing studies have evaluated the role of "atmospherics" on consumer intentions and behavior, finding that indoor environmental elements such as music, product layout, and lighting all contribute to store image (Zimmer and Golden 1988). In turn, store image influences consumers' perceptions (Dodds et al. 1991). Prior research on nature and city streets supports the finding that both evaluative appraisals (Nasar 1987) and affective response (Sheets and Manzer 1991) are boosted by the presence of trees.

The Merchant Interaction category confirms that shoppers infer social factors from physical attributes of a place. A person's cognitive interpretations and representations of place extend to include the quality of social interaction and response that he or she expects. This finding may be of particular importance to businesses that are service oriented. It may also have price behavior implications: Grewal and Baker (1994) found that store settings with interactive, friendly sales personnel produced higher price acceptability in consumers.

Patronage Behavior

Patronage behavior variables consisted of five categorical response questions. Participants were asked to specify

Table 1. Scenario perceptions—categories and comparisons.

Factor categories and items	Factor loading	Response variance (%)	District scenario			ANOVA
			No trees	Trad. trees	Mixed veg.	
Amenity and Comfort		25.31	Mean	Mean	Mean	F = 269.47
Positive image	0.79		3.00	5.35	5.69	p < .000, 2 df
Attractive to tourists	0.78		1.28 SD	1.17 SD	1.05 SD	(2, 3 no sig. Δ*)
Has a pleasant atmosphere	0.78					
Good place to explore	0.78					
Place to browse for future purchases	0.73					
Businesses are friendly and approachable	0.57					
Merchant Interaction		16.96	Mean	Mean	Mean	F = 25.23
Goods and services are fairly priced	0.75		4.24	4.82	4.90	p < .000, 2 df
Shopkeepers are informative	0.72		0.98 SD	0.90 SD	0.94 SD	(2, 3 no sig. Δ*)
Good customer service	0.68					
Diverse businesses and services	0.45					
Quality of Products		14.43	Mean	Mean	Mean	F = 81.03
High-quality brands are available	0.85		3.59	4.69	5.00	p < .000, 2 df
Products are well-made and reliable	0.77		1.07 SD	1.03 SD	1.14 SD	(2, 3 no sig. Δ*)
Merchants will do special orders	0.54					
Maintenance and Upkeep		8.46	Mean	Mean	Mean	F = 110.31
Clean and litter-free	0.66		4.27	5.65	5.94	p < .000, 2 df
Comfortable street spaces	0.41		1.39 SD	1.01 SD	0.87 SD	(2, 3 no sig. Δ*)

*Bonferroni post hoc comparison of means, α = 0.017 (0.05/3).

travel time, travel distance, duration of visit, frequency of visits, and parking fee WTP. Based on response distributions, some variable categories were collapsed. Two-way contingency analysis tables evaluated the relationship of variables to district scenarios using $\mathbf{X}^2$ tests and Cramer's V statistics (Table 2). Response on all patronage variables was found to be significantly related to district vegetation content.

Response to the two vegetated districts was again similar and differed in like ways from the *No Trees* condition. An inverse response pattern is evident. *No Trees* responses are concentrated at the low end of each of the variables' categorical arrays and diminish in frequency moving toward the high end of the arrays. Conversely, responses associated with *Traditional Trees* and *Mixed Vegetation* are less frequent at the lowest end of the arrays, increase in frequency, then slightly decline at the variables' higher value levels but remain at higher frequencies than the *No Trees* scenario.

Another response pattern is evident. Patronage response across all scenarios is greater at mid-array categories. Perhaps there are thresholds to visitation and travel behavior associated with the type of retail environment depicted.

Urban forest advocates are often challenged to demonstrate the fiscal returns associated with tree installation and maintenance expenses in retail settings. The patronage variables specify consumer behaviors that can potentially enlarge a customer base for districts having trees, potentially generating additional revenues. For instance, greater travel distances were reported for the with-trees scenarios; an expanded trade area radius within dense urban populations suggests a larger customer pool. In addition, respondents reported greater WTP for parking in vegetated districts; claims of parking revenues lost due to spaces being displaced by trees may be offset by consumers' WTP higher fees in forested districts.

Products Pricing

The last set of response items assessed the nonmarket, nonutility values of trees in retail environments using CVM. Marketers cluster products and services into three general classes (Kinnear et al. 1995). Convenience goods are widely available and purchased with little deliberation. Shopping goods are purchased after planning and comparison and are selectively distributed. Finally, specialty goods have high brand recognition and consumer loyalty; thus, little comparison shopping is done before purchase.

Economists often use indices to investigate market patterns (e.g., the Consumer Price Index "basket of goods"). Respondents were asked to indicate the price they would be willing to pay for each of 15 items. Three index variables were constructed by aggregating stated values for all items within each product index class for each participant (Table 3). Prior to aggregation, outlier values were identified to avoid strategic behavior effects; approximately seven cases per district per product/service item were removed.

Within each district, shopping goods means are greater than convenience goods, with specialty goods commanding the highest stated values. These pricing trends are consistent with marketing literature (Kinnear et al. 1995) in that the goods classes typically contain products of ascending value, quality, and consequently, price.

Means comparisons between scenarios (one-way ANOVA and Bonferroni post hoc tests) disclosed significant differences. Respondents reported WTP less for equivalent goods in business districts without trees. Price differences between tree and no-tree conditions are considerable: Approximately 50% for convenience, 40% for shopping, and 35% for specialty goods. Analysis using weighted standard scores across all products generated a more conservative 11.95% difference between tree and no-tree conditions. Statistically significant differences demonstrate an "amenity margin" that represents potential revenues for business districts and merchants.

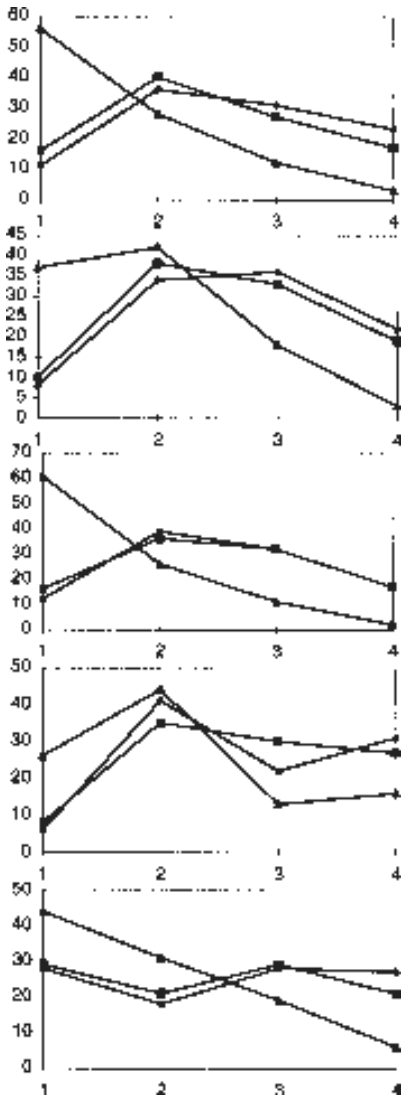
Respondent Comparisons

Given that household samples were drawn from inner-city neighborhoods, an unexpected 45% of respondents had annual household incomes of US$50,000 or greater. Forty-one percent of responding households had two persons, perhaps representing dual-income situations. One-person households tallied at 33%. Regarding shopping frequency for nongrocery goods and services, 40% reported one to two times per week, and 45% indicated less-frequent trips. Age data favored younger people, with 42% in their 40s and 50s, and 42% in their 30s or younger.

Table 2. Scenarios ↔ patronage analysis.

Patronage analysis	Scenario		
	No trees (%)	Trad. tree (%)	Mixed veg. (%)
Time willing to travel to reach place?			
(Pearson X^2 = 117.55, p < .000, Cramer's V = .436)			
Less than 10 minutes	56	16	11
10 to 19 minutes	28	40	36
20 to 29 minutes	12	27	31
30 minutes or more	3	17	23
Total	99*	100	101*
	n = 178	n = 165	n = 169
Distance willing to travel?			
(Pearson X^2 = 84.72, p < .000, Cramer's V = .397)			
Less than 1 mile	37	10	8
1 to 5 miles	42	38	34
5 to 10 miles	18	33	36
More than 10 miles	3	19	22
Total	100	100	100
	n = 177	n = 166	n = 169
Time would spend during visit?			
(Pearson X^2 = 134.15, p < .000, Cramer's V = .507)			
up to 30 minutes	61	16	12
30 to 59 minutes	26	36	39
1 to 2 hours	11	32	32
more than 2 hours	2	17	17
Total	100	101*	100
	n = 178	n = 166	n = 169
Frequency of visits?			
(Pearson X^2 = 49.63, p < .000, Cramer's V = .311)			
Once a year or less	26	8	6
Several times a year to monthly	44	35	41
Two to three times per month	13	30	22
Once a week or more	16	27	31
Total	99*	100	100
	n = 160	n = 158	n = 162
Willing to pay to park?			
(Pearson X^2 = 43.98, p < .000, Cramer's V = .288)			
Free	44	29	28
Up to $0.25 per hour	31	21	18
$0.25 to $0.75 per hour	19	29	28
More than $0.75 per hour	6	21	27
Total	100	100	101*
	n = 176	n = 163	n = 167

*Column total percentages may be more than 100 due to rounding.



Research methods were designed to generate inferences about diverse urban populations; thus, a probability sample was attempted. Business districts having ethnic population concentrations (e.g., African American, Asian American, or Hispanic) were identified for mailings. Nonetheless, 83% of the respondents were White/Caucasian. Low representation of people of color may be due to the composition of mailing lists or ethnicity-associated nonresponse behavior.

Statistical comparisons of respondent characteristics to perception, patronage, and pricing variables were conducted. No relationships were identified between demographic categories and the perception factors, suggesting that people of diverse age, gender, shopping behavior, and income infer similar perceptual traits about consumer places.

Considering the five patronage variables, it was found that respondents who shop frequently indicated a lower patronage frequency in forested business districts (X^2 = 24.366, df = 9, $p < .01$); infrequent shoppers favored vegetated settings. Females reported lower frequencies of short-duration visits, while men claimed higher frequencies of short visits within forested shopping settings (X^2 = 16.126, df = 3, $p < .001$). During pretesting, men claimed to do more focused shopping and less browsing; the behavior may generalize to all shopping experiences.

Of particular interest were respondent characteristics and pricing response. Do respondents, in a hypothetical situation, take into account their ability to pay? Past research suggests that if indicated WTP amounts are nominal, budget constraint bias is minimal and is more evident when major and costly programs or products are valued (Mitchell and Carson 1989). In this study, mean prices for product categories seemed within reasonable ranges. Only convenience goods displayed significant differences in means between household income categories (one-way ANOVA F = 2.455, df = 4,124, $p < .05$). Specialty goods pricing, most likely to be influenced by income, varied due to number of persons in household (ANOVA F = 3.887, df = 2,121, $p < .05$), perhaps again reflecting income correspondence.

Finally, comparing cultural groups, Hispanic respondents reported the lowest valuation for specialty goods (ANOVA F = 3.321, df = 3,117, $p < .05$), an inconclusive result owing to the limited cultural diversity of respondents.

DISCUSSION

Public attitudes about any natural resource issue or topic can span a spectrum from opponents to advocates. Yet the business sector of any community may rely on a narrow range of interests and perceptions as a heuristic base for public dialog on trees in cities. Business peoples' attitudes matter, for the entrepreneurial community can be politically active and influence citywide programs.

Some business communities welcome trees as a consumer-oriented amenity. Yet in many instances, small business owners and managers overlook the contributions of trees to retail success. They focus on the annoyances of trees—reduced signage visibility, seasonal debris, and security issues. Business people can be biased by the situation of a particular tree or two in front of a shop, failing to recognize the districtwide benefits that can be attained by developing a quality urban forest.

This study is a first step in documenting benefits associated with having trees in retail streetscapes. Empirical research can be used to better understand how consumers and the urban forest interact, providing information on both the public value of trees and management practices to optimize returns on public investment. This study used multiple approaches of resource value assessment to understand public response to trees in inner-cities. Consumers value trees, and do so across multiple dimensions.

Streetscape Perceptions and Inferences

Business districts having trees were characterized as being higher in visual quality and comfort, as providing more positive interaction with merchants, as having higher-quality products, and generally appearing to be better maintained and kept up. Such evaluations are reinforced by respondents' claims that they would be willing to travel farther and longer, visit more often and for longer periods of time, and pay more for parking when visiting retail places that have trees.

The discipline of social psychology offers insights for understanding the

Table 3. Product pricing by scenarios.

Index and items	Scenario: No trees	Scenario: Trad. trees	Scenario: Mixed veg.	ANOVA
Convenience Goods	Mean	Mean	Mean	F = 49.91
Ice cream cone, dinner, flower bouquet, lunch sandwich, appointment book	8.98 2.74 SD	13.44 5.20 SD	13.78 5.00 SD	p < .000, 2 df (2, 3 no sig. Δ*)
Shopping Goods	Mean	Mean	Mean	F = 31.11
Sports shoes, watch, light jacket, pots and pans, gallon of paint	33.52 11.49 SD	46.43 16.72 SD	47.36 18.54 SD	p < .000, 2 df (2, 3 no sig. Δ*)
Specialty Goods	Mean	Mean	Mean	F = 23.64
Gift for spouse/partner, new glasses, art print, motel room	51.88 18.30 SD	69.79 30.41 SD	73.24 30.79 SD	p < .000, 2 df (2, 3 no sig. Δ*)

*Bonferroni post hoc comparison of means, α = 0.017 (0.05/3).

cognitive processes of place-based consumer response. Social psychology is defined by Brehm et al. (1999) as "the scientific study of how individuals think, feel, and behave in regard to other people and how individuals' thoughts, feelings, and behaviors are affected by other people."

Social perceivers assemble various bits of information and, mediated by perceiver dispositions, form impressions of others. Leyens and Fiske (1994, p. 40) note that "people continuously build impression theories and use them in their commerce with other people." Observed traits are the indirect cues used to interpret feelings, personality, character, and likely behaviors. Diverse information about a person is integrated to form a coherent impression and guide decisions about how to interact with a person (Wyer and Lambert 1994). Consequent information and experience will be used by the observer to confirm or modify the impression. Rapid cognitive assessment of others provides a basis for inference and evaluation of new acquaintances.

Built settings apparently evoke similar evaluative responses. Respondents' open-ended scenario descriptors go beyond physical traits and include inferences about social and psychological interactions. Social psychological concepts of "social attribution" and "impression formation" readily translate to consumer/environment interactions.

Public Goods and Local Economics

Many benefits of natural and environmental resources cannot be valued in the marketplace because of incomplete or nonexistent markets. Contingent valuation was used in this study to estimate indirect values of public goods generated by trees in retail settings, values that may offset direct costs (e.g., installation and maintenance) districtwide.

Theoretically, given fixed household income, expressions of WTP represent forgone expenditures on other goods and services in expectation of satisfaction achieved from a public good. The additional 12% or more expressed WTP for goods associated with a vegetated streetscape represents an experiential satisfaction utility that is chosen over that available from other purchases.

Cost–benefit analysis premised on consumer expressed values should be a future research focus. Contingent valuation studies of wildland or open space natural resources typically aggregate WTP statements across a selected population, region, or households to assess nonmarket benefit values (Bateman et al. 1996; Tyrväinen and Väänänen 1998). Comparing direct costs of installation and management of a streetscape to the summed indirect benefits valuation reveals net public goods values and can inform decisions about allocating urban forest resources (Prato 1998).

Several results have important implications for budgeting urban forest programs. For instance, no significant differences were found between the ratings for the *Traditional Trees* and *Mixed Vegetation* districts across all perceptual categories and price indices. This finding suggests that consumer behavior is most directly influenced by the dichotomy of presence or absence of trees, irrespective of the design detailing and accessory planting. Future research is needed to determine if this finding is consistent with actual behavior or is an artifact of the survey instrument.

CONCLUSIONS

Consumer purchasing represents about two-thirds of the economic activity of the United States. Independent merchants in inner-city neighborhood business districts, once key retail players, now face competitive pressure from regional malls, "big box" retailers, and e-tailers. How does the local merchant preserve or restore his or her slice of the economic pie?

Study results suggest that higher price valuations are mediated by psychological inferences of district character and product quality. Thus, creating and stewarding an urban forest canopy may enhance revenues for businesses in retail districts that offer diverse products at varied prices. Consumer purchases provide compensatory returns for districtwide costs of tree planting and maintenance, as well as revenue enhancement for individual businesses.

While many conditions contribute to perceptions by consumers of attractive, desirable shopping settings, this study suggests that the urban forest should be a central element of retail place. Many marketing studies have focused on the "micro" level of product packaging and placement, or indoor retail configuration. This study contributes information about the "macro" level of consumer perception; that is, the positive influences of the outdoor environment on consumer choice and behavior.

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Acknowledgments. We thank all project partners for assistance in developing and conducting this research, especially staff of the following organizations: Central Area Development Association (Seattle, Washington), Chinatown/ International District Business Improvement Association (Seattle, Washington), Rainier Chamber of Commerce (Seattle, Washington), City of Chicago Department of Environment, Chicagoland Chamber of Commerce (Chicago, Illinois), Urban Forest Council of Washington, D.C., City of Austin Parks and Recreation (Texas), Korean Business Association of Southern California (Los Angeles, California), Conservation Consultants (Pittsburgh, Pennsylvania), City of Portland Bureau of Planning (Oregon), and the City of Vancouver (Washington).

This research was supported by a grant from the National Urban and Community Forestry Advisory Council (U.S. Forest Service, Project No WAUF-95-001). Correspondence concerning this article should be addressed to the author at kwolf@u.washington.edu. Additional project information can be found at www.cfr.washington.edu/ research.envmind.

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Résumé. Les programmes de revitalisation sont peu mis en branle dans les zones d'affaires des centres-villes. Un programme de foresterie urbaine peut être un élément important pour créer un environnement de consommation attirant, bien qu'il peut ne pas être considéré comme une priorité étant donné qu'il y a beaucoup de besoins en améliorations physiques. Cette recherche évalue le rôle des arbres dans les interactions consommateurs/ environnement. Une enquête nationale a évalué les perceptions du public, les intentions de comportement du patronat et le désir de paiement pour un produit, et ce en relation avec une variété d'aménagement avec des arbres le long des rues commerciales. Les résultats suggèrent que le comportement des consommateurs est positivement corrélé avec la présence d'aménagements verts le long des rues, et ce dans toutes ses dimensions cognitives et comportementales. Les résultats de ces recherches établissent également une base de partenariat avec les communautés d'affaire en regard de la planification forestière urbaine et de la gestion.

Zusammenfassung. In vielen innerstädtischen Geschäftsbezirken sind Revitalisierungsprogramme am Wirken. Ein urbanes Forstprogramm kann ein wichtiges Element bei der Gestaltung eines angenehmen Konsumentenumfelds sein, auch wenn oft nicht einer Priorität Raum gegeben wird, dass zunächst physikalische Verbesserungen notwendig sind. Diese Forschung bewertet die Rolle der Bäume in Konsumenten/Umwelt-Interaktionen und fokusiert dabei auf die bezirkweiten Vorteile, die durch öffentlichen Waldbestand geliefert werden. Eine nationale Untersuchung bewertete die Öffentlichkeitsakzeptanz, Intentionen für Patenschaftsverhalten und Zahlungswilligkeit in Relation zu verschiedenen Baumstandorten in Geschäftsstraßenzügen. Die Ergebnisse verdeutlichen, dass das Konsumentenverhalten positiv korreliert ist mit Straßenbegrünungenm in allen kognitiven und Verhaltensdimensionen. Die Ergebnisse etablieren auch eine Basis für Partnerschaften mit Geschäftsbezirken in Bezug auf Forstpflanzung und Management.

Resumen. Los programas de rehabilitación son poco conocidos en muchos distritos de negocios urbanos. Un programa dasonómico urbano puede ser un elemento importante para la creación de un ambiente favorable para el consumidor. Aunque no son considerados como una prioridad requieren un mejoramiento físico. Esta investigación evalúa el papel de los árboles en las interacciones ambiente / consumidor, poniendo énfasis en los beneficios públicos provistos por la comunidad forestal. Un sondeo nacional evaluó las percepciones del público, los patrones de comportamiento y la buena voluntad para pagar por los productos con relación a la presencia de los árboles en paisajes urbanos. Los resultados sugieren que el comportamiento del consumidor está positivamente relacionado con el enverdecimiento de las calles en todas esas dimensiones cognitivas y de comportamiento. La investigación también sugiere bases para patrocinios en comunidades de negocios con relación a la planeación y manejo del bosque urbano.

Social Aspects of Urban Forestry

THE ROLE OF ARBORICULTURE IN A HEALTHY SOCIAL ECOLOGY

by Frances E. Kuo

Abstract. In urban communities, arboriculture clearly contributes to the health of the biological ecosystem; does it contribute to the health of the social ecosystem as well? Evidence from studies in inner-city Chicago suggests so. In a series of studies involving over 1,300 person–space observations, 400 interviews, housing authority records, and 2 years of police crime reports, tree and grass cover were systematically linked to a wide range of social ecosystem indicators. These indicators included stronger ties among neighbors, greater sense of safety and adjustment, more supervision of children in outdoor spaces, healthier patterns of children's play, more use of neighborhood common spaces, fewer incivilities, fewer property crimes, and fewer violent crimes. The link between arboriculture and a healthier social ecosystem turns out to be surprisingly simple to explain. In residential areas, barren, treeless spaces often become "no man's lands," which discourage resident interaction and invite crime. The presence of trees and well-maintained grass can transform these no man's lands into pleasant, welcoming, well-used spaces. Vital, well-used neighborhood common spaces serve to both strengthen ties among residents and deter crime, thereby creating healthier, safer neighborhoods.

Key Words. Social ecology; strength of community; crime; social benefits; residential.

In urban communities, arboriculture plays an important role in the health of the biological ecosystem. It provides habitat for wildlife and creates a more hospitable setting for many species (for a review of environmental impacts of urban forestry, see Dwyer et al. 1992). Does arboriculture contribute to the health of the social ecosystem as well?

Before examining *whether* trees contribute to a healthy social ecology, it might be reasonable to ask *how* they might do so. One possible answer comes from a body of work that has traditionally had nothing to do with trees: the literature on "defensible space." Defensible space (DS) theory suggests that the physical features of a residential neighborhood can have important impacts on strength of community and rates of crime in that neighborhood (Newman 1972). Defensible space theory posits, among other things, that the architectural features and physical layout of residential buildings substantially influence patterns of informal contact among neighbors and informal surveillance. Contact among neighbors and informal surveillance are, in turn, known to be linked to strength of community and levels of crime (see Taylor 1988 for review). Although not all interventions based on DS theory have been successful (Cisneros 1995), the promise embodied in its sometimes spectacular successes has led the U.S. Department of Housing and Urban Development (HUD) and others to invest millions of dollars in rehabilitating public housing and other neighborhoods in line with DS guidelines (U.S. HUD 1998; Newman 1996).

If defensible space theory is correct, then vital, well-used residential outdoor spaces should play a crucial role in strengthening community and deterring crime. Although defensible space theory says very little about vegetation per se, the theory clearly has implications for natural, as well as built, features of residential outdoor spaces. If the presence of trees and grass in these spaces encourages residents' use of these spaces, perhaps these features too can play a role in strengthening community and deterring crime.

Does arboriculture, in fact, contribute to the health of the social ecosystem? In an urban neighborhood, we might approach this question in a variety of ways. We might ask whether trees play a role in the patterns of interrelation among different resident subpopulations. We might ask whether trees affect patterns of territory within the neighborhood or patterns of resource exchange. And we might ask whether trees enhance resident populations' capacity to resist incursion or outside threats. To the extent that arboriculture contributes to a healthy social ecosystem, we would expect otherwise similar urban areas with and without trees to differ in some or all of these respects.

This article reviews findings from a line of investigation addressing precisely these questions. A series of large-scale studies conducted in inner-city Chicago, Illinois, U.S., systematically compared buildings and spaces with varying levels of tree and grass cover while controlling for numerous social and environmental factors. "Greener" settings were compared to architecturally comparable or identical counterparts in terms of their performance on a wide range of ecosystem indicators.

GENERAL METHOD

A variety of measures, research designs, and statistical tools were used in this line of work; the particulars of different

studies within this line of investigation differed considerably. For the purpose of this review, only a brief overview of methodology is provided here. Detailed descriptions of the methodology for the constituent studies may be found in the original journal articles. Similarly, the specific statistical evidence underlying each link reported here can be found in the original journal articles. In many cases, a link between tree cover and an outcome is documented not only by statistical evidence of a relationship but also by mediation tests examining the proposed mechanism and by numerous, sometimes dozens of, statistical tests for potential confounding factors. While all findings reported here were statistically significant, it should be noted that both effect sizes and certainty levels varied across different analyses and different studies. The purpose of this review is to introduce the commonalities of the work as a whole and to address a larger theme not fully treated in any of the constituent studies—the relationship between trees and a healthy social ecology.

Setting and Overall Research Design

In examining the potential effects of trees on a healthy social ecology, the challenge was to find a setting in which the presence of trees was independent of other factors likely to affect the social ecology. Ideally, any neighborhoods we studied would meet four criteria. First, a potential research setting had to have variation in the amount of green cover immediately outside residences—from places that were full of plants to places that were barren of plants. Second, environmental features other than vegetation should be held constant across residences. Third, residents should be randomly assigned to residences or assigned irrespective of the amount of green cover. Finally, residents should have no influence over the maintenance of the vegetation near their home.

We found two public housing developments in Chicago that met these criteria: Robert Taylor Homes and the Ida B. Wells housing development. Each development has pockets of trees and grass as well as expanses of barren area (Figure 1). Each development is strikingly consistent in architecture. At the time of our studies, Robert Taylor Homes consisted of 28 identical 16-story apartment buildings laid out in single file along a 4.8-km corridor. Each building at Robert Taylor Homes was bordered on the west by an interstate highway and railroad tracks and on the east by a six-lane municipal thoroughfare and wide sidewalk. The Ida B. Wells development included 124 low-rise (2- to 4-story) apartment buildings laid out on a typical grid pattern. Chicago Housing Authority policies result in de facto random assignment of residents to apartment buildings for both developments, and residents have no influence over the location or maintenance of trees or grass at either development. Thus, throughout this review, all comparisons between "greener" and "less green" settings refer to settings which are either roughly matched or identical in a host of architectural characteristics and resident characteristics.

It should be noted that, in the studies reported here, ratings of "greenness" and "green cover" may be regarded as roughly equivalent to ratings of "tree cover." Although "greenness" and "green cover" were defined to include grass cover, the amount of tree cover in a scene is a very strong predictor of overall judgments of greenness; by contrast, the amount of grass cover appears to contribute little to ratings of greenness.

Figure 1. Apartment buildings at Robert Taylor Homes (top) and Ida B. Wells (bottom), without trees (left) and with trees (right).

