Modeling Hydrological Ecosystem Services of Juvenile Trees in Worcester, Massachusetts

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TREES & URBAN HYDROLOGY

As urbanization increases soil compaction and imperviousness, urban hydrological systems are becoming increasingly disrupted (Yang et al. 2015; Arnold and Gibbons 1996). Specific hydrological problems associated with increased impervious surfaces include an increase in stormwater runoff, in both volume and velocity, as well as a decrease in precipitation infiltration, an increase in nonpoint source pollution, and an increase in the frequency and magnitude of post-precipitation flooding events (Sanders 1986). The urban tree canopy can be used to mitigate many issues that are caused by urbanization (Elmqvist et al. 2015). Trees can function as a main water storage facility as they store water both internally and increase the moisture capacity of the soil it inhabits (Prax and Cermak 2015) This study models these hydrological benefits that an urban tree canopy can provide using a case study in Worcester, MA.

Pre-ALB Conditions Post-Tree Removal After Replanting

Figure 1: Granville Street in north Worcester clearly displaying the dramatic tree canopy loss and gain.

Research Question:
What are the hydrological ecosystem services provided by the urban tree canopy in Worcester, Massachusetts:
(a) before tree loss due to the Asian Longhorned Beetle infestation (2008)?
(b) after trees were cut as a result of the infestation (2010)?
(c) after the planting of trees as part of a reforestation effort for Worcester's urban tree canopy (2015)?

