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Planning for Urban Forest Resilience: Managing Invasive Pests and Diseases

By Jennifer Gulick

Close to 80 percent of the U.S. population lives in urban areas and depends on the essential ecological, economic, and social benefits provided by urban trees and forests. Nationally, urban forests are estimated to contain about 3.8 billion trees with an estimated structural asset value of $2.4 trillion (Nowak et al. 2002). But the full value of urban trees far exceeds their structural value.

Trees provide functional ecosystem service benefits such as stormwater reduction, energy conservation, air pollution reduction, carbon sequestration and storage, and a host of additional social and human health benefits that positively influence quality of life. Healthy urban trees increase the value of local real estate and promote increased shopping, retail sales, and tourism (Wolf 2007). They support more livable communities that foster physical and psychological health and provide residents with a greater sense of place (Ulrich 1986; Kaplan 1989).

But trees in urban areas are at risk from the introduction and rapid spread of invasive forest pests and diseases throughout the U.S. Continued loss of major forest species due to nonnative forest pests and disease is the greatest single threat to our nation's urban forests. Destructive pests and diseases introduced from overseas threaten our trees because native species lack effective defense mechanisms and beneficial biological organisms (predators, parasites, and microorganisms) that help to minimize pest population outbreaks and the accompanying tree mortality.

This *PAS Memo* explores the resilience of U.S. urban forests to provide urban planners with insights relative to associated community risks, assessment methodologies, and planning and management strategies to minimize community impacts. Also included are supporting historical and current case examples highlighting invasive forest pest impacts and the accompanying fiscal and operational challenges to affected communities. Finally, the article offers best practices and tools that planners can use to increase urban forest resilience to threatening influences, both natural and man-made.

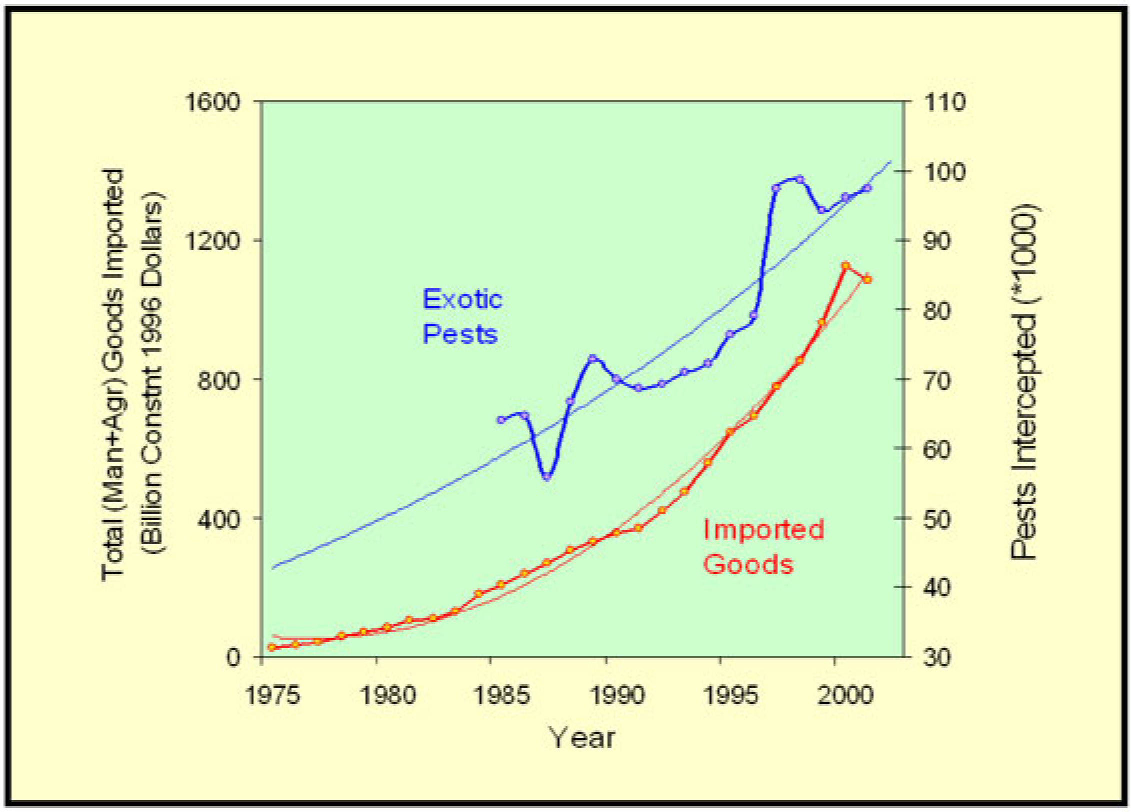
Invasive Forest Pests and Disease

Empirical evidence and various studies have revealed an increasing rate of nonnative insects and diseases that threaten urban forest health. Some introductions such as chestnut blight (*Cryphonectria parasitica*), Dutch elm disease (*Ophiostoma ulmi*), gypsy moth (*Lymantria dispar*(L.)), and, more recently, emerald ash borer (*Agrilus planipennis* Fairmaire) and Asian longhorned beetle (*Anoplophora glabripennis),* have permanently altered forest ecosystems and urban landscapes and collectively cost property owners, businesses, and governments hundreds of millions of dollars to remove and replace impacted trees.

