# Assessing and Addressing Indiana Urban Tree Canopy

Indiana Department of Natural Resources
Division of Forestry
Community and Urban Forestry

**October, 2011**

DAVEY RESOURCE GROUP
*A Division of The Davey Tree Expert Company*

Forestry DNR

Urban & Community Forestry
US FOREST SERVICE

# Assessing and Addressing Indiana Urban Tree Canopy

## Indiana Department of Natural Resources
## Division of Forestry
## Community and Urban Forestry

October, 2011

**Prepared for:** **Indiana Department of Natural Resources**
**Division of Forestry**
**Community and Forestry**
**Pamela Louks**
5785 Glenn Road
Indianapolis, Indiana 46216

**Prepared by:** **Davey Resource Group**
*A Division of The Davey Tree Expert Company*

1500 North Mantua Street
P.O. Box 5193
Kent, Ohio 44240

# Table of Contents



## Tables



## Figures



## Appendices

# Acknowledgement

This project was made possible by the Indiana Department of Natural Resources, Division of Forestry, Community and Urban Forestry Program and a grant from the United States Department of Agriculture (USDA) Forest Service Northeastern Area, Urban and Community.

# Project Introduction

Urban trees play an important role in our daily lives; they provide many economic, environmental, and social benefits and can have far-reaching effects on a community. Trees reduce the urban heat island effect and help to cool the atmosphere, improve water quality, save energy, mitigate air pollution, reduce flooding and stormwater damage, enhance property values, provide wildlife habitat, provide recreation and education opportunities, and foster psychological and aesthetic benefits. The amount of urban tree canopy (UTC) determines many of these environmental and social benefits. Urban tree canopy is composed of the leaves, stems, and branches of all public and private trees within the community's forest as viewed from above. With proper care and protection, trees, as part of a community's infrastructure, can actually appreciate over time. Recognizing the importance of UTC, the State of Indiana developed a project, titled *Assessing and Addressing Indiana Tree Canopy*.

## Background

According to the Urban and Community Forests of the North Central East Region Report (Nowak and Greenfield, 2010), statewide urban or community land in Indiana has an estimated 52 million trees. Indiana's urban trees store approximately 9.9 million metric tons of carbon, and remove approximately 327,000 metric tons of carbon and 8,620 metric tons of air pollutions annually, for a total economic value of $304 million per year.

In 2008, the Indiana Department of Natural Resources, Division of Forestry, Community and Urban Forestry commissioned a study of Indiana's street tree resource through the Sample Urban Statewide Inventory (SUSI) project. The SUSI project reported an estimated 326,788 street trees among 23 communities. The i-Tree Streets benefit model was then used to quantify the benefits that Indiana's street trees provide. Using median SUSI values, Indiana's street tree benefits total approximately $79 million annually when taking into consideration all 567 Indiana communities.

***Trees in urban areas provide economic, environmental, and social benefits. These benefits are both tangible marketable resources we can measure and non-tangible benefits that are more difficult to measure, but that improve our quality of life.***

***Economic Benefits***

***Improve property values, reduce flooding and stormwater management costs, contribute to increased retail sales, and lower cooling and heating costs.***

***Environmental Benefits***

***Improve air and water quality, reduce atmospheric carbon dioxide, improve stream ecology, provide wildlife habitat, reduce ultraviolet radiation loads, mitigate air pollutants, reduce air and surface temperatures, conserve water, and reduce erosion.***

***Social Benefits***

***Calm traffic, reduce noise, encourage physical activity, create feelings of relaxation and well-being, provide educational and recreational opportunities, and reduce incidence of crime.***

## Purpose

The purpose of the *Assessing and Addressing Indiana Tree Canopy* project is to use aerial photographs and satellite imagery with geographic information systems (GIS) data to understand the existing statewide UTC, identify threats and environmental pressures that may influence existing UTC, and target areas to receive tree planting financial assistance to increase UTC.

The project included the following:

- Performing UTC analyses of six communities with data extrapolation to determine regional and statewide UTC estimates.
- Identifying target areas for tree planting financial assistance through the analysis of existing threats and environmental pressures to the UTC.
- Preparing educational fact sheets for each of the six communities presenting the existing UTC and other land cover analysis results.
- Completing a statewide fact sheet summarizing the results of the project and identifying targeted areas for technical and financial assistance to increase canopy cover.

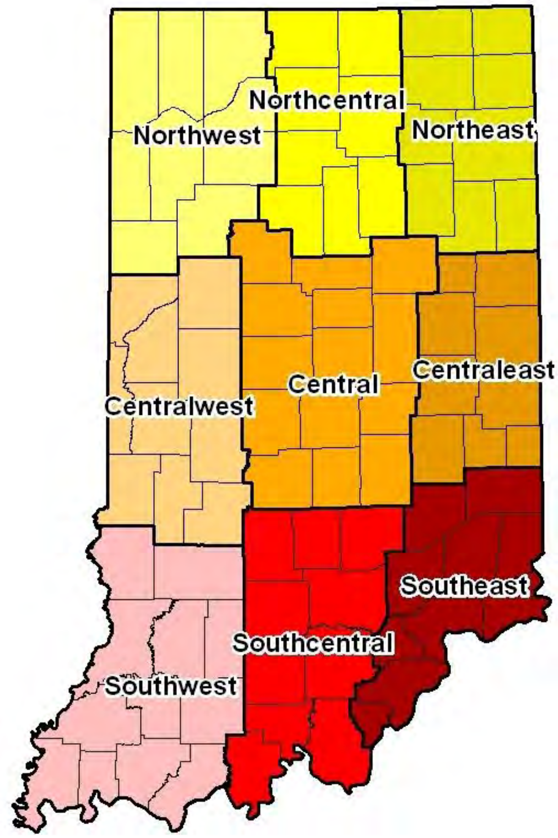


***Figure 1. Indiana was divided into nine regions in order to better understand the regional threats and environmental pressures on canopy and to allow for comparison.***

## Methods

The project used remote sensing surveys to measure the existing UTC of six communities selected from the SUSI project. An additional 102 communities were selected based on population and assessed for UTC using i-Tree Canopy. The resulting data were used to determine the average UTC for Second and Third Class Communities. First, Second, and Third Class Communities are designated by their population, with First Class being the largest. Indianapolis is the only community within the state designated as a First Class Community; therefore, for the purposes of this study, it was included with the Second Class Communities. The State of Indiana was divided into nine regions (Figure 1) and the results of i-Tree Canopy were used to extrapolate regional UTC averages and a Statewide UTC average.

Threats and environmental pressures to existing UTC were mapped and analyzed to identify areas of concern and significance within the State. Threats included the probability of the presence of emerald ash borer, the presence of gypsy moth, and land development as measured by population change. Environmental pressures included the lack of existing UTC, existing impervious land cover, and the presence and number of impaired stream segments. These factors were analyzed and mapped to help identify target areas to receive tree planting financial assistance.

This report summarizes the analysis completed and the findings. A complete description of the methodologies used to complete the analyses is included in Appendix A. References are included in Appendix B, and all GIS files, data sets, and images are included in the DVD contained in Appendix C.

# Indiana's Urban Tree Canopy

Statewide, regional, county, and Second and Third Class Community UTC averages for urban or developed areas were determined as a result of this study. Assessing existing tree canopy coverage has many uses including:

- Supports proactive, responsible tree management
- Facilitates community forestry and UTC goal-setting
- Aids in determining the impact and required response to invasive insect and disease threats
- Allows communities to establish benchmarks and perform monitoring to gauge levels of success of various projects and policies
- Provides educational information for citizens, businesses, schools, and non-profit groups
- Improves community land development and resource planning for healthier and more sustainable community environments

**Many different stakeholders, leaders, and staff can use tree canopy coverage to create more sustainable communities. These groups include:**

Land and Community Planners • Community Foresters

Universities • Conservation Districts • Watershed Groups

Economic Development Agencies • Municipal Managers and Staff

## Statewide Results

Urban land in Indiana covers approximately 453,986 acres (709.3 square miles) and makes up approximately 2 percent (1.95 square miles) of the total land area in the state. Based on the results of the 2011 analysis, the estimated average canopy cover for Statewide urban land is 24.58 percent. This result was derived from interpolating the average UTC percentages from 108 urban communities. Of the 108 communities, 79 Third Class Communities were randomly sampled (9 from each region), as well as all 23 First and Second Class Communities, and the 6 SUSI communities.

