A Revised National Research and Technology Transfer Agenda for Urban and Community Forestry

June 2003

Prepared by the Tree Research and Education Endowment Fund, Champaign, Illinois

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

BACKGROUND

Urban forestry and arboriculture strive to improve the quality of life through the maintenance of healthy, functioning trees and urban ecosystems. United by a common agenda, the urban forestry community will make even greater strides to improve our quality of life. Such an agenda will help allocate resources, determine priorities, and serve as a catalyst for working together.

The National Urban and Community Forest Advisory Council (NUCFAC), established by the 1990 Farm Bill that amended the Cooperative Forestry Assistance Act of 1978, is charged with creating *"a national action plan that includes recommendations for new and expanded research efforts directed towards urban and community forestry concerns; a summary of research priorities; and an estimate of funds needed to implement such research on an annual basis for the next 10 years."* With financial support from NUCFAC and guidance from an advisory committee that included 11 representatives from all areas of the field, the Tree Research and Education Endowment (TREE) Fund convened the second National Research and Technology Transfer Summit in December 2002 to help NUCFAC fulfill this obligation.

ASSESSMENT OF THE FIRST *AGENDA*

The first Summit convened in 1991 and drafted the first *National Research Agenda for Urban Forestry for the 1990's*. Before updating the *Agenda* for 2002, the impact of the 1991 *Agenda* was assessed, and the results were used to guide the 2002 Summit.

The survey found that researchers, research sponsors, and research "users" all agreed that the first Research and Technology Transfer Summit helped to focus attention and efforts; sparked changes in industry practices; produced economic impact; improved technology transfer; and enabled organizations to make informed decisions about supporting areas of research. To improve technology transfer, the survey suggested the highest priorities were to address the practicality of research findings and applications, and to educate public and city officials.

KEY SUMMIT FINDINGS

Technical Disciplines

Thirty-two technical disciplines were identified in two major categories, (1) forest management and resulting benefits to people and (2) tree care practices and the fundamental science supporting them. Research and technology transfer needs were identified within each of the technical disciplines.

FOREST MANAGEMENT AND RESULTING BENEFITS TO PEOPLE

Land-Use Planning and Public Policy

Effective and responsive land-use policy and planning processes are critical to urban and community forestry. Natural systems information must be incorporated to guide land-use planning and policy decisions. Tools and technology transfer materials that support urban ecosystems must also be developed.

Tree and Forest Inventories and Analysis

Many different inventory systems for urban trees and ecosystems are available, but there are no standard protocols that allow data to be merged

for regional or national analyses. Developing these standards and incorporating new technologies are the highest priorities.

Trees and Infrastructure

Millions of dollars of damage to infrastructure by trees and damage to trees themselves could be prevented through the development of better design process and mitigation methods that integrate hardscape, green infrastructure, and greenscape.

Rights-of-Way Management

Effective management of rights-of-way can benefit wildlife, people, and urban ecosystems. Developing and applying new cost-effective technologies to control plant growth and understanding how these technologies impact target plants, non-target plants, and animals are the greatest needs.

Urban Ecosystem Restoration and Sustainability

Urbanization damages the natural ecosystem and diminishes the ecosystem's many benefits that are valued by humans. Management of the urban forest ecosystem must be based on both social context and an understanding of basic ecology.

Urban-Wildland Interface

In the transitional zone between urban and wild areas, conflicts often arise from land-use and management decisions. These areas may be at greater risk from fire or other destructive events. Model strategies that balance conflicting uses while considering the value of the resources and costs must be developed.

Urban Tree Waste Utilization

Each year, 3 to 4 billion board feet of hardwood lumber from urban tree operations is disposed of as waste when it could be turned into marketable lumber. A greater understanding of this potential resource, and the capacity of the organizations involved to deal with it, would allow this valuable resource to be captured.

Watershed Protection

As communities grow, impervious surfaces greatly disrupt watershed function. Creating designs, best management practices, and specifications for preserving and restoring vegetation can help stem the damage. Information that would help foster partnerships between urban and rural areas is also needed.

Urban Forest Health

A standard national assessment of urban forest conditions and health is needed to protect and maintain the urban forests. Basic research is also needed to define natural systems, monitor forest health, and reduce exotic pests and invasive species.

Municipal Forestry Program Status and Scope

All of our urban forestry research and knowledge is of little use if we do not train and adequately fund people to accomplish the work in our towns and cities. It is important to analyze the capacity of municipalities for making good things happen on the ground.

Economic Benefits and Value of Urban Forests

Decisions to effectively allocate the scarce resources needed to manage urban forests require a careful accounting of benefits and costs. A greater understanding of the economic value of the benefits resulting from urban forests and their management must be gained by developing models, inventories, and methods.

Environmental Benefits of the Urban Forest

Urban and community forests are valuable for their contributions to the quality of life, which include moderating temperatures and improving air, water, and soil quality. These contributions should be quantified and measured, and urban ecosystem health should be improved.

Benefit–Cost Analysis and Modeling

The various urban forest benefits and costs must be compared to determine which forest design and management practices produce optimal benefits. Basic information about the urban forest structure and resulting benefits must be quantified, and models to guide management decisions must be developed.

Social Benefits (Impacts on Neighborhood and Community Quality of Life)

Because urban and community forestry helps build human capital and strengthen communities by reducing crime and revitalizing neighborhoods, trees are a critical component of high-quality places to live, work, and play. More research is needed to document this phenomenon and to understand the mechanisms and factors involved.

Human Health Benefits

One of the most important but least recognized benefits of the urban forest is its power to improve physical and mental health. To maximize potential psychological benefits, these health impacts must be more fully understood, quantified, documented, and communicated.

TREE CARE PRACTICES AND THE FUNDAMENTAL SCIENCE SUPPORTING THEM

Tree Dynamics and Worker Safety

Tree work is a high-risk profession. A better understanding of tree dynamics and safety, work systems, and worker behavior can improve safety practices and equipment. Analysis of accidents and evaluation of equipment will improve understanding of how and why accidents occur.

Pruning Trees in Urban and Suburban Landscapes

Landscape trees often grow without appropriate pruning to develop a branch structure consistent with sustainable urban forests. The challenge is to understand the response of urban trees to pruning treatments and to develop protocols that help prevent structural and plant health problems from occurring.

Plant Health Care

Plant health care strives to maintain trees in a strong physiological state so that they can withstand damaging pests and deleterious environmental conditions. Arborists need tools and methods to measure, improve, and maintain plant health and implement Plant Health Care programs safely.

Tree Structure and Risk Assessment

An important part of tree care is managing risk of tree failure. A better understanding of why trees fail, as well as the means of detecting and mitigating tree defects, can reduce the risk to tree workers, communities, and their citizens.

Damage to Mature Trees from Construction and Development

Trees are lost unnecessarily during construction because people lack knowledge about how to prevent serious damage and because of the complexities of development on valuable land. Measuring the cost-benefit ratio of tree preservation and demonstrating it to developers could help prevent damage.

Cable and Bracing, Lightning Protection

Lightning protection and support systems protect trees from damage, helping to maximize their longevity. These systems could be improved by analyzing their design and function, developing protocols for treating trees, and making installation of systems safer, more effective, and less expensive.

Nursery Production and Site Selection

The challenge in this technical discipline is to develop methods of nursery production that meet both the producer's need for rapid growth and the need for survival and rapid establishment after a tree is permanently planted in the urban landscape.

Root Growth on Urban Sites

Compared to natural forests, urban sites and nursery production methods impose artificial conditions and frequent disturbance on tree roots that make it difficult for trees to thrive. The challenge is to understand the requirements of tree roots and to provide these essential requirements in urban landscapes.

Tree Water Management

Understanding water requirements is important for optimum urban tree health and to sustain trees during drought. The basic water needs of different species and other factors must be better understood, and this information must be applied in models and in recommendations that can be useful in the field.

Soil Management

Soils in urban areas are subject to continual degradation and contamination, and trees are planted too often without enough high-quality soil to sustain them. Research and technology transfer is needed to develop and apply evaluation tools, mitigation techniques, and recommendations for better designs.

Genetics and Breeding: Tree Evaluation and Improvement

Urban forests are under increasing assault from a broad range of pests and environmental stresses, and the selection and development of genetically

superior trees is essential to addressing these issues.

Tree Growth Regulators

Because urban trees grow in such restricted spaces, growth regulators hold much potential for giving us trees that will live longer with less maintenance. Research is needed to better understand how tree growth regulators affect trees and the organisms that are interdependent with them.

Plant Pathology

Research is needed to manage native and exotic diseases destructive to the urban and community forest, using cultural, biological, traditional, and/or alternative treatment programs. Product delivery systems that reduce environmental impact and improve plant health should be developed.

Entomology

More research is needed to identify the factors responsible for pest outbreaks in the urban forest and to determine how cultural practices contribute to and mitigate such events. Control methods should be more effective, efficient, and environmentally sensitive. Managing exotic pests is an emerging need.

Decay Development and Wound Closure

Decay and cracks in trees can make trees unstable and potentially hazardous. The highest priorities are gaining a greater understanding of the biology and morphology of decay and developing better tools and techniques to prevent, evaluate, and treat trees with these defects.

Environmental Stress

The life spans of urban trees are shortened by physiological stresses that are caused by a myriad of adverse conditions inherent in the urban growing environment. Better strategies to treat trees that are now afflicted by physiological stress and ways to avoid stress for trees to be established in the future must be developed.

Phytoremediation

Phytoremediation, the use of vegetation to clean up contaminants in the soil and water, promises to be both effective and relatively inexpensive. More research is needed to understand the tree's interaction with the contaminants and the risks and benefits involved in order to realize the potential of phytoremediation.

Themes

Collaboration across the many technical disciplines was noted as lacking during the assessment of the effectiveness of the *1991 Agenda*. To increase cross-disciplinary collaboration in the future, eight common overarching themes that reflected the broad needs for research and technology transfer were identified. All themes were considered equally high in priority.

Benefits and Costs of Urban Forestry

The need to examine the relationship of benefits and costs emerged in about half of the technical disciplines in both urban forestry and arboriculture. The full impact of urban forestry management choices must be traced--from their effects on urban forestry processes and structure, to the resulting functions, to the final value of the urban forest.

Changing Land Use

The technical disciplines of land use, rights-of-way management, and the urban-wildland interface are addressed in this theme. As forests are destroyed and fragmented, ecological and economic quality-of-life factors are compromised. Understanding the nature of this complex issue is the most pressing question. When the issue is understood, effective tools to help structure and implement policies and programs that facilitate the maintenance, transition, and restoration of functional urban forest ecosystems can be developed.

Communications and Technology Transfer

All technical disciplines depend upon effective communication to reach appropriate audiences. The most pressing needs are to know the learning styles, learning preferences, values, and motivators of customers or target publics, and to develop and distribute messages based on the best combination of communication methods, communication material, and best marketing strategies.

Environmental Issues

This theme spans the disciplines involving soil and water and ecological concerns. The environmental

benefits of urban forestry should be measured and modeled into solutions that communities can use to support the preservation and development of urban and community forest resources.

Healthier, Longer-Lived Urban Trees and Forests

Most technical disciplines in arboriculture and biology, as well as forest management disciplines concerned directly with individual trees, were addressed by this theme. A better understanding of tree biology, management practices, design elements, and ecosystem function will result in a more sustainable urban forest.

Response to Critical Events

The technical disciplines that encompass mensuration of urban forest resources, land management, and the many damaging factors and resistance to those factors, are all reflected in this theme. Basic ecological research is necessary to understand how ecosystems function in urban landscapes and to develop management options that minimize the loss of services and maintain ecological integrity.

Risk Management

The urban forest is not a risk-free environment for citizens or for the tree workers who are employed to care for it. Aging tree populations are often associated with an increase in the risk of tree failure. A better understanding of why trees fail, as well as the means of detecting and mitigating tree defects, can reduce the risk to our communities and their citizens. Improved data on accidents can aid in creating a safer environment for tree workers.

Urban Forestry and Arboricultural Tools

Virtually all of the technical disciplines cited a need for more and better tools. The basic needs of trees and ways of providing for their needs must be fully understood in order to inform the best treatment and management decisions to support sustainable, healthy urban and community forests.

Funding Recommendations

More than 80 percent of the population of the United States lives in metropolitan areas and benefits in some way from the forest ecosystem around them. In many states, the urban forestry and horticulture industry is larger than any agronomic crop. Urban forestry research is multidisciplinary in nature. The benefits that trees provide to people must be considered along with the biological and environmental issues. The 1991 NUCFAC strategic plan recommended reallocating USDA funding to commit a minimum of 20 percent of forestry dollars to urban forestry research by 2001 and to increase total urban forestry research funding from public and private sectors by 100 percent above 1991 levels by the year 2001. These goals were not met and are now inadequate to support the priorities of this *Agenda*.

Putting the *Agenda* to Work

Promoting the new *Agenda* initially, and keeping it current and visible over the next decade, are key to making the most of the investment in the Summit. Every organization and agency funding urban forestry and arboricultural research and technology transfer must incorporate the *Agenda* into its programs and ask that proposals for grants directly address its priorities. Several ideas for keeping the *Agenda* current are presented, including "'interim summits," but NUCFAC must identify a champion for this cause or the revised *Agenda* will not remain any more current or visible than the *1991 Agenda*.

INTRODUCTION

Urban foresters, arborists, and educators, research scientists, public administrators, and others working in the fields of urban forestry and arboriculture strive to improve the quality of life through healthy, functioning trees and urban ecosystems. Yet obstacles exist that prohibit all communities from realizing the benefits of ample, robust urban and community forests. Urban forestry research and technology transfer are the keys to removing many of these obstacles. Technology transfer is simply the communication and education necessary to make research findings and knowledge useable.

United by a common agenda, the urban forestry community will make greater strides to improve the quality of life. Such an agenda will help allocate resources, determine priorities, and serve as a catalyst for working together. The National Urban and Community Forest Advisory Council (NUCFAC) creates that agenda every 10 years for its report to the Secretary of Agriculture.

NUCFAC, established by the 1990 Farm Bill that amended by the Cooperative Forestry Assistance Act of 1978, is comprised of 15 representative from all areas of urban and community forestry working to improve America's communities. The bill mandates that NUCFAC ". . . *shall create a national action plan that includes recommendations for new and expanded research efforts directed towards urban and community forestry concerns; and a summary of research priorities; and an estimate of funds needed to implement such research on an annual basis for the next ten years*."

The Tree Research and Education Endowment (TREE) Fund took the lead in facilitating the development of the new National Urban Forestry Agenda for consideration by NUCFAC. With financial support from NUCFAC and guidance from an advisory committee of 11 representatives from all areas of the field, the TREE Fund convened the second National Research and Technology Transfer Summit in December 2002.

This document presents a summary of that assessment, an overview of the Summit decision-making processes, and the key findings resulting from the Summit. There is also a discussion of funding needs and recommendations for putting the *Agenda* to work. We hope that everyone working in the fields of urban and community forestry and arboriculture will find the results of the Summit meaningful and useful. If we will work together on the priorities identified in the Summit process, we will be able to enjoy more thriving trees and urban forests capable of providing significant benefits to residents of communities of all sizes throughout the United States.

NATIONAL URBAN AND COMMUNITY FORESTRY RESEARCH AND TECHNOLOGY TRANSFER ASSESSMENT

The initial phase of this project was to assess the progress of urban and community forestry research and technology transfer since publication of the first agenda, the *1991 National Research Agenda for Urban Forestry in the 1990's*. The results of this assessment would then serve as a sound basis upon which to plan the Summit of 2002. The TREE Fund engaged Environmental Consultants, Inc., and CRA, Inc., to design and implement methodology to assess the effectiveness of the first agenda and to evaluate various stakeholder perceptions of current urban and community forestry research and technology transfer needs. The complete report, *Assessing the Progress of Urban and Community Forestry Research and Technology Transfer*, is available through links at the NUCFAC http://www.treelink.org/nucfac/ and TREE Fund http://www.treefund.org/ websites. A brief summary of the results follows.

OBJECTIVE 1: To evaluate experts' perceptions of the impact of the *1991 National Research Agenda for Urban Forestry*. This research used a Delphi-based approach to gather data from experts across three key audiences—research sponsors, researchers, and research users—to accomplish a solid, expert-based assessment of the *1991 Agenda* and its relationship to subsequent advances in urban and community forest research and technology transfer. The Delphi technique incorporated a two-phased approach to data collection: first, an open-ended survey to explore perceptions and identify primary arguments, and second, a quantitative survey to rate expert agreement to claims about the *Agenda*.