Significant stands of trees are dying because of invasive insects and diseases that are rapidly spreading across the United States. Communities are losing the significant environmental, economic, and social benefits landscape and forest trees provide. Photo Davey Resource Group.

Nonnative forest pests, such as wood-boring beetles, are estimated to cost nearly $1.7 billion in local government expenditures and approximately $830 million in lost residential property values annually (Aukema et al. 2011). Despite efforts to exclude new introductions through quarantine measures, the number of invasive and potentially highly destructive species established worldwide will continue to grow (Aukema et al. 2010). Invasive species increasingly are spread between continents by expanding world trade markets and other human influences related to increased worldwide travel and containerized cargo transport. Once these species invade, they are spread further by the movement of infested plants, firewood, and other articles harboring insects or diseases.

Exotic Pests Linked to Imports



The introduction and numbers of exotic, invasive insect and disease threats has nearly mirrored the increase in foreign imports in the United States over the last 40 years. Image courtesy David Kellum, San Diego County.

In light of these predictions, the catastrophic devastation to urban forests caused by past and current nonnative pests and diseases, coupled with other threats related to severe weather trends — drought, flooding, wind, and extreme temperatures — heighten the importance of planning for greater urban forest resilience.

Historic Examples: Dutch Elm Disease and Gypsy Moth

Dutch elm disease (DED), a fungus spread by the elm bark beetle, was first reported in the United States in 1928. It is believed to have been introduced through European elm bark beetle–infested logs shipped from the Netherlands. Over the next several decades, DED spread from New England westward and southward, destroying millions of elm trees in both urban and rural areas. Some 80 years later, DED still threatens elm trees in plains and western states and major cities, reaching Seattle in 2001. Of the estimated 77 million elms in North America in 1930, more than 75 percent had been lost by 1989 ("New Varieties" 1989).

In the mid-1900s, urban forests in most American cities, towns, and villages were poorly diversified and composed of a high percentage or near monoculture of American elm trees that were highly vulnerable to DED. Many upper Midwest and New England communities that lost a high percentage of their urban tree canopy to DED in the 1950s, 1960s, and 1970s have still not restored the tree canopy or recouped the benefits lost to this single devastating disease.

The costs to homeowners and municipalities to remove and replace tens of millions of American elm trees killed by DED have been estimated at $100 million dollars annually (Mazzone and Peacock 1985). The total cost to the community, however, must also include the lost value of ecosystem services associated with the reduction in tree canopy. The City of Milwaukee is currently analyzing its community forest to quantify and assess the value of the cumulative ecosystems service benefits lost with the death of 200,000 American elm trees over a 60-year period, and it expects to find economic impacts that dwarf the cost of elm removal and replacement.

The European gypsy moth (*Lymantria dispar* L.) has been well-established in the northeast United States and has done considerable damage for decades. It is one of the most damaging pests of hardwood forests and urban landscapes, defoliating a million or more forested acres annually. Gypsy moth caterpillars feed on approximately 500 different plants. The threat of gypsy moth is the repeated defoliation of trees: while healthy trees can withstand one or two defoliations, repeated defoliations weaken trees to the point of death.

Though gypsy moth has been present in North America for more than 100 years, researchers are still at a loss to explain and predict the extent of the changes in forest vegetation likely to take place through gypsy moth disturbance. A major concern is the potential loss of economically critical and ecologically dominant oak species (*Quercus* spp.). The gypsy moth is currently one of the most destructive insects in the eastern United States; it and other foliage-eating pests cause an estimated $868 million in annual damages (Aukema et al. 2011). It is inevitable that gypsy moth will continue to expand its range south and westward in the future.

Modern Examples: Asian Long-Horned Beetle and Emerald Ash Borer

Asian long-horned beetle (ALB), *Anoplophora glabripennis*, is one of the more recent nonnative forest pests introduced in the United States. It was first discovered in 1996 in the New York City area. Since then, ALB has been detected in four additional states: Illinois (1998), New Jersey (2002), Massachusetts (2008), and Ohio (2011).

Asian long-horned beetle (left) and emerald ash borer (right) are two recent invasive insect species capable of causing billions of dollars of damage to U.S. urban forests and dramatically changing community landscapes. Photo Davey Resource Group.