The *Urban and Community Forests of the North Central East Region Report* (Nowak and Greenfield, 2010) used National Land Cover Database (NLCD) from 2007 (processed from 2001 Landsat satellite imagery) to determine land cover for the State of Indiana. According to this report, the State of Indiana tree canopy cover averages 18.2 percent and the urban or community average tree canopy is 14.5 percent. It estimates 52 million trees are present within Indiana.

## Regional Results

The average UTC percent by region is presented in Table 1. Figure 2 is a representation of the average UTC based on sampling of randomly selected urban areas. This image was created by using an interpolation method called Kriging to display the results as a continuous smooth surface across the State.

***Table 1. Average Percent Urban Tree Canopy by Region***

| Region | Average UTC percent |
|---|---|
| Northwest | 23.44 |
| Northcentral | 20.61 |
| Northeast | 18.06 |
| Centralwest | 25.30 |
| Central | 23.32 |
| Centraleast | 21.54 |
| Southwest | 26.71 |
| Southcentral | 30.38 |
| Southeast | 30.71 |

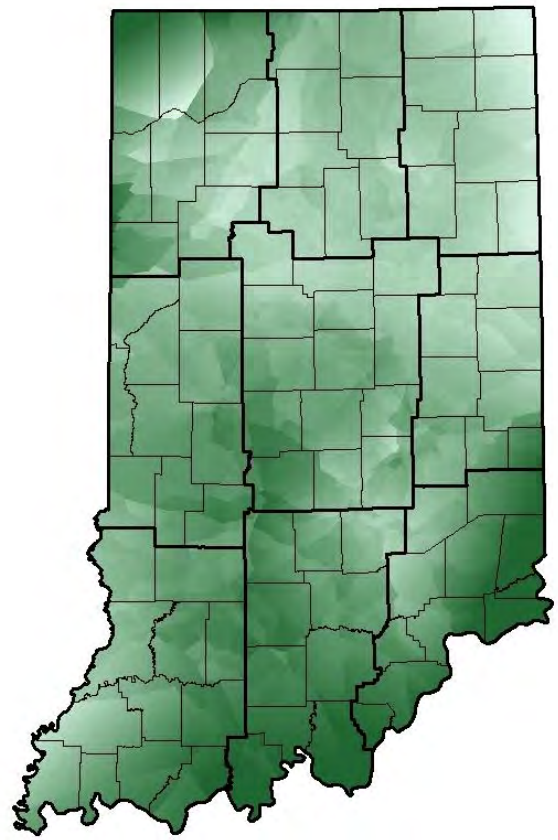


***Figure 2. Average UTC percentages were derived from analyzing randomly selected urban areas and interpolating the results regionally.***

## Second and Third Class Communities Results

An estimation of percent UTC was determined for 102 communities within Indiana using i-Tree Canopy tool. i-Tree Canopy is part of a free suite of software tools developed by the U.S. Forest Service. It was developed to provide a quick and easy way to produce a statistically valid estimate of tree canopy cover.

The 6 SUSI communities were also included in the analysis for a total of 108 communities. Results were recorded based on population size of each community to allow for comparison between the First, Second, and Third Class Communities. The results of the analysis are presented in Tables 2 and 3 by region for Second and Third Class Communities.

***Table 2. Average UTC Percent for Second and Third Class Communities***

| Region | Second Class | Third Class |
|---|---|---|
| Northwest | 25.73 | 25.46 |
| Northcentral | 25.53 | 19.61 |
| Northeast | 26.80 | 20.06 |
| Centralwest | 18.60 | 25.87 |
| Central | 22.56 | 25.81 |
| Centraleast | 21.45 | 21.42 |
| Southwest | 24.80 | 24.38 |
| Southcentral | 24.75 | 30.86 |
| Southeast | 29.70 | 31.19 |
| **Statewide** | **23.75** | **24.96** |

# Selected SUSI Communities Results

The six SUSI communities selected for the most precise UTC analysis included Anderson, Cedar Lake, Evansville, Fort Wayne, Madison, and South Bend (Figure 3).

Davey acquired ancillary spatial data and high-resolution, aerial imagery from all of these communities. Using National Agriculture Imagery Program (NAIP) 4-band imagery acquired from USDA, land cover layers were extracted from the overall imagery to determine land cover acreages for canopy, pervious, impervious surfaces, and open water. Impervious surfaces (areas where the ground is covered with materials that prevent water absorption) included buildings, streets, driveways, and parking lots. Pervious surfaces (areas where water can be more easily absorbed) included grass, low-lying vegetation, and bare soils. Land cover results for each community are presented in Table 3 and land cover images are shown for each of the six SUSI communities in Figure 3. Tree canopy acreages were calculated for parks, neighborhoods, zoning, land use, parcel use, and right-of-ways, if the datasets were available from the community. Communities can use this data to determine potential UTC and planting plans.


***Figure 3. The six communities that received detailed UTC analysis were selected by IN DNR CUF based on their inclusion in the SUSI project (2007), their size, watershed, and their geographic location within the state.***

***Table 3. Land Cover Results for Six SUSI Communities***

| Community | Canopy | | Pervious | | Impervious | | Open Water | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Acreage | Percent | Acreage | Percent | Acreage | Percent | Acreage | Percent | |
| Anderson | 5,104.88 | 19.30 | 14,701.56 | 55.50 | 6,174.88 | 23.30 | 509.65 | 1.90 | 26,490.97 |
| Cedar Lake | 1,808.43 | 33.80 | 1,808.42 | 33.80 | 842.43 | 15.70 | 893.95 | 16.70 | 5,353.23 |
| Evansville | 8,091.33 | 26.40 | 9,465.02 | 30.80 | 12,612.64 | 41.10 | 529.70 | 1.70 | 30,698.68 |
| Fort Wayne | 20,510.90 | 29.00 | 21,414.20 | 30.30 | 27,266.23 | 38.50 | 1,569.22 | 2.20 | 70,760.55 |
| Madison | 1,982.21 | 34.80 | 2,009.98 | 35.20 | 1,544.00 | 27.10 | 166.46 | 2.90 | 5,702.65 |
| South Bend | 6,896.66 | 25.90 | 11,078.10 | 41.60 | 8,281.92 | 31.10 | 384.11 | 1.40 | 26,640.80 |