RESULTS

Welcoming Residents Outdoors

A quarter-century of research (for review, see Kaplan and Kaplan 1989) has indicated that, in general, urban outdoor areas with trees are substantially more preferred than similar settings without trees. Some housing authority managers, however, have the belief that low-income African Americans don't value trees—that trees are a middle-class preference. Moreover, in poor inner-city neighborhoods there is the concern that trees reduce visibility. Housing authority managers and police suggest that trees make residents feel unsafe; if so, the presence of trees in this setting might actually make outdoor spaces less attractive and less usable. How do poor urban residents respond to trees? Would the presence of trees in outdoor areas have no effect or even make these areas less attractive to residents?

Our findings suggest that, in fact, residents' response to trees is extremely positive (Kuo et al. 1998). One hundred residents of a Chicago public housing development were asked to respond to images (photosimulations) depicting their courtyard with and without trees, with other factors (lighting, weather, people in the courtyard, etc.) held constant. Residents strongly preferred images with trees—and the more trees, the stronger their preference. Mean ratings for the high tree density images (54 trees per ha) were 6 standard deviations higher than the mean ratings for treeless images (Ms 3.1 versus 0.2 on a 0 to 4 scale, from "not at all" to "very much"). Further, approximately one-third of residents surveyed claimed that they would use their courtyard more if trees were planted.

These findings suggest that, in urban neighborhoods, trees might play a pivotal role in drawing residents outside. They further suggest a way in which arboriculture might contribute to a healthy social ecosystem—by enhancing residents' use of the spaces just outside their buildings, thereby promoting informal contact among neighbors and introducing informal surveillance.

Adults' Use of Outdoor Spaces

Photosimulations, however, are approximations of reality, and predictions of use are merely predictions. To what extent were inner-city residents accurate in predicting that they would use "greener" outdoor spaces more often?

Quite accurate, it would appear. Findings from three different studies indicate that greener residential outdoor spaces receive more use from adult residents than their barren counterparts. In one study, residents living in greener high-rise apartment buildings reported significantly more use of the area just outside their building than did residents living in buildings with less vegetation (Kuo et al. 1998). In two other studies, adult use of residential spaces was found to be disproportionately concentrated in greener versus more barren spaces (Coley et al. 1997; Sullivan et al., in press). In the Coley et al. study, the greater the number of trees found in a space, the greater the number of people who used the space simultaneously. Moreover, the closer trees were to apartment buildings, and thus the more visually and physically accessible they were, the more people spent time outside near them. In the low-rise development studied, no adults at all were observed in areas devoid of trees.

Children's Use of Outdoor Spaces

We also found differences in children's use of outdoor spaces as a function of tree cover. Children's use of residential outdoor spaces was disproportionately concentrated in greener versus less green spaces—a statistically significant finding in one study (Coley et al. 1997) and a marginally significant one in another ($p = .07$, Sullivan et al., in press). In addition, more detailed observations revealed differences in children's behaviors in greener versus less green spaces. Children in green spaces were more likely to be found engaged in play activities than other kinds of activities, and there was also increased creative play in green spaces (Faber Taylor et al. 1998).

In these studies, both adults' and children's territorial patterns were found to be systematically related to the extent of green cover. Presumably healthier patterns of territoriality—greater use of outdoor spaces by adults, greater use of outdoor spaces by children, and increased play in children—were associated with greener neighborhood spaces. In drawing residents outside, might trees also increase the time residents spend in proximity to one another, thereby promoting social interaction among neighbors?

Resident Interaction Outdoors

Our findings suggest that green cover is indeed related to the amount of social interaction in residential outdoor spaces. Green cover was reliably linked to the number of individuals simultaneously present in areas just outside apartment buildings (Coley et al. 1997). More detailed observations further suggest that the number of explicitly social activities (e.g., talking, playing cards together, working on a car repair together) occurring in residential outdoor spaces is linked to green cover (Sullivan et al., in press). We found 73% more individuals involved in social activities in spaces with high levels of green cover than in spaces with low levels of green cover (Sullivan et al., in press). The pattern was strongest for adults: Compared to more barren spaces, there were 100% more adults engaged in social activities in green spaces.

Children's Access to Adults Outdoors

The more social nature of residents' activities outside their buildings appears to extend not only to adult–adult interactions but to adult–child interactions as well. In one study, the presence of trees consistently predicted greater use of residential spaces by mixed-age groups of youth and adults (Coley et al. 1997). In another, we found systematically higher levels of access to adults for children in greener versus less green spaces (Faber Taylor et al. 1998).

Thus far, we have seen that trees and grass attract people to use inner-city neighborhood spaces and that in greener spaces there is more social contact among neighbors than in comparable barren spaces. We've also seen that the proximity of the trees to apartment buildings matters—when trees are closer to buildings, people use the outdoor spaces more. It appears that trees contribute to systematically healthier patterns of interrelation among adults and children outdoors.

These findings are exciting because access to adults plays such an important role in healthy child development. Children are socialized into the mores and standards of a culture through imitation of adults, explanations from

adults, and, last but not least, corrective feedback from adults (e.g., Miller and Sperry 1987; Ochs and Schieffelin 1984). Further, adult supervision is pivotal in preventing misbehavior; indeed, "lack of parental supervision is one of the strongest predictors of the development of conduct problems and delinquency" (APA Commission on Violence and Youth 1983, p. 19). To the extent that greener residential spaces promote adult supervision, then, we might expect fewer delinquent behaviors in these spaces.

Neighborhood Social Ties, Resource Flows

Thus far in this review, we have focused on outcomes specifically related to residential outdoor spaces—residents' use of these spaces, their activities in these spaces, the amount of socializing in these spaces, children's play in these spaces, etc. Do trees go beyond simply enhancing the vitality of residential outdoor spaces? Here, we turn toward social ecosystem variables that do not pertain specifically to residential outdoor space. The question here is whether, by making residential outdoor spaces more vital, trees contribute to the healthy functioning of a community in general.

There is substantial evidence to suggest that opportunities for casual social interaction provide a rich matrix from which social ties among neighbors develop (e.g., Ebbesen et al. 1976; Perkins et al. 1990). Opportunities for casual social contact, in turn, are greater when neighborhood residents spend more time in the outdoor spaces around their homes (Cooper 1975; Gans 1967; Talbot et al. 1987). If informal social contact among neighbors is a key factor in the development of social ties among neighbors, and trees are a key factor in informal social contact, perhaps trees can ultimately affect the development of neighborhood social ties.

A number of findings suggest that trees do in fact help strengthen neighborhood social ties. In a study of 145 public housing residents randomly assigned to architecturally identical buildings with varying levels of vegetation, the greener the building, the stronger the neighborhood social ties (Kuo et al. 1998). Compared to residents living in relatively barren buildings, individuals living in greener buildings reported more social activities and more visitors, knew more of their neighbors, reported their neighbors were more concerned with helping and supporting one another, and had stronger feelings of belonging. Further, statistical mediation tests indicated that the link between vegetation and neighborhood social ties is explained by residents' greater use of outdoor spaces (Kuo et al. 1998). Together, these findings suggest that by increasing the opportunities for residents to meet and interact, greener common spaces facilitated the development and maintenance of neighborhood social ties. This general pattern of findings has been replicated in a study of senior citizens (Kweon et al. 1998).

It is important to note that in another study comparing neighborhood social ties for residents of greener versus less green buildings (Brunson 1999), no significant differences were found in the number of neighbors with whom residents reported having strong ties. It may be that shared use of common spaces contributes only to the development of strong ties with one or two neighbors, as opposed to fostering a strong network of ties as in a village or small town.

It is also important to note that one component of neighborhood social ties in this work was the sharing of resources between neighbors. For individuals who live in intense poverty, neighborhood social ties are more than a pleasant feature—they are the foundation of an important survival strategy. Social ties among neighbors provide a conduit through which individuals share resources (Belle 1982; Stack 1974). In poor communities, social ties among neighbors are the first line of defense against the ravages of poverty. By contributing to stronger ties among neighbors, trees may enhance residents' resilience in the face of sudden financial setbacks and emergencies.

To summarize thus far, our findings suggest that in poor inner-city neighborhoods, trees not only enhance patterns of resident territoriality but also contribute to healthier, more supportive patterns of interrelations among residents, including greater sharing of resources.

Sense of Safety

At the beginning of this review, we addressed the concern that trees might decrease visibility and thereby reduce either actual safety or residents' sense of safety. Here, we come full circle and address the link between trees and safety directly.

Previous research indicates that neighbors who have strong social ties form more effective social groups (e.g., Greenbaum 1982; Warren 1981). For instance, compared to communities in which neighbors had weaker social ties, those with stronger social ties were more capable of building consensus on values and norms (Dubow and Emmons 1981), monitoring behavior, intervening if problem behaviors occur (Taylor 1988), and defending their neighborhoods against crime (e.g., Perkins et al. 1990). If stronger social ties among neighbors are key to creating more effective, safer neighborhoods, and treed spaces help promote ties among neighbors, perhaps the greenness of neighborhood landscape ultimately affects levels of safety and security in a neighborhood.

In inner-city neighborhoods, do treed spaces influence neighborhood safety and security? It seemed plausible that residents might feel safer in a setting if they knew, trusted, and could count on their neighbors—in other words, if they had strong social ties with their neighbors. At the same time, it seemed possible that even the high-canopy trees characteristic of public housing might reduce visibility, thereby reducing residents' sense of safety.

Our findings suggest that, in fact, residents living in greener buildings feel significantly safer than do their

counterparts living in more barren buildings. Further, our findings suggest that residents of greener buildings feel more comfortable or adjusted in their surroundings in general. We asked 145 public housing residents "How safe do you feel living here?" and "How well have you adjusted to living here?" We then compared the responses for residents assigned to relatively green versus relatively barren buildings. As predicted, individuals living adjacent to greener common spaces reported that they felt both safer and better adjusted than did their counterparts living adjacent to relatively barren spaces (Kuo et al. 1998).

Graffiti and Other Signs of Disorder

Findings from another study suggest that not only do residents in greener settings feel safer but also that they experience systematically fewer "incivilities"—the nuisances and petty crimes that signal the breakdown of normal territorial functioning. We asked 90 residents of an inner-city neighborhood to report on the incidence of graffiti and other so-called incivilities in the spaces adjacent to their apartment building. Residents of greener buildings reported systematically fewer incidences of vandalism, graffiti, and litter than their counterparts assigned to more barren buildings (Brunson 1999). Moreover, greener buildings were subject to significantly fewer "social incivilities"—noisy, disruptive individuals; strangers hanging around; and illegal activities.

There are a number of possible explanations for the link between trees and a lower incidence of incivilities. The presence of trees and grass may signal a more well-cared for space and, therefore, a higher likelihood of perpetrators being noticed (Brown and Altman 1983). Alternatively, the greater use of greener spaces may introduce more "eyes on the street" (Jacobs 1961). Yet another explanation may lie in the greater social cohesiveness around greener spaces—perhaps residents who know and trust each other are more effective in instituting "local social control" over what goes on in the spaces outside their homes (Greenberg et al. 1982). Any and all of these factors might contribute. In any case, it appears that the presence of trees in residential outdoor spaces is linked with more successful territorial functioning. Treed spaces appear to be less vulnerable to incursions and minor outside threats.

Property Crimes, Violent Crimes

To the extent that trees confer some protection against incursions, it seemed possible that they might provide some measure of defense against more significant threats as well. To examine this question, we collected 2 years of police crime reports for 98 apartment buildings in one inner-city neighborhood and used the extent of tree and grass cover outside each apartment building to predict the number of crimes reported for that building (Kuo and Sullivan 2001). We found systematically negative relationships between the greenness of the landscape and the number of crimes per building reported to the police. The greener a building's surroundings, the fewer total crimes; moreover, this relationship extended to both property crimes and violent crimes.

DISCUSSION

The role of the urban forest in the biological health of cities is well established; could the urban forest play a pivotal role in healthy social ecosystems as well? The findings reviewed here suggest so. In a series of large-scale, highly controlled field studies, "greener" buildings and spaces were consistently characterized by better performance on a wide range of social ecosystem indicators. Trees and grass cover were linked with greater use of residential outdoor spaces by adults and children, healthier patterns of children's outdoor activity, more social interaction among adults, healthier patterns of adult–child interaction and supervision, stronger social ties and greater resource sharing among adult residents, greater sense of safety and adjustment, lower levels of graffiti and other signs of social disorder, fewer property crimes, and fewer violent crimes.

When these findings are reframed in the traditional terms used to describe biological ecosystems, interesting parallels emerge. Specifically, green spaces may have a substantial impact on each of the following facets of ecosystem functioning: territorial patterns within an ecosystem (greater use of space, different use of space by children), interrelationships among different resident subpopulations (adult–child interaction, social interaction, and social ties), patterns of resource flow within an ecosystem (greater resource sharing), and residents' capacity to resist incursion and outside threats (reduced graffiti and crime, greater sense of safety).

At present, the most ready explanation for a connection between trees and social ecosystem health lies in a straightforward extension of defensible space theory. Defensible space theory suggests that vital, well-used residential spaces are key to the development of neighborhood social ties and the discouragement of potential perpetrators because they provide opportunities for informal social contact among neighbors and introduce informal surveillance (Newman 1972). Our findings suggest that the presence of trees can be a decisive factor in the extent to which residents actually use and "take ownership of" residential outdoor spaces. In other words, successful residential outdoor spaces are pivotal in the healthy social ecology of a community, and trees are a key element in creating successful residential outdoor spaces.

To what extent might a connection between trees and social ecosystem health extend to contexts other than those studied here? The signs are unsystematic but encouraging. The lore on the value of community gardens in mending the social fabric of poor neighborhoods is impressively consistent

and extensive (Brunson 1999), and the first systematic data on this question echo the lore (Glover et al. 2002). Moreover, there is some indication that a tie between green residential spaces and strength of community is not exclusive to poor neighborhoods. An article in *The Atlantic Monthly* (Drayton 2000) lauds the growing movement toward "community greens," shared parks tucked away on the inside of residential blocks. Most of these community greens have been developed in middle- or upper-income neighborhoods—houses on a community green in New York City's Greenwich Village sell for several million dollars apiece. Yet the pattern of neighborhood ties developing from the shared use of these common green spaces exactly mirrors our findings from some of the poorest communities in the United States; moreover, this pattern appears across different community greens with striking consistency. Clearly, the extent to which trees promote healthy social ecosystems in diverse settings and populations bears further investigation.

Regardless of how widely trees are linked to social ecosystem health, it is important to note that the context of these studies—poor urban neighborhoods—is precisely the context where social ecosystem health is at greatest risk and where urban trees are least present. While poverty is not synonymous with alienation and risk of crime, too many poor urban neighborhoods are characterized by high levels of mistrust, isolation, graffiti, property crime, and violent crime. It may be that the greatest benefits of urban forestry accrue to some of its historically most underserved constituencies.

The findings here have a number of implications for arboriculture and urban forestry. First and foremost, they reinforce the growing recognition of the vital role trees play in the ecological, social, and economic health of our communities. Second, they argue for a much tighter integration of the urban forest into the residential urban fabric. Third, the findings suggest that arborist–resident partnerships may be an important factor in fully reaping the healthy social ecosystem benefits of trees.

Vital Municipal Functions

These findings broaden our understanding of the functions trees serve in urban communities. At present, the role of arboriculture in urban ecosystems is primarily conceptualized in terms of the aesthetic, environmental, and wildlife habitat functions trees serve. The findings reviewed here suggest a substantially expanded conceptualization may be in order. Arboriculture may be vastly undervalued relative to its contributions.

Within the literature on the social benefits of urban forests, this work reinforces and extends the research on trees and healthy human functioning. Recent evidence links green residential settings to reduced aggression (Kuo and Sullivan 2001); enhanced cognitive functioning, life functioning, and well being (e.g., Kuo 2001; Kaplan 2001); and greater capacity for self-discipline (Faber Taylor et al. 2002). Together, the evidence reviewed here suggests a vital role for trees in the healthy functioning of not only individuals, but neighborhoods as well.

More generally, the findings reviewed here complement and extend the larger literature documenting the functions trees provide in urban communities. Together with the evidence linking trees and other vegetation to clean air and clean water, this new evidence linking trees to healthier patterns of individual and neighborhood functioning points to a much larger theme—trees and public health. Far from being an amenity, then, it appears that trees play multiple, fundamental roles in the continued health of urban communities and should be regarded in the same light as other urban infrastructural elements.

In linking trees with some of our most challenging and important civic goals, this work contributes a new and politically compelling addition to the arguments for urban forestry. While providing cleaner air, cleaner water, and other environmental benefits is obviously important and valuable, the fact remains that few urban politicians view these issues as central to their agendas. Stronger communities, reduced crime rates, and healthier, more vital neighborhoods—these are outcomes that mayors and city councils strive for, often with little or no success. The findings here suggest that urban forestry helps address some of our most recognized and most challenging societal needs.

Tighter Integration into the Residential Urban Fabric

One striking implication of this body of work is that the location of trees matters at a surprisingly fine-grained scale. Participants in these studies all have ready access to neighborhood green spaces and live within a few miles of one of the most extensive examples of urban nature in North America—Lake Michigan and the parks along Chicago's Lake Shore Drive. Further, the participants in each study live within the same neighborhood, with the same overall level of tree canopy. Yet in study after study, the finding is that having trees directly outside one's own building is different than having those same trees just outside neighborhood buildings. To fully reap the social benefits of trees then, the urban forest may need to be substantially more tightly integrated into the residential urban fabric than is currently recommended.

Working with Citizens

The focus of this review has been on the physical products of arboriculture, but the process of arboriculture surely has impacts on the social ecosystem of a community as well. That is, urban forestry programs can be structured such that they promote—or undermine—residents' appropriation of their neighborhood outdoor spaces. To the extent that greening is

carried out in a way that respects residents' choices and values with respect to the public and private spaces in their neighborhood, it seems more likely to foster the kinds of local social control so effective in deterring crime. Similarly, by inviting and requiring residents' participation, urban forestry may be carried out in a way that helps transform a mere collection of neighbors into a real, functioning community—watching out for each other, each other's property, and each other's children; helping out in times of need; having barbecues and block parties; exchanging gardening tips and life stories; working together to improve the community.

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Acknowledgments. Space limitations preclude thanking each of the many individuals and institutions that played key roles in this work. Special thanks go to Andrea Faber Taylor for leading the work on children, to William Sullivan for access to the site and help in site analysis, to Rebekah Levine Coley and Esther Davis for their roles in interviewing, to the Chicago Housing Authority and residents for their support and cooperation throughout, and to the National Urban and Community Forestry Advisory Council, the U.S. Forest Service, U.S. Department of Housing and Urban Development, and the Cooperative State Research, Extension and Education Service for funding the research.

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Résumé. Dans les communautés urbaines, l'arboriculture contribue clairement à la santé de l'écosystème biologique; mais contribue-t-elle également à la santé de l'écosystème social? Des faits provenant d'études intrenes de la ville de Chicago suggèrent cela. Dans une série d'études impliquant plus de 1300 observations personnes-milieu, 400 entrevues, des données-maison des autorités et des rapports de police de deux années, il apparaît que le couvert arboré et gazonné était systématiquement lié à un vaste nombre d'indicateurs sociaux. Parmi ces indicateurs, on retrouvait: un lien de voisinage plus fort, un plus grand sens de sécurité et d'adaptation, plus de surveillance des enfants à l'extérieur de la maison, des milieux de jeux plus sains pour les enfants, plus d'utilisation des espaces communs du voisinage, moins de comportements non civilisés, moins de crimes contre la propriété, et moins de crimes violents. Le lien entre l'arboriculture et un écosystème social plus sain est devenu de façon surprenante facile à expliquer. Dans les milieux résidentiels, les zones stériles et sans arbre deviennent souvent des « no man's lands », ce qui décourage les interactions avec les résidants et invite au crime. La présence d'arbres et de gazon bien entretenus peuvent transformer ces no man's lands en espaces plaisants, invitants et utilisés. De plus, les espaces publics bien utilisés par le voisinage favorisent le renforcement des liens entre les résidants et détourne le crime, ce qui crée un milieu plus sain et sécuritaire pour le voisinage.

Zusammenfassung. In Städten und Kommunen trägt die Baumpflege eindeutig zur Gesundheit des Ökosystems bei, ist es aber auch relevant für die Gesundheit des sozialen Ökosystems? Die Ergebnisse einer Studie aus dem Zentrum von Chicago zeigen dies. In einer Studie mit über 1300 Personenbeobachtungen, 400 Interviews, Berichten von Hausgesellschaften und 2 Jahre Polizeiberichten, wurden die Bäume und Grünflächen systematisch verbunden mit einer Reihe von Sozialökosystem-Indikatoren. Diese Indikatoren beinhalten: stärkere Verbindungen mit den Nachbarn, größerer Sinn für Sicherheit und Anpassung, mehr Beaufsichtigung der Kinder draussen, gesünderes Spielverhalten von Kindern, mehr Gebrauch von kommuneeigenen Grünflächen, weniger Straftaten, weniger Eigentumsdelikte und weniger Gewaltverbrechen. Die Verbindung zwischen Baumpflege und gesünderem sozialen Ökosystem ist erstaunlich einfach zu erklären. In bewohnten Gebieten werden aufgelassene Flächen leicht Niemandsland, was die Anwohner entmutigt zu agieren und es lädt zu Verbrechen ein. Die Anwesenheit von Bäumen und gepflegten Grünanlagen kann diese Niemandsbereiche in erfreuliche, willkommenheißende, genutzte Flächen umwandeln. Und vitale viel genutzte Gemeinflächen sorgen für eine positive Verbindung unter den Nachbarn und verhindern viele Verbrechen.

Resumen. En las comunidades urbanas, la arboricultura claramente contribuye a la salud de los ecosistemas biológicos; ¿lo hace también con el ecosistema social? La evidencia de los estudios en la ciudad de Chicago así lo sugiere. En una serie de estudios con 1300 observaciones espacio-persona, 400 entrevistas, registros de autoridades y dos años de reportes criminales de policía, las coberturas de los árboles y pasto fueron sistemáticamente ligadas a un rango amplio de indicadores del ecosistema social. Estos indicadores incluyeron: ligas fuertes entre vecinos, gran sentido de seguridad y regulación, mayor supervisión de los niños en espacios abiertos, patrones de juegos más saludables de los niños, mayor uso de los espacios comunes por los vecinos, menores faltas cívicas, pocos crímenes a la propiedad y pocos crímenes violentos. La liga entre la arboricultura y un ecosistema social saludable es fácil de explicar. En áreas residenciales, los espacios áridos, sin árboles, con frecuencia se convierten en "tierras no-humanas", las cuales no animan la interacción de los residentes e invitan al crimen. La presencia de árboles y céspedes bien mantenidos puede transformar estas tierras "no-humanas" en espacios bien usados y placenteros. Y los espacios comunes, bien utilizados, sirven tanto para estrechar las ligas en el vecindario como para detener el crimen, creando comunidades más seguras y saludables.

CENTER for URBAN HORTICULTURE
University of Washington, College of Forest Resources

Urban Nature Benefits: Psycho-Social Dimensions of People and Plants

America is a nation of cities and towns – more than 80 percent of the U.S. population lives in urban areas. Plants, forests and ecosystems are important in cities. People are working in many cities to preserve existing natural areas and restore or create new ones. Scientific research tells us that urban plants provide many benefits. We know that plants improve the environment by contributing to better air and water quality and helping to reduce energy use.

Social scientists study another level of services that plants provide for urban residents. Parks, green spaces and trees are more than the "lungs of the city" or "pollution scrubbers." They affect our everyday moods, activities and emotional health. They improve our quality of life in ways that are sometimes understood, often underestimated. Whether we are active in urban nature (planting trees, growing gardens) or passively encounter city green (such as a stroll through a park), we experience personal benefits that affect how we feel and function. Proof of psychological and social benefits gives us more reasons to grow more green in cities! Below are examples from many studies.

Individual Benefits

Urban life can be demanding – juggling schedules, work, meeting daily needs and commuting. Our urban open spaces and parks can provide welcome relief, in surprising ways. Everyday nature in cities can help us to calm and cope, to recharge our ability to carry on.

RESTORATIVE EXPERIENCES – Many of the tasks of work and study demand directed attention for long periods of time. As we psychologically filter out extraneous information and distractions our minds can become cognitively fatigued. "Directed attention fatigue" can result in feelings of anxiety or stress, irritability with others and an inability to concentrate. Research has shown that brief encounters with nature can aid cognitive fatigue recovery, improving one's capacity to concentrate. Psychologists Rachel and Stephen Kaplan define the characteristics of natural places that are restorative - being away, extent, fascination and compatibility.

WORKER ATTITUDES AND WELL-BEING – Dr. Rachel Kaplan surveyed deskworkers about their rate of illness and level of job satisfaction. Some study participants could view nature from their desks, others could not. Those without, when asked about 11 different ailments, claimed 23% more times of illness in the prior six months. Desk workers with a view claimed the

following satisfactions more often than their non-view colleagues: 1) found their job more challenging, 2) were less frustrated about tasks and generally more patient, 3) felt greater enthusiasm for the job, 4) reported feelings of higher life satisfaction, and 5) reported better overall health.

STRESS REDUCTION – Stress is often talked about but little understood. We do know that constant stress can impact our immune system as well as diminish the ability to cope with challenging situations. Roger Ulrich has done studies that measure the physiological responses of our bodies (such as blood pressure and heart rate) brought on by stress. He has found that people who view nature after stressful situations show reduced physiological stress response, as well as better interest and attention and decreased feelings of fear and anger or aggression. An interesting effect found in recent studies on driving and road stress is called the "immunization effect" — the degree of negative response to a stressful experience is less if a view of nature preceded the stressful situation.

Families, Children and Youth

Our families and young people are the foundation and future of our society. Many factors, including adequate education and health care, are essential for their strength and success. In addition, children and families need supportive environments that encourage positive behaviors and provide a respite from the challenges of urban living. Recent research reveals the subtle advantages of urban green spaces.

REDUCED DOMESTIC CONFLICT – Surveys of households in Chicago's public housing have explored the role of trees on household interpersonal dynamics. The housing projects' apartment buildings are nearly identical, differing only in the amount of trees and grass growing around them. Drs. Bill Sullivan and Francis Kuo report that residents living in buildings with trees use more constructive, less violent methods to deal with conflict. Residents with green views report using reasoning more often in conflicts with their children and significantly less use of severe violence. They also report less use of physical violence in conflicts with partners compared to those living in buildings without trees.

LESS SCHOOL AGGRESSION AND VIOLENCE – School violence programs help students to control aggressive behavior with training in conflict resolution and peer intervention. Physical environments around a school also appear to play a role. Education scientists at the University of Michigan have found that scenes of neighborhoods with blighted streetscapes are perceived as dangerous and threatening. Those that are more cared for, including tended landscapes, contribute to reduced feelings of fear and violence.

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ENVIRONMENT AND CRIME IN THE INNER CITY
Does Vegetation Reduce Crime?