This part of the assessment revealed that **experts felt the *1991 Agenda***:

- Has had a significant economic impact on the urban forestry industry
- Has helped to focus attention, research efforts, and funding on top priorities and information needs
- Has led to improvements in technology transfer
- Has been effective in advancing general awareness of arboriculture/urban forestry issues
- And that research projects funded since 1991 have resulted in significant practice or policy changes in arboriculture and urban forestry

Further, **experts** noted the following **shortcomings of the *1991 Agenda*:**

- It was not communicated well to those outside the research sponsor circle.
- It was not influential in increasing collaboration among research organizations.
- It should have been reviewed to ensure continued applicability.
- Results depended on actual funding decisions, rather than the Agenda's priorities.

OBJECTIVE 2: To assess experts' perceptions of current research and technology transfer needs related to urban and community forestry. This research used a Delphi-based approach to gather data from experts across key audiences—researchers, arborists, and urban foresters—to assess experts' needs and priorities across a variety of environmental, economic, and social issues. The Delphi technique incorporated a two-phased approach to data collection: first, an open-ended survey to identify experts' primary needs and priorities, and second, a quantitative survey that asked experts to respond to questions based on findings from phase one.

The survey generated these findings about **experts' view of current needs**:

- "Root systems" was identified as the highest research priority and "urban planning" as the area in which technology transfer requires the most improvement.
- The need to "educate public and city officials" surfaced repeatedly throughout the survey.
- The need for practical research and for effectively communicating those results to practitioners was emphasized.
- "Translating research into standards and best practices" was suggested as the most effective approach to bridging the gaps in the application of research findings related to arboricultural practices.
- Not surprisingly, over three-quarters of the experts agreed that technology transfer needs differ across the issues of Benefits, Urban Forest Management, Arboricultural Practices, and Tree Biology/Ecology. The research needs expressed by respondents correlated highly with job responsibilities and professional association membership.

OBJECTIVE 3: To assess non-expert stakeholders' impressions and priorities related to trees and urban forests. This research used a telephone-based qualitative survey assessment to explore perceived needs and priorities related to a variety of environmental, economic, and social issues. Results of this qualitative survey provided a foundation for the development of quantitative surveys to allow generalization across non-expert audiences that included builders, planners, developers, business owners, elected officials, and the general public.

Responses from the groups varied somewhat among non-expert groups, but **general findings were**:

- Benefits of trees were perceived to be clean air, aesthetics, shade, property values, wildlife habitat, and jobs
- The highest concerns expressed were tree removal without replacement, dying/diseased trees, maintenance, quality and selection of planting locations, damage to property/utility wires, and issues regarding ownership
- Suggestions to promote benefits and address concerns included more tree planting and maintenance, education, conservation, regulation, research, zoning, promotions, and financial incentives
- Non-experts nearly always prefer to learn about trees from publications and face-to-face contacts, but some interest was expressed in learning more from Internet-based sources
- Non-experts wanted to learn more about species-specific topics, tree benefits, environmental issues, tree maintenance, and environmental issues

OBJECTIVE 4: To assess non-expert research users' experiences, preferences, and attitudes related to technology transfer. This research used an Internet-based survey to explore various aspects surrounding the effectiveness of current technology transfer as well as users' desire for future technology transfer.

The opinions of non-expert research users' were that:

- More than 90 percent of research users believe that it is important in their jobs to keep up with current research. Roughly 70 percent of research users consider themselves up-to-date on research findings. Only half of research users find it easy to keep up-to-date.
- Those who find it easy to keep up-to-date noted the availability of resources. Those who find it difficult noted that constraints on their time limited their ability to remain technically current.
- The *Journal of Arboriculture* is a preferred source of findings for many research users, and events sponsored by the International Society of Arboriculture are among the most useful face-to-face sources of research findings.
- Respondents describe well-communicated research in the areas of urban forestry management, tree planting, and tree biology.
- Research users indicated that summaries of research and additional Internet-based information exchanges would make it easier to keep up-to-date on research. (Note: this was a Web-based survey.)

THE SUMMIT

The results of *Assessing the Progress of Urban and Community Forestry Research and Technology Transfer* were used as a starting point for planning an effective process for the Summit. Research and technology transfer greatest needs, as identified in the survey, were influential in categorizing the broad realm of technical disciplines. The assessment results helped all participants think broadly in terms of the full scope of research and technology transfer needs.

An advisory committee (listed separately in the participants section), representative of the constituent groups involved in urban and community forestry and arboriculture, was formed to design an effective working agenda and process to achieve the objective.

The Summit sought to gain consensus on the top issues in urban forestry research and technology transfer, satisfying the Congressional reporting requirements of NUCFAC, as stated in the 1990 Farm Bill. Special efforts were made to consider all perspectives and interests. The goal was to foster a sense of collaboration and cooperation. The Advisory Committee established the following Summit objectives:

1. Involve environmental, ecological, biological, social, and practical representation in constructive consensus-driven dialogue and decision processes
2. Assess and incorporate, as appropriate, the existing research opportunities and constraints identified in the *2000–2002 Assessment* into an updated national research agenda
3. Assess and incorporate, as appropriate, the existing technology transfer opportunities and constraints identified in the *2000–2002 Assessment* into an updated national technology transfer agenda
4. Establish urban forestry and arboriculture needs and funding recommendations for research and technology transfer for the next decade

The Advisory Committee carefully and objectively assembled a list of constituents that needed to be represented. The organizations were chosen to represent a full range of perspectives, from small communities or organizations to the national view of federal agencies. Professionals involved in the green industry, from nurseries propagating new trees to commercial arboriculture firms involved in tree maintenance and removal, were invited to participate. Allied professionals, such as landscape architects, public works engineers, and restoration ecologists, were included. A full complement of urban forestry champions representing a number of diverse organizations also contributed. The following organizations and constituent groups agreed to send a representative.

Alliance for Community Trees
American Forests
American Nursery and Landscape Association
American Society of Consulting Arborists
American Society of Landscape Architects
American Public Works Association
ANSI Z60.1 Standard (Nursery Stock)
ANSI Z133 Standard (Safety)
ANSI A300 Standard (Tree Care)
Cities, large and small
Council of Landscape Architects Registration Boards

Commercial Arborists
Conservation organizations
Ecological restoration
Environmental/interpretation educators
International Society of Arboriculture
Minority interests
National Arborist Association
National Association of State Foresters
National Aeronautics and Space Administration
National Recreation and Parks Association
National Association of Homebuilders
National Arbor Day Foundation
National Tree Trust
National Urban and Community Forestry Advisory Council (NUCFAC)
Society of American Foresters
Society of Municipal Arborists
Tree Research & Education Endowment (TREE) Fund
TreeLink
USDA Forest Service (Technology Transfer)
USDA Forest Service (Research)
USDA Forest Service (Director's Office, U&C Forestry)
USDA Cooperative State, Research, Education, and Extension Service
Utility Arborists Association
Urban forestry/arboriculture educators
U.S. Environmental Protection Agency

The Summit was intended to provide an opportunity for research users to interact with research producers as part of the priority-setting process. To provide a framework for discussion and prioritizing, the Advisory Committee also carefully constructed a list of 32 technical disciplines (see next section) that represent the breadth of urban and community forestry and arboriculture. An expert in each of the disciplines was invited to participate as a technical resource and to lead relevant discussions.

When the Summit convened on December 16, 2002, the committee co-chairs and facilitators briefed all participants on the process, expectations, and tasks of the Summit. Participants were asked to think broadly with a vision for the future of urban forestry over the next 10 years. A presentation of the assessment of the *1991 Agenda* gave everyone sufficient background to approach the current agenda. Overview discussions gave way to careful development of technical disciplines or topic areas in small groups. Each technical discipline was considered, and priorities for outstanding research needs and technology transfer needs were identified and confirmed or declined by the full group in a voting process. Once they were fully developed, common themes began to emerge across the individual disciplines. The whole group worked to identify and distill these themes; then small groups worked to refine them.

As the Summit closed on the third day, the entire group considered the funding needed to address these priorities. Strategies for putting the agenda into wide use were also discussed.

Priorities: THE TECHNICAL DISCIPLINES

Urban forestry and arboriculture are complementary, interrelated fields spanning a broad range. Arboriculture may, for example, address structural weakness in individual trees or devise strategies to preserve trees during construction activities. Urban and community forestry may work to address regional concerns of water quality by involving citizens in decisions affecting vegetation in a watershed. Or the role of urban and community forests in improving air quality may be investigated on a national scale.

The two primary fields are completely interdependent on each other to grow and maintain trees and forests for the benefit of communities. For example, a study of a large-scale concern, such as energy consumption, may find that strategically choosing and locating trees in residential landscapes would lower energy demands for cooling. Arboriculture must then ensure that these working landscape trees thrive and are compatible with homes and residents, perhaps through pruning to optimize form and function or through breeding that minimizes the production of volatile organic compounds and maximizes summer shade.

Just as the urban forest ecosystem is composed of interdependent individual trees and organisms, all of urban and community forestry and arboriculture is composed of these technical disciplines. The Advisory Committee identified 32 technical disciplines and grouped them into two major categories.

URBAN FOREST MANAGEMENT AND RESULTING BENEFITS

- Land-Use Planning and Public Policy
- Tree and Forest Inventories and Analysis
- Trees and Infrastructure
- Rights-of-Way Management
- Urban Ecosystem Restoration and Sustainability
- Urban-Wildland Interface
- Urban Tree Waste Utilization
- Watershed Protection
- Urban Forest Health
- Municipal Forestry Program Status and Scope
- Economic Benefits and Value of Urban Forests
- Environmental Benefits of the Urban Forest
- Benefit-Cost Analysis and Modeling
- Social Benefits (Impacts on Neighborhood and Community Quality of Life)
- Human Health Benefits

TREE-CARE PRACTICES AND SUPPORTING TREE BIOLOGY

- Tree Dynamics and Worker Safety
- Pruning Trees in Urban and Suburban Landscapes
- Plant Health Care
- Tree Structure and Risk Assessment
- Damage to Mature Trees from Construction and Development
- Cable and Bracing, Lightning Protection
- Nursery Production and Site Selection
- Root Growth on Urban Sites
- Tree Water Management
- Soil Management

- Genetics and Breeding: Tree Evaluation and Improvement
- Tree Growth Regulators
- Plant Pathology
- Entomology
- Decay Development and Wound Closure
- Environmental Stress
- Phytoremediation

Groups led by technical experts drafted the following summaries of the major research and technology transfer needs and priorities. A list of needs was generated for each technical discipline by small working groups, and then everyone prioritized the needs within each technical discipline by voting. The highest priority research and technology transfer needs are indicated for each technical discipline.

■ Land-Use Planning and Public Policy

GORDON BRADLEY, University of Washington, and ED MACIE, USDA Forest Service

Important Issues: Land-use planning and policy at the regional, state, and local levels is highly influential in the successful resolution of many current urban and community forestry challenges. Planning and policy processes can provide a forum for active and broad participation by people interested in the condition of an urban ecosystem, the development of requisite governance systems to manage across urban forest ecosystems, and the appropriate implementation strategies to maximize ecological and human services. Effective and responsive policy and planning processes are critical to effectively addressing urban and community forestry issues.

Existing and Emerging Priorities: No technology transfer priority emerged as higher than the others.

1. Use natural systems information to guide land-use planning and policy decisions. **Highest Research Priority**
   - Link natural system data to land-use decisions
   - Develop appropriate ecosystem analysis approaches for decision making
   - Integrate environmental, social, psychological, and economic benefits of urban forests into land-use decisions
2. Develop land-use planning and policy decision tools that support urban ecosystems
   - Develop descriptive and prescriptive models for decision making
   - Specify role of utilities in decision models
   - Apply remote sensing and Geographic Information Systems technology
   - Formulate sustainable development strategies
   - Identify specific guidelines to support the maintenance and restoration of healthy urban ecosystems
   - Create concise landscape and tree preservation ordinance models
   - Develop standards for the evaluation and reuse of brownfield sites
3. Develop appropriate technology transfer strategies
   - Share successful community forestry land-use planning and policy cases
   - Develop intra-jurisdictional arrangements to manage at the landscape scale
   - Strengthen the role of resource managers in policy and planning
   - Increase involvement of government and non-government organizations in the decision-making process

■ Tree and Forest Inventories and Analysis

ROBERT MILLER, University of Wisconsin, Emeritus

Important Issues: Urban forest inventories vary from street tree inventories, total tree inventories, urban forest assessments, urban ecosystem analyses, and more. Inventory applications are decided by the users, by selection criteria, and by objective.

Municipalities, ranging in scale from large metropolitan areas to small communities, most commonly use the street tree inventory type. Objectives may be predominantly political, such as describing the extent and value of the resource to influence municipal priorities; or the intention may be to provide an ongoing management tool to improve productivity. Sometimes there are no clear goals or end uses in mind for the system, so valuable information goes unused by the community.

Many different inventory systems are commercially available, but there are no standard protocols guiding data collection, data storage and retrieval, or standard recommended shelf-life of inventory data. This means that there is a wealth of information available in individual communities, but there is no way to merge the data for regional or national analyses.

Systems such as total tree inventories, urban forest assessments, and urban ecosystem analyses are currently available but are not widely used by urban foresters. At present, researchers mostly use these systems to better describe the urban forest and its many functions.

Existing and Emerging Priorities:

1. Improve inventory systems application in communities. **Highest Research Priority and Highest Technology Transfer Priority (shared)**
   - Develop standards of data collection, storage, and retrieval to facilitate use in regional and national urban forestry assessments
   - Develop systems that allow users to apply management goals in system selection
   - Develop guidelines that show users how to best use the information generated

2. Develop and incorporate new technologies. **Highest Technology Transfer Priority (shared)**
   - Incorporate benefit/cost analyses into new and existing programs
   - Apply new data management technologies to urban forestry inventory systems
   - Continue to develop ecosystem and assessment programs and other cutting-edge systems
   - Make ecosystem and assessment computer programs more user-friendly and more readily available to practitioners

■ Trees and Infrastructure

GARY WATSON, The Morton Arboretum

Important Issues: Conflict between trees and infrastructure is a significant economic problem in urban areas. In California alone, approximately $70 million is spent annually to pay for damage resulting from root conflicts with sidewalks, curbs, gutters, and sewers. Attempts to develop methods to exclude roots from these areas have met with limited success. If roots are severed or prevented from developing normally, trees may be more subject to windthrow and resulting injury to people and property. In addition to infrastructure costs associated with repair or replacement, significant losses to the urban forest also occur. Infrastructure damage has been identified as the second most common reason for tree removal. Both trees and money are being lost; this is a lose-lose situation.

Trees are rarely given equal priority to hard infrastructure in engineering aspects of land development. Streets are designed for cars, utilities, and people, with the assumption that trees can grow in wherever space is left. Spaces are usually too small and highly disturbed. In order to have the green cities that are envisioned by planners, greater attention and priority must be given to designing and building adequate tree spaces into the infrastructure. Better design will reduce conflicts in the future and result in far less damage to infrastructure by trees. A greater understanding is needed as to how and when roots can contribute to infrastructure damage.

Existing and Emerging Priorities:

1. Integrate hardscape, green infrastructure, and greenscape. **Highest Research Priority (shared) and Highest Technology Transfer Priority**
   - Develop improved technologies and designs that will enable trees and green areas to thrive as an integral part of the infrastructure
   - Inform policy makers of the function of trees as green infrastructure
2. Resolve existing conflicts between tree roots and infrastructure. **Highest Research Priority (shared)**
   - Understand the development of roots and their effects on structures and underground utilities and vice versa
   - Investigate effects of root pruning to accommodate sidewalks
   - Study the effects of plant growth regulators
   - Develop best management practices for planting and managing trees near overhead utility wires

■ Rights-of-Way Management

HARVEY A. HOLT, Purdue University and GEOFF KEMPTER, Asplundh Tree Expert Co.

Important Issues: Rights-of-way connect people and provide for the movement of goods and services. Yet right-of-way vegetation provides benefits to wildlife, people, and the urban ecosystem too. Vegetation is an integral part of management and maintenance of the right-of-way, although it is not intended to be the end product of management.

Rights-of-way touch a continuous array of neighbors on both sides and therefore are subject to public scrutiny. The methods of managing vegetation that are historically the most economical often elicit the strongest reaction from the public. Public education is expected to provide some amelioration of these conflicts with recognition or acceptance of Best Management Practices (BMPs).