Adult ALB beetles lay eggs in the bark crevices of host trees. Soon after hatching, larvae burrow into the tree and feed on woody tissue, disrupting the flow of water and nutrients and ultimately killing the tree. As larvae age, they burrow deeper into the tree where pesticides have no effect, limiting control efforts to tree removal. The largest ALB infestation discovered to date is in the greater Worchester County, Massachusetts, area; first detected in 2008, the quarantine area has since grown to over 110 square miles. The subsequent eradication policy has required more than 32,000 host trees to be removed, primarily in urban and suburban areas.

ALB has been successfully eradicated in two states, New Jersey (2013) and Illinois (2008). This is one of the relatively few examples where eradication attempts of a destructive nonnative forest pest have proved effective, but at an enormous financial cost: U.S. agencies have spent nearly $375 million on ALB eradication programs. If allowed to spread unchecked, ALB could kill a third of urban trees nationwide, amounting to a compensatory value of $669 billion (Nowak et al. 2001). Approximately 48 million acres of forestland and the associated industries in the United States are at risk from ALB damage.

The costs for eradication are not considered sustainable, yet the alternative of not controlling this insect are devastating impacts on the livability of the nation's population centers and tremendous environmental and economic services loss from the trees destroyed by ALB.

Emerald ash borer (EAB), *Agrilus planipennis Fairmaire*, is an exotic beetle that was discovered in southeastern Michigan near Detroit in the summer of 2002. Since then it has spread east to the mid-Atlantic states and into New England, south as far as Georgia, and most recently is spreading west into Iowa and Colorado. The rapid spread of this nonnative, invasive insect across America is primarily due to human activity.

Emerald ash borer has killed millions of ash trees since its discovery in the U.S., and the number of dead ash is increasing rapidly. Ash species are abundant in both planted and natural areas of urban forests, representing 10 to 40 percent of the canopy cover in many communities. Consequently, widespread ash mortality in urban forests and residential landscapes is having devastating economic and environmental impacts. EAB is predicted to cause an unprecedented $10–20 billion in losses to urban forests over the next 10 years (Kovacs et al. 2009).

Due to an EAB infestation, the entire character of this street and neighborhood in Toledo, Ohio, was dramatically changed in less than two years. Without the mature trees, real estate values, stormwater and particulate matter capture, and local air quality will decrease, and home energy costs will increase. Photo Craig Schaar, City of Toledo.

Other emerging major insect and disease threats to community forests exist from coast to coast. Sudden Oak Death (*Phytophthora ramorum*),which can infect more than 75 plant species, is having devastating effects on forests in California and Oregon. Oak wilt, caused by the fungus *Ceratocystis fagacearum*, is a disease deadly to urban and rural oak trees in Texas and the Midwest. Thousand cankers disease, the result of the combined activity of a fungus (*Geosmithia morbida)* and the walnut twig beetle (*Pityophthorus juglandis*), currently threatens millions of black walnut trees, an important urban and forest species with great economic and ecological value throughout its native range. The European wood wasp (*Sirex noctilio* F.) threatens pine trees and is moving south from Canada into Michigan and the Northeast. And the hemlock woolly adelgid (*Adelges tsugae*) is of great concern to landscape and forest managers in the eastern U.S. Hemlock is the third most common tree species in Vermont.

Lessons Learned

The dramatic and rapid loss of forest and landscape trees to nonnative diseases such as DED and nonnative insects such as gypsy moths and the new threats described above have taught community planners and foresters several important lessons:

- **Tree species diversity is paramount**. Diversity plays an important role in the long-term stability of an ecosystem. When an area has a high diversity of tree species, it is less likely to suffer catastrophic losses from diseases or pests.
- **Canopy recovery requires a 75- to 100-year time frame.** Trees and forests need nearly a century to grow and mature; when trees are lost to invasive insects and disease, the replacement of mature trees and their full benefits will never be witnessed by human adults in their lifetimes.
- **Professional management of the nation's urban forests is needed.** Because of the massive loss of trees and aftereffects of Dutch elm disease experienced by communities, citizens and officials turned to arborists for answers and leadership. The profession of municipal urban forest management arose from the need for better tree care and replacement tree planting after the introduction of this invasive disease, and can be considered one of the first sustainability movements of the mid-20th century.
- **Long-term economic and ecological impacts to communities influenced planning decisions for decades**. The loss of trees and healthy forests due to nonnative insects and diseases changed the characters of entire neighborhoods and business districts and increased stormwater, water quality, and air pollution issues in cities. Planners had very few short-term solutions for these problems.
- **Plans and targeted actions to improve the resilience of urban forests are needed**. Just like the communities where they grow, urban forests are complex, dynamic systems that require plans to set goals and prescribe proper management actions. The impact of DED and gypsy moth prompted communities to include urban forests in comprehensive planning, dedicate staff and resources for tree maintenance and planting, and to involve citizens in actions to restore the community canopy cover.
- **Major port cities or hubs supporting diverse forest types are at the greatest risk of nonnative forest pest and disease introduction and establishment.** Growing global trade markets and use of shipping containers exponentially increases the risk of forest pest and disease introductions into the U.S. Distribution patterns of pests and diseases are also dramatically higher in populated cities in the Northeast because of the rich diversity of eastern forests and influence of human activities, such as movement of firewood, nursery plants, outdoor household articles, and other objects harboring pests and diseases in all life stages (Liebhold et al. 2013).