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ABSTRACT: Although vegetation has been positively linked to fear of crime and crime in a number of settings, recent findings in urban residential areas have hinted at a possible negative relationship: Residents living in "greener" surroundings report lower levels of fear, fewer incivilities, and less aggressive and violent behavior. This study used police crime reports to examine the relationship between vegetation and crime in an inner-city neighborhood. Crime rates for 98 apartment buildings with varying levels of nearby vegetation were compared. Results indicate that although residents were randomly assigned to different levels of nearby vegetation, the greener a building's surroundings were, the fewer crimes reported. Furthermore, this pattern held for both property crimes and violent crimes. The relationship of vegetation to crime held after the number of apartments per building, building height, vacancy rate, and number of occupied units per building were accounted for.

> The highway from one merchant town to another shall be cleared so that no cover for malefactors should be allowed for a width of two hundred feet on either side; landlords who do not effect this clearance will be answerable for robberies committed in consequence of their default, and in case of murder they will be in the king's mercy.
> —Statute of Winchester of 1285, Chapter V, King Edward I

AUTHORS' NOTE: *A portion of these findings was presented in invited testimony to the National Urban and Community Forestry Advisory Council (NUCFAC). This*

ENVIRONMENT AND BEHAVIOR, Vol. 33 No. 3, May 2001 343-367

There is a long tradition of addressing crime in problem areas by removing vegetation. As early as 1285, the English King Edward I sought to reduce highway robbery by forcing property owners to clear highway edges of trees and shrubs (Pluncknett, 1960). Today, that tradition continues as park authorities, universities, and municipalities across North America engage in active programs to remove vegetation because it is thought to conceal and facilitate criminal acts (Michael & Hull, 1994; Nasar & Fisher, 1993; Weisel, Gouvis, & Harrell, 1994).

One of the settings in which crime is of greatest concern today is the inner-city neighborhood. To combat crime in this setting, should vegetation be removed? This article suggests the opposite. We present theory and evidence to suggest that far from abetting crime, high-canopy trees and grass may actually work to deter crime in poor inner-city neighborhoods.

COULD THERE BE EXCEPTIONS TO THE RULE?

As a rule, the belief is that vegetation facilitates crime because it hides perpetrators and criminal activity from view. Here, we review the evidence in support of this "rule" and suggest conditions under which it might not apply.

Although no studies to date have examined whether crime rates are actually higher in the presence of dense vegetation, a variety of evidence links dense vegetation with fear, fear of crime, and possibly crime itself.

It is certainly the case that many people fear densely vegetated areas. In research on urban parks, densely wooded areas have consistently been associated with fear. In one study, safety ratings for 180 scenes of urban parks showed that individuals felt most vulnerable in densely forested areas and safest in open, mowed areas (Schroeder & Anderson, 1984). And in another study, individuals who were asked for their open-ended responses to photo-

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work was also supported by the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture, under Project No. ILLU-65-0387. Weare grateful for the assistance of many individuals and other institutions as well. John Potter and Liesette Brunson assisted in data entry and data analysis in the initial stages of this project. A reviewer's suggestion substantially strengthened the analyses presented here. The Chicago Housing Authority and the management of Ida B. Wells were helpful in many ways, and the Chicago Police Department graciously gave us access to their year-end crime reports. Jerry Barrett helped produce the figures, and Helicopter Transport of Chicago donated the helicopter flight over Ida B. Wells. *Correspondence concerning this article should be addressed to Frances E. Kuo, Human-Environment Research Laboratory, University of Illinois, 1103 S. Dorner, Urbana, IL, 61801; e-mail: f-kuo@uiuc.edu.*

graphs of urban parks indicated that heavily vegetated areas seemed dangerous (Talbot & Kaplan, 1984). Although neither of these studies specifically probed fear of crime (as opposed to more general fear), it was clear that at least some participants had crime in mind; one respondent specifically suggested that weedy areas gave muggers good hiding places (Talbot & Kaplan, 1984).

Dense vegetation has also been linked specifically to fear of crime. In safety ratings for 180 scenes of parking lots, the more a photo was covered by vegetation, the lower the perceived security (Shaffer & Anderson, 1985). And in research examining fear of crime on a university campus, dense understories that reduced views into areas where criminals might hide were associated with fear of crime (Nasar & Fisher, 1993). In these and other studies, view distance seems to be an important factor. Fear of crime is higher where vegetation blocks views (Fisher & Nasar, 1992; Kuo, Bacaicoa, & Sullivan, 1998; Michael & Hull, 1994).

Not only has dense vegetation been linked to general fears and to fear of crime in particular, but two studies have pointed more directly at a facilitative role of vegetation in crime. In the first study, park managers and park police indicated that dense vegetation is regularly used by criminals to conceal their activities (Michael & Hull, 1994). In the second, burglars themselves lent support to this notion. In this study, automobile burglars described how they used dense vegetation in a variety of ways, including to conceal their selection of a target and their escape from the scene, to shield their examination of stolen goods, and finally, in the disposal of unwanted goods (Michael, Hull, & Zahm, 1999). At the same time, Michael and his coauthors made it clear that vegetation was neither necessary nor sufficient for a crime to take place.

The clear theme in all these studies is that dense vegetation provides potential cover for criminal activities, possibly increasing the likelihood of crime and certainly increasing the fear of crime. Large shrubs, underbrush, and dense woods all substantially diminish visibility and therefore are capable of supporting criminal activity.

But, not all vegetation blocks views. A well-maintained grassy area certainly does not block views; widely spaced, high-canopy trees have minimal effect on visibility; and flowers and low-growing shrubs seem unlikely to provide cover for criminal activities. We suggest that although the rule that vegetation aids crime may hold for visibility-decreasing forms of vegetation, there are systematic exceptions to this rule. To wit, we propose that widely spaced, high-canopy trees and other visibility-preserving forms of vegetation do not promote crime.

MIGHT VEGETATION DETER CRIME? THEORY

Furthermore, we propose that in some settings, visibility-preserving forms of vegetation may actually deter crime. Specifically, we propose that in poor inner-city neighborhoods, vegetation can inhibit crime through the following two mechanisms: by increasing surveillance and by mitigating some of the psychological precursors to violence. Let's look at each of these in turn.

Increasing surveillance. Surveillance is a well-established factor in criminal activity. Jane Jacobs (1961) suggested that the simple presence of more "eyes on the street" would deter crime, and this concept was prominent in Oscar Newman's (1972) classic *Defensible Space* and appeared in Jeffery's (1971) *Crime Prevention Through Environmental Design*. Since then, many studies have shown that perpetrators avoid areas with greater surveillance and greater likelihood of intervention (e.g., Bennett, 1989; Bennett & Wright, 1984; Cromwell, Olson, & Avary, 1991; Poyner & Webb, 1992). And, substantial research has shown that criminals avoid well-used residential areas where their activities might easily be observed (Coleman, 1987; Macdonald & Gifford, 1989; Merry, 1981; Rhodes & Conley, 1981).

There is some evidence to suggest that in inner-city neighborhoods, vegetation might introduce more eyes on the street by increasing residents' use of neighborhood outdoor spaces. A series of studies conducted in inner-city neighborhoods has shown that treed outdoor spaces are consistently more well used by youth, adults, and mixed-age groups than are treeless spaces; moreover, the more trees in a space, the greater the number of simultaneous users (Coley, Kuo, & Sullivan, 1997; Kuo, Sullivan, Coley, & Brunson, 1998; W. C. Sullivan, Kuo, & DePooter, 2001). Not surprisingly then, a recent study found that children were twice as likely to have adult supervision in green inner-city neighborhood spaces than in similar but barren spaces (A. F. Taylor, Wiley, Kuo, & Sullivan, 1998). Thus, in these settings, higher levels of vegetation not only preserve visibility but may also increase surveillance.

Perhaps just as important as actual surveillance in deterring crime is implied surveillance. Newman (1972) suggested that criminals might be deterred by environmental cues suggesting that surveillance is likely even when no observers are present (also see Jeffery, 1971; R. B. Taylor, 1988). Consistent with this, territorial markers have been empirically linked to lower rates of incivilities and crime (Brown & Altman, 1983; Perkins, Brown, & Taylor, 1996; Perkins, Wandersman, Rich, & Taylor, 1993; R. B. Taylor, 1988). (And even those *E&B* readers who are not criminals may have

experienced the power of implied surveillance—on the highway after passing an empty police car.)

There is some evidence to suggest that residential vegetation can act as a territorial marker. Chaudhury (1994) showed front views of houses to students and examined how a host of environmental features affected their ratings of *territorial personalization*. He found that the presence and maintenance of vegetative features was the strongest predictor of territorial personalization, with an *R*-squared of .65. Similarly, Brown and colleagues (Brown & Altman, 1983; Brown & Bentley, 1993) found evidence suggesting that plants and other territorial markers make properties less attractive for burglary. We suggest that well-maintained vegetation may constitute a particularly effective territorial marker. Well-maintained vegetation outside a home serves as one of the *cues to care* (Nassauer, 1988), suggesting that the inhabitants actively care about their home territory and potentially implying that an intruder would be noticed and confronted.

Mitigating psychological precursors to violence. Another mechanism by which vegetation might inhibit crime is through mitigating mental fatigue. S. Kaplan (1987) suggested that one of the costs of mental fatigue may be a heightened propensity for "outbursts of anger and potentially . . . violence" (p. 57), and three proposed symptoms of mental fatigue—irritability, inattentiveness, and decreased control over impulses—are each well-established psychological precursors to violence. Irritability is linked with aggression in numerous studies (e.g., Caprara & Renzi, 1981; Coccaro, Bergeman, Kavoussi, & Seroczynski, 1997; Kant, Smith-Seemiller, & Zeiler, 1998; Kavoussi & Coccaro, 1998; Stanford, Greve, & Dickens, 1995). Inattentiveness has been closely tied to aggression in both children (Stewart, 1985) and adolescents (Scholte, van Aken, & van Leishout, 1997). And, impulsivity is associated with aggression and violence in a variety of populations (for reviews, see Brady, Myrick & McElroy, 1998; Markovitz, 1995; Tuinier, Verhoeven, & Van Praag, 1996).

A considerable body of studies indicates that vegetation aids in the recovery from mental fatigue. Contact with nature in a variety of forms—wilderness areas, prairie, community parks, window views, and interior plants—is systematically linked with enhanced cognitive functioning as measured by both self-report and performance on objective tests (e.g., Canin, 1991; Cimprich, 1993; Hartig, Mang, & Evans, 1991; R. Kaplan, 1984; Lohr, Pearson-Mimms, & Goodwin, 1996; Miles, Sullivan, & Kuo, 1998; Ovitt, 1996; Tennessen & Cimprich, 1995). To the extent that irritability, inattentiveness, and impulsivity are symptoms of mental fatigue, as first proposed in

S. Kaplan (1987) and recently elucidated in Kuo and Sullivan (in press), reductions in mental fatigue should decrease violent behavior.

In sum, we propose that vegetation can deter crime in poor urban neighborhoods in any or all of the following ways: by increasing residents' informal surveillance of neighborhood spaces, by increasing the implied surveillance of these spaces, and by mitigating residents' mental fatigue, thereby reducing the potential for violence. Next, we review empirical work pointing at a negative relationship between vegetation and crime.

MIGHT VEGETATION DETER CRIME? CIRCUMSTANTIAL EVIDENCE

There are a number of scattered hints in the empirical literature that vegetation might have a negative relationship to crime in residential settings.

A few studies have used images to examine the relationship between vegetation and sense of safety in residential settings. The findings from residential settings are in direct contrast to those obtained in studies of nonresidential settings: In residential settings, the more vegetation there is, the less fear of crime. One study used photographs of residential sites to examine effects of architectural and landscape features on fear of crime and found that higher levels of vegetation were associated with less fear of crime (Nasar, 1982). Another study used drawings of residences and found that properties appeared safer when trees and shrubs were included than when they were not (Brower, Dockett, & Taylor, 1983). And, similar results were obtained from an experiment using computer-based photo simulations. In that study, an inner-city courtyard was depicted with varying densities of trees: The more dense the tree planting was, the greater the sense of safety (Kuo, Bacaicoa, et al., 1998).

One study used controlled comparisons of real residential settings to examine the relationship between vegetation and sense of safety. In a public housing development where residents were randomly assigned to architecturally identical apartment buildings with varying levels of vegetation immediately outside, those residents who lived in buildings with more trees and grass gave systematically higher endorsements to the statement "I feel safe living here" than did their counterparts living in relatively barren buildings (Kuo, Sullivan, et al., 1998). That is, not only do images of green residential settings evoke a greater sense of safety, but individuals living in such settings report a greater sense of safety as well.

There is some indication that this greater sense of safety is warranted. A few studies have examined the relationship between vegetation and "incivilities." R. B. Taylor, Gottfredson, and Brower (as cited in R. B. Taylor, 1988) compared street blocks with higher and lower levels of high-maintenance

gardening and found fewer problems reported on street blocks with higher levels of high-maintenance gardening. And in another study, Stamen (1993) surveyed landscaped and nonlandscaped areas in a community and found that the incidence of vandalism or graffiti in sites without plantings was 90% as compared to 10% in sites with plantings. Similarly, Brunson (1999) examined both physical and social incivilities in public housing outdoor spaces with trees and grass versus in similar spaces without vegetation. Resident reports indicated that graffiti, vandalism, and littering were systematically lower in outdoor spaces with trees and grass than in comparable, more barren spaces (Brunson, 1999). Furthermore, resident reports indicated that social incivilities, such as the presence of noisy, disruptive individuals, strangers, and illegal activity, were also systematically lower in the greener outdoor spaces (Brunson, 1999).

Additional evidence that vegetation may reduce crime comes from two studies that examined the relationship between residential vegetation and residents' levels of aggression and violence. Mooney and Nicell (1992) compared violent assaults by Alzheimer patients during two consecutive summers in five long-term care facilities—three without gardens and two in which exterior gardens were installed. In Alzheimer patients, increases in the number of aggressive assaults each year are typical because of the progressive deterioration of cognitive faculties; and indeed, in the facilities without gardens, the incidence of violent assaults increased dramatically over time. By contrast, the incidence of violent assaults in the other facilities stayed the same or decreased slightly after gardens were installed.

Another study compared levels of aggression and violence in an urban public housing neighborhood where residents played no role in planting or maintaining the vegetation outside their apartments and were randomly assigned to levels of greenness. Levels of aggression and violence were systematically lower for individuals living in green surroundings than for individuals living in barren surroundings; moreover, lack of nature significantly predicted levels of mental fatigue, which in turn significantly predicted aggression. Mediation testing indicated that the relationship between vegetation and aggression was fully mediated through attention (Kuo & Sullivan, in press).

In sum, there is a variety of evidence suggesting that vegetation may be linked to lower levels of crime in residential neighborhoods, particularly poor inner-city neighborhoods. Residential vegetation has been linked with a greater sense of safety, fewer incivilities, and less aggressive and violent behavior. Of these findings, the most direct evidence of a negative link between vegetation and crime comes from residents' reports of illegal

activities in the space outside their apartment building and from residents' self-reports of (criminally) aggressive behavior.

The study presented here is the first to examine the relationship between vegetation and crime in an inner-city neighborhood using police crime reports. Although police crime reports are far from infallible (O'Brien, 1990), one advantage of such reports is that they are based on actual counts of crimes reported over the course of a year and thus are less subject to the distortions introduced by having residents estimate the frequencies of such events from memory. Thus, the convergence of findings from resident reports and police reports would lend confidence to a negative link between vegetation and crime. In this study, we examined the relationship between the vegetation outside of apartment buildings and the number of police crime reports for those buildings over a 2-year period. We collected police data on property crimes, violent crimes, and total crimes for 98 apartment buildings in one inner-city neighborhood and used the amount of tree and grass cover outside each building to predict crime.

METHOD

Data presented here were collected as part of the Vital Neighborhood Common Spaces archive, a multistudy research effort examining the effects of the physical environment on the functioning of individuals, families, and communities residing in urban public housing.

POPULATION, SETTING, AND DESIGN

Ida B. Wells is a large public housing development in Chicago. Wells provides housing for approximately 5,700 individuals, of which 65% are female, 97% are African American, and 44% are children younger than 14 years old (Chicago Housing Authority, 1995). Ida B. Wells is one of the 12 poorest neighborhoods in the United States (Ihejirika, 1995). At the time of this study, approximately 93% of the people living at Wells were officially unemployed, and roughly 50% of the families received Aid to Families with Dependent Children (Chicago Housing Authority, 1995).

The amount of nature outside apartment buildings at Ida B. Wells varies considerably. When the development was originally built in the 1940s, trees and grass were planted around each of the low-rise buildings. Over time, many of these green spaces have been paved in an effort to keep dust down and maintenance costs low; this paving has killed many of the original trees,

Figure 1: Ground Level View at Ida B. Wells Showing Apartment Buildings With Varying Amounts of Tree and Grass Cover

leaving some areas completely barren, others with small trees or some grass, and still others with mature high-canopy trees (see Figure 1). Because shrubs were relatively rare, vegetation at Ida B. Wells was essentially the amount of tree and grass cover around each building.

A number of apartment buildings at Wells were excluded from this study. First, the high-rise and midrise (seven-story) buildings were excluded to keep the buildings sampled similar in size, number of residents, and amount of outdoor common space. Second, of the 124 low-rise (one to four stories) apartment buildings, those buildings adjacent or nearly adjacent to the police station within the development were excluded because the presence of police officers would be expected to be a significant deterrent to crime. And finally, a small cluster of low-rise buildings was excluded because the buildings' irregular placement with respect to each other and the street made it unclear where the common space associated with one building ended and the next began. The final sample included 98 buildings.

Ida B. Wells offers a number of rare methodological advantages for investigating the relationship between residential vegetation and crime. Although levels of vegetation outside the apartment buildings vary considerably, the residents are strikingly homogeneous with respect to many of the individual characteristics that have been shown to increase vulnerability to crime—income, education, and life circumstances. This similarity among residents coupled with the consistent low-rise architecture decreases the sources of extraneous variability in crime. This increases the power to detect differences in the amount of crime associated with differences in the level of vegetation outside each apartment building.

Perhaps more important, the apartment assignment procedures and landscaping policies of public housing work to ensure that there are no systematic

relationships between the vegetation outside an apartment building and the characteristics of its residents. Applicants for public housing at Ida B. Wells (and elsewhere in Chicago public housing) are assigned to individual apartments without regard for the level of nearby vegetation. And although residents have some choice in accepting or rejecting a particular apartment in theory, in practice the level of nearby vegetation is not a significant factor in residents' choices, and most residents simply accept the first available apartment (Kuo, Sullivan, et al., 1998). Moreover, residents play little or no role in decisions to introduce or remove trees. Thus, in this study, there were no a priori reasons to expect a relationship between the level of vegetation outside an apartment building and the characteristics of its inhabitants—more "responsible" residents might just as likely live in barren buildings as in green buildings.

MEASURES

Crime reports. Chicago Police Department year-end Uniform Crime Reports were analyzed for this study. These crime reports summarize for each address at Ida B. Wells the specific crimes (e.g., aggravated assault and strong-armed robbery) that were reported during the year. These reports include both citizen-initiated complaints and those filed by an officer without a citizen complaint.

When a crime is reported to the police, an officer is dispatched to interview the victim or victims and any witnesses. The officer then files a report about the incident describing the specific crime or crimes, the date, the address where the crime(s) occurred, and other pertinent information. Details from this report are then summarized in the year-end crime reports.

From 2 years of crime reports, we created three summary variables indexing crime for each low-rise apartment building at Ida B. Wells, following the classification scheme used by the Department of Justice (Bureau of Justice Statistics, 1999). In this scheme, property crime is the sum of simple thefts, vehicle thefts, burglaries, and arson; violent crime includes assaults, batteries, robberies, and homicides; and total crimes is the sum of all crimes reported.

Vegetation. To assess the density of trees and grass around each of the low-rise buildings, we took dozens of 35mm slide photographs of the development by helicopter, passing over each cluster of buildings from a number of vantages (see Figure 2). We also took ground-level photographs of many of the outdoor spaces. All the slides were taken in June when the tree canopy

Figure 2: Aerial View of a Portion of Ida B. Wells Showing Buildings With Varying Amounts of Tree and Grass Cover

was full and the grass was green. For each building, the aerial slides were put together with slides taken at ground level; there were at minimum three different views from aerial and ground-level photos of each space (front, back, left side, and right side) around each building. Five students in landscape architecture and horticulture then independently rated the level of vegetation in each space. Each of the individuals rating the spaces received a map of the development that defined the boundaries of the specific spaces under study. The raters viewed the slides and recorded their ratings on the maps. A total of 220 spaces was rated, each on a 5-point scale (0 = no trees or grass, 4 = a space completely covered with tree canopy). Interrater reliability for these ratings was .94.[1] The five ratings were averaged to give a mean nature rating for each space. The nature ratings for the front, back, and side spaces around each building were then averaged to produce a summary vegetation rating. Ratings of vegetation for the 98 buildings ranged from 0.6 to 3.0.

Other factors likely to affect crime. Four additional variables possibly related to vegetation and the number of crimes reported per building were assessed through (a) on-site analysis, (b) Chicago Housing Authority floor

TABLE 1
Simple Ordinary Least Squares Regressions
Using Vegetation to Predict Crimes Per Building

	Total Crimes			*Property Crimes*			*Violent Crimes*		
Predictor	R^2	β	p *Value*	R^2	β	p *Value*	R^2	β	p *Value*
Vegetation	.08	–2.2	< .01	.07	–1.0	< .01	.07	–1.3	<.01

plans of each building type in the development, and (c) Chicago Housing Authority apartment vacancy records.

Number of units is the number of apartment units in a building; the range was from 4 to 20.

Number of occupied units is the average number of units rented in a particular building during the 2 years of the study; the mean was 7.8, and the range was from 0.5 to 15. We were able to obtain data on 84 of the 98 buildings in this sample.

Vacancy is the 2-year average of the number of vacant apartments divided by the number of units in the building; the mean was 13%, and the range was from 0% to 92%. We were able to obtain data on 84 of the 98 buildings in this sample.

Building height is the number of floors in a building; the range was from 1 to 4.

RESULTS

If vegetation reduces crime, then we would expect to find that the greener a building's surroundings are, the fewer crimes reported. Perhaps the most straightforward test of this possibility is to conduct simple regressions with vegetation as the independent variable and the three summary crime indices as dependent variables (see Table 1). Results from these ordinary least squares regressions indicate that vegetation is significantly and negatively related to each of the measures of crime. The greener a building's surroundings are, the fewer total crimes; this pattern holds for both property crimes and violent crimes. For each of the three indices, vegetation accounts for 7% to 8% of the variance in the number of crimes reported per building.

Figure 3 provides a more concrete sense of the amount of crime associated with different levels of vegetation. For this figure, the continuous vegetation variable was recoded into the following three categories: low (ratings from

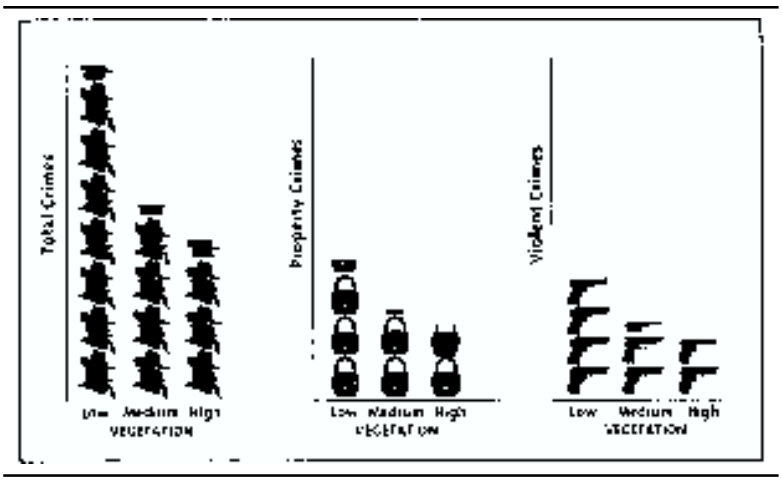

Figure 3: Mean Number of Crimes Reported Per Building for Apartment Buildings With Different Amounts of Vegetation (each icon represents one reported crime)

0.0 up to 1.0), medium (from 1.0 up to 2.0), and high (from 2.0 up to 3.0, inclusive). Figure 3 shows the average number of total, property, and violent crimes reported for buildings with low, medium, and high levels of vegetation. Compared to buildings with low levels of vegetation, those with medium levels had 42% fewer total crimes, 40% fewer property crimes, and 44% fewer violent crimes. The comparison between low and high levels of vegetation was even more striking: Buildings with high levels of vegetation had 52% fewer total crimes, 48% fewer property crimes, and 56% fewer violent crimes than buildings with low levels of vegetation. Fisher's protected least significant difference analyses indicate that for each measure of crime, low and medium buildings were significantly different at $p < .05$. The same pattern held for comparisons between low and high buildings. Although buildings with high levels of vegetation had 17% fewer total crimes, 13% fewer property crimes, and 21% fewer violent crimes than buildings with medium levels of vegetation, these differences were not statistically significant.

These data reveal a clear negative relationship between vegetation and crime and hint that this relationship is strongest when comparing buildings with low levels of vegetation to buildings with either medium or high levels. Although these findings are exciting and intriguing, they do not control for other important variables. The analyses that follow provide a closer look at

TABLE 2
Multiple Regressions Using Number of Units and Vegetation to Predict Crimes Per Building

	Total Crime		*Property Crimes*		*Violent Crimes*	
Predictors	β	p *Value*	β	p *Value*	β	p *Value*
Number of units	0.70	< .0001	0.31	< .0001	0.39	< .0001
Vegetation	−1.44	< .05	−0.63	< .05	−0.81	< .05

NOTE: The multiple regressions for total crimes: adjusted $R^2 = .52$ ($N = 98$, $p < .0001$); for property crime: adjusted $R^2 = .45$ ($N = 98$, $p < .0001$); for violent crime: adjusted $R^2 = .44$ ($N = 98$, $p < .0001$).

the relationship between vegetation and crime, taking into account other factors likely to affect the number of crimes per building.

TESTING POTENTIAL CONFOUNDS

Controlling for number of apartments. Perhaps one of the most important variables to control for in predicting the amount of crime in a setting (e.g., a building, neighborhood, or city) is the number of people in that setting. Because more apartments per building mean more potential perpetrators and more potential victims, one would expect more crimes in buildings with more apartments. Indeed, previous research has shown the number of units in a building to be related to the number of reported crimes (Newman & Franck, 1980). Thus, it is not surprising that in this sample, strong positive linear relationships exist between the number of units and the number of property crimes ($r = .62, p < .0001$), violent crimes ($r = .63, p < .0001$), and total crimes ($r = .67$, $p < .0001$). That is, the more apartments in a building, the more crimes reported for that building.

To examine whether the relationship between vegetation and crime still held when the number of apartments in a building was controlled, a series of multiple regressions were conducted in which both vegetation and number of units were used to predict the number of crimes reported per building. As Table 2 shows, when the number of units per building is controlled, vegetation continues to be a significant negative predictor of total crime, property crime, and violent crime. In other words, the level of greenness around a building at Ida B. Wells predicts the number of crimes that have occurred in that building even after the number of apartments in the building has been accounted for.