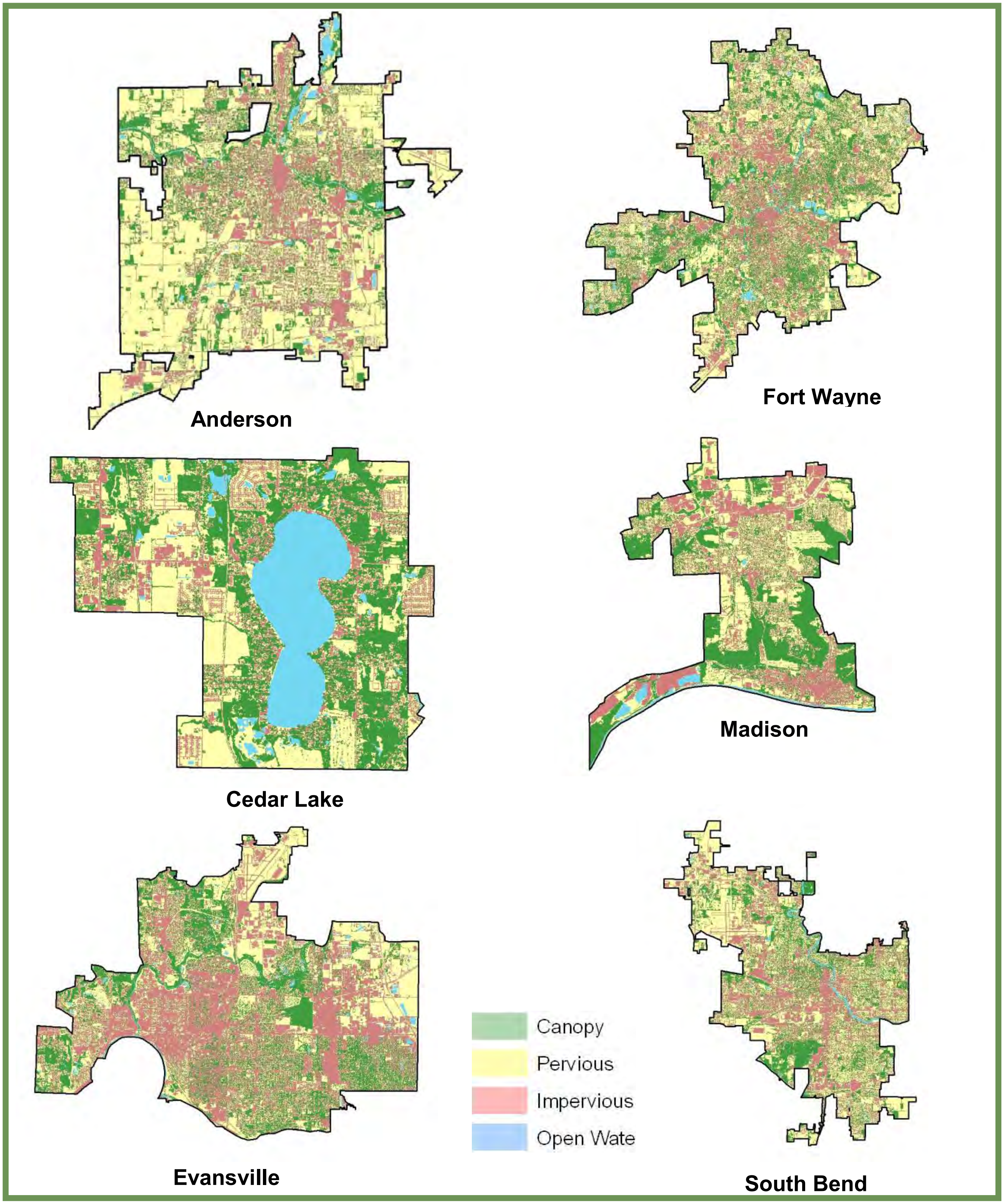


*Figure 4. Land cover analysis for six SUSI communities included tree canopy, impervious, open water, and pervious.*

# Benefits of Knowing Your Urban Tree Canopy

Mapping and quantifying UTC will allow Indiana communities to establish baseline conditions for current use and future monitoring, benchmark against similar communities, set goals for improvement, create plans for planting and protecting trees, and monitor threats to the urban forest. Communities that maintain GIS data for land use or public and private parcel data have the ability to determine the existing canopy for each of these classifications. The following is an overview of how city planners, urban foresters, and council members can use UTC results as a planning, management, and funding tool.

## Goal Setting

One of the most widespread uses of UTC technology is to set canopy coverage goals. American Forests, a recognized leader in conservation and community forestry, has established canopy goals for municipalities and for land use or zoning types within community boundaries. American Forests' goals are the nationally accepted standard. The State of Indiana encourages this standard as a general guideline or target for Indiana communities to achieve.

**American Forest's Canopy Goals**
**For Metropolitan Areas East of the Mississippi River**

Average tree cover for all zones – 40%
Suburban residential zones – 50%
Urban residential zones – 25%
Central business district – 15%

## Benchmarking and Monitoring

Communities can use the results of this report to compare their UTC to the recommended canopy goals, to similar communities, and to regional and statewide averages. The average UTC for similar class communities, regional, and statewide averages are presented in Table 4. UTC results can also be used as a baseline upon which a community can gauge canopy cover changes over time and determine the success or failure of tree protection, tree planting, and public education programs and projects.

***Table 4. Average Urban Tree Canopy Percentages Reported by Region and Community Classification***

| Region | Second Class | Third Class | Regional Average |
|---|---|---|---|
| Northwest | 25.73 | 25.46 | 23.44 |
| Northcentral | 25.53 | 19.61 | 20.61 |
| Northeast | 26.80 | 20.06 | 18.06 |
| Centralwest | 18.60 | 25.87 | 25.30 |
| Central | 22.56 | 25.81 | 23.32 |
| Centraleast | 21.45 | 21.42 | 21.54 |
| Southwest | 24.80 | 24.38 | 26.71 |
| Southcentral | 24.75 | 30.86 | 30.38 |
| Southeast | 29.70 | 31.19 | 30.71 |
| **Statewide** | **23.75** | **24.96** | **24.58** |

## Create Plans for Planting, Protecting, and Preserving Canopy

The results of the UTC analysis should be shared with all stakeholders involved with community planning, development, and community forest management. UTC results can be used to create plans for community tree planting projects and to establish policies for protecting, preserving, and increasing the existing canopy on both public and private property. Using GIS data, land cover information can be used to identify preferred planting locations within the community, such as where there is a total lack of canopy cover, near impaired streams, or in critical watersheds. Reviewing and revising tree ordinances based on desired UTC goals can be used to protect and increase canopy.

## Make Funding Decisions

UTC findings, in conjunction with the information on the benefits of trees, can be used to increase awareness about the relationship between trees and environmental quality and to engage the community in tree planting. Once a higher level of awareness has been achieved and decision-makers understand the benefits trees provide a community and recognize trees as valuable public infrastructure, funding should be increased to support the maintenance, preservation, and expansion of the community's urban forest in prioritized areas. Funding can come from public budgets, state grants, and assistance from private non-profits.

## Grant Proposals

The results of UTC can be included in grant proposals. The relevant statistics will help establish and document the need to increase and preserve a community's canopy, whether the grant is for watershed protection, invasive pest response, stormwater management, or tree planting. Grant-giving organizations are usually more favorable to requests that show an in-depth knowledge of the issues, can document and define the need, and can present a prioritized approach based on sound science and reasoning.

## Community Forestry Education and Outreach

Since most tree canopy is growing on private property, public outreach and education are the true keys to preserving and increasing tree canopy. When citizens, city officials and staff, developers and contractors, and community institutions are educated about the benefits of trees and the threats to the canopy cover, then all can work together to achieve UTC community goals. UTC data and maps can help the public visualize the importance of canopy cover. For the majority of communities, the most significant impact to increasing canopy can only be made by planting on privately held land and, therefore, outreach and education programs designed with canopy goals in mind are important aspects of any community forestry program.

## Understand and Monitor Threats to Canopy

Factors that threaten canopy cover are both human-caused and naturally occurring. Understanding potential and real threats to UTC can help a community prepare for and protect its existing canopy. For example, invasive insects and diseases can have a devastating impact on a community's urban forest and must be planned for and monitored. Land development can be positive for the local economy, but destructive to the environment unless proper planning and appropriate protection measures are in place to help strike a balance between economic development and environmental conservation.

# Urban Tree Canopy Impact Analysis

Potential threats and environmental pressures that influence UTC were identified as part of this study. Threats included the probability of the presence of emerald ash borer, the presence of gypsy moth, and land development as measured by the change in population. Environmental pressures analyzed included lack of existing UTC, existing impervious land cover, and the presence and number of impaired streams. While other threats or environmental pressures that affect canopy exist, such as global climate change, the factors chosen for evaluation were based on the known threat or impact and the availability of data to perform the analyses.