Community Risk Assessment

Currently, the impact of invasive pests on the U.S. economy is estimated at $120 billion annually, and since 1993, there have been 20 exotic tree pathogens and 368 exotic tree pests established in the U.S. It appears the trend of new insect and disease introductions into our landscapes and cities will not be reversed, nor will the destruction of our native and ornamental trees and the loss of the benefits they provide. There is clearly a need for improved assessment and long-range planning to manage these threats and minimize community risk.

Catastrophic urban tree canopy losses and associated costs of devastating nonnative forest pests since the discovery of Dutch elm disease in the 1930s have served as a catalyst for much-needed research and professional management of our nation's urban forests. Decades of research on nonnative forest pests, urban forest management practices, and urban forest assessment and benefit analysis has led to the development of tools and proven methodologies that urban foresters and planners can use to assess risk and ultimately increase community resilience.

A full understanding of the structure (number and types of trees and asset value), function (environmental benefits), and economic value of local urban forests is required first to assess community risk and to support sound planning decisions relative to nonnative forest pests and other threating influences.

Urban Forest Structure

Understanding the type of trees (genera or species) at risk to a specific pest and their relative abundance in the community is essential to answering the critical question, "How big of a problem will this be in our community?" Many progressive communities have conducted spatial street and park tree inventories that provide useful baseline information for quantifying the number — and, equally important, the location and distribution — of publically managed trees at risk, as well as the percentage of tree canopy that represents.

Information relative to the quantity, size, and location of trees at risk also allow a community to estimate the budgetary, resource (personnel and equipment), and operations impacts of responding to a destructive pest. This resource commitment and timeframe may have significant and long-term community impacts on public services delivered, neighborhood stability, infrastructure longevity and functional capacity, economic vitality, and environmental conditions that will influence future planning strategies.

Urban Forest Function

Myriad quantitative and qualitative environmental urban forest benefits that are at risk will also need to be assessed and considered by urban foresters and planners alike. Trees in urban communities reduce peak stormwater flow, reduce ambient temperatures and energy demand for cooling, reduce water demands required to sustain urban landscapes, improve air quality by absorbing and trapping harmful airborne pollutants, increase property values and economic vitality, and provide a host of additional human health and social benefits.

Multi-billion dollar deep-tunnel projects launched in Chicago and Milwaukee in the late 1970s to help reduce combined sewer overflows into Lake Michigan coincided with a significant reduction in percent tree canopy cover resulting from the loss of an estimated 200,000 American elm trees to DED in each city during the 1950s through the 1980s. Tree canopy loss in the suburban Detroit community of Livonia attributed to an Emerald ash borer infestation increased demand for city water by 35 percent to irrigate parched summer lawns, which necessitated water conservation policies (Tinkel 2014). Additionally, as the majority of large shade trees populating most U.S. cities are floodplain species, canopy loss attributed to nonnative forest pests can also have significant local and downstream watershed and erosion impacts that degrade water quality and aquatic habitat in communities built adjacent to waterways.

Economic Contributions

Community impacts related to the loss of forest structure and function present significant fiscal and operations challenges for federal, state, and local governments. As dead and dying large shade trees constitute a public safety risk, communities impacted by an aggressive nonnative forest pest or disease often must redirect scarce taxpayer dollars for years or even decades to tree removal and reforestation projects and forgo or delay important community development and infrastructure projects. Similarly, tree removal and replacement costs incurred by residents and local businesses impact discretionary income for purchases that impact economic vitality.