TABLE 3
Intercorrelations Among Possible Predictors of Crime and Three Crime Scales

	Vegetation	*Number of Units*	*Vacant Rate*	*Number of Occupied Units*	*Building Height*	*Property Crime*	*Violent Crime*
Vegetation							
Number of units	–.15						
Vacancy rate	–.02	.26					
Number of occupied units	.12	.82**	–.31**				
Building height	–.48**	.67**	.40**	.35**			
Property crime	–.27**	.62**	.01	.38**	.53**		
Violent crime	–.27**	.63**	.25**	.30**	.58**	.72**	
Total crime	–.29**	.67**	.16	.38**	.60**	.91**	.95**

**$p < .01$.

Other potential confounds. To identify other potential confounds between vegetation and crime, correlations were conducted between vegetation and the following three factors that have been shown in other studies to be associated with crime: vacancy rate (R. B. Taylor, Shumaker, & Gottfredson, 1985), the number of occupied apartments per building (Newman & Franck, 1980), and building height (Newman, 1972; Newman & Franck, 1980). As the first column in Table 3 shows, vegetation is not related to either vacancy rate or number of occupied units but is strongly and negatively related to building height; the taller the building is, the lower the level of vegetation. The fourth column in Table 3 indicates that building height has a strong positive relationship to total crime, property crime, and violent crime. Thus, the relationship between vegetation and crime is confounded by building height: Taller buildings are both less green and have more reported crimes than shorter buildings. These findings raise the possibility that vegetation predicts crime only by virtue of its shared variance with building height.

To test for this possibility, we examined whether vegetation still predicts crime when building height and number of units are controlled. Table 4 provides the results of a series of multiple regressions in which vegetation, building height, and number of units were used to predict crime. If vegetation predicts crime by virtue of its relationship with building height, then vegetation should no longer predict crime when building height is controlled, and building height should predict crime with vegetation controlled. As Table 4

TABLE 4
Multiple Regression Using Three Independent Variables (number of units, vegetation, and building height) to Predict Crimes Per Building

	Total Crime		*Property Crimes*		*Violent Crimes*	
Predictors	β	p *Value*	β	p *Value*	β	p *Value*
Number of units	0.69	.0001	0.33	.0001	0.34	.0001
Vegetation	–1.41	< .05	–0.69	< .05	–0.55	.07
Building height	0.05	*ns*	–0.13	*ns*	0.18	*ns*

NOTE: The multiple regressions for total crimes: adjusted $R^2 = .51$ ($N = 98$, $p < .0001$); for property crime: adjusted $R^2 = .44$ ($N = 98$, $p < .0001$); for violent crime: adjusted $R^2 = .43$ ($N = 98$, $p < .0001$).

shows, however, this is not the case; vegetation remains a significant or marginally significant predictor of crime with building height and number of units controlled. Moreover, building height has no predictive power when vegetation and number of units are controlled. These findings indicate that although building height is confounded with vegetation, it cannot account for the link between vegetation and crime.

Thus far, the analyses have established that (a) there is a reliable association between the amount of vegetation outside a building and the number of crimes recorded for that building by the police, (b) these relationships are independent of the number of units in a building, and (c) these relationships are independent of building height. These analyses show that vegetation predicts crime and that this relationship cannot be accounted for by these other confounding variables.

DOES ADDING VEGETATION IMPROVE THE CURRENT ARSENAL OF CRIME PREDICTORS?

To determine whether vegetation makes any unique, additional contribution to the current arsenal of predictors, we conducted a multiple regression in which all available significant predictors of crime were entered (i.e., vegetation, other predictors that were confounded with vegetation, and other predictors that were not confounded with vegetation). This kitchen-sink multiple regression, in which vegetation and number of units, building height, vacancy rate, and number of occupied units were entered as predictors, indicated that vegetation does make a unique contribution to the current arsenal of predictors. Vegetation was a significant predictor of total crime ($\beta = -1.1$, $p = .05$) even when all other crime predictors have been accounted for. Moreover, the relatively low variance inflation factor for vegetation in this regression (1.31) indicates that vegetation is relatively independent of the

other predictors. In addition, comparison of the adjusted R^2s of the kitchen-sink multiple regressions with and without vegetation indicated that the additional predictive power gained by adding vegetation outweighs the loss of degrees of freedom incurred in increasing the total number of predictors. The adjusted R^2 for the model with only the current arsenal of predictors was .23; the adjusted R^2 for the model with the current arsenal of predictors plus vegetation was .26. Although this increase represents only 3% of the total variance in crime, it represents a sizable proportion of the current predictive power (13%). Together, these findings indicate that adding vegetation improves the current arsenal of predictors, adding unique explanatory power.

A Cuthbert plot (Cp) analysis yielded additional evidence of the predictive power of vegetation. Cp analysis is a technique for determining the most powerful, most parsimonious model out of a set of multiple predictors (SAS Institute, 1998). Essentially, given a set of predictors, Cp analysis tests all possible combinations of predictors and selects the best model. An alternative to comparing adjusted R^2s, Cp analysis is particularly helpful when there is multicollinearity between predictors, as was the case here. Cp analysis indicated that the best model for predicting total crime, selecting from the entire set of available predictors (number of units, building height, vacancy rate, number of occupied units, and vegetation), comprises only two predictors—number of units and vegetation (Cp = 1.32). Thus, in these data, the best possible model of crime comprises only vegetation and one other predictor.

DISCUSSION

This study examined the relationship between vegetation and crime for 98 apartment buildings in an inner-city neighborhood. Analyses revealed consistent, systematically negative relationships between the density of trees and grass around the buildings and the number of crimes per building reported to the police. The greener a building's surroundings are, the fewer total crimes; moreover, this relationship extended to both property crimes and violent crimes. Levels of nearby vegetation explained 7% to 8% of the variance in the number of crimes reported per building. The link between vegetation and crime could not be accounted for by either of the two confounding variables identified. Vegetation contributed significant additional predictive power above and beyond four other classic environmental predictors of crime. And out of all possible combinations of available predictors, vegetation was identified as one of the two predictors in the best possible model of crime.

The findings contribute to our understanding of the relationship between vegetation and crime and suggest opportunities for intervention and future research.

CONTRIBUTIONS TO THE UNDERSTANDING OF VEGETATION AND CRIME

One contribution of this work is to propose a systematic exception to the rule that vegetation promotes crime. The rule in both folk theory and environmental criminology has been that vegetation promotes crime by providing concealment for criminals and criminal activities. If the mechanism by which vegetation affects crime is indeed concealment, then one implication of this rule is that vegetation should not promote crime when it preserves visibility. The contribution here is simply to point out that many forms of vegetation preserve visibility and therefore ought not promote crime. Indeed, we found that in this sample of inner-city apartment buildings, buildings with widely spaced, high-canopy trees and grassy areas did not experience higher rates of crime. These findings suggest that at the very least, crime prevention concerns do not justify removing high-canopy vegetation in inner-city neighborhoods. They demonstrate that one of the classic suspects in environmental criminology does not always promote crime.

Moreover, the findings indicate a large and systematically negative link between levels of vegetation and police reports of crime in this setting. Although this is the first study to demonstrate such a link, the findings are consistent with previous work linking vegetation with lower levels of incivilities (Brunson, 1999; Stamen, Yates, & Cline, as cited in S. Sullivan, 1993) as well as previous work linking vegetation with lower levels of aggression and violence (Kuo & Sullivan, in press). The results obtained here were based on police crime reports, whereas the Brunson (1999) and the Kuo and Sullivan (in press) findings were based on residents' memories and self- reports. The convergence of findings from such different measures lends confidence that in inner-city residential settings, the relationship between vegetation and crime is negative—the more vegetation, the less crime.

A third contribution of the work here is to help resolve a puzzle in previous work on residential vegetation and sense of safety. A number of studies have found that residential vegetation is associated with greater sense of safety (Brower et al., 1983; Kuo, Bacaicoa, et al., 1998; Kuo, Sullivan, et al., 1998; Nasar, 1982). In combination with the old rule that vegetation promotes crime, such findings raised the disturbing possibility that residents systematically misperceive green areas as safe. And yet other research has found good concurrent validity between measures of fear, perceptions of disorder, and media reports of crime (e.g., Perkins & Taylor, 1996). The finding here that

vegetation is systematically linked with lower levels of crime suggests that individuals are accurate in their perception of green areas as safer.

A final contribution of this work is to propose two mechanisms by which vegetation may deter crime in inner-city neighborhoods. Specifically, we propose that vegetation may deter crime both by increasing informal surveillance and by mitigating some of the psychological precursors to violence. Although neither of these mechanisms—nor the more general question of causality—can be addressed in these data, there is clear empirical support for these mechanisms in other work. Substantial previous research has shown that surveillance deters crime and that in inner-city neighborhoods, greener outdoor spaces receive greater use, thereby increasing informal surveillance. Moreover, Kuo and Sullivan's (in press) work showed that for residents randomly assigned to apartment buildings with different levels of vegetation, higher levels of vegetation systematically predicted lower levels of aggression, and mediation analyses indicated that this link was mediated via attentional functioning. In addition, we can address a number of alternative interpretations for the findings here. Public housing policies in this setting are such that levels of income, education, and employment among residents are largely held constant; residents are randomly assigned to varying levels of vegetation; and the amount of trees and grass outside an apartment is not under residents' control. And the confound analyses conducted here indicate that the link between vegetation and lower crime could not be explained by a number of classic environmental predictors of crime—vacancy rates, building height, the number of apartments, and the number of occupied apartments in a building.

POSSIBILITIES FOR INTERVENTION AND FUTURE RESEARCH

The findings in this study set the stage for more ambitious explorations of the relationship between urban residential vegetation and crime. Now that there is good reason to think that visibility-preserving vegetation does not necessarily promote crime and may even inhibit crime in inner-city neighborhoods, it seems appropriate to attempt an intervention study or two. Intervention studies employing true experimental designs might be used to answer a number of important questions with regard to the effects of vegetation on crime. Urban public housing communities might be especially amenable sites for such research as housing authorities tend to have centralized control over landscaping for dozens and even hundreds of identical buildings.

A study in which identical or matched apartment buildings in a poor urban area were randomly assigned to receive different levels of vegetation could help address the question of causality and the question of the shape of the

relationship between vegetation and crime. Would crime rates decrease linearly or curvilinearly with increasing vegetation? In this sample, the difference between low and moderate green cover buildings was 3.1 crimes, but the difference between moderate and high green cover buildings was only 0.7 crimes. One possible interpretation of this pattern is that the relationship between vegetation and crime is nonlinear with diminishing returns. Another is that the 0.7 crime difference between the moderate and high vegetation conditions is a poor estimate because of the relatively low number of high-vegetation buildings in the sample, and the relationship between vegetation and crime is actually linear across the entire range of vegetation.

Future studies might systematically vary the arrangement and maintenance of vegetation and examine the rates of crime associated with these factors. The vegetation in this study was not configured to provide symbolic barriers or to mark the territory of particular apartment buildings. Would arrangements that create symbolic barriers and delineate the territory of particular residences (e.g., with small hedges) be more effective in decreasing crime than other arrangements? Brown and colleagues (Brown & Altman, 1983; Brown & Bentley, 1993) found evidence suggesting that plants and other territorial markers may make a property less attractive for burglary, but no study has yet randomly assigned different planting arrangements to different buildings and compared the resulting rates of property crime. Analogously, well-maintained vegetation seems to be a particularly effective territorial marker (Chaudhury, 1994), but research has yet to systematically examine the effect of different levels of maintenance on crime.

Future research might also look more closely—and more broadly—at the outcomes of planting interventions. In this sample, vegetation predicted levels of both property crime and violent crime. This is noteworthy given that studies in environmental criminology often find that the relationship between the physical environment and crime depends on the specific category of crime (e.g., Brantingham & Brantingham, 1993). It would be interesting and useful to examine the relationships between vegetation and more specific categories of crime or other categories altogether. For instance, does vegetation have more of an effect on impulsive crimes than on "rational" crimes? We might expect impulsive crimes committed out of frustration or rage to be reduced through the beneficial effects of vegetation on mental fatigue. And to the extent that perpetrators consciously calculate risks in selecting their targets, more "rational," premeditated crimes might be reduced through the beneficial effects of vegetation on informal surveillance.

In examining the outcomes of planting interventions, it will be important to address the possible displacement of crime. One of the standard concerns in efforts to combat crime is that although interventions may reduce crime in

targeted locations, the effect may be to simply displace crime to other areas, yielding no overall decrease in crime (Gabor, 1981). Would adding vegetation and decreasing crime in one part of an inner-city neighborhood simply increase crime in another part of the neighborhood? The answer may depend on the type of crime in question. By reducing the irritability, impulsivity, and cognitive deficits associated with mental fatigue and hence preventing minor conflicts from spiraling out of control, vegetation might inhibit violent crimes in some residences without increasing violent crimes in others. On the other hand, by increasing informal surveillance of some outdoor spaces without reducing the actual impetus for burglary and other premeditated crimes, vegetation might serve to simply shift such crimes to more vulnerable targets. Future research should examine rates of crime both in and around the intervention areas.

Such comparisons might shed light on the mechanisms by which vegetation affects crime. To further address the question of mechanism, levels of informal surveillance and mental fatigue might be measured in buildings receiving the planting intervention and in matched buildings selected as controls. Mediation analyses could then be conducted to examine the joint links between vegetation, crime, and the proposed mediators. Does vegetation affect crime only when it increases residents' use of outdoor spaces and levels of informal surveillance?

Finally, one exciting possibility for future work would be to compare the outcomes from intervention studies in which residents were either involved or uninvolved in the greening process. The question here would be whether the process of tree planting could enhance residents' territoriality, thereby deterring crime over and above the direct effect of the presence of vegetation. Active involvement in tree-planting programs has been claimed to enhance a community's sense of territoriality (Dwyer, McPherson, Schroeder, & Rowntree, 1992), and the community greening lore is replete with stories in which greening efforts have been accompanied by dramatic decreases in crime and incivilities (e.g., Hynes, 1996; Lewis, 1980; Littman, 1996; Trust for Public Lands, 1996). Previous research in inner-city neighborhoods suggests that residents would be willing to help plant and care for trees (Kuo, Bacaicoa, et al., 1998). As planting is the single largest cost associated with the care and maintenance of the urban forest (McPherson, Nowak, & Rowntree, 1994), involving residents would substantially defray the already low costs associated with a planting intervention.

Ultimately, the largest reductions in crime will come from strategies that address the factors underlying crime (e.g., intense poverty and the availability of guns). In the meantime, this study offers a ray of hope by identifying an easily manipulable environmental feature that has a systematic, negative

relationship with property crimes, violent crime, and total crimes. The work presented here suggests the exciting possibility that in barren inner-city neighborhoods, planting a few trees may work to inhibit crime, creating safer neighborhoods for poor families and their children.

NOTE

1. In these data, agreement between raters is analogous to the reliability of items in a scale; the hope is that different raters will respond to a particular building in a similar fashion. Thus, to assess interrater agreement, a Cronbach's alpha was calculated with individual raters treated like individual items in a scale and individual buildings treated like individual respondents.

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AGGRESSION AND VIOLENCE IN THE INNER CITY
Effects of Environment via Mental Fatigue

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ABSTRACT: S. Kaplan suggested that one outcome of mental fatigue may be an increased propensity for outbursts of anger and even violence. If so, contact with nature, which appears to mitigate mental fatigue, may reduce aggression and violence. This study investigated that possibility in a setting and population with relatively high rates of aggression: inner-city urban public housing residents. Levels of aggression were compared for 145 urban public housing residents randomly assigned to buildings with varying levels of nearby nature (trees and grass). Attentional functioning was assessed as an index of mental fatigue. Residents living in relatively barren buildings reported more aggression and violence than did their counterparts in greener buildings. Moreover, levels of mental fatigue were higher in barren buildings, and aggression accompanied mental fatigue. Tests for the proposed mechanism and for alternative mechanisms indicated that the relationship between nearby nature and aggression was fully mediated through attentional functioning.

The power of the physical environment to influence human aggression is well established. Crowding, high temperatures, and noise have all been linked to aggression and violence (Baker, 1984; Baum & Koman, 1976; Donnerstein & Wilson, 1976; Rule, Taylor, & Dobbs, 1987). Each of these features of the physical environment has been associated with heightened levels of aggression; are there features of the physical environment that work to diminish levels of aggression and violence? This study examines whether

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natural elements such as trees and grass can decrease aggression. In addition, it tests a potential mechanism by which natural features—and by extension other environmental features—may affect aggression. In doing so, it suggests a new role for environment and behavior research in an important public policy domain—addressing aggression and violence in inner cities—and contributes possible new insight into the psychological factors underlying human aggression.

There are hints in the literature that exposure to nearby nature, for instance, a garden or a grassy area with trees, may reduce aggression. For instance, violent assaults by Alzheimer patients were compared during two consecutive summers in five long-term care facilities, two in which exterior gardens were installed and three without gardens (Mooney & Nicell, 1992). In Alzheimer patients, increases in the number of aggressive assaults each year are typical as a consequence of the progressive deterioration of cognitive processes; and indeed, in the facilities without gardens, the incidence of violent assaults increased dramatically. By contrast, in the other facilities, the incidence of violent assaults stayed the same or decreased slightly after gardens were installed. More recently in another study, some subsets of prison inmates reported less hostility after participating in a gardening project than before, although these findings were not consistent across different analyses (Rice & Remy, 1998).

Why might we expect the findings from these two studies to reflect a more general, systematic phenomenon? By what mechanism might exposure to nearby nature leave individuals in a less aggressive state? Here, we review

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AUTHORS' NOTE: *A portion of these findings was presented in invited testimony to the National Urban and Community Forestry Advisory Council (NUCFAC) and at the 27th International Conference of the Environmental Design Research Association, Salt Lake City, Utah, May 1996. The data for this study were drawn from the Coping With Poverty archive, a multistudy research effort supported by a grant from NUCFAC (F. E. Kuo and W. C. Sullivan, principal investigators). This work was also supported by the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture, under Project No. ILLU-65-0387. Thanks go to Rebekah Coley for training and supervising resident interviewers, Esther Davis and Doris Gayles for recruiting and interviewing participants, the Robert Taylor Homes residents for their participation, and the management of the Chicago Housing Authority for their assistance throughout. Ann Schlosser suggested the Conflict Tactics Scale and made many contributions during the early stages of this project.* *Correspondence concerning this article should be addressed to Frances E. Kuo, Human-Environment Research Laboratory, University of Illinois, 1103 S. Dorner, Urbana, IL 61801; e-mail: f-kuo@uiuc.edu.*

theory and evidence suggesting first that natural settings assist in recovery from mental fatigue and second that aggression may increase with mental fatigue and decrease with its recovery. We then present an analysis suggesting that residents of disadvantaged inner-city neighborhoods may be subject to chronic mental fatigue. Finally, we test the possibility that, in an urban public housing community, the presence of trees and grass lowers the incidence of aggressive and violent behavior among residents living nearby.

NATURE AND MENTAL FATIGUE

Attention restoration theory (S. Kaplan, 1995) proposes that exposure to nature reduces mental fatigue, or more precisely, directed attention fatigue. S. Kaplan (1995) noted that many settings, stimuli, and tasks in modern life draw on the capacity to deliberately direct attention or pay attention. The information-processing demands of everyday life—traffic, phones, conversations, problems at work, and complex decisions—all take their toll, resulting in mental fatigue, a state characterized by inattentiveness, irritability, and impulsivity. In contrast, natural settings and stimuli such as landscapes and animals seem to effortlessly engage our attention, allowing us to attend without paying attention. For this and a number of other reasons, S. Kaplan suggested, contact with nature provides a respite from deliberately directing one's attention.

Indeed, there is growing empirical evidence of the attentionally restorative effects of natural settings. Evidence of cognitively rejuvenating effects comes from a variety of "natural" settings, including wilderness areas (Hartig, Mang, & Evans, 1991; R. Kaplan, 1984), prairies (Miles, Sullivan, & Kuo, 1998), community parks (Canin, 1991; Cimprich, 1993), views of nature through windows (Ovitt, 1996; Tennessen & Cimprich, 1995), and even rooms with interior plants (Lohr, Pearson-Mims, & Goodwin, 1996). Moreover, these studies have demonstrated links between contact with nature and more effective attentional functioning in a variety of populations—AIDS caregivers, cancer patients, college students, prairie restoration volunteers, participants in a wilderness program, and employees of large organizations.

MENTAL FATIGUE AND AGGRESSION

If contact with nature is attentionally restorative, how then might attentional restoration mitigate aggression? S. Kaplan (1987) suggested that one of the costs of mental fatigue might be a heightened propensity for "outbursts of anger and potentially . . . violence" (p. 57). The following analysis

shows how each of three symptoms of mental fatigue might contribute to aggression.

First, mental fatigue may contribute to aggression because of its effects on cognitive processing. A common theme in some recent theories of aggression is that information processing plays a central role in managing social situations, especially potential conflicts (e.g., Crick & Dodge, 1994; Dodge & Crick, 1990; Dodge & Schwartz, 1997; Martinko & Zellars, 1998). For example, Dodge and Crick (1990) proposed that a child's behavioral response to a social stimulus is a function of the following five steps of information processing: encoding of social cues, interpretation of social cues, response search, response evaluation, and enactment. The proposal here is that in problematic social situations, relatively automatic, effortless cognitive processing (e.g., "Bob took my computer station!") is more likely to generate conflict-escalating behavior than is more reasoned, effortful, reflective processing (e.g., "Hmm . . . did I leave any clues that I was working there?"). As the individual's willingness and ability to engage in more reflective, effortful processing decreases with mental fatigue, social behavior is likely to become increasingly thoughtless, tactless, and unstrategic, allowing conflicts to spiral out of control (see Rubin, Bream, & Rose-Krasnor, 1991, for a similar proposal with respect to children's social problem solving).

There is some evidence to suggest that deficits in effortful processing are indeed associated with aggression. In school settings, deficits in effortful processing are likely to manifest in inattentiveness, and inattentiveness has been closely tied to aggression in both children (Stewart, 1985) and adolescents (Scholte, van Aken, & van Lieshout, 1997). Indeed, the tie between attention deficits and hyperactivity on one hand and conduct problems and aggression on the other has been so strong that there has been some debate as to whether these disorders are distinct (see Hinshaw, 1987, for a meta-analysis indicating that these disorders are distinct although correlated). Conversely, Rabiner, Lenhart, and Lochman (1990) found that when aggressive children were encouraged to be more reflective in their responses to problematic social situations, their generation of conflict-escalating responses dropped to the same levels as their nonaggressive, nonrejected peers. Thus, it seems plausible that the deficits in effortful processing that are symptomatic of mental fatigue may contribute to aggression.

Mental fatigue may also contribute to aggression because of its effects on emotion—specifically, heightened irritability. Irritability appears to be a frequent side effect of mentally fatiguing tasks, such as the vigilance tasks involved in air traffic control (Thackray, Bailey, & Touchstone, 1979; Warm & Dember, 1986). Not surprisingly, irritability is linked with aggression in numerous studies (e.g., Caprara & Renzi, 1981; Coccaro, Bergeman,

Kavoussi, & Seroczynski, 1997; Kant, Smith-Seemiller, & Zeiler, 1998; Kavoussi & Coccaro, 1998; Stanford, Greve, & Dickens, 1995). Irritable individuals are prone to aggression when faced with frustration (Caprara & Renzi, 1981), and pharmacological treatments that reduce aggression also reduce irritability (Kant et al., 1998; Kavoussi & Coccaro, 1998). Thus, it seems plausible that the irritability symptomatic of mental fatigue might contribute to aggression.

Finally, mental fatigue may also contribute to aggression because of its effects on behavior—specifically, decreased control over impulses. S. Kaplan (1987) noted that one of the hallmarks of mental fatigue is a difficulty inhibiting behavioral impulses. Impulsivity in turn is associated with aggression and violence in a variety of populations (for reviews, see Brady, Myrick, & McElroy, 1998; Markovitz, 1995; Tuinier, Verhoeven, & Van Praag, 1996). Violent parolees are more impulsive than nonviolent parolees (Cherek, Moeller, Dougherty, & Rhoades, 1997), maritally violent men are more impulsive than maritally nonviolent men (Barnett & Hamberger, 1992), and among depressed males, impulsive individuals are more likely to be aggressive than nonimpulsive individuals (Hynan & Grush, 1986). Not surprisingly, then, Luengo and colleagues (Luengo, Carrillo-de-la-Pena, Otero, & Romero, 1994) found in their 1-year longitudinal study that present impulsivity ratings predict future antisocial behavior, including aggression.

In sum, each of these factors—impairments in effortful cognitive processing, irritability, and impulsivity—has been independently implicated in aggression. To the extent that mental fatigue combines these three factors, mental fatigue seems likely to contribute substantially to aggression.

INNER CITIES AND CHRONIC MENTAL FATIGUE

Poor, inner-city neighborhoods may be an especially promising context in which to study the effects of nature and attentional restoration on aggression. As the following analysis, drawn from Kuo (1992), suggests, the attentional demands associated with poverty and the inner-city environment are likely to place this population at special risk for chronic mental fatigue and fatigue-related aggression. As a consequence, residents of poor, inner-city neighborhoods may have a special need for the mental respite provided by nearby nature.

The attentional demands of poverty are many and unremitting. For the poor, even basic concerns such as rent, utilities, and food are ongoing challenges that require effortful problem solving and reasoning. Added to these are the attentional challenges posed by major life events. Poverty brings with it a greater susceptibility and vulnerability to drastic life changes.

Underinsured and having no financial cushion against setbacks, even a minor temporary trauma such as a child's illness can have far-reaching effects, eventually necessitating major readjustments in life, family, and work domains. Making these adjustments requires sustained, high levels of mental functioning.

Moreover, the environmental characteristics of inner-city neighborhoods place additional demands on attention. First and foremost, the ever-present possibility of crime or violence places high demands on attention (see Cohen & Spacapan, 1978, for an analysis of the attentional demands imposed by unpredictable stressors). Danger requires individuals to be vigilant for signs of impending trouble, to continuously consider possible responses to new situations, and to consider the ramifications of those responses. Second, the home environment may place further demands on attention; lack of adequate space and facilities makes purposive functioning more effortful as more problem solving is required to accomplish goals in unsupportive or inadequate settings. Problem solving may be made all the more fatiguing by the lack of quiet, safe settings in which to think. And finally, for the many inner-city residents who lack natural settings in their everyday environment (nearby parks, views to green spaces, and gardens), recovery from mental fatigue may be especially rare.

Over time, the ongoing and acute attentional demands of poverty, in combination with the mentally fatiguing characteristics of the inner-city environment, seem likely to yield chronic high levels of mental fatigue. Thus, among inner-city inhabitants lacking ready access to attentionally restorative settings, we might expect chronic high levels of mental fatigue and a heightened propensity for aggressive behavior. Conversely, among residents with ready access to nature, we might expect comparatively low levels of mental fatigue and aggression.