Existing and Emerging Priorities: No research priority emerged as higher than the others.

1. Improve line clearance practices based on a better understanding of plant responses. **Highest Technology Transfer Priority (shared)**
   - Evaluate the short-term and long-term response of vegetation, both beneficial and detrimental, to herbicide, mechanical, fire, biological, and manual treatments
   - Recommend optimal pruning standards specific to species, hardiness zone, and pruning method
   - Establish a national tree-failure data base
   - Recommend more effective use of tree growth regulators
2. Explore new technologies to reduce vegetation management costs along rights-of-way**. Highest Technology Transfer Priority (shared)**
   - Compare values, benefits, and hazards of different methods of line clearance trimming
   - Explore the feasibility and cost/benefit of new or alternate construction methods for electric lines, such as underground installation, taller poles to minimize pruning requirements, vertical construction, and the use of tree wire
   - Study alternative uses and disposal methods for right-of-way vegetation waste
3. Define the right-of-way resource and infrastructure; include ownership, as well as plant types and uses
   - Characterize benefits or beneficial uses of right-of-way corridors
   - Investigate the significance of the right-of-way for preserving and connecting habitat for threatened and endangered species, for genetic diversity, and biodiversity
   - Understand the habits and implications of invasive plants in the right-of-way
   - Detail compatible uses for different types of rights-of-way
   - Detail the contribution of trees in meeting mitigation requirements for impervious surfaces in transportation corridors

■ Urban Ecosystem Restoration and Sustainability

WAYNE C. ZIPPERER, USDA Forest Service

Important Issues: The urban forest plays a key role in sustaining our urban ecosystems, countering human impact by reducing energy consumption through shading, evaporative cooling, and sheltering buildings from winter winds; creating livable and safer areas; and providing cleaner air and water, recreational opportunities, and aesthetics. Unfortunately, the stresses (for example, air pollution, compacted soils, construction activities) of the urban landscape severely affect the urban forest, thereby reducing its benefits. To manage the urban forest effectively, the urban forester must have a basic knowledge of its structure and function, models to tests the efficacy of management decisions and plans, and an understanding of how these benefits will change with changing social structures.

Existing and Emerging Priorities:

1. Management of remnant woodlands in urban areas based on social and ecological factors**. Highest Research Priority and Highest Technology Transfer Priority**
   - Develop management protocols for urban woodlands
   - Evaluate how social contexts influence urban woodland management
   - Assess how social and ecological patterns and processes interact
   - Assess how changes in structure alter processes and subsequent benefits
   - Evaluate how human behaviors affect the urban forest structure and its management
   - Map patterns of social and ecological structures to better manage services
   - Conduct cost/benefits analyses to assess the effectiveness of management recommendations
2. Modeling
   - Develop models that project changes in ecosystem services when land use or tree cover changes
   - Develop models to aid managers in maximizing benefits and minimizing management costs
   - Adapt existing ecological models (for example, successional, nutrient, and carbon cycling) to urban conditions
3. Restore and rehabilitate urban sites based on an understanding of basic ecology
   - Determine how non-native invasive plants affect the regeneration and growth of native species and alter ecosystem functions
   - Evaluate how nutrient and carbon cycling varies across different land uses and social contexts
   - Develop restoration and rehabilitation plans for riparian habitats
   - Establish protocols to restore and rehabilitate brownfields
   - Establish goals and objectives for restoration and rehabilitation efforts that address current needs and conditions

■ Urban-Wildland Interface

GORDON BRADLEY, University of Washington

Important Issues: The urban-wildland interface, a transitional zone located between urban and wild areas, is measured by increased human influences and land-use conversions. Developing such land can cause contention. Until settled, interface lands may retain many wildland characteristics, and their proximity to urban populations often fosters arguments over the loss of wild landscapes. Conflicts may also result from planning decisions about the type of land use proposed, the pattern of development, and the implications on the residual landscape. Uncertainties persist about the viability of remaining terrestrial and aquatic habitat; whether natural processes can continue; and whether the landscape will continue to provide scenic and open-space benefits. Precautions to protect ecosystem health and mitigate the probability of catastrophic events, such as fire, must also be addressed.

Existing and Emerging Priorities:

1. Address resource management issues and conflicts. **Highest Research Priority and Highest Technology Transfer Priority**
   - Broaden understanding of issues and conflicts related to wildlife, forest fuels, water resources, visual resources, and invasive species
   - Identify management models that balance conflicting uses and objectives
   - Study economic impacts of sprawl
   - Estimate cost of services to manage resources, including fire protection, to inform community decision making
2. Develop policy and planning strategies
   - Encourage planning and decision making across jurisdictions and at appropriate scales
   - Understand and manage for risk
   - Develop guidelines for structural safety
   - Develop fire-hazard rating systems
3. Improve public perceptions and understanding of the urban-wildland interface
   - Foster public understanding and acceptance of land-use practices
   - Manage conflicts in values and perceptions related to land use

■ Urban Tree Waste Utilization

SAM SHERRILL, University of Cincinnati

Important Issues: Many of the trees that come down in the urban forest every year are either ground into mulch or cut into firewood. With a few notable exceptions, the rest, containing an estimated 3 to 4 billion board feet of potential hardwood lumber, are disposed of as green waste in landfills. The U.S. consumes about 14 billion board feet of hardwood lumber annually, so roughly one-fourth of that total is thrown away. Assigning a conservative market value of $0.50/board foot, lumber worth from $1.5 billion to $2 billion dollars is wasted. This loss is even greater when hauling costs and landfill tippage fees are added. The value of much of this wood could be recovered if it was sawed into marketable lumber.

Can it actually be sawed into lumber? The machinery and methods for felling, sawing, and drying urban trees exists and are easily put into place. What is not certain is whether individuals, organizations, local governments, and businesses that handle the wood are willing to participate. If they did, local government agencies would realize budget savings and demonstrate fiscal responsibility to taxpayers. Environmental and community interests would appreciate efficient local use of a scarce natural resource. Woodworkers would have greater involvement with the material of their craft and benefit from supplies of rare and expensive lumber available at reduced costs. Tree companies could potentially earn a profit by recycling urban wood waste. Research should focus on the questions and issues that bear directly on the feasibility of reclaiming urban trees for lumber that serves both public purposes and private demand.

Existing and Emerging Priorities:

1. Determine the capacity of urban tree waste producers and potential users. **Highest Research Priority and Highest Technology Transfer Priority**
   - Estimate the current volume and quality of urban tree removals
   - Identify markets for high-value products, such as woodworking or pallet making, by major species of urban trees
   - Determine the extent of current wood waste utilization as lumber by the tree-care industry
   - Determine the extent to which local government agencies utilize removed public trees for lumber for public projects (for example, flooring, picnic tables, outdoor furniture)
   - Propose educational efforts to persuade those in urban forestry to consider felled urban trees a renewable source of lumber, not just green waste or sources of mulch and firewood
2. Identify and overcome obstacles that may prevent full utilization of this lumber
   - Understand the views and practices on reclaiming urban trees
   - Evaluate the suitability of urban trees for lumber, considering such liabilities as imbedded foreign material
   - Investigate the risks of making lumber from trees felled or killed by insect infestation or bacterial infection (for example, the emerald ash borer or sudden oak death syndrome)

■ Watershed Protection

GREG RUARK, USDA National Agroforestry Center

Important Issues: Watersheds contain a variety of land uses, such as forestry, agriculture, residential, and industrial uses, and each of these can impact the others. Typically, communities occupy only a portion of a watershed, but they can greatly disrupt a watershed's ability to function. As communities grow, land is covered with sidewalks, pavement, buildings, and other impervious surfaces, diminishing the ability of the soil to absorb rainfall and increasing stormwater runoff. The conventional solution has been to divert untreated runoff into storm drains, where it concentrates and is eventually emptied into rivers and streams. These massive discharges cause bank erosion, channel cutting, and flooding downstream, while generally disrupting the ecological function and integrity of wetlands and waterways. Similarly, runoff from surrounding agricultural land can contain fertilizers, pesticides, sediments, and animal wastes. Federal laws now require counties and communities to improve the water quality of their stormwater discharge. This demands a coordinated effort between rural and urban watershed partners. Utilizing trees and shrubs to buffer riparian areas from stormwater runoff and incorporating vegetated bioswales into urban designs to allow stormwater to infiltrate naturally can help protect watersheds.

Existing and Emerging Priorities:

1. Best management practices (BMPs) utilizing vegetation to manage water resources. **Highest Research Priority and Highest Technology Transfer Priority**
   - Develop specifications to optimize the retention of trees in new developments
   - Design stormwater BMPs that utilize trees and other vegetation to minimize runoff
   - Develop zero-runoff, tree-based designs for parking lots and other built areas
   - Construct species-suitability guides for trees, shrubs, forbs, and grasses used in riparian areas
   - Design riparian forest buffers for floodplain management in urban environments
   - Develop model ordinances for streams, landscaping, open space, and stormwater utilities
2. Monitor the social, economic, and environmental costs and benefits of water resources
   - Develop watershed simulation models to predict effects of projects and policies
   - Devise an "impervious surface ratio index" to gauge impact of development on runoff
   - Design methods to monitor groundwater levels and quality
3. Facilitate better watershed management by both urban and rural communities
   - Develop methods to better coordinate activities between rural and urban watershed partners
   - Design processes to allow urban input in priority setting in rural conservation programs
   - Incorporate Geographic Information System technology to help manage watersheds
   - Use tree-based designs to restore critical corridors for water quality, wildlife, and recreation

■ Urban Forest Health

DANIEL TWARDUS, USDA Forest Service

Important Issues: Currently no standard protocol is available to assess urban forest health even though significant investments have been made in urban and community forestry. A standard national assessment of urban forest conditions and health is needed in order to assess, protect, and maintain these investments. Urban forest and tree inventories quantify the resource but do little to assess overall health. These inventories routinely detect exotic and invasive species that can be seriously detrimental to the urban forest. More information is needed to identify and define natural areas within the urban context and to understand their significance.

Existing and Emerging Priorities:

1. Improve natural systems maintenance. **Highest Research Priority and Highest Technology Transfer Priority**
   - Identify and define natural systems for urban areas
   - Qualify the value of natural systems within urban areas
   - Explore maintenance issues
   - Develop protocols and standards to measure urban forest conditions and health, including insects, diseases, and abiotic problems
2. Reduce exotic pests and invasive species
   - Improve forest and tree monitoring to detect exotic pests
   - Research the impact of exotic species
   - Research mechanisms to control invasive species

■ Municipal Forestry Program Status and Scope

JOHN ROSENOW, National Arbor Day Foundation, and BOB BENJAMIN, Chicago Bureau of Forestry

Important Issues: A major objective of the national urban and community forestry effort has been to enhance local municipal forestry program capacity. This is most appropriate because well-trained and adequately supported municipal foresters are essential to the application of urban forest management and arboriculture knowledge. It is also important to analyze the trends in municipal urban and community forestry programs and the capacity of these programs to adequately manage their resources. Information about the scope of management, the extent and effectiveness of public investment, and often the size, condition, and composition of the urban forest are matters of public record. It is important to capture and analyze this information over time to determine the components of successful programs and to use this information as a guide in working to enhance the ability of local governments to better manage their urban forests.

Existing and Emerging Priorities:

1. Assess and analyze municipal urban forests and program management. **Highest Research Priority and Highest Technology Transfer Priority**
   - Measure budgets collectively and on a per capita basis
   - Assess the degree of professionalism in local government urban forestry programs and the qualifications of managers
   - Analyze the structure, nature, and effectiveness of municipal ordinances, specifications, and policy
   - Determine the longevity of urban forest programs
   - Analyze the size and composition of the municipal forest
   - Determine the benefit-cost relationship of effective tree establishment and maintenance
2. Understand urban forestry leadership
   - Analyze successful municipal programs to determine the source of influence (that is, effective individual leadership or public mandate)
   - Study the effectiveness of the urban forester in gaining support of elected officials, the public, and other municipal managers
3. Gain understanding of the context of local government
   - Compare structures of local governments at all levels of participation in urban forest stewardship
   - Compare costs (that is, human resources and budgets) and benefits of other city assets and services relative to urban forestry
   - Develop models of optimal structure and function for municipal urban forestry programs

■ Economic Benefits and Value of Urban Forests

J. MICHAEL BOWKER, USDA Forest Service, Southern Research Station

Important Issues: Decisions to effectively allocate scarce financial and spatial resources needed to manage urban forests require a careful accounting of benefits and costs. The economic costs are primarily market-based, involving labor and capital, and are easily identified. However, measuring the benefits of urban forests in economic terms is more challenging. Urban forests, both inside and outside city limits, provide many benefits to humans. These benefits can be classified in a number of ways. They may be environmental, social, psychological, or commercial. They may also be direct, such as improved local air quality and more pleasing aesthetics, or indirect, such as lower crime rates or increased property values. Most benefits can be enjoyed within the urban forest. Yet, other benefits, such as improved stormwater management, can be realized by residents throughout the region. Increased property values are an example of benefits that can be estimated using market data. However, many benefits are more public in nature and must be evaluated by non-market procedures.

Existing and Emerging Priorities:

1. Develop an inventory of economic values of benefits resulting from urban forests and their management. **Highest Research Priority and Highest Technology Transfer Priority**
   - Develop economic models based on market and non-market techniques capable of estimating the economic value of resident benefits of urban forests (for example, phytoremediation and soil quantity and quality)
   - Develop economic models based on non-market techniques capable of estimating the economic value of regional benefits of urban forests (for example, reduction of volatile organic compounds and other pollutants, improved water quality, and greenhouse gas mitigation)
   - Develop and explore methods to transfer benefit value estimates across urban settings
2. Improve development and understanding of underlying benefit relationships or production functions between urban forest structure and composition and resulting benefits to humans
   - Develop and test methods to quantify psychological and sociological benefits from urban forests
   - Develop and test methods to better quantify environmental benefits from urban forests, such as water quality and quantity and ecosystem health
   - Develop and test methods to better quantify commercial benefits from urban forests
3. Estimate the economic impacts of urban forest management on the local economy and population
   - Develop input-output models capable of quantifying changes in jobs and total industrial output resulting from alternative urban forest management schemes
   - Identify and develop input vectors relating expenditures associated with activities stimulated by urban forest management and sectors in urban economies
   - Identify and examine the consequences of the distribution of absolute and relative economic benefits of urban forests across various demographics within and outside the urban setting

■ Environmental Benefits of the Urban Forest

KAMRAN K. ABDOLLAHI, Southern University and A&M College

Important Issues: Urban and community forests are an appreciating resource asset estimated to have a value of nearly $30 billion. This value includes contributions to the quality of life through moderating temperatures and improving air, water, and soil quality.

Urban forests provide a reduction of energy costs through summer shade and winter wind protection. Houses shaded by trees need 4 to 25 percent less energy for cooling. Homes sheltered from wind have winter heat savings of as much as 10.3 thousand BTUs or approximately $52 annually. Urban trees will continue to be increasingly important for their energy-saving value as fossil fuels become more scarce and more expensive in the future and as the impacts of global climate change occur. The cooling effects of trees help reduce the need for utilities to increase power generation capacity to meet peak energy load demand. Consequently, less CO_2 is produced, and energy savings are passed along to the public. Nationally, between 400 and 900 million metric tons of carbon are stored in the country's urban forests.

Tree foliage works as a natural air filter of particulate matter and pollutants such as ozone, nitrogen oxides, ammonia, and sulfur dioxides. Trees also take in carbon dioxide and produce oxygen through photosynthesis. Water evaporating from leaves (a process called evapotranspiration) has natural cooling effects. Combined, these processes can have a significant effect on smog and reduce overall air pollution.

Additional benefits of urban forests include slowing and reducing stormwater runoff, flooding, and erosion, thereby reducing potential sources of water pollution. While they are difficult to quantify, these attributes are important, positive societal benefits of establishing and maintaining healthy urban and community forests.