## Threats that Influence Indiana's Urban Tree Canopy

The emerald ash borer and gypsy moth are two exotic insects that threaten the State's urban forests. The state proactively monitors and manages these existing and potential threats to varying degrees based on available funding. Development can also threaten the urban forest if not properly planned and actively monitored. Unrestricted development can involve significant removal of trees and result in immediate and severe losses to UTC that will take decades or centuries to regain.

### Emerald Ash Borer (*Agrilus planipennis* Fairmaire)

The emerald ash borer (EAB) was discovered in northeastern Indiana in June, 2004. Based on occurrence records obtained from Indiana Department of Agriculture as of August 2011, EAB has been discovered in 43 of the 92 Indiana Counties (Figure 5).

In an effort to assess the risk of EAB in Indiana, a modeling procedure was utilized to predict the probability for EAB presence throughout the State of Indiana. Data sets, including EAB occurrence, campgrounds, nurseries, sawmills, roads, urban areas, harbors, population, secondary homes, housing density change, and ash basal area, were spatially represented using GIS to determine the potential presence of EAB in the future. The probably of presence for each region is provided in Table 5 and illustrated in Figure 6.

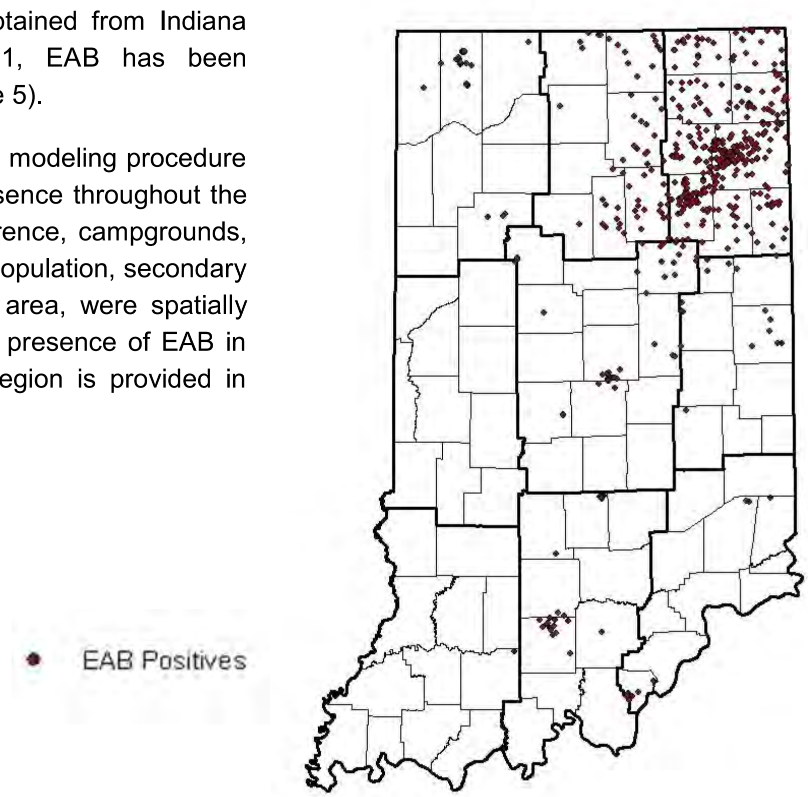


***Figure 5. As of August 2011, EAB has been discovered in 43 of the 92 Indiana Counties.***

As expected, the most vulnerable places were in and around many of the mid- to large-sized communities, but a few locations of interest were predicted outside the current infestation zones. In the Eastcentral region of Indiana, the probability of the presence of EAB was most likely for the communities of Muncie, New Castle, and Rushville because they share many commonalities to those previously reporting heavy EAB discoveries, as indicated by the orange and red colors. Likewise, in the Westcentral region, EAB was predicted to have a fairly high likelihood of presence especially in Terra Haute and its surrounding areas.

***Table 5. Probability of the Presence of EAB***

| Region | Probability of EAB Presence |
|---|---|
| Northwest | 5.23% |
| Northcentral | 15.97% |
| Northeast | 40.68% |
| Centralwest | 19.26% |
| Central | 28.28% |
| Centraleast | 26.52% |
| Southwest | 6.82% |
| Southcentral | 10.66% |
| Southeast | 7.69% |

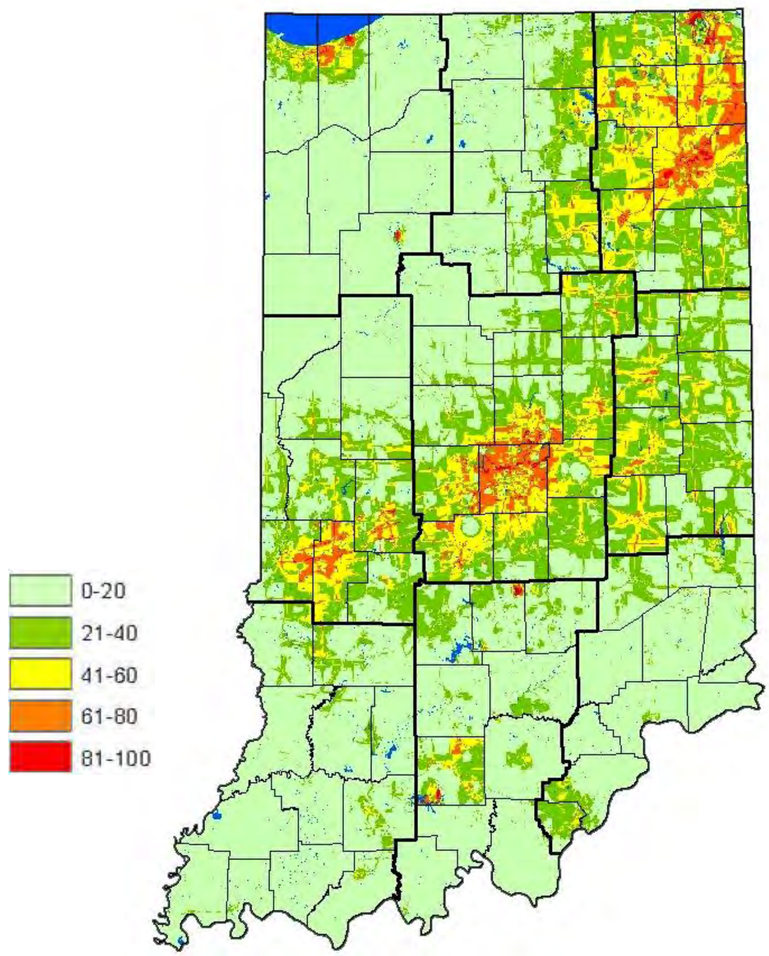


***Figure 6. Based on an analysis of several data sets related to the movement of ash wood and the current known infestation sites of EAB, the probability that EAB would be present was able to be determined through spatial analysis.***

## Gypsy Moth (*Lymantria dispar*)

Based on the Slow-The-Spread (STS) Program developed by the USDA Forest Service, gypsy moth traps were set across the State of Indiana. The results of the 2009 and 2010 trappings were used to identify counties where gypsy moth is a current threat to the urban forest. The number of gypsy moths trapped in 2009 and 2010 is shown in Table 6. Figure 7 illustrates the results of the 2009 and 2010 gypsy moth trappings.

