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A Method for Examining the Ecosystem Services of Roadside Trees: Springfield, Massachusetts

Photo from Picturesque Hampden (1892)

“ …ecosystem services are provided by street trees, and that street trees have the capability to furnish both environmental and economic benefits.”

Project Background

This article outlines a series of simple, easy-to-implement scientific experiments to examine various roadside types and report on the ecosystem services that these typical roadsides provide. There are four distinct quantitative components included in this study and four roadside types: major arterial roadways, minor arterial roadways with no tree setback, collector streets, and a local residential street setting. The initial investigation was conducted in Springfield, Massachusetts, and the roadside types examined are representative of the roadside types crossing the City. Research and field observation provided information on the structure of the roadsides, including the underground and overhead utilities, drainage systems, greenspace components, and shade tree canopy.

Image 1: A typical roadside setting showing a minor arterial roadside type, in Springfield, MA.

Investigation Process

The first component of this study was to identify the specific tree species associated with each roadside type. A 500-foot segment of random roadside for each type was selected for examination. The City of Springfield Forestry Division provided information on the specific tree species, condition, and size for each roadside section that was utilized in the study.

The second component of the study was to estimate the ecosystem services provided by each roadside type, in order to provide an overview of the benefits that the roadsides of Springfield provide citywide. Four aspects of ecosystem services were examined: air quality – how trees improve the overall air quality in Springfield’s neighborhoods, stormwater interception – the amount and degree by which tree canopies intercept rainfall before it reaches the ground, carbon cycling provided by the trees, including capturing and storing carbon emissions before they are released to the atmosphere, and urban heat island mitigation – how trees and other vegetation shade and cool the ground by reducing direct solar receipt on surfaces.