Existing and Emerging Priorities:

1. Quantify the contribution of urban forests to improved air quality. **Highest Research Priority (shared) and Highest Technology Transfer Priority (shared**)
   - Particulate matter and pollutants such as ozone, nitrogen oxides, ammonia, and sulfur dioxides
   - Greenhouse gases, directly through photosynthesis and indirectly through reduced cooling needs
   - Air temperature and heat island effect
   - Volatile organic compounds
2. Investigate the impacts of urban forestry on water and soil quality and quantity. **Highest Research Priority (shared) and Highest Technology Transfer Priority (shared)**
   - Flooding
   - Erosion
   - Water pollution
   - Stormwater runoff
3. Improve urban ecosystem health
   - Expand and improve wildlife habitat
   - Increase nutrient cycling

■ Benefit–Cost Analysis and Modeling

DAVID J. NOWAK, USDA Forest Service, Northeastern Research Station

Important Issues: Urban forests produce numerous environmental, biological, social, physiological, and economic benefits and costs. To yield optimum benefits for society, the various urban forest benefits and costs must be compared to determine which forest design and management practices produce optimal benefits based on societal needs. Not all benefits can be optimized at the same time due to various tradeoffs (for example, optimal wildlife habitats may conflict with optimal designs to improve air or water quality). Design and management decisions must be made to optimize the overall benefits desired by the local population and to sustain these benefits into the future. Integrated modeling approaches that use local data and allow users to quantify and compare the numerous benefits and costs of urban forest design and management decisions will facilitate better urban forest management and improve human health, environmental quality, and living conditions in cities and towns.

Existing and Emerging Priorities:

1. Develop user-friendly, integrated models to quantify urban forest benefits, costs, and values. **Highest Research Priority and Highest Technology Transfer Priority**
   - Quantify net benefits given existing design and management
   - Determine optimal designs and management based on local needs
   - Project future forest benefits and costs given various management and change scenarios
   - Quantify change in benefits and costs given various extreme events (for example, storms)
2. Quantify local urban forest structure
   - Use sampling procedures to accurately provide local urban forest data
   - Analyze remote sensing data to provide local and regional urban forest data in geographic and mapping format
3. Quantify environmental, social and physiological, and economic benefits and costs of the urban forest, and how they relate to urban forest structure

■ Social Benefits (Impacts on Neighborhood and Community Quality of Life)

LYNNE M. WESTPHAL, North Central Research Station, USDA Forest Service

Important Issues: Urban and community forestry (U&CF) can have many impacts on the quality of life in neighborhoods and communities, impacts that make trees a critical component of high-quality places to live, work, and play. U&CF can help build community, reduce crime, and revitalize vacant lots and distressed neighborhoods. Research is just beginning to understand the subtle interplay between the community and the urban forest. General research questions include: How does urban and community forestry help to build and support community? Who benefits from urban and community forestry? How can practitioners ensure the equitable distribution of urban and community forestry benefits? How do these issues vary across and within populations (for example, small town/urban, race/ethnicity, age)? This new knowledge should then inform policy and be implemented. At the same time, urban and community forestry and arboriculture are fields that provide career opportunities. Outreach efforts to further diversify the workforce are needed.

Existing and Emerging Priorities:

1. Investigate the impacts of urban and community forestry on community and quality of life. **Highest Research Priority and Highest Technology Transfer Priority**
   - Understand if and how aesthetics, cultural meanings, reduced stress, recreation, and environmental benefits from U&CF impact neighborhood and community quality of life. Determine the role U&CF can play in fostering social capital and empowerment
   - Compare the impact on social and community outcomes when urban forestry projects arise from within a neighborhood as opposed to projects arising from an outside group
   - Determine the mechanisms through which the urban forest affects local crime and related incivilities like graffiti and litter, and how the urban forest contributes to environmental justice
   - Explore the meaning of trees and tree planting (for example, spiritual values, historical and memorial significance) to urban residents and the extent that these meanings support community well-being.
   - Find effective mechanisms to manage different and often competing social interests
   - Expand U&CF opportunities for stewardship, community service, service learning, and faith-based social programs
2. Study the role of urban and community forestry on human capital.
   - Study the contributions of U&CF to the strength and economic stability of a community by attracting people and jobs. Create effective outreach for U&CF career and volunteer opportunities
   - Study the effects of U&CF on the workplace (for example, increased productivity)
   - Determine whether U&CF-based environmental education broadens understanding and awareness of more general natural processes and broader natural resource management issues
   - Document and promote an understanding of the value that diverse people and cultures bring to U&CF
   - Expand upon the capacity of U&CF to develop new leadership among youth
3. Find additional research methods to produce meaningful information on the benefits of U&CF
   - Develop benefit measures compelling to policy and decision makers to quantify benefits in dollars
   - Develop a tool kit for practitioners interested in empowerment and social capital
   - Develop program evaluation tools and techniques

■ Human Health Benefits

FRANCES E. KUO, University of Illinois at Urbana, Human Environment Research Lab

Important Issues: Some of the most important and least recognized benefits of the urban forest lie in its power to improve human health. Physical health issues are the focus of massive personal and public expenditures, and there is evidence to suggest that the urban forest may combat obesity, counter declining vitality in older adults, and affect other physical health issues. Similarly, mental health is a pressing national concern, and research points to the urban forest as a factor in enhanced social, cognitive, and personal functioning not only in the general population but also in specific populations, such as children with attention deficit/hyperactivity disorder.

If we are to fully reap the human health benefits of the urban forest, these benefits must be more fully communicated, documented, and quantified. Documenting the "dose-response curve" will help generate recommendations for daily or weekly exposure to green spaces for maximum health (for example, "30 minutes a day, 3 times a week"). Identifying the causal mechanisms underlying various health benefits will allow us to tailor exposures and environments to maximize health benefits. And, finally, for these benefits to be most broadly felt, the relationship between the urban forest and health across the population, by race and ethnicity, gender, age, community size, and other demographic variables must be examined.

Existing and Emerging Priorities: No research or technology transfer priority emerged as higher than the others.

1. Document, quantify, and communicate physical health benefits.
   - Health impacts associated with higher levels of outdoor activity (for example, reduced obesity, improved cardiovascular health, increased longevity, and enhanced physical development in children)
   - Health impacts due to improved air quality (for example, reduced asthma, reduced lung disease)
   - Health impacts due to shade (for example, reduced skin cancer)
   - Impacts of green views and scenes in health care settings (for example, reduced pain, speeded recovery)
2. Document, quantify, and communicate mental health benefits.
   - Impacts on healthy social functioning (for example, reduced aggression and rage, increased altruism, strengthened social ties)
   - Impacts on healthy cognitive functioning (for example, increased work productivity, faster performance in the workplace, lower error and accident rates)
   - Impacts on personal functioning (for example, better self-discipline in diet, exercise, alcohol/tobacco use)
   - Enhanced well-being and reduced psychological distress, reduced medication use, reduced suicide
   - Impacts on children's healthy development, functioning, and school performance

■ Tree Dynamics and Worker Safety

JOHN BALL, South Dakota State University

Important Issues: Tree work is a high-risk profession. During the 1990s, more than 600 tree workers were killed, and more than 10,000 sustained injuries that required hospitalization. The most common cause of a fatality is contact with an object, typically a falling branch or tree, closely followed by fatalities from falls and electrocution. The most common serious injury is contact with a falling branch or a chain saw. A better understanding of tree dynamics and safety, climbing and rigging systems, and worker behavior can improve safety equipment and work practices. Analysis of accidents and evaluation of equipment will improve understanding of how and why accidents occur.

Existing and Emerging Priorities: No research priority emerged as higher than the others.

1. Recognize potential hazards of working with trees. **Highest Technology Transfer Priority**
   - Improve documentation of accidents
   - Analyze common fatalities and serious injuries among professional tree workers
   - Analyze accidents to determine safer work practices or ways to improve equipment safety
   - Educate homeowners to improve safety awareness
2. Better understand the relationship of tree-worker behavior to safety
   - Identify behavior that may foster unsafe work practices
   - Improve training techniques to alter such behavior
3. Study tree dynamics and use the knowledge to improve equipment and work practices
   - Improve understanding of how loading is influenced by pruning and rigging
   - Understand the dynamics of felling
   - Create industry laboratory to test tree-work equipment, such as blocks, lines, and harnesses
   - Develop standards to evaluate new climbing and rigging techniques

■ Pruning Trees in Urban and Suburban Landscapes

EDWARD F. GILMAN, University of Florida

Important Issues: Trees are often planted in America's landscapes with little follow-up to develop a structure suitable for sustainable urban forests. The open-grown multi-trunked form that develops in planted landscapes is very different than the natural forest form. Responses to pruning on open-grown trees with co-dominant trunk habits are little understood. Tree managers may often make poor decisions due to a lack of understanding of appropriate pruning requirements. The challenge is to understand how urban trees respond to pruning treatments imposed on them and to develop protocols that help prevent structural and plant health problems from occurring.

Existing and Emerging Priorities: No research or technology transfer priority emerged as higher than the others.

1. Tree species and cultivar response to pruning
    - Understand the effects of pruning cut size and location on the development of internal defects
    - Understand the progression of discoloration and decay related to size of cuts
    - Compare decay rates in good to poor compartmentalizers
    - Learn about the response of cutting into branches with heartwood
    - Know the impacts of removing adjacent multiple branches simultaneously
    - Examine tolerance to pruning dose
    - Recommend optimum tree form for urban landscapes
2. Influence of pruning type
    - Measure the weight distribution and force dynamics of the major pruning types
    - Evaluate the forces generated on structural branches, stem, and roots from major pruning types
    - Study reduction cut influence on breakage and decay
    - Analyze protection zone development in reduced stems
    - Study the influence of pruning type as it relates to failure rate
3. Pruning amount (dose) and frequency
    - Understand dose and frequency influence on structural development
    - Examine pruning dose influence on force and stress changes
    - Compare the influence of pruning dose on plant health
    - Understand dose response to stress reduction on weak unions
    - Examine pruning cycle length on tree failure rate
4. Cost/benefits of pruning programs
    - Compare costs to measured benefits of a preventive pruning program
    - Compare failure rates on pruned to non-pruned trees
    - Compare cost to benefits of the major pruning types

■ Plant Health Care

MICHAEL J. RAUPP, University of Maryland

Important Issues: Trees in urban sites grow in soils with restricted root zones and elevated temperatures, and this diminishes their capacity to retain essential moisture, air, and nutrients. Urban forests are known to have impoverished microbial communities in the rhizosphere and natural enemy communities in and around plants. Shading, pollution, construction, drought, poor drainage, pruning, fertilization, and extremes of temperature and humidity may reduce the abilities of plants to grow and defend themselves from insects and diseases. Existing methods of pesticide application can result in movement of residues offsite and can have adverse effects on beneficial and non-target organisms. Landscape designs that foster plant health, proper plant installation, and appropriate mulching, pruning, irrigation, fertilization, and other cultural practices affect pests and beneficial organisms in urban forests.

Plant health care (PHC) is a management approach emphasizing preventive and ameliorative tactics for maintaining trees in a physiological state that helps them withstand potentially damaging pests and deleterious abiotic environmental conditions. Arborists need methods to measure plant health, improve and maintain plant health, implement plant health care programs safely, and market plant health care programs to clients.

Existing and Emerging Priorities:

1. Understand the link between cultural practices and plant health. **Highest Research Priority (shared) and Highest Technology Transfer Priority**
   - Elucidate the relationships among landscape design, plant culture and management, and their effects on pests and beneficial organisms in urban forests
   - Understand interactions among cultural practices, plant health, pests, and beneficial organisms
   - Identify interactions and relationships in order to develop proactive measures to improve plant health and reduce pest and abiotic problems
   - Develop and communicate plant health recommendations to designers, planners, installers, managers, and residents of the urban forest through print and electronic media
   - Create educational and marketing materials describing Plant Health Care (PHC) and Integrated Pest Management (IPM) programs and their advantages
2. Quantify plant health to guide management decisions. **Highest Research Priority (shared)**
   - Develop clear and specific definitions of plant health
   - Develop rapid, easy, and inexpensive methods for quantifying plant health
   - Make sure that methods for quantifying plant health are accessible in written and electronic form
3. Develop effective, environmentally sensitive pesticides and delivery systems
   - Develop delivery systems such as injectables and systemics that reduce problems associated with current technologies, such as foliar sprays
   - Develop new materials and formulations to control certain key pest groups
   - Train applicators in the safe and efficacious use and disposal of chemicals

■ Tree Structure and Risk Assessment

BRUCE FRAEDRICH, Bartlett Tree Research Laboratory, JOHN BALL, South Dakota State University, and GARY WATSON, The Morton Arboretum

Important Issues: The tree populations in many communities are aging, and aging is associated with an increase in the risk of tree failure. An important part of tree care is managing this risk. A better understanding of why trees fail, as well as the means to detect and mitigate tree defects, can reduce the risk to tree workers, communities, and their citizens. There have been significant advances in our knowledge about tree failures during the past 10 years. A number of studies have improved our understanding of how trees support themselves under natural loading. There are also excellent guides that can assist managers and tree workers in identifying tree defects. Yet, tree workers and citizens are still being injured and killed by trees that fail. This area of research is very new, and there is much more we need to learn and communicate.

Existing and Emerging Priorities:

1. Evaluation of risk factors. **Highest Research Priority**
   - Identify risk factors related to the tree, the site, and environmental conditions
   - Can treatments (remedial, preventive) reduce risk?
   - Develop better techniques and equipment
   - Develop failure profiles for each species
   - Identify root characteristics in the field and predict structural effects from root damage
   - Study the role of wood decay in tree failure
2. Communicating tree risk. **Highest Technology Transfer Priority**

■ Damage to Mature Trees from Construction and Development

GARY WATSON, The Morton Arboretum *

Important Issues: Preserving trees during land development is a difficult process. Land and improvements are expensive, and properties must often be quite small to be economical. The buildings and trees usually compete for the same limited space. Preventing damage to above-ground parts of the tree is relatively simple and involves commonsense measures to protect the trunk and branches from physical damage. The greater challenge is minimizing damage to the root system. Because of the shallow, spreading nature of root systems that extend well beyond the tree branches, completely avoiding damage is impossible. In addition to direct severing, root systems are also affected by soil compaction, changes in surface grade, and drainage patterns. Removing neighboring trees alters the forest environment, and trees may not be able to react to the sudden change. Trees do not always react swiftly to damage on construction sites. Decline may be delayed for years, and death may not occur for a decade or longer. Sometimes trees survive when the odds are against them, or they die for no apparent reason.

Arborists need better indicators of stress, damage, and subsequent recovery in trees. Development is a business, and developers will preserve trees if it is shown to be profitable. Trees do increase property value, however. Only when the cost-benefit relationship of preservation is fully understood will there be incentive for developers to preserve trees.

Existing and Emerging Priorities:

1. Understand how to prevent serious damage **Highest Research Priority and Highest Technology Transfer Priority (shared)**
   - Establish criteria to select which trees to preserve
   - Understand degrees of tolerance to compaction and damage based on size, species, and soil type
   - Establish limits of tolerance for root systems and the "critical root zone"
   - Study the effectiveness of root pruning
   - Predict tree stability following root removal
   - Recommend methods to prevent compaction
   - Compare the effects of temporary root loss from disturbance that is repaired to the permanent loss of root space and reduction of root system
2. Cost-benefit of construction management. **Highest Technology Transfer Priority (shared)**
   - Analyze all the costs necessary to preserve trees beyond direct costs of the consulting arborist, fencing, etc., by factoring in indirect costs, such as less intensive development plans
3. Improve techniques for assessing and ameliorating damage to trees and remnant forests
   - Improve technology to assess tree damage and recovery
   - Develop more effective methods to ameliorate compaction and restore soil structure
   - Enhance root regeneration
   - Develop methods to ameliorate the effects of fill and pavement over roots
   - Identify practical indicators of stress and use them to reduce stress and protect trees from stress-related pests and diseases
   - Enhance regeneration of natives and control invasive species in remnant forests

* Nelda Matheny and Jim Clark of HortScience, Inc., could not attend the Summit but contributed to the development of these priorities.

■ Cable and Bracing, Lightning Protection

THOMAS SMILEY, Bartlett Tree Research Laboratory

Important Issues: Tree lightning protection and support systems are known to protect trees from damage, thus helping to maximize the longevity of a tree. The tools, materials, and techniques used for supporting trees and protecting them from lightning were developed over a long period of time. The benefits of these systems are well known to arborists but poorly documented through research. Additional research on the benefits of lightning protection and support systems is needed. Some of these systems may be overbuilt for the job they are required to do, resulting in greater material costs and installation time than is necessary. This can deter the installation of systems in trees that would greatly benefit from them and may result in the premature or unnecessary loss of the tree. With appropriate research, trees needing these systems could be accurately identified. Ideally, then, hardware sufficient to do the job could be installed efficiently.

Existing and Emerging Priorities: No research priority emerged as higher than the others.