Two questions are central to this study. First, does nearby nature reduce aggression and violence? And second, if so, is this effect mediated via attentional restoration? To examine these questions, structured interviews and attentional tests were conducted with urban public housing residents. Because official adult residents are predominately single mothers, the structured interviews focused on intrafamily aggression and violence rather than other forms of violence. Attentional performance and self-reports of aggression were then compared for residents living in buildings with relatively high versus relatively low levels of nearby nature, and mediation tests were used to examine whether attentional restoration might account for a relationship between nature and aggression.

To explore possible alternative accounts for a nature-aggression relationship, a number of additional tests were conducted. A test for spuriousness

(Evans & Lepore, 1997) was conducted to guard against alternative accounts in general. In addition, the following three particular alternative accounts were given specific attention: (a) Positive mood, (b) stress recovery, and (c) social support were each identified as theoretically plausible explanations for a link between nature and reduced aggression. Positive mood has been linked directly with contact with nature (Hull & Michael, 1995), and it seems plausible that positive moods could reduce the propensity for aggression (Pihl & Zacchia, 1986, tested this notion but found no evidence for it). Similarly, stress (or more precisely, recovery from stress) has been linked directly with contact with nature (Ulrich et al., 1991), and stress also appears to contribute to aggression (Bolger, Thomas, & Eckenrode, 1997; Chang, 1994). And finally, there is some indication that neighborhood social ties and support networks are stronger around greener neighborhood spaces (Kuo, Sullivan, Coley, & Brunson, 1998; Kweon, Sullivan, & Wiley, 1998); in turn, child abuse is less prevalent among parents who have social support (Garbarino & Sherman, 1980; Roth, 1986).

METHOD

THE SITE: A NATURAL EXPERIMENT ON THE EFFECTS OF NEARBY NATURE

A number of methodological criteria were employed in the selection of a site for this research. Robert Taylor Homes (RTH) in Chicago was rare in that it simultaneously met each of these criteria.

First, although the amount of vegetation outside the buildings at RTH varies considerably from building to building, other environmental features are held remarkably constant from one building to another. Because the buildings are architecturally identical, at RTH, building size, building layout, building facilities, architectural detail, and the number of residential units per building are held constant (see Figure 1). Moreover, because the buildings are placed in single file along a 3-mile corridor, the features of the surrounding landscape are similar from one building to another. Each building is bordered on the west by an interstate highway and railroad tracks and bordered on the east by a six-lane municipal thoroughfare and wide sidewalk.

Second, public housing policies result in de facto random assignment of residents with respect to levels of nearby nature at RTH. Although housing applicants to the Chicago Housing Authority can specify their choice of development (e.g., RTH vs. some other development), they have little choice

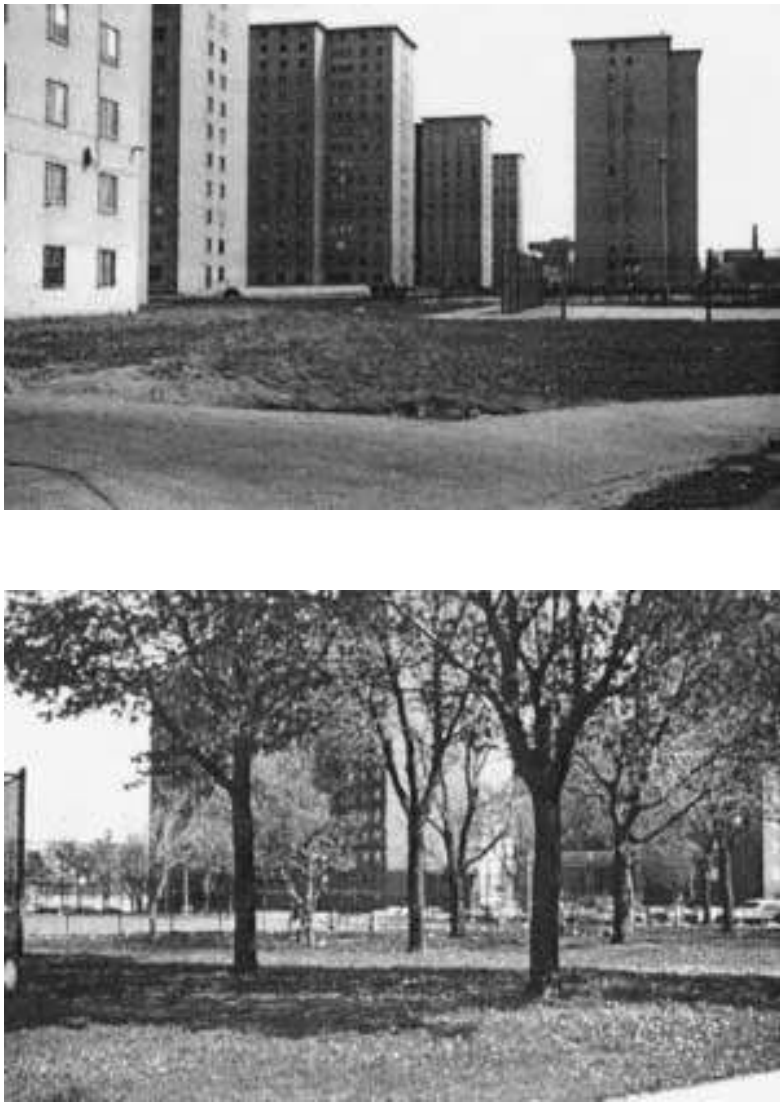

Figure 1: Attrition Has Left Some Buildings Surrounded by Only Concrete and Asphalt and Others With Pockets of Green

of where they will be assigned within a development (i.e., this apartment vs. another apartment within RTH).[1] Moreover, the scale of the Chicago Housing Authority precludes the placement of "better" (e.g., more responsible and less aggressive) residents in "better" (e.g., greener) locations. Clerks in a central office handle all assignments of residents to apartments for 40,700 units in 1,479 buildings across 17 developments throughout the city. They generally have never met or seen the applicants for housing and most likely have never set foot in most of the Housing Authority's developments. It is implausible that anyone could remember the characteristics of so many buildings, let alone take them into account in assigning apartments.

Third, residents at RTH have little role in the landscaping outside their building. When RTH was originally built in the 1960s, trees and grass were planted around each of the 28 high-rise buildings. Over time, the majority of these green spaces have been paved in an effort to keep dust down and maintenance costs low; this paving has killed many of the original trees, leaving some buildings with completely barren common spaces, others with a few scattered trees, and still others with leftover pockets of green. Ongoing landscape maintenance at RTH is handled entirely by a small landscaping crew serving all of the developments managed by the Chicago Housing Authority; residents are not involved in maintenance, and funds are inadequate to fulfill special requests from residents. Thus, a relationship between greenness of common spaces and aggression in this setting cannot be explained by a process in which especially effective or cooperative residents have made their surroundings greener.

In sum, RTH constitutes a naturally occurring experiment on the effects of residential vegetation, with random assignment of residents to vegetation conditions, no control of residents over levels of vegetation, and a host of environmental variables held constant. An additional methodologically desirable feature of RTH for this study is that the residents are strikingly homogeneous with respect to many of the individual characteristics that might be expected to affect aggression—income, education, life circumstances, and perhaps most important, economic opportunities.

PROCEDURE, PARTICIPANTS, AND DESIGN

To maximize participants' ease in responding, interviewers were selected to be as similar to interviewees as possible. Three African American female residents of RTH were hired and trained to conduct the recruitment, interviewing, and testing for this research. All three were longtime residents of RTH (19 years or more) residing in buildings outside the study sample. Thus,

interviewers were matched to interviewees not only in major demographic characteristics such as race, gender, and socioeconomic status but also in life circumstances, background, and more subtle social cues such as patterns of speech and dress.

In preparation for interviewing and testing, interviewers completed extensive training (50 hours of general training in interview methods, 12 hours learning the specific interview measures used, and 14 hours of supervised and unsupervised practice in performing practice interviews). In addition, an on-site research supervisor met regularly with the interviewers to review procedures and address any difficulties or questions. Interviewers did not interview individuals with whom they were previously familiar, and interviewers were counterbalanced for nature condition.

Recruitment was conducted door to door in buildings spanning the range of vegetation of RTH. Sampling was restricted to 18 buildings—buildings adjacent to parks, police stations, and other relatively unique features were excluded to minimize effects of extraneous factors on residents' access to nearby nature. Within buildings, sampling was restricted to apartments on Floors 2 through 4, where residents had maximal physical and visual access to the trees outside their building (there are no residences on the first floor).

Recruitment criteria included not only environmental factors but also resident characteristics. Women heads of household younger than the age of 65 were invited to participate in a University of Illinois study about life at RTH. Recruitment focused on women because official adult residents in urban public housing are overwhelmingly female—80% in RTH (Chicago Housing Authority, 1995).[2] Participants were told that they could refuse to answer any question and could stop the interview at any time and that they would receive $10 on completion of the interview.

Of the 158 qualified residents invited to participate, 92% chose to participate, yielding a final sample of 145 residents, 69 with relatively low levels of nearby nature and 76 with relatively high levels of nearby nature. The composite participant profile is that of a 34-year-old African American single woman with a high school or high school equivalency diploma raising three children on an annual household income of less than $10,000.

Individual interviews were conducted during summer and fall months in participants' apartments. Residents' attentional capacity, aggression, and a number of control variables likely to be associated with aggression were assessed as part of a 45-minute structured interview.

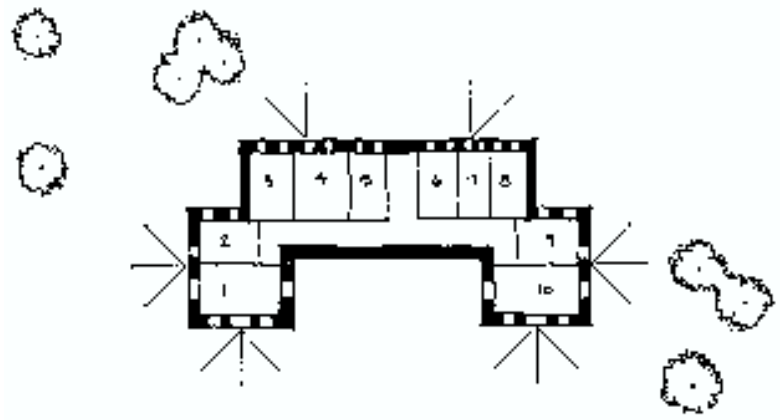

Figure 2: Plan View of an Apartment Building at Robert Taylor Homes With Nearby Trees

NOTE: The numbers within the building indicate apartments. The arrows indicate the position from which photographs were taken (for each building) that were then rated by 22 independent raters. Note that despite the presence of trees outside a building, residents in particular apartments may have little or no visual access to trees.

MEASURES

Nearby nature. Levels of nearby nature were assessed using standardized sets of photographs and multiple independent raters. For each of the 18 buildings to be sampled, a standardized set of photographs was taken from eye level of the area immediately surrounding the building. As Figure 2 shows, each standardized set comprises 16 photographs taken from specified vantage points; most showed views looking out from the building, and the remaining showed views looking across the building.

To obtain ratings of the nearby nature for each building, the photographs were arranged at 18 stations (drawing tables in a design studio), with each station showing all 16 photographs for a given building. Undergraduate and graduate students in horticulture then independently rated levels of nearby nature for each of the 18 buildings. First, raters visited each of the stations to familiarize themselves with the range of vegetation in the 18 buildings. Second, they visited each station again in turn and provided a single greenness rating for each building based on the 16 photographs. Raters were encouraged to use the entire response scale from 0 to 4 (0 = *not at all green*, 1 = *a*

little green, 2 = *somewhat green*, 3 = *quite green*, and 4 = *very green*). For each building, greenness ratings from the 22 raters were averaged to produce a summary greenness rating. These averaged greenness ratings ranged from 0.8 for the building with the least nearby nature to 3.6 for the greenest building.

With these data, agreement between raters is analogous to the reliability of items in a scale; the hope is that different raters will respond to a particular building in a similar fashion. Thus, to assess interrater agreement, a Cronbach's alpha was calculated, with individual raters treated as individual items in a scale and individual buildings treated as individual respondents. This procedure yielded an alpha of .97, indicating a high level of agreement between raters with regard to building greenness.

Greenness ratings were used as the basis for assignment to conditions. Buildings whose ratings fell below the midpoint of the range were designated *barren*; buildings whose ratings were at or above the midpoint were designated *green*. Greenness ratings for the 7 buildings in the barren condition ranged from 0.8 to 1.7, with a mean of 1.2. Greenness ratings for the 11 buildings in the green condition ranged from 2.0 to 3.6, with a mean of 2.6. In interpreting these ratings, it should be noted that because raters were encouraged to use the entire response scale, even a high greenness rating of 3.6, or *very green*, is relative to the range of vegetation at RTH; as Figure 1 shows, even the greenest pockets at RTH are neither especially large nor especially lush in vegetation.

There were no systematic differences between barren and green buildings in environmental factors such as pedestrian or automobile traffic, nearness to parking, or nearness to parks, schools, or other facilities. There was no systematic pattern in the sequence of green and barren buildings along the 3-mile corridor; green and barren buildings were not clustered but rather haphazardly interspersed. Some barren buildings were oriented north-south, others east-west; similarly for green buildings. For barren buildings, in the places where trees or grass might have been, there was only bare dirt or asphalt, and even the green buildings were surrounded by large areas of bare dirt or asphalt.

To check for possible condition differences in participant characteristics for barren versus green buildings, a series of *t* tests was conducted. As would be expected given random assignment of residents to nature conditions, no significant condition differences were found in demographic characteristics, household characteristics, or other variables potentially related to aggression. Specifically, green and barren participants did not differ in age, education, employment, income, size of household, marital status, number of

children, years in apartment, years in public housing, health ratings, health symptoms, alcohol use, prescription drug use, or other drug use.

Attentional functioning. The capacity for directed attention was assessed with the Digit Span Backwards (DSB) test. Digit Span Backwards is a standardized neurocognitive measure and is used in the measurement of attentional fatigue (Cimprich, 1993; Schwartz, 1994; Tennessen & Cimprich, 1995) and in the clinical measurement of attention (Lezak, 1983; Mesulam, 1985). DSB is particularly useful for field settings because it is easy to administer: The administrator reads aloud a series of digits (e.g., "2, 5, 1"), and participants are asked to repeat back the series in reverse order (e.g., "1, 5, 2"). Series are administered in increasing length; if a participant fails a series of a given length, a second series of equal length is administered. Scoring was based on the longest series performed correctly within two attempts.

Aggression. The Conflict Tactics Scale (CTS) (Straus, 1979) is a widely used self-report measure designed to assess levels of intrafamily aggression and violence. It has been used in more than 100 studies (see bibliography in Straus, 1995). The CTS has a test-retest reliability of .97 (parent-to-child aggression) (DuRant, Pendergrast, & Cadenhead, 1994), an internal consistency of .88 (wife-to-husband aggression) (Straus, Gelles, & Steinmetz, 1980), and good concurrent validity with other measures of parental psychosocial distress (Wissow, Wilson, Roter, Larson, & Hope, 1992).

To elicit reports of aggressive behavior, participants are asked to think of situations in which they had a disagreement or were angry with a specified family member and to indicate how often they used each of 18 conflict tactics, beginning with socially acceptable tactics (e.g., reasoning) and ending with violent tactics. Table 1 shows the 14 aggressive conflict tactics from the CTS. The responses to these 14 items provide an index of overall aggression. The first 6 items index psychological aggression: verbal and symbolic acts intended to cause psychological pain or fear. The remaining 8 items index violence: the use of physical force or violence. These 8 items comprise both mild violence (3 behaviors unlikely to cause injury) and severe violence (5 behaviors likely to cause injury).

For each of the specific conflict tactics, participants are asked to indicate how often they have used it in the past 12 months on a 7-point scale (0 = *never* to 6 = *more than 20 times*, with X = *don't know*). If participants reply never or don't know, they are then asked, "Did you ever . . . ?" (yes/no). These questions are asked in reference to two specified family members—first the

TABLE 1
Overall Aggression Items From the Conflict Tactics Scale

Psychological aggression
Insulted or swore at the other
Sulked or refused to talk
Stomped out of the room or house
Did or said something to spite the other
Threatened to hit or throw something
Threw or smashed or hit or kicked something
Violence
Mild violence
Pushed, grabbed, or shoved the other one
Slapped the other one
Threw something at the other one
Severe violence
Kicked, bit, or hit with a fist
Hit or tried to hit with something
Beat up the other one
Threatened with a knife or gun
Used a knife or gun

respondent's partner (or the adult with whom they are closest) and then their child (or if they have more than one, the child with whom they have the most conflicts).

This procedure yields estimates of both the frequency of specific aggressive behaviors used in the past year and the range of aggressive behaviors employed over the respondent's lifetime. In general, more aggressive persons employ a wider range of aggressive behaviors; for instance, Person A might only use verbally aggressive tactics, whereas Person B might use not only verbally aggressive tactics but also physically aggressive tactics. For each of the different categories of aggression (overall aggression, psychological aggression, and so forth), the range of tactics a respondent has used in that category is calculated by taking the proportion of the number of different tactics employed out of the total number of different tactics. For instance, an individual who has employed each of the 14 different overall aggression tactics would have an overall aggression range of 1.0; an individual who has employed only 7 of those tactics (typically, the less serious ones) would have an overall aggression range of 0.5. Similarly, the range of violent tactics would refer to the proportion of the 8 violent tactics that a respondent had employed. It should be noted that the term *range* is not used in the statistical sense here; the different conflict tactics are not assumed to be on an interval scale.

Other factors likely to affect aggression. Three additional variables that seemed likely to be related to nearby nature, attention, or aggression were assessed through self-report using a 5-point scale (0 = *not at all*, 1 = *a little*, 2 = *a medium amount*, 3 = *quite a lot*, and 4 = *very much*). Positive mood was assessed with the Positive Mood subscale of the Profile of Mood States (POMS). Participants rated themselves on six adjectives (lively, active, energetic, cheerful, full of pep, and vigorous). The POMS has been shown to be a valid and reliable instrument for the measurement of mood (McNair, Lorr, & Droppleman, 1981). Stress was assessed with the question "How stressful is this period in your life?" And social integration was assessed with an 8-item scale, alpha = .80, that included items such as "How well do you know the people next door?"; "Are people here concerned with helping and supporting one another?"; and "Is there a strong feeling of belonging here?" (see Kuo et al., 1998, for details).

RESULTS

Results are presented in three subsections. First, descriptive statistics on intrafamily aggression and participants' attentional resources are presented. Second, the central hypothesis is tested. And third, potential mechanisms underlying the relationship between nearby nature and aggression are explored.

AGGRESSION AND MENTAL FATIGUE AT ROBERT TAYLOR HOMES

Consistent with previous research, levels of aggression in this population were much higher than in national samples. A majority of participants in this sample (61%) reported having engaged in a violent act against their partner at least once in their lives, a rate approximately 4 times that reported in two national probability samples of couples in the United States (Straus, 1979; Straus & Gelles, 1988) but consistent with rates from a sample of formerly married African American women (57%) (Neff, Holamon, & Schluter, 1995). Aggression against children showed much the same pattern. A majority of the participants in this sample reported hitting their child with something at least once in their lives (56%), approximately 4 times the rate reported in a national sample of two-caretaker households with at least one child (Straus & Gelles, 1986).

Participants' DSB scores provide an index of attentional resources in this inner-city population. According to Lezak (1983), scores of 4 or 5 on this version of the DSB test are within normal limits, depending on the individual's educational level. In this sample, the mean DSB score was 4.8, with a standard deviation of 1.1, indicating substantial variation in attentional functioning.

TESTING THE CENTRAL HYPOTHESES

If the availability of nearby nature reduces the propensity for aggression, then residents living in green conditions should report less aggression than their counterparts living in barren conditions: less frequent aggression in the past year and a narrower range of aggressive tactics used over the course of their lifetime. A series of planned, one-tailed *t* tests were conducted to examine condition differences in frequency and range of aggression, first against the respondent's partner and then against their child.

Aggression against partner. Tables 2 and 3 show the findings with respect to the frequency of aggression against partner in the past year and the range of aggressive tactics used against partner over the lifetime.

As the first row of Table 2 shows, there was a significant condition difference in the frequency of overall aggression against partner during the past year. That is, residents living in green conditions reported significantly less overall aggression against their partners than did their counterparts living in barren conditions. The following rows in Table 2 show the findings for specific forms of aggression. The second row indicates that there was a significant condition difference in psychological aggression against partner; residents living in green conditions were significantly less likely to have engaged in psychological aggression against their partners than were residents living in barren conditions. Does this effect extend to more violent forms of aggression? Because the violence indices produce extremely skewed distributions, Straus (1979) recommended dichotomizing these indices into violent and nonviolent categories. If a participant had engaged in at least one of the eight violent conflict tactics during the past year, they were designated violent; otherwise, they were designated nonviolent. As rows 3 through 5 of Table 2 show, nearby nature is related to the use of violence against partner during the past year. Violence scores were significantly lower for residents living in green conditions than those living in barren conditions. Furthermore, this pattern held for both the more mild forms of violence and the more severe forms of violence. Both mild violence rates and severe

TABLE 2
Mean Rates of Aggression Against Partner During Past Year in Green Versus Barren Condition

	Barren		*Green*			
	M	SD	M	SD	t	p
Overall aggression	1.04	0.88	0.76	1.07	1.68	< .05
Psychological aggression	1.47	1.20	1.00	1.26	2.24	.01
Violence	0.73	0.45	0.49	0.50	2.99	< .01
Mild violence	0.73	0.45	0.49	0.50	3.06	.001
Severe violence	0.48	0.50	0.31	0.47	2.10	< .05

NOTE: The response scale for the original items in this table was from 0 (*never*) to 6 (*more than 20 times*). Because the violence, mild violence, and severe violence indices were skewed, we followed Straus's (1979, p. 80) recommendation that these scales be dichotomized into violent and nonviolent categories. Thus, for these three indices, 0 indicates having engaged in none of the specific tactics during the past year, and 1 indicates having engaged in at least one of the tactics during the past year. Degrees of freedom ranged from 136 to 140.

TABLE 3
Range of Aggression Tactics Used Against Partner in Lifetime in Green Versus Barren Conditions

	Barren		*Green*			
	M	SD	M	SD	t	p
Overall aggression	.44	.28	.32	.30	2.39	< .01
Psychological aggression	.58	.36	.44	.35	2.46	< .01
Violence	.32	.27	.24	.32	1.54	.06
Mild violence	.52	.39	.35	.40	2.50	< .01
Severe violence	.19	.24	.16	.29	0.80	.22

NOTE: In response to questions about having ever used specific aggressive conflict tactics, participants responded never (0) or yes (1). Standard deviations are in parentheses; degrees of freedom ranged from 136 to 140.

violence rates were significantly lower in the green condition than in the barren condition. Mean differences between the green and barren conditions for the various aggression subscales ranged from one third to one half of a standard deviation.

Table 3 shows the findings with respect to the range of aggressive conflict tactics used against partner over the participant's lifetime. As the first row shows, there was a significant condition difference in the range of overall aggression tactics used. That is, residents living in green conditions report

using a narrower set of aggressive conflict tactics against their partners over their lifetime than did their counterparts living in barren conditions. The following rows in Table 3 show the findings for specific forms of aggression. The second row indicates that there was a significant condition difference in psychological aggression against partner; residents living in green conditions used a significantly narrower set of psychologically aggressive conflict tactics than did residents living in barren conditions. The third row of the table suggests that nearby nature may be related to the range of violent conflict tactics used against partners. For residents living in green conditions, the set of violent tactics used was 25% smaller than for those living in barren conditions, a marginally significant difference ($p = .06$). Although there was no difference in the range of severe forms of violence used against partners, there was a significant condition difference in more mild forms: Residents living in green conditions report using a smaller set of mildly violent conflict tactics against their partners over their lifetime than did their counterparts living in barren conditions. Mean differences between the green and barren conditions ranged from more than one quarter to one half of a standard deviation.

Aggression against a child. The conditions leading to aggression against an adult family member may be quite different from those leading to aggression against one's child. Conflicts with children are likely to be more frequent than those with adult family members and often center around disciplinary issues. At the same time, some forms of aggression may be less socially acceptable against children than against adults. Does the relationship between nearby nature and aggression found for women and their partners exist for women and their children? Condition differences were examined for aggressive conflict tactics used with children, specifically, the child with whom the participant had the most conflicts. A t test showed that greenness was related to the range of psychologically aggressive tactics used against children: Lifetime scores for proportion of psychologically aggressive tactics used were significantly lower for participants living in the green condition than for their counterparts living in the barren condition (.54 vs. .62), $t(140) = 1.83$, $p < .05$. But the effect did not hold for the frequency of psychological aggression during the past year or for the frequency or range of more violent forms of aggression against children.

In sum, there were a number of indications that nearby nature has a mitigating effect on aggression and violence: Nearby nature was systematically related to lower scores on multiple indices of aggression against partners and one index of aggression against children.

TESTING FOR UNDERLYING MECHANISMS

What mechanism or mechanisms might underlie the association between nearby nature and aggression? The following analyses tested for each of the following: the proposed mechanism, the possibility that some unspecified mechanism might be at work, and three specific alternative mechanisms.

If effects of nearby nature on aggression operate through attentional restoration, a number of predictions follow. First, residents living in green conditions should show higher levels of attentional functioning than their counterparts living in barren conditions. A planned student *t* test showed that indeed, mean DSB scores were significantly higher in the green condition ($M = 5.0$, $SD = 1.0$) than in the barren condition ($M = 4.6$, $SD = 1.2$), $t(138) = 1.74$, $p < .05$, differing by more than one third of a standard deviation.

Second, if effects of nearby nature on aggression operate through attentional restoration, then attentional functioning should be systematically related to aggression. Using the lifetime measure of overall aggression against partner as a summary index of aggression, an ordinary least squares regression was conducted using DSB scores to predict levels of aggression. As predicted, there was a significant negative relationship between DSB performance and overall aggression ($\beta = -.26$, $R^2 = .07$, $F = 9.9$, $p < .0025$). By this summary measure of aggression, the better a participant's attentional functioning, the less aggression she had engaged in.

And finally, if effects of nearby nature on aggression operate through attentional restoration, the relationship between nature and aggression should statistically depend on the relationship between attention and aggression. These interdependencies are important to examine when hypothesizing mediation because significant associations among three variables are possible without there being a mediation relationship between them. For example, in this case, nearby nature might enhance attention and reduce aggression but influence aggression through some other mechanism than attention. In that case, the nature-aggression relationship would most likely be statistically independent of the nature-attention relationship. If, on the other hand, contact with nearby nature reduces aggression via the restoration of attentional resources, we would expect the nature-aggression relationship to diminish or disappear when attention is statistically controlled.

Accordingly, a multiple regression was used to test for the joint relationships among nearby nature, attentional performance, and levels of aggression. When DSB (the proposed mediator) was controlled in a regression between greenness and overall aggression, greenness was no longer a significant predictor ($\beta = -.13$, $p = .11$, $R^2 = .09$, $F = 6.5$, $p < .0025$). Complete, or

"perfect," mediation requires that the independent variable has no additional predictive power when the mediator is controlled (Baron & Kenny, 1986); thus, these findings indicate that attentional restoration could be the sole mechanism underlying the nature-aggression relationship found here.