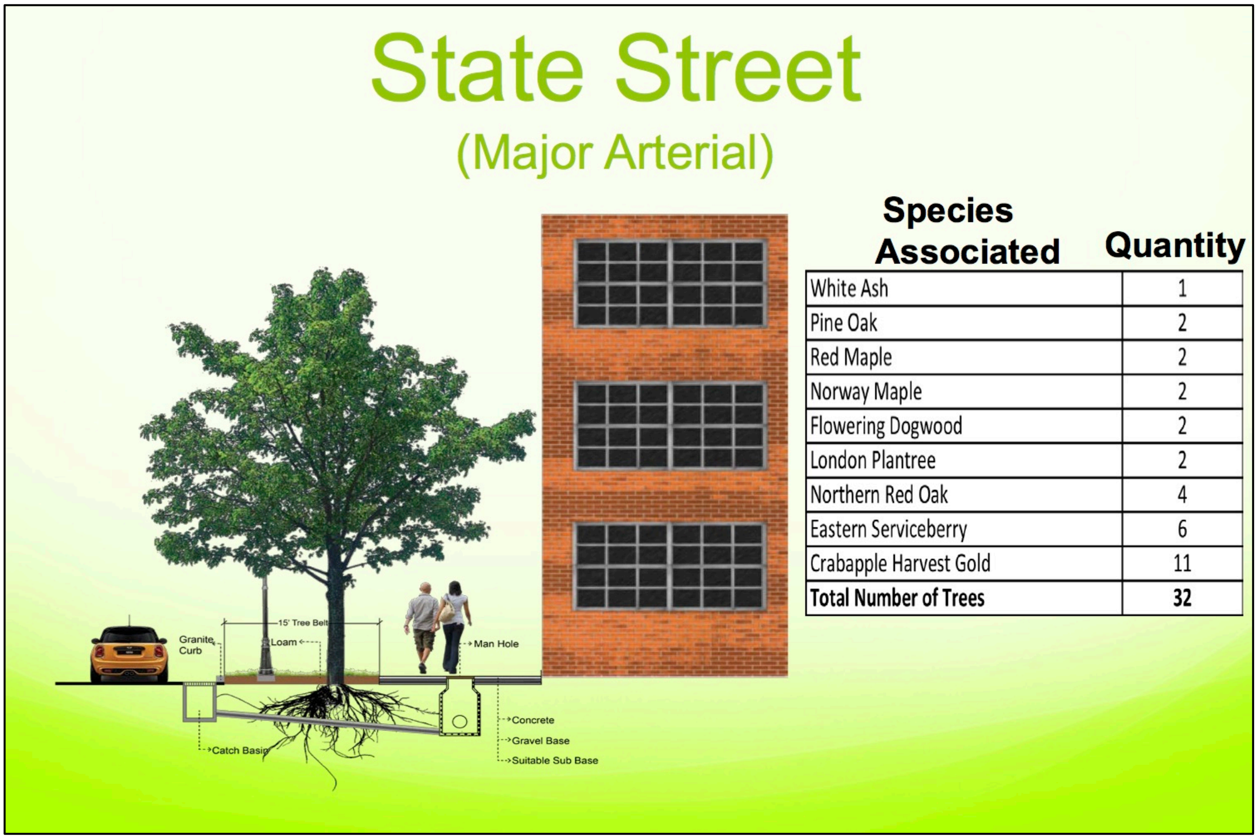


Image 2: This diagram shows the current layout of State Street, a major arterial roadside, in Springfield, MA. The table shows the species associated and the quantity of trees within the area analyzed.

i-Tree Design Analysis Tool

Reporting on Ecosystem Services – To generate quantitative data on the ecosystem services provided by street trees, the online software tool i-Tree Design was used in this study. This software tool "allows anyone to make a simple estimation of the benefits provided by individual trees" (United States Forest Service, 2006). i-Tree Design estimated the approximate amount of carbon storage and sequestration, stormwater interception, and air quality improvements based on the specific tree types, sizes, and conditions over a 50-year time period for each of the four road types analyzed. Table One, below, shows the results of the i-Tree Design analysis completed on these four roadside types in Springfield. State Street (Major Arterial), Union Street (Minor Arterial with no tree setback), Pine Street (Collector), and Cedar Street (Local) were examined. Table 1 indicates the amount of carbon sequestered and gallons of rainfall intercepted by the trees on these streets. Also, using calculations from models developed by the U.S. Forest Service and the U.S. Environmental Protection Agency, an approximate dollar value was established.

Time Frame: 2015-2065

	Pounds of Carbon Sequestration	Gallons of Rainfall Interception	Savings in Air Quality Improvements
State Street	217,845	1,576,716	$1,622.00
Union Street	229,857	1,724,691	$1,845.00
Pine Street	232,860	5,232,454	$4,801.00
Cedar Street	255,436	1,360,042	$1,393.00

Table 1: A 50-year projection of ecosystem services of typical roadside types in Springfield, MA as calculated by i-Tree Design

Urban Heat Islands

Since urban heat island mitigation is an important ecosystem service that impacts roadside locations, this aspect of tree benefits should be considered in any roadside study, but it cannot be specifically calculated using i-Tree Design. Researchers have studied and quantified the relative impact of trees on urban streetscape settings, examining the difference between temperatures in areas under trees compared with open areas. A review of publications that evaluated the difference between temperatures in areas under trees compared with open areas was undertaken. Although, not specific to the study sites in Springfield, the literature shows that air temperatures of grassy areas under trees located in urban areas can be 1.3 - 2.4° F cooler than in adjacent areas with no tree cover (Souch and Souch, 1993). Similarly, there can be up to a 4 - 6° F difference in air temperature under mature trees in a suburban neighborhood than in newer developments with new or no trees (McGinn et. al, 1982).

Ecosystem Services of Street Trees

The third component of this project was to examine factors that can affect the performance of ecosystem services along roadside networks. Tree belt size and space, occurrence of underground utility infrastructure, surrounding hardscapes, and stormwater infrastructure are four factors that are likely to interfere with the ecosystem performance level that these trees provide.

Limited tree belt size and soil volume is a key and limiting factor affecting a tree's ability to deliver the greatest potential benefit. A tree tends to be healthier when there is a larger tree belt, because with a smaller tree belt the roots are likely constricted with less rooting space for the tree to thrive. "If the tree roots have no more room to grow, branches die, twigs do not grow as long, and the tree produces smaller and/or fewer leaves" (Urban, 2008).