1. Develop more economical systems. **Highest Technology Transfer Priority**
   - Analyze the costs and benefits of systems
   - Find more efficient methods of installation
2. Improve tree selection criteria
   - Identify weaknesses in trees for which cables or braces would be effective
   - Identify species and sizes that are more susceptible to lightning damage
   - Identify locations that are more susceptible to lightning strikes
3. Verify the *ANSI A300 Standard* for cabling and bracing
   - Measure the forces on tree limbs in varying wind speeds
   - Measure shock loads on cables
   - Evaluate the effectiveness of smaller cable sizes used in conjunction with springs or other mechanisms to reduce shock loads
   - Compare the effectiveness of fabric cables to steel cables
   - Find the point at which lags pull out of the trees, based on species
   - Find the minimum brace-rod size necessary to eliminate the breakage of co-dominant stems.
   - Determine the minimum wire size to conduct a lightning strike
   - Evaluate the effect of air terminal shape, size, and location on the receptivity of a lightning protection system
   - Determine if different ground systems are necessary in varying soil textures and depths
   - Find the minimum ground resistance necessary for a functional lightning ground
4. Effects of systems on the tree
   - Analyze positive and negative effects on trees
   - Study tree propping systems to gain sufficient knowledge to use as a basis for a standard
   - Understand how support systems change the dynamics of trees and their long-term effects
   - Investigate the impact on the branches or roots of the explosion that commonly occurs as lightning enters or leaves the protection system

■ Nursery Production and Site Selection

DANIEL K. STRUVE, The Ohio State University

Important Issues: Nursery production practices affect plant establishment and long-term performance. Practices such as fertilization meet the producer's need for rapid growth in the nursery but may produce planting stock that fails to meet the urban forester's needs for survival and rapid establishment in the landscape. These deficits may include low shoot-to-root ratios or inability to produce adequate levels of natural defensive compounds. Plant quality measures based on morphological standards should be supplemented with physiological and genetic standards. The challenge is to develop Best Management Practices for nursery production that meet both the need for rapid growth and for survival and rapid establishment in the urban landscape.

Existing and Emerging Priorities:

1. Study the influence of production methods on establishment and long-term performance of nursery stock**. Highest Research Priority**
   - Measure shoot-to-root ratio, levels of defensive compounds, nutrient loading, and distribution of mineral nutrients and biomass
   - Study nutrition during plant production
   - Evaluate effect of production methods on plant hardiness
   - Examine the root ball–native soil interface and root growth into native soils
   - Explore the water-holding capacity of organic-based container substrates relative to the soil root ball
   - Study the development of malformed roots resulting from nursery practices and recommend methods to identify and correct them at planting
   - Compare container diameter to buttress root development
2. Convey the importance of matching the planting stock genetics (that is, provenance, clone) with the soil type and other site factors**. Highest Technology Transfer Priority**
   - Consider irrigation volume and frequency necessary for rapid establishment
3. Develop physiological and genetic quality standards to supplement morphological standards
   - Develop assays for pathogens
   - Formulate methods to track genetic identity

■ Root Growth on Urban Sites

GARY WATSON, The Morton Arboretum

Important Issues: Environmental conditions for roots vary widely in nature, and root systems of many species have adapted successfully to these varying conditions. The conditions under which tree roots are expected to grow in urban areas often do not match the natural conditions that trees need. Too often, trees are planted to satisfy aboveground design criteria without fully considering below-ground limitations. Factors such as soil drainage and pH are commonly not considered. The challenge is to understand the requirements of tree roots and to provide as many essential elements from the natural landscape as possible in urban settings that may be hostile or unnatural. When the challenge is met, excellent root development will follow.

Existing and Emerging Priorities: No research priority emerged as higher than the others.

1. Better understand how disturbance effects roots. **Highest Technology Transfer Priority (shared)**
   - Compare effects of severing and regeneration among different species
   - Study tree mechanisms for coping with permanent reduction of root space (for example, increase density, etc.)
   - Compare effect of compaction on root growth among various species
   - Design equipment to locate tree roots
2. Reduce abnormalities resulting from nursery production and planting. **Highest Technology Transfer Priority (shared)**
   - Research girdling, circling, and misdirected roots (for example, "J" roots)
   - Study effects of planting trees with the roots too deep in the nursery and/or in the landscape
3. Improve tree root system development on poor-quality sites typical of urban areas
   - Study the effects of commercial rooting products, including biostimulants
   - Establish nutrient benchmarks for use of fertilizers
   - Compare the quantity and quality of root spaces required by different species
   - Develop methods to prevent and detect girdling roots
   - Study rhizosphere interactions
   - Measure and understand the forces exerted by growing roots

■ Tree Water Management

ROGER KJELGREN, Utah State University

Important Issues: Understanding water requirements of urban trees is important for appropriate application of supplemental water, both to maintain optimal tree health and to sustain trees during drought. In arid regions, trees need supplemental water on a permanent basis, but the increasing frequency of drought presses for a greater understanding of optimal and minimal water requirements on the East Coast and in the Midwest. Knowledge of tree water requirements is also important for successful transplanting, especially in situations where the root zone is constrained, such as in above-ground planters. Empirical determination of water requirements of the broad diversity of landscapes is not feasible economically and logistically. Grouping species with similar phenological and water-loss characteristics, such as broadleaf, deciduous, and coniferous trees, is a much more practical approach. Signature species representative of the group can be selected for empirical determination of water requirements that then can be related to standardized reference evapotranspiration. The ratio of empirically measured water loss to reference evapotranspiration can then be used to estimate water loss for a particular tree type. When reference evapotranspiration is measured, recommendation for the optimal or minimal amount of water can be made.

Existing and Emerging Priorities:

1. Understand basic tree water. **Highest Research Priority**
   - Model water demands in varying urban conditions
   - Model tree water use by species
   - Study water interaction with mycorrhizae
   - Understand water requirements at the stand level in relation to stormwater management and cooling benefits

2. Communicate tree water needs. **Highest Technology Transfer Priority**
   - Recommend proper irrigation and scheduling
   - Recommend best use of various delivery systems
   - Develop and disseminate models of water-independent landscapes

3. Convert basic understanding to practical application
   - Model minimal water to sustain established trees during drought
   - Determine irrigation needs of new trees following transplant for optimal survival
   - Research effectiveness of anti-transpirants
   - Experiment using secondary water or effluent water

■ Soil Management

PATRICK KELSEY, Christopher B. Burke Engineering, Ltd.

Important Issues: Soils in urban areas are subject to constant degradation. Excavation during construction destroys the natural soil profile, and poor-quality subsoils end up close to the surface where tree roots grow. Naturally occurring aggregates are destroyed by manipulation and construction traffic. Evaluation of soil condition is difficult without special training and tools. Mitigation of the damage is expensive, difficult to accomplish effectively, and often not done. Trees are often not given enough soil for their roots. This is especially true in downtown areas and in parking lots where pavement predominates. Designing urban spaces with appropriate soil and adequate space to allow for the full and vigorous growth of tree root systems is the best approach. Heavy nitrogen fertilization may contribute to groundwater contamination. Deicing salts contaminate soils for hundreds of feet. However, repair of damaged soil and construction of new soils may offer some solutions. Greater recognition of soil problems and increased efforts to mitigate them are needed for better tree growth in the urban forest.

Existing and Emerging Priorities:

1. Design urban landscapes that provide adequate soil for sustaining trees. **Highest Research Priority (shared) and Highest Technology Transfer Priority**
   - Collaborate on research to formulate and construct topsoil substitutes to supplement diminishing supplies of natural topsoil
   - Design constructed soils that support vigorous root growth and stable pavements
   - Recommend the most effective type and quantity of organic amendments to incorporate in urban soils
   - Determine appropriate volume and depth of soil to allow trees to be vigorous and stable
   - Collaborate on design and recommend the use of semi-permeable infrastructure to facilitate water infiltration, drainage, and gas exchange
2. Manage and mitigate soil damage. **Highest Research Priority (shared)**
   - Recommend measures to control human impacts that degrade soil quality (intense traffic, construction damage, etc.)
   - Experiment with remediation of chemical contamination (heavy metals, salt, herbicides, etc.)
   - Experiment with remediation of physical degradation (structure, aeration, drainage, etc.)
   - Explore soil manipulation, reaggregation, and the use of artificial structure as mitigation options
   - Determine adequate nitrogen levels for tree growth and vigor while reducing or eliminating pollution of ground and surface waters
   - Mitigate soil pH in order to manage micro-elements
   - Evaluate the long-term costs and benefits of soil preparation and modification
   - Find a way to maintain needed water levels while minimizing nutrient losses
3. Evaluation techniques
   - Design simple, accurate, and inexpensive tools for measuring soil properties
   - Fine-tune interpretations of urban soil nutrient tests for the wide diversity of species used

■ Genetics and Breeding: Tree Evaluation and Improvement

THOMAS G. RANNEY, North Carolina State University

Important Issues: Efforts to plan, manage, enjoy, and benefit from our urban forests depend on the strength of genetic building blocks. The need for future research and technology transfer in urban tree genetics is escalating. Urban forests are under increasing assault from a broad range of pests and environmental stresses. Besides established threats, the threats posed by exotic pathogens and arthropod pests have risen dramatically in the last decade. Expanding urbanization and habitat modification have created challenging and adverse conditions for the culture and maintenance of these forests. The selection and development of superior trees is essential to addressing these issues. Using resistant germplasm and maintaining broad genetic diversity are fundamental tenets of urban forest management and are among the most ecologically sound solutions for these problems.

Concerns over ecological impacts of invasive species have been mounting. Although non-native trees are extremely valuable components of our urban forests, precautions should be taken so they do not invade and disrupt sensitive ecosystems. Unwanted fruit litter and allergy-aggravating pollen are also problems in urban areas that can be addressed with the development of sterile trees. Molecular approaches to genetic improvement provide both opportunities and risks. The benefits of rapid and significant advances need to be weighed against the risks of genetic out-crossing, human allergies, and philosophical opposition.

Existing and Emerging Priorities:

1. Select and develop sustainable trees**. Highest Research Priority and Highest Technology Transfer Priority**
   - Improve pest resistance
   - Enhance tolerance to environmental stresses
   - Lower volatile organic compound emissions
   - Cultivate superior rootstocks
   - Develop plant evaluation protocols
2. Maintain and enhance genetic diversity of urban forests
3. Select and breed sterile trees
   - Reduce invasiveness of non-natives
   - Reduce pollen and allergens
   - Eliminate fruit litter

■ Tree Growth Regulators

GARY WATSON, The Morton Arboretum

Important Issues: Traditional use of tree-growth regulators has focused on controlling twig growth, primarily to reduce pruning needs under utility lines. Some of these compounds could also be used to control the growth of trees in landscapes with restricted growing spaces. Size control, combined with secondary effects such as root stimulation, improved water status, and disease control, could result in healthier, longer-lived urban trees. A better understanding of how tree growth regulators are absorbed from the soil and how they alter tree physiology is needed to understand the potential benefits tree growth regulators may have for tree health.

Existing and Emerging Priorities:

1. Longer-lived trees with less maintenance. **Highest Research Priority and Highest Technology Transfer Priority**
   - Reduce twig growth and extend utility pruning cycles for cost savings
   - Control size of trees and shrubs in smaller landscapes
   - Investigate root stimulation on both transplanted and established trees
   - Research symbionts and rhizosphere organisms
   - Reduce stress and stress-related diseases and insects through improved water status and fungicidal properties
   - Reduce nuisance fruits
2. Better understand how tree growth regulators work
   - Study the absorption of tree growth regulators by roots
   - Determine mode of action
   - Investigate carbon reallocation
3. Improve tree growth regulator compounds and improve their ease of use
   - Compare differing rates by species
   - Study non-target effects

■ Plant Pathology

DR. BAL RAO, Davey Institute, The Davey Tree Expert Company

Important Issues: Plant health in urban growing conditions is declining due to destructive diseases. In recent years, we have seen increasing concern about global climate change and its effects on predisposing plants for various destructive, native, and invasive disease agents. In addition, due to increased global trade, there is added concern about the movement of disease agents from one area to another. Monocultural landscapes are in particular danger. Researching new resistant genetic materials and diversity in planting are warranted. Current diagnostic methods are slow and difficult. An expert, non-invasive, and efficient diagnostic system is desirable for many diseases, but such a system is currently lacking. Research is needed to manage diseases using cultural, biological, and traditional and/or alternative treatment programs, and to develop product delivery systems that reduce environmental impact and improve plant health.

Existing and Emerging Priorities: No research priority emerged as higher than the others.

1. Design expert disease diagnostic tools and techniques for field and lab. **Highest Technology Transfer Priority (shared)**
   - Develop an expert and efficient system to spot and treat pathogens and diseases
   - Develop a non-invasive disease diagnostic technique
   - Create a global diagnostic network and data bank of plant diseases
2. Study the global influence on diseases
   - Track movement of exotic disease-causing agents on current genetic plant materials
   - Proactively predict, assess, and intervene invasive disease agents
   - Study impact of climatic stresses associated with global climate change, such as exposure to extremes in moisture and/or temperature, on diseases
3. Improve biotic and abiotic disease identification, epidemiology, and management. **Highest Technology Transfer Priority (shared)**
   - Study the role of Integrated Pest Management (IPM) and Plant Health Care (PHC) in disease management
   - Develop biological, biorational, and other alternative products and practices
   - Manage insect vectors of disease
   - Examine the impact of cultural practices, such as watering, fertilizing, and pruning, in disease management
   - Examine the role of mulch, compost, and yard waste in disease management
   - Recommend proper plant diversity in urban settings
   - Breed and evaluate disease-resistant and stress-tolerant plants
   - Formulate safer, systemic, and low-odor chemical products and improve delivery systems
   - Develop guidelines for managing tree decline
   - Find management options for foliar, canker, wilt, rots, and decay diseases

■ Entomology

FREDRIC MILLER, Joliet Junior College

Important Issues: Why do we see pest outbreaks? More research is needed to identify the factors responsible for pest outbreaks and to determine how cultural practices contribute and mitigate such events. Many traditional pest-control products are being phased out or limited in their application, and the list of effective and available insecticides and miticides is shrinking. Identifying new active ingredients and formulations can help replace lost products. Genetic factors that can predispose a plant to pest outbreaks should be identified and utilized in host plant resistance. Biological control is a viable component of Plant Health Care (PHC), but a better understanding of products and practices is needed. Global trade and travel has vastly increased the opportunity for exotic arthropod pests to enter the United States (for example, Asian longhorned beetle, gypsy moth, and Japanese beetle). New technologies could improve techniques for diagnosing pest problems on individual plants and whole landscapes.

Existing and Emerging Priorities:

1. Develop more effective, efficient, and environmentally sensitive control methods and products. **Highest Research Priority and Highest Technology Transfer Priority (shared)**
   - Develop better techniques for diagnosing pest problems on individual plants and whole landscapes (video imaging, GPS, and real-time analysis)
   - Explore new biorationals (such as oils, soaps, botanicals, and microbials) for use on ornamental plants
   - Identify potential biological control agents and determine their effectiveness, release rates, and their compatibility with biorational and systemic pesticides; determine the overwintering capability of pests and pest thresholds
   - Increase research and training on application techniques, timing, compatibility with natural enemies, potential phytotoxicity, environmental and non-target effects of insecticides and miticides
   - Integrate products into IPM/PHC programs and gain industry and public acceptance
2. Better understand ecosystem interactions and the impacts of pest outbreaks. **Highest Technology Transfer Priority (shared)**
   - Study the impact of cultural practices (that is, host plant selection, mulching, watering, pruning, and fertilization) in contributing to and mitigating outbreaks
   - Investigate the impact of weather (that is, moisture, snow depth, frost, cold hardiness) and its possible role in both pest suppression and prediction
   - Develop predictive models incorporating the above recommendations to assist end users in predicting and mitigating potential pest outbreaks
3. Predict, assess, and interdict exotic arthropod pests
   - Develop methods to assess and mitigate exotic pests' potential for economic damage
   - Find the best methods for interdicting exotics before their arrival and establishment
4. Determine genetic predisposition of woody plants to arthropod pest outbreaks and host plant resistance
   - Better understand why certain plants are attacked by insect pests and others are not
   - Research genetic factors and determine how to identify and utilize them in host plant resistance
   - Recommend strategies to integrate host plant resistance into IPM/PHC programs

■ Decay Development and Wound Closure

EDWARD F. GILMAN, University of Florida; BAL RAO, Davey Institute, The Davey Tree Expert Company

Important Issues: Decay and cracks in trees are major concerns because they can make trees unstable and potentially hazardous. Better tools and techniques are needed to prevent, evaluate, and treat trees with these defects. Decay can result from organisms invading injured or infected wood in living trees, and decay is the last stage in the wounding process. Injury may be the result of neglect, improper pruning, construction practices, insects or other mechanical means, and other factors. In response to wounding, trees can produce chemical and structural barriers to retard the invasion of decay-causing microbial agents. However, depending upon tree health, ability to compartmentalize, and a host of other poorly understood factors, decay organisms spread rapidly or not at all. The factors affecting this process should be well understood before treatment options are recommended.