***Table 6. Presence of Gypsy Moth Based on 2009 and 2010 Trappings***

| Region | 2009 Trappings | 2010 Trappings | Total |
|---|---|---|---|
| Northwest | 3,768 | 3,575 | 7,343 |
| Northcentral | 6,569 | 10,551 | 17,120 |
| Northeast | 40,889 | 12,312 | 53,201 |
| Centralwest | 5 | 0 | 5 |
| Central | 64 | 216 | 280 |
| Centraleast | 72 | 374 | 446 |
| Southwest | 0 | 0 | 0 |
| Southcentral | 4 | 0 | 4 |
| Southeast | 0 | 6 | 6 |

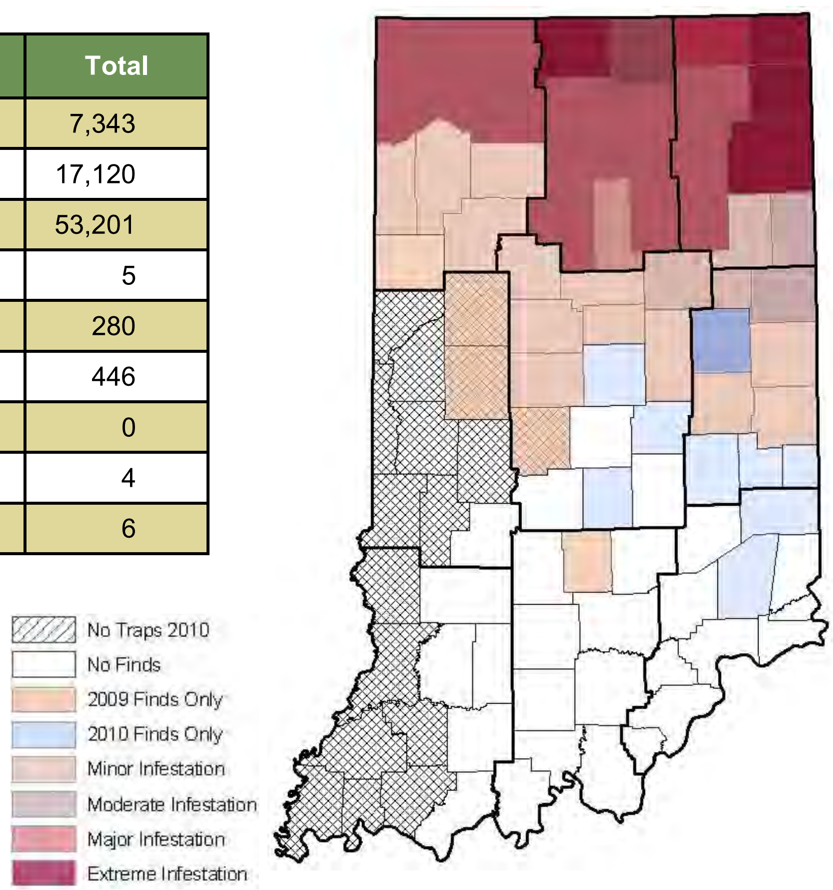


***Figure 7. Gypsy moths trapped in 2009 and 2010 as reported by the Indiana Department of Natural Resources, Division of Forestry.***

## Land Development

Land development often involves the removal of trees and, therefore, is considered a potential threat to urban tree canopy. For the purposes of this study, population change from 2000 to 2010 was used to measure the potential impact to urban tree canopy. Areas experiencing greater positive population change may be experiencing greater development. Communities within these areas should consider a review of existing tree preservation ordinances and policies to ensure a balance of economic development and urban tree resource conservation. Figure 8 illustrates the percent change in population. Table 7 shows the percent change in population for the nine regions.

***Table 7. Development Based on Percent Population Change***

| Region | 2000 to 2010 Percent Population Change |
|---|---|
| Northwest | 1.43 |
| Northcentral | 1.31 |
| Northeast | 3.58 |
| Centralwest | 1.91 |
| Central | 11.20 |
| Centraleast | -2.87 |
| Southwest | 2.35 |
| Southcentral | 5.01 |
| Southeast | 7.54 |

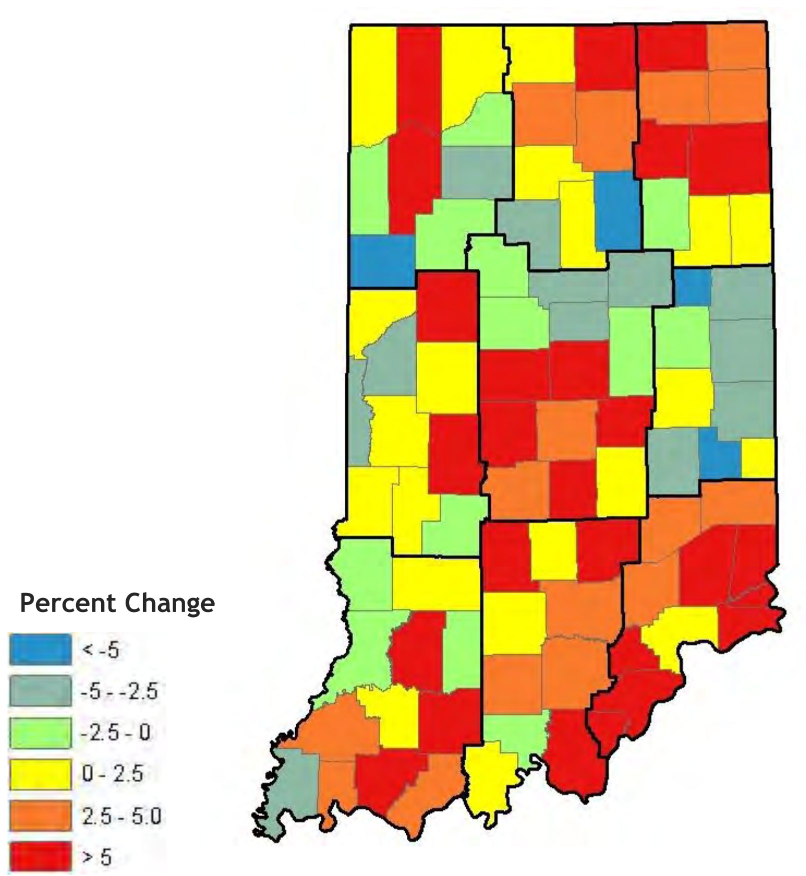


***Figure 8. Development trends as measured by change in population from the 2000 and 2010 U.S. Census Data.***

# Environmental Pressures that Influence Urban Tree Canopy

In order to increase urban tree canopy, communities must first know their existing urban tree canopy and existing impervious land cover. The location of urban tree canopy and impervious land cover (made up of buildings, streets, driveways, parking lots, etc.) can be used to assist communities in addressing their potential for increasing urban tree canopy.

Streams are a sensitive part of our ecosystem and runoff from urban lands can negatively impact water quality and directly affect the overall health of the watershed. Trees and tree canopy help intercept stormwater to help mitigate peak runoff amounts, provide shade, improve water quality, and contribute to fish and aquatic vegetation habit. The presence and number of impaired streams within the watershed can be used to identify areas to where targeted increases in tree canopy are most needed.

## Lack of Existing Urban Tree Canopy

The average UTC percent by region is presented in Table 8. Figure 9 is a representation of the average urban tree canopy based on sampling of randomly selected urban areas. Using an interpolation method called Kriging, Figure 9 was created to display the results as a continuous smooth surface across the State. The regions with the lowest amounts of canopy may warrant greater financial and technical assistance towards setting and reaching canopy cover goal.