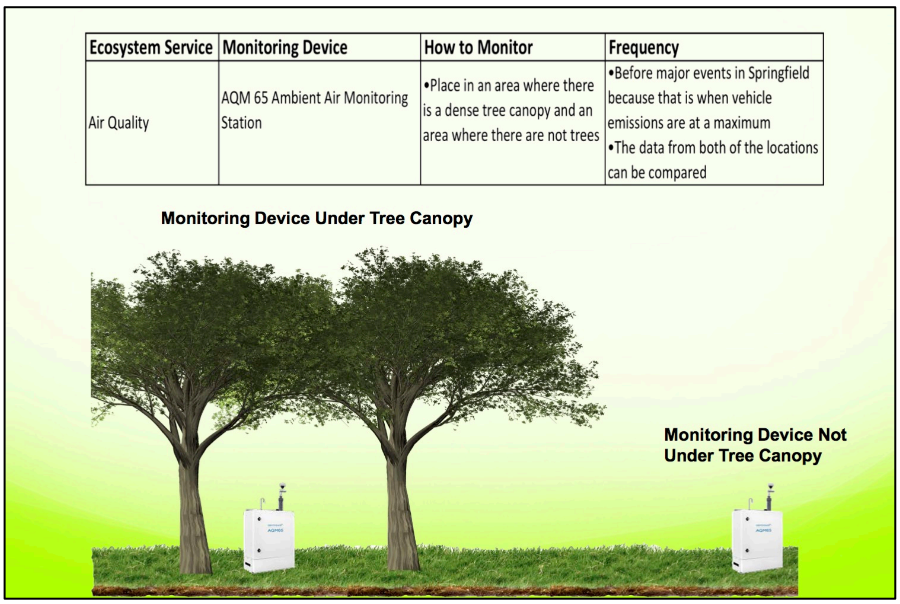
Underground pipes, conduits, and utility lines are other factors that affect the ecosystem services that roadside trees provide. Tree roots may penetrate into sewer and other underground utility lines causing damage to both the tree and the piping because these underground utilities are not always able to withstand the pressure of the growing root system. When pipelines or cable lines are installed and maintained, it may become necessary to cut and/or remove tree roots. This can have a major negative effect on tree health and ecosystem services.

Surrounding hardscape material is a third factor that may affect the ecosystem services provided by trees. The rooting space of trees conflicts with the pavement causing damage and deterioration. This has the potential to be very costly to repair or maintain. As a result of the damage, trees are removed and may not be replaced. In addition, excavation near trees damages their roots. This process may remove some of the required soil and the transport and use of heavy machinery outside of the paved surfaces compacts the soil, which also affects root growth. This has resulted in decline and loss of street trees within Springfield.

Lastly, stormwater management infrastructure is a major factor that may affect the ecosystem services that trees provide. In Springfield the stormwater runs along the side of the road directly into a catch basin or sewer. The vegetation and trees are most often separated from the stormwater by the roadside curb, so the stormwater falling on the roadside surface rarely gets absorbed by the trees. Trees need this water during the summer months to help supply nutrients and adequate moisture in order to remain healthy (Chuyong, et. al., 2004). “There is evidence that only one drought episode can be detrimental to tree establishment. Restricted water flow through roots can potentially increase dieback” (Watson, 2009). Altogether, this scenario results in decreased nutrients for the trees and increased runoff whereas, if the stormwater were to be intercepted by the trees, it would supply additional nutrients for the trees. Also, the roots enable increased rainfall infiltration through the soil and store water, which reduces the overland flow.

A Framework for Examining Ecosystem Services of Street Trees

The fourth component of this study examines how to monitor the ecosystem service performance that these trees provide. One monitoring method would be used for each of the ecosystem services, as noted: air quality, urban heat island mitigation, stormwater interception, and carbon sequestration.



Ecosystem Service	Monitoring Device	How to Monitor	Frequency
Air Quality	AQM 65 Ambient Air Monitoring Station	•Place in an area where there is a dense tree canopy and an area where there are not trees	•Before major events in Springfield because that is when vehicle emissions are at a maximum •The data from both of the locations can be compared

Image 3: Placing an AQM 65 Ambient Air Monitoring Station under a tree canopy and another one in an open area with no trees to compare the different in air quality measurements.

Air Quality - An AQM 65 Ambient Air Monitoring Station can be used to examine air quality along urban roadsides. In order to properly obtain results, one station must be placed in an area where there is a dense tree canopy and another station in an area where there are no trees. This is because the difference in air quality between these two areas is likely to have the greatest relative difference, thus one could see that the trees have an impact on improving the air quality near these trees, compared with the air quality in areas where there are no trees. In determining the frequency of monitoring the air quality, it is recommended that readings should be taken throughout the year. Also, additional monitoring of major arterial roadways might be considered when major public events take place in Springfield, such as the Big E, concerts, sporting events, and other civic activities where vehicle emissions are likely to be at a maximum. Once the data is collected from each area, the results could be compared to see if there are variations in air quality between the two areas. This will likely demonstrate an improvement in air quality in the tree area as compared to the other.