Research is needed to quantify the effects of injuries typical of the urban environment on the development of cracks and on wood decay. There is a need for efficient and non-invasive detection methods to determine the threshold levels for different decay types and degrees of decay on common urban landscape trees. Information on the biology and morphology of decay-causing agents and their identification and management is needed. Research is also needed to understand the wounding response of common species to the size and number of wounds inflicted, time of wounding, location, and other factors.

Existing and Emerging Priorities:

1. Understand the biology and morphology of wound reaction and decay development. **Highest Research Priority and Highest Technology Transfer Priority**
   - Identify factors influencing decay and crack development and compartmentalization of barrier walls
   - Determine the specific fungal role in decay and its impact on tree health
   - Investigate the impact of species, wound size, timing, location, age, and number of wounds on decay and crack development
   - Compare the response of cutting through heartwood to cutting through sapwood
2. Reduce decay through management and Plant Health Care
   - Develop efficient, non-invasive decay detection tools
   - Determine the decay thresholds for various decay types, degree, and location in the tree
   - Standardize diagnostic techniques and management options
   - Develop guidelines to evaluate treatment options (that is, when to remove the tree, treat the tree, or do nothing) for trees with decay of varying types and severity
   - Recommend decay-prevention strategies
   - Publish a pictorial guide of biotic and abiotic decay-causing agents with prevention and management options

■ Environmental Stress

WILLIAM R. GRAVES, Iowa State University

Important Issues: Life spans of urban trees are shortened by physiological stresses evoked by a myriad of adverse conditions called environmental stressors. Better strategies to treat trees now afflicted by physiological stresses and trees that will be established and maintained in the future must be developed. Approaches needed include understanding the regulation and symptoms of stress, creating and selecting trees with improved stress tolerance, and designing urban environments in which potential stressors to trees are mitigated. Research and technology transfer to identify, treat, understand, and ultimately avoid physiological stresses of city trees will allow the potential benefits of urban forests to be realized and will ultimately lead to healthier urban ecosystems.

Existing and Emerging Priorities:

1. Accurately identify and ameliorate stress symptoms and long-term damage linked to stress. **Highest Research Priority**
   - Focus research on species-specific symptoms for tree-care professionals to use in diagnosis
   - Establish tolerance limits, both biological and aesthetic
   - Account for likely interacting effects of multiple stressors, like salt, drought, etc.
   - Enhance the root-zone environment (pore space, organic matter, fertility)
   - Recommend water- and temperature-management approaches
2. Better understand how to avoid stress. **Highest Technology Transfer Priority**
   - Compare individual tree planting pits or containers to continuous planting strips
   - Recommend planting space designs to minimize future retrofitting and physical disruption
   - Expand on recent progress with custom media for beneath pavement, etc.
   - Establish genetic control of variation in stress resistance among and within species
   - Breed trees, including root stock, with genetically improved resistance to stressors
   - Broaden knowledge of single stressors by learning how multiple factors interact
3. Enhance communication of existing information on stress of trees
   - Disseminate researchers' knowledge to growers supplying plants to municipalities
   - Improve communication between researchers, designers, and arborists
   - Foster better sharing of knowledge and experiences among urban tree practitioners

■ Phytoremediation

LYNNE M. WESTPHAL, USDA Forest Service, North Central Research Station

Important Issues: Phytoremediation is the use of vegetation to clean up and contain contaminants in the soil and in ground and surface water. The method promises to be both effective and relatively inexpensive. Effective and efficient cleanup tools are needed to manage growth and changes in land use. Specifically, phytoremediation may increase the viability of in-fill development. Trees, particularly hybrid poplars and willows, are planted to handle a variety of contaminants, including volatile organic compounds and heavy metals. Though tree biomass must often still be disposed of as hazardous waste, the volume is much smaller than traditional "dig and haul" methods. Most phytoremediation practitioners are engineers with little or no training in tree physiology, tree selection, or other aspects of tree growth and care. Urban and community forestry, therefore, has much to offer the growing field of phytoremediation. A number of areas need further research, including determining the right tree to treat a given contaminant, tree waste disposal methods, and landscape design techniques.

Existing and Emerging Priorities:

1. Determine which species addresses which contaminants. **Highest Research Priority and Highest Technology Transfer Priority**
   - Match species and subspecies capable of treating individual and multiple contaminants
   - Understand the process by which the trees contain or transform the contaminant (for example, phytoextraction, rhizofiltration, or other means)
   - Investigate whether trees, herbaceous plants, or a combination of both will be the most effective for a given contaminated site.

2. Understand ecotoxicity and the risk of phytoremediation applications
   - Determine the risk of creating habitat sinks by moving contaminants into the food chain via the phytoremediation plantings
   - Explore methods to minimize the risk of ecotoxicity
   - Measure risk of exposure by the public to phytoremediation plantings using trees in combination with grasses or forbs
   - Research the use of non-native plant species and potential release of these species into sensitive habitat
   - Identify benefits to nearby communities

3. Research the feasibility of using removed phytoremediation plants to produce energy and determine if contaminants in the plant material will be released

Priorities: DISTILLED THEMES

As needs and priorities of each technical discipline were developed, common needs and priorities emerged. Only by considering each discipline carefully were commonalties noted. At first glance, Cabling, Bracing and Lightning Protection and Human Health Benefits would seem to have very different research and technology transfer needs. But both groups working with these technical disciplines cited the need for benefit/cost studies. Likewise, Entomology and Municipal Forestry Program Status and Scope both cited the need for communication. Thus began the process of "distilling" these varying topics into common themes.

Common overarching themes also help to foster collaboration among scientists and institutions. This kind of collaboration was noted as being inadequate in the assessment of the *1991 Agenda*. Collaboration may also help to guide funding decisions in urban and community forestry and arboriculture. Focusing on common needs and priorities strengthens the field rather than divide it. The eight overarching themes that emerged at the Summit were:

- Benefits and Costs of Urban Forestry
- Changing Land Use
- Communication and Technology Transfer
- Environmental Issues
- Healthier, Longer-Lived Urban Trees and Forests
- Response to Critical Events
- Risk Management
- Urban Forestry and Arboricultural Tools

An attempt was made to prioritize the eight themes. In the end, all eight themes were determined to be equally critical to the progress of urban forestry and arboriculture. Research and technology transfer efforts over the next decade should be specifically targeted to address these themes. Descriptions of the eight themes follow. Each one includes a list of the technical disciplines that, according to the descriptions in the previous section, are encompassed by the theme. By considering these themes as the core of the National Agenda, attention to the technical disciplines will follow based on their contribution toward developing the themes and, ultimately, advancing urban forestry and arboriculture.

■ BENEFITS AND COSTS OF URBAN FORESTRY

Champion: FRANCES E. KUO

Working Group: John Hendricksen, William R. Jordan III, David J. Nowak, Frances E. Kuo, Peter Harnick, Kamran K. Abdollahi, Alice Ewen Walker, Lynne M. Westphal

Technical Disciplines Encompassed:

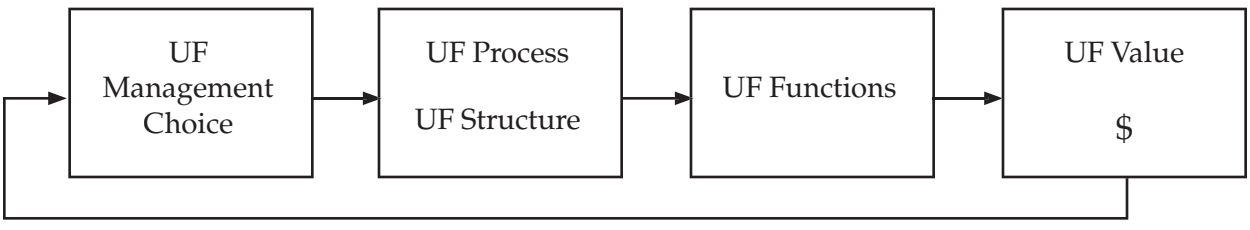
- Land-use Planning and Public Policy
- Tree/Forest Inventory and Analysis
- Trees and Infrastructure
- Urban Ecosystem Restoration and Sustainability
- Urban-Wildland Interface
- Watershed Protection
- Economic Benefits and Value of Urban Forest
- Environmental Benefits of the Urban Forest
- Benefit-Cost Analysis and Modeling
- Social Benefits
- Human Health Benefits
- Pruning Trees in Urban and Suburban Landscapes
- Damage to Mature Trees from Construction and Development
- Cable and Bracing, Lightning Protection

Problems: Urban forestry programs yield important social, environmental, and economic benefits, but these benefits are currently insufficiently documented and recognized. Further, urban forests cannot be managed to maximize these benefits without an understanding of how different management options affect them.

Solution: Research and technology transfer on urban forestry benefits and costs will enable urban forestry programs to attain appropriate levels of funding and to more effectively and efficiently create healthier environments, healthier citizens, and healthier communities.

Background: Despite their documented and surprisingly central role in sustaining human health, environmental health, and economic health in communities, urban and community forests are still largely considered amenities and managed as such. Public policy and decisions about resource allocation are unkind to amenities, especially during economic downturns that force budget reductions. Until policy makers and the public have an accurate understanding of the true value of urban and community forestry, budgets that support them will remain inappropriately vulnerable.

In an important sense, managing the urban forest without an understanding of how different management options impact it is operating in the dark. To better understand the full impact of urban forestry management choices on the urban forest's benefits, we must trace the effects of management options step by step—from their effects on urban forestry processes and structure, to the resulting functions, to the final value of the urban forest (see model below). For example, foresters need to



know how a particular management option will affect the number of healthy trees along a street (UF structure), levels of citizen involvement in tree planting (UF process), the resulting impacts on carbon sequestration (UF function) and residents' health (UF function), and the ultimate effects on urban forest value, in economic or other terms.

Emerging Needs: More research on the effects of management options on benefits is needed, including the links between different components and their integration. Each management choice entails different benefits and costs; what are the tradeoffs between these benefits and costs? Are there management choices of roughly equal cost that yield strikingly different benefits?

There is a knowledge gap between citizens' and policy makers' current perceptions of urban forest benefits and documented benefits. Assess which benefits citizens and policy makers value most, and direct research and technology transfer efforts where they are likely to have the most impact.

The benefits of urban trees must be communicated in an audience-appropriate, compelling way, using the vehicles most likely to reach those audiences. To do this, we need to identify what sources of information policy makers and the public use and trust, and we need to understand what kinds of arguments our audiences find most compelling.

Vision for 2012:

1. To have quantified, compelling evidence of urban forestry benefits (functions)
2. To know the impacts of different management options on urban forestry benefits so that benefits can be maximized
3. That every policy maker and citizen would know that urban forestry programs are vital to healthy humans and healthy ecosystems.

■ CHANGING LAND USE

Champions: GORDON BRADLEY, ED MACIE

Technical Disciplines Encompassed:

Land-use Planning and Public Policy
Right-of-Way Management
Urban-Wildland Interface

Problem: Impacts of changing land use are significant. The decline and fragmentation of vegetative cover significantly compromise ecological and economic quality-of-life factors and contribute to urban heat island effects, fire hazard, changes in biological diversity, flooding, and other risks to the well-being of communities.

Solution: Understand the intricacies and interactions of urban ecosystems. Know how the impacts of human influences on the landscape affect an ecosystem's ability to produce goods and services. Then implement policies and programs that are adaptive in nature, utilize the best available science, and serve the needs of the community.

Background: A range of disturbances, such as impervious surfaces and altered hydrologic regimes, occurs along the gradient from the central business district to wild land settings. Although the disturbance resembles a mosaic more than a continuum, it is more prevalent near city centers. Landscapes are generally more intact as one moves out toward suburban, rural, and wild land settings. While small patches of residual wild land in urban areas may produce substantial human benefit, their ability to provide significant ecological services will be limited unless these remnants are plentiful and connected. More significant levels of ecological services are derived from larger, intact landscapes that have not been fragmented by urban development.

Understanding the intricacies and interactions of urban ecosystems is important because the significant variation in urban forest structure and ecosystems is seldom distinguished in a meaningful way. Depending on spatial and temporal location, forest ecosystems take on different structures that vary by size, shape, composition, and age. This variation significantly affects the functionality of urban ecosystems and the ability to produce a mix of human and ecological goods and services.

When land use changes and their associated impacts become obvious and significant, behaviors of individuals and institutions shift to produce more of the positive effects, or they seek to eliminate or mitigate negative impacts. Behaviors will lead to new processes, policies, plans, and practical guidelines.

Emerging Needs: Understanding policies, plans, and processes that facilitate the maintenance, transition, and restorations of sustainable and functional urban forest ecosystems is a challenge to contemporary urban and community forestry research and technology transfer.

For comprehensive assessments and understanding of urban forest structure and complex urban ecosystems, new technologies must be used. Remote sensing and Geographic Information Systems should be used for data acquisition, analysis, and management. Descriptive and prescriptive modeling of system relationships and ecosystem services are helpful in making rational decisions about changing land use.

Procedurally, urban and community forestry planning must be inclusive and participatory to serve community needs. Planning processes must also incorporate multiple ownerships, authorities, and jurisdictions among land managers. They should be adaptive, consider multidisciplinary perspectives, be adjustable to varying spatial and temporal scales, and apply the best available science. To effectively address the complexity and functionality of urban ecosystems, policies, plans, and guidelines must be integrated and monitored.

For policies and plans to make a significant difference, they must effectively be translated from knowledge to specific action. Meaningful direction for the retention, restoration, and management of urban ecosystems can be conveyed in design guidelines, Best Management Practices, and other protocols for actions.

Vision for 2012:

1. The complexity and functionality of urban forests is understood, and a science-based approach drives effective policies that sustain them. Communities are involved in decisions about land-use change and derive maximum benefits from urban forest ecosystems.

■ COMMUNICATION AND TECHNOLOGY TRANSFER

Champion: JIM GEIGER

Working Group: Gracie Joy, Larry Biles, Donna Yowell, Ann Bates, Pepper Provanzano, James R. Fazio, Burnell C. Fisher

Technical Disciplines Encompassed: Improved technology transfer is essential for disseminating information from all technical disciplines to the people who want and need the information

Problem: There is a significant gap between what is known about urban forestry and what is practiced in our communities, and it is having detrimental effects on the condition and extent of urban forests. This gap formed because traditional methods of disseminating the information haven't changed to meet changing customer needs. Urban and community forestry information and technology transfer materials compete with many other products for the time and attention of the target audience. Sufficient understanding of learning styles, learning preferences, values, motivators, and other traits that underlie the successful reception of communication is lacking.

Solution: Identify the learning styles, learning preferences, values, motivators, and other communication-related characteristics of our customers/target publics, and develop and distribute messages based on the best combination of communication methods, communication material, and best marketing strategies.

Background: A primary goal of urban forestry practitioners is to increase the health and sustainability of the urban ecosystem. But there are many obstacles to reaching the goal: incorrect or incomplete understanding of how trees fit into the urban ecosystem; lack of understanding or misunderstanding of the value of trees; lack of funding and manpower to care for trees; inappropriate or ineffective regulations; poor or nonexistent long-term planning; and lack of cooperation between organizations involved in the process. For nearly 30 years, the number of influential individuals and tree groups has been growing in communities across the country, and these individuals and groups are promoting the principles of urban forestry, encouraging more community participation, and soliciting more funds from community budgets. Yet we continue to encounter these barriers. Why? We hope that new research will uncover the answers to this question.

Current Status: According to the *Urban and Community Forestry Research and Technology Transfer Progress Assessment*, nearly all non-expert users of urban forestry information (builders, developers, business owners, elected officials, and members of the general public) prefer to learn about trees and urban forests in their community through publications. Planners, however, prefer websites. This is new information that provides insight into customers' desires. However, if this information is to be useful in designing communication and technology transfer material, we need to know the best method of information delivery so that it will be meaningful and useful to them and result in implementation of the principles. Achieving this result depends on the customers' learning styles, learning preferences, values, motivators, and other communication-related characteristics that are essentially unknown. And marketing the benefits of urban forests has become a key ingredient of successful urban forestry programs.