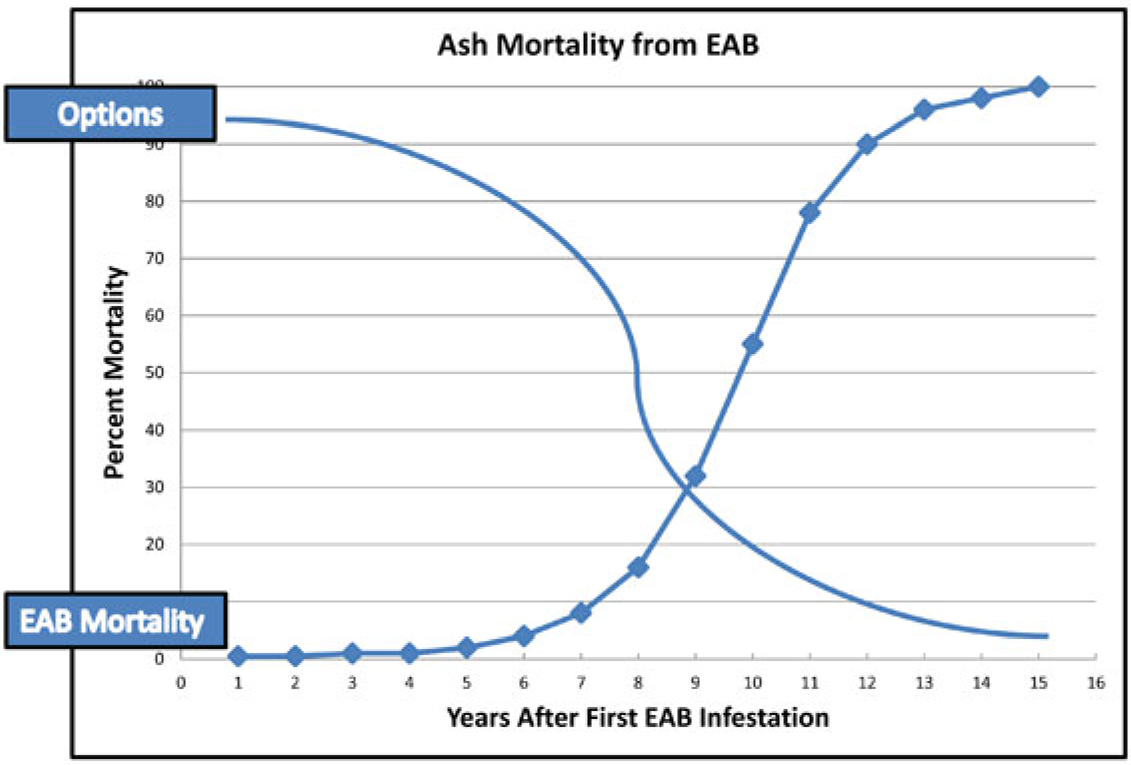
Many smaller communities also either lack sufficient staff, equipment, or expertise to address forest pest and disease outbreaks or must suspend important core services to redirect personnel and equipment to tree removal and replanting efforts. The high number of American elm street trees killed by Dutch elm disease in the Midwest and New England forced cities with professionally managed urban forests to suspend proactive pruning activities, often for decades, while crews focused on removing and replacing tens of thousands of diseased elm trees. The suspension of cyclical pruning activities during the "DED years" negatively impacted the branch structure, health, and longevity of immature and replacement trees planted during that period. Those "under-maintained" trees now compose a significant percentage of the current, mature street tree population and require even more resources to be maintained for health and safety.

Planning for Urban Forest Resilience: Strategies and Tools

Planning for urban forest resilience begins with a comprehensive communitywide plan supported by a full assessment of community risks and impacts. This baseline information provides a sound basis for an evaluation and adoption of appropriate planning strategies, policies, and tools needed to effectively manage and minimize associated threats to the urban forest.

The degree of urban forest assessment necessary is a function of community responsibility for risk and degree of active management of its urban forest. Planning strategies for communities that manage trees on public property only may pursue very different strategies and tools than communities with responsibility for dead and hazardous trees on private property as well.

An Inverse Relationship



Using the emerald ash borer as an example, there are more management options available to communities when the insect or disease is detected early and there is a proactive strategy in place. The longer communities wait to take action, the fewer options there are and the greater the financial burdens and liability issues. Image courtesy Davey Resource Group.

Inventories

Common to all communities is the need for a comprehensive understanding of the tree population managed. As forest pests and diseases are typically host specific, targeting trees at the species level (i.e., sugar maple) or genus level (i.e., *Acer* or all maples), it is important to know the type and location of trees in the community.

Public Tree Inventories. As mentioned previously, an assessment for publicly managed urban forests in parks, greenspaces, and along parkways and streets is normally accomplished through a sample or complete tree inventory. Tree inventories in major cities often include detailed information about the type, size, location (address or GPS spatial), condition, and maintenance needs of managed trees in the population. Tree inventories in smaller communities are usually less detailed and may be based on statistically representative sample data from the tree population. Either method will provide a listing or percentage of various tree species in the population needed to quantify the number of trees at risk and their overall percentage of the tree population. For communities without any tree inventory, this is the first step that must be completed to assess and manage risk.

Communitywide Inventories. Because public trees usually represent a small percentage (typically less than 15 percent) of the overall urban forest, communities with responsibility for identifying and abating hazardous trees on private property — and those that want information for the entire community forest — will need to rely on communitywide assessments and advanced tools to quantify the number or trees at risk or identify the location of host trees threatened by a forest pest or disease.

One excellent resource is i-Tree (**www.itreetools.org**), a suite of free software tools developed by the USDA Forest Service to assess urban forests. There are two i-Tree applications particularly useful for planners:

- **i-Tree ECO** can be used to establish a statistically accurate estimate of the type and quantities of trees in the urban forest. While cost effective, a communitywide i-Tree ECO analysis is best performed by qualified forestry staff or professional consultants.
- **i-Tree Canopy** utilizes aerial images in Google maps to generate statistically accurate estimates of land cover, including tree cover. This tool can also be useful for monitoring changes in tree canopy over time.