***Table 8. Average Urban Tree Canopy Cover for Urban Areas***

| Region | Percent Urban Tree Canopy Cover |
|---|---|
| Northwest | 23.44 |
| Northcentral | 20.61 |
| Northeast | 18.06 |
| Centralwest | 25.30 |
| Central | 23.32 |
| Centaleast | 21.54 |
| Southwest | 26.71 |
| Southcentral | 30.38 |
| Southeast | 30.71 |

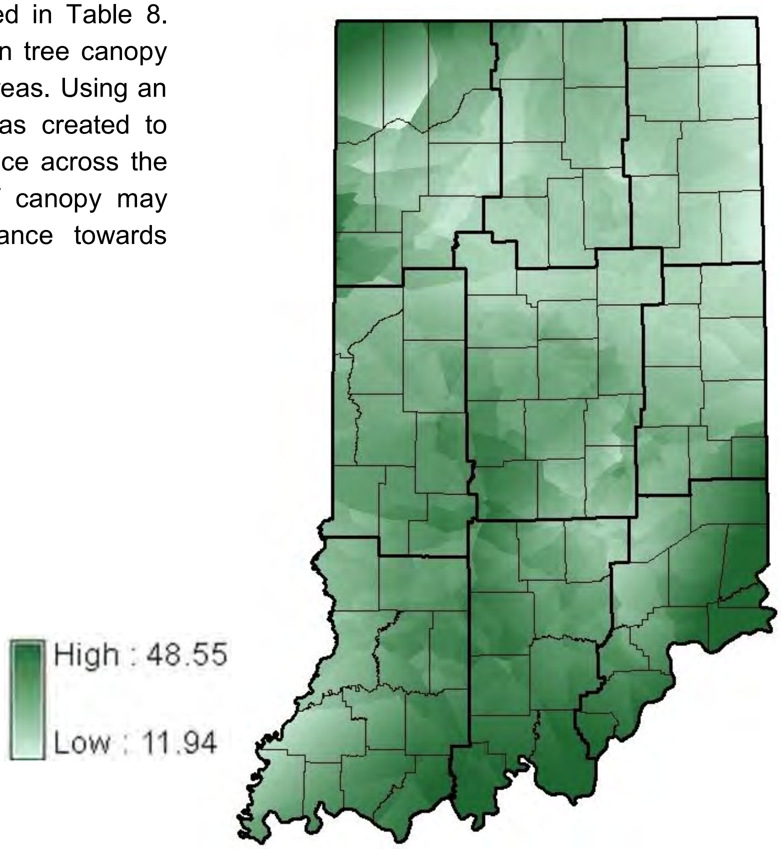


***Figure 9. Representation of the average urban tree canopy percentages for urban areas across Indiana.***

## Impervious Land Cover

The average impervious land cover by region is presented in Table 9. Impervious surfaces include buildings, streets, driveways, and parking lots. Impervious surfaces produce heat islands and increase stormwater runoff. Figure 10 is a representation of the average impervious land cover based on sampling of randomly selected urban areas. Using an interpolation method called Kriging, Figure 10 was created to display the results as a continuous smooth surface across the State. Regions with the greatest amount of impervious cover may warrant greater technical and financial assistance for tree planting. Communities with relatively high amounts of impervious land cover must strategically plant trees and evaluate current land uses to make improvements to canopy cover.

***Table 9. Average Impervious Land Cover Percentages for Urban Areas***

| Region | Percent Land Cover |
|---|---|
| Northwest | 28.26 |
| Northcentral | 30.54 |
| Northeast | 28.16 |
| WestCentral | 27.04 |
| Central | 27.38 |
| EastCentral | 30.73 |
| Southwest | 24.27 |
| Southcentral | 21.27 |
| Southeast | 22.07 |

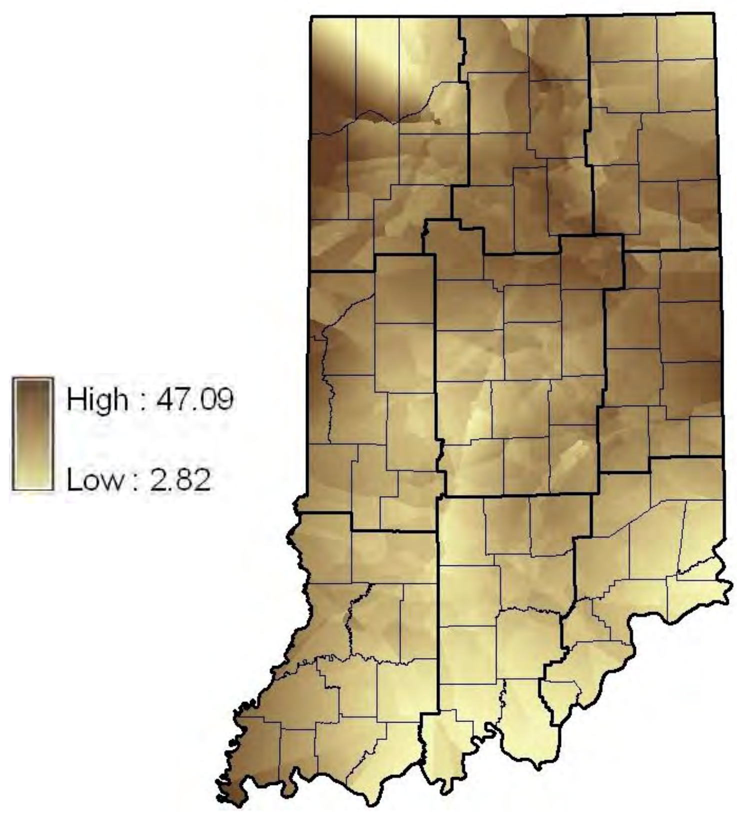


***Figure 10. Representation of the average impervious land cover percentages for urban areas across Indiana.***

## Impaired Stream Segments

There are 35,673 miles of rivers, streams, ditches, and drainage ways in the State of Indiana. Watershed health is a direct result of the water quality of streams. Impaired stream segments are defined by the Indiana Department of Environmental Management as “not meeting water quality goals”. Areas that exhibit the highest amounts of impaired stream segments should consider the strategic use of tree planting to achieve water quality improvement goals, in addition to increasing canopy goals.

Indiana Department of Environmental Management records were used to map the number of stream segments located within Indiana. Impaired stream segments by region are shown in Table 10. The presence and number of impaired stream segments are illustrated in Figure 11.

***Table 10. Number of Impaired Stream Segments***

| Region | Number of Impaired Streams |
|---|---|
| Northwest | 860 |
| Northcentral | 693 |
| Northeast | 696 |
| WestCentral | 586 |
| Central | 828 |
| EastCentral | 449 |
| Southwest | 428 |
| Southcentral | 317 |
| Southeast | 212 |

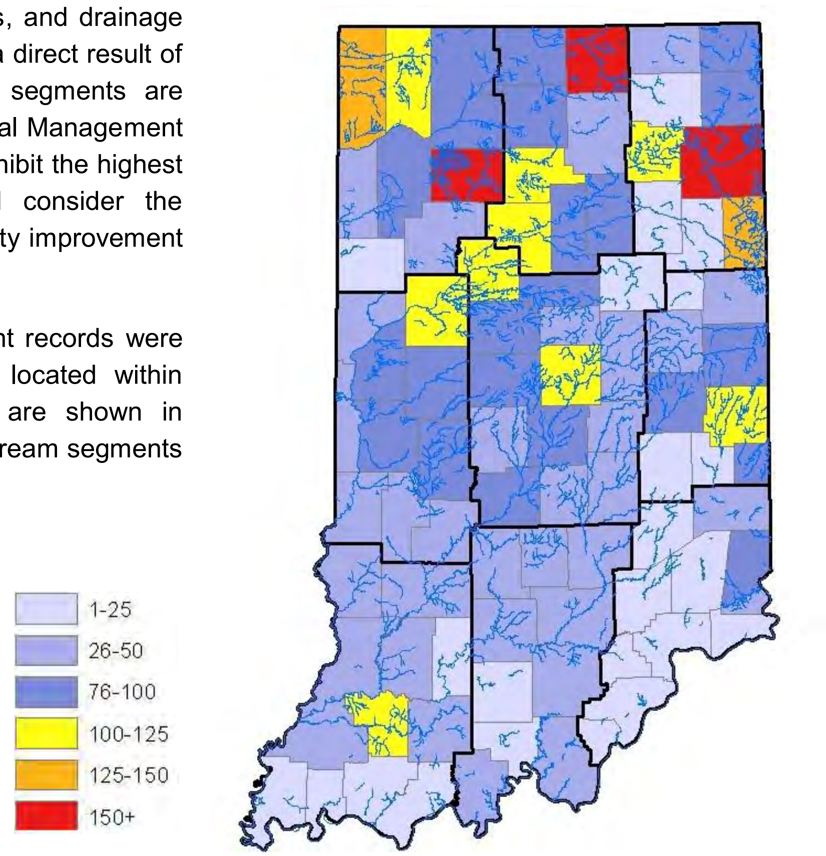


***Figure 11. Impaired stream segments based on Indiana Department of Environmental Management records.***

# Urban Tree Canopy Recommendations

Factors that threaten and influence urban tree canopy were evaluated to determine their potential impact on urban tree canopy within the nine regions within Indiana. Threats included the probability of the presence of emerald ash borer, the presence of gypsy moth, and land development as measured by the change in population. Environmental pressures analyzed included lack of existing urban tree canopy, existing impervious land cover, and the presence and number of impaired stream segments. The results of this analysis can be used by communities to set urban tree canopy goals and to identify tree planting target areas both regionally and by county.