STUDY AREA

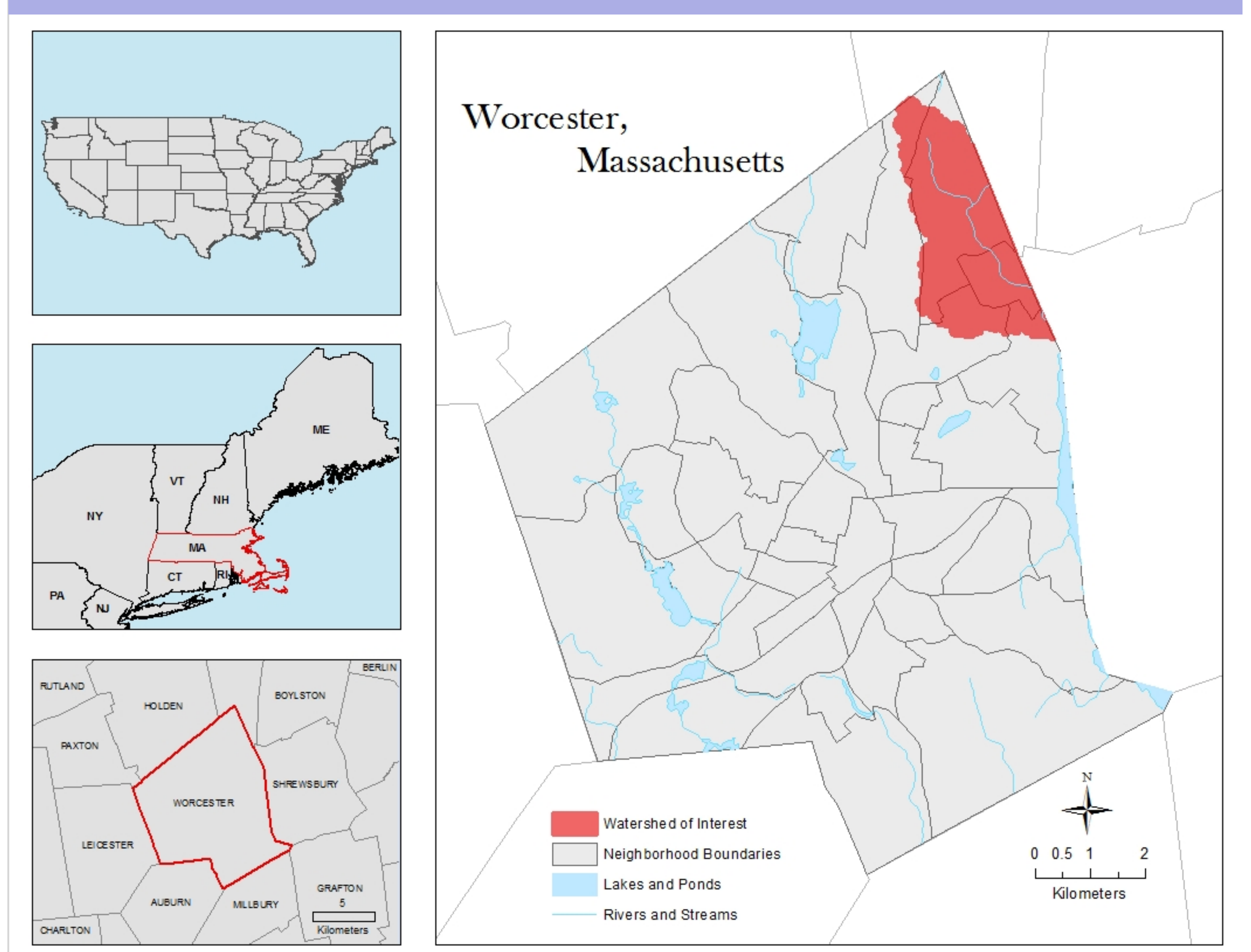

Figure 2: Study area map depicting the watershed being modeled.

Between 2008 and 2015, Worcester went through a period of tree cutting and tree planting due to an Asian Longhorned Beetle infestation that drastically affected the landcover. The watershed above, which covers a highly effected area, allows for a real study displaying the effects of canopy loss on the hydrological system, as well as provides evidence on the success of the planting program on mitigating hydrological problems caused by the tree loss.

ITREE *HYDRO* & MODEL PARAMETERS

The modeling for this study was done using iTree *Hydro*, a software developed by the U.S. Forest Service.