Neither i-Tree ECO or Canopy, however, provides information relative to the *location* of host trees at risk. Options for identifying the location of host or at-risk trees include:

- A comprehensive ground inventory (typically cost prohibitive for larger communities if public and private trees are included).
- A windshield survey targeting certain species based on unique identifying features such as flowering attributes, bark attributes (i.e., birch), or fall color (i.e., green ash's early yellow fall coloration). Windshield surveys are relatively quick and low cost, and can provide fairly accurate inventory information of trees visible from streets, alleys, and trails.
- Advanced remote sensing or aerial applications such as hyperspectral imaging. Hyperspectral imaging typically costs approximately $2,000 per square mile for image acquisition and host feature extraction and GIS mapping. While accurate at detecting the target feature, this tool requires considerable ground verification of results to eliminate "false positives" incorrectly identified as the target species.

Planners, typically more highly skilled in spatial analysis mapping applications than are urban foresters, can use these tools and play critical roles in short-term or long-range strategic planning efforts to increase urban forest resiliency to destructive forest pests and diseases or other threats.

Community Forest Benefits Assessment

When trees are lost to invasive pest species and disease, the functional environmental benefits they provide are lost as well. Planners can use various tools to quantity the environmental contribution and economic value of these important benefits.

- **i-Tree ECO** uses complete or partial (sample) inventories at a community scale to quantify and estimate the economic value of the urban forest's benefits, including energy conservation, stormwater interception, air pollutant removal, public health incidence reduction, carbon storage, and annual carbon sequestration.
- **i-Tree Vue** uses freely available **National Land Cover Database (NLCD)** Landsat satellite imagery to assess land cover classifications, including tree cover, carbon storage/sequestration, and air quality benefit estimates.
- **i-Tree Streets** uses complete or sample street tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits of street tree populations, including energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increase attributed to the street tree population. Both the ECO and Streets applications can be used to estimate the canopy cover and associated benefit loss attributed to a specific forest pest or disease.
- **i-Tree Hydro** is a new beta application designed to simulate the effects of changes in tree and impervious cover characteristics within a defined watershed on stream flow and water quality. It was designed specifically to enable natural resource managers and planners to quantify the impacts of changes in tree and impervious cover on local hydrology to aid in management and planning decisions.

Community Response Capacity

Once the structural and environmental risks have been defined, communities will also need to consider the operational and budgetary impacts associated with a forest pest or disease. Major outbreaks or extreme weather events or conditions often create significant operational, fiscal, and policy challenges that can disrupt normal service delivery for years and may also impact the implementation of short- and long-term plans.

Strategic action plans prepared well in advance of precipitating events place communities in the best position to manage adversity and protect public safety with least disruption to other core services and budgets. Typical components of strategic action plans include prioritized strategies to preserve public health and safety-dependent core services, contingency plans to use emergency contract services, goals to ensure cross-trained personnel, identification of major local partners and stakeholders, and the actual means to effectively manage pest outbreaks.

STRATEGIES AND TOOLS FOR URBAN FOREST RESILIENCE

In cities and counties across the country, community foresters have used a variety of strategies and tools to understand their forests, identify the threats, and plan for action. Exploring the following examples will show you the power and value of these tools.

Public Tree Inventories:

The City of Orlando, Florida, has developed a website that displays its public tree inventory and the value of the environmental services the trees provide. **http://orlando.mytreekeeper.com**

Communitywide Urban Forest Inventories:

The Delaware Forest Service has completed urban tree canopy (UTC) analyses for all cities and has made the data available for planning purposes. **http://delawaretrees.com/resources/urban-tree-canopy-maps/**

Emerald Ash Borer Response Plans:

The following documents from the City of Northbrook, Illinois, as well as several Ohio municipalities are good examples of municipal EAB response plans that can be used as a model for EAB and other invasive insect action plans.
www.northbrook.il.us/Modules/ShowDocument.aspx?documentid=2351
www.emeraldashborer.info/cdfiles/municipalplans.html

Strategic Plans:

The State of Indiana's strategic plan for mitigating gypsy moth damage provides a good example of the components found within such plans. **www.in.gov/dnr/entomolo/files/gypsy.pdf**

Community Forest Benefit Analysis:

The U. S. Forest Service's suite of software applications for community forest benefits and planning is free and can be explored and downloaded at this website. **www.itreetools.org**

Overview of Tools for Invasive Pest Management:

The Illinois Department of Natural Resources project, "A Tale of Four Cities: Exotic and Invasive Pest Analysis and Issue Characterization," is a comparative analysis of ordinances, management plans, i-Tree tools, urban tree canopies, and hyperspectral imagery as tools for invasive pest management. Excellent information on the pros and cons of these tools for invasive insect and disease management is contained in this report.
http://dnr.state.il.us/ORC/urbanforestry/TaleFourCities/ TOFC%20Report%20FINAL.pdf

Additional Tools and Strategies for Urban Forest Resiliency

There are a number of additional strategies and actions that planners may want to consider in addition to a natural resource assessment to understand and prepare for nonnative insects and diseases.