Emerging Needs: The overarching focus for communication and technology transfer must be on a better understanding of audiences. Specifically, we need to gain insight into audiences that might influence more effective planning, care, and funding for urban and community forests. To close the gap, those involved in information dissemination should work with professionals who know and understand how to reach target audiences with

the urban forestry message. Work is needed that leads to:

1. Insight and understanding of our customers or target audiences—knowledge about their perceptions, barriers to participation, and the key messages that would gain their attention, awareness, and support
2. New insights to effectively target these audiences with outreach and marketing strategies, specific products, and improved techniques for packaging and delivering urban forestry information
3. Better-defined audience subpopulations that have a stake in the welfare of urban and community forests

Vision for 2012:

1. There is a complete understanding of issues and our customers/target audiences. We know their learning styles, learning preferences, values, motivators, and other communication-related characteristics. We comprehend key messages and can translate research results and new technology into understandable language. New information is effectively summarized, packaged into the most effective communication products, and delivered in the most efficient manner.

Dissemination of urban and community forest research information over the next 10 years will continue to include the environmental, social, and economic benefits, but a fundamental shift will occur in where the emphasis is placed. Traditional benefits, such as energy conservation, improved air quality, and stormwater retention, will continue to receive wide distribution. However, with the increased national interest in health and safety, the value of tree benefits to human health and public safety will be given a much higher priority in future products.

There will also be a tremendous increase in the use of electronic dissemination. The ever-expanding number of websites, list serves, and other network capabilities will greatly increase the capacity of technology transfer to reach customers. This capability will lead to fully stocked, healthier, and more sustainable urban forests.

■ ENVIRONMENTAL ISSUES

Champions: JEFFREY C. LUVALL, GREG RUARK

Working Group: Don Fielding, Bailey Hudson, Greg Ruark, Phillip Rodbell

Technical Disciplines Encompassed:

- Urban Ecosystem Restoration and Sustainability
- Watershed Protection
- Environmental Benefits of the Urban Forest
- Soil Management
- Genetics and Breeding: Tree Evaluation and Improvement
- Phytoremediation

Problem: Communities are faced with the need to provide a high-quality living environment and to comply with regulatory measures, particularly those concerning air and water quality. Communities alter both the local and regional environment as they grow and develop, changing land-use patterns. This urbanization compromises or eliminates ecological services provided by the urban and community forest.

Solution: The value of the urban forest should be recognized as part of the overall community planning process. The environmental benefits urban forests provide should be measured and modeled into solutions that communities can use to support the preservation and development of urban and community forest resources.

Background: *Heat Islands*. On warm summer days and nights with calm winds, the surface temperature and overall ambient air temperature in a city can be 2 to 5 degrees Centigrade hotter than the surrounding countryside. This phenomenon is called the "urban heat island" effect. It occurs because there are fewer trees and other vegetation in urban areas to shade buildings, roofs, and pavement; block solar radiation; and cool the air by plant evapotranspiration. Urban heat islands increase the demand for energy needed to cool homes and buildings. Currently, one-sixth of the electricity consumed in the United States is used for cooling at an annual cost of $40 billion. Reductions in urban air temperature by just a few degrees could save millions of dollars in energy costs, while reducing the emission of sulfur dioxides and nitrogen oxides, produced when fossil fuels are burned to generate electricity.

Air Quality. Air pollution, a problem of national importance, contributes to significant public health and economic impacts throughout the United States. Under the more stringent air-quality guidelines established by the U.S. Environmental Protection Agency (U.S. EPA), nearly 300 counties in 34 states will not meet the new air-quality standards for ground-level ozone, one of six EPA "criteria pollutants," and will be considered in "non-attainment." Even at very low levels, ozone can cause acute respiratory problems, increasing hospital admissions and emergency room visits (10 to 20 percent of all summertime respiratory-related hospital visits in the northeastern U.S. are associated with ozone pollution). Ozone can also impair the body's immune system, making people more susceptible to respiratory illnesses, including asthma, bronchitis, and pneumonia.

Water Quality. Watersheds contain a variety of land uses, including forestry, agriculture, residential, and industrial uses. As communities grow, land is covered with sidewalks, pavement, buildings, and other impervious surfaces, impairing the ability of the soil to absorb rainfall and increasing stormwater runoff. The conventional solution has been to divert untreated runoff into storm drains, where it concentrates and is eventually emptied into rivers and streams. These massive discharges cause bank erosion, channel cutting, and flooding downstream, while producing a disruption in the ecological function and integrity of wetlands and waterways.

Current Status: Urban areas within the United States have experienced rapid growth and development over the last 25 years. This urbanization has significantly altered the land-use patterns of these areas. In the Atlanta metropolitan region, for example, forest and agricultural lands decreased by about 15 and 6 percent, respectively, between 1973 and 1992. At the same time, high-density urban areas increased by 6 percent and low-density residential areas increased by 14 percent. This urbanization pattern is causing significant environmental impacts.

Emerging Needs: Well-designed, thriving urban and community forests can mitigate the impacts of urbanization. Though research has documented these contributions to environmental health, trees and urban forests are not widely maintained with air and water quality, or urban heat island mitigation, in mind. More research is needed to quantify the function of the urban and community forest. Models and effective technology transfer could put trees, still viewed as amenities by most environmental engineers and civic leaders, to work.

The urban forest has a valuable role in heat island reduction strategies. The EPA national policy under section 110 of the Clean Air Act is to allow additional State Implementation Plan credit for urban forests in reducing the urban heat islands. There are two important roles tree canopies play: 1) they can dissipate solar energy by transpiring water from leaf surfaces, thereby removing "heat" from the air in evaporating the water, and 2) trees shade surfaces like asphalt, roofs, and concrete parking lots to reduce the storage of heat. Once trees reach sufficient size, they can reduce heating and cooling costs for a typical home by 10 to 20 percent.

Mitigating the impact of the urban heat island also slows the production of ozone, which is affected by high temperatures. Trees also dilute polluted air as they release fresh oxygen in the respiration process, and they filter particulate pollution from the air by trapping particles on rough leaf surfaces. All vegetation, of course, sequesters atmospheric carbon dioxide, a primary greenhouse gas. Technology transfer for this area should be directed at state and municipal environmental agencies that can most readily employ urban and community forests on a large scale to improve air quality.

Communities and counties are now required by federal law to treat their stormwater discharges for water quality. This will require a coordinated effort between rural and urban watershed partners. Designs that utilize trees and shrubs to buffer riparian areas from stormwater runoff, like bioswales that utilize vegetation to infiltrate stormwater naturally, can help protect watersheds. Model projects should be implemented and technology transferred to capture this potential.

Vision for 2012:

1. The contributions of urban and community forests to environmental health are well understood and quantified by scientists and broadly recognized by urban policy makers and constituents. Policies at all levels reflect the value of the forests. Design, maintenance, and funding for urban and community forestry all maximize the environmental benefits for human and ecosystem health.

■ HEALTHIER, LONGER-LIVED URBAN TREES AND FORESTS

Champion: GARY WATSON

Working group: Michael J. Raupp, Roger Kjelgren, Bal Rao, Thomas G. Ranney

Technical Disciplines Encompassed:

- Tree/Forest Inventories and Analysis
- Urban Forest Health
- Trees and Infrastructure
- Pruning Trees in Urban and Suburban Landscapes
- Plant Health Care
- Damage to Mature Trees from Construction and Development
- Tree Risk Assessment/Tree Structure
- Cable and Bracing, Lightning Protection
- Nursery Production, Matching Trees to Site
- Root Growth on Urban Sites
- Irrigation Requirements/Water Conservation
- Soils Management/Fertilization
- Genetics and Breeding: Tree Evaluation and Improvement
- Plant Growth Regulators
- Plant Pathology
- Entomology
- Decay Development and Wound Closure/ Wound Reactions
- Environmental Stresses/Water Relations
- Phytoremediation

Problem: The urban environment is stressful, and most trees in the urban forest experience chronic or episodic stress. The health of trees needs to be improved.

Solution: A better understanding of tree biology, management practices, design elements, and ecosystem function will result in a more sustainable urban forest.

Background: With 69 million acres of urban forests across the country and the majority of the population living in urban areas, urban forests touch the lives of nearly everyone. Maintaining the health and sustainability of the urban forest is vital. The research and technology transfer needs vary widely. The building blocks of the urban forest are primarily single trees or small groups of trees managed by millions of individuals on their own properties. The health management approach at this level is often based on amenity value. Research and technology transfer needs at this level are quite different from those of the broader urban ecosystem that requires collaborative stewardship among different owners and managers across jurisdictions.

Current Status: According to the *Urban Forest Health Needs Assessment Survey* (USDA Forest Service Publication NA-TP-01-98), only 22 percent of urban forestry professionals ranked the health of their state or city urban forests as good, and only 1 percent rated it as excellent. More than 95 percent identified long-term tree care and maintenance as critical to preserving the health and sustainability of urban forests. The report recommends the development of comprehensive programs that address issues critical to preserving the health and sustainability of urban trees and forests and implementation of long-term Plant Health Care practices and strategies.

Emerging Needs: For healthier urban trees, urban foresters and arborists have expressed a need for better information on the following topics: insect and disease management; tree root systems; watering, fertilizing, and pruning maintenance practices; construction damage; and the development of better trees. A better understanding of tree biology and a proactive approach to maintaining tree health may refine and improve the effectiveness of tree care services and shift their focus to preventive rather than therapeutic treatments. For healthier urban forests and ecosystems, research and technology needs include: identification of the direct impacts of human activities, such as disturbance

and pollution; improved systems of tree health monitoring; and techniques for ecological restoration of a wide range of diverse plant communities in urban areas.

Among the actions essential to addressing these emerging needs are:

1. A significant increase in the number of urban and community forestry programs that include preserving the health and sustainability of urban forests as an integral component. Currently, only 46% of urban forestry programs include this component.
2. A greater focus on tree maintenance. Lack of tree care and maintenance has been cited by urban foresters as the factor most detrimental to the condition of urban forests.
3. A fundamental understanding of how habitat fragmentation and the loss of biological diversity affect the sustainability and ecological function of urban forests
4. Improved training and better access to information for arborists and urban foresters; only half of them now find it easy to keep up-to-date.
5. Developing and implementing monitoring methods
6. Providing decision-making guidelines that are relevant, unambiguous, and easy to use
7. Providing new and more effective tools for managing biotic and abiotic stressors in urban forests
8. Developing effective ways to communicate needs and progress to stakeholders and sources of funding
9. Assisting arborists in ways to market their services

Vision for 2012:

1. Measured improvement in urban forest health and sustainability

■ RESPONSE TO CRITICAL EVENTS

Champions: WAYNE C. ZIPPERER, ED DICKERHOOF

Working group: Ed Macie, David J. Nowak, Daniel Twardus

Technical Disciplines Encompassed:

- Tree/Forest Inventory and Analysis
- Right-of-Way Management
- Urban Ecosystem Restoration and Sustainability
- Urban-Wildland Interface
- Watershed Protection
- Urban Forest Health
- Root Growth on Urban Sites
- Genetics and Breeding: Tree Evaluation and Improvement
- Plant Pathology
- Entomology

Problem: Urbanization alters ecosystems in many ways. These changes affect ecosystem services needed by humans, increase the susceptibility of natural communities to invasion by non-native species, and increase the risk of highly adverse disturbances.

Solution: Basic ecological research is necessary to understand how ecosystems function in urban and urbanizing landscapes in order to develop management options that minimize the loss of ecosystem services and maintain ecological integrity of natural ecosystems.

Narrative: Humans modify landscapes for habitation, often drastically changing the ecology of urbanized areas. Watersheds are being paved over, wildlife habitat destroyed, and the sustainability of the natural ecosystem jeopardized, just when these and other natural resources are most needed by the urban populations.

Of particular concern are the introduction of non-native species; the plants, animals, insects, and microbes intentionally and accidentally introduced to urbanized areas. Non-native species, such as the starling, purple loosestrife, and Japanese knotweed, are introduced for aesthetic and recreational purposes. Global trade also facilitates the introduction of harmful insect pests, such as the Asian longhorned beetle and hemlock-woolly adelgid. Although, most of these species are innocuous, about 5 percent can become invasive. These non-native species often proliferate rapidly and may significantly affect ecosystems by altering species composition and structure. They also modify natural disturbance patterns and other processes.

Through proper screening, future introductions of non-native species can be minimized, though current and past introductions remain problematic. Basic ecological research is needed to understand how non-natives modify ecosystems; methodologies need to be developed to eradicate or contain current problems; and management prescriptions are needed to minimize the susceptibility of communities to invasive, non-native species.

As humans develop a landscape, they modify disturbance patterns to reduce deleterious risk to themselves and their community. Disturbances like fire and floods are often suppressed, giving a short-term reprieve, but in the long term, suppression may create catastrophic conditions. For example, fires are suppressed to reduce property loss and loss of timber resources, but this policy allows fuel loads to accumulate to hazardous levels. As a result, when a fire does occur, there is a high probability of conflagration that often destroys homes and forest ecosystems instead of a low-intensity surface fire normally associated with many fire-dependent ecosystems.

In addition, altered disturbance patterns change the spatial heterogeneity of a landscape, which is critical because it influences how disturbance and species move across a landscape. Also important is an understanding of how a series of small-scale disturbances (for example, building homes) influ-

ences the colonization of non-native species and affects the movement of large-scale disturbances (for example, fires and insect outbreaks) across a landscape.

Basic ecological research is needed to assess how humans have altered the duration, magnitude, severity, and frequency of natural disturbances of urban and urbanizing landscapes and the subsequent effect on human safety and landscape and ecosystem patterns and processes. Cost-benefit analysis is needed before landscapes are changed, and also after landscapes have been altered, to assess effects. In addition, research is needed to evaluate the synergistic effect of large-scale natural disturbances, such as fire and floods, in combination with small-scale, incremental land-use changes on ecosystem structure and function.

Vision for 2012:

1. Basic understanding of human influence on urban landscapes has led to development of management scenarios that reduce the effects of altered disturbance patterns on ecosystems.

■ RISK MANAGEMENT

Champion: JOHN BALL

Working Group: John Ball, Russ Carlson, Mike Dirksen, Bruce Fraedrich

Technical Disciplines Encompassed:

Trees and Infrastructure
Tree Dynamics and Worker Safety
Pruning Trees in Urban and Suburban Landscapes
Tree Risk Assessment/Tree Structure
Cable and Bracing, Lightning Protection
Root Growth on Urban Sites
Decay Development and Wound Closure

Problem and Solution: The urban forest is not a risk-free environment, neither for the citizens who work and reside within the forest nor the tree workers who are employed to care for the trees. The tree populations in many communities are aging. This natural decline is often associated with an increase in the risk of tree failure. A better understanding of why trees fail, as well as a means of detecting and mitigating tree defects, can reduce the risk to our communities and their citizens. In addition, workers who are engaged in the maintenance and removal of trees are working in a very high-risk environment. Improved data on accidents can aid in creating a safer environment for tree workers.

Narrative: The risk management theme has two major risk reduction components: tree risk and tree worker safety. Trees, while providing many benefits to communities, also represent some risk. In that way, they are no different than other components of the community infrastructure, such as roads and utilities. An important part of tree care is managing this risk. There have been tremendous strides in our knowledge of tree failure during the past 10 years. A number of studies have improved our understanding of how trees support themselves under natural loading. There are also excellent guides that can assist managers and tree workers in identifying tree defects. However, there is little data that examines how defective trees react when they are undergoing the stresses of removal. There is a need to increase our understanding of how trees, particularly trees with defects, respond to the stresses of rigging and removal.

The environment in which our tree workers must operate is extremely risky. The fatality rate of tree workers is at the same level as logging, commercial fisheries, and several other high-risk professions. In the past 10 years, approximately 590 fatalities have occurred among tree workers. This is actually the minimum number as it does not include the many fatalities that have occurred among tree workers employed in the landscape or logging professions. Unfortunately, there has not been much research conducted in the field of tree worker safety. A glance at the *Journal of Arboriculture* issues from the last 10 years reveals only about five articles that address worker safety. At this time, we are lacking the baseline data that would allow the industry to analyze current work practices and make improvements. An example is aerial rescue. The industry currently has guidelines for practicing aerial rescue that call for the rapid extraction of a "victim" from a height of approximately 35 feet. These guidelines were developed with the expectation that the most common aerial accident requiring a rescue would be electrical shock. However, recent data indicates that this is not the most common accident and that our current guidelines may create a more hazardous situation. There is a need for the development of more baseline information on accidents to help guide future studies in safety.