Could the links among nature, attention, and aggression be explained by some unspecified confounding variable or some alternative mechanism? Evans and Lepore (1997) suggested addressing what they referred to as "the spuriousness problem" by conducting an analysis in which the relationship between the hypothesized mediator and the outcome variable is examined while the independent variable is controlled. By their reasoning, if there is some unspecified confounding variable responsible for the relationships among nature, attention, and aggression, then attention will not be significantly related to aggression when nature is controlled. In fact, the multiple regression described earlier addresses this possibility: DSB was a significant predictor of overall aggression ($\beta = -.24$, $p < .01$) when greenness was controlled. This finding indicates that some unspecified mechanism cannot account for the relationships among DSB, greenness, and overall aggression.

These findings were echoed in follow-up analyses examining the following three specific, theoretically plausible, alternative mechanisms: positive mood, stress, and social integration. Planned student t tests showed that greenness was unrelated to positive mood, $t(142) = -.04$, $p = .48$, and stress, $t(140) = .17$, $p = .43$, but was related to social integration, $t(140) = 2.7$, $p < .01$. Correlational analyses showed that overall aggression was related to neither mood, $r(141) = -.07$, $p = .48$, nor stress, $r(139) = .135$, $p = .11$, nor social integration, $r(142) = -.06$, $p = .48$. Together, these results indicate that neither positive mood, nor stress, nor social integration mediate the nature-aggression relationship found here. Moreover, these analyses reinforce the aforementioned mediation and spuriousness findings, indicating that the effect of nature on aggression found here may be wholly mediated through attentional restoration.

DISCUSSION

In 145 adult women randomly assigned to a series of architecturally identical apartment buildings, levels of aggression and violence were significantly lower among individuals who had some nearby nature outside their apartments than among their counterparts who lived in barren conditions. Furthermore, as would be predicted if this relationship were mediated by mental (attentional) fatigue, (a) residents living in greener settings

demonstrated reliably better performance on measures of attentional functioning, (b) attentional performance predicted scores on a summary index of aggression, and (c) the relationship between nearby nature and aggression scores became nonsignificant when attention was controlled. Finally, follow-up analyses examining potential alternative mediators revealed no significant relationships between aggression and mood, stress, or social integration, and a test for unspecified mediators similarly ruled out alternative mechanisms.

It should be noted that the predicted relationship between nearby nature and aggression was not consistently found for more violent forms of aggression or for aggression against children. Of the various forms of aggression examined in this study, these may be the most susceptible to social desirability effects. Future research might use other strategies to examine the nature-aggression relationship for forms of aggression that are most difficult to assess through self-report.

To what extent can the nature-aggression relationship found here be interpreted as an effect of nearby nature on aggression? The following considerations lend confidence in a causal interpretation of these data: the random assignment of residents to nature condition; the consistently negative findings across numerous checks for condition differences in participant, household, and interviewer characteristics; the consistency of architectural and other environmental features over the two conditions; the use of multiple buildings per condition; and the use of double-blind measures for both nearby nature and aggression. Numerous tests were conducted to identify the particular causal pathway between nature and aggression. Results from all of these tests were of one accord: The mediation tests indicated a pathway through attention, and the spuriousness test and direct tests of alternative mediators all worked to rule out other possible pathways. Although other possibilities cannot be ruled out entirely, the only interpretation consistent with the complete set of findings here is that nearby nature reduces aggression by supporting attentional functioning. At this juncture, attention restoration theory (S. Kaplan, 1995) provides the best explanation for the link between nature and aggression.

Having addressed the question of internal validity, we turn now to external validity. To what extent do the relationships found in this study generalize to the real world? External validity depends in large part on how the constructs in a study are operationalized. In this study, the constructs were operationalized as directly as possible; to the extent we could, we avoided using surrogates or proxies. For example, measuring the vegetation around participants' homes was a more direct way to assess the effects of residential

nature than, say, showing slides of nature in a classroom. Similarly, using a performance measure of attention provided a more direct measure of attentional functioning than asking participants to rate how attentive they feel. And, asking participants to estimate the actual frequency of specific aggressive behaviors in the past year provided a more direct measure of in situ aggression than obtaining ratings of feelings of aggression in a laboratory setting or eliciting hostile attributions in hypothetical contexts. Relying on relatively direct measures of nature, attention, and aggression lends greater confidence that the relationships found here are true outside of this study. The large sample size employed (145 participants) further strengthens the case for external validity.

At the same time, there is reason for caution in assuming that these effects generalize to forms of aggression not studied here or to aggression in other populations and settings. Although the mental fatigue hypothesis should apply to many forms of aggression and it is quite clear that both men and women are subject to mental fatigue, this work examined only intrafamily aggression by women. Future research should examine effects of nature on aggression by men and other forms of aggression (e.g., road rage and gang violence).

These qualifications notwithstanding, domestic violence is an important topic in and of itself, and findings with regard to domestic violence have far-reaching implications. A substantial literature has established that compared with children from nonviolent families, children of violent families are more likely to grow up to be violent. This increased risk for violent behavior includes not only children who were victims of abuse but also those who witnessed abuse (Bandura, 1973, 1978; DuRant et al., 1994; Rice & Remy, 1998; Wissow et al., 1992; Wolfe, Jaffe, Wilson, & Zak, 1985). Thus, identifying possible avenues to reducing domestic violence may pay benefits for generations to come. By reducing intrafamily aggression and thus children's socialization into aggressive and violent behaviors, green neighborhood spaces may indirectly reduce aggression in future generations.

This work has implications for understanding and preventing aggression and for our understanding of the psychological effects of natural environments.

UNDERSTANDING AND PREVENTING AGGRESSION

One contribution of this work is to suggest a potential explanation for a number of poorly understood phenomena in the environment-behavior literature on human aggression. Mental fatigue might help account for the relationships found between crowding and aggression (Ani & Grantham-McGregor,

1998; Nijman & Rector, 1999; Palmstierna, Huitfeldt, & Wistedt, 1991) and noise and aggression (Donnerstein & Wilson, 1976; Gaur, 1988; Geen & McCown, 1984; Sherrod, Moore, & Underwood, 1979), and for urban-rural differences in aggression (Fingerhut, Ingram, & Feldman, 1998). Noise and crowding both seem likely to place demands on attention (Cohen & Spacapan, 1978), and urban environments tend not only to be noisier and more crowded than rural environments but also less green than rural environments. Thus, urban environments seem likely to be more attentionally fatiguing and less attentionally restorative in general than rural environments. Future research might examine whether these phenomena are indeed fatigue related.

This work may also offer insight into some phenomena in human aggression that do not necessarily involve the physical environment. For example, both the extremely high rates of aggression and violence in poor families and the link between stressful life events and aggression (Guerra, Huesmann, Tolan, Van Acker, & Eron, 1995; Hammond & Yung, 1991; Patterson, Kupersmidt, & Vaden, 1990; Spencer, Dobbs, & Phillips, 1988; Straus et al., 1980) might be explained at least in part by mental fatigue. As described in the introduction, poverty is likely to place relatively high, unremitting demands on attention. And stressful life events such as moving to a new home or having a family member become seriously ill can involve substantial amounts of problem solving, contingency planning, and other attentionally demanding, mentally fatiguing forms of cognition. If the relatively high rates of aggression associated with poverty and stressful life events are indeed partially attributable to mental fatigue, future research should find links between poverty and mental fatigue as well as links between stressful life events and mental fatigue.

This work also suggests a number of possible interventions for addressing aggression and violence in the inner city. Specifically, efforts to improve conflict behavior might involve preventing, detecting, and treating attentional fatigue. For example, conflict behavior might be improved by preventing attentional fatigue through reducing the attentional demands of the environment by means of soundproofing, reducing crowding, and increasing safety. Similarly, providing insurance against the drastic life changes to which the poor are most susceptible might also help prevent fatigue and fatigue-related aggression. DSB and other tests of attentional functioning might help detect fatigue and let individuals know when they are most at risk for aggressive or violent behavior. Finally, strategies for treating attentional fatigue, including taking green breaks and getting more sleep, might help prevent fatigue-related aggression.

UNDERSTANDING THE EFFECTS OF NATURAL ENVIRONMENTS ON HUMAN BEHAVIOR

This work contributes to our understanding of the psychological effects of natural environments in a number of ways. First, the findings provide strong evidence for a potential effect of nature that has been largely unexplored—reducing aggression and violence. Previous research on the effects of nature has focused on its effects on mood, recovery from stress, everyday functioning, and attention (e.g., Cimprich, 1993; Hartig et al., 1991; Hull & Michael, 1995; Ulrich et al., 1991), and only two previous studies have hinted at a potential effect of nature on aggression (Mooney & Nicell, 1992; Rice & Remy, 1998). This study demonstrates a link between nature and reduced aggression in an experimental design and provides clear support for the proposed mechanism of attentional restoration. In doing so, it extends attention restoration theory and shows that the theory has implications for a concern as important and socially relevant as levels of aggression and violence in inner-city neighborhoods.

A second contribution is to raise an interesting question with regard to the benefits of residential nature. In these data, the vegetation around apartment buildings was significantly related to measures of attentional functioning but not to measures of stress or positive mood. This is consistent with the previous literature: Other studies have found significant relationships between residential vegetation and measures of attention (R. Kaplan, 2001 [this issue]; Tennessen & Cimprich, 1995), and to date we are unaware of any studies demonstrating links between residential nature and either stress or positive mood. Are there in fact no relationships between residential nature and stress or residential nature and mood? Perhaps these relationships exist and the procedures in this study simply failed to uncover them. It also seems possible that mood and stress are simply not affected by highly habituated forms of nature. This seems a fascinating question for future research.

A third contribution of this work concerns the density and extent of nature necessary to convey benefits. It might seem implausible that a few trees and grass in relatively small areas outside public housing apartment buildings could have any clear effects on residents' levels of aggression. Yet this low dose of vegetation has been shown to have far-reaching and positive effects on a number of other important outcomes, including residents' management of major life issues (Kuo, 2001) and neighborhood social ties (Kuo et al., 1998; Kweon et al., 1998). Future research might explore how the benefits of contact with nature vary as a function of the density of vegetation.

A final contribution of this work is to suggest that the geographic distribution of natural areas matters. Although large central or regional parks are

clearly important components of urban design, the results of this study suggest that a few major parks are not enough. All residents of RTH live within 2 miles of one of the most extensive examples of urban nature in North America—Lake Michigan and the parks along Lake Shore Drive in Chicago. Yet the proximity to these tremendous natural resources is apparently insufficient to keep all residents of RTH at similar levels of attentional functioning. Perhaps, as Rachel Kaplan (1985) suggested, cities should be designed with nature at every doorstep.

NOTES

1. Given that residents do have some choice of apartment within Robert Taylor Homes (RTH), it seemed possible (although not likely) that better functioning and therefore potentially less aggressive residents might self-select into greener buildings. As a check on that possibility, participants were asked what criteria were important to them in choosing a place to live: Of 118 responses, 93% were clearly unrelated to levels of vegetation (47% of respondents "just needed a place;" 12% desired safety or cleanliness; 10% were concerned about access to work, school, or family; 9% were concerned about cost; 8% were concerned about space or number of bedrooms; 6% wanted an apartment on a "low floor," perhaps because of the frequency of elevator malfunctions; and 1 participant mentioned sense of community). Seven percent of respondents expressed concerns that might be interpreted as related to levels of vegetation (e.g., location, neighborhood, area, and environment), and 1 participant of the 145 specifically reported that a "natural setting" was important to her. However, analyses indicated that these participants lived in no greener areas on average than the remainder of the participants in this study. Thus, the level of nearby nature does not seem to be an important criterion in residents' selection of apartments within RTH; moreover, it appears that the level of choice residents have in selecting an apartment is sufficiently low that even residents who might strongly value access to nature are no more likely to be assigned to a green area.

2. Eligibility requirements for public housing and some other forms of public aid favor single mothers. This creates a pressure for families not to list adult males as official residents (and for these unofficial residents not to participate in studies about life at RTH).

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COPING WITH ADD
The Surprising Connection to Green Play Settings

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ABSTRACT: Attention Restoration Theory suggests that contact with nature supports attentional functioning, and a number of studies have found contact with everyday nature to be related to attention in adults. Is contact with everyday nature also related to the attentional functioning of children? This question was addressed through a study focusing on children with Attention Deficit Disorder (ADD). This study examined the relationship between children's nature exposure through leisure activities and their attentional functioning using both within- and between-subjects comparisons. Parents were surveyed regarding their child's attentional functioning after activities in several settings. Results indicate that children function better than usual after activities in green settings and that the "greener" a child's play area, the less severe his or her attention deficit symptoms. Thus, contact with nature may support attentional functioning in a population of children who desperately need attentional support.

Over 2 million children in the United States alone are struggling to cope with a chronic attentional deficit, Attention Deficit Disorder (ADD) (Barkley,

AUTHORS' NOTE: *This research was conducted in partial fulfillment of the requirements for a doctoral degree in Natural Resources and Environmental Sciences at the*

ENVIRONMENT AND BEHAVIOR, Vol. 33 No. 1, January 2001 54-77

1995).[1] ADD reduces children's attentional capacity and in doing so, has detrimental effects on many aspects of life (e.g., school, interpersonal relationships, personal growth). Unfortunately, of the available treatments, some have costly side effects, and the remaining have limited effectiveness. Surprisingly, the physical environment has not been examined as a potential source of support for children with ADD. Attention Restoration Theory (Kaplan, 1995) proposes that nature may support attentional functioning, and a growing body of evidence indicates that, in adults with regular attentional capacity, nature is supportive of attentional functioning. Could natural environments support attentional functioning in children with attention deficits? The study presented here examined the effects of children's afterschool and weekend activity settings on their attention deficit symptoms.

In this section, we describe ADD and its treatment, review the previous work on nature and attention, and present the central questions motivating this study.

ATTENTION DEFICIT DISORDER

Attention Deficit Disorders are surprisingly common and have far reaching consequences. ADD occurs in about 3% to 7% of school-age children (Barkley, 1997; Bender, 1997; Hinshaw, 1994). Moreover, there is substantial evidence that ADD in childhood can disrupt cognitive and social development in several pivotal areas. First, children with ADD tend to have poor academic performance (for reviews, see Barkley, 1997; Bender, 1997; Hinshaw, 1994). Second, they are at increased risk for problems in the social arena as well. For example, they tend to have poor peer relationships and are often rejected by their peers (Alessandri, 1992; for reviews, see Bender, 1997; Berk, 1994; Hinshaw, 1994). They also tend to have poor relations with their parents and have a higher rate of family conflict (Barkley, Anastopoulos, Guevremont, & Fletcher, 1992). In addition, children with ADD tend to display more aggressive and antisocial behavior (for reviews,

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University of Illinois, Urbana-Champaign. *This research was supported by a grant from the National Urban and Community Forestry Advisory Council, and the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture under Project No. ILLU-65-0387l. We thank all the parents who participated in this research project, especially Patrick Sullivan. We also thank Dr. Lisa Monda-Amaya, Dr. Annette Lansford, and Dr. William Stewart for their helpful suggestions.* *Correspondence concerning this article should be addressed to Andrea Faber Taylor, Human Environment Research Laboratory, University of Illinois, 1103 S. Dorner Dr., Urbana, IL 61801, or a-faber@uiuc.edu.*

see Barkley, 1997; Hinshaw, 1994). Perhaps it is not surprising, then, that children with ADD are often also at greater risk for low self-esteem, anxiety, and depression (for reviews, see Barkley, 1997; Bender, 1997; Hinshaw, 1994).

ADD is essentially defined as a developmental lag in the specific area of attentional control. Thus, diagnosis involves evaluating a child's attentional control relative to their same-age peers (American Psychiatric Association, 1994). Specifically, the *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)* defines ADD as a persistent pattern of inattention "that is more frequent and severe than is typically observed in individuals at a comparable level of development" (American Psychiatric Association, 1994, p. 78). Barkley (1998) suggests that children with ADD can be expected to display attentional control at a level 30% behind their same-age non-ADD peers; for example, a 10-year-old ADD child generally displays behaviors more typical of a 7-year-old child.

Current evidence suggests that this lag in attentional development is due to biological factors (Barkley, 1995; Shue & Douglas, 1992). For example, physiological recordings obtained through magnetic resonance imaging show physical differences in the brain morphology of children with ADD. Specifically, the right frontal lobe, which plays a key role in directed attention (Foster, Eskes, & Stuss, 1994), was found to be smaller in children with ADD (Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990) than in children with age-appropriate attentional control. Thus, although folk theory holds that the immaturity of behaviors in ADD children is the product of social factors such as poor parenting, the evidence suggests that ADD is a biologically based disorder and not the product of the social or physical environment (Barkley, 1998; National Institute of Mental Health [NIMH], 1994).

HOW IS ADD TREATED?

Current treatments for ADD are limited in effectiveness and have many shortcomings (for reviews, see Fiore, Becker, & Nero, 1993; Hinshaw, 1994). Stimulant medications, such as Ritalin, Dexedrine, and Cylert, are the primary treatment for ADD (Hinshaw, 1994; NIMH, 1994; Swanson et al., 1993). In 9 out of 10 children, these medications help sustain attention and provide temporary gains in academic productivity (NIMH, 1994), but unfortunately, they fail to improve children's long-term social and academic outcomes (for review, see Hinshaw, 1994). In addition, these medications have serious side effects. They often suppress appetite and disrupt sleep (Hinshaw, 1994; NIMH, 1994), and in some children, they induce extreme depression and unusually flattened affect (Douglas, 1972).

Behavioral therapies are a second form of treatment for ADD. These include direct contingency management, in which children earn or lose points for specific behaviors, and cognitive behavioral procedures, in which children learn how to self-monitor attention and impulsive behavior (for review, see Fiore et al., 1993; Hinshaw, 1994). Unfortunately, these therapies are typically not sufficient to bring children into normal ranges of functioning (Fiore et al., 1993; Hinshaw, 1994).

Given the difficulties associated with medication and behavior therapy-based treatments, there is a clear need to explore alternative means of treating ADD. Could contact with nature support the attentional functioning of children who have ADD? Both theory and evidence regarding the relationship between contact with nature and attentional functioning suggest it might.

NATURE AND ATTENTION

Attention Restoration Theory (Kaplan, 1995) proposes that natural environments can assist attentional functioning. To understand how this might be so, let us review James's (1892/1962) theory of attention, and then Kaplan's (1995) application of that theory to Attention Restoration Theory.

James proposed that humans have two types of attention: voluntary and involuntary. Voluntary attention, or what Kaplan (1995) calls directed attention, is the kind of attention we use when we deliberately pay attention. This form of attention is employed in attending to tasks (e.g., problem solving) or situations (e.g., driving in heavy traffic) that require sustained attention and that are not inherently easy to attend to. After prolonged and intense use, directed attention becomes fatigued (Glosser & Goodglass, 1990; Kaplan, 1995). By contrast, involuntary attention is easy and does not require effort (James, 1892/1962). James suggested that certain elements in the environment draw on our involuntary attention: "strange things, moving things, wild animals, bright things, pretty things, words, blows, blood, etc. etc. etc." (James, 1892/1962, p. 231). Reliance on involuntary attention can be useful for the rest and recovery of fatigued directed attention. Kaplan (1995) proposes that stimuli and environments that draw primarily on involuntary attention give directed attention a chance to rest. Attention Restoration Theory suggests that natural environments assist in recovery from directed attention fatigue in part because they draw on involuntary attention rather than directed attention (Kaplan, 1995).

A number of studies in adult populations support Attention Restoration Theory. Several studies have shown that nature draws on involuntary attention (e.g., Kaplan, 1973, 1983; Kaplan & Talbot, 1983; Ulrich, 1981). In

addition, a number of other studies have shown that exposure to natural environments can be effective in restoring directed attention from fatigue (Canin, 1991; Cimprich, 1990; Hartig, Mang, & Evans, 1991; Kuo, in press; Lohr, Pearson-Mims, & Goodwin, 1996; Miles, Sullivan, & Kuo, 1998; Ovitt, 1996; Tennessen & Cimprich, 1995). In one study, exposure to natural environments through leisure activities was shown to be related to attentional functioning in adults. A study of AIDS caregivers found that nature activities and quiet activities were associated with robust attentional functioning, whereas activities such as TV watching, shopping, and watching or playing organized sports were associated with poorer attentional functioning (Canin, 1991).

NATURE AND ATTENTION IN CHILDREN

Could contact with nature support attention in children? Theoretical and empirical work in landscape architecture and environmental psychology has addressed numerous possible other benefits of nature for children, including providing privacy, mental stimulation, and sensory stimulation and supporting important developmental activities such as play, creative forms of play, and exploratory and divergent thinking (Heseltine, 1987; Jansson, 1984; Kirkby, 1989; Miller, 1972; Moore, 1986, 1989; Nabhan & Trimble, 1994; Senda, 1992; Striniste & Moore, 1989; Taylor, Wiley, Kuo, & Sullivan, 1998; Trancik & Evans, 1995). Only one article has raised the question of nature's potential impacts on children's attention (Trancik & Evans, 1995). Trancik and Evans (1995) suggest that the design of day care settings should include spaces supporting "restoration," such as natural areas, because preschool children may be susceptible to mental fatigue as they adapt to a new preschool environment. However, this idea has not been empirically examined.

There are reasons to think that Attention Restoration Theory extends to children. Like adults, children may become attentionally fatigued. For example, children's schoolwork requires extended periods of deliberate, effortful attention. And like adults, children often must carry out these tasks in a context filled with powerful distractions that constantly demand attention, making it extremely difficult to concentrate on the task at hand. In addition, because children's attention is not fully developed (Mackworth, 1976; Shaffer, 1985), they may be fighting off distractions with less attentional control than adults. Thus, children may need attentionally supportive environments where they can go to restore. It seems plausible that natural environments might support attention in children, including children with ADD.

This study examined whether contact with nature assists attentional functioning in children with ADD. Two hypotheses were formulated and tested: one regarding the immediate aftereffects of contact with nature, and the other regarding the general effects of nature on the severity of a child's ADD symptoms. Specifically, we proposed that

Hypothesis 1: Attention deficit symptoms will be more manageable after activities in green settings than after activities in other settings.
Hypothesis 2: The greener a child's everyday environment, the more manageable their attention deficit symptoms will be in general.

To address these hypotheses, we conducted a survey of parents of children with ADDs. For each child, we collected information about the aftereffects of leisure activities conducted in different settings, the amount of nature in their everyday environment, and the severity of their symptoms in general. In addition, six possible alternative explanations for a nature-attention relationship were examined.

METHOD

The questionnaire and procedures for this study were developed through a multifaceted qualitative data collection effort. The methodology was guided by interviews with children with ADD, their parents, and a variety of professionals with expertise in ADD (pediatricians, a professor of special education, and a fifth-grade teacher). The methodology was also guided by classroom observations of four ADD children (10-11 years old).

The questionnaire was pretested with four different families, one family at a time. As parents completed each section of the questionnaire, the following concerns were addressed: (a) whether the activities included in the survey adequately covered the range of activities 7- to 12-year-olds engage in, (b) whether parents understood the concept of post-activity attentional functioning, (c) whether the rating scales were appropriate, and (d) whether the nature measures were easily interpretable and usable. After each pretest, revisions were made to the questionnaire before further pretesting.

It is worth noting that an effort was made to develop a questionnaire for the ADD children themselves; however, pretesting indicated that the children were not able to reliably report on any aftereffects of their activities on their attention deficit symptoms.

QUESTIONNAIRE

The final version of the questionnaire was printed as a small booklet that took about 30 to 40 minutes to complete. On the cover, the following narrative introduced participants to the idea that children's activities might have aftereffects on their attention.

> Think about how you feel after a difficult week. You may find it more difficult than usual to pay attention. On the other hand, after a good vacation, you may find that it's relatively easy to focus your attention.
>
> We suspect that the same may be true for children. There are many different ways children can spend their time outside of school. For children with attention deficits, it's possible that some activities leave children functioning better than usual, while other activities leave children in worse shape.
>
> In other words, perhaps during the hour or so *after* your child does a certain activity, you find that their ADD/ADHD symptoms are worse than usual. Or vice versa; perhaps *after* doing another activity, you find that your child is functioning better than usual.

To make the concept *attentional functioning* more concrete, four specific attention deficit symptoms were listed:

- Can't stay focused on unappealing tasks (homework or chores)
- Can't complete tasks
- Can't listen and follow directions
- Easily distracted

These symptoms are modified selections from the diagnostic criteria for Attention Deficit/Hyperactivity Disorder (pp. 83-84 of *DSM-IV*; APA, 1994). Because Attention Restoration Theory suggests a relationship between nature and attentional functioning, but not necessarily between nature and hyperactivity-impulsivity, only symptoms of *inattention* were selected. In addition, because parents rarely observe their children in the classroom, only symptoms readily apparent in a home setting were presented.

In the first section of the questionnaire, participants were asked to nominate up to two afterschool and weekend activities that they felt left their child functioning especially well and up to two activities that they felt left their child functioning especially poorly. Parents completed the sentence, "After ____ my child's ADD symptoms are much *less* noticeable than usual. My child is in good shape." Parents were asked to nominate up to two best activities. Parents then did the same for worst activities: "After ____ my

child's ADD symptoms are much *more* noticeable than usual. My child is in bad shape." For both items, parents had the option of marking *none*, if they had not noticed any activities that were particularly helpful or harmful for their child's attention. About 66% of parents were able to nominate at least one activity that was best for their child; 68% were able to nominate at least one that was worst. Parents' nominations were later coded in terms of their likely settings by an individual blind to the best and worst labels. Each of the activities was classified as either Green (likely to take place in a relatively natural setting), Not Green (unlikely to take place in a relatively natural setting), or Ambiguous (ambiguous with respect to physical setting). For example, camping trip, fishing, and soccer were coded as Green, whereas video games, TV, and homework were coded as Not Green. Activities such as playing outside and rollerblading were coded as Ambiguous.

In the second section, participants were presented with a list of afterschool and weekend activities and asked to rate each activity in terms of any aftereffects of that activity on their child's attention deficit symptoms. These postactivity attentional functioning ratings, or PAAF ratings, were made on a 5-point Likert-type scale from 1 = *much worse* to 5 = *much better*, with a midpoint of 3 = *same as usual*; *don't know* was also an option. Twenty-five activities were presented in three lists: 11 activities conducted indoors, 6 activities conducted in built outdoor spaces (defined as mostly human-made areas—parking lots, downtown areas, or just a neighborhood space that doesn't have much greenery), and 8 activities conducted in green outdoor spaces (defined as mostly natural areas—a park, a farm, or just a "green" backyard or neighborhood space). Each activity was rated for two social contexts: after the activity was conducted alone, or with one person, and after the activity was conducted with two or more people.

In the final section of the questionnaire, parents answered a series of general questions about their child, their household, and the child's everyday surroundings. Parents answered the question, In general, how severe would you say your child's ADD or ADHD symptoms are (when not on medication)? using a 5-point Likert-type scale, from 1 = *very mild* to 5 = *very severe*. They reported their child's age, sex, grade in school, diagnoses other than ADD/ADHD, number of adult caregivers, and the household income. In addition, parents assessed the greenness of their child's everyday surroundings.