Pest Risk Assessments. The types and percentages of trees represented in a community can be correlated with a list of known major pest and disease infestations located within a given radius of the community to estimate relative risk in terms of canopy and associated benefit loss for each threatening pest. Knowledge of the natural and artificial spread of a respective pest or disease can also be helpful in predicting the timing or likelihood of an infestation. GIS mapping tools that graphically display risk zones based on radial distance of the closest known location of a specific forest pest/disease to the community can be a very helpful in communicating relative risk to elected officials and other key personnel. The **i-Tree Pest Detection** utility can also be utilized in conjunction with tree inventory and urban forest assessment tools such as i-Tree Streets or i-Tree ECO to identify existing pest and disease symptoms or signs in the tree population.

Resource and Operations Assessment. The capacity of a community to respond in a timely way to a pest or disease outbreak and the impacts to other services should be assessed. Communities with insufficient resources to manage public safety risk based on worst-case scenarios should identify and prioritize strategies to preserve safety-dependent core services, and develop contingency plans utilizing emergency contract services, cross-trained personnel, utility partnerships, and other creative means to effectively manage pest outbreaks.

Community capacity to replace trees lost to a forest pest or disease outbreak should also be considered to ensure that the structural and functional benefits of the community urban forest continue. Maximizing diversity within the tree population at the block or street level will help increase community resiliency to future urban forest threats.

Creative funding alternatives. Most urban forestry programs are funded through the general tax levy which also supports important public services that are also valued by the community. Major midwestern cities are spending in excess of $1 million annually to treat or remove ash trees killed by emerald ash borer. Clearly, funding strategies that support routine public services may not be sufficient to combat destructive forest pests and diseases. Some creative alternative funding strategies adopted by communities include:

- *Capital Improvement Funds*. Because of their longevity and ecological-services value to infrastructure, communities have justified funding tree planting and tree canopy protection activities through capital improvement budgets.
- *Service-Based Fee Assessments*. Communities that have assessed the ecological service benefits of their urban forests are funding tree canopy establishment and maintenance costs through stormwater management, air quality improvement, or other infrastructure or environmental fees. Fees, which are typically assessed to all property owners (including tax-exempt properties), help to distribute associated costs more uniformly.
- *Special Bonds.* Like capital improvement projects, some communities fund emergency maintenance or operational needs through special bonds or mill taxes dedicated for a specific purpose such as invasive pest management. Bonds that protect public safety or valued community assets at risk are often supported by residents.
- *Contingent Funding*. Many communities will budget unallocated contingent funds for emergency needs which can be allocated to prevent or abate infested hazardous trees that threaten public safety.
- *Public/Private Partnerships*. Many communities with overhead utilities in the street rights-of-way develop funding agreements to treat, remove, and replace at-risk trees that threaten utility infrastructure.
- *Deferred Property Assessments*. Certain communities with statutory authority to abate hazardous trees on private property that threaten public rights-of-way or public safety at large have adopted ordinances or policies that allow property owners to pay the cost of a regulatory action related to abatement of a hazardous tree over multiple years to reduce the financial burden.

Ordinance and Policy Revisions. Many communities do not regulate or have policies that address infested or hazardous trees on private property. All trees within a community, regardless of their location on public or private property, are at risk to nonnative forest pests and diseases. Accordingly, readiness and response plans should include a thorough review of existing ordinances and policies and changes needed to protect the public from dead and dying trees. For instance, ordinances can give local governments the authority to declare an infested or infected public or private tree a public nuisance and order its removal at the cost of the property owner.

Intragovernmental Communication and Cooperation. A good working relationship between planners and community foresters is critical to the success of any proactive invasive pest management program and the creation of a resilient urban forest. Open, regular communication and mutual cooperation between planners and urban foresters will allow both to extend their agencies' resources and find appropriate solutions for the threats to the community at hand.

Whether the position is classified as Urban Forester, Municipal Arborist, or Tree Warden within the local government, planners should seek out the person who has the primary responsibility for tree care and planting. Urban foresters have the technical knowledge, professional experience, and data needed to contribute to almost any short- or long-term plan related to the urban forest. If no official urban forester position exists in the community, seek out those who have that responsibility, such as public works managers and park staff.

In addition to intragovernment communication, information and advice can come from state forestry staff, county cooperative extension offices, and consulting foresters and arborists.