## Community Urban Tree Canopy Goal Setting

Urban tree canopy can be used to understand current urban forest conditions and to set urban tree canopy goals for maintaining and increasing urban tree canopy. It is recommended that individual communities look to setting an overall goal consistent with American Forests' recommendation of 40 percent for cities east of the Mississippi River. Over a period of years, simple benchmarks can be established at intermediate steps along the way to achieving the overall goal. Communities can use the results of this study to compare to similar sized (class) communities within their region.

Potential tree canopy for any community can be measured by combining the total UTC and all other viable areas including pervious areas. Some impervious areas can also become part of the tree canopy if redeveloped or retrofitted. To increase canopy, communities should review the pervious areas closely for possible planting sites and establish realistic goals. Potential sites can be impacted by land use constraints, social and cultural preferences, and by whether or not the land is physically conducive to planting sites.

# Regional Tree Planting Target Areas

The presence of a threat or influence of an environmental pressure within a region can be used to identify target areas for tree planting. As shown in Table 11, the results were ranked as high, medium, or low. These categories were determined by statistically identifying natural breaks in the data. Regions where threats or environmental pressures are significant are indicated as high.

***Table 11. Regions Identified as Exhibiting Low, Medium, or High Threats or Environmental Pressures***

| Region | Existing UTC (percent) | Probability of EAB Presence (percent) | Presence of Gypsy Moth (number) | Development as Measured by Population Change (percent) | Existing Impervious Land Cover (percent) | Impaired Stream Segments (number) |
|---|---|---|---|---|---|---|
| Northwest | 23.44% | 5.23% | 7,343 | 1.43% | 28.26% | 860 |
| Northcentral | 20.61% | 15.97% | 17,120 | 1.31% | 30.54% | 693 |
| Northeast | 18.06% | 40.68% | 53,201 | 3.58% | 28.16% | 696 |
| Centralwest | 25.30% | 19.26% | 5 | 1.91% | 27.04% | 586 |
| Central | 23.32% | 28.28% | 280 | 11.20% | 27.38% | 828 |
| Centraleast | 21.54% | 26.52% | 446 | -2.87% | 30.73% | 449 |
| Southwest | 26.71% | 6.82% | 0 | 2.35% | 24.27% | 428 |
| Southcentral | 30.38% | 10.66% | 4 | 7.54% | 21.27% | 212 |
| Southeast | 30.71% | 7.69% | 4 | 5.01% | 22.07% | 317 |

Level of Threat or Environmental Pressures that Influence Indiana UTC

Low Medium High

# Conclusion

Establishing a tree canopy goal essential for communities seeking to improve and create a sustainable urban forest. Knowing the urban tree canopy present is the first step in this goal-setting process, followed by determining the amount of tree canopy that could theoretically be established.

The results of this report can be used by Indiana communities to establish benchmark against similar communities, set goals for improvement, create plans for planting and protecting trees, and monitor threats to the urban forest.

Each of the factors that influence urban tree canopy can used separately, or combined, to make determination of technical and financial support to aid the State's efforts to preserve and increase canopy cover. Based on the analysis, the Northeast region has the lowest existing UTC and the greatest threat of EAB and gypsy moth, while the Central region has the greatest population change and number of impaired streams and the Central region has the most impervious land cover.

When considering the results of this study, the assessed factors should be evaluated with respect to the natural and cultural geography of the State and its various regions.

# Appendix A
# Methodology and Definitions

# Methodology

## Overview

As more communities focus attention on environmental sustainability, community forest management has become increasingly dependent on GIS for Urban Tree Canopy (UTC) Mapping and Analysis. Understanding the importance of existing UTC is a key measure for identifying various types of community forestry management opportunities.

Urban forestry research and applications aid in determining a balance between growth and preservation by identifying and assessing existing forestry opportunities. In order for urban planners, foresters, and elected officials to achieve a balance between development and conservation, a GIS based analysis must be completed to determine the amount of current canopy coverage in urban areas.

### Image Analysis

With advanced GIS and remote sensing software capabilities, in addition to advances in image acquisition, a top-down canopy assessment approach using remote sensing data is recommended to quantify the extent of tree canopy. Davey utilized an object based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution, color infrared (CIR) aerial imagery, remotely sensed data to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage, which supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning of healthier and more sustainable urban environments.

Davey acquired ancillary GIS data and high-resolution, aerial imagery from the six selected UTC communities. In addition, National Agricultural Imagery Program (NAIP) 4-band imagery acquired by the United States Department of Agriculture (USDA) in 2010 was also obtained. The NAIP, administered by the USDA's Farm Service Agency, acquired the imagery at a one-meter ground sample distance (GSD) with a horizontal accuracy that matched within six meters of photo identifiable ground control points (www.fsa.usda.gov). Acquired during the agricultural growing season (or leaf on), NAIP imagery provided the base layer for the object based image analysis.

Advanced image analysis method was used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst®, an extension of ArcGIS®. Feature Analyst ® uses an object-oriented approach to cluster together objects with similar spectral (*i.e.,* color) and spatial/contextual (*e.g.,* texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process was post-processed and clipped to each project boundary prior to the manual editing process in order to create smaller manageable and more efficient file sizes. Secondary source data, high-resolution, aerial imagery provided by each UTC community, and custom ArcGIS® tools were used to aid in the final manual editing and quality checking and quality assurance processes (QA/QC). The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

### Accuracy Assessment

Random point locations were generated throughout each community boundary to ensure that the automated mapping and data analysis performed by GIS specialists reflected the true nature and extent of the canopy cover. Sample points were created by using the Create Random Points tool within ArcGIS®. For these accuracy assessments, a sample of 100 or 200 random points was chosen relative to community size with larger communities receiving more points. Points were then compared with the NAIP and high-resolution imagery to determine the accuracy of the final land cover layer. Results of the random point assessment were recorded in a classification matrix for further analysis.

To assess accuracy among individual land cover classes, a statistical metric called the Kappa coefficient was derived from the classification matrix. This metric was chosen because it represents the data more precisely (rather than using an overall accuracy percentage of correct land cover classifications) because it partly accounts for chance, or variance, among random sample sets. The Kappa does not yield a result in percentages but rather in terms of agreement with values ranging from zero to one. Although definitive ranges of the Kappa have not been established, it has been generally accepted that a value of 0.80 or higher results in "very good" agreement between layers. Davey used this statistic to measure agreement between the aerial imagery and extracted land cover. The summary table below shows the overall accuracy and Kappa coefficient for each of the six UTC assessments for Indiana. All UTC communities were considered statistically significant in terms of agreement according to the Kappa values; therefore, the results of the land cover feature extraction were deemed to sufficiently represent the true nature of the landscape.