Vision for 2012:

1. Reduction of tree-related accidents by 50 percent.

■ URBAN FORESTRY AND ARBORICULTURAL TOOLS

Champion: TOM SMILEY

Working Group: Robert Miller, John Rosenow, Nate Mathews

Technical Disciplines Encompassed: Improved "tools" are needed for every aspect of urban forestry and arboriculture, and this theme encompasses all technical disciplines.

Problem: The term "tools" is interpreted in the broadest possible sense. Practitioners need better equipment and technology, Best Management Practices, standards, ordinances, guidelines, computer programs, chemicals, protocols, and management options to put research information to work.

Solution: Research is needed to develop better tools to understand and deliver the essential factors that trees in urban landscapes need to thrive and produce urban and community forests that provide the most benefits to communities. Develop Best Management Practices (BMPs) for all aspects of urban forest management and individual tree care.

Background: Urban forestry and arboriculture are young, quickly evolving professions. The demand for action and results often exceeds our ability to get the job done. It is one thing to understand and visualize the objective and another to have the tools to achieve the objective quickly, reliably, and economically. In addition, arborists work in a risky field in which technology has evolved slowly. There is much room for improvement in assessing and measuring the needs of trees for improved effectiveness of treatments, for cost-effectiveness, and for worker safety.

Current Status: The technical fields comprising urban forestry and arboriculture are diverse. No one set of tools can fulfill the needs of them all. On the contrary, each discipline may have unique needs for tools. The spectrum runs from tools (in the literal sense) for specific tasks, such as pruning, to broadly based computer models to show the benefits of increased tree cover in urban landscapes.

Emerging Needs: By definition, the urban environment is designed for the benefit of its human inhabitants. Clients and community residents expect landscape trees to behave in a predictable manner that produces no negative effects. The specific tools needed to achieve this goal are too numerous to detail here and can be found in the pages of the Technical Disciplines section.

Best Management Practices (BMPs) are needed for every discipline. Publications outlining these practices focus on specific areas and present research-based guidelines for these practices. As research discovers more information on the underlying topic or new successful projects are completed and serve the test of time, best management practices are refined and improved. Many industries use BMPs to improve the quality and uniformity of service and to minimize negative environmental practices. Examples include the landscape nursery industry's BMP for nursery management and the International Society of Arboriculture's BMP for tree pruning, fertilization, and support systems.

Vision for 2012:

1. Arborists can measure and assess tree needs and accurately prescribe effective treatments to support tree longevity, stability, and aesthetic qualities in a safe and efficient manner. Urban planners and land managers have the tools to understand the environmental factors that support trees and provide the best environment in which trees can survive. As a result, stronger, longer-lived, and more resistant trees provide optimal benefits for urban constituents.

FUNDING RECOMMENDATIONS

Background

The Summit participants were charged with recommending funding for research and technology transfer for the next decade, based on needs and priorities emerging from the summit. The entire process for achieving these recommendations was established by the planning committee. It began with a series of national questionnaires; then the actual Summit meeting of over 60 urban forestry experts; and finally a post-Summit review. Several priorities emerged.

Funding for urban forestry research and related technology transfer efforts has been historically low relative to the constituency served. More than 80 percent of the population of the United States lives in metropolitan areas and benefits in some way from the forest ecosystem around them. In many states, including some in the Midwest "Farm Belt," the urban forestry and horticulture industry is larger than any agronomic crop, and the size and diversity of the workforce is considerable. While more needs to be done to compile data about the urban forest ecosystem, a convincing argument for increased research and technology transfer funding can be made.

The Forestry Title of the 1990 Farm Bill created the National Urban and Community Forestry Advisory Committee (NUCFAC) to advise the Secretary of Agriculture on the direction of the federal urban forestry program. Much of the focus of the Forestry Title of this Bill was on the implementation of urban forestry organizational development in states and communities. However, the need to keep abreast of and fund research and technology transfer needs and priorities was also included in the Bill.

In the last decade, urban forestry programs have become more and more popular in the mix of federal, state, and local government-sponsored programs. Many universities have added urban forestry to their instructional and research mix. And substantial numbers of private organizations and foundations have recognized the evolving discipline.

Funding Current Status and Future Needs

Within the federal government, urban forestry research and development (R & D) is being conducted by several departments and agencies, including the USDA Forest Service, USDA Cooperative State Research, Education, and Extension Service (CSREES), the U. S. Environmental Protection Agency (EPA), and the U. S. Department of Energy (DOE).

The R & D Division of the USDA Forest Service has been conducting urban forestry research for more than 20 years. Appropriations have grown steadily, from about $1 million in Fiscal Year (FY) 1992 to about $2.6 million in FY 1997, to $3.5 million in FY 2003. This figure for urban forestry research still represents only about 1 percent out of a total USDA Forest Service R & D program of approximately $250 million.

The USDA Forest Service R & D currently identifies the following high-priority research areas. These research areas correspond to the technical disciplines identified at the Summit as indicated in parentheses. Future funding will need to be sufficient to address these priorities:

1. Societal expectations and interactions with the urban environment (Social and Psychological Benefits, Municipal Urban Forestry Status and Scope)
2. Urban air quality (Environmental Benefits)

3. Urban forest management for sustainable landscapes (Urban Forest Health, Land-use Planning and Public Policy)
4. Watershed management for improved quality and quantity (Watershed Protection, Urban Ecosystem Restoration and Sustainability)
5. Energy conservation and carbon sequestration (Environmental Benefits, Benefit/Cost Analysis and Modeling)
6. Urban/rural interface (Urban-Wildland Interface, Rights-of-Way)
7. Wildland fire (Urban Ecosystem Restoration and Sustainability)
8. Management of development in sensitive environmental landscapes (Damage to Mature Trees from Construction and Development, Plant Health Care, Root Growth on Urban Sites, Soil Management, Entomology, Plant Pathology)

New Urban Forestry R & D Centers, with interdisciplinary research staffs and technology transfer specialists, are needed in a number of regions with high population growth that are now underserv-ed by the current program. Full funding for R & D in these areas is conservatively estimated to be $12 million in FY 2008 and $24 million in FY 2013.

Also, three critical emerging needs must be addressed by special initiatives involving:

1. Development and implementation of a national urban forest inventory and health monitoring system (Urban Forest Health, Tree/Forest Inventories and Analysis)
2. Development and implementation of a national invasive insect and plant species detection and mitigation system (Entomology, Plant Pathology, Plant Health Care, Genetics and Breeding: Tree Evaluation and Improvement, Urban/Wildland Interface)
3. Acceleration of research to collect and conserve water, especially for lawn and landscape purposes (Tree Water, Watershed Protection)

The water research would complement Secretary of the Interior Gale Norton's initiative Water 2025, which was created in May 2003, as a result of "explosive population growth in western urban areas," in Secretary Norton's words. Funding for these three initiatives is estimated to be $15 million in FY 2008 and $30 million in FY 2013.

In addition to the USDA Forest Service R & D budget, the U.S. Congress annually appropriates approximately $36 million for the USDA Forest Service State and Private Forestry Division, Urban and Community Forestry Program. The program assists local communities, often through grants, and is administered in partnership with state forestry agencies. This network of state forestry programs serves as an important technology transfer link. The Urban and Community Forestry budget supports the National Urban and Community Forestry Advisory Committee's (NUCFAC) Challenge Grant Program, which usually totals approximately $1 million. Applied research is generally a NUCFAC granting priority.

The USDA Forest Service Urban and Community Forestry Program now has technology transfer specialists co-located with several USDA Forest Service R & D research work units and anticipates higher levels of demand for technology transfer. An optimal organizational arrangement would be to have technology transfer specialists co-located at each research work unit. Under this arrangement, basic annual technology transfer funding needed for eight regional co-located units would be approximately $2.5 million in FY 2008, and $3.5 million in FY 2013.

Cooperative State Research, Education and Extension Service (CSREES) Urban and Community Forestry/Arboriculture research funding is largely supported by the McIntire–Stennis Cooperative Forestry Research Program. This program supports all aspects of forestry research; yet only a small portion is devoted to Urban and Community Forestry and Arboriculture. In federal FY 2001, CSREES reported $1.6 million for Parks/Urban Green Space (urban forestry) research. From this investment, only $257,000 was attributed to the agency appropriations. The balance resulted from fiscal resource leveraging with state, private, and other federal sources.

Repeatedly, the nation's forestry school leaders cite urban forestry as an underserved specialty in the forestry discipline. Altering this position will require an "order of magnitude" increase in fiscal resources. A conservative estimate is $8 million in appropriated funds by 2008 and $20 million by 2013.

Not enough is known about urban forestry and arboriculture funding outside of the federal government. In 1995, a report to NUCFAC showed that non-government organizations, largely arboretums, associations, and institutions, were annually spending $1.4 million on urban and community forestry research. Universities were not included in the report. No current information is available. Recent and comprehensive figures are needed for comparison. These figures will not be easy to obtain since faculty and staff at universities with responsibilities related to producing, planting, maintaining and managing trees in urban landscapes are spread across many departments, and each may have research, teaching, extension and service responsibilities. Smaller companies and non-profits may be very regional and focus research and outreach in very specific geographic areas, or specific technical disciplines. Many of them may be hard to identify in a national effort to quantify non-government organization funding. It will be important to quantify the current effort so that future expansion can be done efficiently and effectively.

The federal government could provide impetus to increase funding in the private sector. Without a doubt, if more cost-share grants were available, universities and non-profit organizations would increase the size of their urban forestry programs to take advantage of this source of funding.

The need for urban and community forestry research and technology transfer parallels the need for a sustained environmental and social quality of life. There has been growth in both the public and private sectors' interest in urban and community forestry and arboriculture research and technology transfer. This growth is evidence that such research is indeed a sound investment. Strengthened and continued investment will provide a great and enduring return in knowledge about trees, urban and community forests, and about benefits people gain when they live, work, and play in urban forests.

It is an obvious inequity that 80 percent of the population lives in urban areas and 99 percent of the U.S. Forest Service R & D funding goes to research that does not directly benefit them. Similar imbalances exist with other agencies. Future funding appropriations must better balance the needs of residents in urban areas with available resources.

Needs Emerging from the Summit

The need for support in collaborating, sharing information, transferring technology, and coordinating research was heard again and again. This support could come in the form of new Centers of Excellence, regional USDA Forest Service resource centers that serve an important technology transfer role; and there should be a central repository for research and technology transfer information. The *Assessment* survey revealed that nearly one in three urban forestry and arboriculture professionals does not consider him- or herself up-to-date on the latest research findings. Half of the professionals find it difficult to keep up-to-date. A nationally coordinated, easily accessible collection of information would help to solve this serious problem.

The diversity of audiences for urban forestry presents significant challenges. Research must include the needs, perspectives, and interests of many groups. Technology transfer must reach groups of people with diverse language and cultures. Methods of communication and technology transfer that are targeted and more easily accessible to all audiences should be developed. People learn in different ways. In the survey, professionals stated that they prefer to learn from publications, but experienced teachers and extension professionals will tell you that "seeing is believing" and that demonstrations are more meaningful to people. In 1991, when the first *Agenda* was published, few people had used the Internet. What new advances in information delivery will come in the next decade? One thing is certain: new technology will cost money. Ultimately, we may also have to consider, "What is the cost of not spending more on urban forestry and arboriculture research and technology transfer?"

While everyone seems to recognize the importance of technology transfer, it may not always receive the attention and support that it deserves. The budget for technology transfer is not always separate from the more dominant research programs. A separate line item for technology transfer in every budget would help to focus attention on it.

Urban forestry research is multidisciplinary in nature and encompasses everything from the planting and care of individual trees through regional or national concerns about forests' role in stormwater runoff, changing land use, air quality,

and smart growth. The benefits that trees provide to people must also be considered along with the biological and environmental issues. Current research funding sources available do not provide for the broad-based collaborative projects needed to examine the interaction at these various levels. Funding from a variety of sources may be required for projects that are this broad in scope.

People working in urban forestry and arboriculture research and technology transfer positions are few in number and scattered mostly across universities and a few privately funded institutions across the country. Often, there are only one or two individuals in an entire state working at this level; sometimes there are none. Funding for graduate students is scarce, so the next generation of researchers and teachers is not being trained. The solution envisioned has two components:

1. Funding for scientists, postdoctoral, and graduate students in universities and within the Forest Service itself must be increased. Clearly, the scale and scope of the priorities described in this *Agenda* cannot be accomplished at existing staffing levels.
2. Also, this loosely connected and geographically separated network of professionals must be afforded greater opportunity to interact so that their work is synergistic and coordinated. This could take the form of sponsored workshops on different topics and funding for scientist exchange programs.

Conclusion

The recommendation to NUCFAC is that future funding should be sufficient to support a strong national research and development effort in urban forestry and arboriculture that will begin to address the many critical needs identified in this report. Rapid urbanization and land fragmentation threatens livability in the areas where more than 80 percent of the U.S. population lives and works. It also threatens the habitat of many animal and plant species. Urban ecosystem sustainability is critical to our future.

PUTTING THE AGENDA TO WORK

A great deal of time, talent, and hard work went into the creation of this *Agenda*. The *Agenda* achiev-ed its objective of involving participants in constructive, consensus-driven dialogue and decision processes. This document reflects decisions, visions, and critical thinking by a large group of dedicated individuals representing all aspects of urban and community forestry and arboriculture. It is an agenda for all involved in urban and community forestry and arboriculture.

Keeping up the momentum created through this process is the next concern. The Assessment pointed out that the *1991 Agenda* did not remain fresh or visible. Many felt that it should have been reviewed to ensure continued applicability.

Experts responding to the survey felt that the impact of the *1991 Agenda* could have been greater if it had been more accessible and better communicated to those outside the research sponsor circle. The 2002 Summit participants expressed a need for an organized campaign to promote the new *Agenda* not only to government agencies and research sponsors, but also to researchers, urban foresters, and arborists throughout the country.

Summaries of this report, tailored to reach different audiences, should be prepared and distributed widely. Audiences may include elected officials, government officials, universities, nongovernment organizations, community tree advocacy groups, professional urban foresters and arborists, and the general public.

Electronic communication has developed tremendously since the first *Agenda* was published in 1991. The Internet was not generally available then, but now it can serve as the primary tool for making the new *Agenda* accessible to everyone. It should be available on the NUCFAC website and promoted through list serves, links from other sites, email, and every means now available through modern electronic communication.

Promoting the new *Agenda* initially and keeping it current and visible over the next decade were recognized as being two very different issues. Keeping the *Agenda* fresh in everyone's mind will be much more difficult over time. There were several suggestions for keeping the *Agenda* fresh well into the future.

Taking ownership of the *Agenda* can keep it dynamic. It will be necessary to ask every organization and agency funding in urban forestry and arboriculture to incorporate the *Agenda* into their own programs. It would be ideal if these granting organizations called for proposals that directly address the priorities of the *Agenda*.

Reconvening the Summit more often would refocus attention and make changes more incremental than would be likely if another 10 years pass. Without the need to perform an assessment at the same time, such an Interim Summit, attended by many of the same participants, could be efficiently and economically accomplished. An interim report would serve to refocus attention on the *Agenda*.

Eight multidisciplinary themes, each encompassing many of the areas of active research and technology transfer, were identified at the Summit. These themes were developed to promote the collaboration that was notably absent over the last 10 years. These themes emerged near the end of the Summit, and not enough time was available to fully flesh out the needs and opportunities in each area. In a very real sense, the Summit was only the beginning of what should be a continual effort to refine our priorities. Focusing on each of these themes individually in a series of annual mini-Summits would help to keep attention focused on the *Agenda*.

These eight theme "mini-Summits" and an "Interim Summit" would provide an opportunity to revisit and reinforce the new *Agenda* regularly. While all the experts were gathered, a conference open to all interested parties for a registration fee could also be held in conjunction with these theme mini-Summits, providing an excellent technology transfer opportunity and a means to help support the mini-Summit. Published proceedings of the mini-Summit and the conference would help both to keep the Summit fresh and to encourage technology transfer on each theme. NUCFAC sponsorship and support will be critical to this endeavor.

No doubt, additional ideas for putting the *Agenda* to work will emerge as it is circulated and studied by others. A special group or committee designated by NUCFAC should take ownership of putting the *Agenda* to work and making adjustments to it based on feedback and accomplishments. Without a champion for this cause, this revised *Agenda* will not remain any more fresh or visible than the previous agenda.

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