Conclusion

Faced with the threats of invasive insects and diseases, planners and urban foresters should consider themselves allies in the defense of their communities. When the unique perspectives, skill sets, and bodies of knowledge of each profession are combined, significant progress can be made in protecting their communities' forests and futures.

Advanced planning and assessment of urban forest composition and risk to threats, coupled with proactive management strategies, will help minimize tree canopy and associated benefit losses. Expertise in spatial analysis and community planning mean that planners have an important role in achieving resilience of the urban forest to destructive nonnative forest pests and diseases.

About the Author

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References and Resources

Aukema, J.E., D.G. McCullough, B. Von Holle, A.M. Liebhold, K. Britton, and S.J. Frankel. 2010. "Historical Accumulation of Nonindigenous Forest Pests in the Continental US." *BioScience* 60: 886–97.

Aukema, J.E., B. Leung, K. Kovacs, C. Chivers, K.O. Britton, J. Englin, S.J. Frankel, et al. 2011. "Economic Impacts of Nonnative Forest Insects in the Continental United States." *PLoS ONE* 6(9): e24587. Available at **www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0024587** .

Huntley, G.D. 1982. "The Elm – a Resurgent Resource or a Persistent Problem?" Pp. 103–11in*Proceedings of the Dutch elm Disease Symposium and Workshop,* eds. E.S. Kondo, Y. Hiratsuka, and W.B.G. Denyer. Winnipeg, Manitoba, October 5–9, 1981. Manitoba Department of Natural Resources, Manitoba, Canada.

Kaplan, Rachel, and Stephen Kaplan. 1989. *The Experience of Nature: A Psychological Perspective.*Cambridge: Cambridge University Press.

Kovacs, Kent F., R.G. Haight, D.B. McCullough, R.J. Mercader, N.W. Siegert, and A.M. Liebhold. 2009. "Cost of Potential Emerald Ash Borer Damage in U.S. Communities, 2009–2019." *Ecological Economics* 69(2010): 569–78. Available at **www.nrs.fs.fed.us/pubs/jrnl/2010/nrs_2010_kovacs_001.pdf**.

Liebhold, A.M., D.G. McCullough, L.M. Blackburn, S.J. Frankel, B.Von Holle, and J.E. Aukema. 2013. "A Highly Aggregated Geographical Distribution of Forest Pest Invasions in the USA." *Diversity and Distributions* 19(9): 1208–16. Abstract available at **http://onlinelibrary.wiley.com/doi/10.1111/ddi.12112/abstract**.

Mazzone, H.M., and J.W. Peacock. 1985. "Prospects for Control of Dutch Elm Disease - Biological Considerations. " *J. Arboriculture* 11: 285–92.

McPherson, G.E., J. Simpson, P. Peper, S. Maco, S. Gardner, S. Cozad, and Q. Xiao. 2005. *City of Minneapolis, Minnesota Municipal Tree Resource Analysis*. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. Available at **www.itreetools.org/resources/reports/Minneapolis%20Municipal%20Tree%20Resource%20Analysis.pdf**.

National League of Cities Sustainable Cities Institute. "Benefits of Trees and the Urban Forest." Available at **www.sustainablecitiesinstitute.org/view/page.basic/class/feature.class/Lesson_Benefits_Urb_Forest_Trees**.

"New Varieties of Elm Raise Hope of Rebirth For Davastated [sic] Tree." 1989. *New York Times*, December 5. Available at **www.nytimes.com/1989/12/05/science/new-varieties-of-elm-raise-hope-of-rebirth-for-davastated-tree.html**.

Nowak, D.J., J. Pasek, R. Sequeira, D.E. Crane, and V. Mastro. 2001. "**Potential Effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on Urban Trees in the United States**." *J. Econon. Entomol*. 94(1): 116–22. Available at **www.nrs.fs.fed.us/pubs/jrnl/2001/ne_2001_nowak_001.pdf**.

Nowak, D.J., D.E. Crane, and J.F. Dwyer. 2002. "Compensatory Value of Urban Trees in the United States." *Journal of Arboriculture* 28(4): 194–99. Available at **www.nrs.fs.fed.us/pubs/jrnl/2002/ne_2002_nowak_003.pdf**.

Tinkel, Chad. 2014. "Dealing with EAB from a City Forester's Perspective." Presentation at 2014 Wisconsin Arborists Association / Department of Natural Resources Annual Conference, January 28.

Ulrich, Roger S. 1986. "Human Responses to Vegetation and Landscapes." *Landscape and Urban Planning* 13: 29–44.

U.S. Forest Service, et al. "i-Tree: Tools for Assessing and Managing Community Forests." Available at **www.itreetools.org**.

Wolf, Kathleen L. 2007. "The Environmental Psychology of Shopping: Assessing the Value of Trees."*International Council of Shopping Centers Research Review* 14(3): 39–43. Available at **www.fs.fed.us/pnw/pubs/journals/pnw_2007_wolf001.pdf**.