***Accuracy Assessment Summary Statistics***

| Community | Overall Accuracy | Kappa |
|---|---|---|
| Anderson | 92.00% | 0.89 |
| Cedar Lake | 90.00% | 0.82 |
| Evansville | 91.00% | 0.87 |
| Ft. Wayne | 92.00% | 0.88 |
| Madison | 95.00% | 0.92 |
| South Bend | 90.00% | 0.85 |

## GIS Analysis and Final Deliverables

All land cover classes were merged into a final 4-class land cover layer and acreage calculations were generated using ArcGIS® geoprocessing, analysis, and data management tools. Land cover acreages and percentages were calculated for the overall project boundary for each of the six communities. Canopy summary statistics were also calculated for parks, neighborhoods, zoning, land use, parcel use, and right-of-ways (ROW) if the datasets were provided by the community.

The final 4-class land cover layer included:

- Canopy Cover (includes trees and shrubs)
- Impervious surfaces (includes buildings, streets, driveways, and parking lots)
- Pervious surfaces (includes grass, low-lying vegetation, and bare soils)
- Open water

## EAB Risk Model

In order to assess the risk of emerald ash borer (EAB) in Indiana, Davey compiled spatial data layers that are important to the spread and establishment of EAB. The goal was to develop and assemble a modeling procedure in order to utilize data using GIS. These objectives were accomplished by developing spatial datasets using mostly human causal vectors combined with a maximum entropy (Maxent) modeling approach to predict probability distributions. The development of spatial data layers were completed using ArcGIS® for analysis and dataset creation.

## Occurrence Data

Occurrence records of EAB were obtained from the Indiana Department of Agriculture and contain EAB positive identifications as of August 2011 (n=613). These records indicate where EAB has been located by coordinate points. Since the range of EAB is not yet known in the United States, it is assumed that EAB can and will survive throughout Indiana as long as ash is the host species. Therefore, the entire state was included in the analysis with no omissions.

## Variables

Ten environmental variables were spatially represented as potential predictors of EAB spread and distribution. These variables were selected based on human spread mechanics and past modeling studies. All variables are associated with anthropogenic spread vectors with the exception of an ash basal area grid. All datasets were assembled using ArcGIS Version 10. All environmental layers were set to 30m spatial resolution to correspond for efficiently running Maxent while still properly representing ground resolution. Variables included: campgrounds, nurseries, sawmills, roads, urban areas, harbors, population, secondary homes, housing density change, and ash basal area.

## Data Preprocessing

Data pre-processing was conducted in three steps: re-projection, clipping the study area boundary, and creation of ASCII files for the Maxent model. All vector data formats were transformed to raster grids with 30m resolution. Geographic dimensions for all layers must match exactly for the Maxent model to run.

Maxent performs best when working with presence-only (or known location) data. For this analysis, the list of current EAB positive locations were used as presence data. This file must be in CSV format and contain three essential columns: species, longitude, and latitude. The column headings must match for the model to run. If the headings are not labeled correctly, the Maxent program will not recognize the CSV file appropriately resulting in an error. It is possible to have other information include in the file, but Maxent will not recognize these data fields. Extra data will not affect the outcome of the model.

## Results

The risk map results serve as a vital tool by providing the ability to make decisions involving pre-emptive management strategies such as monitoring, trapping, awareness, and treatment. By understanding the current infestation environment, the process of pinpointing locations with similar factors can aid in potentially slowing or stopping the spread.

While a majority of the model predicted high likelihood of EAB presence in areas already with high positive rates (as intended), it was able to interpolate other distinct areas throughout the state that could potentially become risks at a future date. As expected, the most vulnerable places were in and around many of the mid- to large-sized communities, but a few locations of interest were predicted outside the current infestation zones. In the Eastcentral region of Indiana, the probability of EAB presence was most likely for the communities of Muncie, New Castle, and Rushville because they share many commonalities to those previously reporting heavy EAB discoveries, as indicated by the orange and red colors. Likewise, in the Westcentral region, EAB was predicted to have a fairly high likelihood of presence especially in Terra Haute and its surrounding communities.

**Predictive Power**

Accuracy is always crucial in the modeling process. Interpreting results correctly depends on model accuracy. Since Maxent is a probability statistical model, the results can be assessed by statistical backing. While some models use a p-value to interpret model significance, Maxent provides a slightly different approach by using a receiver operating curve (ROC), which applies an area under the curve (AUC) value. The AUC statistic represents the predictive power of the model. When the AUC value is high (greater than 0.80), the ability to correctly predict distributions strengthens which empowers users to make more informed and decisive decisions.

Maxent yielded a maximum AUC value of 0.88, which was considered "very good" in terms of predictive power.

## Statewide Canopy and Impervious Interpolation

In order for Davey to estimate urban canopy throughout Indiana, the state was divided into nine regions. To comprehensively represent all community sizes, Davey completed an i-Tree Canopy assessment on all communities with a population greater than 35,000 (n=23). In addition, Davey randomly selected nine smaller towns (population less than 35,000) in each region to sample with the i-Tree Canopy application. The percentages from these 102 cities/towns were combined with land cover figures from the six communities that Davey conducted an UTC assessment, bringing the total sample size to 108 communities evenly distributed spatially throughout Indiana. The i-Tree Canopy results were recorded in a spreadsheet to examine and compare average urban canopy and impervious coverage for each region of Indiana.

Rather than displaying the average canopy/impervious percentage as a solid, blocky color scheme for each region, Davey represented the data with a continuous monochromatic scheme for the entire state. To achieve this design, Davey took the percent canopy/impervious from each i-Tree sampled city/town and used an interpolation method called Kriging. This tool allows Davey to display the results over a continuous smooth surface across Indiana.

The newly interpolated grid was used to derive average percentages for the counties, regions, and state independently. Applying Zonal Statistics, a function within the ArcGIS® Spatial Analyst, Davey was able to determine average urban canopy/impervious percentage within each of the specified polygon boundaries based on the mean pixel value and display them in a table.

# Appendix B
# References


American Forests. *Setting Urban Tree Canopy Goals*. (http://www.americanforests.org/resources/urbanforests/treedeficti.php, November 2010)

Indiana Department of Environmental Management. 2006. *Impaired Stream Segments*. Vector Data Format. (Downloaded from <http://igs.indiana.edu/arcims/statewide/download.html>, August 2011)

Indiana Department of Natural Resources. 2011. *EAB Presence Data and Gypsy Moth Trap Data*. Vector Data Format. Contact Philip Marshall, Division of Entomology & Plant Pathology, 402 West Washington Street, Room W-290, Indianapolis, IN. 46204-2739. (317-232-4120).

Indiana Department of Natural Resources, Division of Forestry, Community & Urban Forestry. 2009. *Sample Urban Statewide Inventory (SUSI).*

International Society of Arboriculture. 2005. *Benefits of Trees*. Tree Care Bulletin.

i-Tree Tools. USDA Forest Service. www.itreetools.org

Nowak, David J; Greenfield, Eric J. 2010. *Urban and Community Forests of the North Central East Region.* General Technical Report NRS-54. Newtown Square, Pennsylvania. United States Department of Agriculture, Forest Service, Northern Research Station.

USDA-FSA-APFO Aerial Photography Field Office. *NAIP 2010: Orthoimagery (1-meter GSD)*. 1:24,000. Various Indiana Photos, UTM Zone 16N. Salt Lake City, Utah. December 1, 2010.

United States Department of Agriculture Forest Service. *2010 Indiana Forest Health Highlights*. (http://fhm.fs.fed.us/fhh/fhh_10/in_fhh_10.pdf. August 2011).

United States Department of Agriculture Forest Service. *Urban Forests and Climate Change.* (Downloaded from http://www.fs.fed.us/ccrc/topics/urban-forests/, August 2011).

United States Census Bureau. 2011. TIGER/line Census Data Shapefiles. Vector Data Format. (Downloaded from http://www.census.gov/geo/www/tiger/shp.html, June 2011).

# Appendix C
# DVD Containing GIS Files and Data Sets