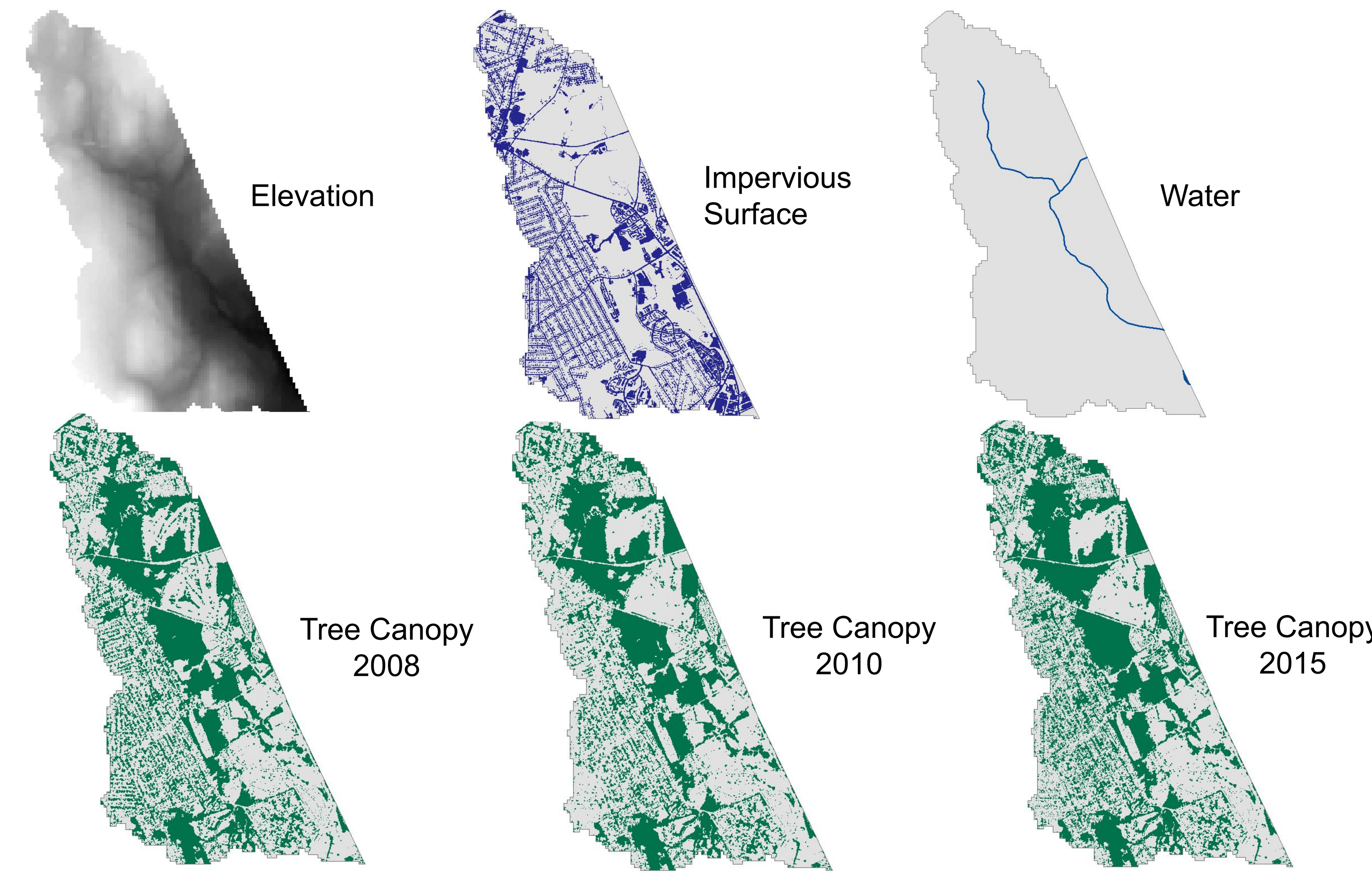

Figure 3: Land cover parameters needed for the model.

In order to model change between all three dates, it was necessary to complete two different model runs: first, modeling changes from 2008 to 2010, next, modeling changes from 2010 to 2015. All models were run with consistent weather data from Worcester Regional airport in 2005 and hydrologic parameters from within *Hydro* in order to maintain the ability to compare all three dates.

Table 1: Proportions of each landcover input in each model run.

LANDCOVER	2008	2010	2015
% Tree Cover	42.5	38.7	42.0
% Shrub	9.9	9.9	9.9
% Herbaceous Cover	9.9	13.1	11.2
% Water Cover	0.1	0.1	0.1
% Impervious Cover	27.7	28.3	26.9
% Soil Cover	9.9	9.9	9.9
% Impervious Beneath Canopy	5.9	4.9	5.5
% Pervious Beneath Canopy	94.1	95.1	94.5

RESULTS – 2008 TO 2010

The model output comparing 2008 to 2010 showed an increase in total stormwater volume of approximately **1.9%**. There is an increase in impervious flow volume of **0.3%.**