Urban Heat Island Mitigation - To monitor urban heat island mitigation by street trees, a thermometer is recommended. Similar to setting up the monitoring system for air quality, a thermometer would be placed on the trunk of a tree and another placed on a pole, or tripod, in an open area with no trees. The National Weather Service suggests that in order to get the highest level of accuracy of temperature a thermometer should be place four to six feet above ground and “should be freely exposed to sunshine and wind and not close to or shielded by trees, buildings, or other obstructions” (National Weather Service Instruction, 2014). The best time of day to monitor temperature differences is at the hottest time of the day, which is usually around 2:00 p.m., and in the late overnight period, about 3:00 a.m. In this case, one is likely to get the greatest difference in temperature between the shaded and the non-shaded areas. It is recommended that the air temperatures should be monitored on a daily basis, and averaged on a weekly and monthly basis.

Ecosystem Service	Monitoring Device	How to Monitor	Frequency
Urban Heat Island Mitigation	Thermometer	•Place thermometer under a tree another one not under a tree	•Hottest time of the day to get maximum temperature and maximum difference •Monitor daily

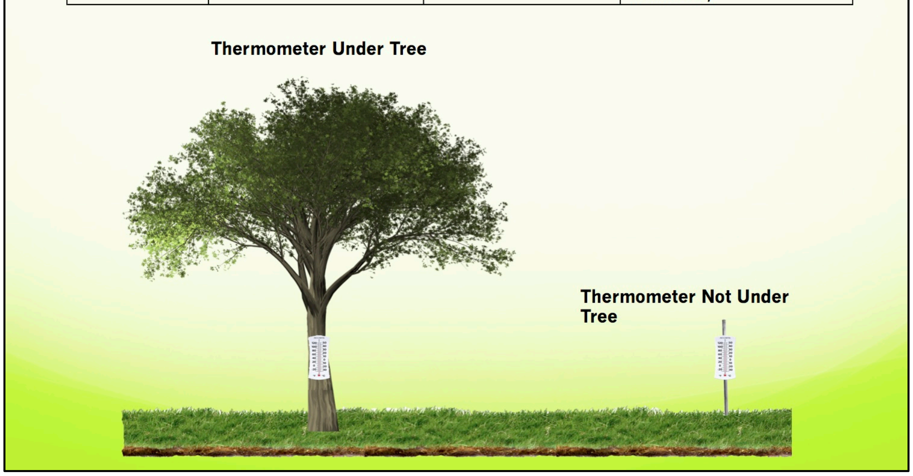
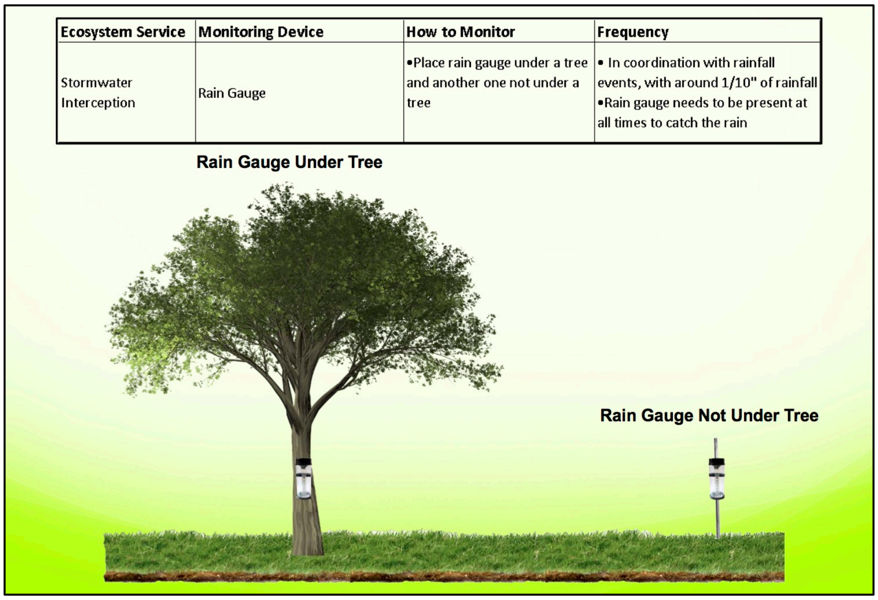


Image 4: Placing a thermometer under a tree canopy and another one in an open area with no trees to compare the differences in temperatures. How to monitor the temperature and the frequency is discussed in the table above.