To assist parents in assessing the level of nature in their child's everyday surroundings, parents were first presented with a set of six photo pairs of possible play settings ranging from *places indoors where it feels very much indoors* (two photos of windowless rooms) to *places where there might be "wild" things: flowers, trees, animals, etc*. (two photos of relatively untamed landscapes). The photo pairs were independently rated by 21 horticulture

students for greenness or naturalness on a scale of 1 = low to 10 = high), with an interrater reliability of .994. To avoid collecting information about play spaces used during other seasons (e.g., winter), parents were asked to select one photo pair description as representative of where their child played during the previous week. Parents were then asked whether their child's activities in the previous week were representative of their normal routine (yes/no).

In addition to assessing the level of nature in their child's typical play settings, parents were asked to assess the overall greenness of their family's residence, the amount of tree cover in their yard, and the amount of grass in their yard. Overall greenness around the home was rated on a 5-point Likert-type scale (1 = *not at all green*, 5 = *very green*). To assess tree cover, parents were shown four photos depicting yards with different levels of tree cover and asked to select one that best represented the amount of tree cover in their front yard and one that best represented the amount of tree cover in their back yard. The amount of grass was measured through the same procedure.

PARTICIPANTS AND PROCEDURE

Participation was limited to parents or legal guardians of children 7 to 12 years old who had been formally diagnosed with ADD or ADHD (i.e., diagnosed by a physician, psychologist, or psychiatrist).

Participants were recruited through flyers distributed to pediatricians' offices, medical clinics, schools, and parent support groups such as Children and Adults with Attention Deficit/ Hyperactivity Disorder (CHADD). Participants were also recruited through advertisements placed in major newspapers. Newspaper advertisements were restricted to the midwestern United States to ensure roughly comparable climate and vegetation across the sample. The flyers and advertisements invited parents to participate in a mail-back or Internet-based survey about the effects of ADD/ADHD children's afterschool and weekend activities on their symptoms. Two incentives were offered: a list of recommendations based on the study's findings and a choice of a pizzeria gift certificate or a children's book about ADD.

Questionnaire data were collected, as suggested by a pediatrician and special education professor, when the attentional demands of school would make potential effects of nature on attention most salient to parents. Data were collected from mid-September, after children's school routines were well established, through the end of October, before inclement weather might significantly limit outdoor play. Paper copies of the questionnaire were mailed to parents who volunteered by phone or by e-mail, and an electronic version of the questionnaire was also made available on the Internet. The Dillman (1978) follow-up methodology was employed to encourage participants to

return the mail-back questionnaire within the time frame of the study. By the deadline, 77 paper copies of the questionnaire were returned, or 58% of those mailed. An additional 19 questionnaires were completed on the Internet, for a total of 96 completed questionnaires.

Given the use of convenience sampling, it is important to note that this sample was similar to other samples of children with ADDs. The ratio of boys to girls with attention deficits in the general population is estimated to be 3:1 (Barkley, 1990; Bender, 1997) or even 4:1 (American Psychiatric Association, 1994); the ratio of boys to girls in this sample was 3:1. Overall, this sample had more children with ADHD (61%) than ADD (39%). The ratio of ADD to ADHD in the general population is estimated at 1:1.7 for boys and 1:2.2 for girls (Szatmari, Offord, & Boyle, 1989); the ratio of ADD to ADHD in this sample was 1:1.6 for boys and 1:1.5 for girls. The percentage of ADD or ADHD boys having at least one comorbid disorder in the general population is 44%, whereas 29% of girls have at least one comorbid disorder (Szatmari et al., 1989); in our sample, 52% of boys had one comorbid disorder, and 36% of girls had one comorbid disorder. The mean age of children in this sample was 9.4 years, with a standard deviation of 1.5 years. About 63% of the parents reported their household income to be $50,000 or greater.

After the questionnaire data from the complete sample were analyzed, a subset of questionnaire participants was invited to a focus group dinner to discuss the findings. Eight questionnaire participants who had indicated interest in a follow-up interview attended. Focus group participants first briefly reacquainted themselves with the questionnaire and were asked to discuss any parts of the questionnaire they had found difficult to understand or complete. They were then asked if they had any guesses about the central hypothesis of the study, or "what the study was after." Some of the major findings were then presented, and participants were asked to describe any experiences they had had related to each of these findings, either in keeping with the findings or in contrast to the findings. Finally, participants were asked to describe their observations regarding different activities, different activity settings, and their aftereffects on their children's symptoms

RESULTS

Does contact with nature assist attentional functioning in children with ADD? First, we present tests of the central hypotheses, along with relevant quotes and anecdotes from interviews with parents. Then, we present tests of several alternative explanations for the central findings.

TABLE 1
Activities Nominated as Best and Worst for Attention Deficit Disorder Symptoms, Classified by Likely Setting

Likely Setting	*Best*	*Worst*
Green (e.g., fishing, soccer)	85% (17)	15% (3)
Ambiguous (rollerblading, playing outside)	56% (43)	44% (34)
Not Green (video games, TV)	43% (53)	57% (69)

NOTE: Numbers in parentheses are *n*s for each group.

TESTING OF CENTRAL HYPOTHESES

Each of the two central hypotheses was tested in multiple ways. Tests of the first hypothesis involved within subjects comparisons; tests of the second hypothesis involved between subjects comparisons.

Hypothesis 1. The first hypothesis was that attention deficit symptoms will be more manageable after activities in green settings than after activities in other settings. This hypothesis was first tested by examining the activities nominated by parents as particularly helpful (best) or harmful (worst) for their children's attention deficit symptoms: 113 best activities and 106 worst activities were nominated. If green settings are more attentionally supportive, then activities typically conducted in green settings should be overrepresented among the activities nominated as best and underrepresented among the activities nominated as worst. Indeed, as Table 1 shows, of the 20 Green activities (activities judged by an independent coder as likely to take place in a relatively natural setting), 17 were nominated as best, and 3 were nominated as worst (85% vs. 15%). Furthermore, Not Green activities were overrepresented among the activities nominated as worst (57%; 43% best). A chi-square confirmed that the likelihood that an activity would be nominated as best or worst significantly differed for different settings, $\chi^2(2) = 12.74$, $p < .01$. This finding raises the possibility that participants nominated Green activities as best because they had guessed the central hypothesis of the study. However, during the focus group, questionnaire participants said they had not guessed that the study was about the relationship between nature and attention.

The first hypothesis was then tested by examining parents' ratings of their children's attention deficit symptoms after participating in various activities in one of three settings. The mean PAAF rating for all activities was 3.22 (between 3 = *same as usual* and 4 = *better than usual*) with a standard deviation of .48. Mean PAAF ratings for specific activities ranged from 2.14, for homework with others indoors, to 3.80, for riding bike alone in green set-

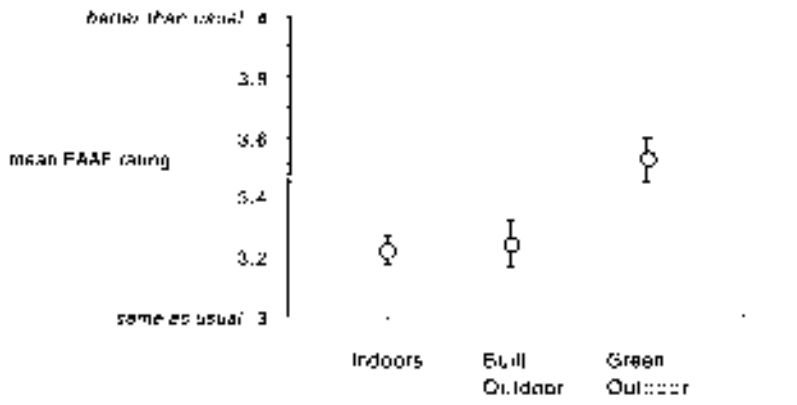

Figure 1: Mean Postactivity Attentional Functioning Ratings for Indoor, Built Outdoor, and Green Outdoor Activities

tings. If nature is supportive of ADD children's attentional functioning, activities conducted in green outdoor settings should receive higher PAAF ratings, on average, than activities conducted in indoor settings or built outdoor settings. In fact, a repeated measures ANOVA indicates that PAAF ratings do differ by setting, $F(2, 82) = 15.51$, $p < .0001$ (see Figure 1). Green activities received a significantly higher PAAF rating on average than indoor activities, Fishers PLSD $d = .30$, $p < .0001$, ($M = 3.53$ versus 3.22, respectively) and a significantly higher rating than built outdoor activities, Fishers PLSD $d = .28$, $p < .0001$, ($M = 3.53$ versus 3.24, respectively).

In the comparison of PAAF ratings for indoor versus green outdoor settings reported above, homework was included as one of the indoor activities because it constitutes an important afterschool and weekend indoor activity. However, whereas the other activities rated in the survey are truly leisure activities, homework is not a leisure activity, and is particularly attentionally demanding. Thus, it seems unfair to compare indoor activities to outdoor activities with homework included as an indoor activity. Hence, we compared PAAF ratings for indoor versus green outdoor activities, excluding homework from the analysis. Even with homework excluded, the pattern held, with green outdoor activities still receiving significantly greater PAAF scores than indoor activities, Fisher's PLSD $d = .25$, $p = .0001$.

The aftereffects of activities on children's attention deficit symptoms were further explored in the focus group. Participants were asked if they had had any experiences, either positive or negative, related to any aftereffects of green settings on their child's attention. One parent said she had recently begun taking her son to the local park for 30 minutes each morning before

school because the weather was nice, and they "had some time to kill." She then said,

> Come to think of it, I have noticed his attitude toward going to school has been better, and his school work has been better this past week. I think it's because spending time at the park is pleasurable, peaceful, quiet, calming.

Another parent suggested that his son, although usually struggling against his attention deficit symptoms, can "hit golf balls with me for 2 hours at a time," and "he fishes for hours at a time alone." This father reported that, after these activities, his son's attention deficit symptoms "are minimal," and "he's very relaxed." "When I read the results of your study, they hit me in the face," continued this parent. "I thought, yes I've seen this!" (referring to the positive effects of nature on ADD children's attentional functioning). In contrast, none of the focus group participants could report any instances in which green outdoor activities exacerbated their child's attention deficit symptoms.

Hypothesis 2. The second central hypothesis in this study was that the greener the child's everyday environment, the more manageable their attention deficit symptoms will be in general. This hypothesis was first tested by examining the relationship between the greenness of the child's play setting during the previous week and the severity of their attention deficit symptoms. The mean rating of children's overall severity of symptoms fell between average and severe ($M = 3.53$, range = 1-5). Many (39%) were rated as having average severity of symptoms, whereas half (50%) had symptoms that were rated as severe or very severe. Most parents reported that their children played in places with big trees and grass (44%), or indoor places without windows (16%), or places where there is a lot of open grass (13%). If greenness of play environment affects attentional functioning, then children who play in greener settings should receive lower severity of symptoms ratings. Indeed, a regression analysis between horticulture students' greenness ratings of the play setting categories and parents' severity of symptoms ratings revealed a significant positive relationship, $R^2 = .08$, $F(1, 91) = 8.18$, $p < .01$. The greener the child's play environment during the previous week, the less severe their symptoms.

Does this relationship hold when children were excluded from the analyses if their play environments during the previous week was atypical of their usual play environments? Yes, the relationship still held; $R^2 = .06$, $F(1, 70) = 4.48$, $p < .05$.

To further explore this relationship, Figure 2 shows the mean severity of ADD symptoms associated with different play settings, excluding the built

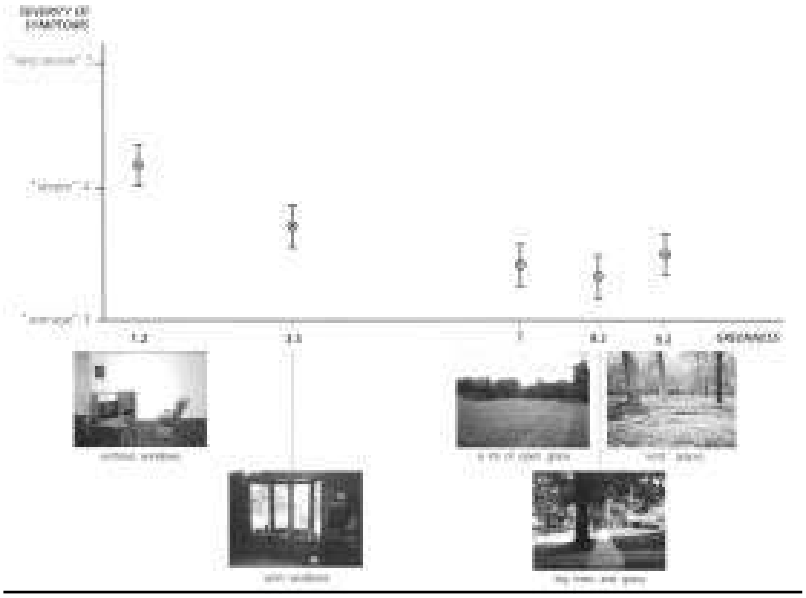

Figure 2: Mean Severity of Attention Deficit Symptoms for Five Play Settings

outdoors setting due to the few children in that category. The pattern of means reinforces the regression findings. In addition, the pattern of means raises the intriguing possibility that indoor settings *with* windows may be more supportive than indoor settings *without* windows and that there are minimal differences between open grassy settings and settings that include trees.

This hypothesis was also examined by testing for a relationship between various measures of residential greenness and the overall severity of symptoms. Most children's residential surroundings (overall greenness) were rated as being quite green ($M = 4.26$, on a 5-point scale). Most children had a large area of grass in their front yard and in their back yard ($M = 2.91$ and 3.27, respectively, on a 1 to 4-point scale). Children also had large amounts of tree cover in front and in back of their homes ($M = 2.92$ and 3.15, respectively, on a 4-point scale). Based on our second hypothesis, children who live in residential areas rated as highly green should receive lower overall severity of symptoms ratings than children who live in less green residential settings. However, we did not find this to be the case; regression analyses indicate that measures of overall greenness, grass cover, and tree cover in the front and back yards were not significantly related to severity of symptoms.[2]

Given that three measures of nature were found to be related to attention, why didn't we find a relationship between residential nature and severity of

symptoms? One possible explanation is that the children in this sample do not gain much exposure to the nature surrounding their homes. It is plausible that these children do not spend much time in their yards, especially because there was such a clear, significant relationship between the greenness of where they played and the severity of their symptoms. The fact that most of the sample (75%) were boys may explain the nonsignificant relationship between residential nature and these children's attentional functioning (severity of symptoms). Interviews with parents during pretesting, as well as comments from the focus group, indicate that boys rarely play in their own yards; they generally choose to play elsewhere.

The effects of extended contact with nature on overall severity of symptoms were further explored in the focus group. Parents were asked, "Has anyone taken your ADD child on a 'pure' nature experience, such as camping, hiking, fishing, biking, etc. in a State park, National park, or other natural area? If so, what happened? Anything memorable?" One parent's response was "Pure nature vacations are the only vacations we *can* take! Theme parks are a nightmare. Two weeks camping in a pop-up camper is just bliss. We have a great time. He's great."

TESTING OF ALTERNATIVE EXPLANATIONS

The findings above indicate that there is a relationship between nature and attentional functioning in children with ADD. This is consistent with Kaplan's theory that contact with nature leads to attentional restoration. Might it be, however, that the correlations reported above were obtained in the absence of any real relationship between nature and attentional functioning? In other words, does the nature-attention relationship exist merely because both nature activities and attentional functioning are related to some other, third, factor? In search of a potential third factor, six alternative hypotheses are considered below.

First, could it be that green activities enhance attentional functioning not because they are green, but because they are conducted outdoors? If so, we would expect that green outdoor activities and built outdoor activities to have average PAAF scores that would not differ significantly. However, a paired *t* test examining differences in PAAF scores between green outdoor activities and built outdoor activities indicates that green activities received significantly higher average PAAF scores than built outdoor activities, $t(82) = 4.38$, $p < .0001$ ($M = 3.54$ versus 3.24, respectively). Not only did built outdoor activities receive lower PAAF scores than green outdoor activities, but a paired *t* test indicates that built outdoor activities' PAAF scores are not significantly greater than indoor activities' PAAF scores, $t(82) = .29$, $p = .77$, ($M =$

3.24 and 3.24, respectively). Thus, green activities' relationship to attention cannot be explained by green activities taking place outdoors.

Second, could it be that green activities enhance attentional functioning not because they are green but because they are conducted in a particular social context, either alone or with one person, or with larger groups? If so, we would expect that when social context is controlled, the physical environment in which an activity takes place would have no effect on attention deficit symptoms. A 2×2 (2 physical settings $\times$ 2 social contexts) repeated measures ANOVA indicates that green outdoor activities received higher PAAF scores, on average, than did indoor activities, $F(1, 85) = 44.69$, $p < .0001$, or built outdoor activities, $F(1, 72) = 13.04$, $p < .01$. Furthermore, no interaction was found between physical setting and social setting in either of these analyses. Thus, the social environment cannot explain the relationship between PAAF scores and green settings.

Third, could it be that green activities enhance attentional functioning not because they are green, but because they are physically active? If so, we would expect that physically active green outdoor activities would receive higher PAAF scores than passive green activities. To examine this possibility, an independent coder coded all the activities as active or passive. For example, reading books or magazines and creative activities were coded as passive, whereas bike, skate or skateboard, explore, climb tree, or play in tree houses were coded as active. A paired t test indicates no significant difference between PAAF scores of active and passive activities done in green settings, $t(83) = 1.13$, $p = .26$. Thus, green activities' relationship to attention cannot be explained by green activities being either active or passive.

Fourth, could it be that green activities enhance attentional functioning not because they are green, but because these activities are qualitatively different from activities done in other settings? Could it be that the activities we selected to measure PAAF for green outdoor settings happen to be uniquely supportive of attentional functioning whereas the activities selected for the indoor and built outdoor settings are uniquely unsupportive of attentional functioning, thus making the differences found not due to setting but due to the activities themselves. If so, we would expect that we would not find setting differences when comparing PAAF ratings for a single set of activities after a child does the activities in each of the three settings. The activities matched across setting were creative activities (art, music, models, Legos, collections, etc.), pretending (house, action figures, Power Rangers, etc.), and organized sports. A repeated measures ANOVA comparing three different physical settings and controlling for two social settings indicates that attentional functioning differs systematically by physical setting, $F(2, 62) = 3.06$, $p = .05$. Moreover, paired comparisons indicated that the same

activities, when conducted in green outdoor settings, were associated with better attentional functioning than when they were conducted in either built outdoor settings or indoor settings, $F(1, 63) = 6.17$, $p < .05$, and $F(1, 81) = 4.14$, $p = .05$, respectively). Thus, the differences in attentional functioning between green activities and activities conducted in other settings seem to be due to setting rather than activity.

Fifth, could it be that green activities enhance attentional functioning not because they are green but because they are preferred? If this is the case, then preferred activities should be attentionally supportive. Consistent with this idea, attentionally supportive activities were indeed preferred; a t test indicated that the mean preference rating for activities nominated as attentionally best for ADD children was significantly greater than 3.0 (a neutral preference rating), $t(62) = 29.70$, $p < .0001$ ($M = 4.70$). However, preferred activities were also nominated as attentionally worst for ADD children, $t(64) = 3.03$, $p < .01$ ($M = 3.45$). Thus, worst activities were preferred as well as best activities. Both means are more positive than neutral. Thus, preference does not appear to be responsible for making an activity attentionally supportive, and the relationship between green activities and attention cannot be explained by green activities being preferred.

Finally, could it be that some activities are more supportive of attentional functioning because they coincide with medicated periods? Although our data do not permit a direct test of this possibility, we can test for a relationship between medication effects and activities nominated as best and worst. If medication effects are related to activities being nominated as attentionally supportive, then we would expect best activities to have been conducted while a child was medicated and worst activities to have been conducted while a child was unmedicated. However, parents' reports indicate that most activities (64%) nominated as best occur while medications are no longer effective (the dose has worn off). Conversely, 54% of activities nominated as worst occur while medications are still effective. Thus, the relationship between green activities and attention cannot be explained by green activities coinciding with medicated periods.

These analyses indicate that of the six alternative explanations tested, none could explain the nature-attention relationship found.

DISCUSSION

Does nature support attentional functioning in children with ADDs? Several analyses suggest that contact with nature is systematically related to less-

ened attention deficit symptoms. Activities nominated as helpful in reducing attention deficit symptoms were disproportionately likely to take place in green outdoor settings. Conversely, activities nominated as exacerbating symptoms were disproportionately likely to take place in non-green outdoor settings. Parent ratings of PAAF were also systematically higher, on average, for activities conducted in green outdoor settings than for activities conducted in either built outdoor or indoor settings. Although the greenness of a child's residential setting was unrelated to the severity of their ADD symptoms, the greenness of their play setting was related to symptom severity; ADD symptoms were milder for those children with greener play settings. Children who played in windowless indoor settings had significantly more severe symptoms than children who played in grassy outdoor spaces with or without trees did.

Multiple alternative explanations for these findings were tested. The relationship between nature and attention could not be explained by confounds between contact with nature and any of the following factors: being outdoors, social environment, amount of physical activity, types of activity, preference for nature, or timing of medication.

Although these findings are based on correlational data, the design of this study provides more support for a causal interpretation than is typical for correlational work. First, most correlational work gives no confidence in the temporal order of the relationship found, establishing only that A is related to B. This study not only establishes a strong nature-attention relationship, it also suggests a direction to that relationship. Because this study specifically focuses on attentional functioning *after* activities, it seems more plausible that participation in green activities causes improved attentional functioning than that improved attentional functioning causes participation in green activities. Remember that parents had the option of indicating that their child's attentional functioning was the same as usual, if indeed the child did not improve after the activities. Second, most correlational work involves between-subjects comparisons, in which individual differences may account for the findings. This study establishes a strong nature-attention relationship within subjects. We found that green activities are associated with better attentional functioning within the same individual. Such within-individual fluctuations in attentional functioning cannot be accounted for by between-individual differences such as intelligence or wealth. Moreover, the combination of between- and within-subjects comparisons in this study overcomes the limitations of a within-subjects comparison alone. For example, parents might rate their child as functioning better attentionally after activities in green settings simply because they believe spending time in green settings is good for children. This would explain the within-subjects findings

but not the between-subjects findings. Thus, although definitive evidence of a causal relationship awaits a true experiment, we believe the current findings strongly merit a causal interpretation.

GENERALIZABILITY

Before we discuss the contributions and implications of these findings, a few cautions regarding their generalizability are in order. The sample used here, although relatively representative of the general population of ADD children, does have some potential limitations. The children in this sample were perceived by their parents to have relatively severe attention deficit symptoms. Also, the families were relatively wealthy, with 63% earning an annual household income of $50,000 or more. And the majority of this sample lived in relatively green residential areas. Thus, the findings may not generalize to children with milder symptoms, who have families with lower incomes, or who live in relatively barren residential surroundings.

In addition, the location and timing of the data collection may pose some limitations regarding generalizability. The data were collected from a limited geographic region, the midwestern United States. Thus, the question arises, do these findings apply to children living in regions without green trees and grass? For example, children in desert settings may not receive the same benefits from contact with nearby natural outdoor settings. Furthermore, this study was conducted within a short period of time during a single season, autumn. Is the nature-attention relationship still as strong during the summer months, when children have fewer attentional demands (i.e., no schoolwork)? Is the nature-attention relationship as strong during the winter months, when there is very little green vegetation available?

CONTRIBUTIONS

This work contributes to the research on nature and attention in three ways. The work here extends Attention Restoration Theory, expands the literature concerning children and nature, and provides a potential new methodology for studying directed attention in children.

This study extends Attention Restoration Theory to a new population, providing evidence that the theory may apply to children. Whereas Attention Restoration Theory suggests that nature supports directed attention functioning in all humans, previous research has only provided evidence that the theory applies to adults (Canin, 1991; Cimprich, 1990; Hartig et al., 1991; Kuo, in press; Lohr et al., 1996; Miles et al., 1998; Tennessen & Cimprich, 1995). This study is the first to indicate that the theory applies to at least a subpopu-

lation of children, children with ADD. Thus, there is now evidence that Attention Restoration Theory applies to both adults with normal attentional functioning and children whose attentional functioning is compromised. Together, these findings provide some indication that the nature-attention relationship may apply to all children.

This study also extends the literature on the benefits of nature for children. The previous literature has provided some evidence that green spaces foster play and—of particular importance—creative play (Kirkby, 1989; Moore, 1989; Taylor et al., 1998). In addition, previous investigators have suggested that contact with nature supports children's general well-being by providing children with privacy and mental and sensory stimulation (Heseltine, 1987; Jansson, 1984; Miller, 1972; Nabhan & Trimble, 1994; Senda, 1992; Striniste & Moore, 1989). To date, however, no studies have examined the effects of contact with nature on children's attentional functioning. Trancik and Evans (1995) did speculate that, for preschoolers, the stress of the new school environment might cause attentional fatigue and that, therefore, preschoolers might benefit from opportunities to play in green settings. The findings here suggest that Trancik and Evans's ideas are worth testing.

Finally, this study provides a potential new methodology for studying directed attention in children. The consistent and statistically significant differences between different activities found here suggest that parents are able to systematically assess the aftereffects of activities on their children's attentional functioning and can estimate the magnitude of these effects on a Likert-type scale. Furthermore, it appears that most parents are able to nominate activities that have especially positive and negative effects on their child's attention. Future research should assess the reliability and concurrent validity of these measures.

IMPLICATIONS FOR PRACTICE AND FUTURE RESEARCH

The findings here have a number of implications for practice and future research. For children with ADD and their parents, these findings have a clear and inexpensive implication: Children with ADD can support their attentional functioning and minimize their symptoms simply by spending time in green settings. More specifically, children with ADD might use these findings in the following ways. First, before engaging in attentionally demanding tasks such as schoolwork and homework, ADD children might maximize their attentional capacity by spending time in green settings. Second, ADD children might reduce the overall severity of their symptoms by spending time in green settings on a daily basis. According to parents in the focus group, children with ADD who engage in green activities function

better both during the activity and for some time afterward. It is worth noting that children with ADD can follow these recommendations at little or no financial cost by using public and private green areas.

The findings of this study have implications for the design of children's environments such as school yards. Given that maximal attentional functioning is necessary for optimal academic performance, one implication of these findings is that green schoolyards could play an important role in children's academic pursuits. For example, recess may be more than just a time for releasing physical energy but also an important time for restoring attention. Children with ADD, and possibly all children, may perform better throughout the school day if given breaks in a green environment. In addition, perhaps something as simple as a view out the classroom window onto a green space may be providing children with much needed rest of their directed attention.