Change in Impervious Surface Runoff: 2010-2008

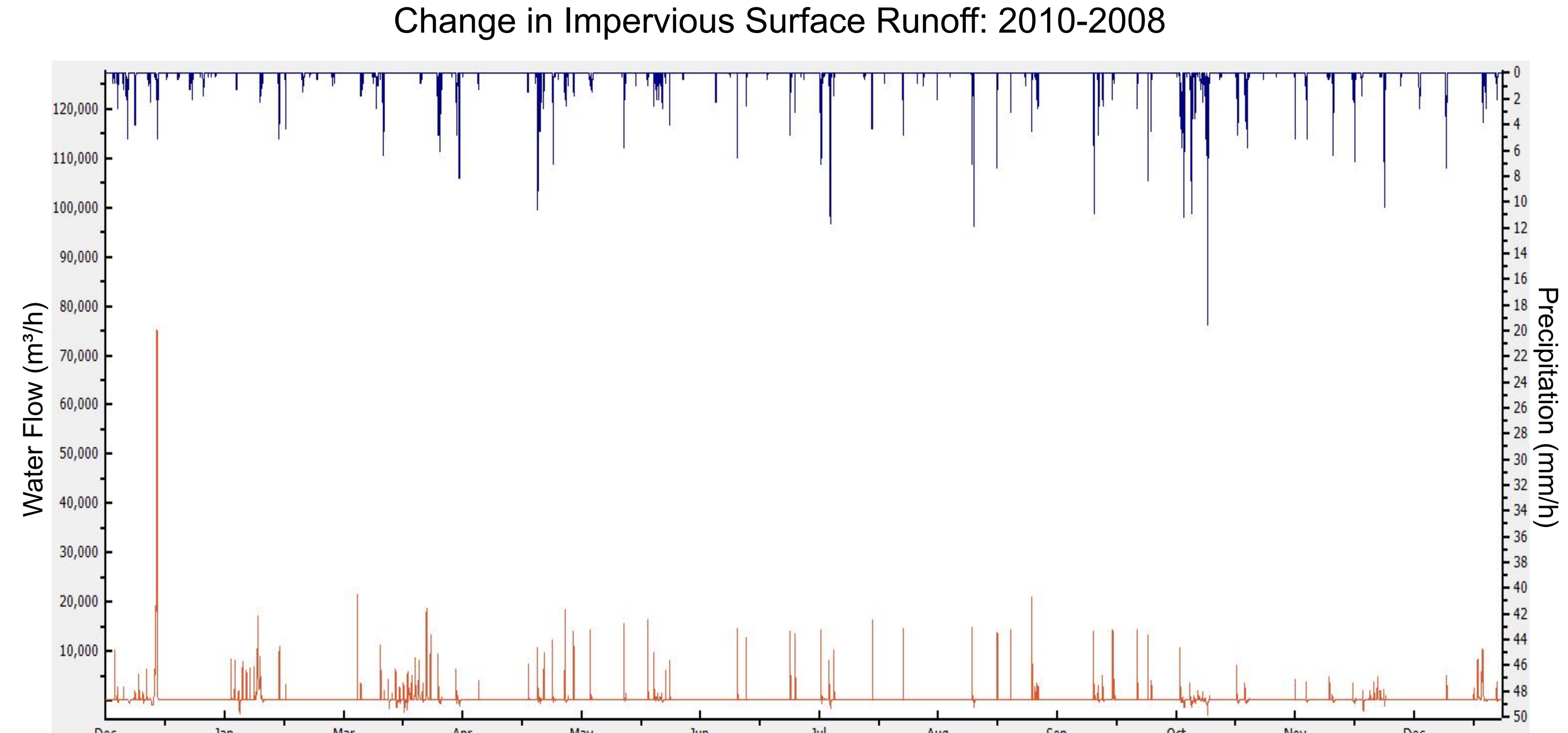

Figure 4: The graph above subtracts the flow rates modeled for 2008 from 2010 to show the net difference between the two years. The bottom line in each shows that difference in impervious surface flow, while the top line shows precipitation.

RESULTS – 2010 TO 2015

The model output comparing 2010 to 2015 shows a decrease in total stormwater volume of approximately **3.3%**. There is a decrease in impervious flow volume of **3.5%.**