Stormwater Interception - The third ecosystem service that can be monitored is stormwater interception. A rain gauge can be used to measure the quantity of rainfall in a storm event. Similar to monitoring the last two ecosystem services, one rain gauge under a tree canopy and another rain gauge in an open area with no trees. In order to obtain the highest level of temperature accuracy, the NationalWeather Service suggests a rain gauge “should be “horizontal and locatedapproximately 3 feet above the ground” (National Weather Service Instruction, 2014). In most cases, street trees can reduce the amount urban stormwater since some of the rainfall never reaches the ground; it remains on the leaves of the tree and then evaporates.

The best time to monitor this would be when there is at least one-tenth of an inch of rain forecast to ensure that a measurable level of rainfall from under the tree compared with levels outside of the tree area will be obtained. It is important to monitor weather forecasts to know the amount of expected precipitation anticipated and when the rain event will occur. If one-tenth of an inch is anticipated, then it would be appropriate for the rain gauges to be set up.



Ecosystem Service	Monitoring Device	How to Monitor	Frequency
Stormwater Interception	Rain Gauge	•Place rain gauge under a tree and another one not under a tree	• In coordination with rainfall events, with around 1/10" of rainfall •Rain gauge needs to be present at all times to catch the rain

Image 5: Placing a rain gauge under a tree canopy and another one in an open area with no trees to compare the differences in collected rainwater. How to monitor stormwater interception and the frequency is discussed in the table above.

When there is a greater rainfall event there often will be less of an interception effect because the leaves on the trees can only intercept so much water. During greater rainfall events, the leaves are not capable of collecting all of the rainwater, and so the tree canopy becomes saturated and unable to hold any more water. If the data on rainfall interception between under a tree canopy and outside the tree canopy is compared over time, it will show whether the trees are providing this type of ecosystem service.

Carbon Sequestration - The fourth ecosystem service that was chosen to monitor was carbon sequestration in the soil surrounding a tree. This can be done using a soil auger. Soil samples are taken directly beside the trunk of a tree at different depths to determine the carbon accumulation in the soil and roots over time. Once the soil samples are taken, they can be analyzed by a scientific laboratory to determine the carbon that is sequestered in the soil near a particular tree (Rowell, 2014). It is recommended that soil samples for any given tree should be taken once a year.

Ecosystem Service	Monitoring Device	How to Monitor	Frequency
Carbon Sequestration	Soil Auger	•Collect a soil samples to bring to a lab for an analysis to determine the carbon sequestered by that individual tree •Take samples at various depths to see how the carbon accumulates in the soil and roots overtime	•For an individual tree it should not be anymore than once a year because it may damaging the tree and negatively impacts its health

Soil Auger to Extract Soil at Various Depths

Source: Google Images

Image 6: A soil auger would be used to collect soil samples around a tree. This sampling will assist in calculating carbon storage and sequestration in the roadside setting and an open area with no trees to compare the differences of collected carbon in the two areas. How to monitor carbon storage and sequestration and the frequency is discussed in the table above.

Conclusion

This field methodology explored several tools that can be used to gauge the level of ecosystem services provided by street trees in a community. The street types examined included a major arterial, a minor arterial with no tree setback, a collector street, and a local street. Based on reviewing research reports, scholarly journals, and using the i-Tree Design tool for quantitative measurements, it is clearly evident that street trees have the capability to provide a substantial amount of benefits to a community.

Flooding, carbon emissions, degraded air quality, and urban heat island effects are critical issues that the built environment is currently facing. Whether these issues continue to worsen or not in the built environment, there is no question that implementing street trees throughout a community will help offset and mitigate these ongoing issues. This initial research demonstrates that multiple ecosystem services are provided by street trees, and that street trees have the capability to furnish both environmental and economic benefits that are guaranteed to improve the overall quality of life.

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