The findings of this study also have a number of implications for future research. Future research might replicate these findings both in similar settings (children's afterschool and weekend play environments), with other populations (e.g., ADD children in the southwest United States, non-ADD children), and in other settings. For example, do children who attend schools with particularly green school yards function better attentionally throughout the day than children who attend less green schools? Does the physical setting of summer camp affect ADD children's attention deficit symptoms? Perhaps, summer camps in natural settings (e.g., camping in a state park) are more beneficial for children with ADD than indoor summer camps (e.g., indoor sports camps or arts camps). Furthermore, future research might explore which specific elements of green settings are crucial in supporting attentional functioning.

Future research might also explore the temporal characteristics of the nature-attention relationship. In this study, we examined functioning immediately after participation in green activities but did not measure the duration of the activities or the duration of the effects. Is it necessary to spend some minimum amount of time in nature-related activities to experience the restorative benefits of nature? For children with ADD, how does a 10-minute walk in the park compare to a 30-minute walk in the park in terms of restoring attentional functioning? Kuo (in press) has proposed that future research should determine the shape of the *dose response curve* for nature and attention. For example, perhaps attentional functioning increases with increasing exposure to nature only up to a point, after which the benefits level out and additional exposure to nature produces little additional benefit. Another issue that deserves investigation concerns the duration of the effects. How long do

they last? Do the effects degrade in a linear fashion or do they degrade suddenly?

This study has shown that nature may support attentional functioning in children with ADD. These finding have tremendous implications for a large number of children (more than 2 million in the United States alone) struggling day-in and day-out with attention deficit symptoms. These children and their families could potentially benefit from something as simple as spending time in green areas. In addition, these findings hold potential value for children who do not have ADD. Optimal levels of attentional functioning are essential for *all* children so that they maximize learning and achievement in school. Thus, all children's attentional functioning may benefit from something as inexpensive and direct as incorporating vegetation into places where children live, learn, and play.

NOTES

1. The acronym ADD will be used throughout this article because this research theoretically hinges on children's attention deficits. However, the information also applies to ADHD, as ADHD is a broader diagnostic term under which a child can be diagnosed as predominantly inattentive (attention deficit), or inattentive *and* hyperactive/impulsive (American Psychiatric Association, 1994).

2. It is striking that in spite of a small *n* and thus low power for analysis, girls' severity of symptoms were significantly related to several measures of residential greenness.

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Trees & Sustainable Urban Air Quality

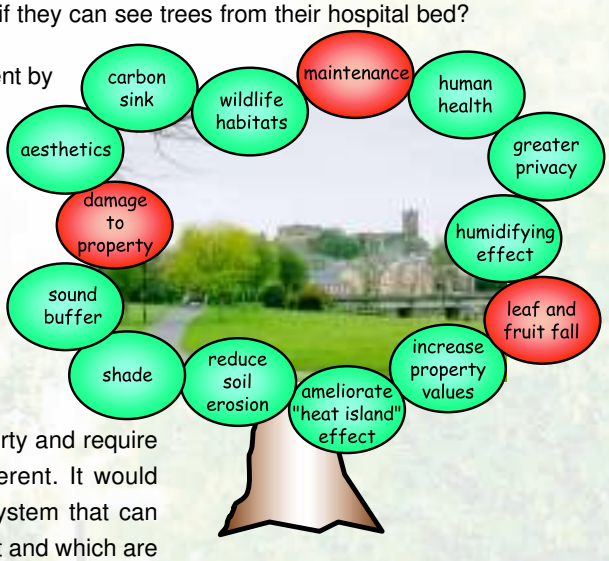
Using Trees to Improve Air Quality in Cities

Trees in the urban environment

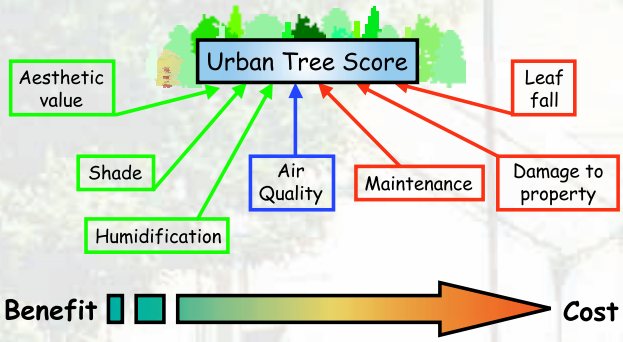
You don't have to be a tree surgeon to appreciate the value of urban trees. They affect our lives in more ways than we realise. Did you know that patients recover more quickly from major surgery if they can see trees from their hospital bed?

Trees can improve the environment by

- benefitting human health
- affecting air quality
- providing shade and humidity
- having aesthetic qualities
- increasing biodiversity
- creating a sense of community
- increasing property prices



But they can also damage property and require maintenance. Trees are all different. It would therefore be useful to have a system that can show which tree species are best and which are bad for the urban environment.



People plant trees for so many reasons that it is not possible to produce a scoring system that considers all the factors. Here, we focus on the ability of urban trees to improve air quality. Some trees are better than others at doing this.

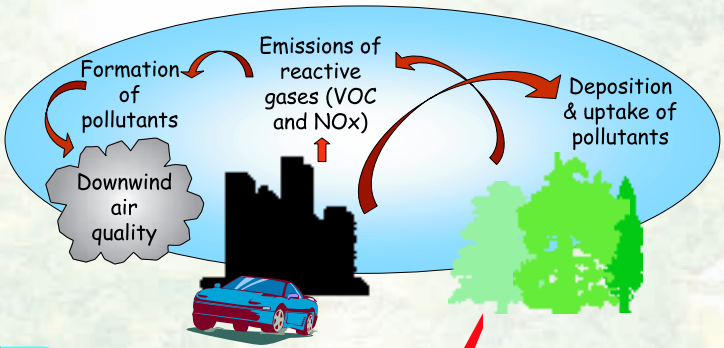
To do this, we have developed an **U**rban **T**ree **A**ir **Q**uality **S**core (UTAQS), using the West Midlands as a typical urban region in Great Britain. This pamphlet describes

- the way trees affect air quality
- the system we have developed to test the ability of trees to influence air quality
- the final tree ranking or UTAQS.

We hope urban planners and policy makers will consider the effects trees can have on air quality and that UTAQS will be a useful tool for them.

Urban trees and air quality

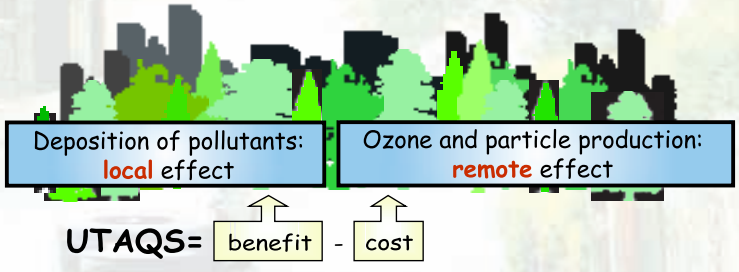
Most people assume that trees only benefit air quality. In fact, some tree species can have a negative effect and actually help to form pollutants in the atmosphere.



Trees can emit gases known as volatile organic compounds (VOCs). These are what you can smell in forests. VOCs, in combination with the man-made oxides of nitrogen (NOx), can contribute to the production of other pollutants, especially ozone and particles, which damage human health when in the lower atmosphere.

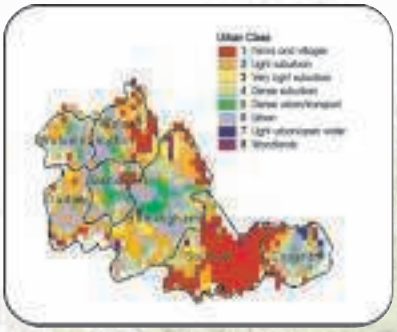
Trees can remove pollutants, especially ozone, nitrogen dioxide, and particles) from the air which makes the atmosphere cleaner. Trees also remove carbon dioxide from the atmosphere but we treat this separately on page 9. Carbon dioxide is a greenhouse gas which is having effects on the earth's climate.

The removal of pollutants by trees is a local effect, whereas the formation of pollutants from compounds emitted by trees happens downwind of the trees themselves. To generate an Urban Tree Air Quality Score, we need to weigh the local benefits against the remote costs. In order to do this, we have used a case study, and this is described in the rest of the brochure.



A case study - trees in the West Midlands

1 Land classification



The West Midlands urban area is 900 km^2 in size. We divided it into eight different urban land classes using maps of land cover in the area. Each km^2 belongs to one of the eight classes as shown on the left. The descriptions of the land classes give a general idea of the dominant land cover in the class, but don't mean that the whole km^2 is covered with that land cover type. For example, on average only 42% of woodland (land class 8) is actually covered with woodland.

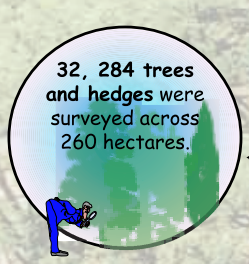
2 Tree Survey

We surveyed 32,000 randomly chosen trees in the West Midlands in 1999, recording tree age, condition, height and trunk diameter. The survey process is described on the right.

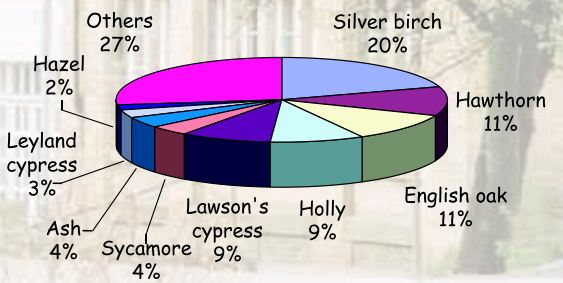
Twenty-two 1 km squares were randomly selected across the 8 urban land classes.

Three 2x2 ha blocks were randomly selected and every tree and hedge within that area >2m in height was recorded.

Attributes such as age, trunk height (TH), crown height (CH), crown spread (CS) and diameter at breast height (DBH) were recorded.



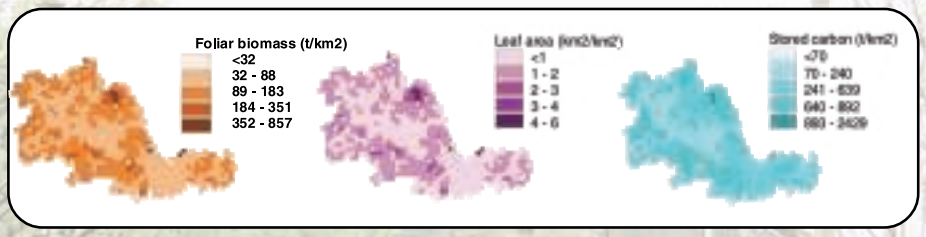
Using these results, we were able to predict the tree population of each urban land class and hence the species composition and size of the whole West Midlands tree population. The pie chart shows the composition of species in the West Midlands and the table shows the number of trees in each land class and in the West Midlands conurbation as a whole.



Urban land class	Tree count (million trees)
1 Farms and villages	1.4
2 Light suburban	2.1
3 Very light suburban	0.8
4 Dense suburban	1.2
5 Dense urban/transport	0.7
6 Urban	1.5
7 Light urban/open water	0.03
8 Woodloand	0.3
West Midlands	8.1

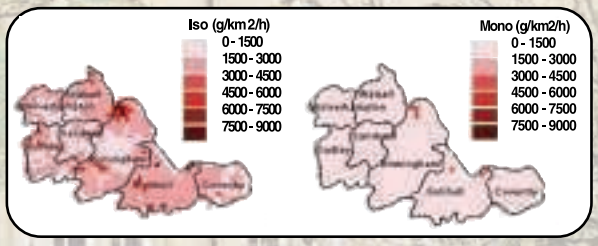
3 Calculating foliar biomass, leaf area and stored carbon

We calculated leaf area, foliar biomass and stored carbon from the tree size data collected in the West Midlands survey for each land class and scaled the leaf attributes monthly to account for the growth cycle of deciduous trees. These maps show the distributions of these attributes in the West Midlands during the month of August.

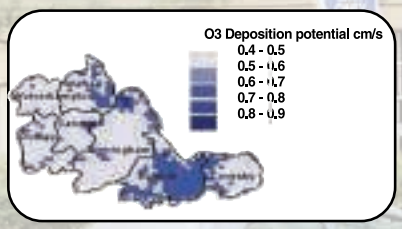


4 Estimating emission potential (EP)

The emissions of volatile organic compounds that would take place at a temperature of 30°C in bright sunlight were calculated by multiplying the foliar biomass of each tree species by the relevent emission potential for each species, found at www.es.lancs.ac.uk/cnhgroup/iso-emissions.pdf. Isoprene and the monoterpene family are the most important naturally emitted VOCs so the assignment was limited to these compounds. Summing the EPs for each land class gives the isoprene and monoterpene emission distributions shown here.



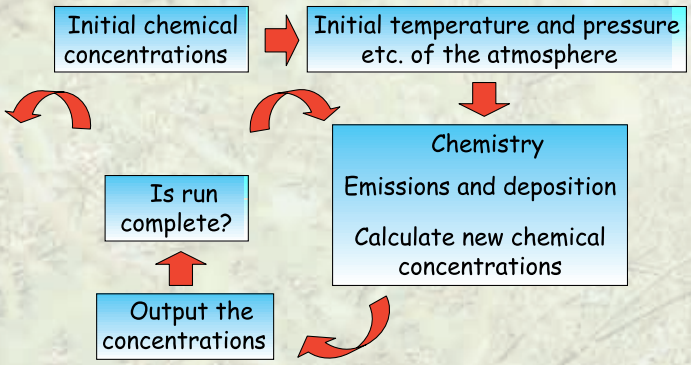
5 Estimating deposition potential (DP)



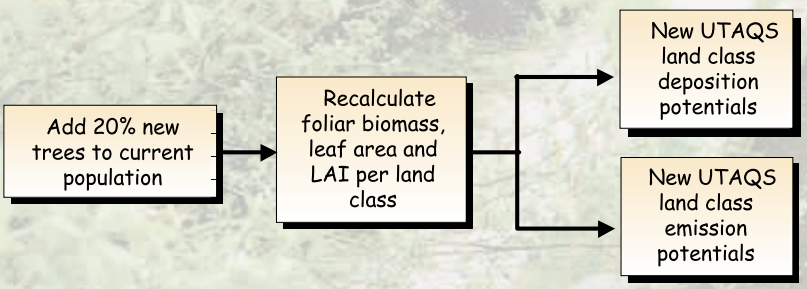
The proportions of grass, water, trees and built-up land in each land class are unique. Each surface has a unique capacity to capture chemical species (i.e. has a unique deposition potential). The DPs of five chemical compounds important to urban air quality (ozone, nitric oxide, nitrogen dioxide, nitric acid and carbon monoxide) were weighted in proportion to the land cover areas to generate land class DPs. This map shows the distribution of ozone DP in the West Midlands in August, the highest values being in the most vegetated areas.

Introducing our air quality modelling tool - CiTTyCAT

CiTTyCAT (the Cambridge Tropospheric Trajectory model of Chemistry and Transport) is a computer model that simulates the chemistry of the lowest part of the atmosphere by picking up emissions, performing chemical reactions and depositing some of the products of the reactions at the earth's surface. The diagram below shows the way CiTTyCAT works.



We used CiTTyCAT to simulate atmospheric chemistry over the current West Midlands tree population for a five-day period. This gives the model enough time for the chemistry to reach a steady daily cycle. We then tested the effects of planting different tree species on the air quality in the region. We selected the 30 most common tree species in the West Midlands, making up 90% of the total population, and added 20% more trees of each of the 30 species in turn to the existing population. We recalculated the biomass and leaf area of each land class for each new tree population, and then calculated new emission and deposition potentials.



Finally, we ran the CiTTyCAT model for five days for each scenario and simulated air quality in the West Midlands with each of the different tree populations.

Urban tree air quality score

To rank the ability of the different tree species to affect air quality, we compared the concentrations of pollutants with each new tree population against those produced by the current one. We used a simple equation that takes into account the effect of changing tree species on pollutant formation and deposition, using ozone to represent all the relevant pollutants. The change in ozone concentration with each tree population was compared to the air quality standard for ozone* to estimate the significance of the change.

$$\text{UTAQS} = \frac{\text{Change in ozone concentration}}{\text{Air Quality Standard for ozone}}$$

We grouped the tree species according to their effect on air quality. They are grouped below as

- trees that have the greatest capacity to improve air quality
- trees that have a smaller capacity to improve air quality
- trees that have the potential to worsen air quality.

Best → Worst

Ash	Apple	Holly
Common alder	Cherry laurel	Italian alder
Field maple	Common elm	Lawson cypress
Larch	Common lime	Leyland cypress
Norway maple	Elder	Lilac
Scots pine	Grey alder	Mountain ash
Silver birch	Hawthorn	Sycamore
	Hazel	Wild cherry
		Crack willow
		English oak
		Goat willow
		Poplar
		Red oak
		Sessile oak
		White willow

* The air quality standard for ozone in the UK is an 8-hour running mean of 50 ppb not to be exceeded on more than 10 days in one year. This is set as part of the government's National Air Quality Strategy. Details are found at www.aeat.co.uk/netcen/airqual/index.html.

Reducing airborne pollutants in urban areas with trees

1. The effects of land-type and 'edge' trees

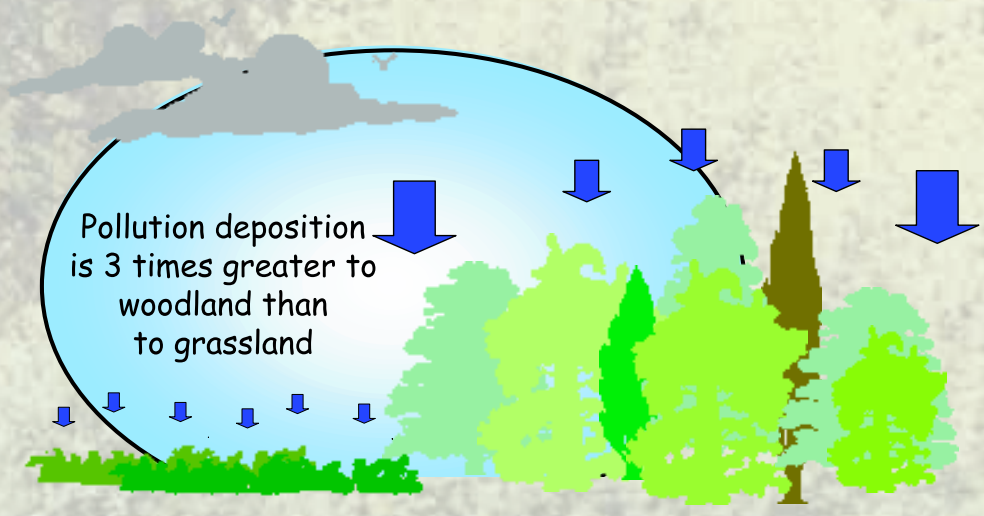
Trees are popularly believed to remove pollution from the atmosphere, removing both gases and particles. However, this idea has developed largely without careful measurements in real-life conditions to show

a) how large the effect is,
b) what processes control it and
c) how it might be exploited to improve air quality in urban areas.

To try to answer some of these questions, we measured the long-term (50 year) average deposition rate of airborne particles in urban air, such as those emitted by cars, on woodland, grassland and other short vegetation in the West Midlands conurbation. We did this by measuring the amount of naturally occurring radioactive compounds, found as particles in the atmosphere and soils, and then worked out the effect of trees on the rates of pollutant deposition.

The measurements show that

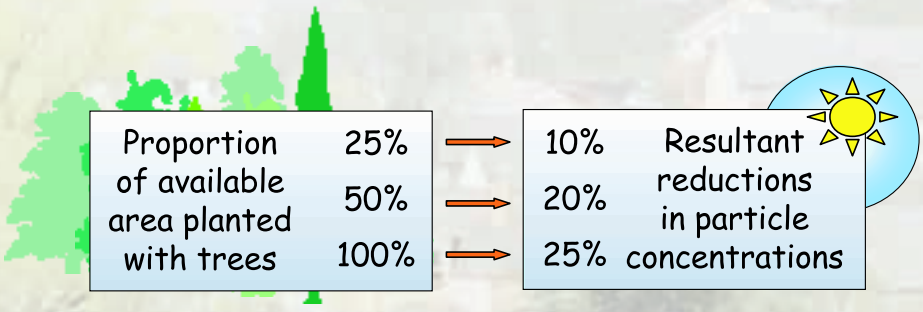
- mature, mixed woodland captures airborne particles at approximately three times the rate of grassland.
- trees on the edge of woodland are more effective at capturing airborne particles than the trees in the centre of the wood because they have larger leaf areas and are exposed to the wind.



2. How big is the effect?

We wanted to see the effect of various tree-planting schemes on the deposition of pollutants in the West Midlands so once again we used computer models that simulate atmospheric dispersion, transport and deposition.

In our tree survey of West Midlands, the area of land in each sampled hectare that was potentially available for tree-planting in the future was noted. This was used to caluate a land class average 'future planting potential' area, or FPP. We used the computer models to plant the FPP areas with 'instant' mature woodland, and then calculated the change in atmospheric concentration of PM10 (particles smaller than about 10 μm aerodynamic diameter)*. There were reductions in PM10 concentration with each scenario as shown below.



3. Human health

The main concern over airborne particles in cities is their effect on human health. A number of epidemiological studies have shown that a rise in PM10 concentrations of 10 μg m^{-3} (as a 24 hour average) is associated with an increase in mortality of 1%. The reduction in PM10 concentrations which would result from future tree planting would therefore be beneficial to human health. Quantifying this benefit is more difficult. However, using these health statistics and our predictions of the effects of tree planting on urban air quality, we estimate that doubling the number of trees in the West Midlands could reduce excess deaths due to particles in the air by up to 140 per year.

*We used PM10 because the Government's air quality standard for particles (50 μg m^{-3} as a 24 hour running mean) is based on this definition of size. These particles are believed to be small enough to reach the lungs.

Trees as carbon stores*

The total amount of carbon stored in the West Midlands tree population is equivalent to only 6% of the carbon dioxide emitted to the atmosphere from the West Midlands in a single year. In other words, all the trees in the West Midlands hold the equivalent of three weeks worth of emissions of CO_2 from the conurbation. Given the relatively small amount of carbon stored in the trees, we have not included carbon storage (sequestration) in our tree score. However, we have grouped the thirty species considered in our score into those that have high, medium or low growth rates, i.e. carbon sequestration rates, so that this factor can be considered when developing planting schemes.

High — Medium — Low

High		Medium	Low
Crack willow	Apple	Italian alder	Common elm
Goat willow	Ash	Lilac	English oak
Larch	Cherry laurel	Mountain ash	Field maple
Lawson cypress	Common alder	Norway maple	Hazel
Leyland cypress	Common lime	Red oak	Holly
Poplar	Elder	Scots pine	Sessile oak
Silver birch	Grey alder	Sycamore	
White willow	Hawthorn	Wild cherry	

Which species have stored the most carbon so far?

We calculated the total amount of carbon stored by each tree species in the West Midlands. The top ten carbon storing species are shown on the right. By far the most important is the English oak (*Quercus robur*) with 36% of the total stored carbon because these trees are so big. However, it is slow growing so it has taken longer to accumulate it s carbon than some of the other species listed.

English name	Stored Carbon (kt)	% total
English oak	180	36.7
Austrian pine	35	7.1
Ash	27	5.5
Common lime	26	5.2
Silver birch	25	5.1
Sessile oak	22	4.4
Sycamore	16	3.3
Lombardy poplar	16	3.2
Horse chestnut	15	3.0
Common alder	11	2.3

*In all of this, we have not considered the effect trees have on the storage of carbon in soils (soils are a major store of carbon).

Summary

Trees are an integral part of the urban environment, affecting communities ecologically, socially, economically and physically and they benefit human health. We have looked at the effects of trees on air quality, trying to answer two questions:

1. **Which trees** are the best to plant to sustain and improve air quality?
2. **How big** is the effect trees have on urban air quality?

Which trees?

Trees that don t emit the most reactive volatile organic compounds (VOCs), but do have large leaf surface areas have the best effect on air quality. Scots pine, common alder, larch, Norway maple, field maple, ash and silver birch remove the most pollutants without contributing to the formation of new pollutants. Oaks, poplars and willows can have detrimental effects on air quality downwind, so care needs to be taken when planting these species in very large numbers. Overall, the effects on air quality of very large scale planting of almost all tree species in cities would be positive.

How big?

Trees remove airborne pollutants at three times the rate of grassland. Trees at the edge of woodland are more effective at removing atmospheric pollutants than trees in the centre of woodland. This is due to both larger leaf areas and greater exposure to the wind. By planting trees in all possible sites in the West Midlands (doubling the number of trees), the concentration of small particles could be reduced by 25%. This could lead to a reduction of 140 deaths caused by airborne particles each year in the West Midlands.

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CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

This guide was compiled by Hope Stewart, Sue Owen, Rossa Donovan, Rob MacKenzie & Nick Hewitt of Lancaster University and Ute Skiba & David Fowler of CEH Edinburgh. The research was funded by the Natural Environment Research Council's Urban Regeneration and the Environment (URGENT) programme (grant GST/02/2236).

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THE EFFECTS OF URBAN TREES ON AIR QUALITY

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Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmospheric environment. The four main ways that urban trees affect air quality are[a]:

Temperature reduction and other microclimatic effects
Removal of air pollutants
Emission of volatile organic compounds and tree maintenance emissions
Energy effects on buildings

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[b]. Although trees usually contribute to cooler summer air temperatures, their presence can increase air temperatures in some instances[c]. 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[d]. 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[e]. Below individual and small groups of trees over grass, mid-day air temperatures at 1.5 m above ground are 0.7°C to 1.3°C cooler than in an open area[f]. 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[g]. 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[g]. 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. 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^2 of canopy cover was fairly similar among these cities (New York: 13.7 $g/m^2/yr$; Baltimore: 12.2 $g/m^2/yr$; Atlanta: 10.6 $g/m^2/yr$)[h]. 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)[k].

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[h].

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[i,j]. 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[l].

VOC emission rates also vary by species. Nine genera that have the highest standardized isoprene emission rate[m,n], 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* sp.)[n].

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 equipment 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[o]) and other chemicals such as VOCs, carbon monoxide, nitrogen and sulfur oxides, and particulate matter[p].

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%[q].

Energy Effects on Buildings: Trees reduce building energy use by lowering temperatures and shading buildings during the summer, and blocking winds in winter[r]. 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[s]. 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.

Combined 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[l]. 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[t].

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[u].

Urban Forest Management: Urban forest management strategies to help improve air quality include[v]:

- 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).
- Utilize evergreen trees for particulate matter reduction (year-round removal of particles).

[a]Nowak, D.J.. 1995. Trees pollute? A "TREE" explains it all, in: Proc. 7th Natl. Urban For. Conf., (C. Kollin and M. Barratt, eds.), American Forests, Washington, DC, pp. 28-30.

[b]Nowak, D.J., McHale P.J., Ibarra, M., Crane, D., Stevens, J., and Luley, C. 1998. Modeling the effects of urban vegetation on air pollution, In: Air Pollution Modeling and Its Application XII. (S. Gryning amd N. Chaumerliac, eds.) Plenum Press, New York, pp. 399-407.

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