Change in Impervious Surface Runoff: 2015-2010

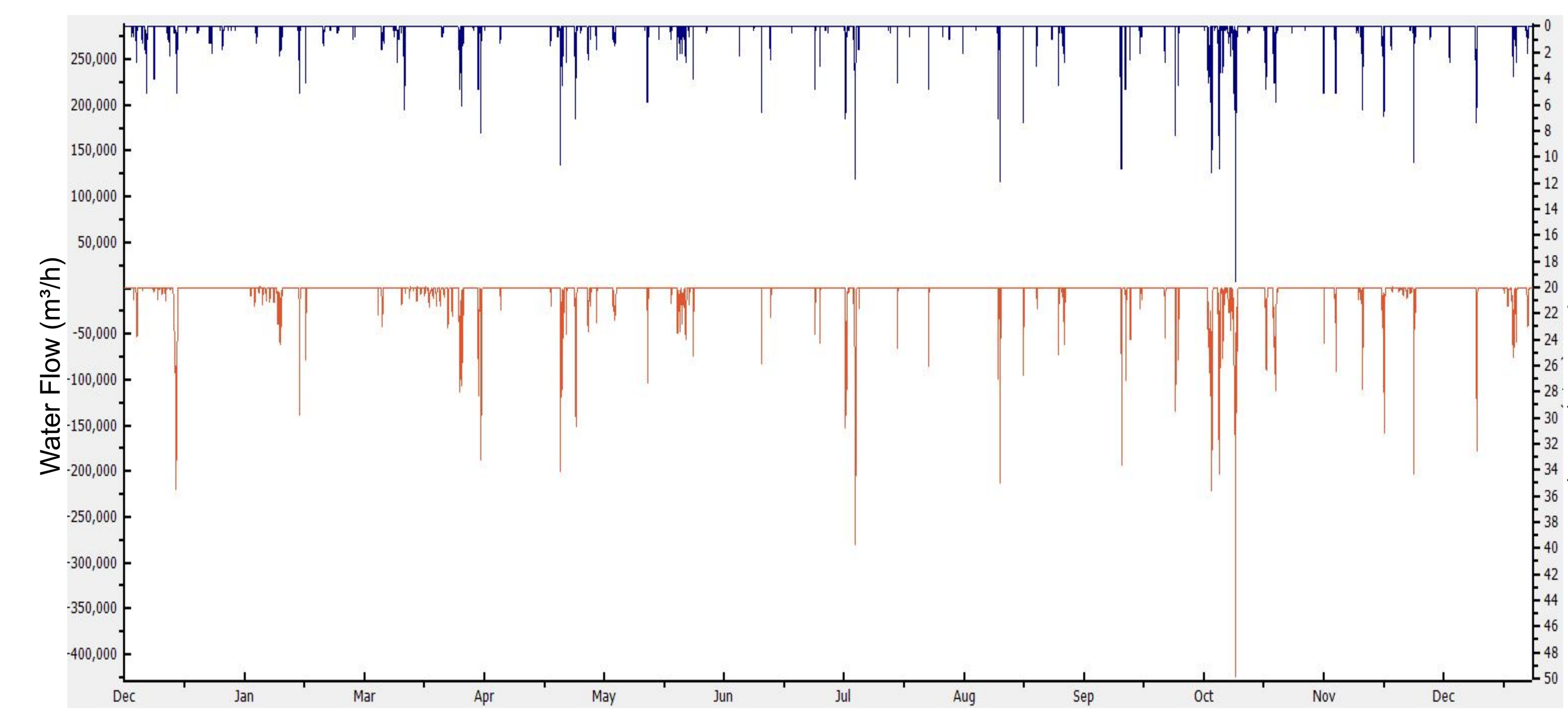

Figure 4: The graph above subtracts the flow rates modeled for 2010 from 2015 to show the net difference between the two years. The bottom line shows that difference in impervious surface flow, while the top line shows precipitation.

HOW LANDCOVER CHANGE AFFECTS HYDROLOGY

This study is unique in that it uses real landcover observations for all three scenarios, making it possible to assess the conditions of Worcester's hydrological system.

Based on the presented results, it is clear that the loss of canopy leads to an increase in stormwater volume and rates, and a gain in canopy leads to a decrease in stormwater volume and rates. The percentages of increase and decrease are consistent with other studies of similar nature and were expected based on consultation with experts of both urban hydrological modeling and tree planting. One outcome that is important to note is the particular effect of the exposing and covering of impervious surface. The results show that the component of flow that is most affected by the changing landcovers is impervious surface runoff. For each transition, the biggest landcover change was canopy. There was also a greater loss between 2008 and 2010 than there was gain between 2010 and 2015. And yet, the difference in flow volume and rate is larger in the gain years. This outcome is consistent with other literature that states that the effect of impervious surface is actually more important to changes in urban hydrology than the size of the tree canopy.

For a place like Worcester that is actively trying to restore an urban tree canopy, the results are important for organizations investing time and money towards these planting efforts. The Massachusetts Department of Conservation and Recreation, along with the Worcester Tree Initiative and the city of Worcester, are greatly involved in Worcester's tree planting initiative. By having these results, they will not only be able to assess the effects of their efforts, but will also potentially be able to predict future benefits of a continuously increasing canopy.

REFERENCES

Arnold, C. I. Jr., Gibbons, C. J. 1996. Impervious Surface Coverage: The Emergence of a key Environmental Indicator. *Journal of the American Planning Association,* 62:2 243-258
Elmqvist, T., Setälä, H., Handel, S. N., van der Ploeg, S., Aronson, J., Blignaut, J. N., Gómez-Baggethun, E., Nowak, D. J., Kronenberg, J., and de Groot, R., 2015. Benefits of restoring ecosystem services in urban areas, *Current Opinion in Environmental Sustainability,* 14: 101-108.
Prax, P., Cermak, J. 2004. Urban tree root systems and tree survival near sewers and other structures, *Enhancing Urban Environment by Environmental Upgrading and Restoration,* 45-56
Sanders, R. A. 1986. Urban vegetation impacts on the hydrology of Dayton, Ohio. *Urban Ecology,* 9:361-376
Yang, Y., Endreny, T. A., and Nowak, D. J., 2015. Simulating the effect of flow path roughness to examine how green Infrastructure restores urban run-off timing and magnitude, *Urban Forestry and Urban Greening,* 14: 361-367

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